TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. coli

in the

Pickwick -- Shoal Creek Watershed (HUC 06030005)

Hardin, Lawrence, and Wayne County, Tennessee

FINAL

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LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DMR	Discharge Monitoring Report
DWPC	Division of Water Pollution Control
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NOV	Notice of Violation
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Pickwick -- Shoal Creek Watershed (HUC 06030005)

Impaired Waterbody Information

State: Tennessee
Counties: Hardin, Lawrence, and Wayne
Watershed: Pickwick -- Shoal Creek (HUC 06030005)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN06030005082 – 1000	SHOAL CREEK	2.3

Designated Uses:

The designated use classifications for waterbodies in the Pickwick -- Shoal Creek Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Shoal Creek, from the Alabama state line to Mile 56.9, is also designated for domestic and/or industrial water supply.

Water Quality Goal:

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

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

TMDL Scope:

Waterbodies identified on the Final 2004 303(d) list as impaired due to E. coli. TMDLs are generally developed for impaired waterbodies on a HUC-12 basis.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Pickwick -- Shoal Creek Watershed were developed using data summary analysis and calculation of in-stream geometric mean E. coli concentrations.

Critical Conditions:

Critical conditions cannot be determined with limited available data. Further sampling and analysis required.

Seasonal Variation:

Seasonal variation cannot be determined with limited available data. Further sampling and analysis required.

Margin of Safety (MOS):

Explicit MOS = 10% of the water quality standard for each impaired subwatershed.

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs		LAs	
			WWTFs [a]		Precipitation Induced Nonpoint Sources	Other Direct Sources [b]
			Monthly Avg.	Daily Max.		
		[% Red.]	[CFU/day]	[CFU/day]	[% Red.]	[CFU/day]
Shoal Creek	TN06030005082 – 1000	48.0	2.146×10^{10}	8.295×10^{10}	48.0	0

Note: Load reductions were determined based on comparison of the geometric mean of all monitoring data to the 30-day geometric mean target concentrations. Additional monitoring is recommended.

a. Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

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 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

PROPOSED PATHOGEN TOTAL MAXIMUM DAILY LOAD (TMDL) PICKWICK -- SHOAL CREEK WATERSHED (HUC 06030005)

1.0 INTRODUCTION

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

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Pickwick -- Shoal Creek Watershed, identified on the Final 2004 303(d) list as not supporting designated uses due to E. coli.

3.0 WATERSHED DESCRIPTION

The Pickwick -- Shoal Creek Watershed (HUC 06030005) is located in Middle Tennessee (Figure 1), primarily in Wayne County. The Pickwick -- Shoal Creek Watershed lies within two Level III ecoregions (Southeastern Plains, Interior Plateau) and contains four Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- **Southeastern Plains and Hills (65e)** contain several north-south trending bands of sand and clay formations. Tertiary-age sand, clay, and lignite are to the west, and Cretaceous-age fine sand, fossiliferous micaceous sand, and silty clays are to the east. With elevations reaching over 650 feet, and more rolling topography and ore relief than the Loess Plains (74b) to the west, streams have increased gradient, generally sandy substrates, and distinctive faunal characteristics for west Tennessee. The natural vegetation type is oak-hickory forest, grading into oak-hickory-pine to the south.

- **Fall Line Hills (65i)** ecoregion, comprising the Tennessee or Tombigbee Hills in Mississippi and the Fall Line Hills in Alabama, is composed primarily of Cretaceous-age coastal plain sandy sediments. The sand and chert gravel surficial materials are covered by sandy loam topsoils. It is mostly forested terrain of oak-hickory-pine on open hills with 100-200 feet of relief. Elevations in the small Tennessee portion, roughly between Chambers Creek and Pickwick Lake in Hardin County, are 450-685 feet.

- **Transition Hills (65j)** have the highest elevation in Ecoregion 65, and contain characteristics of both the Southeastern Plains (65) and the Interior Plateau (71) ecoregions. Many streams of this transition area have cut down into the Mississippian, Devonian, and Silurian-aged rocks and may look similar to those of the Interior Plateau (71). Cretaceous-age coastal plain deposits of silt, sand, clay, and gravel, however, overlie the older limestone, shale, and chert. It is a mostly forested region of oak-hickory-pine, and has had pine plantation activities associated with pulp and paper operations.

- **Western Highland Rim (71f)** is characterized by dissected, rolling terrain of open hills, with elevations of 400 to 1000 feet. The geologic base of Mississippian-age limestone, chert, and shale is covered by soils that tend to be cherty, acidic and low to moderate in fertility. Streams are characterized by coarse chert gravel and sand substrates with areas of bedrock, moderate gradients, and relatively clear water. The oak-hickory natural vegetation was mostly deforested in the mid to late 1800's, in conjunction with the iron ore related mining and smelting of the mineral limonite, but now the region is again heavily forested. Some agriculture occurs on the flatter areas between streams and in the stream and river valleys: mostly hay, pasture, and cattle, with some cultivation of corn and tobacco.

The Pickwick -- Shoal Creek Watershed, located in Hardin, Lawrence, and Wayne Counties, Tennessee, has a drainage area of approximately 609 square miles (mi^2). Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Pickwick -- Shoal Creek Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Pickwick -- Shoal Creek Watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Pickwick -- Shoal Creek Watershed is forest (66.7%) followed by pasture (19.1%). Urban areas represent approximately 1.1% of the total drainage area of the watershed.

