STAGE I
TOTAL MAXIMUM DAILY LOAD (TMDL)

for

Low Dissolved Oxygen & Nutrients

in the

Stones River Watershed (HUC 05130203)

Cannon, Davidson, Rutherford, & Wilson Counties, Tennessee

FINAL

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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

Stage I Total Maximum Daily Load for Low Dissolved Oxygen & Nutrients in Selected Waterbodies in the Stones River Watershed (HUC 05130203)

Impaired Waterbody Information

State: Tennessee
Counties: Cannon, Davidson, Rutherford, & Wilson
Watershed: Stones River (HUC 05130203)
Constituents of Concern: Low dissolved oxygen & nutrients

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	RM Not Fully Supporting
TN05130203001 - 0100	MCCRORY CREEK	1.4
TN05130203001 - 0150	MCCRORY CREEK	10.7
TN05130203018 - 7000	WEST FORK STONES RIVER	7.2
TN05130203022 – 0100	UNNAMED TRIBUTARY TO LYTLE CREEK	1.0
TN05130203023 - 0310	BEAR BRANCH	3.5
TN05130203029 – 0100	JARMAN BRANCH	4.4
TN05130203029 – 0200	UNNAMED TRIBUTARY TO BRADLEY CREEK	2.7
TN05130203029 - 0300	UNNAMED TRIBUTARY TO BRADLEY CREEK	1.7
TN05130203036 - 0200	WEST BRANCH HURRICANE CREEK	3.5
TN05130203036 - 1000	HURRICANE CREEK	8.5

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 focus on HUC-12 subwatersheds that contain impaired headwater and tributary streams (wadeable) and do not contain existing wastewater treatment facilities (WWTFs). In some cases, where impaired streams are located in the upstream portion of a subwatershed, TMDL are developed for the impaired drainage area only. In Stage II & III 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 Stages II & III.

Water Quality Target:

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 targets 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 targets are a numeric interpretation of narrative criteria for nutrients and biological integrity and are derived from the 75^{th} 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 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 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 annual loads, on a unit area basis, for reference sites in the same Level IV ecoregion and applying these loads to subwatersheds or delineated drainage areas containing impaired waterbodies in the Stones River watershed. TMDLs are expressed as average annual loads (lbs/yr).

- The failed collection system in the vicinity of Finch Branch is considered to be part of the LaVergne STP and in violation of its State Operating Permit (SOP 88-061). Correction of this condition will be accomplished through appropriate enforcement action rather than TMDL development.

- WLAs for CAFOs are considered to be 0 lbs/yr.

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

- $CBOD_5$ TMDLs, WLAs, & LAs were developed for impaired subwatersheds only in cases where low dissolved oxygen was identified as a cause of waterbody impairment and/or subwatersheds containing impaired waterbodies with measured diurnal dissolved oxygen concentrations that drop below 5 mg/l.

- Daily expressions of TMDLs, WLAs, & LAs were developed from statistical analysis of Level IV ecoregion reference site monitoring data. Daily values are expressed as a function of stream flow at the pour point of the impaired subwatershed or drainage area.

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, Total Phosphorus, & $CBOD_5$ TMDLs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL					
			Total Nitrogen		Total Phosphorus		$CBOD_5$	
			[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]
0106	Jarman Branch	TN05130203029-0100	112,695	$2.157 \times 10^1 * Q$	22,655	$1.008 \times 10^1 * Q$	224,597	$4.046 \times 10^1 * Q$
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	169,007	$2.200 \times 10^1 * Q$	34,899	$1.045 \times 10^1 * Q$	336,300	$4.046 \times 10^1 * Q$
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	25,354	$1.243 \times 10^1 * Q$	2,090	$2.116 \times 10^0 * Q$	NA [b]	NA [b]
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	41,786	$2.038 \times 10^1 * Q$	7,760	$9.031 \times 10^0 * Q$	83,642	$4.046 \times 10^1 * Q$
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	8,019	$2.243 \times 10^1 * Q$	1,699	$1.082 \times 10^1 * Q$	NA [b]	NA [b]
Unnamed Trib. to Lytle Ck. DA [c]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	534	$2.243 \times 10^1 * Q$	113	$1.082 \times 10^1 * Q$	1,061	$4.046 \times 10^1 * Q$

Notes:
a. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
b. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).
c. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Summary of Stage I Total Nitrogen WLAs & LAs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA				LA	
			MS4 [a]		CAFO [b]			
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day]	[lbs/ac/yr]	[lbs/ac/day] [c]
0106	Jarman Branch	TN05130203029-0100	4.2206	8.505×10^{-4} * Q	0	0	4.2206	8.505×10^{-4} * Q
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	4.2241	5.789×10^{-4} * Q	0	0	4.2241	5.789×10^{-4} * Q
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	4.1470	2.140×10^{-3} * Q	0	0	4.1470	2.140×10^{-3} * Q
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	4.2110	2.161×10^{-3} * Q	0	0	4.2110	2.161×10^{-3} * Q
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	4.2275	1.245×10^{-2} * Q	0	0	4.2275	1.245×10^{-2} * Q
Unnamed Trib. to Lytle Ck. DA [d]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	4.2275	1.869×10^{-1} * Q	0	0	4.2275	1.869×10^{-1} * Q

Notes:
a. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
b. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
d. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Summary of Stage I Total Phosphorus WLAs & LAs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA				LA	
			MS4 [a]		CAFO [b]			
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day]	[lbs/ac/yr]	[lbs/ac/day] [c]
0106	Jarman Branch	TN05130203029-0100	0.8485	3.972×10^{-4} * Q	0	0	0.8485	3.972×10^{-4} * Q
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	0.8722	2.749×10^{-4} * Q	0	0	0.8722	2.749×10^{-4} * Q
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	0.3418	3.643×10^{-4} * Q	0	0	0.3418	3.643×10^{-4} * Q
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	0.7820	9.580×10^{-4} * Q	0	0	0.7820	9.580×10^{-4} * Q
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	0.8959	6.005×10^{-3} * Q	0	0	0.8959	6.005×10^{-3} * Q
Unnamed Trib. to Lytle Ck. DA [d]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	0.8959	9.018×10^{-2} * Q	0	0	0.8959	9.018×10^{-2} * Q

Notes:
a. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
b. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
d. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Summary of Stage I $CBOD_5$ WLAs & LAs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA				LA	
			MS4 [b]		CAFO [c]			
			[lbs/ac/yr]	[lbs/ac/day] [d]	[lbs/ac/yr]	[lbs/ac/day]	[lbs/ac/yr]	[lbs/ac/day] [d]
0106	Jarman Branch	TN05130203029-0100	8.4115	$1.595 \times 10^{-3} * Q$	0	0	8.4115	$1.595 \times 10^{-3} * Q$
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	8.4053	$1.064 \times 10^{-3} * Q$	0	0	8.4053	$1.064 \times 10^{-3} * Q$
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	NA [a]	NA [a]	0	0	NA [a]	NA [a]
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	8.4290	$4.292 \times 10^{-3} * Q$	0	0	8.4290	$4.292 \times 10^{-3} * Q$
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	NA [a]	NA [a]	0	0	NA [a]	NA [a]
Unnamed Trib. to Lytle Ck. DA [e]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	8.3990	$3.371 \times 10^{-1} * Q$	0	0	8.3990	$3.371 \times 10^{-1} * Q$

Notes:
a. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).
b. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
c. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
d. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
e. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

STAGE I LOW DISSOLVED OXYGEN & NUTRIENT TOTAL MAXIMUM DAILY LOAD (TMDL) STONES RIVER WATERSHED (HUC 05130203)

1.0 INTRODUCTION

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

2.0 SCOPE OF DOCUMENT

Due to the complexity of processes associated with instream dissolved oxygen levels, TDEC has developed a three-stage strategy for nutrient TMDL development. The strategy considers impairment status, subwatershed type, limiting nutrients, and point source contribution to the total nutrient load to identify TMDL development methodologies, monitoring requirements, allocations, implementation measures, and other requirements appropriate for each impaired subwatershed.

Stage I TMDLs will focus on HUC-12 subwatersheds or delineated waterbody drainage areas 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. This document presents details of Stage I TMDL development for waterbodies impaired by low dissolved oxygen or nutrients.

Stage II & III 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 & III TMDL development will be conducted on a larger area scale (HUC-10 watershed or larger area) and will utilize a number of data resources and analysis tools, including the effluent and instream nutrient data collected by WWTFs. It is expected that implementation of Stage II & III 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).

No TMDL was developed for the segment of the Stones River below Percy Priest Dam since the impairment was attributed to the upstream impoundment rather than excess nutrient loading.

3.0 GENERAL WATERSHED OVERVIEW

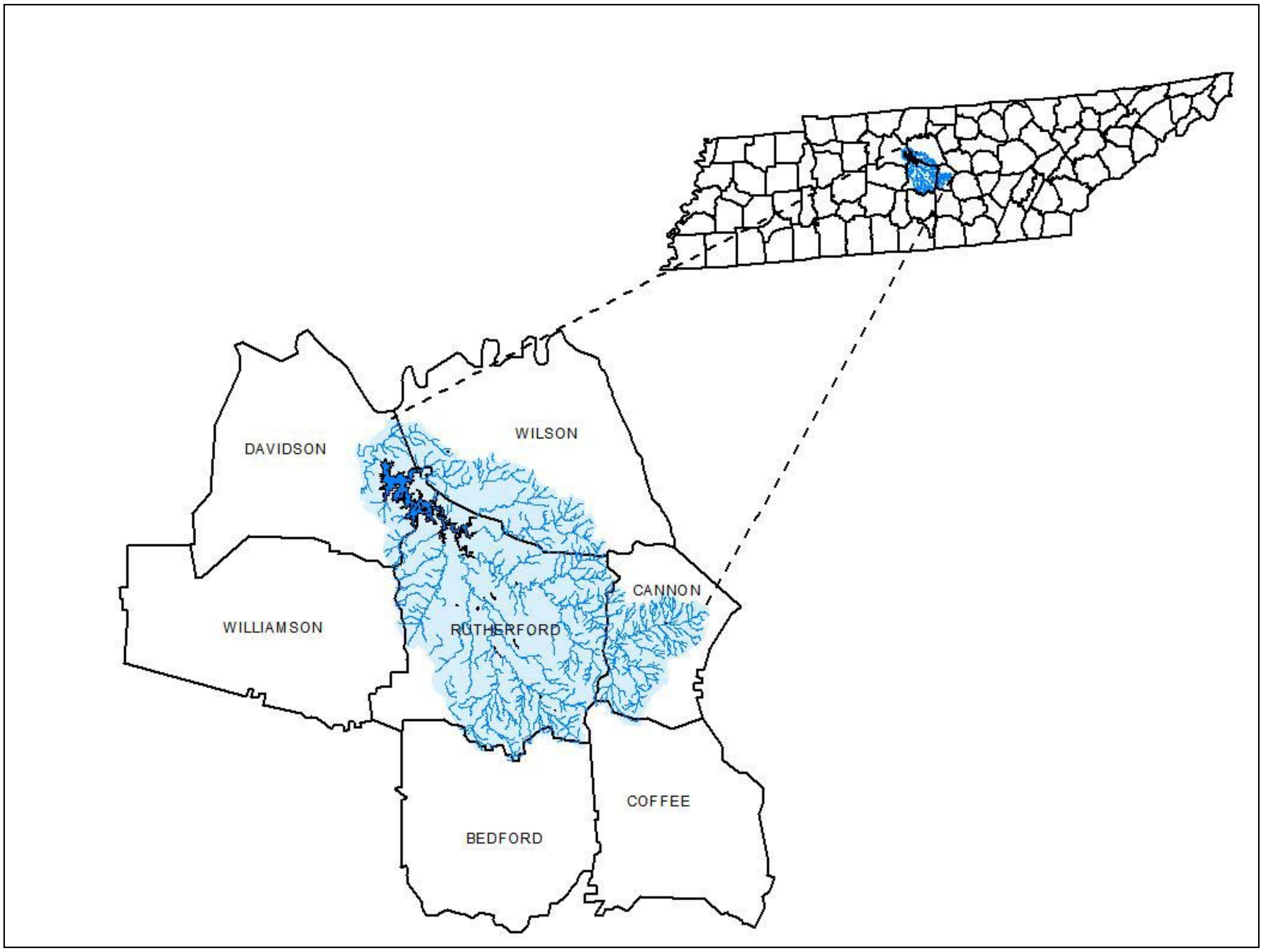
The Stones River watershed (HUC 05130203) is located in Middle Tennessee (Figure 1) and is primarily located in Cannon, Davidson, Rutherford, and Wilson Counties. The watershed lies within the Level III Interior Plateau (71) ecoregion and contains three Level IV ecoregions as shown in Figure 2 (USEPA, 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.

