TOTAL MAXIMUM DAILY LOAD (TMDL)

for
Low Dissolved Oxygen & Nutrients
in the
Upper Duck River Watershed (HUC 06040002)
Bedford, Coffee, Marshall, & Maury Counties, Tennessee

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July, 12, 2005

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
DO	Dissolved Oxygen
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
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
NHD	National Hydrography Dataset
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
PCS	Permit Compliance System
Rf3	Reach File v.3
RM	River Mile
STP	Sewerage 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
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for Low Dissolved Oxygen & Nutrients in Selected Waterbodies in the 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: Low dissolved oxygen & nutrients

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	RM Not Fully Supporting
TN06040002030 – 0310	CASCADE CREEK	2.7
TN06040002032 – 0300	CLEAR BRANCH	7.3
TN06040002038 – 0300	HURRICANE CREEK	29.4
TN06040002038 – 1000	FALL CREEK	11.4
TN06040002039 – 0100	CLEM CREEK	14.2
TN06040002039 – 0250	WEAKLEY CREEK	13.1
TN06040002039 – 3000	NORTH FORK CREEK	9.2
TN06040002046 – 1000	WILSON CREEK	19.5
TN06040002048 – 1000	CANEY CREEK	13.1

Designated Uses: The designated use classifications for the impaired waterbodies addressed in this document include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Scope of TMDLs: Stage I TMDLs will focus on HUC-12 subwatersheds that contain impaired headwater and tributary streams (wadeable) and do not contain existing wastewater treatment facilities (WWTFs). In Stage II, TMDLs, wasteload allocations (WLAs), and load allocations (LAs) for mainstem portions of larger waterbodies (non-wadeable) and waterbodies that receive wastewater treatment facility discharges will be developed. This document contains Stage I TMDLs, WLAs, and LAs for headwater and wadeable streams, as well as planning expectations for wastewater treatment facility dischargers to be covered in Stage II.

Water Quality Goal:

Dissolved oxygen criteria (most stringent – fish & aquatic life) of 5 mg/l minimum.

Instream dissolved oxygen concentrations are affected by a number of physical factors (sunlight, water velocity, ambient temperature, etc.) and pollutant loading. The most significant pollutant loading parameters include total nitrogen, total phosphorus, and carbonaceous biochemical oxygen demand ($CBOD_5$). For the purposes of TMDL development, the water quality goals specified for these parameters were determined to comply with the water quality criteria specified for dissolved oxygen, nutrients, and biological integrity in support of the fish & aquatic life classification.

Nutrient goals are a numeric interpretation of narrative criteria for nutrients and biological integrity and are derived from the 75th percentile values of total nitrogen (TN) and total phosphorus (TP) data collected at Level IV ecoregion reference sites. Ecoregion reference sites are considered to be "least impacted" and supportive of designated use classifications.

Since $CBOD_5$ was not routinely collected at ecoregion reference sites, an instream $CBOD_5$ concentration equal to the value specified in the Tennessee/EPA Stream Model Agreement as the background concentration (to be used for DO sag analysis when instream data is not available) was considered to be appropriate. This value is lower than the limited number of data points at ecoregion reference sites (typically <2 mg/l).

Level IV Ecoregion	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	$CBOD_5$ (mg/l)
71g	0.690	0.020	1.5
71h	0.728	0.060	1.5
71i	0.755	0.160	1.5

TMDL Development

Nutrients

Analysis Methodology:

- Calibrated LSPC model used to simulate daily mean flow at Level IV ecoregion (71g, 71h, & 71i) reference sites for a 10-year period. Daily nutrient loads were calculated through application of target ecoregion nutrient concentrations for each reference site.

- TMDLs were developed for total nitrogen, total phosphorus, and $CBOD_5$ by calculating the geometric mean of average semiannual loads, on a unit area basis, for reference sites in the same Level IV ecoregion and applying these loads to subwatersheds containing impaired waterbodies in the Upper Duck River watershed. TMDLs are expressed as average semiannual loads (lbs/6 mos).

- No WLAs are specified for existing WWTFs. WLAs for existing WWTFs are part of Stage II analysis.

- The failed collection system in the vicinity of Bomar Creek is considered to be part of the Shelbyville STP and is in violation of its NPDES permit (TN0024180). Correction of this condition will be accomplished through appropriate enforcement action rather than TMDL development.

- WLAs for CAFOs are considered to be zero.

- WLAs for MS4s and LAs are considered to be equal and are expressed as average semiannual loads per unit area (lbs/ac/6 mos).

- $CBOD_5$ TMDLs, WLAs, & LAs were developed for impaired subwatersheds only in cases where low dissolved oxygen was identified as a cause of waterbody impairment.

Seasonal Variation: Methodology addresses all seasons.

Margin of Safety (MOS): Explicit – 5% of the TMDL for each impaired subwatershed.
Implicit – Conservative modeling assumptions.

TMDL, WLAs, & LAs

Summary of Stage I Total Nitrogen TMDLs, WLAs, & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	26,580	NA	0	0.693	83,951	NA	0	2.187
0106	6,314	Cascade Creek	6,458	0.972	0	0.972	20,131	3.029	0	3.029
0308	25,097	Fall Creek Hurricane Creek	29,810	1.128	0	1.128	83,025	3.143	0	3.143
0401	11,446	North Fork Creek	13,697	NA	0	1.137	37,881	NA	0	3.144
0404	11,658	Weakley Creek	13,951	NA	0	1.137	38,582	NA	0	3.144
0405	9,496	Clem Creek	11,364	NA	0	1.137	31,427	NA	0	3.144
0502	10,248	Wilson Creek	12,264	NA	0	1.137	33,916	NA	0	3.144
0504	18,948	Caney Creek	22,449	NA	0	1.126	62,675	NA	0	3.142

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

Summary of Stage I Total Phosphorus TMDLs, WLAs, & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	769	NA	0	0.020	2,432	NA	0	0.063
0106	6,314	Cascade Creek	507	0.076	0	0.076	1,580	0.238	0	0.238
0308	25,097	Fall Creek Hurricane Creek	6,100	0.231	0	0.231	16,918	0.640	0	0.640
0401	11,446	North Fork Creek	2,903	NA	0	0.241	8,028	NA	0	0.666
0404	11,658	Weakley Creek	2,956	NA	0	0.241	8,177	NA	0	0.666
0405	9,496	Clem Creek	2,408	NA	0	0.241	6,660	NA	0	0.666
0502	10,248	Wilson Creek	2,599	NA	0	0.241	7,188	NA	0	0.666
0504	18,948	Caney Creek	4,538	NA	0	0.228	12,599	NA	0	0.632

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

Summary of Stage I $CBOD_5$ TMDLs, WLAs, & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	57,787	NA	0	1.506	182,509	NA	0	4.755

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

LOW DISSOLVED OXYGEN & NUTRIENT 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 pollutant loads from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

TMDLs for waterbodies in the Upper Duck River Watershed identified on the 2004 303(d) list as not fully supporting designated uses due to low dissolved oxygen (Low DO) or nutrients will be developed using a staged approach. Stage I TMDLs will focus on HUC-12 subwatersheds that contain impaired headwater or tributary streams (wadeable) and do not contain existing wastewater treatment facilities (WWTFs). For impaired waterbodies receiving WWTF discharges, near-field dissolved oxygen (DO) sag analysis will continue to be conducted on stream segments immediately downstream of WWTFs to verify compliance with water quality standards as required (*Note: DO sag analyses for WWTFs are not included in this document, but may be found in the appropriate permit modeling file*). In cases where waterbody impairment is attributed solely to a source that is the result of a violation of NPDES permit conditions, no TMDL will be developed. Corrective measures to eliminate the source of pollution will be accomplished through appropriate enforcement action.

Stage II TMDLs will address larger waterbodies (non-wadeable) that are impaired due to Low DO or nutrients and the far-field effects of WWTF nutrient discharges. Stage II TMDL development will be conducted on a larger area scale (up to a HUC-8 watershed area) and will utilize a number of data resources and analysis tools, including the effluent and instream nutrient data collected by WWTFs during Stage I. It is expected that implementation of Stage II TMDLs will include nutrient trading among point and nonpoint sources, if appropriate. Pollutant trading, including pollutant suitability analysis, financial attractiveness, identification of potential participants, and trading procedures, are presented in some detail in the *Water Quality Trading Assessment Handbook*, EPA 841-B-04-001 (USEPA, 2004).

This document presents details of Stage I TMDL development for waterbodies impaired by low dissolved oxygen or nutrients.

3.0 GENERAL WATERSHED OVERVIEW

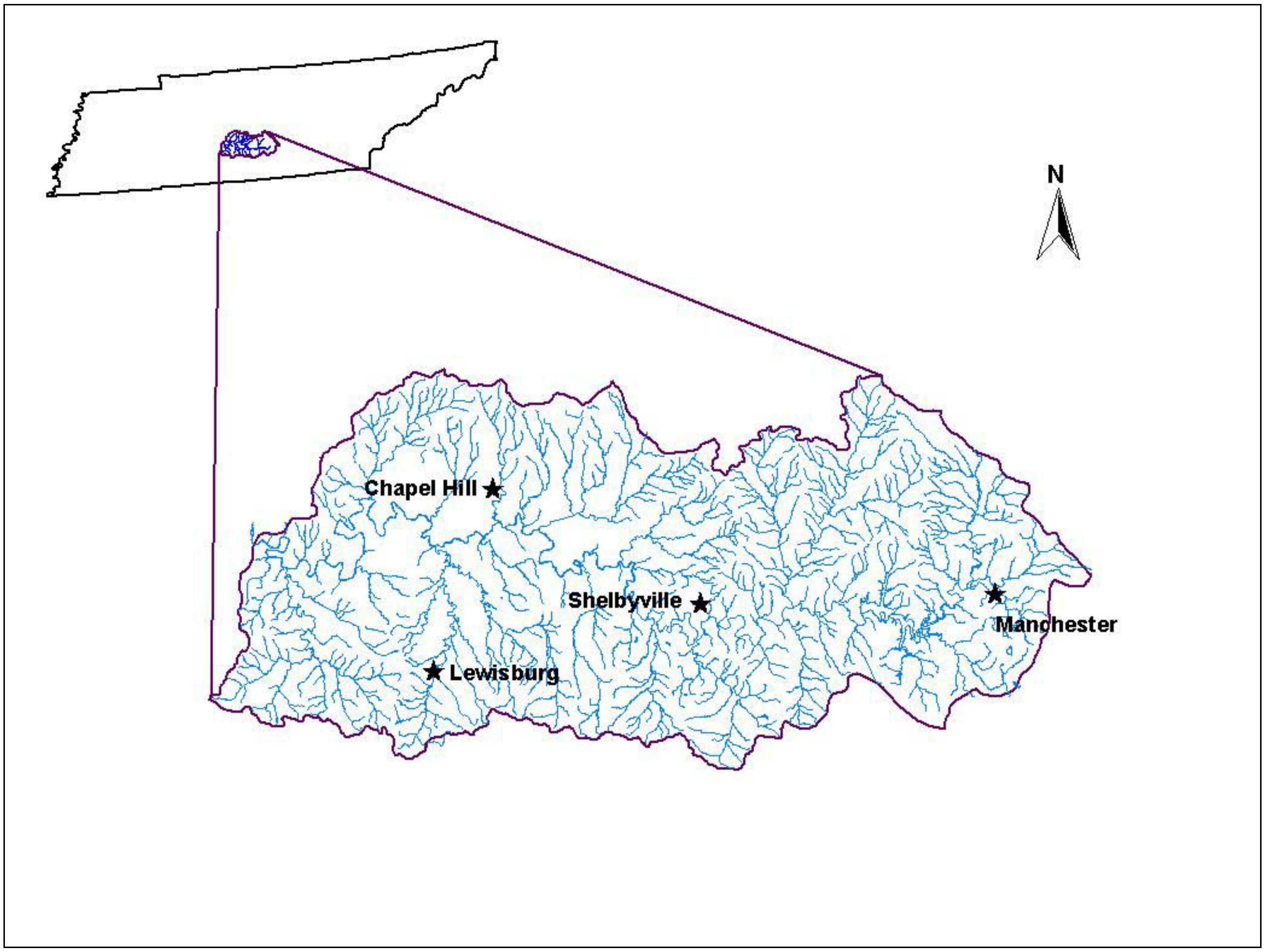
The Upper Duck River watershed (HUC 06040002) is located in Middle Tennessee (Figure 1) and is primarily located in Bedford, Coffee, Marshall, and Maury Counties. The watershed lies within the Level III Interior Plateau (71) ecoregion and contains three Level IV ecoregions as shown in Figure 2 (USEPA,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

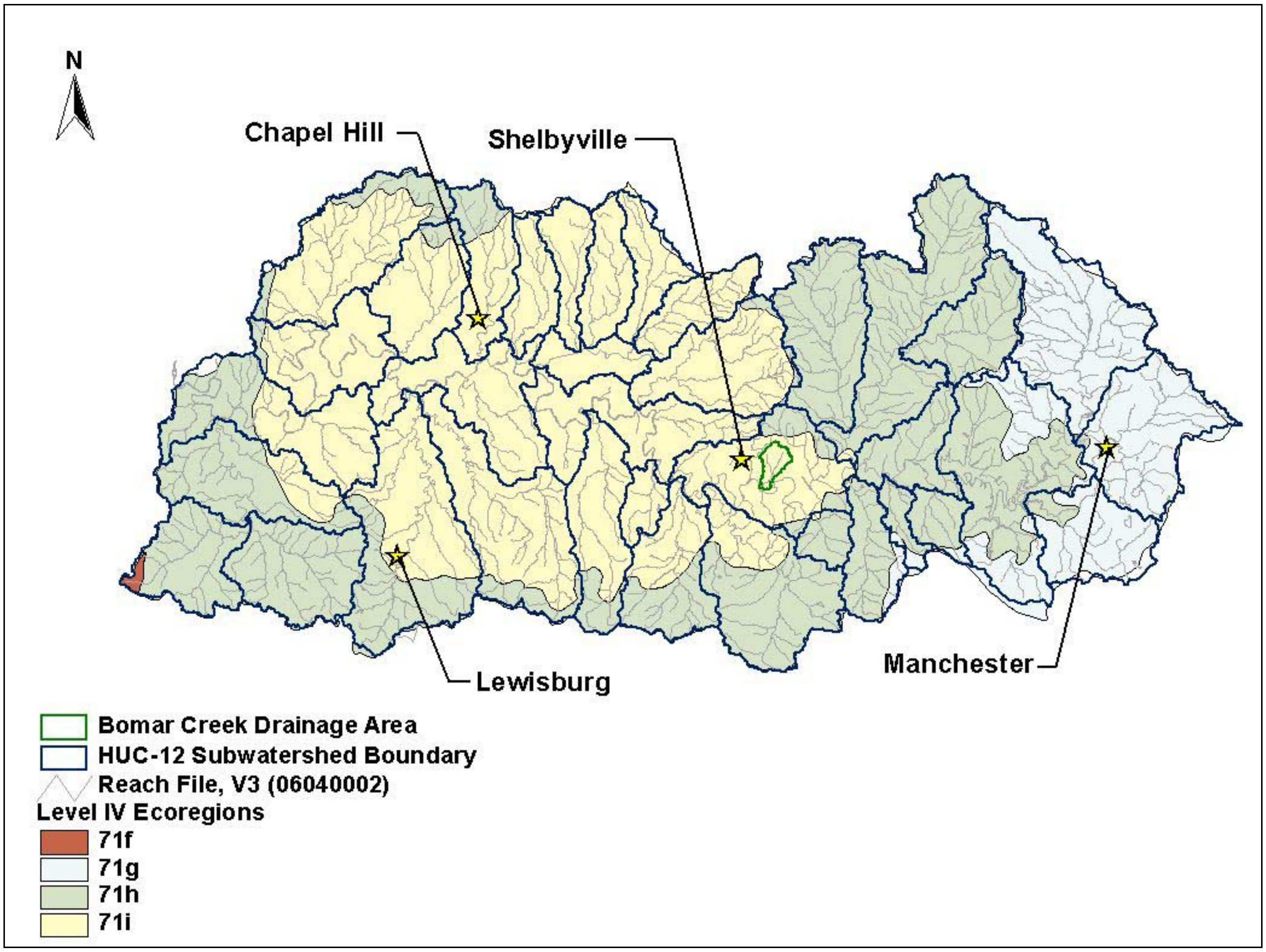
- Inner Nashville Basin (71i) is less hilly and lower than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the Outer Basin. Streams are lower gradient than surrounding regions, often flowing 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 1,182 square miles. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Upper Duck River watershed have occurred since 1993 as a result of rapid development, this is the most current land use data available. Land use for the Upper Duck River watershed is summarized in Table 1 and shown in Figure 3.

Figure 2 Level IV Ecoregions in the Upper Duck River Watershed



Note: Stage I TMDLs will be developed primarily on a HUC-12 subwatershed or a waterbody drainage area basis. HUC-12 subwatershed boundaries and waterbody drainage areas are shown in figures for reference.

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

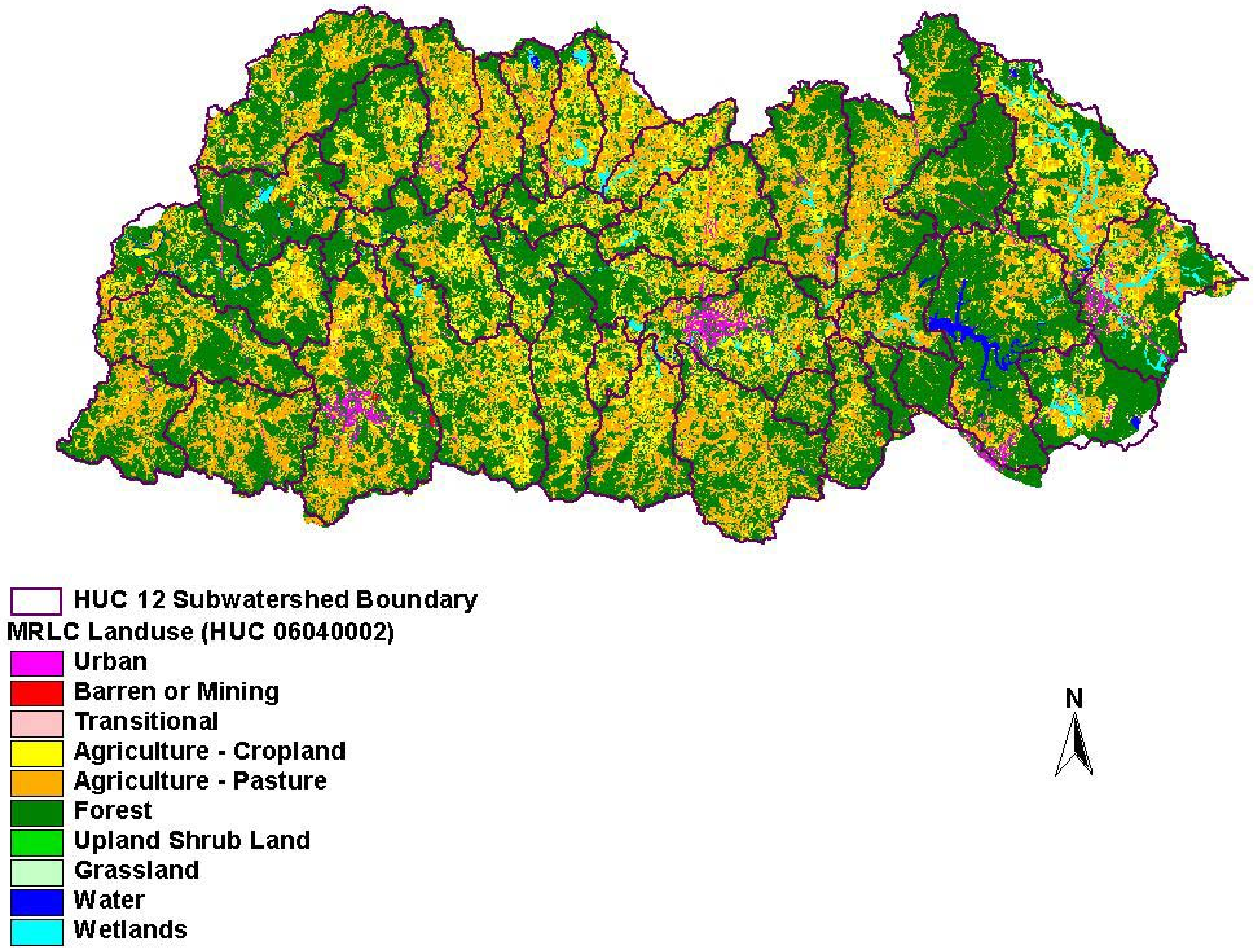


Table 1 MRLC Land Use Distribution – Upper Duck River Watershed

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**

A comprehensive general resource for information regarding the Upper Duck River watershed is the *Upper Duck River Watershed (06040002) of the Tennessee River Basin, Watershed Water Quality Management Plan* (TDEC, 2005). This document includes chapters on watershed description, water quality assessment, point and nonpoint sources, water quality partnerships, and future direction. The plan is available on the TDEC website at:
http://www.state.tn.us/environment/wpc/watershed/wsmplans/.

4.0 PROBLEM DEFINITION

The State of Tennessee's proposed final 2004 303(d) list (TDEC, 2005a) identified a number of waterbodies in the Upper Duck River watershed as not fully supporting designated use classifications due to low dissolved oxygen or nutrients. 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. This section includes all of Normandy Lake to approximately 4.6 miles downstream of Normandy Dam. Waterbodies in the Upper Duck River watershed identified as impaired for low dissolved oxygen or nutrients on the proposed 2004 303(d) list are summarized in Table 2 and shown in Figure 4.

Instream dissolved oxygen concentrations are affected by a number of physical factors (sunlight, water velocity, ambient temperature, etc.) and pollutant loading. The most significant pollutant loading parameters include total nitrogen, total phosphorus, and carbonaceous biochemical oxygen demand ($CBOD_5$).

Nutrient rich waters entering streams can cause abundant algae growth. The right combination of nutrients, algae, and sunlight may result in extreme dissolved oxygen fluctuations in the stream. Oxygen is produced during photosynthesis and consumed during respiration and decomposition. Because it requires light, photosynthesis occurs only during daylight hours. At night, photosynthesis cannot counterbalance the loss of oxygen through respiration and decomposition so dissolved oxygen concentrations decline (TDEC, 2003). CBOD5 is a measure of the oxygen demand associated with the biochemical oxidation of carbonaceous organic matter. The interrelationship of major kinetic processes associated with instream dissolved oxygen are shown schematically in Figure 5. A more detailed discussion of the relationship between nutrients and water quality is presented in Appendix A.

A description of the stream assessment process in Tennessee can be found in *2004 305(b) Report, The Status of Water Quality in Tennessee* (TDEC, 2004). This document states that "biological surveys using macroinvertebrates as the indicator organisms are the preferred method for assessing support of the fish & aquatic life designated use." With respect to nutrients, the document also states "Waters are not generally assessed as impaired by nutrients unless biological or aesthetic impacts are also documented." The waterbody segments listed in Table 2 were assessed as impaired based primarily on biological surveys. The results of these assessment surveys are summarized in Table 3. The assessment information presented is excerpted from the EPA/TDEC Assessment Database (ADB) and is referenced to the waterbody IDs in Table 2. ADB information may be accessed at: http://gwidc.memphis.edu/website/dwpc/ . A typical example of a stream assessment (Fall Creek) is shown in Appendix B.

Table 2 Proposed 2004 303(d) List – Stream Impairment Due to Low Dissolved Oxygen & Nutrients in the Upper Duck River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE (Pollutant)	Pollutant Source	**TMDL Development Stage**
TN06040002012 - 2000	BIG ROCK CREEK	9.0	Nutrients Siltation Low Dissolved Oxygen	Major Municipal Point Source Discharges from MS4 area	II
TN06040002027 – 0200	BOMAR CREEK	4.1	Nutrients Low Dissolved Oxygen	Collection System Failure	NA *
TN06040002030 – 0310	CASCADE CREEK	2.7	Nutrients Escherichia coli	Confined Animal Feeding Operations (NPS)	I
TN06040002032 – 0300	CLEAR BRANCH	7.3	Phosphate Low Dissolved Oxygen Escherichia coli	Agriculture	I
TN06040002038 – 0300	HURRICANE CREEK	29.4	Escherichia coli Nutrients Loss of biological integrity due to siltation Other Habitat Alterations	Pasture Grazing	I
TN06040002038 – 1000	FALL CREEK	11.4	Escherichia coli Nutrients Loss of biological integrity due to siltation Other Habitat Alterations	Pasture Grazing	I
TN06040002039 – 0100	CLEM CREEK	14.2	Nutrients Escherichia coli	Pasture Grazing	I
TN0604002039 - 0250	WEAKLEY CREEK	13.1	Loss of biological integrity due to siltation Nutrients Escherichia coli	Agriculture	I

* No TMDL will be developed for Bomar Creek. The collection system failure is prohibited by the Shelbyville STP NPDES permit (TN0024180). Correction of this condition will be accomplished through appropriate enforcement action.