Figure 1. Location of the Pickwick -- Shoal Creek Watershed.

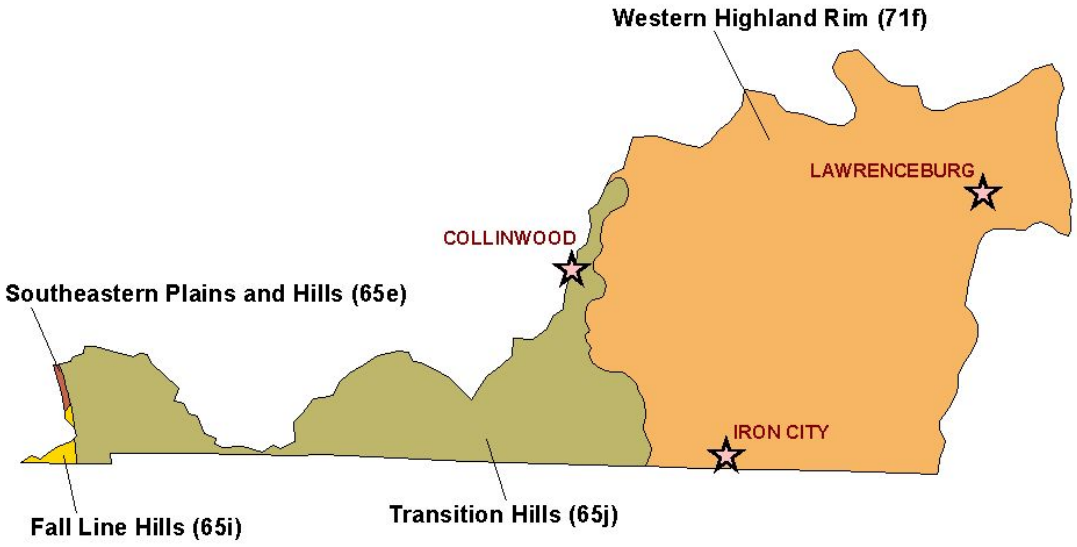

Figure 2. Level IV Ecoregions in the Pickwick -- Shoal Creek Watershed.

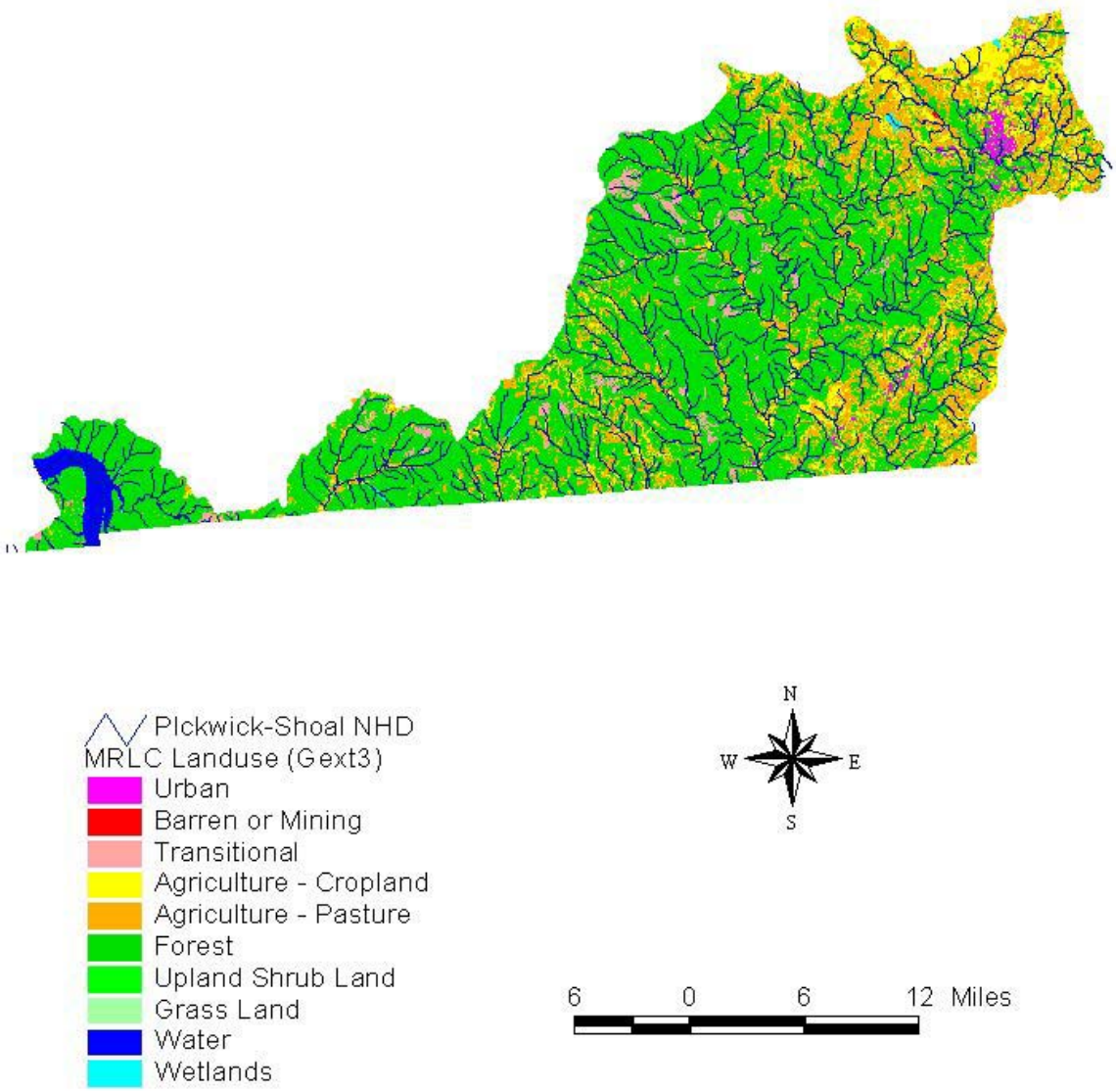

Figure 3. Land Use Characteristics of the Pickwick -- Shoal Creek Watershed.