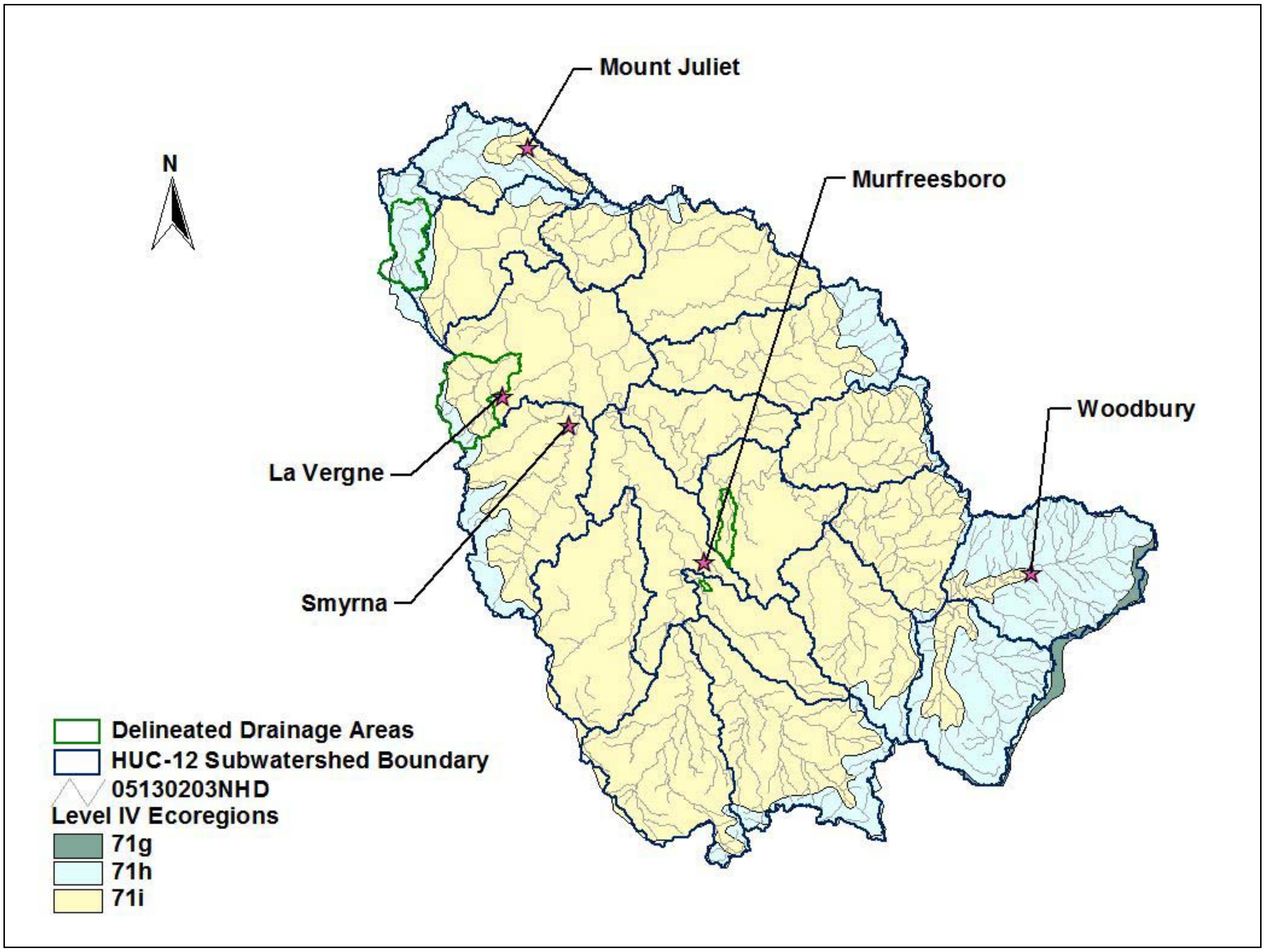
- Inner Nashville Basin (71i) is less hilly and lower than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the Outer Basin. Streams are lower gradient than surrounding regions, often flowing 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 Stones River Watershed



The Stones River watershed has approximately 1,083 miles of streams (NHD) and drains a total area of approximately 936 square miles. The mouth of the Stones River is at Cumberland River (Cheatham Lake) mile 205.8. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from around 2001. Although changes in the land use of the Stones River watershed have occurred since 2001 as a result of rapid development, this is the most current land use data available. Land use for the entire Stones River watershed is summarized in Table 1 and shown in Figure 3.

Figure 2 Level IV Ecoregions in the Stones 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 delineated waterbody drainage areas are shown in figures for reference.

Figure 3 2001 MRLC Land Use Distribution in the Stones River Watershed

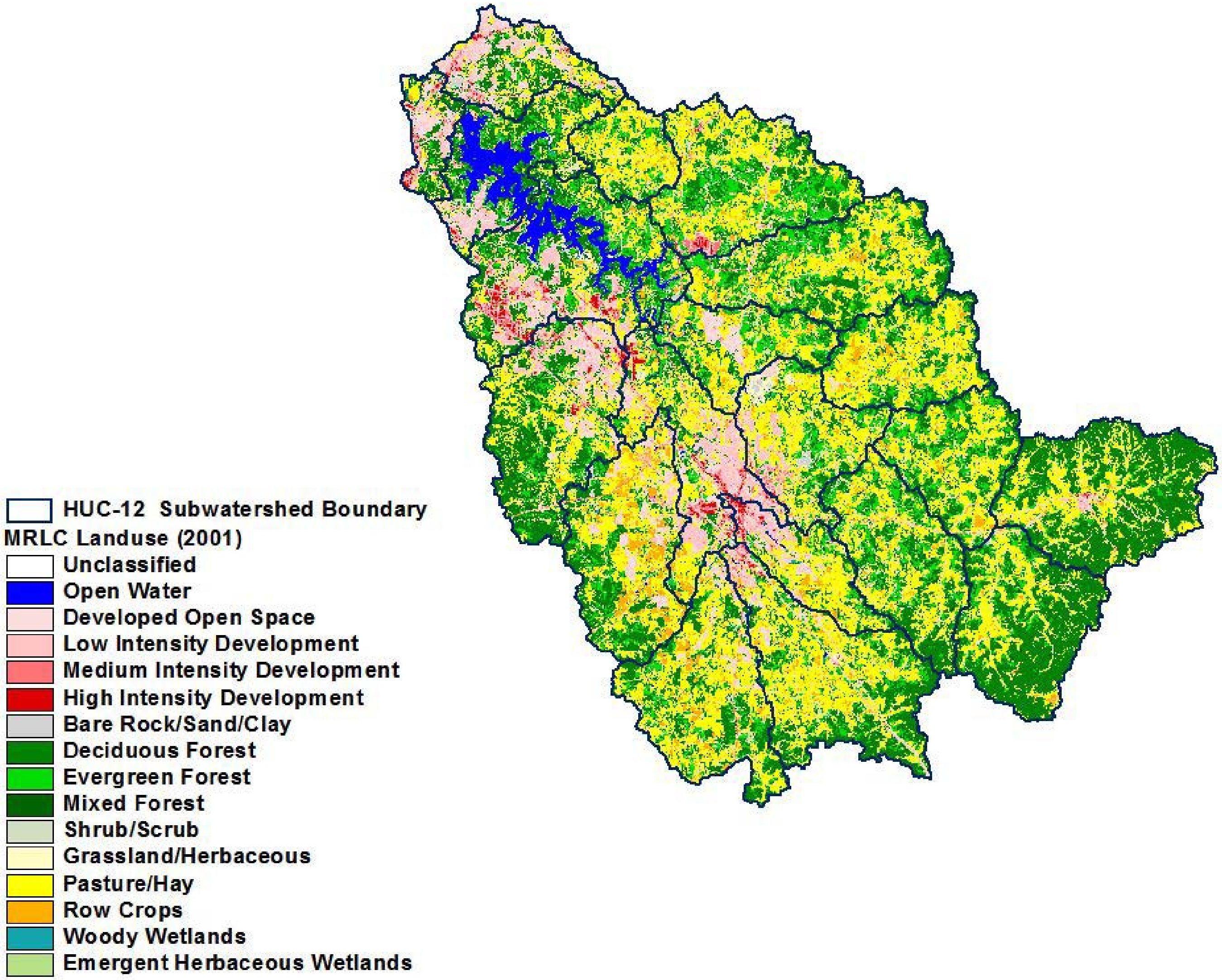


Table 1 2001 MRLC Land Use Distribution – Stones River Watershed

Land Use	Area	
	[acres]	[%]
Unclassified	1	0.00
Open Water	13,554	2.26
Developed Open Spaces	46,453	7.77
Low Intensity Residential	33,327	5.56
Medium Intensity Residential	8,433	1.41
High Intensity Residential	3,755	0.63
Bare Rock/Sand/Clay	2,112	0.35
Deciduous Forest	141,923	23.70
Evergreen Forest	66,238	11.06
Mixed Forest	35,469	5.92
Shrub/Scrub	22,139	3.70
Grasslands/Herbaceous	13,209	2.21
Pasture/Hay	182,349	30.45
Row Crops	27,967	4.67
Woody Wetlands	1,747	0.29
Emergent Herbaceous Wetlands	127	0.02
Total	**598,893**	**100.0**

A comprehensive general resource for information regarding the Stones River watershed is the *Stones River Watershed (05130203) of the Cumberland River Basin, Watershed Water Quality Management Plan* (TDEC, 2000). 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 final 2006 303(d) list (TDEC, 2006) identified a number of waterbodies in the Stones River watershed as not fully supporting designated use classifications due to low dissolved oxygen or nutrients. The designated use classifications for the Stones 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 (J. Percy Priest Lake). Waterbodies in the Stones River watershed identified as impaired for low dissolved oxygen or nutrients on the 2006 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). $CBOD_5$ 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 *2006 305(b) Report, The Status of Water Quality in Tennessee* (TDEC, 2006a). With respect to nutrients, this document states: "Waters are not assessed as impaired by nutrients unless biological or aesthetic impacts are also documented." Assessment information for waterbodies impaired due to low dissolved oxygen and/or nutrients in the Caney Fork watershed is summarized in Table 3 This information 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 (Jarman Branch) is shown in Appendix B.