Table 2 (Contd.) Proposed 2004 303(d) List – Stream Impairment Due to Low Dissolved Oxygen & Nutrients in the Upper Duck River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE (Pollutant)	Pollutant Source	**TMDL Development Stage**
TN06040002039 - 2000	NORTH FORK CREEK	4.0	Escherichia coli Nutrients	Agriculture	II
TN06040002039 - 3000	NORTH FORK CREEK	9.2	Loss of biological integrity due to siltation Nutrients Escherichia coli	Agriculture	I
TN06040002046 – 1000	WILSON CREEK	19.5	Escherichia coli Nitrate Other Habitat Alterations	Pasture Grazing	I
TN06040002048 – 1000	CANEY CREEK	13.1	Nitrate Loss of biological integrity due to siltation	Livestock in Stream Removal of Riparian Vegetation	I

Figure 4 Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients (Documented on the Proposed 2004 303d List)

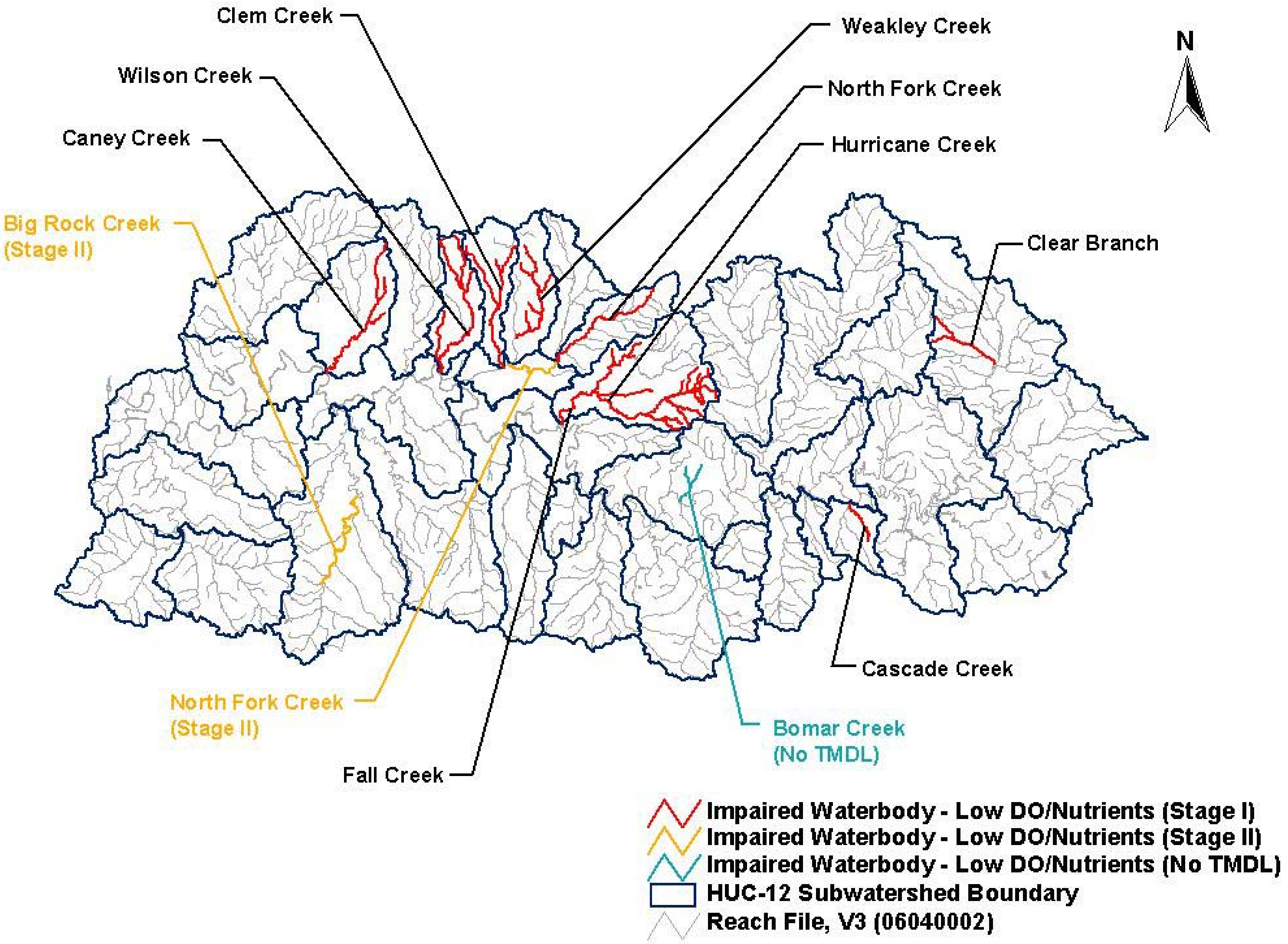


Figure 5 Interrelationship of Major Kinetic Processes Associated with Instream Dissolved Oxygen (USEPA, 1997a)

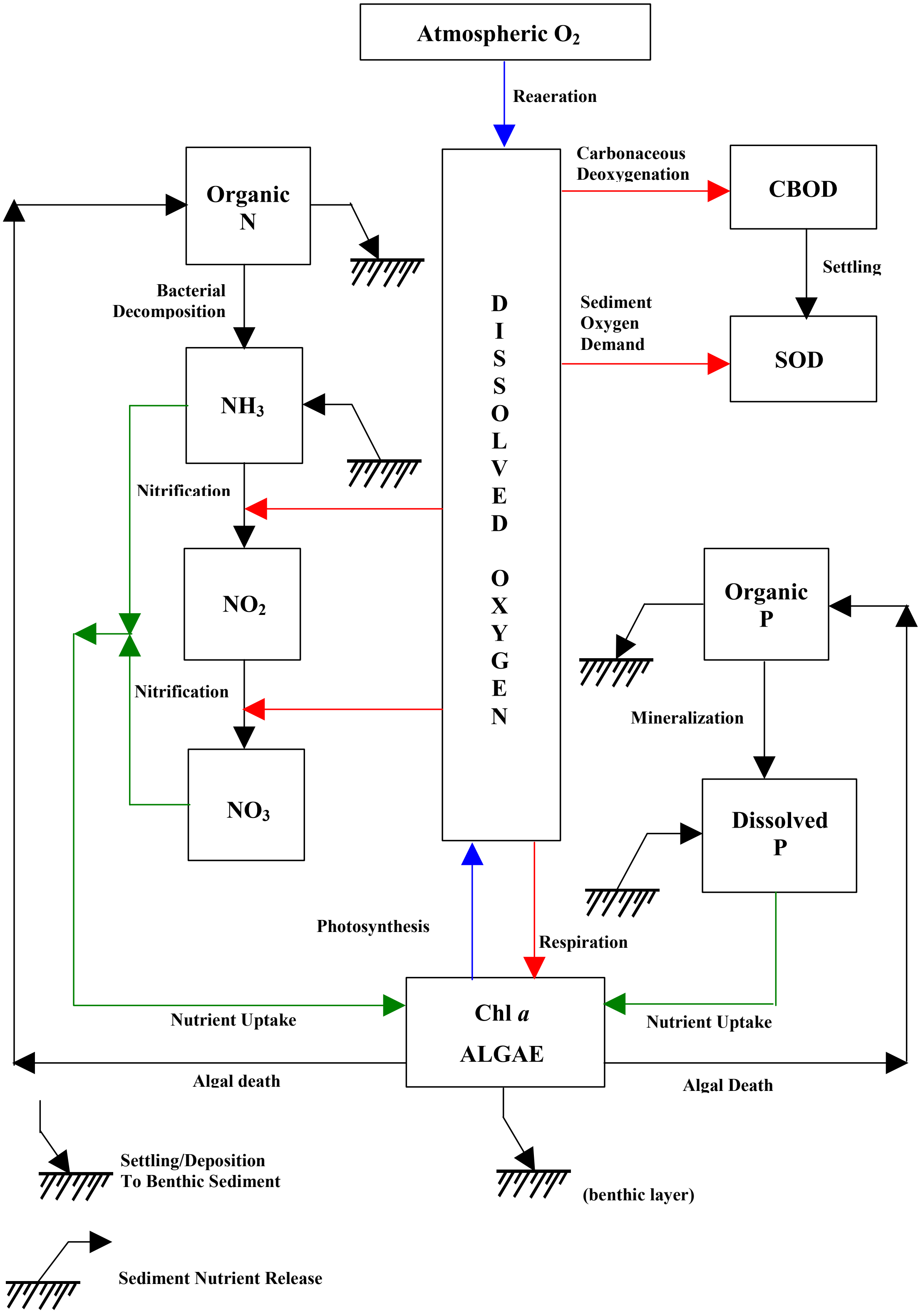


Table 3 Water Quality Assessment of Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients – Upper Duck River Watershed

Waterbody ID	Segment Name	Comments
TN06040002012_2000	Big Rock Creek (Dry Branch to Collins Hollow Road)	1999 TDEC biological survey at RM 16.8 (Hwy 431, d/s STP). 3 EPT families, 21 total families. Habitat score = 123. Chemical samples also at Highway 31A. Nutrients elevated. 1997 TVA survey at RM 11.5 (McBride Road). 4 EPT families.
TN06040002027 - 0200	Bomar Creek (Duck River to headwaters)	TDEC biological survey at RM 0.6 (off Highway 64). 1 EPT family, 14 total families. Habitat score = 130.
TN06040002030 - 0310	Cascade Creek (Norman Creek to headwaters)	Complaint investigation to animal waste practices.
TN06040002032 - 0300	Clear Branch (Duck River to headwaters)	1999 TDEC biological station at RM 1.1 (Dawson Road). Zero EPT family, 6 total families. Habitat score = 117.
TN06040002038 - 0300	Hurricane Creek (Fall Creek to headwaters)	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 (Duck River to headwaters)	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 (North Fork Creek to headwaters)	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 - 0250	Weakley Creek (Unnamed tributary to headwaters)	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.

Table 3 (Contd.) Water Quality Assessment of Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients – Upper Duck River Watershed

Waterbody ID	Segment Name	Comments
TN06040002039 - 2000	North Fork Creek (Weakley Creek to Alexander Creek)	TDEC 2000 probabilistic monitoring station at mile 7.7 at Highway 41A. Violated proposed biocriteria for 71i. 1997 TVA biological survey at Highway 41A. 8 families, 27 total families.
TN06040002039 - 3000	North Fork Creek (Alexander Creek to headwaters)	TDEC 2000 probabilistic monitoring station at mile 16.4 d/s of Squire Hall Road. Violated proposed biocriteria for 71i.
TN06040002046 - 1000	Wilson Creek (Duck River to headwaters)	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.
TN06040002048 - 1000	Caney Creek (Duck River to headwaters)	2001 TVA biorecon at Lunns Store Rd. 3 EPT families, 1 intolerant, 17 total families. 1999 TDEC biorecons at mile 2.6 & 4.2. 5 EPT families, 20 total, habitat = 124, at mile 2.6. 1997 TVA biorecon at Lunns Store. Road. 6 EPT families, 21 total.

5.0 WATER QUALITY GOAL

5.1 Water Quality Criteria

Several narrative criteria, applicable to nutrients, are established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, January, 2004* (TDEC, 2004a):

Applicable to all use classifications (except for fish & aquatic life):

> Dissolved Oxygen – There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

Applicable to fish & aquatic life and recreation (fish & aquatic life shown):

> Nutrients - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and /or the biological integrity fails to meet regional goals. Additionally, the quality of downstream waters shall not be detrimentally affected.
>
> Interpretation of this provision may be made using the document Development of Regionally based Interpretations of Tennessee’s Narrative Nutrient Criterion and/or other scientifically defensible methods.

Applicable to the fish & aquatic life use classification:

> Biological Integrity - The waters shall not be modified through the addition of pollutants or through physical alteration to the extent that the diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or adversely affected, except as allowed under 1200-4-3-.06.
>
> Interpretation of this provision for any stream which (a) has at least 80% of the upstream catchment area contained within a single bioregion and (b) is of the appropriate stream order specified for the bioregion and (c) contains the habitat (riffle or rooted bank) specified for the bioregion, may be made using the most current revision of the Department’s Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys and/or other scientifically defensible methods.
>
> Interpretation of this provision for all other streams, plus large rivers, reservoirs, and wetlands, may be made using Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA/841-B-99-002) and/or other scientifically defensible methods. Effects to biological populations will be measured by comparisons to upstream conditions or to appropriately selected reference sites in the same bioregion if upstream conditions are determined to be degraded.

In addition, numerical dissolved oxygen criteria are specified for the protection of fish & aquatic life:

> Dissolved Oxygen - The dissolved oxygen shall not be less than 5.0 mg/l with the following exceptions. In streams identified as trout streams, including tailwaters, dissolved oxygen shall not be less than 6 mg/L. The dissolved oxygen concentration of trout waters designated as supporting a naturally reproducing population shall not be less than 8.0 mg/L. (Tributaries to trout streams or naturally reproducing trout streams should be considered to be trout streams or naturally reproducing trout streams, unless demonstrated otherwise. Additionally, all streams within the Great Smoky Mountains National Park should be considered naturally reproducing trout streams.) In wadeable streams in subecoregion 73a and subecoregion 71i, dissolved oxygen levels shall not be less than a daily average of 5 mg/L with a minimum dissolved oxygen level of 4 mg/L. The dissolved oxygen level of streams in ecoregion 66 (Blue Ridge Mountains) not designated as naturally reproducing trout streams shall not be less than 7.0 mg/L.
>
> Substantial and/or frequent variations in dissolved oxygen levels, including diurnal fluctuations, are undesirable if caused by man-induced conditions.
>
> In lakes and reservoirs, the dissolved oxygen concentrations shall be measured at mid-depth in waters having a total depth of ten feet or less, and at a depth of five feet in waters having a total depth of greater than ten feet and shall not be less than 5.0 mg/L.

Note: Revisions to Tennessee's Water Quality Standards were adopted by the Tennessee Water Quality Control Board on September 23, 2003 and submitted to EPA Region IV for approval on October 24, 2003. With the exception of four provisions that were still under review, EPA approved the revisions on September 30, 2004 (USEPA, 2004a). These exceptions include:

- *Revision to dissolved oxygen criteria in subecoregion 71i for the fish & aquatic life use classification.*
- *Revision to pH criteria in subecoregions 68a, 65j, & 74b for the fish & aquatic life use classification.*
- *Revision to pH criteria for the recreation use classification.*
- *Revision to minimum flows in the interpretation of criteria.*

The 1999 Standards (TDEC, 1999) will be applied in cases where revisions were not approved by EPA.

These TMDLs are being established to attain the fish and aquatic life designated use, which is the most stringent. A TMDL established to protect the fish and aquatic life use will protect all other uses for the identified waterbodies from adverse alteration due to low dissolved oxygen and excessive nutrient loading.

5.2 TMDL Water Quality Goal

As discussed in Section 4.0 and Appendix A, instream dissolved oxygen concentrations are affected by a number of physical factors (sunlight, water velocity, ambient temperature, etc.) and pollutant loading. The most significant pollutant loading parameters include total nitrogen, total phosphorus, and carbonaceous biochemical oxygen demand ($CBOD_5$).

Nutrients

In order for a TMDL to be established, a numeric "goal" protective of the uses of the waterbody must be identified to serve as the basis for the TMDL. Where State regulation provides a numeric water quality criteria for the pollutant, the criteria is the basis for the TMDL. Where state regulation does not provide a numeric water quality criteria at present, as in the case of nutrients, a numeric interpretation of the narrative water quality standard must be determined.

One of the three methods mentioned in *Nutrient Criteria Technical Guidance Manual, Rivers and Streams* (USEPA, 2000) that can be used in developing nutrient criteria is the reference stream reach approach. Reference reaches are relatively undisturbed stream segments that can serve as examples of the natural biological integrity of a region. One of the ways to establish criteria (or goal) is the selection of a percentile from the distribution of primary variables of known reference systems. Primary variables include both causal variables, total nitrogen (TN) and total phosphorus (TP), and response variables, algal biomass as chlorophyll *a* and turbidity or transparency. EPA recommends the use of the 75th percentile value as the reference condition.

For the purposes of this TMDL, and in accordance with the standards for nutrients and biological integrity, the 75th percentile values of total nitrogen (TN) and total phosphorus (TP) data collected at Tennessee's Level IV ecoregion reference sites were determined to be the appropriate numeric interpretation of the narrative water quality standard (the location of these reference sites are shown in Figure E-1). The watersheds corresponding to these reference sites are considered the "least impacted" in the ecoregion and, as such, nutrient loading from these subwatersheds may serve as the appropriate basis for the TMDL water quality goal. The nutrient concentration goals, corresponding to the 75th percentile data for Level IV ecoregions 71g, 71h, & 71i are:

Level IV Ecoregion	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)
71g	0.690	0.020
71h	0.728	0.060
71i	0.755	0.160

Note: Ecoregion reference sites are continuously sampled and evaluated, with sites added or deleted as circumstances warrant. The values shown were determined based on ecoregion reference sites as of June 3, 2003.

$CBOD_5$

Since $CBOD_5$ was not routinely collected at ecoregion reference sites, an instream $CBOD_5$ concentration of 1.5 mg/l was considered to be an appropriate water quality goal for Stage I TMDL development. This value is specified in the Tennessee/EPA Stream Model Agreement as the background concentration to be used for DO sag analysis when instream data is not available and is lower than the limited number of data points at ecoregion reference sites (typically <2 mg/l).

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM WATER QUALITY GOAL

There are a number of water quality monitoring stations that provide chemical data for Stage I TMDL development for waterbodies identified as impaired for low dissolved oxygen or nutrients in the Upper Duck River watershed:

- CANEY002.6ML – Caney Creek at Pyles Road. (~RM 2.6)
- CASCA000.7BE – Cascade Creek at Cascade Hollow Road (~RM 0.7).
- CLEAR001.1CE – Clear Branch, 100 feet downstream of Dawson Road. (~RM 1.1).
- CLEAR001.8CE - Clear Branch at Elrod Road. (~RM 1.8).
- CLEM000.4BE – Clem Creek, 200 yards downstream of Old Pencil Mill Road (~RM 0.4).
- FALL001.2BE – Fall Creek at Highway 41A (~RM 1.2).
- FALL003.0BE – Fall Creek downstream of Gregory Mill Road (~RM 3.0).
- FALL004.7BE – Fall Creek at Old Nashville Dirt Road (~RM 4.7).
- 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).
- NFORK009.4BE – North Fork Creek, off Unionville-Deason Road (~RM 9.4).
- NFORK016.4BE – North Fork Creek, ¼ mile downstream of Squire Hall Road (~RM 16.4).
- WEAKL000.2BE – Weakley Creek at Halls Mill Road (~RM 0.2).
- 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 6. Water quality monitoring results for all stations are tabulated in Appendix C and summarized in Table 4 (see note below). Examination of this data shows occasional violation of the instream dissolved oxygen standard and a number of instances where the target total nitrogen and total phosphorus concentrations are exceeded. Based on a review of available instream monitoring data and stream assessment data sheets, impairment causes of low dissolved oxygen nutrients in these waterbodies are considered to be primarily due to high nutrient loading.

Figure 6 Selected Water Quality Monitoring Stations in the Upper Duck River Watershed

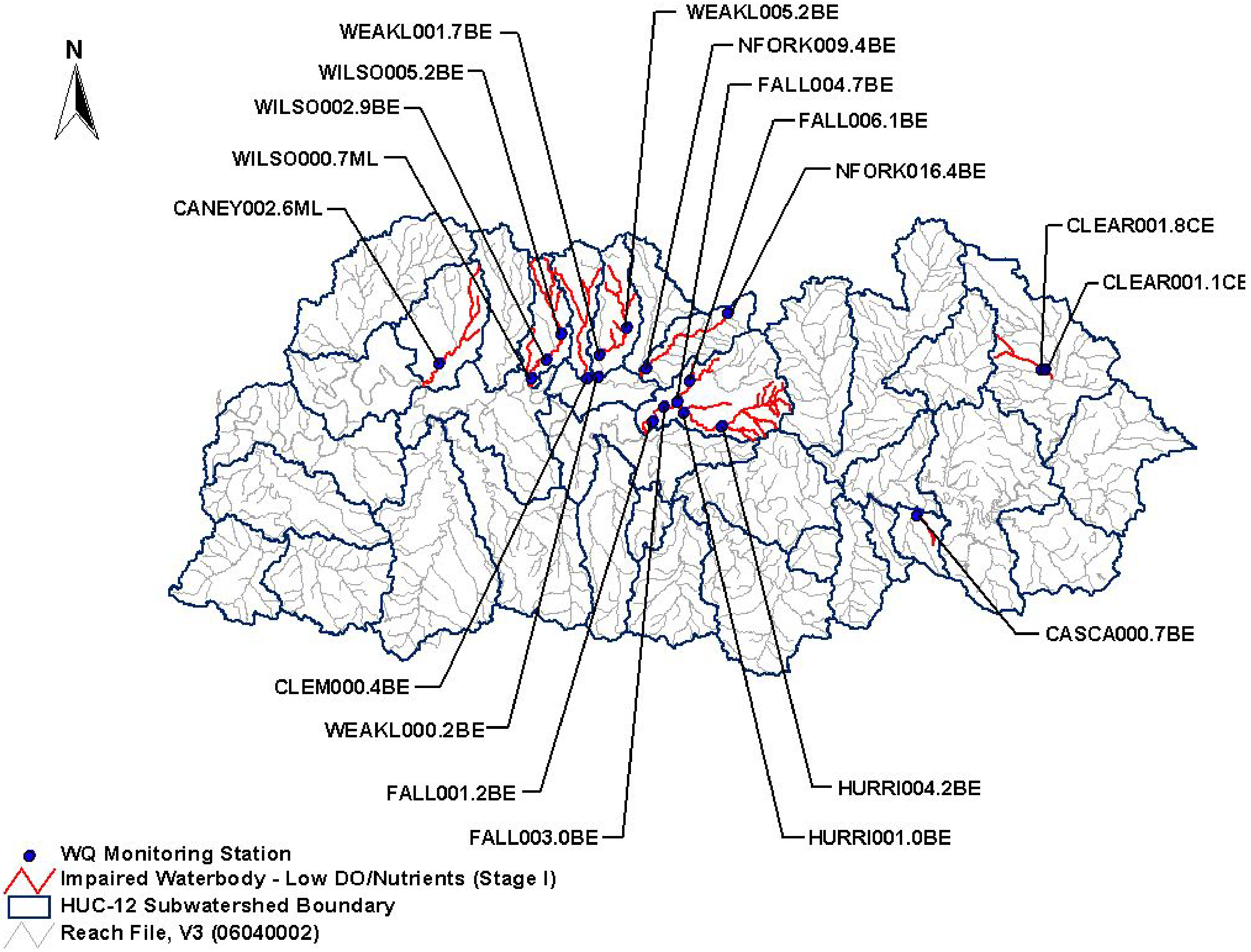


Table 4 Summary of Water Quality Monitoring Data

Monitoring Station	Dissolved Oxygen					Total Nitrogen *				Total Phosphorus			
	Data Pts.	Min.	Avg.	Max.	No. Viol. WQ Std.	Data Pts.	Min.	Avg.	Max.	Data Pts.	Min.	Avg.	Max.
		[mg/l]	[mg/l]	[mg/l]			[mg/l]	[mg/l]	[mg/l]		[mg/l]	[mg/l]	[mg/l]
CANEY002.6ML	7	7.01	12.05	15.0	0	3	1.42	2.25	3.56	3	0.01	0.04	0.07
CASCA000.7BE	13	7.27	10.99	14.41	0	10	0.29	0.76	1.11	9	0.004	0.01	0.05
CLEAR001.1CE	12	2.09	7.43	11.4	4	9	0.35	1.46	2.4	11	0.004	0.42	2.0
CLEAR001.8CE	1		2.55		1	1		6.97		1		0.63	
CLEM000.4BE	5	3.73	11.09	16.37	1	4	1.13	1.43	1.73	5	0.004	0.01	0.05
FALL001.2BE	1		8.24		0	1		0.8		1		0.004	
FALL003.0BE	5	3.10	7.67	10.41	1	4	0.11	1.13	2.24	5	0.004	0.03	0.07
FALL004.7BE	5	2.25	8.23	15.63	1	6	0.19	0.64	1.39	6	0.004	0.04	0.09
FALL006.1BE	1		5.02		0	1		0.99		1		0.12	
HURRI001.0BE	7	3.62	8.81	13.8	1	7	0.23	0.60	1.1	7	0.004	0.04	0.12
HURRI004.2BE	5	3.28	9.55	14.77	1	4	0.35	1.03	2.58	5	0.004	0.005	0.009
NFORK009.4BE	5	4.55	8.54	15.24	1	6	0.22	0.95	1.81	60.025	0.303	1.29	
NFORK016.4BE	3	7.17	8.39	9.05	0	2	1.67	3.77	5.87	3	0.02	0.03	0.04
WEAKL000.2BE	5	5.4	9.79	15.82	0	6	0.19	0.80	1.36	6	0.004	0.02	0.03
WEAKL001.7BE	1		3.79		1	1		0.12		1		0.01	
WEAKL005.2BE	3	6.90	9.98	13.37	0	2	1.68	2.29	2.90	3	0.019	0.056	0.10
WILSO000.7ML	3	10.1	12.2	14.85	0	—				—			
WILSO002.9ML	4	10.7	11.9	13.6	0	1		1.26		1		0.14	
WILSO005.2ML	6	6.93	9.10	12.1	0	5	1.66	2.80	5.26	6	0.004	0.039	0.097

* For all stations, total nitrogen data corresponds to sum of NO3+NO2 plus TKN for each sample date (see Tables C-1 & C-2). Values shown are a summary of calculated total nitrogen data.

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 nutrient loading and the amount of loading contributed by each of these sources. Pollutants of concern include total nitrogen (composed of organic nitrogen, ammonia, nitrate, & nitrite), and total phosphorus. Nitrogen and phosphorus indirectly affect dissolved oxygen levels as nutrients that are essential to algae growth. Algal oxygen production, due to photosynthesis, and oxygen consumption, due to respiration, cause diurnal variations in stream dissolved oxygen levels.

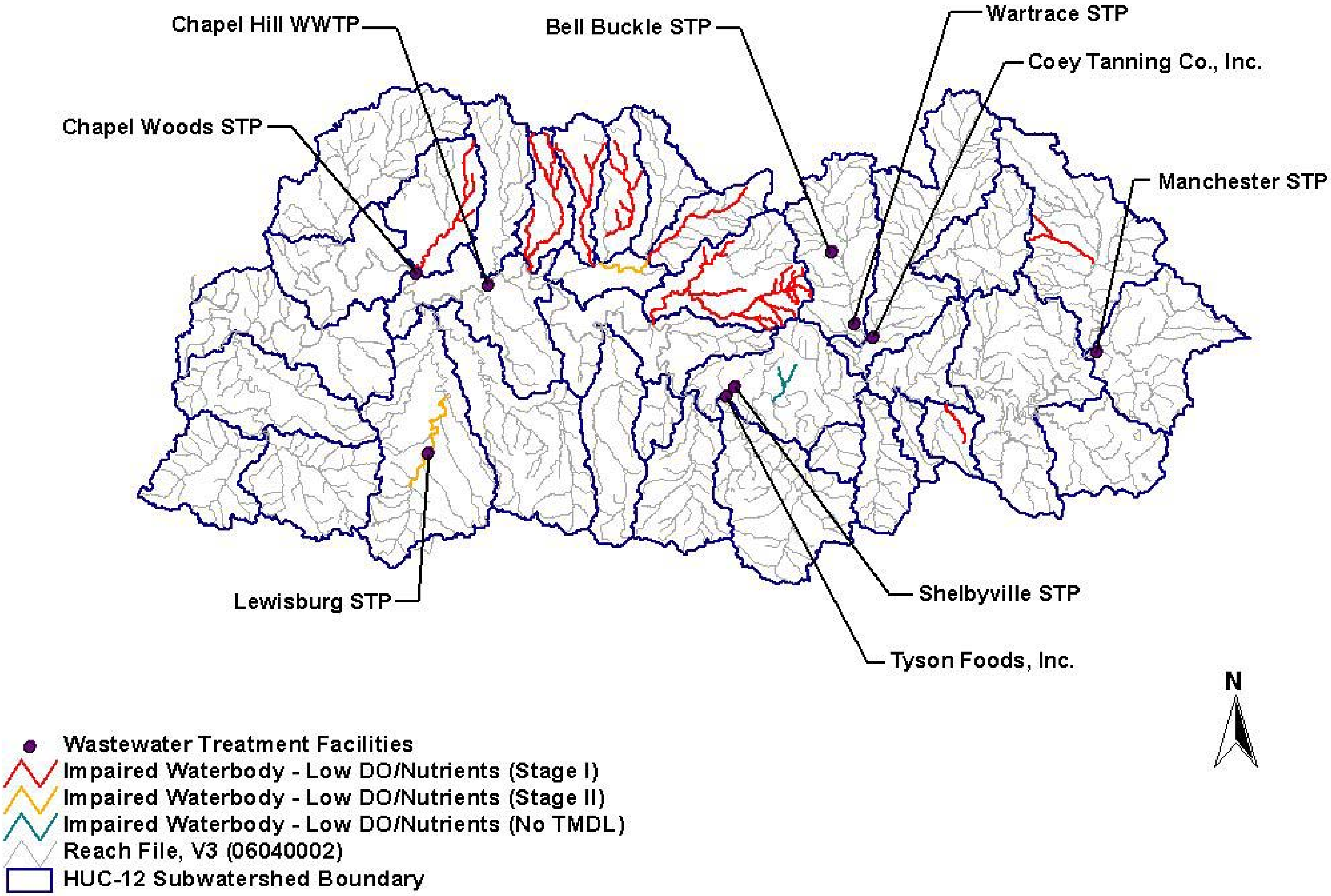
Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by two broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs) and 2) NPDES regulated industrial and municipal storm water discharges. 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 these TMDLs, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for nonpoint sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain the primary nutrients nitrogen (organic nitrogen, ammonia, nitrate, & nitrite) and phosphorus (organic & inorganic). There are seven NPDES permitted WWTFs in the Upper Duck River watershed that discharge treated sanitary wastewater. In addition, the Tyson Foods and Coey Tanning Company facilities are permitted to discharge process wastewater containing BOD and ammonia. Of these nine WWTFs, three are located in impaired HUC-12 subwatersheds and only the Lewisburg STP discharges directly to an impaired waterbody (see Figure 7). As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing existing WWTFs will be developed as part of Stage II and are not included in this document. In addition, the failed collection system in the vicinity of Bomar Creek is considered to be part of the Shelbyville STP and is in violation of its NPDES permit (TN0024180). Correction of this condition will be accomplished through appropriate enforcement action rather than TMDL development.

Figure 7 NPDES Permitted Wastewater Treatment Facilities with Discharges Containing BOD or Nutrients



7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of nutrients . 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 Phase II storm water regulations. 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. With respect to Stage I TMDL development, it appears that small portions of the Tullahoma and Shelbyville MS4s are located in impaired subwatersheds (060400020106 & 060400020308, respectively). 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 nutrient loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*, while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of May 11, 2005, there are 30 Class II CAFOs in the Upper Duck River watershed with coverage under the general NPDES permit. There are three CAFOs with individual permits located in the watershed. The location of these facilities is shown in Figure 8. It should be noted that facilities are located both in subwatersheds containing impaired waterbodies and subwatersheds that do not contain impaired waterbodies.