Table 1. MRLC Land Use Distribution – Pickwick -- Shoal Creek Watershed

Land Use	Entire HUC8		Shoal Creek Watershed	
	[acres]	[%]	[acres]	[%]
Deciduous Forest	196,410	50.4	116,873	53.0
Emergent Herbaceous Wetlands	120	0.0	18	0.0
Evergreen Forest	27,628	7.1	10,213	4.6
High Intensity Commercial/Industrial/ Transportation	1,456	0.4	1,152	0.5
High Intensity Residential	378	0.1	317	0.1
Low Intensity Residential	2,418	0.6	1,788	0.8
Mixed Forest	35,936	9.2	17,481	7.9
Open Water	6,105	1.6	266	0.1
Other Grasses (Urban/recreational)	1,814	0.5	1,194	0.5
Pasture/Hay	74,228	19.1	44,596	20.2
Quarries/Strip Mines/ Gravel Pits	42	0.0	40	0.0
Row Crops	34,619	8.9	22,075	10.0
Transitional	7,210	1.9	4,2389	1.9
Woody Wetlands	983	0.3	345	0.2
Total	**389,347**	**100.0**	**220,596**	**100.0**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2004 303(d) list (TDEC, 2005) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in August of 2005. This list identified a portion of one waterbody in the Pickwick -- Shoal Creek Watershed as not supporting designated use classifications due, in part, to E. coli (see Table 2). The designated use classifications for the waterbody include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Shoal Creek, from the Alabama state line to Mile 56.9, is also designated for domestic and/or industrial water supply.

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

5.0 WATER QUALITY CRITERIA & TMDL TARGET

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

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

Shoal Creek, from mile 55.2 to mile 56.4, has been classified as a Tier II stream.

The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/199 ml) and the sample maximum of 487 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development.