Table 2 2006 303(d) List – Stream Impairment Due to Low Dissolved Oxygen & Nutrients in the Stones River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE (Pollutant)	Pollutant Source	TMDL Development Stage
TN05130203001 - 0100	MCCRORY CREEK	1.4	Nitrates Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Highways, roads, bridges, infrastructure construction Discharges from MS4 area Collection System Failure	I
TN05130203001 - 0150	MCCRORY CREEK	10.7	Nitrates Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 area	I
TN05130203001 - 1000	STONES RIVER	6.7	Sulfide-hydrogen sulfide Low dissolved oxygen Habitat loss due to stream flow alteration Odor threshold number	Upstream impoundment	NA [a]
TN05130203003T - 0100	FINCH BRANCH	5.7	Nutrients Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Land development Collection System Failure	NA [b]
TN05130203010 - 1000	STEWARTS CREEK	7.0	Nitrates Loss of biological integrity due to siltation	Municipal point source Discharges from MS4 area	II/III
TN05130203018 - 2000	WEST FORK STONES RIVER	1.3	Nitrates Loss of biological integrity due to siltation	Municipal point source Land development	II/III
TN05130203018 - 7000	WEST FORK STONES RIVER	7.2	Low dissolved oxygen	Pasture grazing Livestock in stream	I
TN05130203022 - 0100	UNNAMED TRIB TO LYTLE CREEK	1.0	Low dissolved oxygen Escherichia coli	Undetermined source	I

Table 2 (Contd.) 2006 303(d) List – Stream Impairment Due to Low Dissolved Oxygen & Nutrients in the Stones River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE (Pollutant)	Pollutant Source	TMDL Development Stage
TN05130203023-0310	BEAR BRANCH	3.5	Habitat loss due to alteration in stream-side or littoral vegetative cover Loss of biological integrity due to siltation Nutrients	Pasture grazing Land development	I
TN05130203029 - 0100	JARMAN BRANCH	4.4	Habitat loss due to alteration in stream-side or littoral vegetative cover Loss of biological integrity due to siltation Nutrients	Pasture grazing Land development	I
TN05130203029 - 0200	UNNAMED TRIB TO BRADLEY CREEK	2.7	Habitat loss due to alteration in stream-side or littoral vegetative cover Nutrients	Pasture grazing Livestock in stream	I
TN05130203029 - 0300	UNNAMED TRIB TO BRADLEY CREEK	1.7	Habitat loss due to alteration in stream-side or littoral vegetative cover Nutrients	Pasture grazing Livestock in stream	I
TN05130203036-0200	WEST BRANCH HURRICANE CREEK	3.5	Nutrients Loss of biological integrity due to siltation	Land development	I
TN05130203036-1000	HURRICANE CREEK	8.5	Nutrients Loss of biological integrity due to siltation	Industrial point source Land development	I

Notes: a. Due to the nature of the cause of impairment, no TMDL development is planned for this waterbody segment at this time.
b. No TMDL will be developed for Finch Branch. The collection system failure is prohibited by the LaVergne State Operation permit (SOP 88-061). Correction of this condition will be accomplished through appropriate enforcement action.

Figure 4 Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients (Documented on the 2006 303d List)

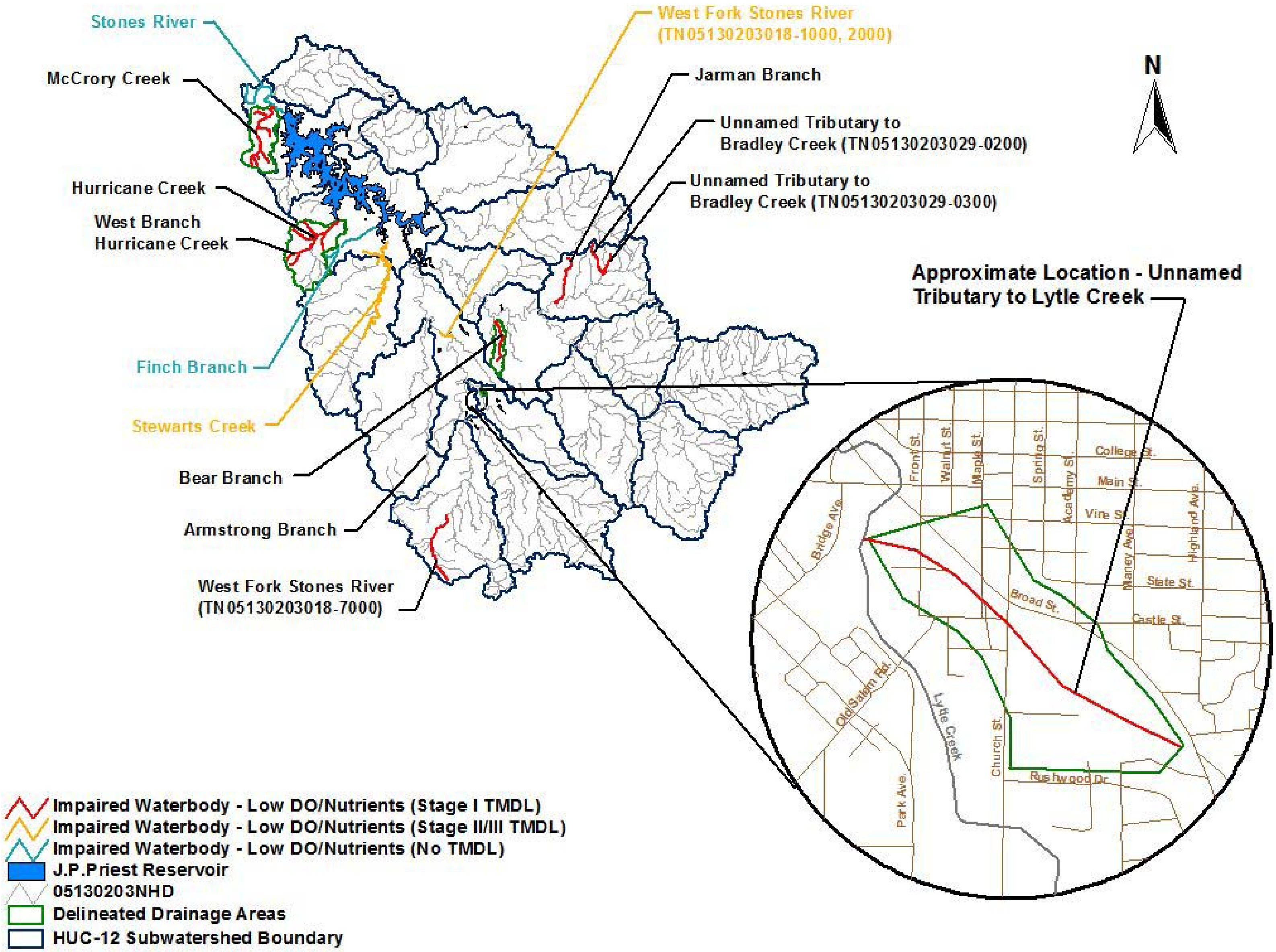


Figure 5 Interrelationship of Major Kinetic Processes Associated with Instream Dissolved Oxygen (USEPA, 1997a)

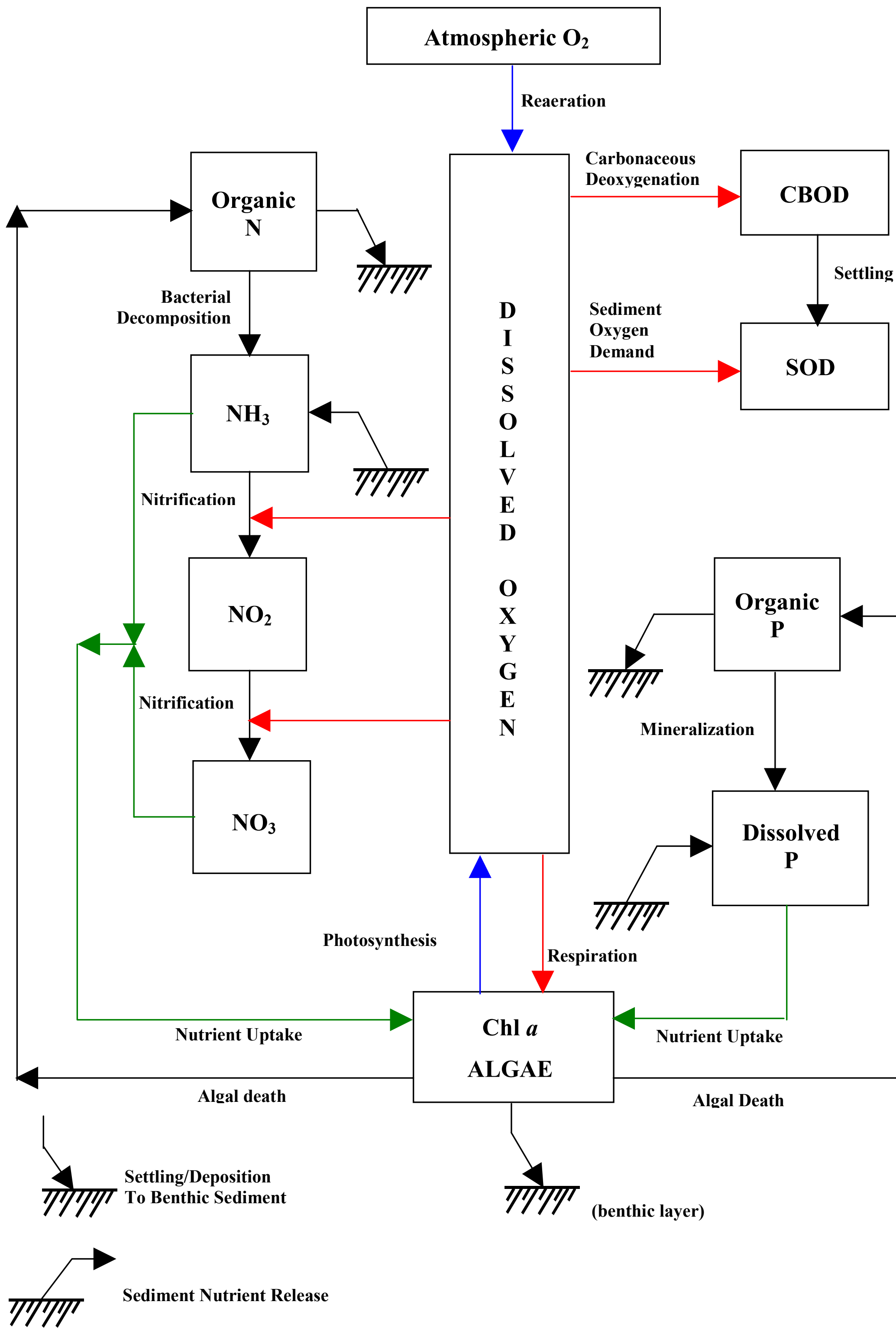


Table 3 Water Quality Assessment of Waterbodies Impaired Due to Low Dissolved Oxygen & Nutrients – Stones River Watershed

Waterbody ID	Segment Name	Assessment Information
TN05130203001 - 0100	McCrory Creek (Stones River to Stewarts Ferry Pike)	2002 TDEC biological and chem. survey at mile 1.5 (Stewarts Ferry Pike). 3 EPT families, 2 intolerant, 13 total families. BR score = 7. Habitat = 123. Failed biorecon criteria. Metro pathogen sampling at mile 0.4 and 1.3. Also, Metro bypassing reports. 1997 TDEC biorecon. Pathogens (e. coli) elevated.
TN05130203001 - 0150	McCrory Creek (Stewarts Ferry Pike to headwaters)	TDEC biorecon and chemical sampling station at mile 1.5 (McCrory Creek Road). 5 EPT families, 2 intolerant, 15 total families. BR score = 7. Habitat score = 113. Low ambig. Metro pathogen monitoring site at mile 4.1 (Elm Hill Pike). Levels O.K. 1997 TDEC biorecon at same spot.
TN05130203001 - 1000	Stones River (Cumberland River to J. Percy Priest Dam)	TDEC ambient monitoring site at Highway 70 (Mile 3.9). Some low DOs. Manganese and sulfides cause taste and odor problems. Corps of Engineers station at mile 6.7. Low DO observed.
TN05130203003T-0100	Finch Branch (J. Percy Priest Lake to headwaters)	2002 TDEC chemical survey at mile 1.4 (Jones Mill Road) and bio. screening at mile 2.0 (Fergus Road). Benthic survey also done (1999). EPT families noted but not counted.
TN05130203010 - 1000	Stewarts Creek (J. Percy Priest Lake to Old Nashville Hwy.)	2002 TDEC chemical stations at miles 5.3, 5.7, & 6.0 (d/s Sam Davis Dam). Diurnal DO monitoring = low DO. Nutrients elevated below STP. Corps chemical and biological station at mile 5.5. Corps RBPIII results: 7 EPT genera, 20 total genera. Biocriteria score: 30. Passed. 1999 Lab biorecons at miles 5.2 & 5.7. 4 & 5 EPT families, all tolerant. 1999 fish kill.
TN05130203018 - 2000	W. Fork Stones River (SR 840 to Sinking Creek)	2001 EPA RBPIII study at mile 10.4 (below STP) 7 EPT genera, 39 total genera. NCBI=7.07. Scored as "impacted". Habitat = 105. Serious fish kill in 1998.
TN05130203018 - 7000	W. Fork Stones River (Dry Fork Creek to headwaters)	Old ecoregion station (mile 32.3) before moved downstream. 2002 diurnal sampling shows low DO. 2002 RBPIII survey.
TN05130203022 - 0100	Unnamed Tributary to Lytle Creek	2002 TDEC chemical station at mile 0.1 (Cannonbough). Diurnal DO sampling. Fish kill in Sept. 1999. Very high fecal coliform levels from spring on Sept 8 = 290,000 colonies.