7.2 Nonpoint Sources

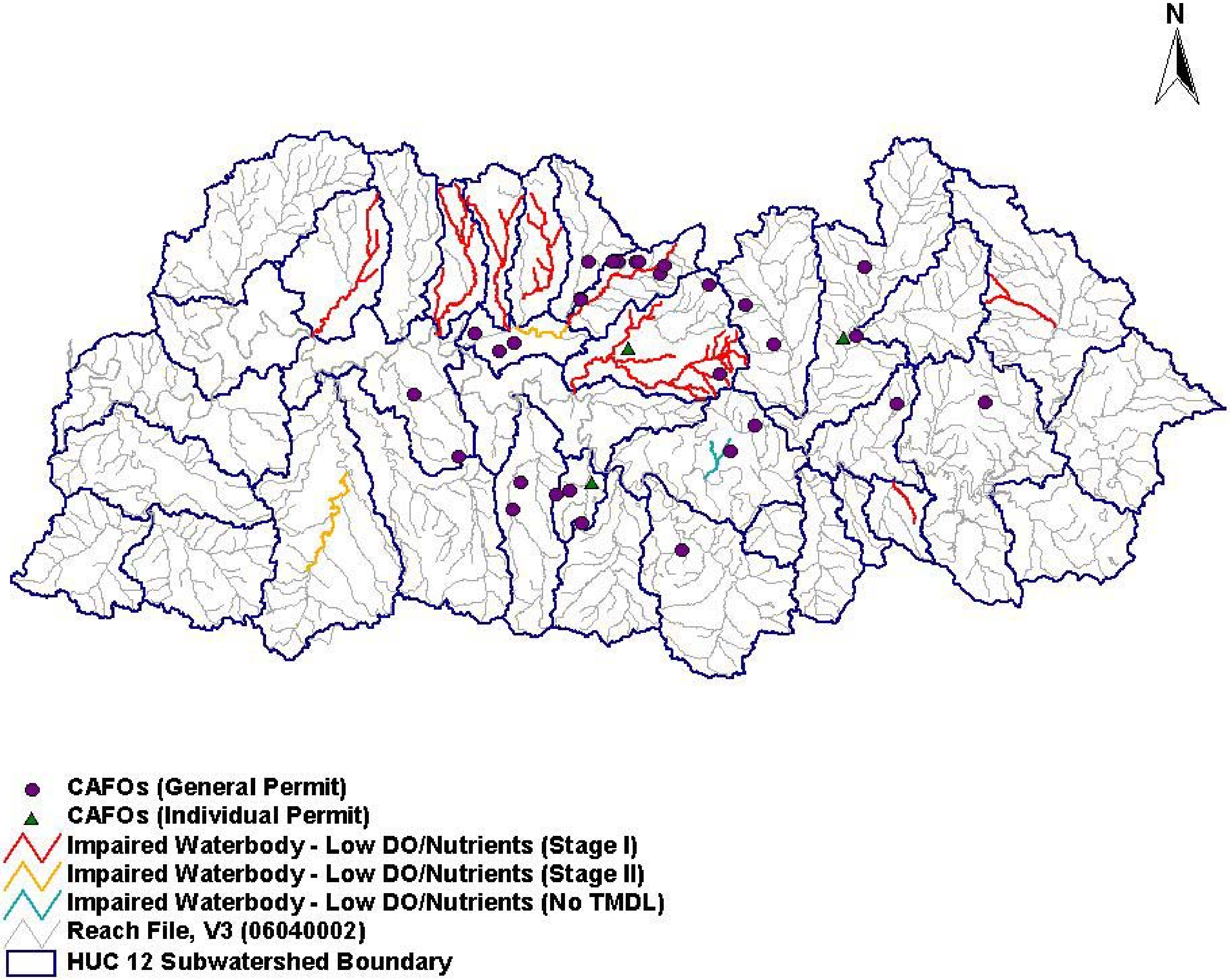
For most of the waterbodies identified as impaired due to low dissolved oxygen or nutrients in the Upper Duck River watershed, nonpoint sources are listed as the source of pollution. Possible nonpoint sources of nutrients and organic materials include urban runoff (from areas not covered under an MS4 permit), atmospheric deposition, geology, failing septic systems, and agricultural runoff on land associated with fertilizer application and livestock waste. Typical nutrient loading ranges for various land uses is shown in Table 5. The geology of some watershed areas is dominated by highly phosphatic limestone that creates a significant background source component. Phosphorus can be sorbed to sediment particles, transported to waterbodies, and released to the water column under certain circumstances. This can result in high concentrations of total phosphorus during runoff events , as well as during low flow conditions.

Table 5 Typical Nutrient Loading Ranges for Various Land Uses

Land Use	Total Phosphorus [kg/ha-y]			Total Nitrogen [kg/ha-y]		
	Minimum	Maximum	Median	Minimum	Maximum	Median
Roadway	0.59	1.50	1.10	1.3	3.5	2.4
Commercial	0.69	0.91	0.80	1.6	8.8	5.2
Single Family – Low Density	0.46	0.64	0.55	3.3	4.7	4.0
Single Family – High Density	0.54	0.76	0.65	4.0	5.6	5.8
Multifamily Residential	0.59	0.81	0.70	4.7	6.6	5.6
Forest	0.10	0.13	0.11	1.1	2.8	2.0
Grass	0.01	0.25	0.13	1.2	7.1	4.2
Pasture	0.01	0.25	0.13	1.2	7.1	4.2

Source: Horner et al., 1994 in *Protocol for Developing Nutrient TMDLs* (USEPA 1999).

Figure 8 Location of CAFOs in the Upper Duck River Watershed



Watershed livestock, population on septic systems, and land use (MRLC) data for drainage areas in the Upper Duck River watershed (see Figure 3) were compiled 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 and population on septic systems for impaired HUC-12 subwatersheds (Stage I TMDLs) are presented in Tables 6 and 7, respectively. Land use for these subwatersheds is summarized in Figures 9 & 10 and tabulated in Appendix D.

Table 6 Livestock Distribution in Impaired HUC-12 Subwatersheds

HUC-12 Subwatershed (06040002__) / Drainage Area	Livestock Population (1997 Census of Agriculture)						
	Beef Cow	Cattle	Milk Cow	Chickens		Hogs	Sheeps
				Layers	Broilers Sold		
0101	1,598	4,146	380	4	434,953	377	31
0106	398	891	67	1	263,998	63	6
0308	2,037	4,213	280	6	2,010,492	299	29
0401	914	1,892	126	3	876,778	132	13
0404	937	1,940	129	3	909,935	136	14
0405	763	1,578	105	2	738,584	111	11
0502	803	1,737	153	2	396,847	139	11
0504	1,475	3,347	358	4	—	307	18

Table 7 Population on Septic Systems in Impaired HUC-12 Subwatersheds

HUC-12 Subwatershed (06040002__) / Drainage Area	Population On Septic Systems
0101	2,597
0106	482
0308	1,318
0401	727
0404	687
0405	568
0502	621
0504	900

Figure 9 Land Use Area of Impaired HUC-12 Subwatersheds

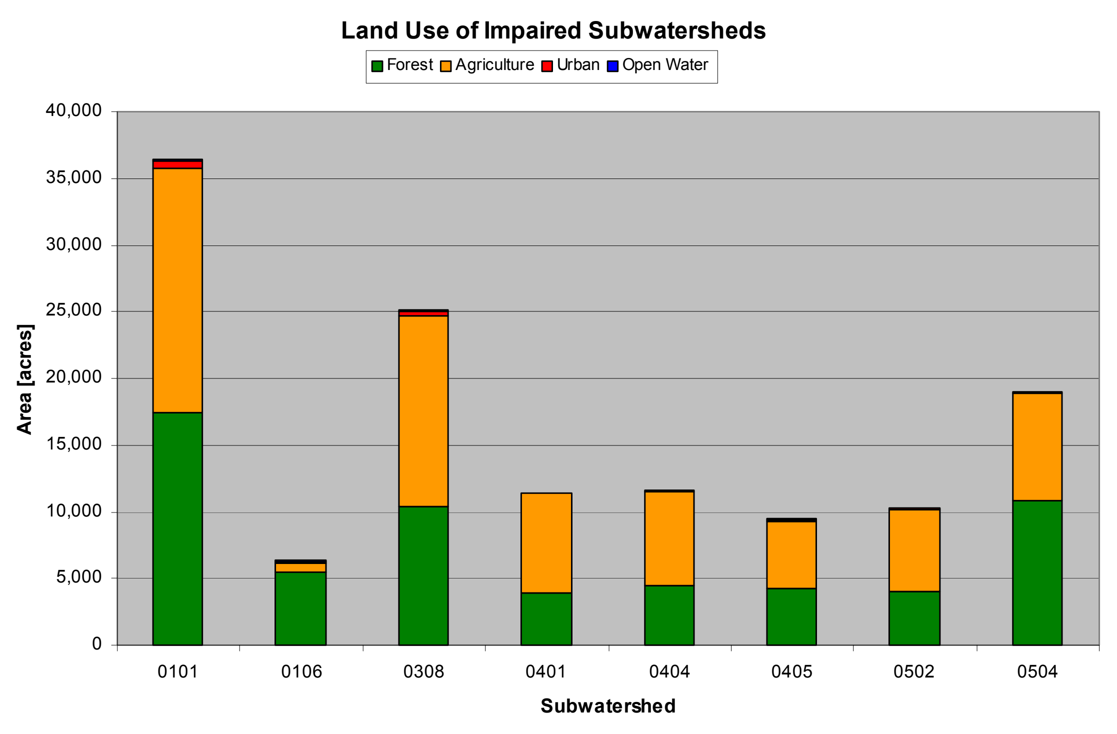
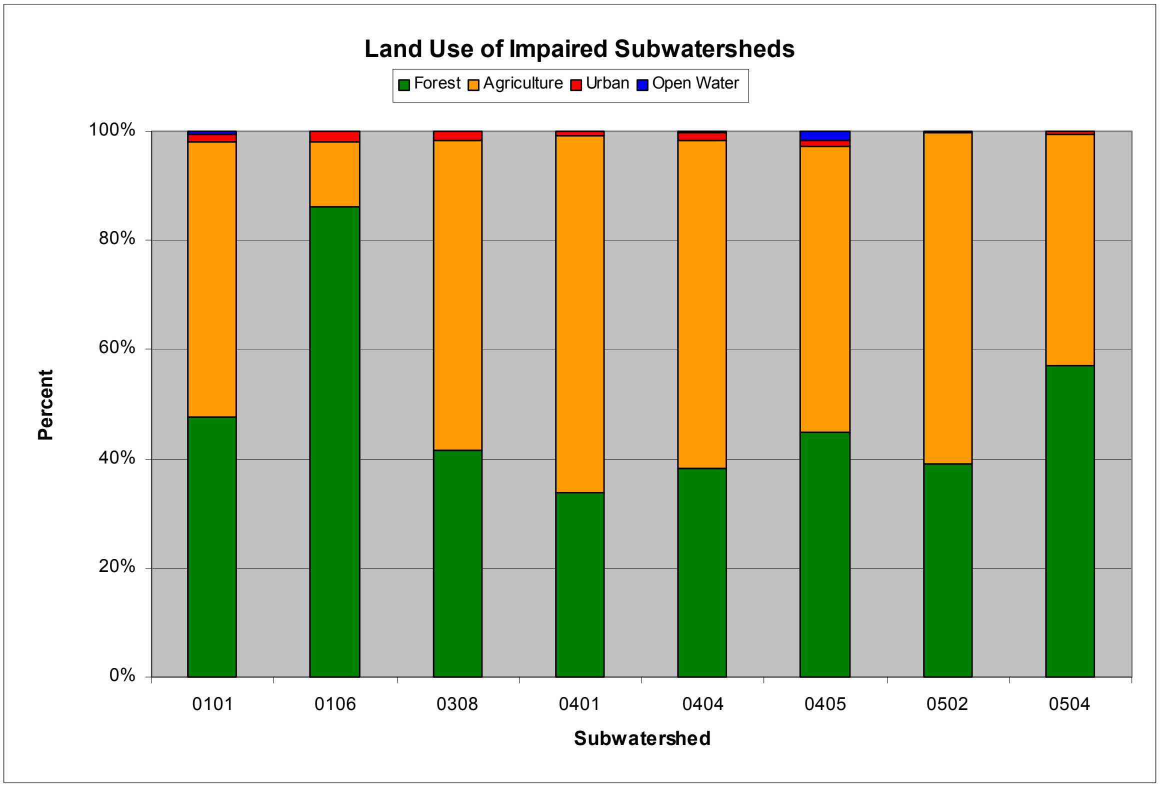


Figure 10 Land Use Percentage of Impaired HUC-12 Subwatersheds



From the data presented in Tables 6, 7, D-1, & D-2 and Figures 3, 9, & 10, it can be seen that there is a significant livestock population in the impaired subwatersheds with the percentage of agricultural land uses ranges from 11.9% to 65.4% (except for subwatershed 0106). Agricultural sources are a significant source of nutrient loading. This is reflected in the proposed 2004 303(d) list where agriculture related sources are noted as the source of pollutants for most waterbodies identified as impaired for low dissolved oxygen or nutrients. Cascade Creek was listed as impaired as a result of animal operations.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

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), 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:

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

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.

Stage I TMDL analyses are performed primarily on a 12-digit hydrologic unit code (HUC-12) area basis for subwatersheds containing waterbodies identified as impaired due to low dissolved oxygen or nutrients on the proposed 2004 303(d) list. HUC-12 subwatershed boundaries are shown in Figure 11. As stated in Section 2.0, TMDL development for impaired subwatersheds containing existing WWTFs are part of Stage II and are not included in this document.

8.1 Development of Nutrient & CBOD_5 TMDLs

Stage I TMDLs were developed for impaired subwatersheds based on the proposed ecoregion-based nutrient and CBOD_5 concentrations specified in Section 5.2 and according to the procedure described in Appendix E (*Note: CBOD_5 TMDLs were only developed for subwatersheds with low dissolved oxygen specifically identified as a cause of impairment*). Impaired subwatersheds are defined as HUC-12 subwatersheds that contain waterbodies identified as impaired due to low dissolved oxygen or nutrients on the 2004 303(d) list. In order to apply the proposed targets over the range of flow conditions encountered in the Upper Duck River watershed throughout the year, Stage I TMDLs for total nitrogen, total phosphorus, and CBOD_5 are expressed as average semiannual loads. Average semiannual loads were considered to be more appropriate than daily loads for representing the seasonal and long-term processes of algal growth in streams and the associated effects on aquatic life. Semiannual summer (May–October) and winter (November–April) periods were selected to correspond to seasonal periods used in NPDES permits. Nutrient and CBOD_5 TMDLs are summarized in Table 8.

Figure 11 HUC-12 Subwatershed Boundaries in the Upper Duck River Watershed

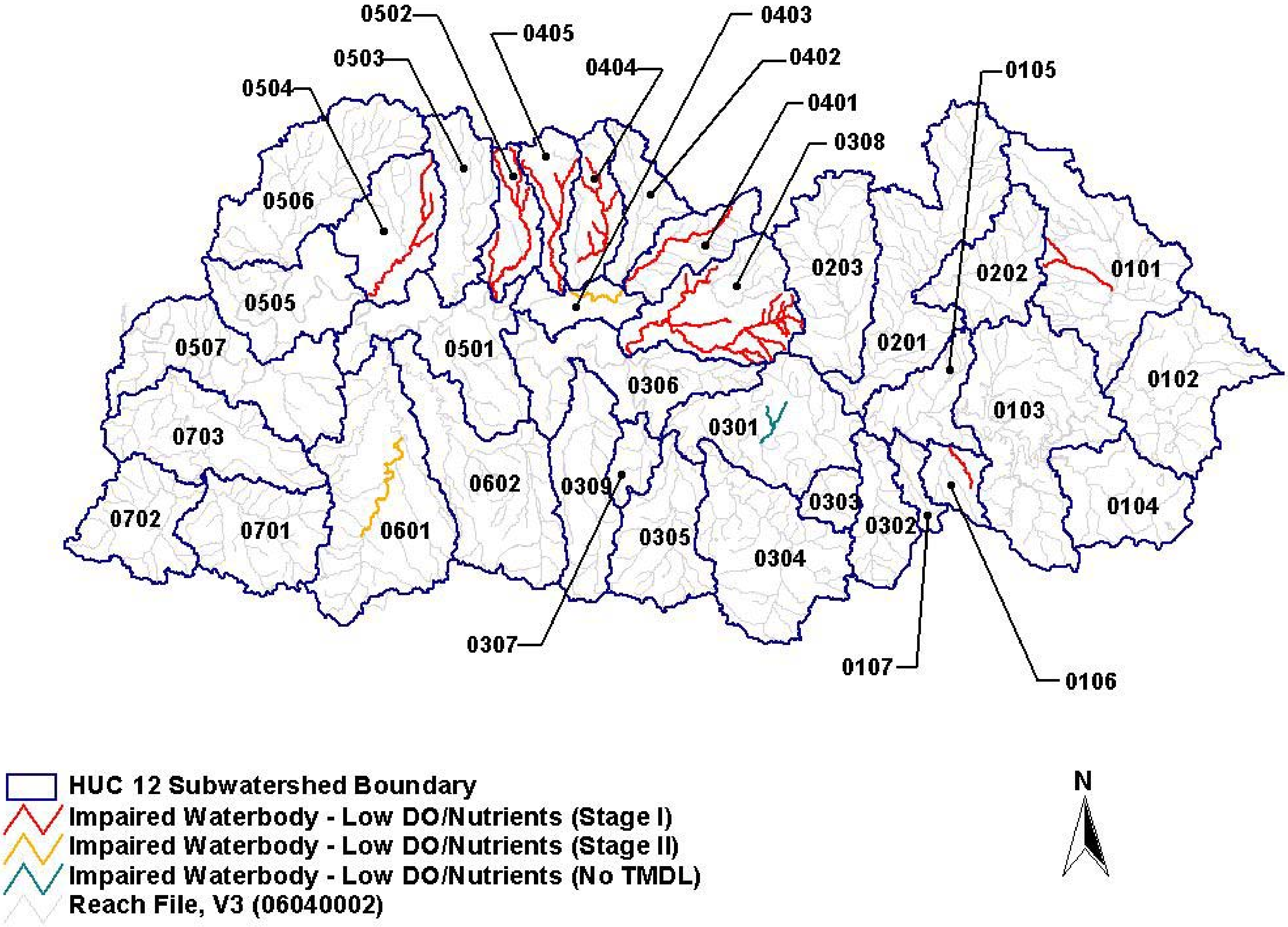


Table 8 Stage I Nutrient & CBOD$_5$ TMDLs for Impaired HUC-12 Subwatersheds

HUC-12 Subwatershed (06040002__)	Impaired Waterbody	TMDL					
		Total Nitrogen		Total Phosphorus		CBOD$_5$	
		Summer [lbs/6 mos.]	Winter [lbs/6 mos.]	Summer [lbs/6 mos.]	Winter [lbs/6 mos.]	Summer [lbs/6 mos.]	Winter [lbs/6 mos.]
0101	Clear Branch	26,580	83,951	769	2,432	57,787	182,509
0106	Cascade Creek	6,458	20,131	507	1,580	NA	NA
0308	Fall Creek Hurricane Creek	29,810	83,025	6,100	16,918	NA	NA
0401	North Fork Creek	13,697	37,881	2,903	8,028	NA	NA
0404	Weakley Creek	13,951	38,582	2,956	8,177	NA	NA
0405	Clem Creek	11,364	31,427	2,408	6,660	NA	NA
0502	Wilson Creek	12,264	33,916	2,599	7,188	NA	NA
0504	Caney Creek	22,449	62,675	4,538	12,599	NA	NA

Note: Summer: May 1 – October 31; Winter: November 1 – April 30.
NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment).

Estimates of reductions in existing nutrient loading required to attain TMDLs in impaired HUC-12 subwatersheds were calculated using a load duration curve methodology according to the procedure in Appendix F. Except for Clear Creek, estimated reductions in $CBOD_5$ loading were not developed due to lack of monitoring data. These estimated reductions are summarized in Table 9 and are provided as a guide for implementation only.

Table 9 Estimates of Required Load Reductions for Impaired HUC-12 Subwatersheds

HUC-12 Subwatershed (06040002__)	Impaired Waterbody	Estimated Load Reduction		
		Total Nitrogen	Total Phosphorus	CBOD5
		[%]	[%]	[%]
0101	Clear Branch	50.5	85.5	67.0
0106	Cascade Creek	14.4	NR	—
0308	Fall Creek Hurricane Creek	44.2	NR	—
0401	North Fork Creek	57.9	45.2	—
0404	Weakley Creek	24.5	NR	—
0405	Clem Creek	43.3	NR	—
0502	Wilson Creek	61.9	NR	—
0504	Caney Creek	67.2	NR	—

NR = No reduction required.

8.2 Units Used to Express WLAs & LAs

For analysis purposes, loading sources such as WWTFs are considered to discharge continuously at their design flow. Since the discharges from these facilities are principally independent of subwatershed drainage area and the occurrence of storm events, WLAs are expressed as average semiannual loads. Discharges from MS4s and nonpoint sources, however, are primarily dependent on both drainage area size and precipitation. Therefore, for precipitation induced loading, it is more appropriate to express WLAs for MS4s and LAs for nonpoint sources as average semiannual loads per unit area.

8.3 Waste Load Allocations

8.3.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing existing WWTF discharges will be developed as part of Stage II and are not included in this document. In addition, the failed collection system in the vicinity of Bomar Creek is considered to be part of the Shelbyville STP and in violation of its NPDES permit (TN0024180). Correction of this condition will be accomplished through appropriate enforcement action rather than TMDL development.

8.3.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

NPDES regulated Municipal Separate Storm Sewer Systems (MS4s) are considered point sources of nutrients. Stage I WLAs for MS4s are calculated for impaired subwatersheds 060400020106 & 060400020308 according to the procedure in Appendix G. Since loading from these entities occurs primarily in response to storm events, WLAs are expressed as average semiannual loads on a unit area basis and are applied only to MS4 discharges into these subwatersheds. Stage I WLAs for existing MS4s are tabulated in Table 10.

Table 10 Nutrient Waste Load Allocations for MS4s

MS4	Impaired Subwatershed (06040002____)	WLAs			
		Summer (May 1 – October 31)		Winter (November 1 – April 30)	
		Total Nitrogen [lbs/ac/6 mo]	Total Phosphorus [lbs/ac/6 mo]	Total Nitrogen [lbs/ac/6 mo]	Total Phosphorus [lbs/ac/6 mo]
Tullahoma	0106	0.972	0.076	3.029	0.238
TDOT *					
Shelbyville	0308	1.128	0.231	3.143	0.640
TDOT *					

* WLAs are applied to State roads in urban areas.

8.3.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

All wastewater discharges from a CAFO to waters of the state of Tennessee are prohibited, except when either chronic or catastrophic rainfall events cause an overflow of process wastewater from a facility properly designed, constructed, maintained, and operated to contain:

- All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,

- All runoff from a 25-year, 24-hour rainfall event for the existing CAFO or new dairy or cattle CAFOs; or all runoff from a 100-year, 24-hour rainfall event for a new swine or poultry CAFO.

A WLA of zero has been assigned to this class of facilities.

8.4 Load Allocations for Nonpoint Sources

Load allocations for nonpoint sources in impaired HUC-12 subwatersheds and the Bomar Creek drainage area were calculated according to the procedure in Appendix G. These LAs are expressed as average semiannual loads on a unit area basis and are considered to be equal to the WLAs for MS4s (ref: Section 8.3.2). LAs apply to any nonpoint source loading in the impaired subwatershed .

8.5 Margin of Safety

There are two methods for incorporating a 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 explicit and implicit MOS were utilized. An implicit MOS was incorporated through the use of conservative modeling assumptions. The primary conservative assumption was the selection of target concentrations based on the 75th percentile of nutrient data collected from Level IV ecoregion reference sites. These sites represent the least impacted streams in the ecoregion. In addition, 5% of summer and winter TMDLs were reserved as explicit MOS.

8.6 Seasonal Variation

Nutrient loading is expected to fluctuate during the year according to season and the amount and distribution of rainfall. The determination of nutrient & $CBOD_5$ loads on an average semiannual basis accounts for seasonal variation of loading.

8.7 Waste Load Allocation & Load Allocation Summary

Stage I TMDLs, WLAs, and LAs for total nitrogen, total phosphorus, and $CBOD_5$ in the Upper Duck River watershed are summarized in Tables 11, 12, & 13.

Table 11 Summary of Stage I Total Nitrogen TMDLs, WLAs, & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	26,580	NA	0	0.693	83,951	NA	0	2.187
0106	6,314	Cascade Creek	6,458	0.972	0	0.972	20,131	3.029	0	3.029
0308	25,097	Fall Creek Hurricane Creek	29,810	1.128	0	1.128	83,025	3.143	0	3.143
0401	11,446	North Fork Creek	13,697	NA	0	1.137	37,881	NA	0	3.144
0404	11,658	Weakley Creek	13,951	NA	0	1.137	38,582	NA	0	3.144
0405	9,496	Clem Creek	11,364	NA	0	1.137	31,427	NA	0	3.144
0502	10,248	Wilson Creek	12,264	NA	0	1.137	33,916	NA	0	3.144
0504	18,948	Caney Creek	22,449	NA	0	1.126	62,675	NA	0	3.142

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

Table 12 Summary of Stage I Total Phosphorus TMDLs, WLAs, & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	769	NA	0	0.020	2,432	NA	0	0.063
0106	6,314	Cascade Creek	507	0.076	0	0.076	1,580	0.238	0	0.238
0308	25,097	Fall Creek Hurricane Creek	6,100	0.231	0	0.231	16,918	0.640	0	0.640
0401	11,446	North Fork Creek	2,903	NA	0	0.241	8,028	NA	0	0.666
0404	11,658	Weakley Creek	2,956	NA	0	0.241	8,177	NA	0	0.666
0405	9,496	Clem Creek	2,408	NA	0	0.241	6,660	NA	0	0.666
0502	10,248	Wilson Creek	2,599	NA	0	0.241	7,188	NA	0	0.666
0504	18,948	Caney Creek	4,538	NA	0	0.228	12,599	NA	0	0.632

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

Table 13 Summary of Stage I CBOD$_5$ TMDLs, WLAs, & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	57,787	NA	0	1.506	182,509	NA	0	4.755

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the biological health of impaired waters in the Upper Duck River watershed through reduction of excessive $CBOD_5$ and nutrient loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals. Stage I TMDLs focus on HUC-12 subwatersheds and drainage areas that contain impaired headwater and tributary streams (wadeable) and do not contain wastewater treatment facilities (WWTFs).

9.1 Point Sources

9.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing existing WWTF discharges will be developed as part of Stage II and are not included in this document. In order to make possible the future development of Stage II nutrient TMDLs, however, WWTFs will be expected to: 1) reduce nutrient discharges to the maximum extent feasible; 2) characterize facility nutrient loads through effluent nutrient monitoring; 3) determine the effect of facility nutrient discharges on impaired receiving waters by (but not necessarily limited to) monitoring instream nutrient levels upstream and downstream of the facility outfall; and 4) establish, improve, and increase canopy and provide a riparian buffer along stream banks downstream of facility outfalls to minimize diurnal dissolved oxygen fluctuations due to excessive algal growth. These expected actions may be implemented through appropriate NPDES permit provisions.

> *Note: Where suitable, trading may offer opportunities for overall reductions in watershed nutrient loading. Pollutant trading, including pollutant suitability analysis, financial attractiveness, identification of potential participants, and trading procedures, are presented in the Water Quality Trading Assessment Handbook (USEPA, 2004).*

Also as previously stated, correction of the failed collection system in the vicinity of Bomar Creek will be accomplished through appropriate enforcement action rather than TMDL development.

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

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

Implementation of the nutrient & $CBOD_5$ WLAs for MS4s in this TMDL document will require effluent or instream monitoring to evaluate SWMP effectiveness with respect to total nitrogen, total phosphorus, and $CBOD_5$ loading.

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:
    a. Includes best management practices (BMPs) and procedures necessary to implement applicable limitations and standards;
    b. Ensures adequate storage of manure, litter, and process wastewater including provisions to ensure proper operation and maintenance of the storage facilities.
    c. Ensures proper management of mortalities (dead animals);
    d. Ensures diversion of clean water, where appropriate, from production areas;
    e. Identifies protocols for manure, litter, wastewater and soil testing;
    f. Establishes protocols for land application of manure, litter, and wastewater;
    g. Identifies required records and record maintenance procedures.

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

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

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

9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of nutrient 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.

The actions of local government agencies and watershed stakeholders should be directed to accomplish the goal of a reduction of nutrient loading in the watershed. There are a number of measures that are particularly well-suited to action by local stakeholder groups. These measures include, but are not limited to:

- Detailed ground truthing and sanitary surveys of drainage areas to waterbodies impaired for low dissolved oxygen & nutrients in order to identify additional sources of nutrient and organic loading.
- Advocacy of local area zoning that will minimize nutrient and organic loading to waterbodies in the Upper Duck River watershed.
- Educating the public as to the detrimental effects of nutrient and organic loading to waterbodies and measures to minimize this loading.

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

9.3 Use of Load Duration Curve as a Guide to Implementation

In discussing the use of load duration curves in TMDL development, Cleland states:

> A major advantage of the duration curve framework in TMDL development is the ability to meaningfully connect allocations to implementation efforts. Because the flow duration interval (FDI) provides a general indication of hydrologic condition (i.e. wet versus dry and to what degree), allocations and reduction targets can be linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g. high flow, moist, median flows, dry, and low flow) allows the development of allocation tables, which can be used to summarize potential implementation actions that most effectively address water quality concerns (Cleland, 2003).

Table 14 illustrates a hypothetical example of an approach, which could be used to assess management options in a way that considers the potential relative importance of hydrologic conditions using a duration curve framework (potential management practices may vary according to pollutant considered). A similar approach could be used based on the load duration curves developed in Appendix F.

9.4 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 nutrient loading reduction measures can be evaluated. Additional monitoring data, ground-truthing activities, and 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 $CBOD_5$ and nutrient loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure attainment of applicable water quality standards.