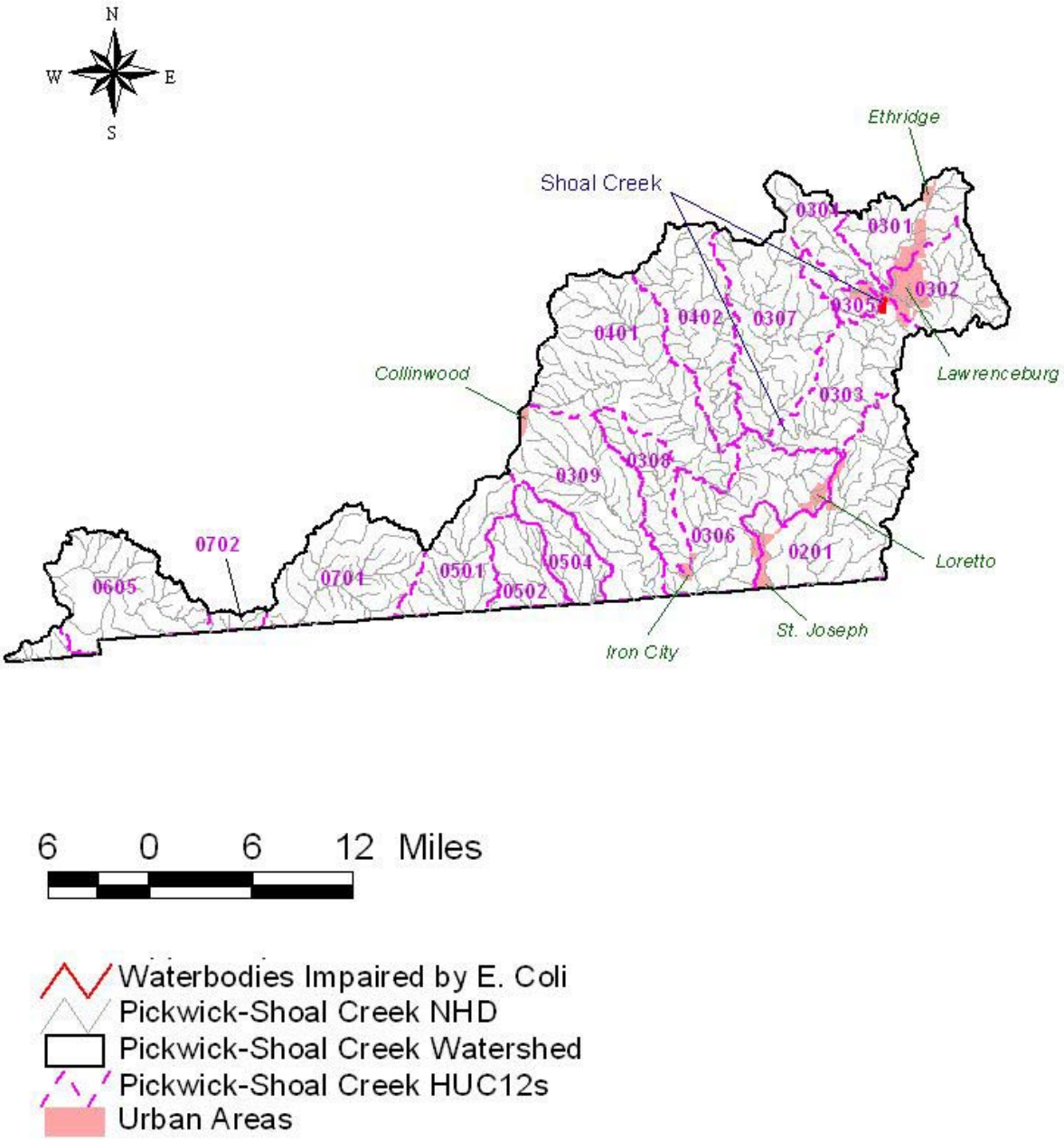

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2004 303(d) List).

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM GOAL

There are several water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Pickwick -- Shoal Creek Watershed:

- Shoal Creek Subwatershed:
    - SHOAL032.2LW – Shoal Creek, at West Point Bridge (Busby Rd.)
    - SHOAL055.2LW – Shoal Creek, d/s of Lawrenceburg STP
    - SHOAL055.7LW – Shoal Creek, at Hope Springs; 200 yds u/s of Hwy 64 @ Eaton Springs Park

The location of these monitoring stations is shown in Figure 5. Water quality monitoring results for these stations are tabulated in Appendix A. Examination of the data shows exceedances of the 487 CFU/100 mL maximum E. coli standard at many monitoring stations. Water quality monitoring results for those stations with 10% or more of samples exceeding water quality maximum criteria are summarized in Table 3.

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

Table 2. Final 2004 303(d) List for E. coli Impaired Waterbodies – Pickwick -- Shoal Creek Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06030005082 – 1000	SHOAL CREEK	2.3	Nitrates Siltation Escherichia coli	Nonirrigated Crop Production Industrial Point Source Municipal Point Source Pasture Grazing Land Development Collection System Failure

Table 3. Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 487 Counts/100 mL)				
		Data Pts.	Min. (CFU/100 ml)	Avg. (CFU/100 ml)	Max. (CFU/100 ml)	No. Exceed. WQ Max Target
SHOAL055.2LW	2002 – 2003	10	33	352	1,000	3