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

Waterbody ID	Segment Name	Assessment Information
TN05130203023 - 0310	Bear Branch (Dry Branch to headwaters)	2002 TDEC biorecon at mile 0.8 (Compton Road). 1 EPT families, 1 intolerant, 5 total. Habitat = 116. 1996 TDEC biological survey at mile 0.8 (Comption Road). Zero EPTs families, 5 total families. Habitat score = 80.
TN05130203029 - 0100	Jarman Branch (Bradley Creek to headwaters)	2002 TDEC biorecon at mile 0.3 (Highway 96). 4 EPT families, 2 intolerant, 16 total families. BR score = 11. Habitat score = 103. 1997 TDEC biological survey at mile 0.3 (Highway 96). 3 EPT families, 12 total families. Habitat score = 105.
TN05130203029 - 0200	Unnamed Tributary to Bradley Creek (Bradley Creek to headwaters)	2002 TDEC observations at miles 0.7 & 1.5 (Oregon Road). Also assessed visually in 1997 based on presence of cows in creek.
TN05130203029 - 0300	Unnamed Tributary to Bradley Creek (Bradley Creek to headwaters)	2002 observations at mile 0.7 (Oregon Road). Stream very impacted by cattle.
TN05130203036 - 0200	West Branch Hurricane Creek (Hurricane Creek to headwaters)	2002 TDEC biorecon at mile 0.1 (Gate 2, Bridgestone). 3 EPT families, 2 intolerant, 10 total families. BR score = 11. Habitat score = 137.
TN05130203036 - 1000	Hurricane Creek (J. Percy Priest Lake to headwaters)	2002 TDEC biorecon at mile 3.7 (Hurricane Cr pump station). 3 EPT families, 1 intolerant, 17 total, habitat = 122. 1997 TDEC biorecon at mile 4.2 (Murfreesboro Rd). 4 EPT families, 18 total families. Habitat score = 114. Corps of Engineers RBPIII results from mile 4.4 (Murfreesboro Road): 6 EPT genera, 14 total genera. Biocriteria score: 22. Failed.

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, October, 2007* (TDEC, 2007):

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 the recreation use classification:

> Nutrients - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that the public's recreational uses of the waterbody or other downstream waters are detrimentally affected. Unless demonstrated otherwise, the nutrient criteria found in 1200-4-3-.03(3)(k) will be considered adequately protective of this use.
>
> *Note: Section 1200–4-3-.03(3)(k) is the nutrient criteria applicable to the fish & aquatic life use classification cited below.*

Applicable to the fish & aquatic life use classification:

> 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.
>
> 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 wadeable streams, lakes, and reservoirs may be made using Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA/841-B-99-002) or Lake and Reservoir Bioassessment and Biocriteria (EPA 841-B-98-007), and/or other scientifically defensible methods. Interpretation of this

> provision for wetlands or large rivers may be made using 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.
>
> 1. In streams identified as trout streams, including tailwaters, dissolved oxygen shall not be less than 6.0 mg/L.
>
> 2. 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.)
>
> 3. In wadeable streams in subecoregion 73a, dissolved oxygen levels shall not be less than a daily average of 5.0 mg/L with a minimum dissolved oxygen level of 4.0 mg/L.
>
> 4. 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. Diurnal fluctuations shall not be substantially different than the fluctuations noted in reference streams in that region.
>
> 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.

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 Water Quality Indicators & TMDL Targets

In order for a TMDL to be established, appropriate indicators and target values that are 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 forms the basis for the TMDL. Where state regulation does not provide a numeric water quality criteria at present, as in the case of nutrients and biological integrity, numeric interpretations of narrative water quality standards must be determined.

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 (TN), total phosphorus (TP), and carbonaceous biochemical oxygen demand ($CBOD_5$). These constituents have been selected as the appropriate indicators for TMDL development. It should be noted that total nitrogen and total phosphorus are not toxics. The primary importance of these nutrients with respect to water quality is in enabling the growth of algae and the ultimate effect on instream dissolved oxygen concentrations.

The nutrient and $CBOD_5$ targets established below are considered to support instream dissolved oxygen concentrations above the minimum specified by State water quality standards for the fish & aquatic life use classification.

<u>Nutrients</u>

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 75^{th} percentile value as the reference condition.

For the purposes of this TMDL, and in accordance with the standards for nutrients and biological integrity, the 75^{th} 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 targets, corresponding to the 75^{th} 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 April 30, 2005.

$\underline{CBOD_5}$

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 TARGET

Chemical water quality data, relevant to Stage I TMDL development for waterbodies identified as impaired for low dissolved oxygen or nutrients in the Stones River watershed, are available from a number of sources and are summarized in the following sections.

6.1 STORET Data

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

- BEAR000.8RU – Bear Creek at Highway 268 (~RM 0.8)
- HURRI003.7RU – Hurricane Creek ½ mile downstream of Murfreesboro Road (~ RM 3.7)
- HURRI004.2RU – Hurricane Creek at Murfreesboro Road (~RM 4.2)
- JARMA000.3RU – Jarman Branch at Highway 96 (~RM 0.3)
- LYTLE1T0.1RU – Unnamed tributary to Lytle Creek near S. Front Street (~RM 0.1).
- MCCRO001.5DA – McCrory Creek at Stewart Ferry Pike (~RM 1.5)
- WFSTO032.1RU – West Fork Stones River d/s of Rock Springs Road (~RM 32.1)
- WFSTO032.3RU – West Fork Stones River 25 yards u/s of Rock Springs Road (~RM 32.3)

Note: Monitoring Station WFSTO032.3RU, located at RM 32.3 on the West Fork Stones River, was formerly known as ECO71I09, an ecoregion reference site. This station was dropped as a reference site as of 5/13/03 due to impairment based primarily on biological data (ref.: Table 3).

The location of these monitoring stations is shown in Figure 6. Water quality monitoring results for all stations are tabulated in Appendix D and summarized in Table 4. 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 and nutrients in these waterbodies are considered to be primarily due to high nutrient loading.

Figure 6 Selected Water Quality Monitoring Stations in the Stones River Watershed

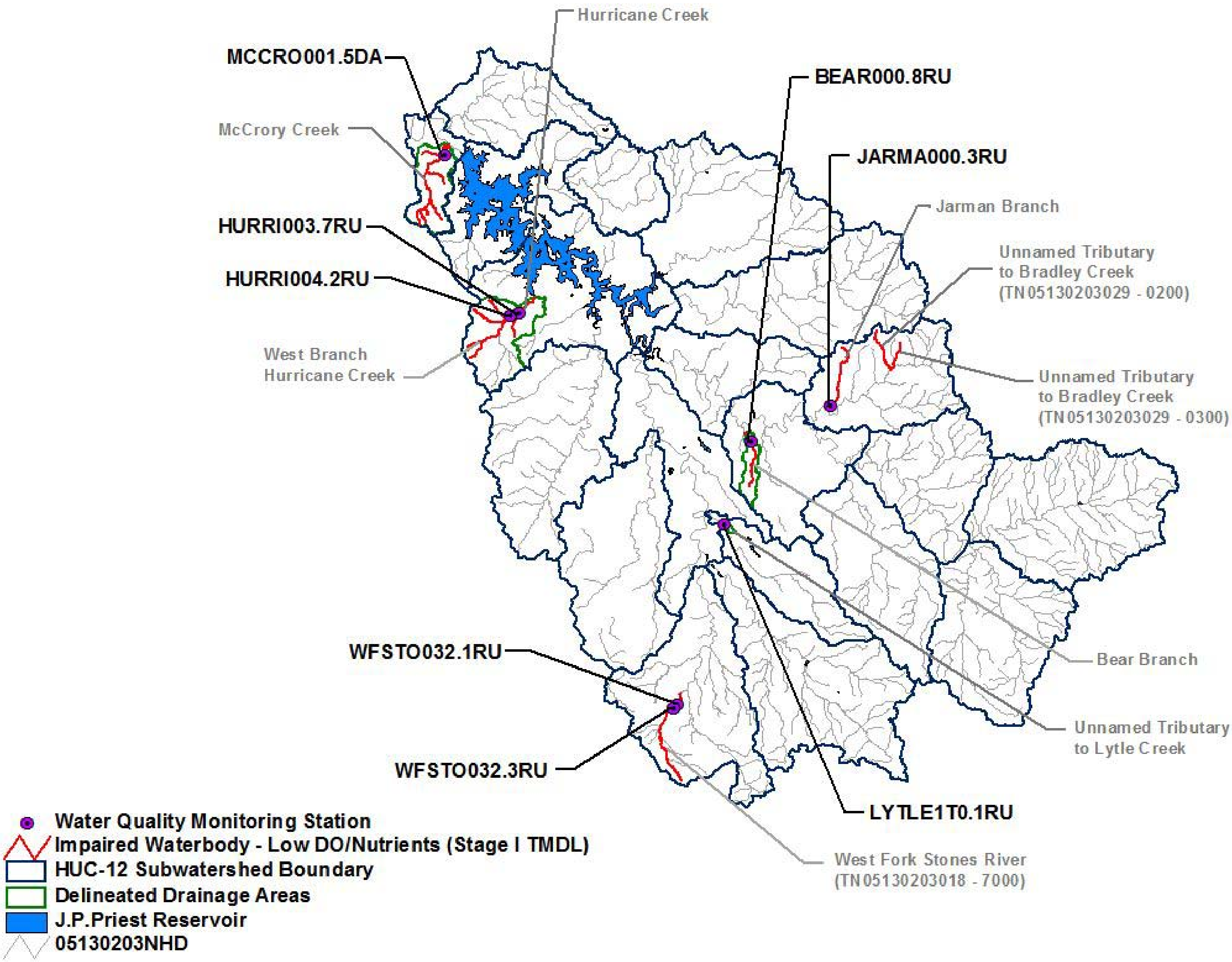


Table 4 Summary of Water Quality Monitoring Data [a]

Monitoring Station	Sample Dates	Dissolved Oxygen					Total Nitrogen [b]				Total Phosphorus			
		Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]	No. Viol. WQ Std.	Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]	Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]
BEAR000.8RU	9/06 – 3/07	4	6.22	10.91	14.32	0	4	0.51	0.98	1.48	4	0.005	0.004	0.02
JARMA000.3RU	7/02 – 8/02	—	—	—	—	—	2	0.61 [c]	1.40 [c]	2.20 [c]	2	0.053	0.262	0.470
HURRI003.7RU	10/06	1	11.35	—	—	—	—	—	—	—	—	—	—	—
HURRI004.2RU	7/02 – 6/07	18	5.61	11.18	16.51	0	5	0.28	0.63	0.85	2	0.148	0.229	0.309
LYTLE1T0.1RU	10/01 – 5/07	18	3.35	6.53	8.82	1	20 [d]	0.26 [d]	0.77 [d]	1.55 [d]	21	0.002	0.025	0.075
MCCRO001.5DA	10/01 – 5/07	20	3.88	7.78	10.47	1	8	0.44	1.03	2.18	8	0.014	0.223	0.623
WFSTO032.1RU	6/05 – 7/05	—	—	—	—	—	2	0.17	0.31	0.45	2	0.002	0.011	0.02
WFSTO032.3DA (Former ECO71I09)	5/96 – 6/05	30	2.53	8.70	12.51	5	34	0.07	0.82	2.81	34	0.002	0.036	0.302

Notes: a. For cases where data were reported as less than an analytical detection level, ½ the detection level was used to determine average, maximum, and minimum values.
b. 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.
c. Values are NO_2+NO_3.
d. Includes one data point that is NO_2+NO_3.