Table 14 Example Use of Load Duration Curves to Evaluate Potential Control Measures (Based on Cleland, 2004)

Developing Solutions

Linking Load Duration Curves to Potential Control Measures

Control Measure		Duration Curve Zone				
		High	Moist	Mid-Range	Dry	Low
Agricultural Areas	Manure/Fertilizer Management		H	H	M	L
	Establish Riparian Buffer Zones		H	H	M	
	Erosion Control Measures		H	H	M	
	Limit Livestock Access to Streams		M	M	H	H
	Water Flow Management (Slow water flow, discharge runoff into filter areas, etc.)	M	H	H	M	
Urban Areas	Public Education/Outreach (Proper use of lawn fertilizers, water conservation, pet waste management, recycling, etc.)		M	H	M	L
	Laws & Ordinances (Pet waste disposal, low impact development, zoning, etc.)		M	H	M	L
	Elimination of Illicit Discharges			M	H	H
	SSO Repair/Abatement	H	H	M		
	Septic System Inspection/Repair	L	M	H	H	M
	Storm Drain Identification		M	H	H	M
	Establish Riparian Buffer Zones		H	H	M	
	Structural BMPs (Retention ponds, constructed wetlands, filtration systems, etc.)		M	H	H	
	Point Source Controls			M	H	H

Note: Potential relative importance of practice effectiveness under given hydrologic condition (H= High, M = Medium, L = Low)

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed low dissolved oxygen/nutrient TMDLs for the Upper Duck River watershed were placed on Public Notice for a 35-day period (6/6/05 through 7/11/05) 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 identified water quality partners in the Upper Duck River watershed advising them of the availability of the proposed TMDLs on the TDEC website and invited comments. These partners include:

   United States Environmental Protection Agency, Region IV
   Natural Resources Conservation Service
   Tennessee Department of Agriculture
   Tennessee Duck River Development Agency
   The Water Resources Council
   The Nature Conservancy Duck River Project

4) A letter was sent to the Tullahoma STP, Lewisburg STP, and Tyson Foods, Inc. advising them of the availability of the proposed TMDLs on the TDEC website

5) A draft copy of the proposed TMDLs was sent to the Shelbyville STP (TN0024180), which has responsibility for the collection system in the Bomar Creek drainage area.

6) A draft copy of the proposed TMDLs was sent to the City of Lewisburg, City of Shelbyville, City of Tullahoma, and Tennessee Department of Transportation. These entities are covered by MS4 permits under the Phase II storm water regulations.

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

Nutrients & Water Quality

Nutrients and Water Quality

The following information was excerpted from *Protocol for Developing Nutrient TMDLs, First Edition* (USEPA, 1999). Minor formatting changes and the identification of the table have been made for inclusion in this TMDL document. References cited have been included on the last page of this Appendix.

Impact of Nutrients on Designated Uses

Excess nutrients in a waterbody can have many detrimental effects on designated or existing uses, including drinking water supply, recreational use, aquatic life use, and fishery use. For example, drinking water supplies can be impaired by nitrogen when nitrate concentrations exceed 10 mg/L and can cause methemoglobinemia (Blue Baby Syndrome) in infants. Water supplies containing more than 100 mg/L of nitrate can also taste bitter and can cause physiological distress (Straub, 1989).

Although these are examples of the direct impacts that can be associated with excessive nutrient loadings, waters more often are listed as impaired by nutrients because of their role in accelerating eutrophication. Eutrophication, or the nutrient enrichment of aquatic systems, is a natural aging process of a waterbody that transforms a lake into a swamp and ultimately into a field or forest. (The term *eutrophication* as used in this document refers to the nutrient enrichment of both lakes and rivers, although it is recognized that rivers do not have the same natural aging process.) This aging process can accelerate with excessive nutrient inputs because of the impact they have without other limiting factors, such as light.

A eutrophic system typically contains an undesirable abundance of plant growth, particularly phytoplankton, periphyton, and macrophytes. Phytoplankton, photosynthetic microscopic organisms (algae), exist as individual cells or grouped together as clumps or filamentous mats. Periphyton is the assemblage of organisms that grow on underwater surfaces. It is commonly dominated by algae but also can include bacteria, yeasts, molds, protozoa, and other colony forming organisms. The term macrophyte refers to any larger than microscopic plant life in aquatic systems. Macrophytes may be vascular plants rooted in the sediment, such as pond weeds or cattails, or free-floating plant life, such as duckweed or coontail.

The eutrophication process can impair the designated uses of waterbodies as follows:

- *Aquatic life and fisheries.* A variety of impairments can result from the excessive plant growth associated with nutrient loadings. These impairments result primarily when dead plant matter settles to the bottom of a waterbody, stimulating microbial breakdown processes that require oxygen. Eventually, oxygen in the hypolimnion of lakes and reservoirs can be depleted, which can change the benthic community structure from aerobic to anaerobic organisms. Oxygen depletion also might occur nightly throughout the waterbody because of plant respiration. Extreme oxygen depletion can stress or eliminate desirable aquatic life and nutrients, and toxins also might be released from sediments when dissolved oxygen and pH are lowered (Brick and Moore, 1996).

Breakdown of dead organic matter in water also can produce un-ionized ammonia, which can adversely affect aquatic life. The fraction of ammonia present as un-ionized ammonia depends on temperature and pH. Fish may suffer a reduction in hatching success, reductions in growth rate and morphological development, and injury to gill tissue, liver, and kidneys. At certain ammonia levels fish also might suffer a loss of equilibrium, hyperexcitability, increased respiratory activity and oxygen uptake, and increased heart rate. At extreme ammonia levels, fish may experience convulsions, coma, and death (USEPA, 1986a; revised 1998b).

- *Drinking water supply.* Diatoms and filamentous algae can clog water treatment plant filters and reduce the time between backwashings (the process of reversing water flow through the water filter to remove debris). Disinfection of water supplies impaired by algal growth also might result in water that contains potentially carcinogenic disinfection byproducts, such as trihalomethanes. An increased rate of production and breakdown of plant matter also can adversely affect the taste and odor of the drinking water.

- *Recreational use.* The excessive plant growth in a eutrophic waterbody can affect recreational water use. Extensive growth of rooted macrophytes, periphyton, and mats of living and dead plant material can interfere with swimming, boating, and fishing activities, while the appearance of and odors emitted by decaying plant matter impair aesthetic uses of the waterbody.

Nutrient Sources and Transport

Both nitrogen and phosphorus reach surface waters at an elevated rate as a result of human activities. Phosphorus, because of its tendency to sorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments. Inorganic nitrogen, on the other hand, does not sorb as strongly and can be transported in both particulate and dissolved phases in surface runoff. Dissolved inorganic nitrogen also can be transported through the unsaturated zone (interflow) and ground water. Because nitrogen has a gaseous phase, it can be transported to surface water via atmospheric deposition. Phosphorus associated with fine-grained particulate matter also exists in the atmosphere. This sorbed phosphorus can enter natural waters by both dry fallout and rainfall. Finally, nutrients can be directly discharged to a waterbody via outfalls for wastewater treatment plants and combined sewer overflows. Table A-1 presents common point and nonpoint sources of nitrogen and phosphorus and the approximate associated concentrations.

Table A-1. Sources And Concentrations Of Nutrients from Common Point and Nonpoint Sources

Source	Nitrogen (mg/l)	Phosphorus (mg/l)
Urban Runoff	3-10	0.2 – 1.7
Livestock operations	6 – 800 [a]	4 – 5
Atmosphere (wet deposition)	0.9	0.015 [b]
Untreated wastewater	35	10
Treated wastewater (secondary treatment)	30	10

a As organic nitrogen; b Sorbed to airborne particulate
Source: Novotny and Olem, 1994

Once in the waterbody, nitrogen and phosphorus act differently. Because inorganic forms of nitrogen do not sorb strongly to particulate matter, they are more easily returned to the water. Phosphorus, on the other hand, can sorb to sediments in the water column and on the substrate and become unavailable. In lakes and reservoirs, continuous accumulation of sediment can leave some phosphorus too deep within the substrate to be reintroduced to the water column, if left undisturbed; however, a portion of the phosphorus in the substrate might be reintroduced to the water column. The activities of benthic invertebrates and changes in water chemistry (such as the reducing conditions of bottom waters and sediments often experienced during the summer months in a lake) also can cause phosphorus to desorb from sediment. A large, slow-moving river also might experience similar phosphorus releases. The sudden availability of phosphorus in the water column can stimulate algal growth. Because of this phenomenon, a reduction in phosphorus loading might not effectively reduce algal blooms for many years (Maki et al., 1983).

Nutrient Cycling

The transport of nutrients from their sources to the waterbody of concern is governed by several chemical, physical, and biological processes, which together compose the nitrogen or phosphorus cycle. Nutrient cycles are important to understand for developing a TMDL because of the information they provide about nutrient availability and the associated impact on plant growth.

Nitrogen

Nitrogen is plentiful in the environment. Almost 80 percent of the atmosphere by volume consists of nitrogen gas (N2). Although largely available in the atmosphere, N2 must be converted to other forms, such as nitrate ($NO3^-$), before most plants and animals can use it. Conversion into usable forms, both in the terrestrial and aquatic environments, occurs through the four processes of the nitrogen cycle. Three of the processes—nitrogen fixation, ammonification, and nitrification—convert gaseous nitrogen into usable chemical forms. The fourth process, denitrification, converts fixed nitrogen back to the gaseous N2 state.

- *Nitrogen fixation.* The conversion of gaseous nitrogen into ammonia ions (NH3 and $NH4^+$). Nitrogen-fixing organisms, such as blue-green algae (cyanobacteria) and the bacteria *Rhizobium* and *Azobacter*, split molecular nitrogen (N2) into two free nitrogen molecules. The nitrogen molecules combine with hydrogen molecules to yield ammonia ions.

- *Ammonification.* A one-way reaction in which decomposer organisms break down wastes and nonliving organic tissues to amino acids, which are then oxidized to carbon dioxide, water, and ammonia ions. Ammonia is then available for absorption by plant matter.

- *Nitrification.* A two-step process by which ammonia ions are oxidized to nitrite and nitrate, yielding energy for decomposer organisms. Two groups of microorganisms are involved in the nitrification process. First, *Nitrosomonas* oxidizes ammonia ions to nitrite and water. Second, *Nitrobacter* oxidizes the nitrite ions to nitrate, which is then available for absorption by plant matter.

- *Denitrification.* The process by which nitrates are reduced to gaseous nitrogen by facultative anaerobes. Facultative anaerobes, such as fungi, can flourish in anoxic conditions because they break down oxygen containing compounds (e.g., $NO3^-$) to obtain oxygen.

Once introduced into the aquatic environment, nitrogen can exist in several forms—dissolved nitrogen gas (N2), ammonia ($NH4^{+}$ and NH3), nitrite ($NO2^{-}$), nitrate ($NO3^{-}$), and organic nitrogen as proteinaceous matter or in dissolved or particulate phases. The most important forms of nitrogen in terms of their immediate impact on water quality are the readily available ammonia ions, nitrites, and nitrates (dissolved nitrogen). (Note that plants cannot directly use nitrate but must first convert it to ammonium using the enzyme nitrate reductase. Because the ability to do this is ubiquitous, nitrate is considered to be bioavailable.) Particulate and organic nitrogen, because they must be converted to a usable form, are less important in the short term. Total nitrogen (TN) is a measurement of all forms of nitrogen.

Nitrogen continuously cycles in the aquatic environment, although the rate is temperature-controlled and thus very seasonal. Aquatic organisms incorporate available dissolved inorganic nitrogen into proteinaceous matter. Dead organisms decompose, and nitrogen is released as ammonia ions and then converted to nitrite and nitrate, where the process begins again. If a surface water lacks adequate nitrogen, nitrogen-fixing organisms can convert nitrogen from its gaseous phase to ammonia ions.

Phosphorus

Under normal conditions, phosphorus is scarce in the aquatic environment. Unlike nitrogen, phosphorus does not exist as a gas and therefore does not have gas-phase atmospheric inputs to aquatic systems. Rocks and natural phosphate deposits are the main reservoirs of natural phosphorus. Release of these deposits occurs through weathering, leaching, erosion, and mining. Terrestrial phosphorus cycling includes immobilizing inorganic phosphorus into calcium or iron phosphates, incorporating inorganic phosphorus into plants and microorganisms, and breaking down organic phosphorus to inorganic forms by bacteria. Some phosphorus is inevitably transported to aquatic systems by water or wind.

Phosphorus in freshwater and marine systems exists in either an organic or inorganic form.

- *Organic phosphorus.* Organic particulate phosphorus includes living and dead particulate matter, such as plankton and detritus. Organic nonparticulate phosphorus includes dissolved organic phosphorus excreted by organisms and colloidalphosphorus compounds.

- *Inorganic phosphorus.* The soluble inorganic phosphate forms $H2PO4^{-}$, $HPO4^{2-}$, and $PO4^{3}$, known as soluble reactive phosphorus (SRP), are readily available to plants. Some condensed phosphate forms, such as those found in detergents, are inorganic but are not available for plant uptake. Inorganic particulate phosphorus includes phosphorus precipitates, phosphorus adsorbed to particulate, and amorphous phosphorus.

The measurement of all phosphorus forms in a water sample, including all the inorganic and organic particulate and soluble forms mentioned above, is known as total phosphorus (TP). TP does not distinguish between phosphorus currently unavailable to plants (organic and particulate) and that which is available (SRP). SRP is the most important form of phosphorus for supporting algal growth because it can be used directly. However, other fractions are transformed to more bioavailable forms at various rates dependent on microbial action or environmental conditions. In streams with relatively short residence times, it is less likely that the transformation from unavailable to available forms will have time to occur and SRP is the most accurate estimate of biologically available nutrients. In lakes, however, where residence times are longer, TP generally is considered an adequate estimation of bioavailable phosphorus.

Phosphorus undergoes continuous transformations in a freshwater environment. Some phosphorus will sorb to sediments in the water column or substrate and be removed from circulation. Phytoplankton, periphyton, and bacteria assimilate the SRP (usually as orthophosphate) and change it into organic phosphorus. These organisms then may be ingested by detritivores or grazers, which in turn excrete some of the organic phosphorus as SRP. Some previously unavailable forms of phosphorus also convert to SRP. Continuing the cycle, the SRP is rapidly assimilated by plants and microbes.

Human activities have resulted in excessive loading of phosphorus into many freshwater systems. Overloads result in an imbalance of the natural cycling processes. Excess available phosphorus in freshwater systems can result in accelerated plant growth if other nutrients and other potentially limiting factors are available.

Other Limiting Factors

Many natural factors combine to determine rates of plant growth in a waterbody. First of these is whether sufficient phosphorus and nitrogen exist to support plant growth. The absence of one of these nutrients generally will restrict plant growth. In inland waters, typically phosphorus is the limiting nutrient of the two, because blue-green algae can “fix” elemental nitrogen from the water as a nutrient source. In marine waters, either phosphorus or nitrogen can be limiting. Although carbon and trace elements are usually abundant, occasionally they can serve as limiting nutrients. However, even if all necessary nutrients are available, plant production will not necessarily continue unchecked. Many natural factors, including light availability, temperature, flow levels, substrate, grazing, bedrock type and elevation, control the levels of macrophytes, periphyton, and phytoplankton in waters. Effective management of eutrophication in a waterbody may require a simultaneous evaluation of several limiting factors.

- *Light availability.* Shading of the water column inhibits plant growth. Numerous factors can shade waterbodies, including: (1) as plant production increases in the upper water layer, the organisms block the light and prevent it from traveling deeper into the water column; (2) riparian growth along waterbodies provides shade; and (3) particulates in the water column scatter light, decreasing the amount penetrating the water column and available for photosynthesis.

  With seasonally high particulate matter or shading (e.g., in deciduous forests), the high nutrients may cause excessive growth only during certain times of the year: for example, streams where snowmelt is common in the spring. Snowmelt could lead to high levels of suspended particulate matter and low algal biomass. During stable summer flows, however, there will be lower levels of suspended matter and hence higher algal biomass.

- *Temperature.* Temperature affects the rates of photosynthesis and algal growth, and composition of algal species. Depending on the plant, photosynthetic activity increases with temperature until a maximum photosynthetic output is reached, when photosynthesis declines (Smith, 1990). Moreover, algal community species composition in a waterbody often changes with temperature. For example, diatoms most often are the dominant algal species at water temperatures of 20 ° to 25 °C, green algae at 30 ° to 35 °C, and blue-green algae (cyanobacteria) above 35 °C (Dunne and Leopold, 1978; USEPA, 1986b).

- *Water Velocity.* Water movement in large lakes, rivers, and streams influences plant production. Stream velocity has a two-fold effect on periphyton productivity: increasing velocity to a certain level enhances biomass accrual but further increases can result in substantial scouring (Horner et al., 1990). Large lakes and estuaries can experience the scouring action of waves during strong storms (Quinn, 1991). In rivers and streams, frequent disturbance from floods (monthly or more frequently) and associated movement of bed materials can scour algae from the surface rapidly and often enough to prevent attainment of high biomass (Horner et al., 1990). Rapid flows can sweep planktonic algae from a river reach, while low flows may provide an opportunity for proliferation.

- *Substrate.* Macrophytes and periphyton are influenced by the type of substrate available. Macrophytes prefer areas of fine sediment in which to root (Wright and McDonnell, 1986, in Quinn, 1991). Thus, the addition and removal of sediment from a system can influence macrophyte growth. Periphyton, because of its need to attach to objects, grows best on large, rough substrates. A covering of sediment over a rocky substrate decreases periphyton biomass (Welch et al., 1992).

- *Grazing.* Dense populations of algae-consuming grazers can lead to negligible algal biomass, in spite of high levels of nutrients (Steinman, 1996). The existence of a “trophic cascade” (control of algal biomass by community composition of grazers and their predators) has been demonstrated for some streams (e.g., Power, 1990). Managers should realize the potential control of algal biomass by grazers, but they also should be aware that populations of grazers can fluctuate seasonally or unpredictably and fail to control biomass at times. Consideration of grazer populations might explain why some streams with high nutrients have low algal biomass.

- *Bedrock.* The natural effects of bedrock type also might help explain trophic state. Streams draining watersheds with phosphorus-rich rocks (such as rocks of sedimentary or volcanic origin) can be enriched naturally and, therefore, control of algal biomass by nutrient reduction in such systems might be difficult. Review of geologic maps and consultation with a local soil scientist might reveal such problems. Bedrock composition has been related to algal biomass in some systems (Biggs, 1995).

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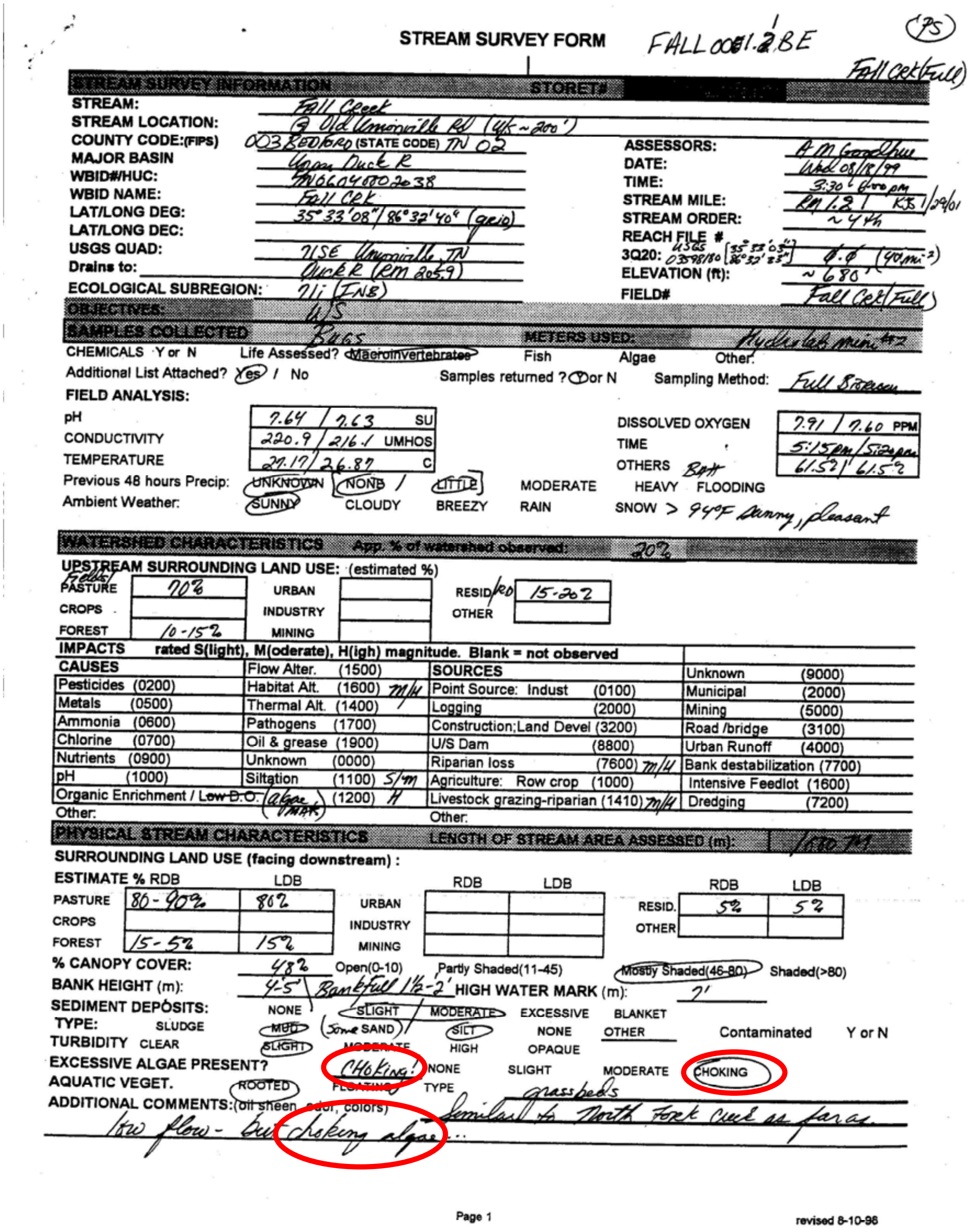
APPENDIX B

Example of Stream Assessment
(Fall Creek)

Example of Stream Assessment – Fall Creek at RM 1.2 (6 pages)



STREAM SURVEY FORM FALL001.2BE (PS)

Fall Crk(Full)

STREAM SURVEY INFORMATION **STORET#**

STREAM: Fall Creek
STREAM LOCATION: @ Old Unionville Rd (u/s ~200')
COUNTY CODE:(FIPS) 003 Bedford (STATE CODE) TN 02
MAJOR BASIN Upper Duck R
WBID#/HUC: TN06040002038
WBID NAME: Fall Crk
LAT/LONG DEG: 35°33'08"/86°32'40" (geio)
LAT/LONG DEC:
USGS QUAD: 71SE Unionville, TN
Drains to: Duck R (RM 205.9)
ECOLOGICAL SUBREGION: 71i (INB)

ASSESSORS: A M Goodhue
DATE: Wed 08/18/99
TIME: 3:30 - 6:00 pm
STREAM MILE: RM 1.2 / KJS 1/29/01
STREAM ORDER: ~4th
REACH FILE #
3Q20: USGS 03598180 [35°33'03" 86°32'33"] 0.0 (40mi^{2})
ELEVATION (ft): ~680'
FIELD# Fall Crk(Full)

OBJECTIVES: WS

SAMPLES COLLECTED Bugs **METERS USED:** Hydrolab mini #2

CHEMICALS Y or N Life Assessed? [✓ Macroinvertebrates] Fish Algae Other:
Additional List Attached? [✓ Yes] / No Samples returned ? [✓ Y] or N Sampling Method: Full Stream

FIELD ANALYSIS:

pH	7.64 / 7.63	SU
CONDUCTIVITY	220.9 / 216.1	UMHOS
TEMPERATURE	27.17 / 26.87	C
DISSOLVED OXYGEN	7.91 / 7.60	PPM
TIME	5:15pm / 5:20pm	
OTHERS Batt	61.5% / 61.5%	

Previous 48 hours Precip: [✓ UNKNOWN] [✓ NONE] / [✓ LITTLE] MODERATE HEAVY FLOODING
Ambient Weather: [✓ SUNNY] CLOUDY BREEZY RAIN SNOW > 94°F sunny, pleasant

WATERSHED CHARACTERISTICS App. % of watershed observed: 20%

UPSTREAM SURROUNDING LAND USE: (estimated %)

Fields/ PASTURE	70%	URBAN		RESID/RD	15-20%
CROPS		INDUSTRY		OTHER	
FOREST	10-15%	MINING			

IMPACTS rated S(light), M(oderate), H(igh) magnitude. Blank = not observed

CAUSES		**SOURCES**	
	Flow Alter. (1500)		Unknown (9000)
Pesticides (0200)	Habitat Alt. (1600) M/H	Point Source: Indust (0100)	Municipal (2000)
Metals (0500)	Thermal Alt. (1400) /	Logging (2000)	Mining (5000)
Ammonia (0600)	Pathogens (1700)	Construction;Land Devel (3200)	Road /bridge (3100)
Chlorine (0700)	Oil & grease (1900)	U/S Dam (8800)	Urban Runoff (4000)
Nutrients (0900)	Unknown (0000)	Riparian loss (7600) M/H	Bank destabilization (7700)
pH (1000)	Siltation (1100) S/M	Agriculture: Row crop (1000)	Intensive Feedlot (1600)
Organic Enrichment / ~~Low D.O.~~ (algae VMAX) (1200) H		Livestock grazing-riparian (1410) M/H	Dredging (7200)
Other:		Other:	

PHYSICAL STREAM CHARACTERISTICS LENGTH OF STREAM AREA ASSESSED (m): 1680 m

SURROUNDING LAND USE (facing downstream) :

ESTIMATE %	RDB	LDB		RDB	LDB		RDB	LDB
PASTURE	80-90%	80%	URBAN			RESID.	5%	5%
CROPS			INDUSTRY			OTHER		
FOREST	15-5%	15%	MINING					

% CANOPY COVER: 48% Open(0-10) Partly Shaded(11-45) [✓ Mostly Shaded(46-80)] Shaded(>80)
BANK HEIGHT (m): 4-5' \ Bankfull 1½-2' **HIGH WATER MARK** (m): 2'
SEDIMENT DEPOSITS: NONE [✓ SLIGHT] / [✓ MODERATE] EXCESSIVE BLANKET
TYPE: SLUDGE [✓ MUD] (Some SAND) / [✓ SILT] NONE OTHER Contaminated Y or N
TURBIDITY CLEAR [✓ SLIGHT] MODERATE HIGH OPAQUE
EXCESSIVE ALGAE PRESENT? CHoKing! NONE SLIGHT MODERATE [✓ CHOKING]
AQUATIC VEGET. [✓ ROOTED] [✓ FLOATING] TYPE grassbeds
ADDITIONAL COMMENTS:(oil sheen, odor, colors) Similar to North Fork Creek as far as low flow - but choking algae...

Page 1

revised 8-10-98

STREAM SURVEY FORM

PHYSICAL STREAM CHARACTERISTICS (cont.)

	RIFFLE	RUN	POOL
DEPTH (m)			1'-2'
WIDTH (m)			10'-20'
REACH LENGTH (m)			30'(+)

Staff Gauge/Bench Ht:
VELOCITY (CFS)
FLOW (CFS)
HABITAT ASSESSMENT SCORE #: 103
RR # **GP #**

Gradient (sample reach): [✓ Flat]/[✓ Low] Mode. High Cascade
Size (stream width) : V. Small (<1.5m) Small (1.5-3m) [✓ Med (3-10m)] Large (10-25m) Very Lrg (>25m)

BIOLOGICAL ASSESSMENT

LIST LOG NUMBERS OF SAMPLES: #1095

RELATIVE ABUNDANCE OF TAXA HABITAT

DOMINANT (>=50): (see attached)
VERY ABUND.(30-49):
ABUNDANT (10-29):
COMMON (3-9):
RARE (<3):

STREAM USE SUPPORT: **SPECIFICALLY CLASSIFIED FOR: (circle)**

Dom. H2O Supply Ind. H2O Supply Navigation TIER II/TIER III Trout >> Nat. Repr?

WATER WITHDRAWL NOTED

IS STREAM POSTED? (circle) Fish Tissue Advis.: Do Not Consume Precautionary
Bacteriological Advis.