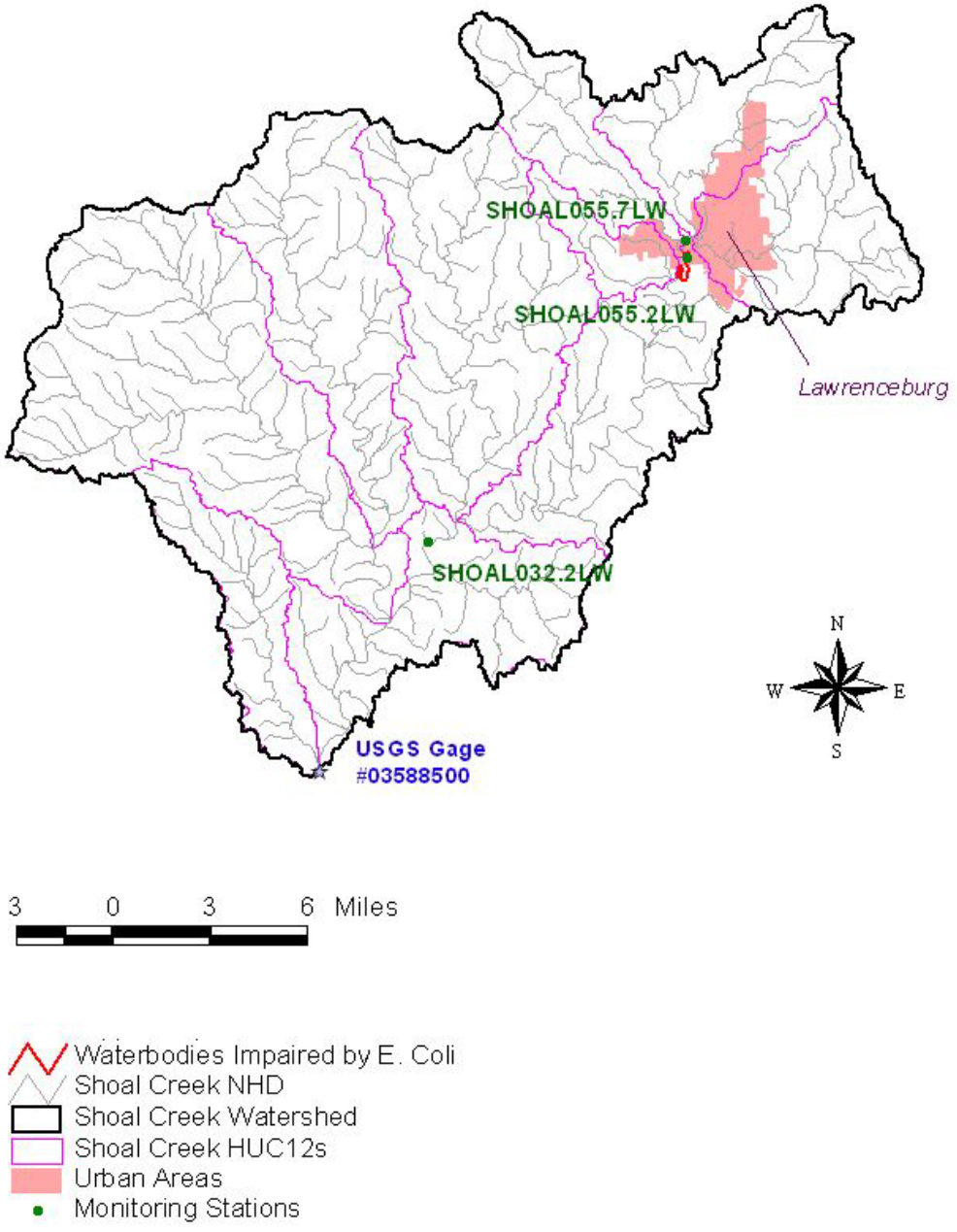

Figure 5. Water Quality Monitoring Stations in Shoal Creek

7.0 SOURCE ASSESSMENT

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

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

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There are 2 WWTFs in the Pickwick – Shoal Creek Watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. The permit limits for discharges from these WWTFs are in accordance with the coliform criteria specified in the Tennessee Water Quality Standards for the protection of the recreation use classification.

One of these facilities is located in an impaired subwatershed of the Pickwick -- Shoal Creek Watershed (see Figure 6). The Lawrenceburg Sewage Treatment Plant (STP) (TN0022551), with a design capacity of 4.5 MGD, discharges to Shoal Creek at Mile 55.4. According to a Compliance Evaluation Inspection conducted in June 2002, there have been numerous problems with excessive influent flows due to expansion of sewer service and increased infiltration and inflow. A discussion of the Shoal Creek data summary and the Enforcement Action (Agreed Order) in effect follows.

7.1.1.1 Background

On November 19, 1998, the division issued Lawrenceburg Utility Systems (hereinafter the "Respondent") a Director's Order number 98-027D that required a schedule for repairs of the STP and collection system, and implementation of that schedule. The order also required the Respondent to comply with the permit no later than March 1, 1999. The Respondent continued to have effluent violations and bypasses beyond the March 1, 1999, deadline.

On October 27, 2000, the division issued the Respondent a Commissioner's Order. The Respondent appealed the order and on March 21, 2001, the Tennessee Water Quality Control Board approved Agreed Order number 00-0487. The order required the Respondent to submit an engineering report outlining the city's corrective action plan (CAP) to bring the collection system into compliance with the permit, schedule of implementation of the CAP, and implementation of the CAP, to be completed by December 31, 2011.

During the monitoring period March 2001, through March 2003, the Respondent reported on discharge monitoring reports the following violations of permit parameters: 55 overflow or bypass events in the system constituting unpermitted discharges; 45 Carbonaceous Biochemical Oxygen Demand (CBOD) violations; 7 suspended solids violations; 2 *Fecal coliform* violations; 2 residual Chlorine violations; 10 Ammonia violations; 5 settleable solids violations; and 1 failure each of whole effluent toxicity testing for *Ceriodaphnia dubia* and *Pimephales promelas* species. In calendar year 2004, 12 overflows were reported and another 3 overflows were reported in the first three months of 2005.

The Respondent has continued to have operational difficulties, as indicated by the bypass and overflow events as well as the numerous effluent violations. The Respondent was in significant non-compliance for eleven consecutive quarters and listed on the United States Environmental Protection Agency's Quarterly Non-Compliance Report for BOD exceedances.

To date the Respondent appears to be in compliance with the 2000 commissioner's order. The Respondent received approval from the division to start implementing the rehabilitation. A $500,000.00 grant to fund the rehabilitation of the collection system has been approved according to the yearly progress report sent in by the Respondent on January 27, 2003. Plans and specification for plant expansion were approved by TDEC in April 2004. Plant expansion, combined with the sewer rehabilitation program, is expected to bring the plant back into compliance.

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 NPDES storm water permits. At present, there are no MS4s of this size in the Pickwick -- Shoal Creek 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, 2003). 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 least 1,000 people per square mile. There are no small MS4s in the Pickwick – Shoal Creek Watershed. 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, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point