6.2 Diurnal Dissolved Oxygen Data

Diurnal dissolved oxygen data were collected in a number of wadeable streams as part of a 2002 study (TDEC, 2003). Three probes were placed in impaired waterbodies in the Stones River watershed for which Stage I TMDLs were developed:

Station ID	Location	Dates
HURRI004.2RU	Hurricane Creek at RM 4.2	7/31/02 – 8/7/02
JARMA000.3RU	Jarman Creek at RM 0.3	7/31/02 – 8/7/02
LYTLE1T0.1RU	Unnamed tributary to Lytle Creek at RM 0.1	7/31/02 – 8/8/02

Plots of this data are presented in Figures 7, 8, & 9. In each case, a portion of the diurnal cycle is lower than the 5 mg/l minimum dissolved oxygen specified by Tennessee water quality standards for the protection of fish & aquatic life. Diurnal variation ranges from approximately 3 mg/l to 9 mg/l at the three sites.

Figure 7 Diurnal Dissolved Oxygen Data in Hurricane Creek at RM 4.2

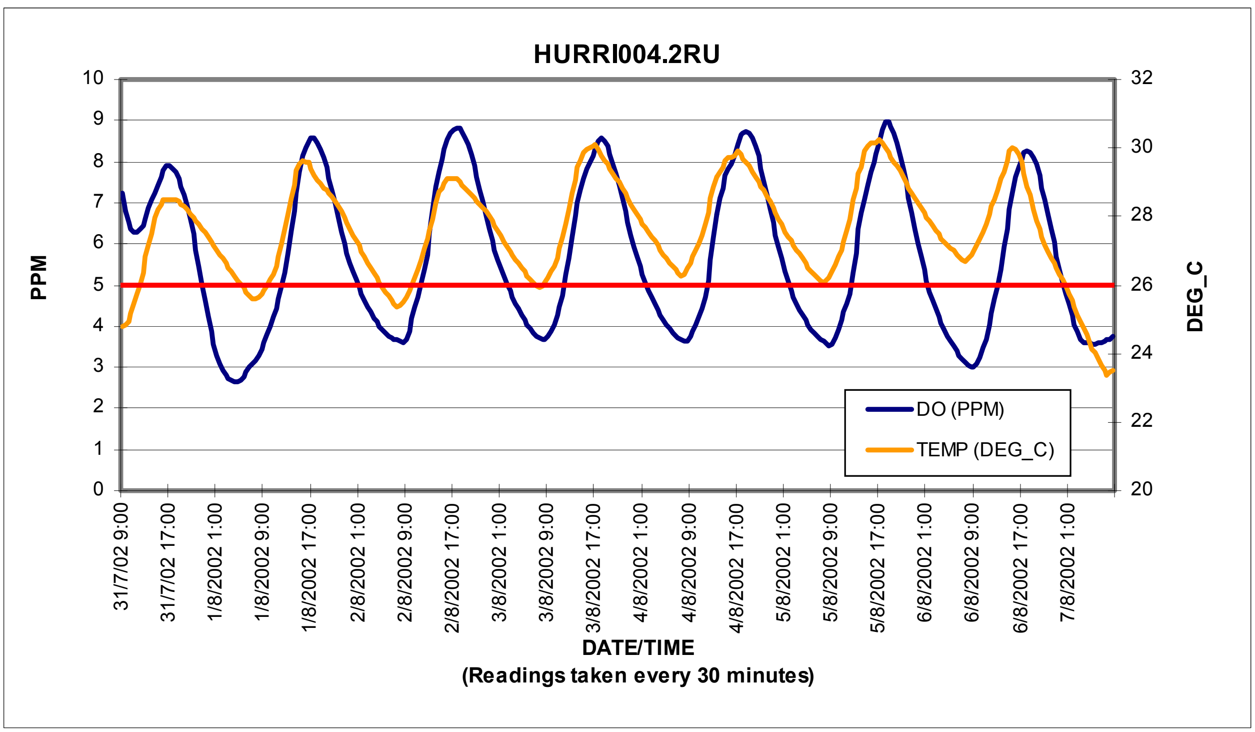


Figure 8 Diurnal Dissolved Oxygen Data in Jarman Creek at RM 0.3

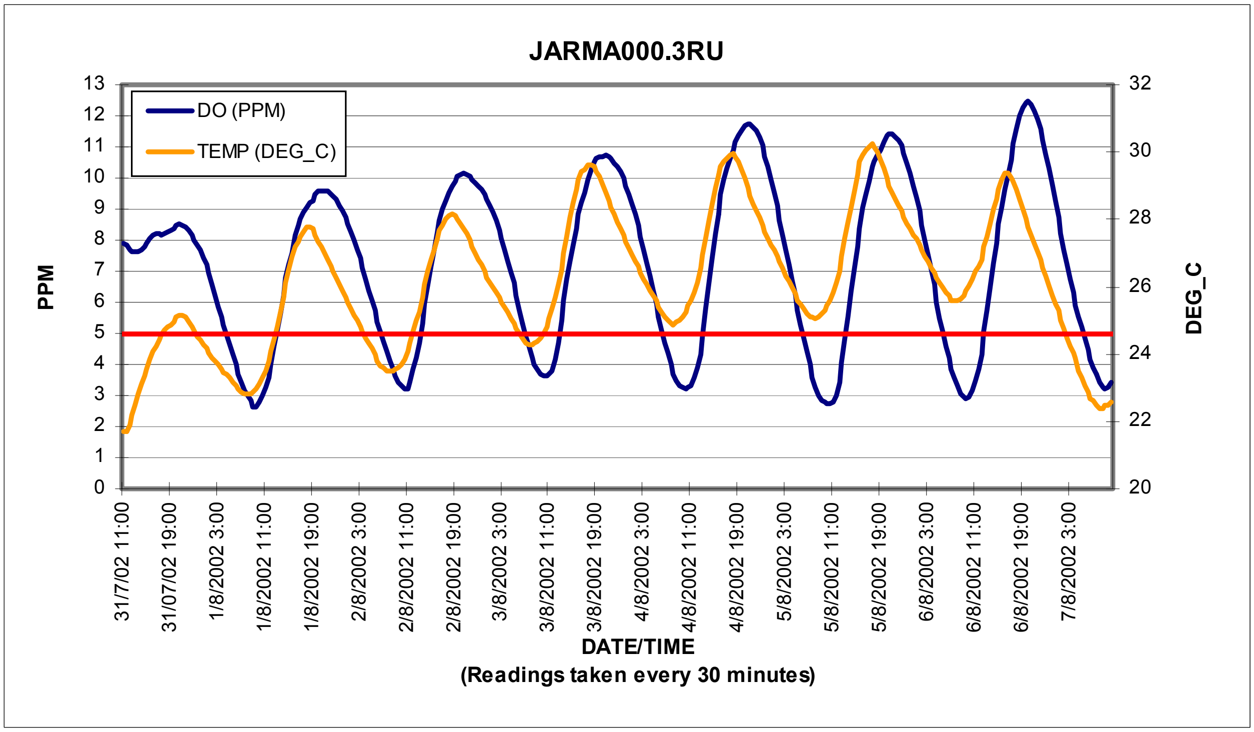
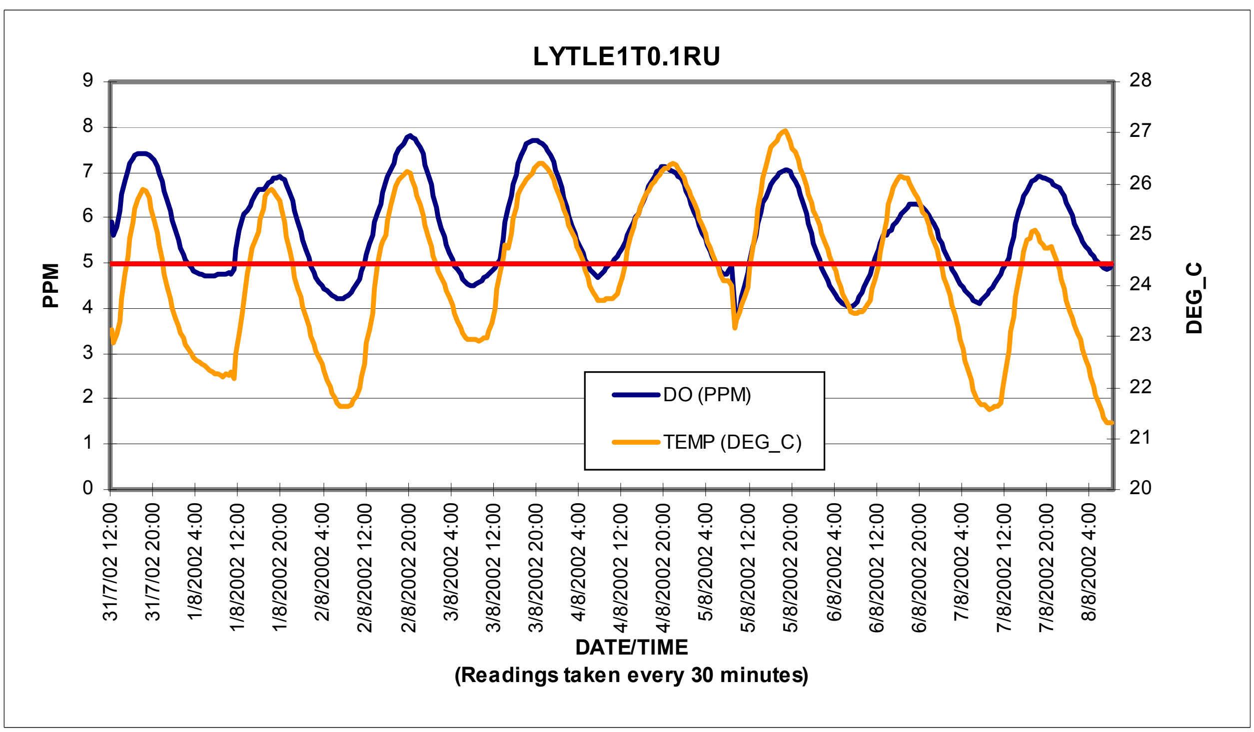


Figure 9 Diurnal Dissolved Oxygen Data in Unnamed Tributary to Lytle Creek at RM 0.1



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 instream dissolved oxygen levels and the amount of loading contributed by each of these sources. Pollutants of concern include $CBOD_5$,as well as excess amounts of total nitrogen (composed of organic nitrogen, ammonia, nitrate, & nitrite) and total phosphorus. $CBOD_5$ is an indicator of the oxygen consumed during the oxidation of organic matter, whereas 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 three broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