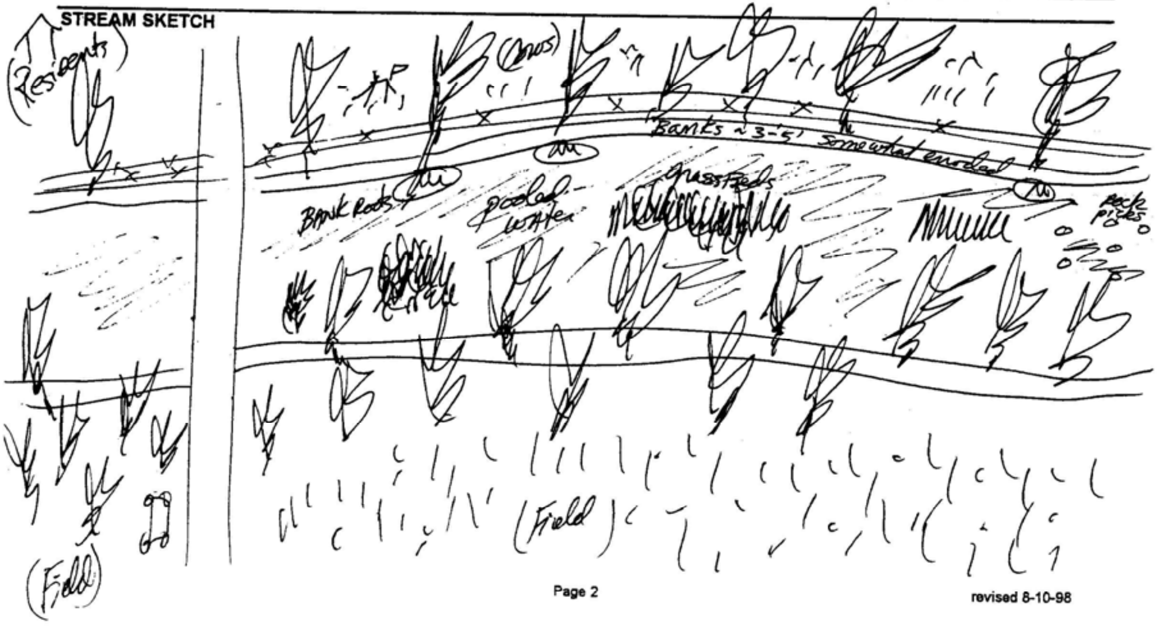
BASED ON OBSERVATIONS AND DATA, STREAM IS:(circle)

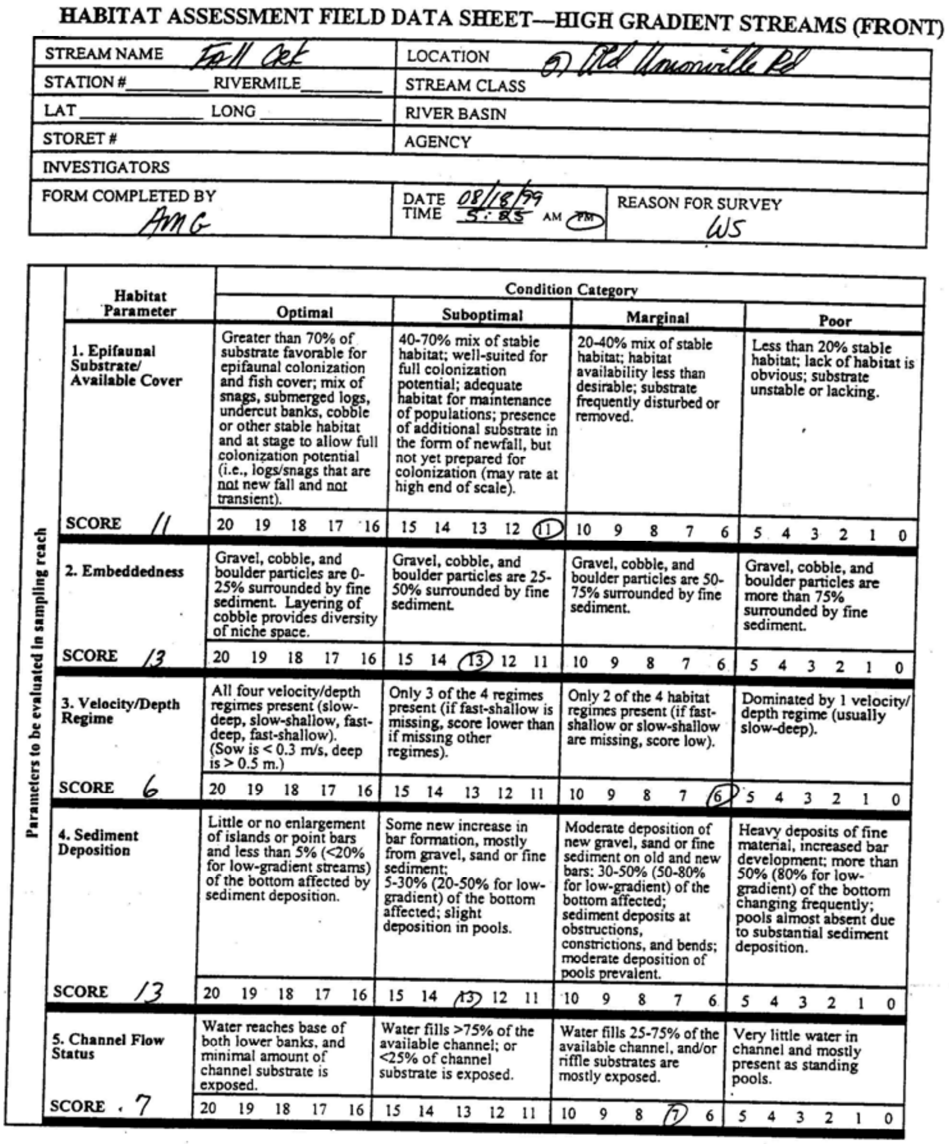
FULLY SUPPORTING (FS) SUPPORTING, BUT THREATENED (TH) [✓ PARTIALLY SUPPORTING (PS)] NONSUPPORTING (NS)

COMMENTS: photos ? [✓ Y] or N Roll # Photo # 4 u/s, #5 d/s, #6 algae mats (digital #33 u/s, #32 d/s, #31 algae mats)

This creek is similar to North Fork Creek in this area - very low flow @ this time + extensive habitat search = bank roots, grass beds, + cobble boulder rock piles... EPT (total) revealed ~ 5/24 suggestive of a (PS) status @ this time - this stream was already on the 303d list (agriculture) - some bank erosion - but algae is "choking" stream @ present - numerous fish schools present...

STREAM SKETCH





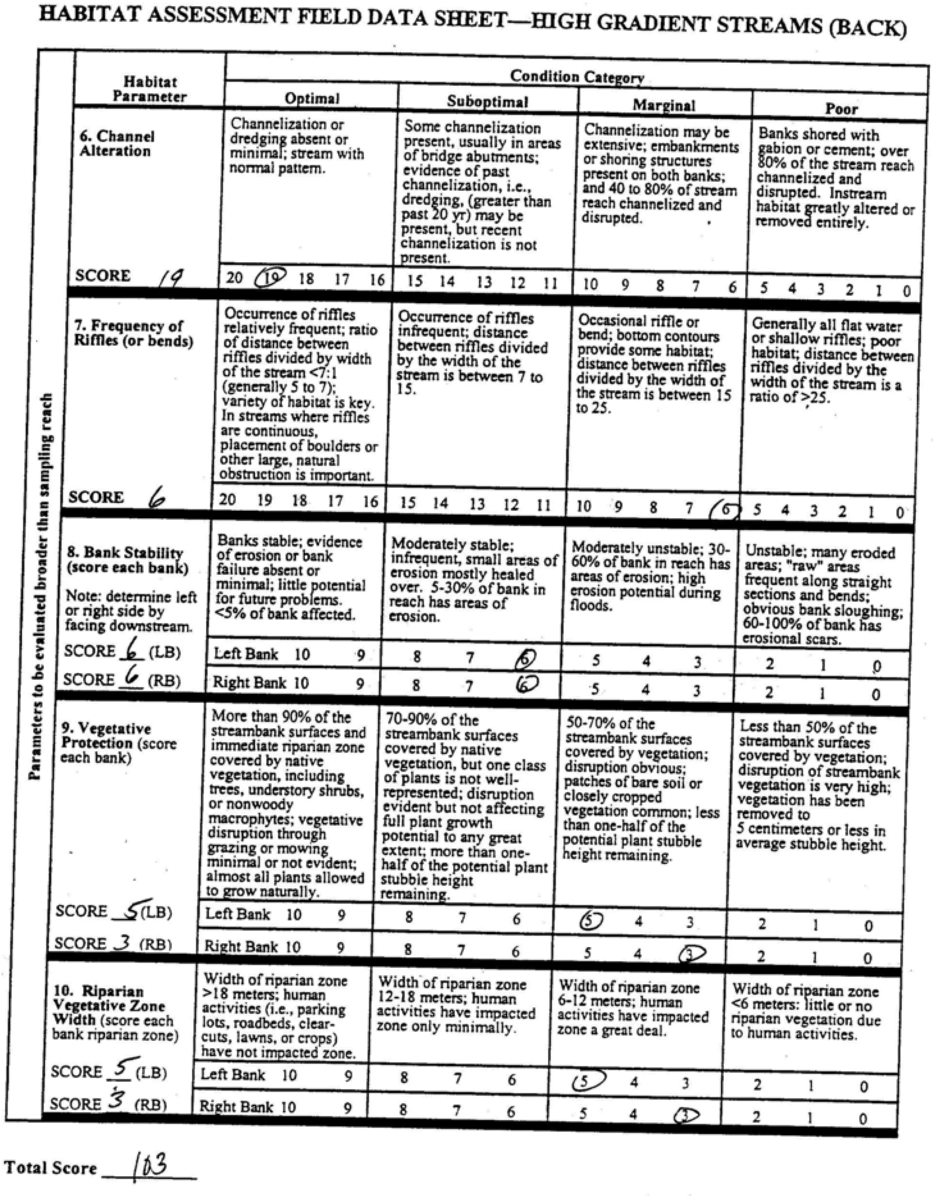
HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Fall Crk	LOCATION @ Old Unionville Rd
STATION #________ RIVERMILE________	STREAM CLASS
LAT ____________ LONG ____________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY AMG	DATE 08/18/99 TIME 5:25 AM [✓ PM] · REASON FOR SURVEY WS

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Sow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars: 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1 0

Total 103: Fair Habitat, but low flow - no riffles - bedrock bottom stream + choking algae + cows along side creek + riparian loss....



HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	**Condition Category** **Optimal**	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 19	20 [✓ 19] 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 6 (LB)	Left Bank 10 9	8 7 [✓ 6]	5 4 3	2 1 0
SCORE 6 (RB)	Right Bank 10 9	8 7 [✓ 6]	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 5 (LB)	Left Bank 10 9	8 7 6	[✓ 5] 4 3	2 1 0
SCORE 3 (RB)	Right Bank 10 9	8 7 6	5 4 [✓ 3]	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 5 (LB)	Left Bank 10 9	8 7 6	[✓ 5] 4 3	2 1 0
SCORE 3 (RB)	Right Bank 10 9	8 7 6	5 4 [✓ 3]	2 1 0

63 **Total Score** 103

STORET# TN06040002038 FALL001.2BE
STREAM NAME: Fall Crk
STREAM LOCATION: @ Unionville Rd (old) ~200' u/s N9908~~08~~10
ASSESSORS: A M Goodhue
DATE: Wed 08/18/99 **TIME:** Collection: 3:45-4:15
Pick 4:15-5:15

FIELD OBSERVATION OF MACROBENTHOS

Indicate estimated abundance (EA) and assessor (ASR):
1 = rare (1-3 organisms) 3 = abundant (10-29 organisms) 5 = dominant (> 50 organisms)
2 = common (4-9 organisms) 4 = very abundant (30-49 organisms)

NOTES: #1095 (Full Biorecon)

Habitats Sampled # of jabs in habitat	Cobble	Aquatic vegetation	Sediment	Stream banks	Woody debris/snags	Leaf packs
	1	1		2		

Taxa	EA/NO	
Ephemeroptera		
Baetidae		
Heptageniidae	✓	✓
Isonychia		
Caenidae	✓	✓
Ephemerellidae		
Leptophlebiidae		
Trichoptera		
Hydropsychidae		
Philopotamidae		
Rhyacophilidae		
Leptoceridae	✓	✓
Helicopsychinae	✓ ✓	✓ I
Limnephilinae	✓	✓ I
Plecoptera		
Leuctriform		
Perlidae		
Perlodidae		

Taxa	EA/NO	
Isopoda		
Amphipoda (not collected)	✓	✓
Decapoda - Cambaridae (Not collected)	✓	✓
Gastropoda	✓	✓
Ancylidae		
Physidae		
Bivalvia-Corbicula	✓	✓
Sphaeridae		
Diptera		
TAXA	✓	✓
Simuliidae		
Tabanidae		
Tipulidae		
Chironomidae - Red	✓	✓
Non-Red		
Tanypodinae		
Oligochaeta		
Hemiptera Hydrometridae	✓	✓
Corixidae	✓	✓
(2 TAXA)	\ (✓)	

Taxa	EA/NO	
Odonata		
Calopterygidae		
Argia	✓	✓
Boyeria	✓	✓
MACROMIIDAE	✓	✓
Coleoptera		
Elmidae	✓	✓
HALPLIDAE	✓	✓
Beetle larvae (Heliodidae-like)	✓	✓
Psephenidae (not collected)	✓	✓ I
Dryopidae		
Dystiscidae -like	✓	✓
Lepidoptera		
Megaloptera - Sialidae		
Corydalidae (not collected)	✓	
OTHER		
Porifera (sponges)		
Hydracarina (mites)	✓	
Platyhelminthes (flatworms) (not collected)	✓	
Hirudinea (leeches)		

TAXA RICHNESS 24 (+1)
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FOR ADDTIONAL INFO REFER TO STREAM SURVEY SHEET

TN0604000 2038 FALL CRK (7/SE)
(Full) FAll Crk (Upper Duck)

Figure B-1 Fall Creek at RM 1.2 – Upstream View

Figure B-2 Fall Creek at RM 1.2 – Downstream View

Figure B-3 Fall Creek at RM 1.2 – Algae Mats

APPENDIX C

Water Quality Monitoring Data

There are a number of water quality monitoring stations that provide data for waterbodies (Stage I) identified as impaired for low dissolved oxygen or nutrients in the Upper Duck River watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded at these stations for low dissolved oxygen or nutrient parameters since 11/1/99 are tabulated in Table C-1.

Table C-1 Water Quality Monitoring Data – Stage I TMDL Development

Monitoring Station	Date	NH_3 (as N)	BOD_5	DO	NO_3+NO_2	TKN	Total Phosphorus	Temp	Flow
		[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
CANEY002.6ML	11/9/99			15	2.77	0.79	0.01	15.2	0.08
	12/2/99	<0.02	<2	10.76				5.81	0.05
	1/6/00			14.29	1.72	<0.1	0.03	6.62	6.92
	2/8/00			14.91				5.17	1.64
	4/6/00	0.05	<2	12.2	1.18	0.24	0.07	15.2	
	5/4/00			10.2				18.3	39.01
	6/20/00			7.01				28.7	0.01
CASCA000.7BE	12/15/99	<0.02	<2	11.35	0.62 [b]	<0.1		6.56	3.59
	1/26/00			14.41				1.53	3.25
	2/10/00	0.09	<2	14.34	0.28	<0.1	0.01	4.94	2.36
	3/13/00			10.9				7.82	7.51
	5/2/00	<0.02	<2	10.5	0.19	<0.1	<0.004	17.3	8.45
	6/1/00			7.27				18.33	3.79
	8/19/03	<0.02		9.23	0.73	<0.1	<0.004	21.63	3.68
	9/10/03	<0.02		10.33	0.68	<0.1	<0.004	20.09	3.56
	10/15/03	0.04		11.05	0.76	<0.1	<0.004	<2	3.57
	11/5/03	<0.02		10.21	0.68	<0.1	0.016	18.22	3.60
	12/11/03	0.06		11.73	0.93	<0.1	0.05	9.25	7.07
	1/6/04	<0.02		12.34	0.89	0.22	0.004	8.37	6.38

Table C-1 (Contd.) Water Quality Monitoring Data – Stage I TMDL Development

Monitoring Station	Date	NH_3 (as N)	BOD_5	DO	NO_3+NO_2	TKN	Total Phosphorus	Temp	Flow
		[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
CLEAR001.1CE	12/16/99	0.29	4.4	8.62	0.70 [b]	0.99	0.49	6.64	0.45
	1/26/00			12.7				1.79	1.01
	2/9/00	0.23	7.7	11.55	0.66	1.04	0.27	7.26	0.96
	3/13/00			9.76				9.67	8.15
	5/11/00	0.15		7.32	0.50	0.68	0.16	15.9	1.80
	6/1/00			**3.74**				20.2	0.83
	8/6/02				0.12		2.00		
	8/13/02				0.09		0.66		
	8/19/03	1.03		**2.65**	0.18	1.73	0.23	21.94	0.49
	9/10/03	0.5		**2.47**	0.17	2.23	0.49	18.69	0.28
	10/15/03	0.13		5.21	0.13	0.74	0.19	12.67	0.93
	11/5/03	0.45		**2.09**	0.05	0.3	0.068	17.31	0.58
	12/11/03	<0.02		11.4	1.02	0.58	0.06	6.45	15
	1/6/04	<0.02		11.6	0.93	0.50	<0.004	5.82	16.42
CLEAR001.8CE	9/20/01	1.93		**2.55**	0.07	6.90	0.63	19.92	0.16
CLEM000.4BE	2/8/00	0.02		14.34	1.42	0.11	0.004		
	4/17/00	<0.02		10.44	1.63	<0.1	0.005	16.55	14.7
	5/10/01			**3.73**	0.07		0.05	17.95	~0
	12/10/03	<0.02		10.57	1.03	<0.1	<0.004	9.29	37.38
	1/22/04	<0.02		16.37	1.22	<0.1	<0.004	4.71	
FALL004.7BE	8/28/03	0.06		**2.25**	0.15	0.56	0.05 [c]	24.01	1.06
	9/30/03	0.06		7.54	0.25	0.3	0.09	14.5	2.41
	10/8/03	0.09		6.28	0.23	<0.1	0.027	7.42	0.66
	11/6/03	0.02			0.03	0.16	0.045	7.32	0.72
	12/10/03	<0.02		9.43	1.29	<0.1	0.009	10.82	74.08
	1/22/04	<0.02		15.63	0.04	0.60	<0.004	4.01	
FALL001.2BE	9/11/01	<0.02		8.24	0.03	<0.1	<0.004	23.29	0.67
FALL003.0BE	1/12/00	0.16		10.41	2.19	<0.1	<0.004	7.35	12.11
	4/13/00	<0.02		10.4	0.92	0.15	0.066	12.3	156.2
	7/24/00[a]	0.09		**3.1**	0.07	0.47	0.019	20.63	
	10/16/00	0.42		6.59	0.71	0.39	0.047	13.97	
	5/8/01			7.83	0.24		0.03	19.9	3.86
FALL006.1BE	9/10/01	<0.02		5.02	0.94	<0.1	0.12	21.1	0.59

Table C-1 (Contd.) Water Quality Monitoring Data – Stage I TMDL Development

Monitoring Station	Date	NH$_3$ (as N)	BOD$_5$	DO	NO$_3$+NO$_2$	TKN	Total Phosphorus	Temp	Flow
		[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
HURRI001.0BE	9/11/01	<0.02		9.71	0.13	<0.1	0.007	26.71	0.004
	8/11/03	0.05		7	0.09	0.21	0.06	24.63	0.02
	9/3/03	0.05		**3.62**	0.06	0.65 [c]	0.06 [c]	23.89	0.01
	10/29/03	<0.02		7.35	<0.01	0.45	0.124	12.24	
	11/17/03	<0.02		7.77	0.5	0.27	0.009	15.05	3.48
	12/3/03	<0.02		12.45	0.9	0.2	<0.004	7.46	8.81
	1/14/04	<0.02		13.8	0.52	0.1	0.025	5.45	4.10
HURRI004.2BE	1/12/00	<0.02		12.26	2.53	<0.1	<0.004	8.75	3.16
	4/19/00	0.02		11.7	0.45	0.18	0.005	12.1	8.33
	7/25/00	0.11		5.73	0.08	0.46	<0.004	22.7	
	10/17/00	0.04		**3.28**	0.04	0.31	<0.004	14.45	
	5/10/01			14.77	0.04		0.009	22.6	
NFORK009.4BE	8/28/03	<0.02		**4.55**	0.71	1.1	1.29 [c]	22.88	4.69
	9/30/03	0.02		7.71	0.46	0.22	0.06	13.85	2.34
	10/8/03	0.08		5.76	0.12	<0.1	0.025	7.3	0.60
	11/6/03	<0.02			0.03	0.4	0.202	16.67	0.29
	12/10/03	<0.02		9.45	0.67	0.21	0.2	10.17	
	1/22/04	<0.02		15.24	0.79	0.87	0.041	4.17	
NORK016.4BE	1/11/00	0.18		9.05	5.49	0.38	0.03	8.24	0.71
	4/19/00	<0.02		8.96	1.53	0.14	0.04	12.6	0.89
	5/10/01			7.17	0.76		0.02	16.97	0.02
WEAKL000.2BE	8/28/03	0.02		5.4	0.1	0.44	0.032 [c]	23.95	0.09
	9/30/03	<0.02		9.34	0.89	<0.1	0.03	14.17	1.38
	10/8/03	0.08		8.34	0.34	<0.1	0.005	7.68	0.64
	11/6/03	0.02			0.09	0.1	0.009	16.88	0.17
	12/10/03	<0.02		10.03	1.26	<0.1	0.031	10.45	58.07
	1/22/04	<0.02		15.82	1.20	<0.1	<0.004	5.55	
WEAKL001.7BE	9/10/01	<0.02		**3.79**	0.07	<0.1	0.01	23.43	0.05
WEAKL005.2BE	1/10/00	0.10		9.67	2.54	0.36	0.10	9.49	12.45
	4/17/00	<0.02		13.37	1.51	0.17	0.019	16.0	9.28
	5/8/01			6.9	0.19		0.05	19.5	0.04

Table C-1 (Contd.) Water Quality Monitoring Data – Stage I TMDL Development

Monitoring Station	Date	NH_3 (as N)	BOD_5	DO	NO_3+NO_2	TKN	Total Phosphorus	Temp	Flow
		[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
WILSO000.7ML	11/9/99			10.1				14.3	0.01
	12/2/99			11.64				5.4	0.12
	1/6/00			14.85				5.8	
WILSO002.9BE	2/9/00							6.25	4.29
	3/8/00								8.63
	4/6/00			11.9				14.2	
	5/4/00			10.7				19.1	30.78
	6/20/00			13.6				26.5	0.51
	12/11/03	0.05		11.56	1.13	0.13	0.142	7.56	
WILSO005.2BE	1/10/00	0.04		8.12	2.95	0.15	0.06	11.23	8.66
	4/17/00	<0.02		8.23	1.60	0.14	0.097	15.08	16.22
	7/25/00	5.0		12.1	0.26	5.0	<0.004	24.23	
	10/16/00[a]	0.13		6.93	1.12	0.54	0.037	13.98	0.03
	5/10/01			8.64	1.26		0.03	18.18	1.19

Notes: a. Multiple samples taken on date indicated. Values shown reflect sample with most parameters analyzed.
b. Sum of NO_3 sample and NO_2 sample.
c. Sample out of holding time.

Table C-2 Water Quality Monitoring Data – TN/TP Ratio

Monitoring Station	Date	Flow	Total Nitrogen [b]	Total Phosphorus	TN/TP
		[cfs]	[mg/l]	[mg/l]	
BOMAR000.8BE	8/11/03	0.01	0.15	0.05	3.0
	9/3/03	0.05	0.31	0.03 [c]	10.3
	10/29/03		0.65	0.075	8.7
	11/17/03	1.41	1.13	<0.004	282.5
	12/3/03	0.96	1.00	0.03	33.3
	1/14/04	0.96	0.42	0.008	52.5
				Geometric Mean	**22.6**
BOMAR001.0BE	9/4/01	0.59	1.94	0.30	6.5
CANEY002.6ML	11/9/99	0.08	3.56	0.01	356
	12/2/99	0.05			
	1/6/00	6.92	1.82	0.03	60.7
	2/8/00	1.64			
	4/6/00		1.42	0.07	20.3
	5/4/00	39.01			
	6/20/00	0.01			
				Geometric Mean	**76.0**
CASCA000.7BE	12/15/99	3.59	0.72		
	1/26/00	3.25			
	2/10/00	2.36	0.38	0.01	38
	3/13/00	7.51			
	5/2/00	8.45	0.29	<0.004	72.5
	6/1/00	3.79			
	8/19/03	3.68	0.83	<0.004	207.5
	9/10/03	3.56	0.78	<0.004	195
	10/15/03	3.57	0.86	<0.004	215
	11/5/03	3.60	0.78	0.016	48.8
	12/11/03	7.07	1.03	0.05	20.6
	1/6/04	6.38	1.11	0.004	277.5
				Geometric Mean	**103.7**

Table C-2 (Contd.) Water Quality Monitoring Data – TN/TP Ratio

Monitoring Station	Date	Flow	Total Nitrogen [b]	Total Phosphorus	TN/TP
		[cfs]	[mg/l]	[mg/l]	
CLEAR001.1CE	12/16/99	0.45	1.69	0.49	3.4
	1/26/00	1.01			
	2/9/00	0.96	1.70	0.27	3.4
	3/13/00	8.15			
	5/11/00	1.80	1.18	0.16	7.4
	6/1/00	0.83			
	8/6/02			2.00	
	8/13/02			0.66	
	8/19/03	0.49	1.91	0.23	8.3
	9/10/03	0.28	2.40	0.49	4.9
	10/15/03	0.93	0.87	0.19	4.5
	11/5/03	0.58	0.35	0.068	5.1
	12/11/03	15	1.60	0.06	26.7
	1/6/04	16.42	1.43	<0.004	357.5
				Geometric Mean	**10.4**
CLEAR001.8CE	9/20/01	0.16	6.97	0.63	11.1
CLEM000.4BE	2/8/00		1.53	0.004	382.5
	4/17/00	14.7	1.73	0.005	346
	5/10/01	~0		0.05	
	12/10/03	37.38	1.13	<0.004	282.5
	1/22/04		1.32	<0.004	330
				Geometric Mean	**333.3**
FALL004.7BE	8/28/03	1.06	0.71	0.05 [c]	14.2
	9/30/03	2.41	0.55	0.09	6.1
	10/8/03	0.66	0.33	0.027	12.2
	11/6/03	0.72	0.19	0.045	4.2
	12/10/03	74.08	1.39	0.009	154.4
	1/22/04		0.64	<0.004	160
				Geometric Mean	**21.9**
FALL001.2BE	9/11/01	0.67	0.13	<0.004	32.5
FALL003.0BE	1/12/00	12.11	2.29	<0.004	572.5
	4/13/00	156.2	1.07	0.066	16.2
	7/24/00[a]		0.54	0.019	28.4
	10/16/00		1.10	0.047	23.4
	5/8/01	3.86		0.03	
				Geometric Mean	**49.8**
FALL006.1BE	9/10/01	0.59	1.04	0.12	8.7

Table C-2 (Contd.) Water Quality Monitoring Data – TN/TP Ratio

Monitoring Station	Date	Flow [cfs]	Total Nitrogen [b] [mg/l]	Total Phosphorus [mg/l]	TN/TP
HURRI001.0BE	9/11/01	0.004	0.23	0.007	32.9
	8/11/03	0.02	0.30	0.06	5.0
	9/3/03	0.01	0.71	0.06 [c]	11.8
	10/29/03		0.46	0.124	3.7
	11/17/03	3.48	0.77	0.009	85.6
	12/3/03	8.81	1.10	<0.004	275.0
	1/14/04	4.10	0.62	0.025	24.8
				Geometric Mean	**23.7**
HURRI004.2BE	1/12/00	3.16	2.63	<0.004	657.5
	4/19/00	8.33	0.63	0.005	126.0
	7/25/00		0.54	<0.004	135.0
	10/17/00		0.35	<0.004	87.5
	5/10/01			0.009	
				Geometric Mean	**176.9**
NFORK009.4BE	8/28/03	4.69	1.81	1.29 [c]	1.4
	9/30/03	2.34	0.68	0.06	11.3
	10/8/03	0.60	0.22	0.025	8.8
	11/6/03	0.29	0.43	0.202	2.1
	12/10/03		0.88	0.2	4.4
	1/22/04		1.66	0.041	40.5
				Geometric Mean	**6.1**
NFORK016.4BE	1/11/00	0.71	5.87	0.03	195.7
	4/19/00	0.89	1.67	0.04	41.8
	5/10/01	0.02		0.02	
				Geometric Mean	**90.4**
WEAKL000.2BE	8/28/03	0.09	0.54	0.032	16.9
	9/30/03	1.38	0.99	0.03	33.0
	10/8/03	0.64	0.44	0.005	88.0
	11/6/03	0.17	0.19	0.009	21.1
	12/10/03	58.07	1.36	0.031	43.9
	1/22/04		1.30	<0.004	325.0
				Geometric Mean	**49.5**
WEAKL001.7BE	9/10/01	0.05	0.17	0.01	17.0
WEAKL005.2BE	1/10/00	12.45	2.90	0.1	29.0
	4/17/00	9.28	1.68	0.019	88.4
	5/8/01	0.042		0.05	
				Geometric Mean	**50.6**

Table C-2 (Contd.) Water Quality Monitoring Data – TN/TP Ratio

Monitoring Station	Date	Flow	Total Nitrogen [b]	Total Phosphorus	TN/TP
		[cfs]	[mg/l]	[mg/l]	
WILSO000.7ML	11/9/99	0.01			
	12/2/99	0.12			
	1/6/00				
WILSO002.9BE	2/9/00	4.29			
	3/8/00	8.63			
	4/6/00				
	5/4/00	30.78			
	6/20/00	0.51			
	12/11/03		1.26	0.142	8.9
WILSO005.2BE	1/10/00	8.66	3.10	0.06	51.7
	4/17/00	16.22	1.74	0.097	17.9
	7/25/00		5.26	<0.004	1315.0
	10/16/00[a]	0.03	1.66	0.037	44.9
	5/10/01	1.19		0.03	
				Geometric Mean	**86.0**

Notes: a. Multiple samples taken on date indicated. Values shown reflect sample with most parameters analyzed.
b. Sum of NO_2 + NO_3 sample and TKN sample.
c. Sample out of holding time.