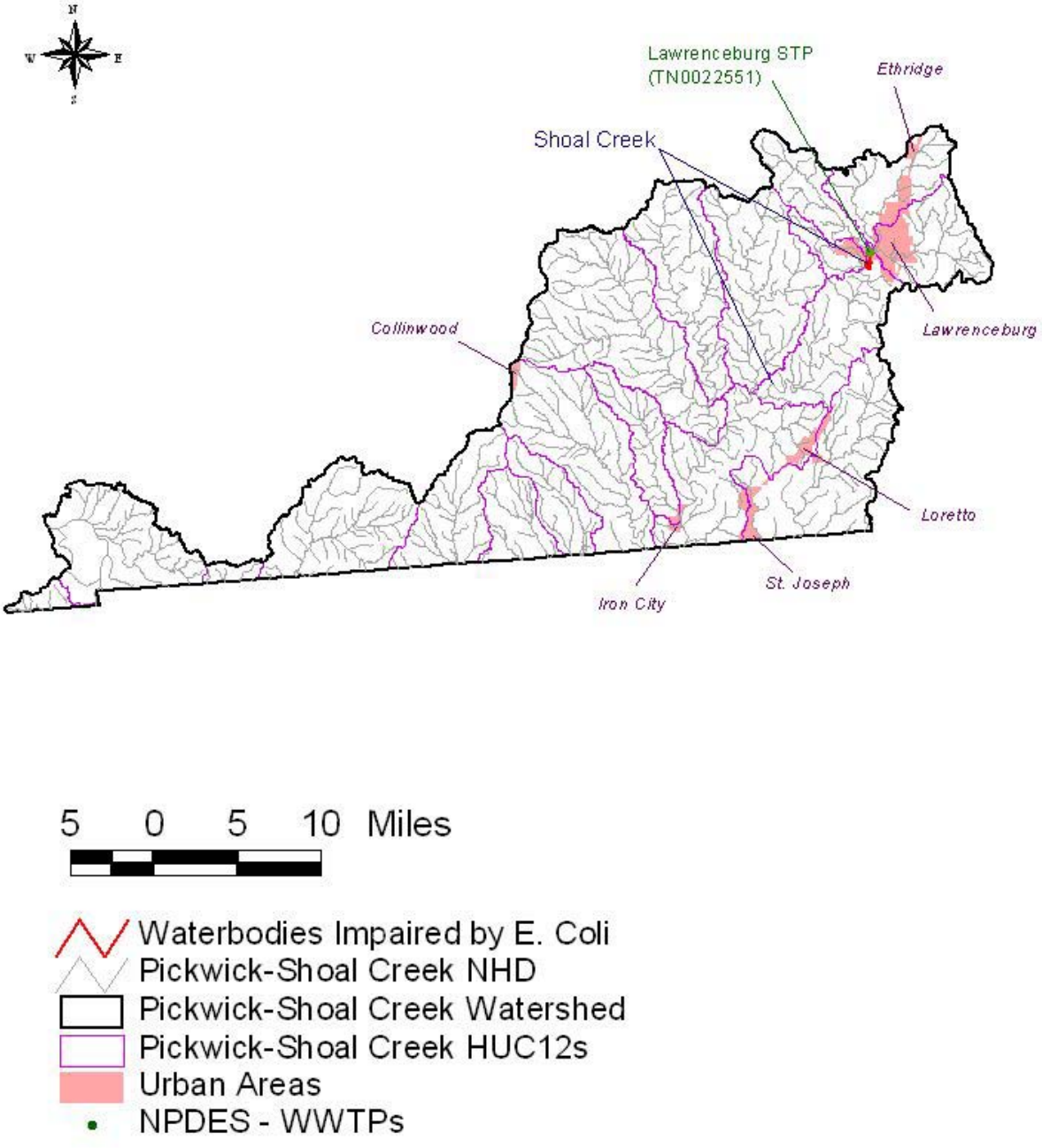

Figure 6. NPDES Regulated Point Sources in the Pickwick -- Shoal Creek Watershed.

sources of pathogen loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*, while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of May 5, 2005, there are no Class II CAFOs in the Pickwick -- Shoal Creek watershed with coverage under the general NPDES permit. There are also no Class I CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

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

7.2.1 Wildlife

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

7.2.2 Agricultural Animals

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

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

Potential data sources related to livestock operations include the 2002 Census of Agriculture, which was compiled for the Pickwick -- Shoal Creek Watershed utilizing the Watershed Characterization System (WCS). WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development. Livestock information provided in WCS is based on the ratio of watershed pasture area to county pasture area

applied to the livestock population within the county. Livestock data for the pathogen-impaired watershed is summarized in Table 5. Populations were rounded to the nearest 25 cows, 50 poultry, and 5 hogs, sheep, and horses.

Table 5. Livestock Distribution in the Pickwick -- Shoal Creek Watershed

Subwatershed	Livestock Population (WCS)					
	Beef Cow	Milk Cow	Poultry	Hogs	Sheep	Horse
Shoal Creek	12,575	1,275	50	3,670	95	3,365

7.2.3 Failing Septic Systems

Some coliform loading in the Pickwick -- Shoal Creek Watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in the Pickwick -- Shoal Creek Watershed utilizing septic systems were compiled using the WCS and are summarized in Table 6. In middle and eastern Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

Table 6. Population on Septic Systems in the Pickwick -- Shoal Creek Watershed

Subwatershed	Population on Septic Systems
Shoal Creek	12,971

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. All impaired subwatersheds in the Pickwick -- Shoal Creek Watershed have less than 2.0% urban land area.

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

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

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

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

8.1 Expression of TMDLs, WLAs, & LAs

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

8.2 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.

For Shoal Creek, a TMDL was developed by data summary and a simple mass balance approach. The TMDL for the Pickwick -- Shoal Creek Watershed was developed to assure compliance with the E. coli 126 CFU/100 mL geometric mean and 487 CFU/100 mL maximum.

The geometric mean of the E. coli data was calculated and the results compared to the E. coli geometric mean water quality standard of 126 CFU/100 mL. Results indicate that the geometric mean standard for E. coli was exceeded. For the purpose of expressing the TMDL as a percent reduction, the percent reduction relative to the water quality criteria (minus the MOS) results in a required reduction of 48.0%.

8.3 Critical Conditions and Seasonal Variation

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

Neither critical conditions nor seasonal variation could be determined with the limited available data. Further sampling and analysis is required.