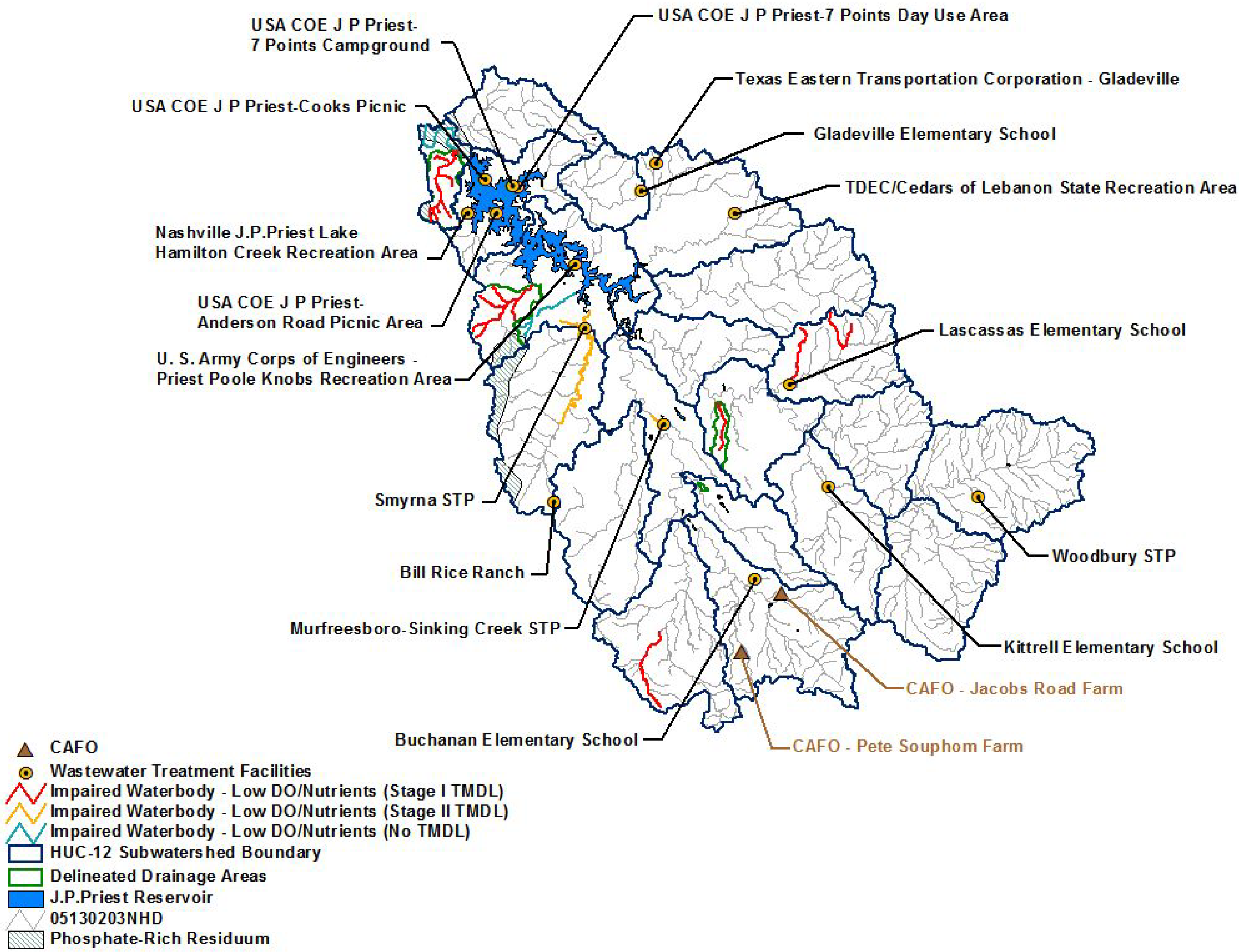
7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain the primary nutrients nitrogen (organic nitrogen, ammonia, nitrate, & nitrite) and phosphorus (organic & inorganic). There are 15 NPDES permitted WWTFs in the Stones River watershed that discharge treated sanitary wastewater. In addition, the Texas Eastern Transportation Corporation – Gladeville facility is permitted to discharge non-process wastewater and storm water containing ammonia. Of these WWTFs, two discharge directly to an impaired waterbody (see Figure 10). As stated in Section 2.0, nutrient TMDLs for impaired subwatersheds containing existing WWTFs will be developed as part of Stages II & III and are not included in this document.

The substantial majority of the collection system in the Finch Branch drainage area is in the City of LaVergne. LaVergne is authorized by a State Operating Permit (SOP 88-061) to collect and transport untreated municipal wastewater to the Metro Nashville sewer system. Since this collection system provides wastewater influent to a NPDES permitted STP, it is considered to be a point source for the purposes of TMDL development. No discharges to surface waters are authorized by the SOP. An Agreed Order was issued by the Tennessee Water Quality Control Board on October 24, 2000. This order resolved an appeal of a Director’s Order issued by the Division of Water Pollution Control on November 8, 1999 for unauthorized discharges from the LaVergne collection system.

Figure 10 CAFOs & 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, Metro Nashville/Davidson County (TNS068047) is the only MS4 of this size in the Stones River watershed.

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

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State road and interstate highway rights-of-way that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas.

Information regarding storm water permitting in Tennessee may be obtained from the 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* (this permit may be obtained from the TDEC website at http://state.tn.us/environment/permits/cafo.shtml), while larger, Class I CAFOs are required to obtain an individual NPDES permit. Requirements of both the general and individual CAFO permits include:

- Development of a Nutrient Management Plan (NMP), and approval of the NMP by the Tennessee Department of Agriculture (TDA).
- Liquid waste handling systems, if utilized, be designed, constructed, and operated

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

- Other Best Management Practices (BMPs).

As of September 14, 2007, there are two Class II CAFO in the Stones River watershed with coverage under the general NPDES permit. The location of these facilities is shown in Figure 10. It should be noted that these facilities are not located HUC-12 subwatersheds containing waterbodies identified as impaired for low dissolved oxygen or nutrients. There are no CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

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 (see Figure 13) 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. For the majority of the waterbodies undergoing Stage I TMDL development in the Stones River watershed, nonpoint sources are listed as the primary sources of pollution.

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).

Watershed livestock, population on septic systems, and land use (MRLC) data for subwatersheds in the Stones River watershed 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. Estimates of livestock and population on septic systems for impaired HUC-12 subwatersheds an drainage areas are presented in Tables 6 & 7, respectively. Land use for these subwatersheds and drainage areas is summarized in Figures 11 & 12 and tabulated in Appendix C.

Note: The unnamed tributary to Lytle Creek (ref: Tables 2, 3, & 4) is not a part of the National Hydrology Database (NHD) or Reach File v.3. Therefore, WCS methods could not be utilized to estimate land use, livestock population, or population on septic systems.

Table 6 Estimated Livestock Distribution in Impaired Subwatersheds & Drainage Areas

Impaired Subwatershed (05130203__) or Drainage Area	Livestock Population - 2002 Census of Agriculture (USDA, 2004)							
	Beef Cow	Cattle	Milk Cow	Chickens		Hogs	Sheep	Horses
				Layers	Broilers Sold			
0106	1,955	3,682	143	3,407	4,534	109	64	486
0201	2,490	4,771	205	5,295	27,990	139	81	660
McCrory Ck. DA		157		15				20
Hurricane Ck. DA	51	387	<5	116	118	<5	<5	51
Bear Br. DA	99	188	8	209	280	5	<5	27

Note: D = Number withheld for Davidson County.

Table 7 Estimated Population on Septic Systems in Impaired Subwatersheds & Drainage Areas

Impaired Subwatershed (05130203____) or Drainage Area	Population On Septic Systems
0106	3,104
0201	5,649
McCrory Creek DA	633
Hurricane Creek DA	2,235
Bear Branch DA	216

Figure 11 Land Use Area of Impaired Subwatersheds & Drainage Areas

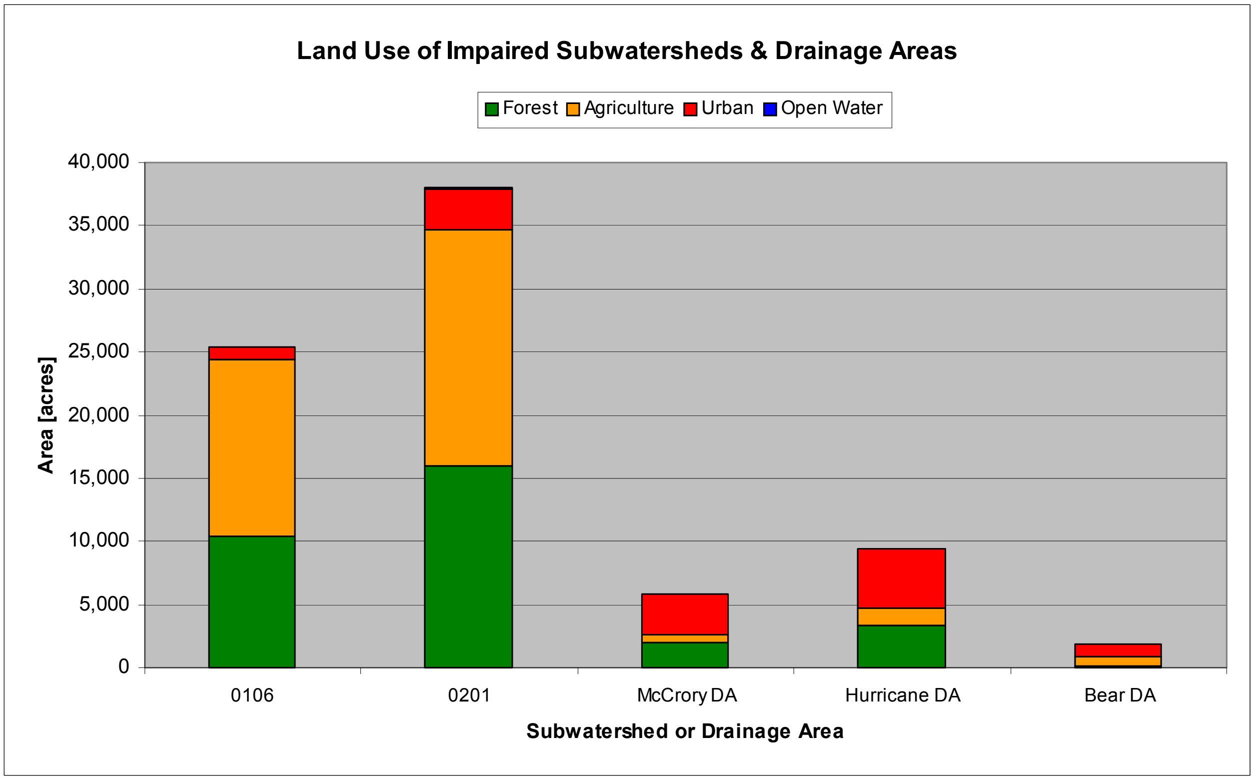
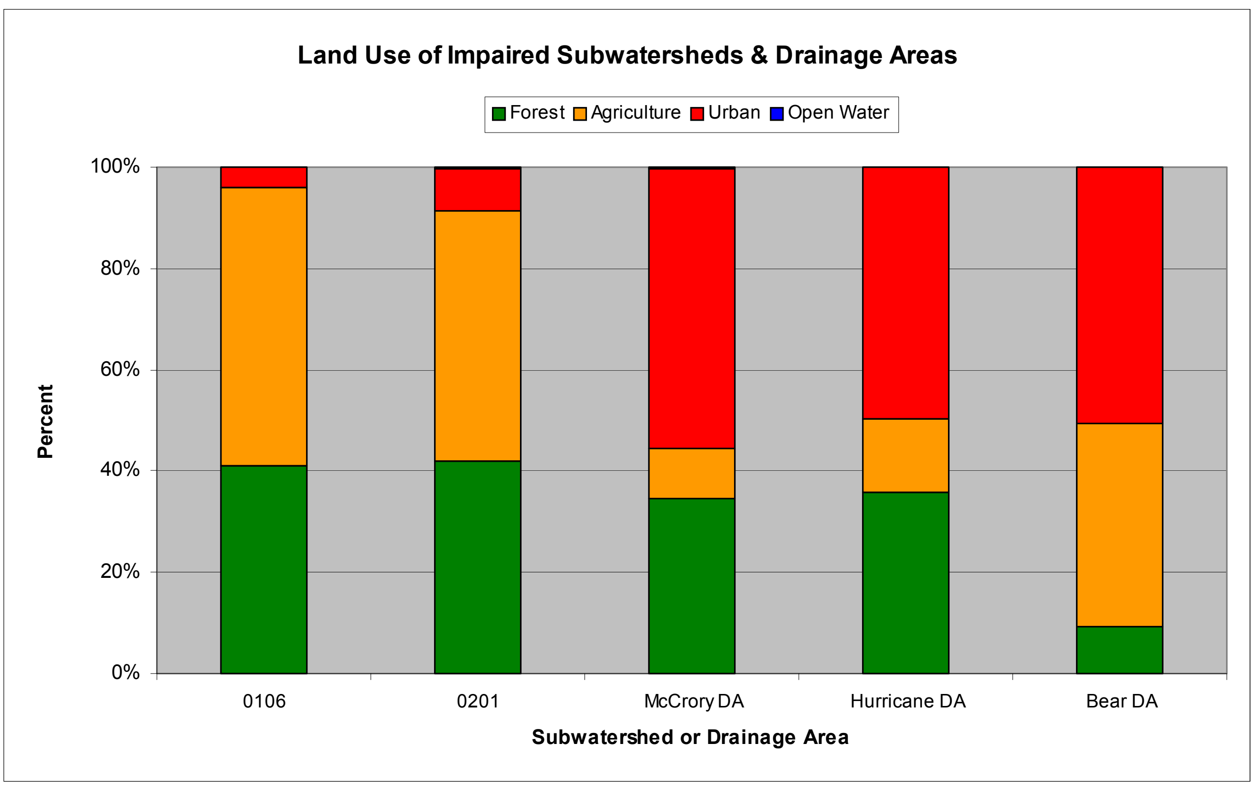