APPENDIX D

Land Use Distribution in Impaired HUC-12 Subwatersheds

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

Land Use	HUC-12 Subwatershed (06040002__)							
	0101		0106		0308		0401	
	[acres]	[%]	[acres]	[acres]	[acres]	[%]	[acres]	[%]
Open Water	157	0.4	3	0.1	19	0.1	4	0.0
Low Intensity Residential	205	0.5	109	1.7	115	0.5	32	0.3
High Intensity Residential	26	0.1	6	0.1	0	0.0	0	0.0
High Intensity Commercial /Industrial/Transportation	147	0.4	13	0.2	244	1.0	46	0.4
Bare Rock/Sand/Clay	2	0.0	0	0.0	0	0.0	0	0.0
Transitional	139	0.4	0	0.0	7	0.0	0	0.0
Deciduous Forest	14,147	38.8	4,930	78.1	6,917	27.6	2,604	22.7
Evergreen Forest	132	0.4	105	1.7	826	3.3	206	1.8
Mixed Forest	729	2.0	354	5.6	2,285	9.1	778	6.8
Pasture/Hay	10,056	27.6	547	8.7	8,941	35.6	4,507	39.4
Row Crops	8,325	22.8	204	3.2	5,337	21.2	2,973	26.0
Other Grasses (Urban/Recreational)	63	0.2	41	0.6	129	0.5	0	0.0
Woody Wetlands	2,280	6.3	2	0.0	272	1.1	279	2.4
Emergent Herbaceous Wetlands	53	0.1	0	0.0	5	0.0	17	0.2
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	0	0.0	0	0.0
Subtotal – Urban	517	1.4	128	2.0	366	1.5	78	0.7
Subtotal - Agriculture	18,381	50.4	751	11.9	14,278	56.8	7,480	65.4
Subtotal - Forest	17,406	47.8	5,432	86.0	10,434	41.6	3,884	33.9
Total	**36,461**	**100.0**	**6,314**	**100.0**	**25,097**	**100.0**	**11,446**	**100.0**

Land Use	HUC-12 Subwatershed (06040002__)							
	0404		0405		0502		0504	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Open Water	38	0.3	146	1.5	4	0.0	4	0.0
Low Intensity Residential	66	0.6	30	0.3	13	0.1	47	0.3
High Intensity Residential	6	0.0	2	0.0	0	0.0	6	0.0
High Intensity Commercial /Industrial/Transportation	76	0.7	80	0.9	11	0.1	28	0.2
Bare Rock/Sand/Clay	0	0.0	0	0.0	0	0.0	0	0.0
Transitional	0	0.0	0	0.0	0	0.0	0	0.0
Deciduous Forest	2,325	20.0	2,338	24.6	2,417	23.6	7,167	37.8
Evergreen Forest	374	3.2	611	6.5	486	4.7	993	5.3
Mixed Forest	981	8.4	1,215	12.8	1,093	10.7	2,642	13.9
Pasture/Hay	3,990	34.2	3,432	36.1	4,362	42.6	4,428	23.4
Row Crops	3,020	25.9	1,532	16.1	1,862	18.2	3,610	19.0
Other Grasses (Urban/Recreational)	5	0.0	1	0.0	0	0.0	0	0.0
Woody Wetlands	678	5.8	101	1.1	0	0.0	23	0.1
Emergent Herbaceous Wetlands	99	0.9	8	0.1	0	0.0	0	0.0
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	0	0.0	0	0.0
Subtotal – Urban	148	1.3	112	1.2	24	0.2	81	0.5
Subtotal - Agriculture	7,010	60.1	4,964	52.2	6,224	60.8	8,038	42.4
Subtotal - Forest	4,462	38.3	4,274	45.1	3,996	39.0	10,825	57.1
Total	**11,658**	**100.0**	**9,496**	**100.0**	**10,248**	**100.0**	**18,948**	**100.0**

APPENDIX E

Development of Nutrient & $CBOD_5$ TMDLs

DEVELOPMENT OF STAGE I NUTRIENT & CBOD$_5$ TMDLS

Target nutrient concentrations for Level IV ecoregions 71g, 71h, & 71i were used to develop nutrient TMDLs for the Upper Duck River watershed using the procedure outlined below.

Development of Target Nutrient Loads for Level IV Ecoregions

1. Reference sites for Level IV ecoregions 71g, 71h, & 71i were identified (see Figure E-1) and the watershed, corresponding to USGS 8-digit hydrologic unit codes (HUCs), in which each site was located noted. This information is summarized in Table E-1.

Table E-1 Location of Level IV Ecoregion Reference Sites

Level IV Ecoregion	Reference Site	Stream	Watershed	
			Name	HUC
71g	ECO71G03	Flat Creek	Upper Cumberland (Cordell Hull Lake)	05130106
	ECO71G04	Spring creek	Upper Cumberland (Cordell Hull Lake)	05130106
	ECO71G10	Hurricane Creek	Upper Elk	06030003
71h	ECO71H03	Flynn Creek	Upper Cumberland (Cordell Hull Lake)	05130106
	ECO71H06	Clear Fork	Caney Fork	05130108
	ECO71H09	Carson Fork	Stones	05130203
71i	ECO71I03	Stewart Creek	Stones	05130203
	ECO71I10	Flat Creek	Upper Duck	06040002
	ECO71I12	Cedar Creek	Cumberland (Old Hickory Lake)	05130201
	ECO71I14	Little Flat Creek	Upper Duck	06040002
	ECO71I15	Harpeth River	Harpeth	05130204

Note: Ecoregion reference sites are continuously reviewed, with sites added or deleted as circumstances warrant. The sites shown were the ecoregion reference sites as of June 3, 2003.

2. Using the Loading Simulation Program in C++ (LSPC), each 8-digit HUC containing a Level IV ecoregion reference site was calibrated for hydrology (LSPC is based on the Hydrological Simulation Program – Fortran [HSPF] and has been utilized extensively for pathogen TMDLs in EPA Region IV). The calibrations were performed over a 10-year period using an appropriate USGS continuous gaging station. Special attention was paid to total volume of water, both on a yearly basis as well as for the entire 10-year period. The hydrologic parameters in the calibrated model were validated where possible using another USGS continuous gaging station.

3. The calibrated watershed models were then utilized to simulate the daily flow at each ecoregion reference site for a 10-year period.

4. The total nitrogen concentration, serving as the water quality goal, (ref. Section 5.2) was applied to each daily flow at each ecoregion reference site to generate daily total nitrogen loads.

5. The average monthly total nitrogen loads for January were calculated for each site by summing the daily loads for each January during the 10-year period and dividing by 10. This process was repeated for all other months.

6. Average semiannual total nitrogen loads were calculated for reference sites by summing the average monthly loads for each six month period (May-October & November-April).

7. The average semiannual total nitrogen loads, on a unit area basis, were calculated for each ecoregion reference site by dividing the average semiannual loads (Step 6) by the corresponding reference site drainage areas. Average semiannual total nitrogen loads per unit area are shown in Table E-2 for each ecoregion reference site.

8. The average semiannual total nitrogen load per unit area for Level IV ecoregion 71g was determined by calculating the geometric mean of semiannual total nitrogen loads per unit area (Step 7) of the three ecoregion 71g reference sites. The target average semiannual total nitrogen loads per unit area for Level IV ecoregions 71h (3 sites) & 71i (5 sites) were determined in a similar manner.

9. Steps 4 through 8 were repeated for total phosphorus and $CBOD_5$. Target nutrient and $CBOD_5$ loads, on a unit area basis, for Level IV ecoregions 71g, 71h & 71i are summarized in Table E-3.

Table E-2 Average Semiannual Nutrient & CBOD$_5$ Loads for Ecoregion Reference Sites

Ecoregion Reference Site	Total Nitrogen		Total Phosphorus		CBOD$_5$	
	Summer	Winter	Summer	Winter	Summer	Winter
	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]
ECO71G03	0.7493	1.9072	0.0217	0.0553	1.6288	4.1460
ECO71G04	0.9099	2.2970	0.0264	0.0666	1.9781	4.9934
ECO71G10	0.5683	2.7868	0.0165	0.0808	1.2355	6.0583
ECO71H03	1.8732	4.3209	0.1544	0.3561	3.8596	8.9029
ECO71H06	0.8439	2.7838	0.0696	0.2294	1.7387	5.7358
ECO71H09	0.7452	2.9570	0.0614	0.2437	1.5354	6.0927
ECO71I03	0.7812	3.0813	0.1656	0.6530	1.5521	6.1218
ECO71I10	1.1073	3.4787	0.2347	0.7372	2.2000	6.9114
ECO71I12	1.4027	3.2069	0.2973	0.6796	2.7869	6.3714
ECO71I14	1.6895	3.6258	0.3580	0.7684	3.3566	7.2036
ECO71I15	1.1970	3.1854	0.2537	0.6751	2.3781	6.3286

Note: Summer: 5/1 – 10/31; Winter: 5/1 – 10/31

Table E-3 Target Semiannual Nutrient & CBOD$_5$ Loads for Level IV Ecoregions 71g, 71h, & 71i

Level IV Ecoregion	Total Nitrogen		Total Phosphorus		CBOD$_5$	
	Summer	Winter	Summer	Winter	Summer	Winter
	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]	[lbs/ac/6 mo.]
71g	0.7290	2.3025	0.0211	0.0667	1.5849	5.0056
71h	1.0561	3.2887	0.0870	0.2710	2.1760	6.7761
71i	1.1967	3.3095	0.2536	0.7014	2.3775	6.5752

Note: Summer: 5/1 – 10/31; Winter: 5/1 – 10/31

Development of Nutrient TMDLs for Subwatersheds in the Upper Duck River Watershed

Note: Calculations for Subwatershed 060400020504 (Caney Creek) are shown. The procedure for other subwatersheds is similar.

10. Since the Subwatershed 0604000504 is approximately 8.5% in ecoregion 71h and 91.5% in ecoregion 71i, target nutrient loads for the subwatershed as a whole were based on an area-weighted combination of the ecoregion target loads:

$$TMDL_{0504} = (TL_{71h})\,(A_{71h}) + (TL_{71i})\,(A_{71i})$$

where: $TMDL_{0504}$ = TMDL for Subwatershed 060400020504 [lbs/6 mo.]
TL_{71h} = Target load for ecoregion 71h [lbs/acre/6 mo.]
A_{71h} = Area of Caney Creek subwatershed in ecoregion 71h [acres]
TL_{71i} = Target load for ecoregion 71i [lbs/acre/6 mos.]
A_{71i} = Area of Caney Creek subwatershed in ecoregion 71i [acres]

As an example, for total nitrogen during the period from 5/1 through 10/31:

$$TMDL_{0504} = (1.0561 \text{ lbs/ac/6 mos.})\,(1{,}606 \text{ ac}) + (1.1967 \text{ lbs/ac/6 mos.})\,(17{,}342 \text{ ac})$$

$$TMDL_{0504} = 22{,}449 \text{ lbs/6 mos.}$$

For total phosphorus:

$$TMDL_{0504} = (0.0870 \text{ lbs/ac/6 mos.})\,(1{,}606 \text{ ac}) + (0.2536 \text{ lbs/ac/6 mos.})\,(17{,}342 \text{ ac})$$

$$TMDL_{0504} = 4{,}538 \text{ lbs/6 mos.}$$

Note: Stage I TMDLs for $CBOD_5$ were not developed for Subwatershed 0504 (Caney Creek) since low dissolved oxygen was not specifically identified as a cause of impairment.

Calculations were performed using a spreadsheet program and may differ slightly from example values due to round off.

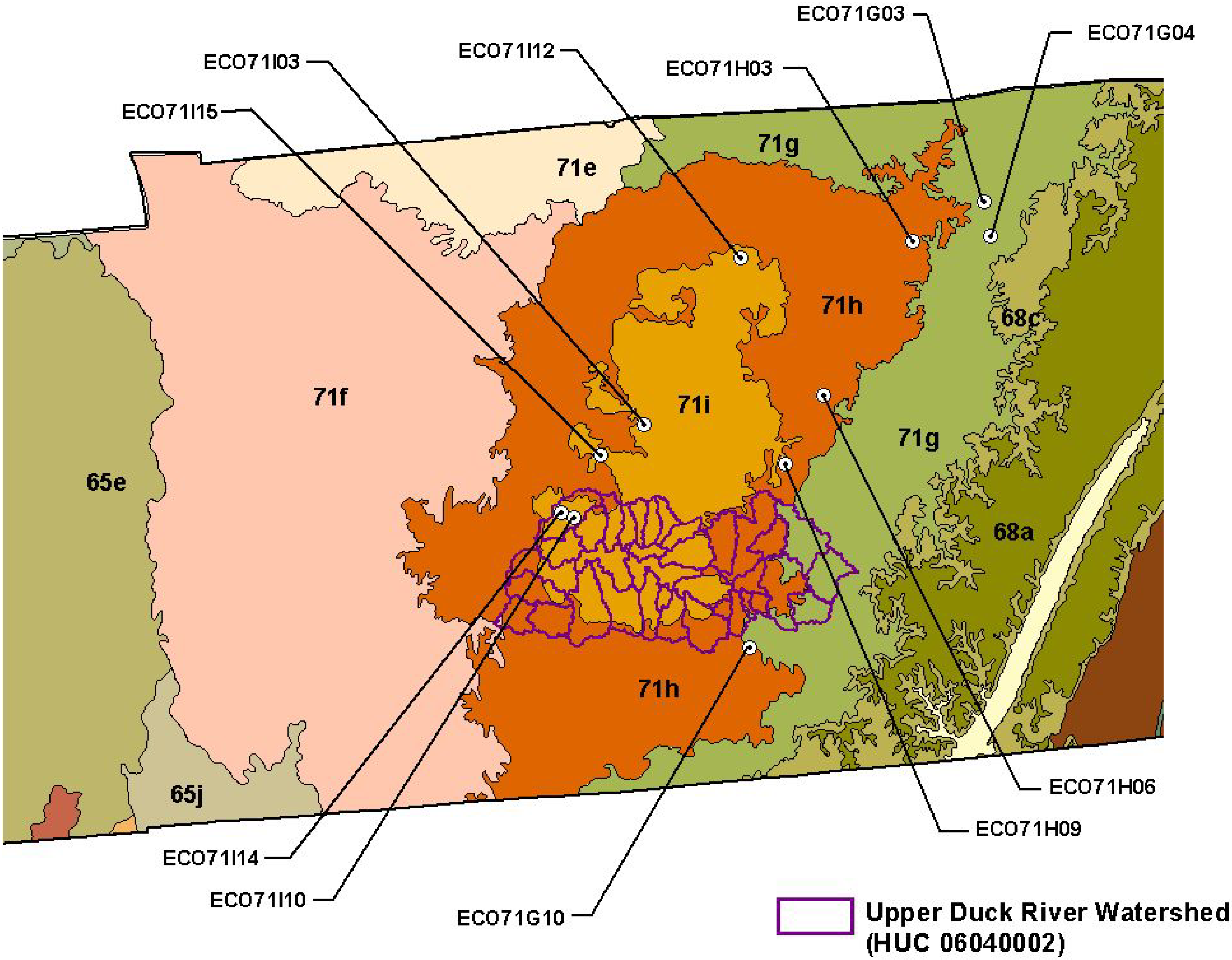
TMDLs for impaired HUC-12 subwatersheds and impaired waterbody drainage areas are summarized in Table E-4. Since Clear Branch was the only waterbody (Stage I TMDL) that was identified as impaired due to low dissolved oxygen, $CBOD_5$ TMDLs were developed only for Subwatershed 0101.

Table E-4 Stage I Nutrient & CBOD$_5$ TMDLs for Impaired HUC-12 Subwatersheds

HUC-12 Subwatershed (06040002__) or Drainage Area	Impaired Waterbody	TMDL					
		Total Nitrogen		Total Phosphorus		CBOD$_5$	
		Summer [lbs/6 mos.]	Winter [lbs/6 mos.]	Summer [lbs/6 mos.]	Winter [lbs/6 mos.]	Summer [lbs/6 mos.]	Winter [lbs/6 mos.]
0101	Clear Branch	26,580	83,951	769	2,432	57,787	182,509
0106	Cascade Creek	6,458	20,131	507	1,580	NA	NA
0308	Fall Creek Hurricane Creek	29,810	83,025	6,100	16,918	NA	NA
0401	North Fork Creek	13,697	37,881	2,903	8,028	NA	NA
0404	Weakley Creek	13,951	38,582	2,956	8,177	NA	NA
0405	Clem Creek	11,364	31,427	2,408	6,660	NA	NA
0502	Wilson Creek	12,264	33,916	2,599	7,188	NA	NA
0504	Caney Creek	22,449	62,675	4,538	12,599	NA	NA

Note: Summer: May 1 – October 31; Winter: November 1 – April 30.
NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment).

Figure E-1 Reference Sites in Level IV Ecoregions 71g, 71h, & 71i



APPENDIX F

Estimation of Required Reduction in Nutrient & $CBOD_5$ Loading

ESTIMATION OF REQUIRED REDUCTION IN NUTRIENT & CBOD$_5$ LOADING

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. When a water quality target (or criteria) concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: one representing high flows, another for moist conditions, one covering median or mid-range flows, another for dry conditions, and one representing low flows. Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left generally reflect potential nonpoint source contributions (Cleland, 2003).

The reductions in existing nutrient loading required to achieve specified TMDLs were estimated using load duration curves and water quality monitoring data.

Development of Load-Duration Curve and Estimation of Required Load Reductions

Nutrient load-duration curves for HUC-12 subwatershed 060400020504 (Caney Creek) were developed from the flow-duration curve of North Fork Creek at USGS continuous record station 03598250 near Poplins Crossroads (RM 3.4), the appropriate drainage areas, and monitoring data collected in 1999 & 2000 using the following procedure:

1. A flow-duration curve for USGS 03598250 was constructed using daily mean flows for the period from 10/1/99 through 9/30/02. A flow duration curve is a cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the largest daily mean flow during this period is exceeded 0% of the time and the smallest daily mean flow is exceeded ~100% of the time). USGS 03548250 is a continuous record station located on North Fork Creek at RM 3.4, near Poplins Crossroads.

2. Each ranked daily mean flow was divided by the drainage area upstream of the USGS station to create a flow-duration curve on a unit drainage area basis. (There is, therefore, a "percent of days that the flow per unit area is exceeded" associated with each of the 1,096 measured daily mean flows per unit area).

3. Each ranked daily mean flow on a unit area basis was multiplied by the drainage area upstream of water quality monitoring station CANEY002.6ML to create a flow duration curve for Caney Creek at the station location.

4. A composite target total nitrogen concentration was determined for the CANEY002.6ML drainage area using the water quality goal concentrations for Level IV ecoregions 71h & 71i (ref.: Section 5.2) and the fraction of the drainage area in each ecoregion:

$$TN_{Composite} = \frac{[(TN_{71h})\,(DA_{71h})] + [(TN_{71i})\,(DA_{71i})]}{(DA_{71h} + DA_{71i})}$$

$$TN_{Composite} = \frac{[(0.728\ mg/l)\ (1{,}606\ acres)] + [(0.755\ mg/l)\ (17{,}342\ acres)]}{(1{,}606\ acres + 17{,}342\ acres)}$$

$$TN_{Composite} = 0.753\ mg/l$$

5. A target load-duration curve was generated for Caney Creek at the CANEY002.6ML station location the by applying the composite target nitrogen water quality goal concentration to each of the 1,096 ranked flows:

   $$(Target\ Load)_{CANEY002.6ML} = (TN_{Composite})_{CANEY002.6ML} \times (Q) \times (UCF)$$

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

6. Total Nitrogen loads were calculated for each of the samples collected at the CANEY002.6ML monitoring station (ref.: Table C-1) by multiplying the sample concentration by the measured flow (and the required unit conversion factor).

7. Using the flow duration curve developed in Step 3, the "percent of days the flow (associated with the sampling event) was exceeded" (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curve developed in Step 5 according to the PDFE. The resulting curve is shown in Figure F-1.

8. The percent load reduction corresponding to each sample load was determined through comparison with the target load corresponding to the PDFE. The overall reduction of existing nutrient load required to meet the TMDL target was estimated to be the geometric mean of the individual sample reductions. Negative reductions were not used in the estimation of the overall reduction.

   Note: The geometric mean was used in cases where the number of individual sample reductions was less than ten. The arithmetic mean (average) was used where the number of individual sample reductions was ten or greater.

9. Steps 1 through 8 were repeated for total phosphorus. The load duration curve for total phosphorus is shown in Figure F-2. Sample loads, target loads, PDFEs, and approximate required reductions in nutrient loading for Caney Creek are summarized in Table F-1. Since low dissolved oxygen was not identified as a cause of impairment and the two BOD_5 samples collected were below the sample quantitation limit (ref: Appendix C), a load duration curve was not developed for $CBOD_5$.

Load duration curves for other HUC-12 subwatersheds and drainage areas containing waterbodies identified as impaired due to low dissolved oxygen or nutrients were developed using a similar methodology and are shown in Figures F-3 through F-17. Sample loads, target loads, PDFEs, and approximate required reductions in nutrient loading for these waterbodies are summarized in Tables F-2 through F-9 (Clear Branch was the only impaired waterbody with low dissolved oxygen identified as a cause of impairment and with BOD_5 data above the sample quantitation level).