8.4 Margin of Safety

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

8.5 Determination of TMDLs

Load reductions were developed for impaired segments in the Pickwick -- Shoal Creek Watershed to achieve compliance with the maximum target concentration for E. coli (Table 7). When sufficient data were available, load reductions were also developed to achieve compliance with the 30-day geometric mean target concentrations. The instream load reductions determined by these two methodologies were compared and the largest required load reduction was selected as the TMDL. TMDL load reductions for the impaired segments are shown in Table 8. In cases where the geometric mean could not be developed, it is assumed that achieving the load reduction based on the maximum target concentrations should result in attainment of the geometric mean criteria.

8.6 Determination of WLAs & LAs

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

Table 7. Required Load Reduction for Shoal Creek – Mile 55.2

Sample Date	E. Coli	
	Sample Concentration [cts/100 ml]	Required Reduction [%]
9/12/02	150	**NR**
10/9/02	690	29.4
11/13/02	150	**NR**
12/18/02	170	**NR**
1/22/03	55	**NR**
2/12/03	33	**NR**
3/11/03	1000	51.3
4/16/03	440	**NR**
5/29/03	660	26.2
6/24/03	170	**NR**
90th Percentile	**721**	**32.4**
Geometric Mean of All Sampling Data	**217.5**	**48.0**

Note: NR = Not Required
* 30-day Geometric Mean could not be calculated due to insufficient data.

Table 8. Determination of TMDLs for Impaired Waterbodies, Pickwick -- Shoal Creek Watershed

Impaired Waterbody Name	Impaired Waterbody ID	Required Load Reduction		
		Based on 90th Percentile	Based on Geometric Mean	TMDL [%]
SHOAL CREEK	TN06030005082 – 1000	**32.4**	**48.0**	**48.0**

Note: Load reductions were determined based on comparison of the geometric mean of all monitoring data to the 30-day geometric mean target concentrations. Additional monitoring is recommended.

Table 9 TMDLs, WLAs, & LAs for Impaired Waterbodies in the Pickwick-Shoal Watershed

Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs		LAs	
			WWTFs [a]		Precipitation Induced Nonpoint Sources	Other Direct Sources [b]
			Monthly Avg.	Daily Max.		
		[% Red.]	[CFU/day]	[CFU/day]	[% Red.]	[CFU/day]
Shoal Creek	TN06030005082 – 1000	48.0	2.146×10^{10}	8.295×10^{10}	48.0	0

a. Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.
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 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

9.0 IMPLEMENTATION PLAN

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

9.1 Point Sources

9.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times. 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 average loads in CFU per day. WLAs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day. In order to meet water quality criteria for the Pickwick -- Shoal Creek Watershed, all STPs must meet the provisions of their NPDES permits, including elimination of bypasses and overflows. The Lawrenceburg STP must also continue comply with the 2000 commissioner's order.

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, 2003) 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 proposed 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.

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

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

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

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

- Requirements regarding manure, litter, and wastewater land application BMPs.

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

Provisions of individual CAFO permits are similar. NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* is available on the TDEC website at http://www.state.tn.us/environment/wpc/programs/cafo/CAFO_GP_04.pdf

9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of pathogen loading from nonpoint sources (NPS) will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. 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.

BMPs have been utilized in the Pickwick -- Shoal Creek Watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in the Pickwick -- Shoal Creek Watershed during the TMDL evaluation period. The TDA keeps a database of BMPs implemented in Tennessee. Those listed in the Pickwick -- Shoal Creek Watershed are shown in Figure 7. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future modeling efforts.

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

9.3 Additional Monitoring

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

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

Additional monitoring and assessment activities are recommended for impaired waterbodies in the Pickwick -- Shoal Creek watershed. Examination of monitoring data indicates that few sampling events have occurred during the summer, no sampling events have occurred during periods of high flow, and few sampling events have occurred during dry periods and periods of low flow. Once monitoring representing all seasons and a full range of flow and meteorological conditions has been