Figure 12 Land Use Percentage of Subwatersheds & Drainage Areas



From the data presented in Tables 5, 6, 7, & C-1 and Figures 11, & 12, it can be seen that approximately 50% of the land use in Subwatersheds 0106, & 0201 is associated with agricultural activities. Agricultural sources are a significant source of nitrogen loading. This is reflected in the 2006 303(d) list (ref.: Table 2) where agriculture related sources are noted as the source of pollutants for impaired waterbodies in these subwatersheds. A significant portion of land use in the McCrory Creek, Hurricane Creek, Bear Branch, and, probably, the unnamed tributary to Lytle Creek drainage areas is classified as urban. Urban land has the highest loading rates for both phosphorus and nitrogen.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

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 is equal to 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.

8.1 Area Basis for TMDL Analysis

The basic area unit of analysis for Stage I TMDL development was the headwater HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to low dissolved oxygen or nutrients, as documented on the 2006 303(d) List. In some cases, for impaired tributaries in non-headwater subwatersheds, TMDLs were developed for the impaired waterbody drainage area only. HUC-12 subwatersheds and delineated drainage areas are shown in Figure 13. As stated in Section 2.0, TMDL development for impaired subwatersheds containing existing WWTFs are part of Stages II & III and are not included in this document.

8.2 TMDL Analysis Methodology

Since the acceleration of the eutrophication is one of the significant effects of excess nutrient loading, an annual time scale for TMDL analysis was considered to be the most appropriate for representing the seasonal and long-term processes of algal growth in streams and the associated effects on instream dissolved oxygen and aquatic life (ref.: Appendix A). Accordingly, TMDLs, WLAs, and LAs were developed as annual average loads.

However, in response to a recent court decision, EPA issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et al., No.05-5015, (April 25, 2006) and Implications for NPDES Permits* (USEPA 2006) to clarify expectations regarding the appropriate time increment used to express TMDLS. In this document, EPA recommends that future TMDLs, WLAs, and LAs include a daily time increment in conjunction with other appropriate temporal expressions. In accordance with this guidance, daily expressions of allowable annual average loads were developed.

For each impaired subwatershed or waterbody drainage area, the TMDL (and associated WLAs & LAs) consists of: a) an allowable average annual load and b) a daily expression of that allowable average annual load.

8.2.1 Annual Loading Analysis

Stage I TMDLs were developed for impaired subwatersheds and drainage areas based on the target nutrient and $CBOD_5$ concentrations specified in Section 5.2. Utilizing these concentrations and simulated flow data for each ecoregion reference site, annual average loading targets were calculated for Level IV ecoregions 71h & 71i. Total nitrogen, total phosphorus, and $CBOD_5$ TMDLs were determined by applying these ecoregion-based loading targets to each impaired subwatershed and drainage area. An explicit MOS was used and WLAS for MS4s and LAs for nonpoint sources were calculated on a unit area basis. $CBOD_5$ TMDLs were only developed for subwatersheds with low dissolved oxygen specifically identified as a cause of impairment and/or subwatersheds containing impaired waterbodies with measured diurnal dissolved oxygen concentrations that fall below 5 mg/l (ref.: Figures 7, 8, & 9). The annual loading analysis methodology is described in detail in Appendix E.

8.2.2 Daily Expression of Allowable Annual Loads

One of the options discussed in *Options for Expressing Daily Loads in TMDLs* (USEPA 2007) is the use of statistical analysis to identify a daily maximum load. The statistical approach selected to derive daily load expressions for Stage I TMDLs, WLAs, & LAs in the Stones River watershed was based on a procedure described in the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991a). Using this methodology, allowable daily maximum concentrations for total nitrogen and total phosphorus were calculated from monitoring data collected at Level IV ecorgion ecoregion reference sites (71 h & 71i). Daily maximum nutrient loads were expressed as functions of stream flow for TMDLs, WLAs, & LAs. Derivation of daily expressions of annual average loads are detailed in Appendix F.

8.3 TMDLs for Impaired Subwatersheds and Drainage Areas

Stage I nutrient and $CBOD_5$ TMDLs are expressed as annual average loads (lbs/yr) for impaired subwatersheds and drainage areas and are summarized in Table 8.

8.4 Waste Load Allocations for Point Sources

8.4.1 NPDES Regulated Concentrate Animal Feeding Operations (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.

8.4.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

NPDES regulated Municipal Separate Storm Sewer Systems (MS4s) are considered point sources of nutrients. Since loading from these entities occurs primarily in response to storm events, WLAs are expressed as average annual loads on a unit area basis (lbs/ac/yr) and applied according to the subwatershed or drainage area into which the MS4 discharges. Stage I nutrient and $CBOD_5$ WLAs for MS4s are tabulated in Tables 9, 10, &11.

8.5 Load Allocations for Nonpoint Sources

Load allocations for nonpoint sources are numerically equal to the WLAs for MS4s (ref: Section 8.4.2) and are also expressed as average annual loads on a unit area basis (lbs/ac/yr). LAs apply to any nonpoint source loading in the impaired subwatershed or drainage area. Stage I nutrient and $CBOD_5$ LAs for nonpoint sources are tabulated in Tables 9, 10, &11.

8.6 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 75^{th} percentile of nutrient data collected from Level IV ecoregion reference sites. These sites represent the least impacted streams in the ecoregions. In addition, 5% of each TMDL was reserved as explicit MOS.

8.7 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 annual basis accounts for seasonal variation of loading.

Figure 13 HUC-12 Subwatershed Boundaries & Delineated Drainage Areas in the Stones River Watershed

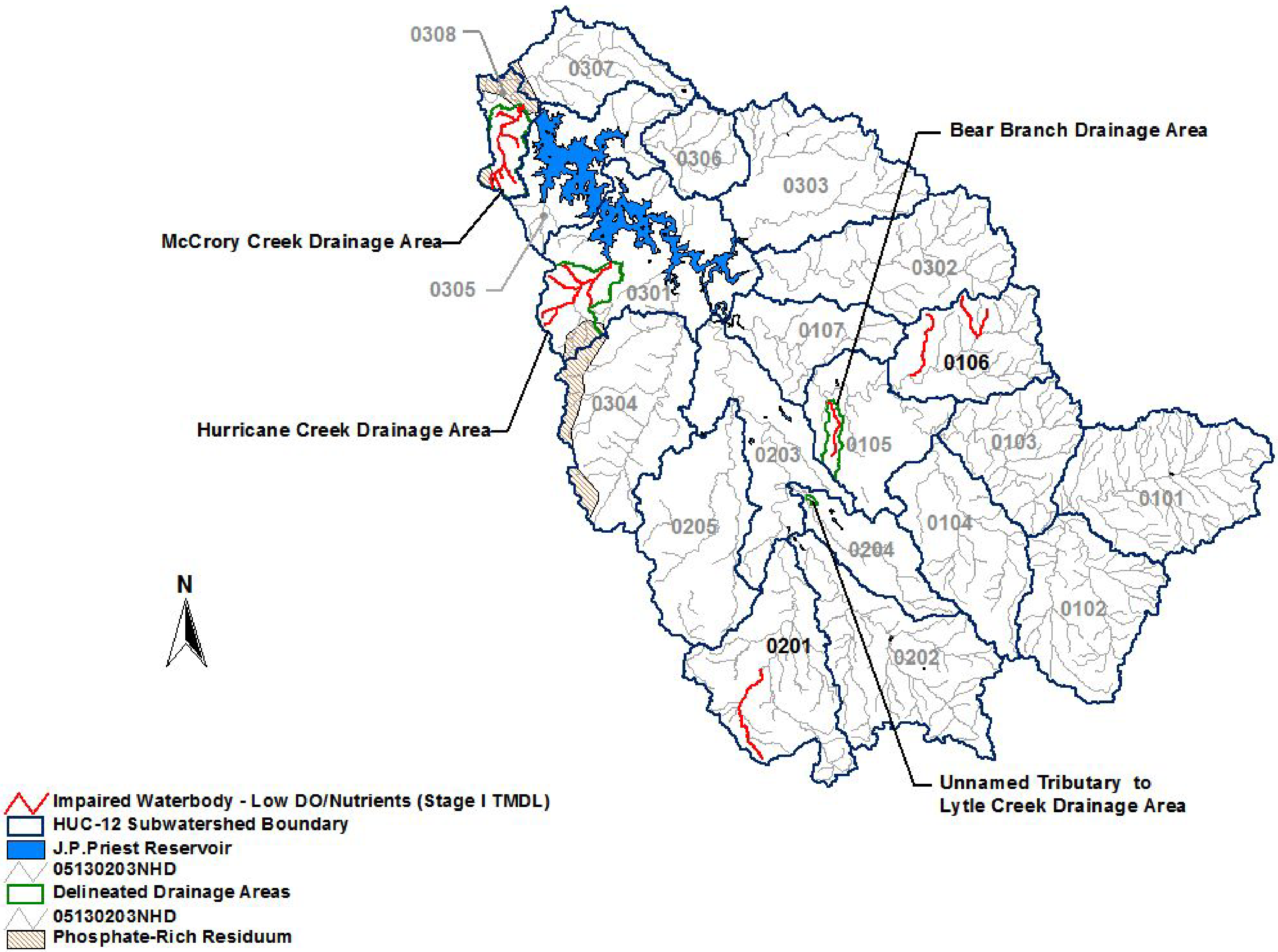


Table 8 Summary of Stage I Total Nitrogen, Total Phosphorus, & $CBOD_5$ TMDLs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL					
			Total Nitrogen		Total Phosphorus		$CBOD_5$	
			[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]	[lbs/yr]	[lbs/day] [a]
0106	Jarman Branch	TN05130203029-0100	112,695	$2.157 \times 10^1 * Q$	22,655	$1.008 \times 10^1 * Q$	224,597	$4.046 \times 10^1 * Q$
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	169,007	$2.200 \times 10^1 * Q$	34,899	$1.045 \times 10^1 * Q$	336,300	$4.046 \times 10^1 * Q$
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	25,354	$1.243 \times 10^1 * Q$	2,090	$2.116 \times 10^0 * Q$	NA [b]	NA [b]
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	41,786	$2.038 \times 10^1 * Q$	7,760	$9.031 \times 10^0 * Q$	83,642	$4.046 \times 10^1 * Q$
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	8,019	$2.243 \times 10^1 * Q$	1,699	$1.082 \times 10^1 * Q$	NA [b]	NA [b]
Unnamed Trib. to Lytle Ck. DA [c]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	534	$2.243 \times 10^1 * Q$	113	$1.082 \times 10^1 * Q$	1,061	$4.046 \times 10^1 * Q$