Figure F-1 Total Nitrogen Load Duration Curve – Caney Creek at CANEY002.6ML

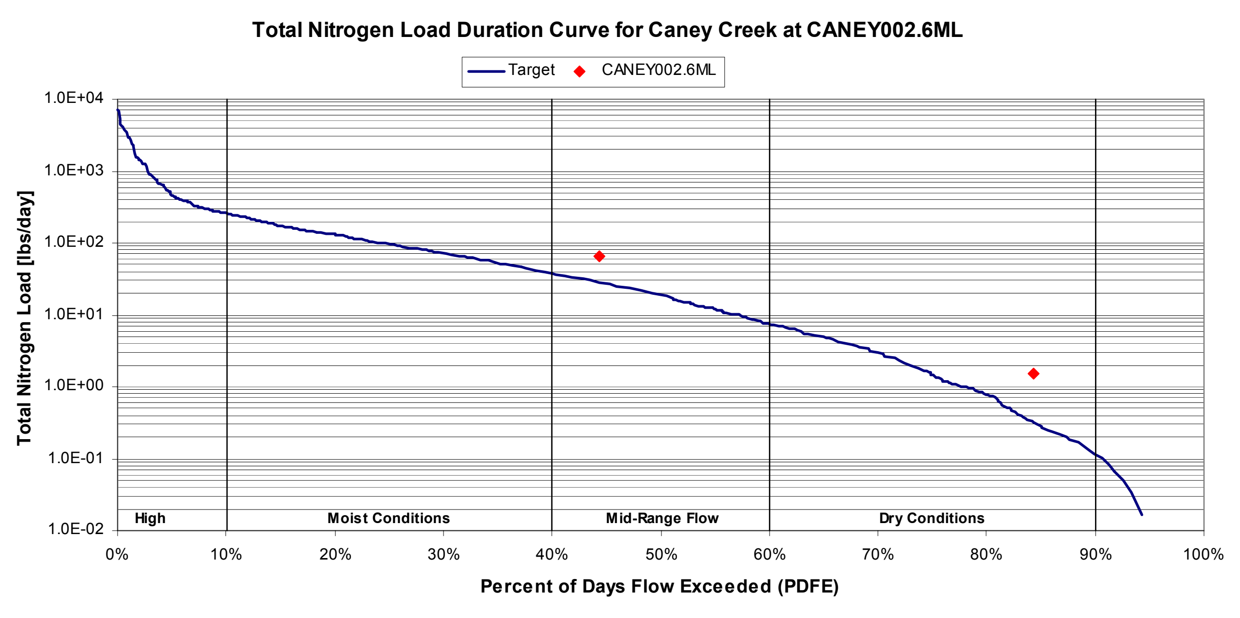


Figure F-2 Total Phosphorus Load Duration Curve – Caney Creek at CANEY002.6ML

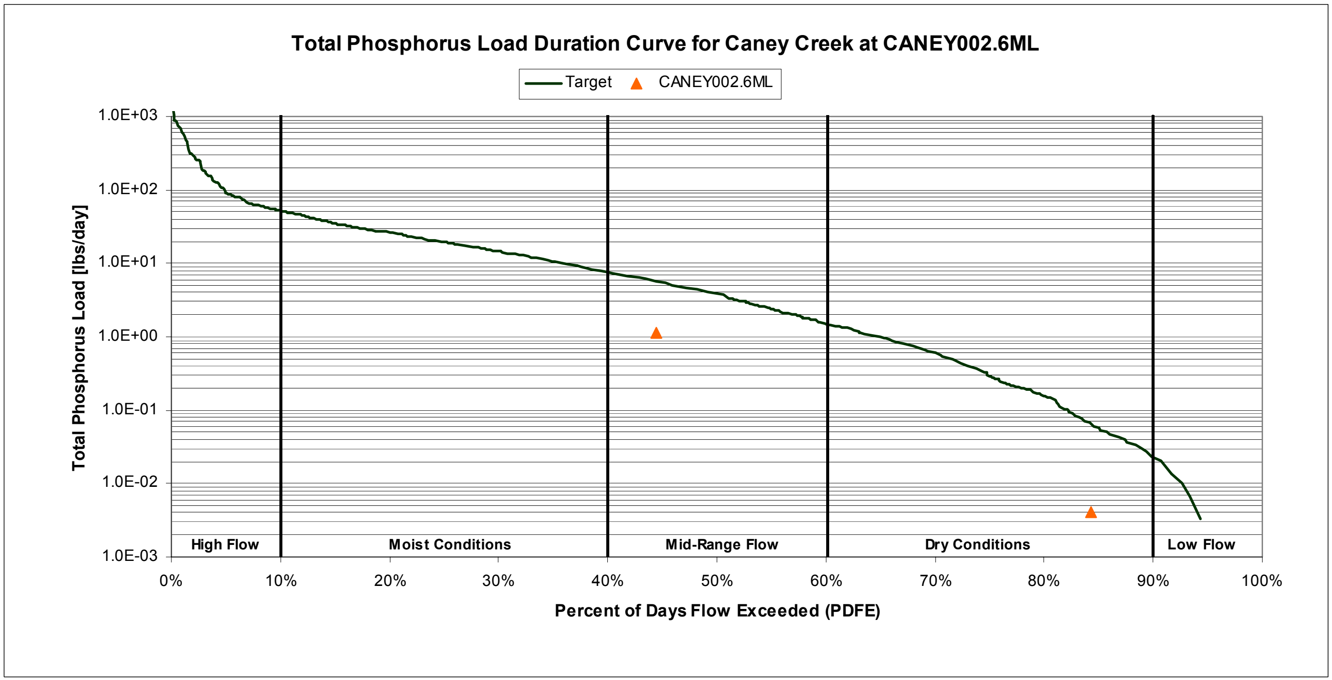


Figure F-3 Total Nitrogen Load Duration Curve – Wilson Creek at WILSO005.2BE

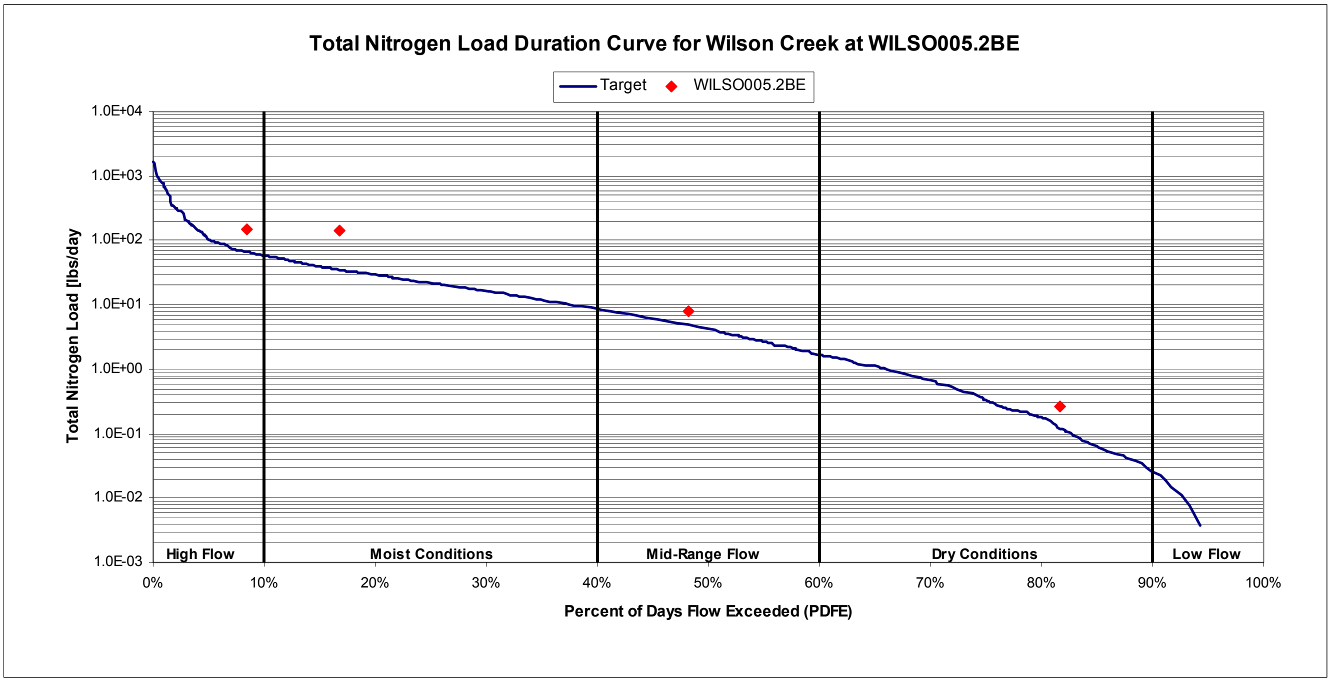


Figure F-4 Total Phosphorus Load Duration Curve – Wilson Creek at WILSO005.2BE

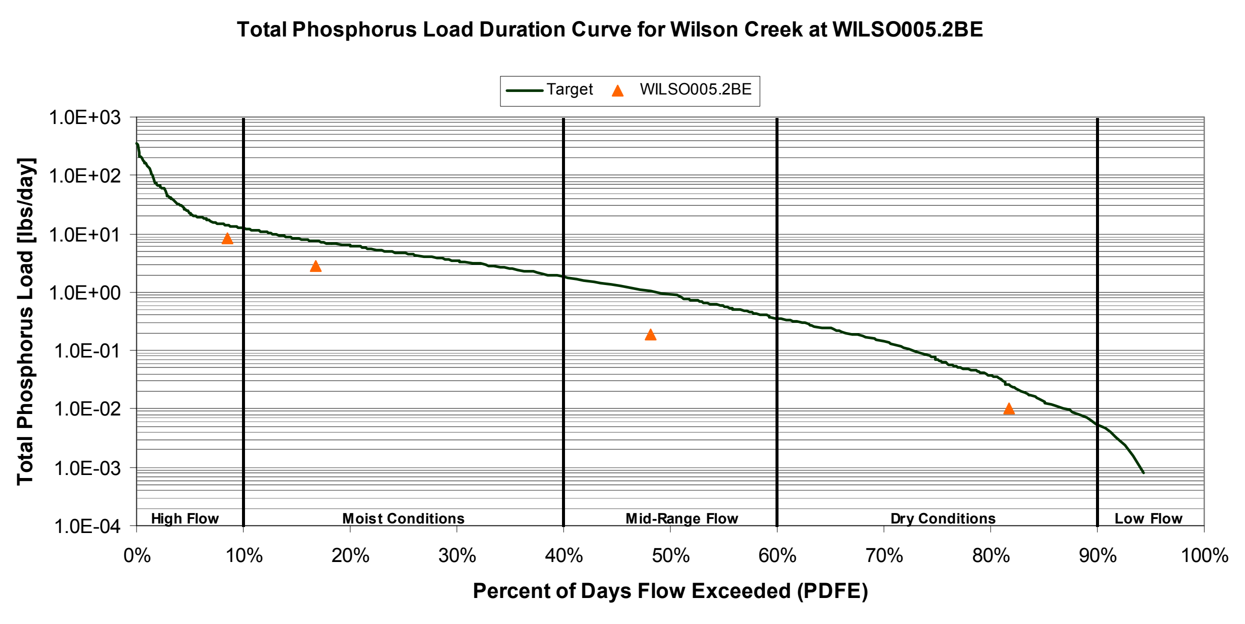


Figure F-5 Total Nitrogen Load Duration Curve – Clem Creek at CLEM000.4BE

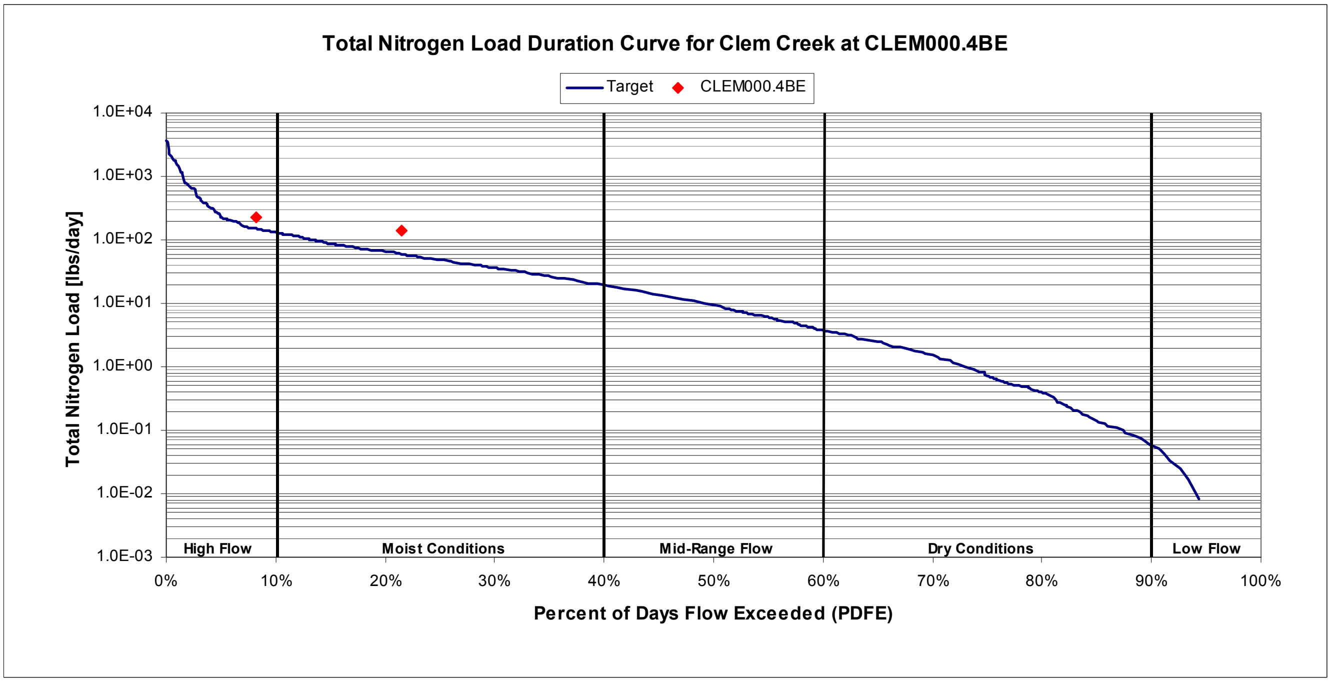


Figure F-6 Total Phosphorus Load Duration Curve – Clem Creek at CLEM000.4BE

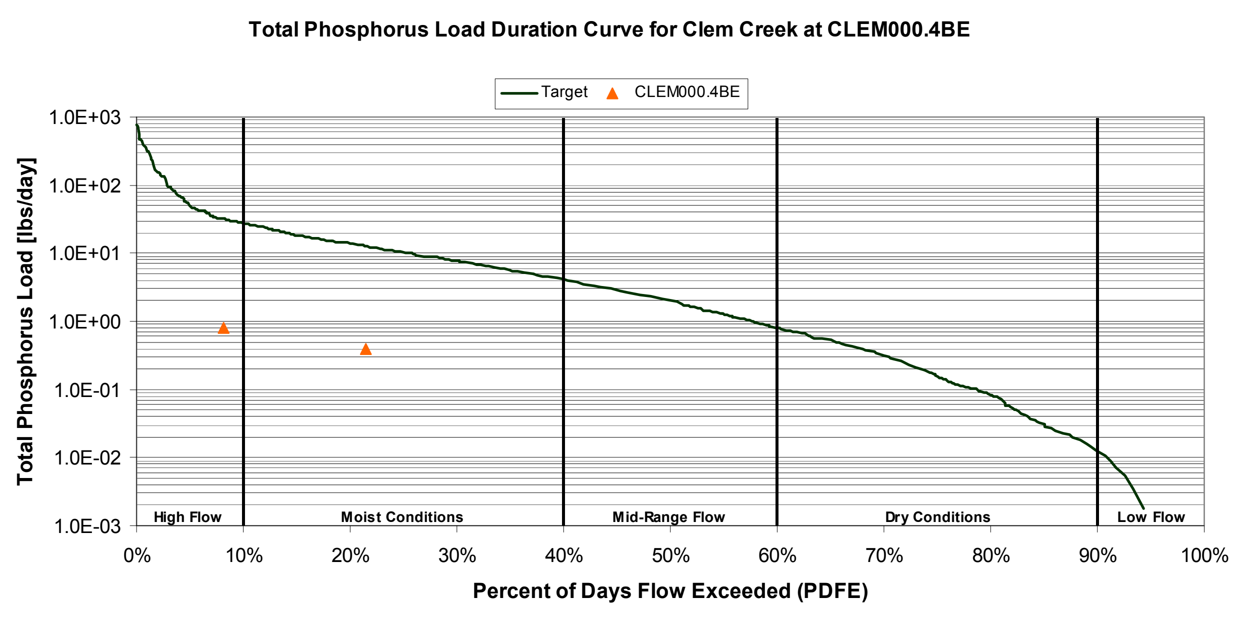


Figure F-7 Total Nitrogen Load Duration Curve – Weakley Creek at WEAKL000.2BE

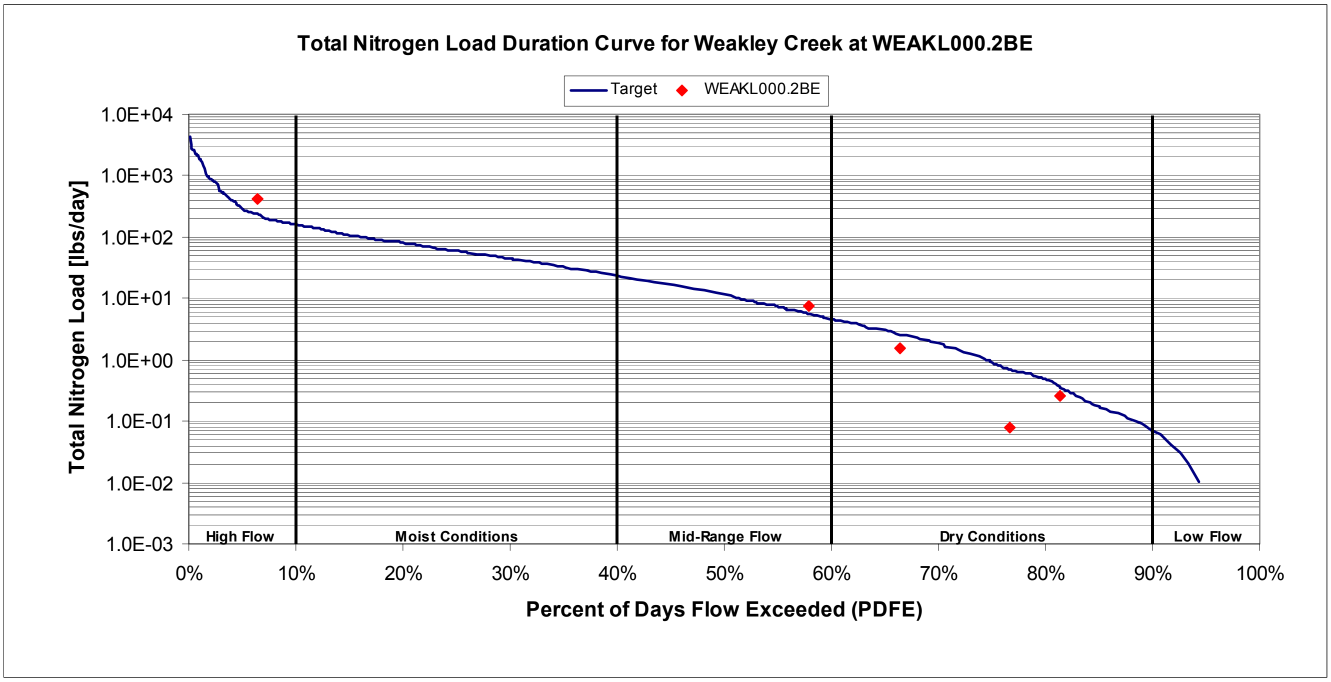


Figure F-8 Total Phosphorus Load Duration Curve – Weakley Creek at WEAKL000.2BE

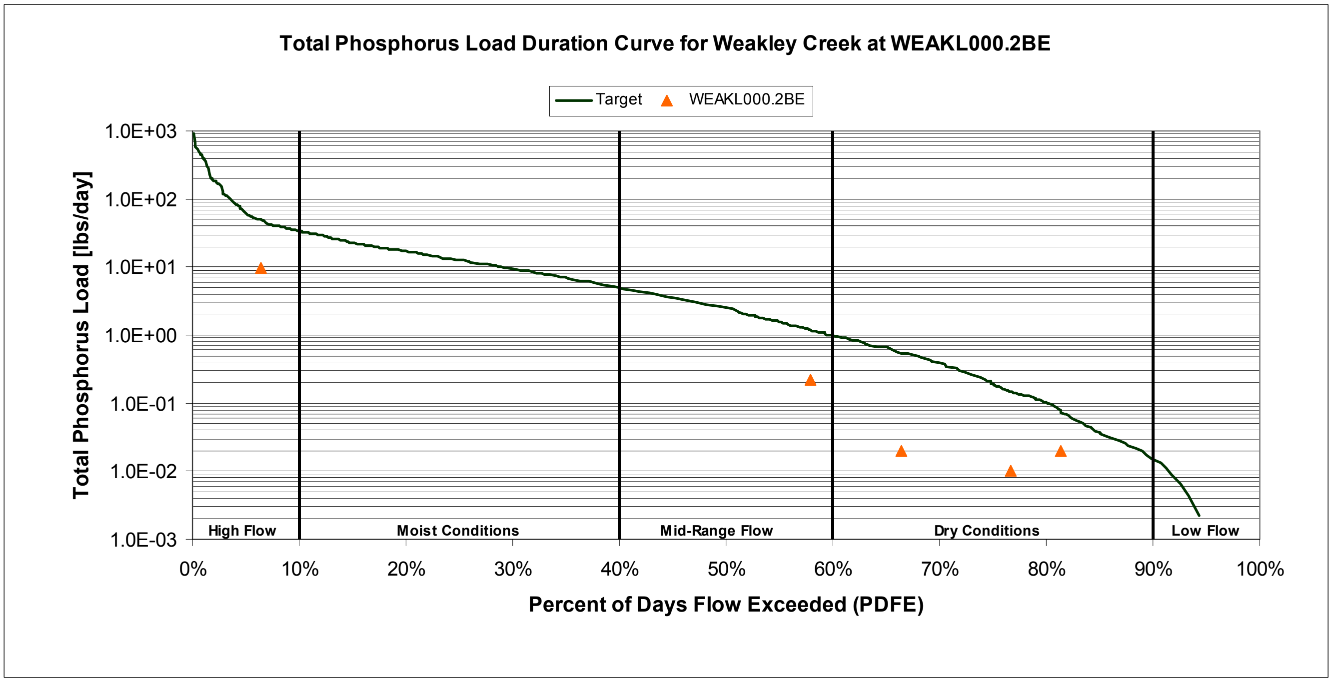


Figure F-9 Total Nitrogen Load Duration Curve – North Fork Creek at NFORK009.4BE

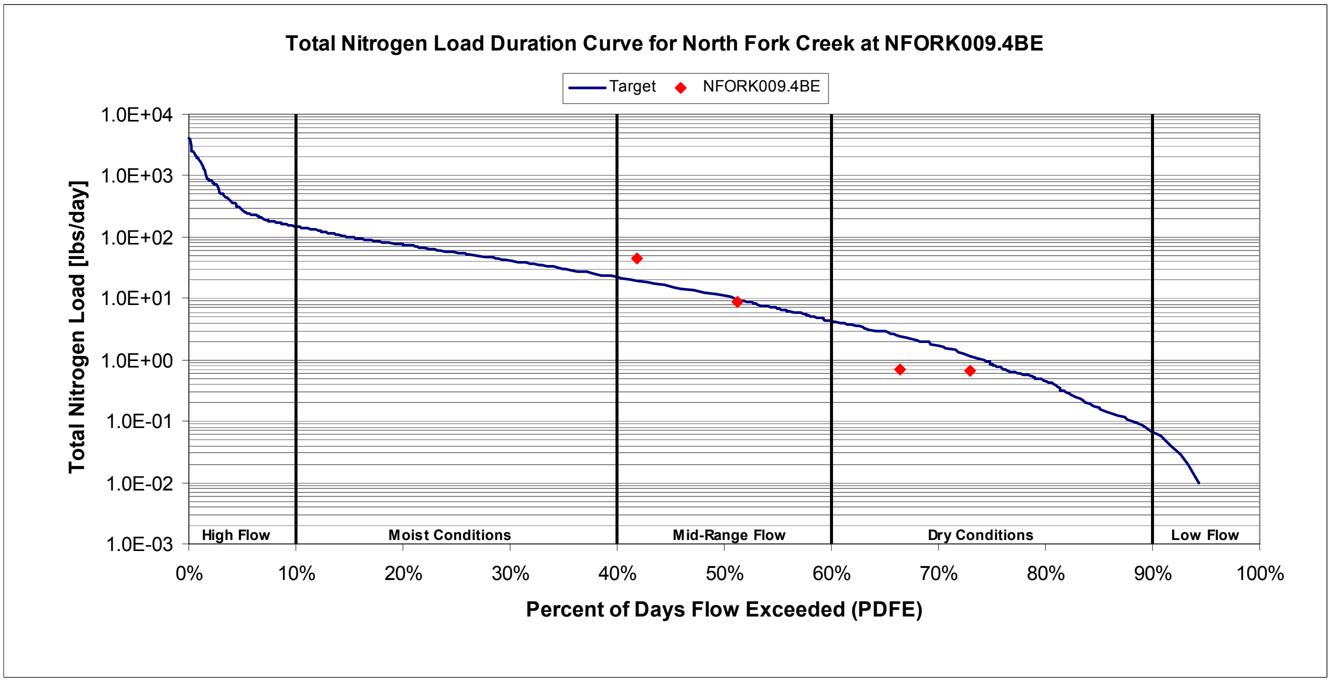


Figure F-10 Total Phosphorus Load Duration Curve – North Fork Creek at NFORK009.4BE