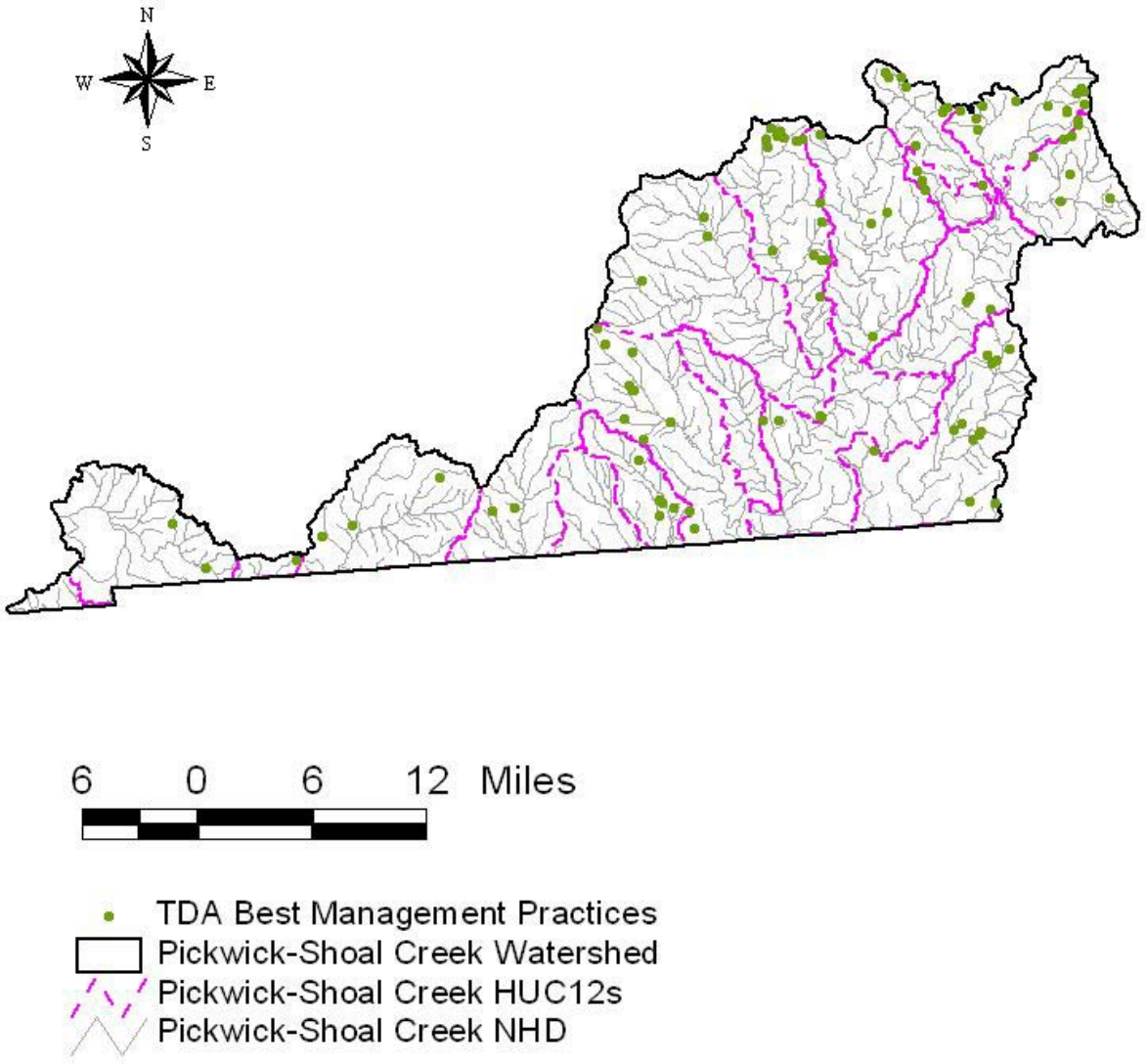

Figure 7. Tennessee Department of Agriculture Best Management Practices located in the Pickwick -- Shoal Creek Watershed.

obtained, the required load reductions may be revised. If additional monitoring indicates that Shoal Creek is no longer impaired, then Shoal Creek should be removed from the 303(d) list.

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 pathogen impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and pathogens affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in E. coli impaired waterbodies.

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

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

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

9.5 Evaluation of TMDL Implementation Effectiveness

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

10.0 PUBLIC PARTICIPATION

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

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

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

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

Lawrenceburg STP (TN0022551)

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:

Vicki S. Steed, P.E., Watershed Management Section
e-mail: Vicki.Steed@state.tn.us

Sherry H. Wang, Ph.D., Watershed Management Section
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APPENDIX A

Water Quality Monitoring Data

There are several water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Pickwick -- Shoal Creek Watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded by TDEC at these stations are tabulated in Table A-1.

Table A-1. Water Quality Monitoring Data – Pickwick – Shoal Creek Subwatersheds

Monitoring Station	Date	E. Coli [CFU/100 mL]
SHOAL032.2LW	9/23/98	78
	12/10/98	49
	3/17/99	1
	6/17/99	38
	9/1/99	77
	10/25/99	19
	1/20/00	11
	4/13/00	230
	7/25/00	20
	11/2/00	45
	3/28/01	7
	7/11/01	71
	10/24/01	93
	9/12/02	49
	11/13/02	90
	12/18/02	37
	1/22/03	10
	2/12/03	9
	3/11/03	2
	4/16/03	31
	5/29/03	20
	6/24/03	130
	7/15/03	100
	10/9/03	770

Monitoring Station	Date	E. Coli [CFU/100 mL]
SHOAL055.2LW	9/12/02	150
	10/9/02	690
	11/13/02	150
	12/18/02	170
	1/22/03	55
	2/12/03	33
	3/11/03	1000
	4/16/03	440
	5/29/03	660
	6/24/03	170
SHOAL055.7LW	9/12/02	130
	10/9/02	290
	11/13/02	410
	12/18/02	70
	1/22/03	23
	2/12/03	21
	3/11/03	98
	4/16/03	84
	5/29/03	630
	6/24/03	50

APPENDIX B

Public Notice Announcement

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

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN PICKWICK-SHOAL CREEK WATERSHED (HUC 06030005), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for E. coli in the Pickwick-Shoal Creek 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 single waterbody in the Pickwick-Shoal Creek watershed is listed on Tennessee's Final 2004 303(d) list as not supporting designated use classifications due, in part, to discharge of pathogens from sanitary sewer overflows (collection system failure). The TMDL utilizes Tennessee's general water quality criteria, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, site specific water quality monitoring data, a calibrated hydrologic model, load duration curves, and an appropriate Margin of Safety (MOS) to establish allowable loadings of pathogens which will result in the reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of pathogen loading on the order of 48% in the listed waterbody.

The proposed Pickwick-Shoal Creek E. coli TMDL may be downloaded from the Department of Environment and Conservation website:

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

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

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

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

Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than March 13, 2006 to:

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

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

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