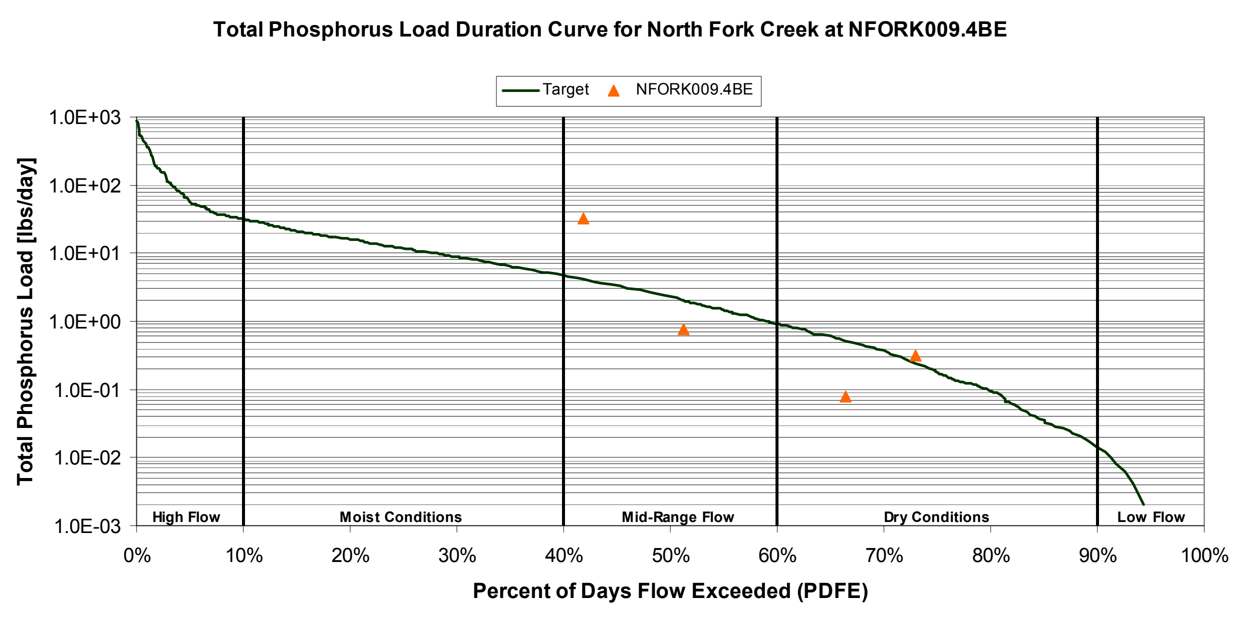


Figure F-11 Total Nitrogen Load Duration Curve – Fall Creek at FALL003.0BE

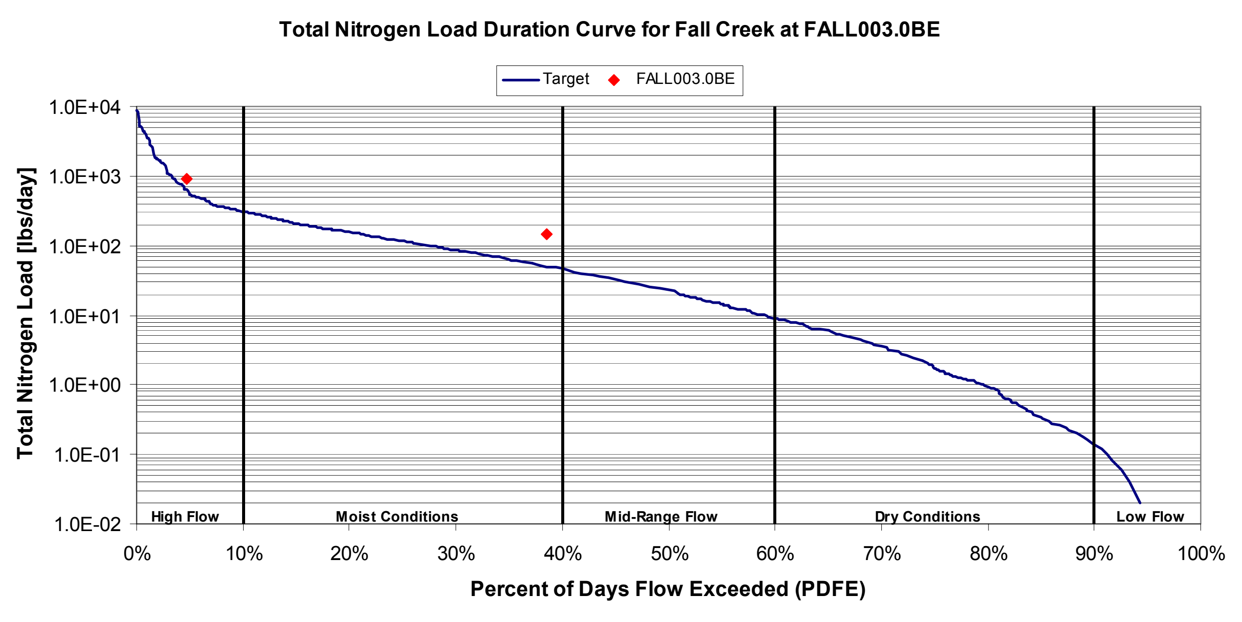


Figure F-12 Total Phosphorus Load Duration Curve – Fall Creek at FALL003.0BE

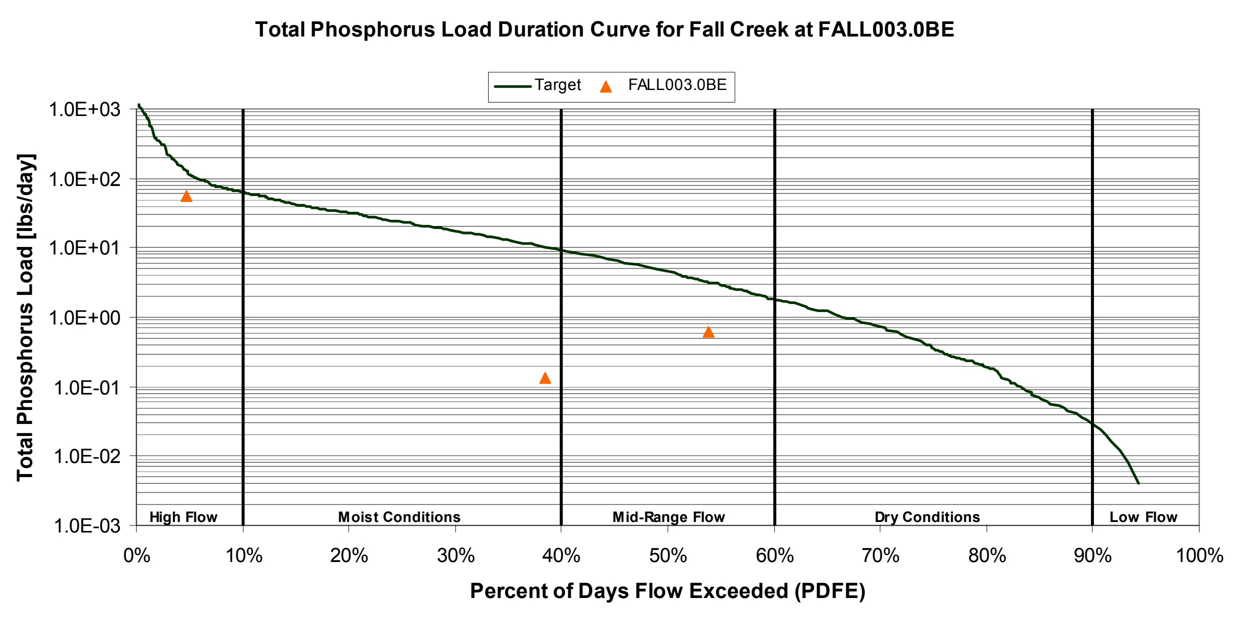


Figure F-13 Total Nitrogen Load Duration Curve – Cascade Creek at CASCA000.7BE

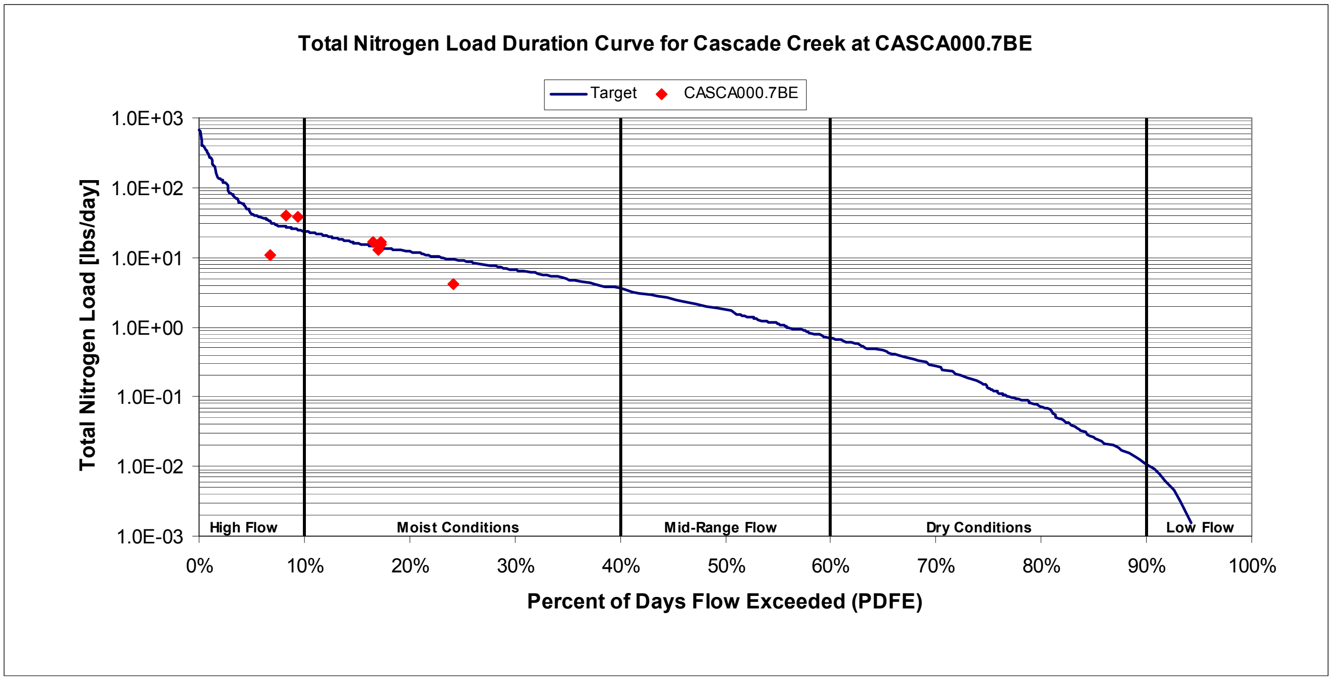


Figure F-14 Total Phosphorus Load Duration Curve – Cascade Creek at CASCA000.7BE

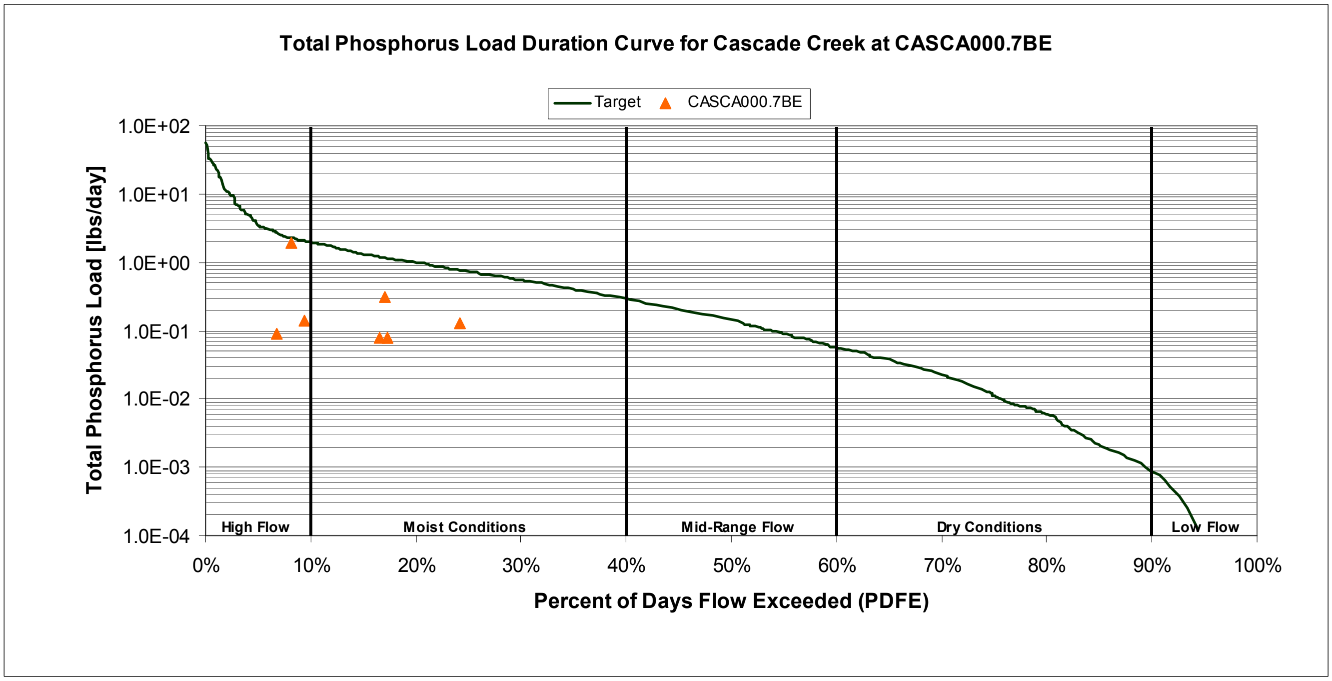


Figure F-15 Total Nitrogen Load Duration Curve – Clear Branch at CLEAR001.1CE

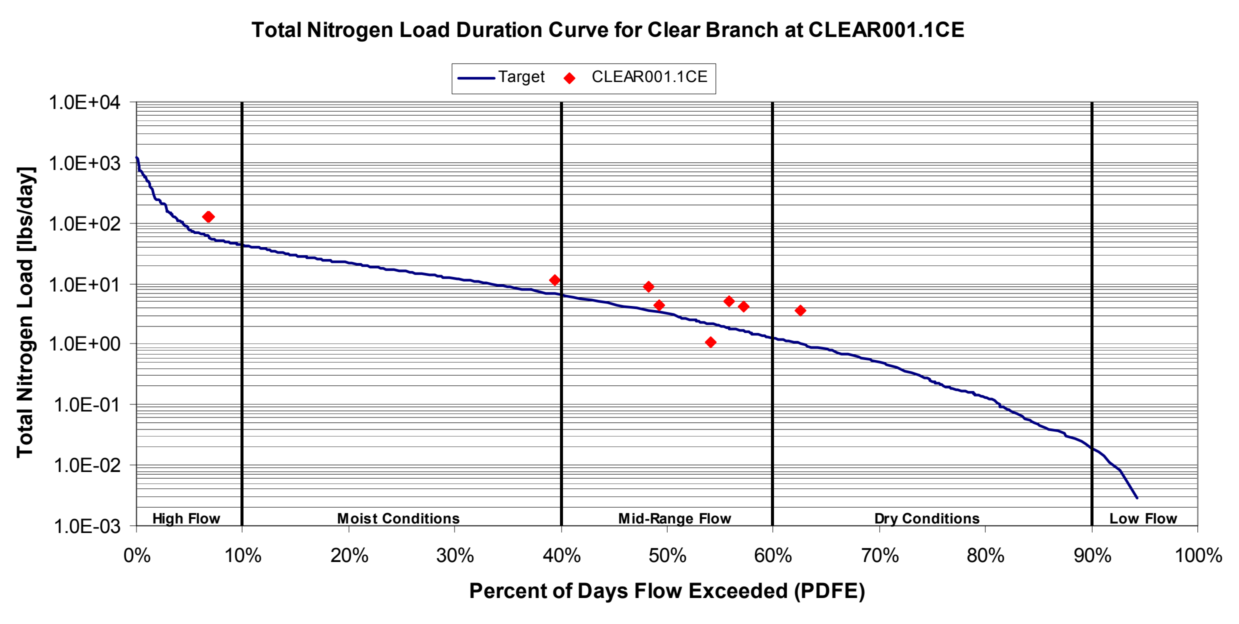


Figure F-16 Total Phosphorus Load Duration Curve – Clear Branch at CLEAR001.1CE

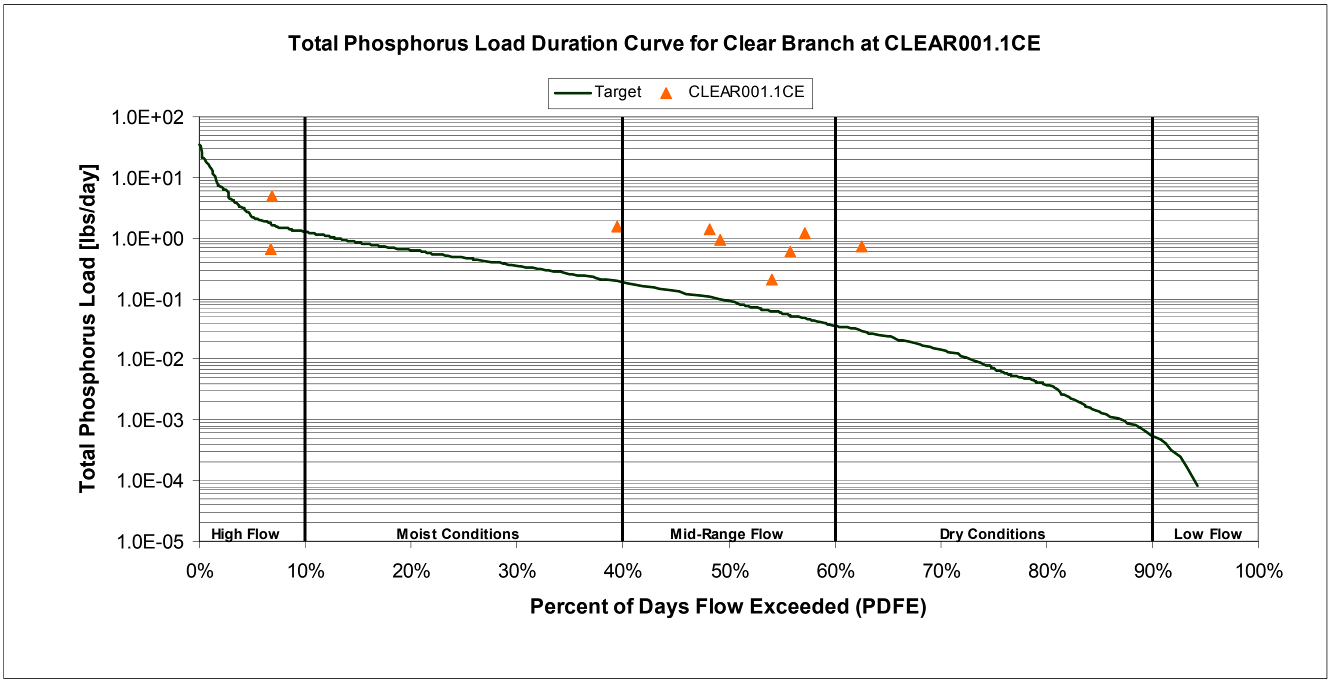


Figure F-17 CBOD$_5$ Load Duration Curve – Clear Branch at CLEAR001.1CE

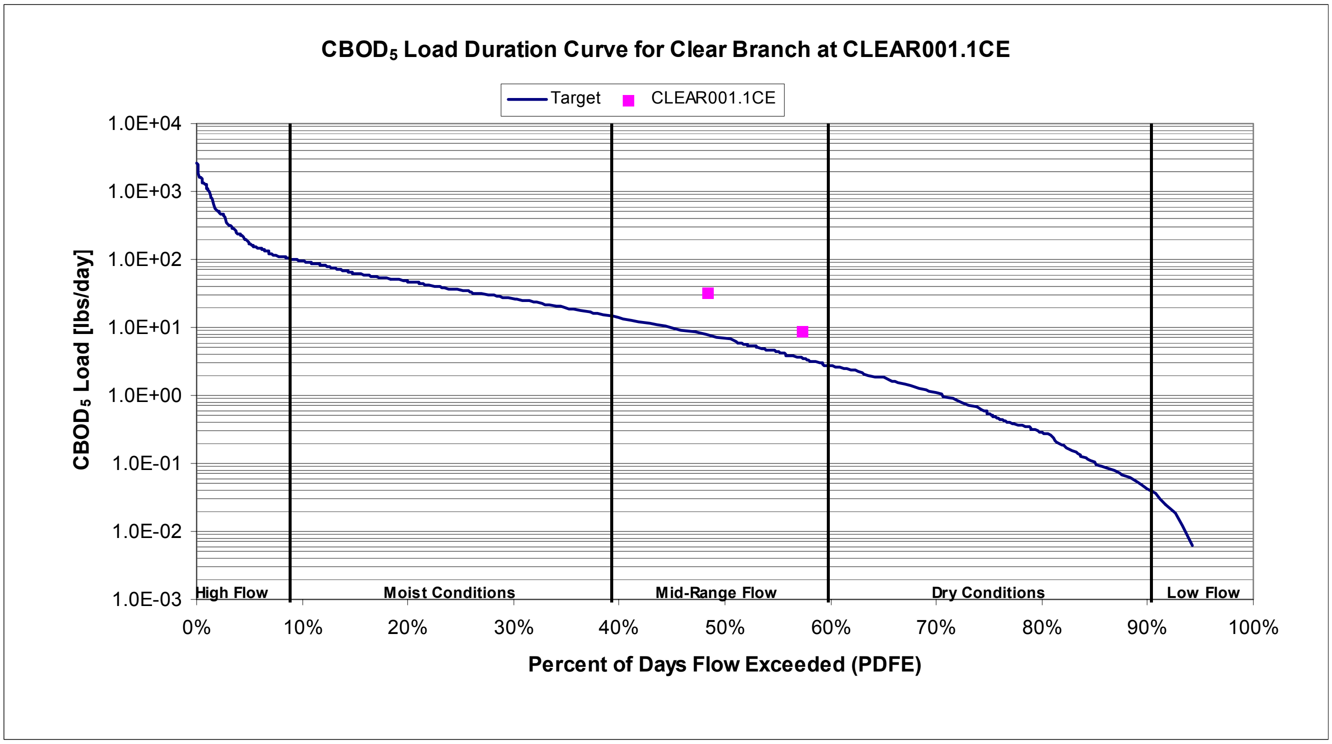


Table F-1 Determination of Overall Required Nutrient Reduction for Caney Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
11/9/99	0.08	84.3	3.56	1.54	0.32	79.3	0.01	0.004	0.064	NR
1/6/00	6.92	44.4	1.77	66.03	28.41	57.0	0.03	1.12	5.72	NR
			Geometric Mean →			**67.2**	**Geometric Mean →**			**NR**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-2 Determination of Overall Required Nutrient Reduction for Wilson Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
1/10/00	8.66	16.8	3.10	144.7	35.08	75.8	0.06	2.80	7.43	NR
4/17/00	16.22	8.5	1.74	152.2	66.00	56.6	0.097	8.48	13.99	NR
10/16/00	0.03	81.7	1.66	0.27	0.12	55.3	0.037	0.01	0.026	NR
5/10/01	1.19	48.2	—	—	4.90	—	0.03	0.19	1.04	NR
			Geometric Mean →			**61.9**	**Geometric Mean →**			**NR**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-3 Determination of Overall Required Nutrient Reduction for Clem Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
4/17/00	14.7	21.5	1.73	137.1	59.64	56.5	0.005	0.40	12.64	NR
12/10/03	37.4	8.2	1.13	227.7	152.0	33.2	0.004	0.81	32.22	NR
			Geometric Mean →			**43.3**	**Geometric Mean →**			**NR**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-4 Determination of Overall Required Nutrient Reduction for Weakley Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/28/03	0.09	81.3	0.54	0.26	0.37	NR	0.03	0.02	0.08	NR
9/30/03	1.38	57.9	0.99	7.37	5.57	24.5	0.03	0.22	1.18	NR
10/8/03	0.64	66.4	0.44	1.52	2.58	NR	0.005	0.02	0.55	NR
11/6/03	0.17	76.7	0.19	0.08	0.69	NR	0.01	0.01	0.15	NR
12/10/03	58.1	6.4	1.36	425.8	237.2	44.3	0.03	9.70	50.3	NR
			Geometric Mean →			**24.5**	**Geometric Mean →**			**NR**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-5 Determination of Overall Required Nutrient Reduction for North Fork Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
8/28/03	4.69	41.8	1.81	45.8	19.27	57.9	1.29	32.6	4.08	87.5
9/30/03	2.34	51.2	0.68	8.58	9.44	NR	0.06	0.76	2.00	NR
10/8/03	0.60	66.4	0.22	0.71	2.41	NR	0.025	0.08	0.51	NR
11/6/03	0.29	73.0	0.43	0.67	1.16	NR	0.20	0.32	0.25	23.4
			Average →			**57.9**	**Geometric Mean →**			**45.2**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-6 Determination of Overall Required Nutrient Reduction for Fall Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
1/12/00	12.11	38.5	2.24	146.2	50.04	65.8	0.002	0.13	10.18	NR
4/13/00	156.2	4.7	1.07	901.0	634.5	29.6	0.066	55.6	129.2	NR
5/8/01	3.86	53.9	—	—	15.61	—	0.03	0.62	3.18	NR
			Geometric Mean →			**44.2**	**Geometric Mean →**			**NR**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-7 Determination of Overall Required Nutrient Reduction for Cascade Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
12/15/99	3.59	17.0	0.67	12.97	14.19	NR	—	—	—	—
2/10/00	2.36	24.2	0.33	4.20	9.41	NR	0.01	0.13	0.762	NR
5/2/00	8.45	6.8	0.24	10.93	33.00	NR	0.002	0.09	2.72	NR
8/19/03	3.68	16.5	0.83	16.47	14.49	12.0	0.004	0.08	1.20	NR
9/10/03	3.56	17.3	0.78	14.97	13.88	7.3	0.004	0.08	1.14	NR
10/15/03	3.57	17.3	0.86	16.55	13.88	16.2	0.004	0.08	1.14	NR
11/5/03	3.60	17.0	0.78	15.14	14.19	6.3	0.016	0.31	1.17	NR
12/11/03	7.07	8.2	1.03	39.26	27.91	28.9	0.05	1.91	2.30	NR
1/6/04	6.38	9.4	1.11	38.18	25.13	34.2	0.004	0.14	2.08	NR
			Geometric Mean →			**14.4**	**Geometric Mean →**			**NR**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-8 Determination of Overall Required Nutrient Reduction for Clear Branch

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction	Sample Concen.	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
12/16/99	0.45	57.2	1.68	4.08	1.68	58.7	0.49	1.19	0.05	95.9
2/9/00	0.96	48.2	1.70	8.80	3.65	58.6	0.27	1.40	0.11	92.4
5/11/00	1.80	39.4	1.18	11.45	6.73	41.2	0.16	1.55	0.20	87.4
8/19/03	0.49	55.8	1.91	5.05	1.85	63.3	0.23	0.61	0.05	91.2
9/10/03	0.28	62.6	2.40	3.62	1.04	71.4	0.49	0.74	0.03	95.9
10/15/03	0.93	49.2	0.87	4.36	3.37	22.9	0.19	0.95	0.10	89.8
11/5/03	0.58	54.1	0.35	1.09	2.16	NR	0.07	0.21	0.06	70.6
12/11/03	15.00	6.9	1.60	129.4	56.64	56.2	0.06	4.85	1.64	66.2
1/6/04	16.42	6.7	1.43	126.6	61.68	51.3	0.004	0.35	1.79	
					Geometric Mean →	**50.5**			**Geometric Mean →**	**85.5**

Notes: NR = Sample load is lower than target load; no reduction required.
* Value shown is the calculated sum of NO_3+NO_2 & TKN sample concentrations.

Table F-9 Determination of Overall Required $CBOD_5$ Reduction for Clear Branch

Sample Date	Flow	PDFE (Approx.)	$CBOD_5$			
			Sample Concen. *	Sample Load	Target Load	Reqd. Reduction
	[cfs]	[%]	[mg/l]	[lbs/day]	[lbs/day]	[%]
12/16/99	0.45	57.2	3.67	8.90	3.66	58.9
2/9/00	0.96	48.2	6.42	33.2	7.92	76.1
					Geometric Mean →	**67.0**

* CBOD5 concentration shown was estimated as 5/6 of BOD_5 sample measurement.

APPENDIX G

Development of Stage I Nutrient & $CBOD_5$ WLAs & LAs

Determination of Waste Load Allocations for WWTFs

As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing WWTF discharges will be developed as part of Stage II and are not included in this document. In addition, the failed collection system in the vicinity of Bomar Creek is considered to be part of the Shelbyville STP and in violation of its NPDES permit (TN0024180). Correction of this condition will be accomplished through appropriate enforcement action rather than TMDL development.

Determination of Waste Load Allocations for CAFOs

CAFOs are not authorized to discharge process wastewater from a liquid waste handling system except during a catastrophic or chronic rainfall event. Any discharges made under these circumstances, or as a result of a system upset or bypass, are not to cause an exceedance of Tennessee water quality standards. Therefore, a WLA of zero has been assigned to this class of facilities.

Determination of Waste Load Allocations for Municipal Separate Storm Sewer Systems & Load Allocations for Nonpoint Sources

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:

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

where (ΣWLAs) includes the contributions from all WWTFs, CAFOs, and MS4s

Expanding the terms:

$$\text{TMDL} = (\Sigma\ \text{WLA}_{\text{WWTF}}) + [\text{Load}]_{\text{MS4}} + (\Sigma\ \text{WLA}_{\text{CAFO}}) + [\text{Load}]_{\text{NPS}} + \text{MOS}$$

where:
TMDL = [lbs/6 mos.]
Σ WLA_{WWTF} = WLA for all WWTFs in the subwatershed [lbs/6 mos.]]
Σ WLA_{CAFO} = WLA for all CAFOs in the subwatershed [lbs/6 mos.]
$[\text{Load}]_{\text{MS4}}$ = Average semiannual nutrient load from all MS4 discharges [lbs/6 mos.].
$[\text{Load}]_{\text{NPS}}$ = Average semiannual nutrient load from all nonpoint sources [lbs/6 mos.]
MOS = Explicit Margin of Safety[lbs/6 mos.]

Solving for $[\text{Load}]_{\text{MS4}} + [\text{Load}]_{\text{NPS}}$:

$$[\text{Load}]_{\text{MS4}} + [\text{Load}]_{\text{NPS}} = (\text{TMDL}) - (\Sigma\ \text{WLA}_{\text{WWTF}}) - (\Sigma\ \text{WLA}_{\text{CAFO}}) - \text{MOS}$$

If the $[\text{Load}]_{MS4}$ & $[\text{Load}]_{NPS}$ terms are expanded:

$$\Sigma[(WLA_{MS4})\ (A_{MS4})] + \Sigma[(LA_{NPS})\ (A_{NPS})] = (TMDL) - (\Sigma\ WLA_{WWTF}) - (\Sigma\ WLA_{CAFO}) - MOS$$

where:
WLA_{MS4} = WLA for MS4s on a unit area basis [lbs/ac/6 mos.]
LA_{NPS} = LA for nonpoint sources on a unit area basis [lbs/ac/6 mos.]
A_{MS4} = Drainage area of MS4s [acres]
A_{NPS} = Drainage area of nonpoint sources [acres]

If $(WLA_{MS4}) = (LA_{NPS})$, and noting that $(\Sigma\ A_{MS4}) + (\Sigma\ A_{NPS}) \approx (A_{subw})$, then the left side of the above equation can be rewritten as:

$$\begin{aligned}\Sigma[(WLA_{MS4})\ (A_{MS4})] + \Sigma[(LA_{NPS})\ (A_{NPS})] &= (LA_{NPS})\ [(\Sigma\ A_{MS4}) + (\Sigma\ A_{NPS})] \\ &= (LA_{NPS})\ (A_{subw})\end{aligned}$$

therefore:

$$(LA_{NPS})\ (A_{subw}) = (TMDL) - (\Sigma\ WLA_{WWTF}) - (\Sigma\ WLA_{CAFO}) - MOS$$

Solving for (LA_{NPS}):

$$(LA_{NPS}) = \frac{(TMDL) - (\Sigma\ WLA_{WWTF}) - (\Sigma\ WLA_{CAFO}) - MOS}{(A_{subw})}$$

The calculation for total nitrogen in HUC-12 Subwatershed 0106 (Cascade Creek) is shown as an example. Calculations for total phosphorus & $CBOD_5$ (in Subwatershed 0101) are similar.

<u>Total Nitrogen in Subwatershed 0504 (Caney Creek)</u>

$$LA_{NPS} = \frac{TMDL - (\Sigma WLA_{WWTP}) - (\Sigma WLA_{CAFO}) - MOS}{(A_{subw})}$$

Using an explicit MOS = equal to 5% of the TMDL and noting that for Stage I, $\Sigma WLA_{WWTF} = 0$:

$$LA_{NPS} = \frac{TMDL - (0) - (\Sigma WLA_{CAFO}) - \{(0.05)\ (TMDL)\}}{(A_{subw})}$$

$$LA_{NPS} = \frac{\{(0.95)\ (TMDL)\} - (\Sigma WLA_{CAFO})}{(A_{subw})}$$

Substituting the appropriate values from Tables 8 & D-1 and information from Sections 8.3.3:

During summer (5/1 – 10/31)

$$LA_{NPS} = \frac{[(0.95)\ (6{,}458\ \text{lbs/6 mos.})] - (0)}{(6{,}314\ \text{ac})}$$

therefore:

$$LA_{NPS} = WLA_{MS4} = 0.9716\ \text{lbs/ac/6 mos.}$$

Likewise during winter (11/1 – 4/30)

$$LA_{NPS} = \frac{[(0.95)\ (20{,}131\ \text{lbs/6 mos.})] - (0)}{(6{,}314\ \text{ac})}$$

therefore:

$$LA_{NPS} = WLA_{MS4} = 3.0289\ \text{lbs/ac/6 mos.}$$

Note: Impaired subwatersheds that receive existing WWTF discharges will be addressed in Stage II.

Stage I nutrient WLAs for MS4s & CAFOs and LAs for nonpoint sources are summarized in Table G-1 for total nitrogen, Table G-2 for total phosphorus, and Table G-3 for $CBOD_5$. WLAs for MS4s in Subwatersheds 0106 & 0308 apply only to MS4 discharges into these subwatersheds. WLAs for CAFOs apply to existing and future entities.

Table G-1 Summary of Stage I Total Nitrogen WLAs & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	26,580	NA	0	0.693	83,951	NA	0	2.187
0106	6,314	Cascade Creek	6,458	0.972	0	0.972	20,131	3.029	0	3.029
0308	25,097	Fall Creek Hurricane Creek	29,810	1.128	0	1.128	83,025	3.143	0	3.143
0401	11,446	North Fork Creek	13,697	NA	0	1.137	37,881	NA	0	3.144
0404	11,658	Weakley Creek	13,951	NA	0	1.137	38,582	NA	0	3.144
0405	9,496	Clem Creek	11,364	NA	0	1.137	31,427	NA	0	3.144
0502	10,248	Wilson Creek	12,264	NA	0	1.137	33,916	NA	0	3.144
0504	18,948	Caney Creek	22,449	NA	0	1.126	62,675	NA	0	3.142

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

Table G-2 Summary of Stage I Total Phosphorus WLAs & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	769	NA	0	0.020	2,432	NA	0	0.063
0106	6,314	Cascade Creek	507	0.076	0	0.076	1,580	0.238	0	0.238
0308	25,097	Fall Creek Hurricane Creek	6,100	0.231	0	0.231	16,918	0.640	0	0.640
0401	11,446	North Fork Creek	2,903	NA	0	0.241	8,028	NA	0	0.666
0404	11,658	Weakley Creek	2,956	NA	0	0.241	8,177	NA	0	0.666
0405	9,496	Clem Creek	2,408	NA	0	0.241	6,660	NA	0	0.666
0502	10,248	Wilson Creek	2,599	NA	0	0.241	7,188	NA	0	0.666
0504	18,948	Caney Creek	4,538	NA	0	0.228	12,599	NA	0	0.632

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

Table G-3 Summary of Stage I CBOD$_5$ TMDLs, WLAs, & LAs

HUC-12 Subwatershed (06040002__)	Subwatershed Area	Impaired Waterbody	Summer (May 1 – October 31)				Winter (November 1 – April 30)			
			TMDL	WLAs		LAs	TMDL	WLAs		LAs
				MS4s	CAFOs *			MS4s	CAFOs *	
	[acres]		[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]	[lbs/6 mos.]	[lbs/ac/6 mo.]	[lbs/6 mo.]	[lbs/ac/6 mo.]
0101	36,461	Clear Branch	57,787	NA	0	1.506	182,509	NA	0	4.755

Notes: NA = No MS4s within subwatershed.
* WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.

APPENDIX H

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 LOW DISSOLVED OXYGEN & NUTRIENTS FOR WATERBODIES 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 low dissolved oxygen and nutrients 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 identified on Tennessee's proposed 2004 303(d) list as not supporting designated use classifications due, in part, to low dissolved oxygen or nutrients associated with urban storm water runoff, point source discharges, collection system failure, and agriculture. Using a staged approach, the TMDLs utilize Tennessee's general water quality criteria, data from ecoregion reference sites, in-stream water quality monitoring data, load duration curves, and an appropriate Margin of Safety (MOS) to establish nutrient loading levels which will result in lower in-stream concentrations and the attainment of water quality standards. The TMDLs require reductions in nutrient loading of approximately 15% to 86% in subject waterbodies.

The proposed low dissolved oxygen and nutrient 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 July 11, 2005 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.