Notes:
a. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
b. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).
c. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Table 9 Summary of Stage I Total Nitrogen WLAs & LAs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA				LA	
			MS4 [a]		CAFO [b]			
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day]	[lbs/ac/yr]	[lbs/ac/day] [c]
0106	Jarman Branch	TN05130203029-0100	4.2206	$8.505 \times 10^{-4} * Q$	0	0	4.2206	$8.505 \times 10^{-4} * Q$
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	4.2241	$5.789 \times 10^{-4} * Q$	0	0	4.2241	$5.789 \times 10^{-4} * Q$
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	4.1470	$2.140 \times 10^{-3} * Q$	0	0	4.1470	$2.140 \times 10^{-3} * Q$
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	4.2110	$2.161 \times 10^{-3} * Q$	0	0	4.2110	$2.161 \times 10^{-3} * Q$
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	4.2275	$1.245 \times 10^{-2} * Q$	0	0	4.2275	$1.245 \times 10^{-2} * Q$
Unnamed Trib. to Lytle Ck. DA [d]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	4.2275	$1.869 \times 10^{-1} * Q$	0	0	4.2275	$1.869 \times 10^{-1} * Q$

Notes:
a. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
b. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
d. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Table 10 Summary of Stage I Total Phosphorus WLAs & LAs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA				LA	
			MS4 [a]		CAFO [b]			
			[lbs/ac/yr]	[lbs/ac/day] [c]	[lbs/ac/yr]	[lbs/ac/day]	[lbs/ac/yr]	[lbs/ac/day] [c]
0106	Jarman Branch	TN05130203029-0100	0.8485	3.972×10^{-4} * Q	0	0	0.8485	3.972×10^{-4} * Q
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	0.8722	2.749×10^{-4} * Q	0	0	0.8722	2.749×10^{-4} * Q
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	0.3418	3.643×10^{-4} * Q	0	0	0.3418	3.643×10^{-4} * Q
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	0.7820	9.580×10^{-4} * Q	0	0	0.7820	9.580×10^{-4} * Q
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	0.8959	6.005×10^{-3} * Q	0	0	0.8959	6.005×10^{-3} * Q
Unnamed Trib. to Lytle Ck. DA [d]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	0.8959	9.018×10^{-2} * Q	0	0	0.8959	9.018×10^{-2} * Q

Notes:
a. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
b. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
c. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec]
d. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Table 11 Summary of Stage I $CBOD_5$ WLAs & LAs

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	WLA				LA	
			MS4 [b]		CAFO [c]			
			[lbs/ac/yr]	[lbs/ac/day] [d]	[lbs/ac/yr]	[lbs/ac/day]	[lbs/ac/yr]	[lbs/ac/day] [d]
0106	Jarman Branch	TN05130203029-0100	8.4115	$1.595 \times 10^{-3} * Q$	0	0	8.4115	$1.595 \times 10^{-3} * Q$
	Unnamed Tributary to Bradley Creek	TN05130203029-0200						
	Unnamed Tributary to Bradley Creek	TN05130203029-0300						
0201	West Fork Stones River	TN05130203018-7000	8.4053	$1.064 \times 10^{-3} * Q$	0	0	8.4053	$1.064 \times 10^{-3} * Q$
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	NA [a]	NA [a]	0	0	NA [a]	NA [a]
		TN05130203001-0150						
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	8.4290	$4.292 \times 10^{-3} * Q$	0	0	8.4290	$4.292 \times 10^{-3} * Q$
	Hurricane Creek	TN05130203036-1000						
Bear Branch DA	Bear Branch	TN05130203023-0310	NA [a]	NA [a]	0	0	NA [a]	NA [a]
Unnamed Trib. to Lytle Ck. DA [e]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	8.3990	$3.371 \times 10^{-1} * Q$	0	0	8.3990	$3.371 \times 10^{-1} * Q$

Notes:
a. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).
b. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
c. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
d. Q = Stream flow at pour point of subwatershed or drainage area [ft^3/sec].
e. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first stage of a long-term effort to restore the biological health of impaired waters in the Stones 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 Stages II & III 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).*

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For existing and future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs will be implemented through Phase I and II MS4 permits. These permits will require the development and implementation of a Storm Water Management Plan (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. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003a) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include the following six minimum control measures:

1) Public education and outreach on storm water impacts;
2) Public involvement/participation;
3) Illicit discharge detection and elimination;
4) Construction site storm water runoff control;
5) Post-construction storm water management in new development and re-development;
6) Pollution prevention/good housekeeping for municipal (or TDOT) operations.

The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and description of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs. In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.

- Analytical monitoring of pollutants of concern in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time.

- Instream biological monitoring at appropriate locations to demonstrate recovery of biological communities after implementation of storm water control measures.

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

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

The WLAs provided to NPDES-regulated CAFOs will be implemented through the Nutrient Management Plan (NMP), liquid waste handling system, and Best Management Practices (BMP) provisions of NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*. All discharges, except during a catastrophic or chronic rainfall event, are not authorized by this permit. Any discharge shall not cause an exceedance of Tennessee water quality standards.

9.2 Nonpoint Sources

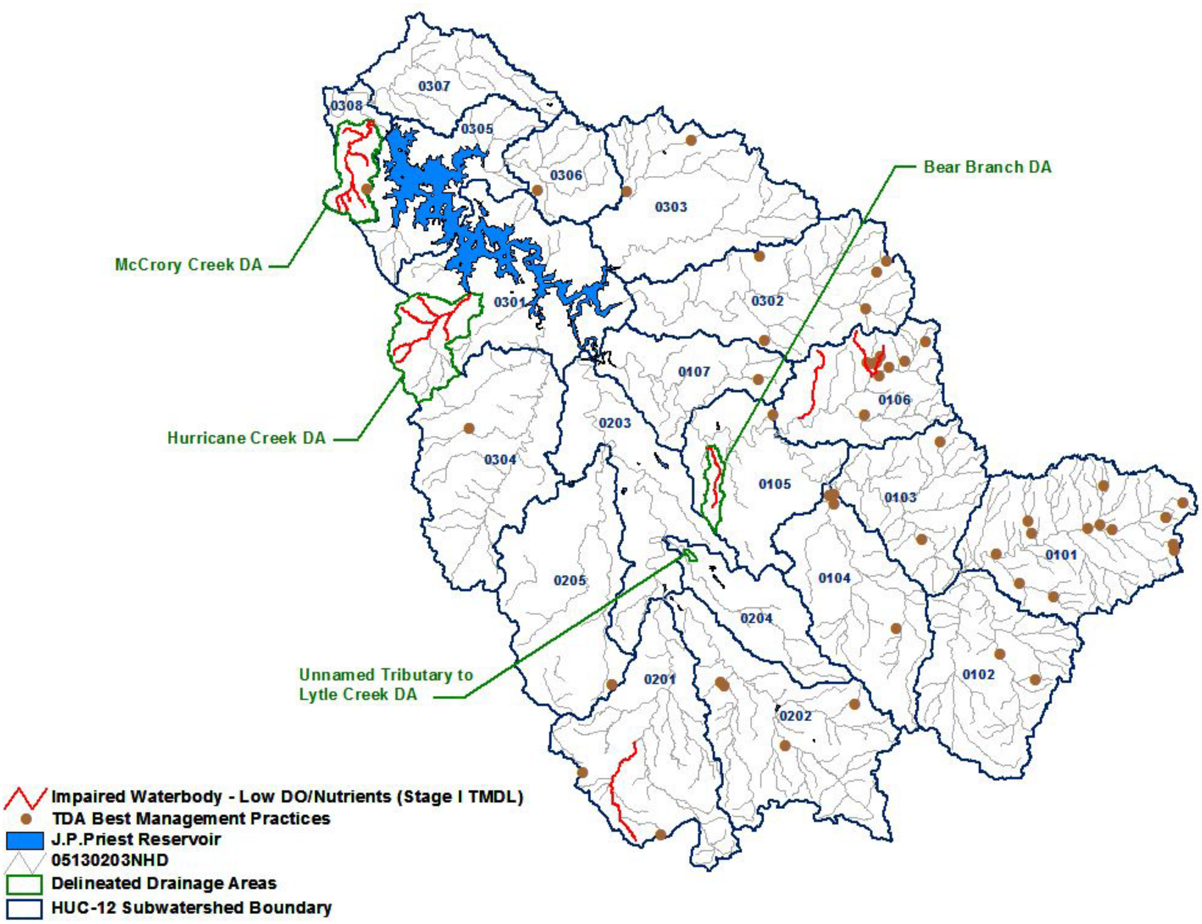
The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of nutrient loading from nonpoint sources (NPS) will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS 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.

Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. One local stakeholder group, Stones River Watershed Association (SRWA), is dedicated to protecting, preserving, enhancing, and restoring the natural resources within the Stones River Watershed. The SRWA has recently received a grant to develop a watershed restoration plan for Lytle Creek. Participants include city and county governments and MTSU. Details regarding activities of the SRWA are available at their web site (http://stoneswatershed.org).

BMPs have been utilized in the Stones River Watershed to reduce the amount of pollutants transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of nutrients and organic material in the Stones River Watershed during the TMDL evaluation period. The TDA keeps a database of BMPs implemented in Tennessee. Those listed in the Stones River Watershed are shown in Figure 14.

Figure 14 Tennessee Department of Agriculture Best Management Practices in the Stones River Watershed



9.3 Use of Load Duration Curve as a Guide to Implementation

The Load Duration Curve methodology (Appendix G) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. 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 12 illustrates one example of an approach which could be used to assess management options for nutrient control 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 for Bear Branch, Hurricane Creek, McCrory Creek and the headwaters of West Fork Stones River (ref.: Figures F-1 through F-7).

Estimates of overall reductions in existing nutrient loading required to attain TMDLs were also calculated in Appendix G using the load duration curve methodology (Tables G-1 through G-5). These estimated reductions are summarized in Table 13 and are provided as a guide for implementation only. Estimated reductions in $CBOD_5$ loading were not developed due to lack of monitoring data.

Table 12 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)

Table 13 Estimates of Required Load Reductions for Impaired Subwatersheds & Drainage Areas

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Estimated Load Reduction	
		Total Nitrogen [%]	Total Phosphorus [%]
Bear Branch DA	Bear Branch	10.5	NR
Hurricane Creek DA	Hurricane Creek West Branch Hurricane Creek	8.7	ND
McCrory Creek DA	McCrory Creek	17.3	48.3
0201	West Fork Stones River (Headwaters)	28.2	NR
Unnamed Tributary to Lytle Creek DA	Unnamed Tributary to Lytle Creek	16.4	NR

NR = No reduction required; ND = No Data.

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.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed low dissolved oxygen & nutrient TMDLs for the Stones River watershed was placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard include:

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

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

3) A letter was sent to the Water Quality Partners in the Stones River watershed These partners include:

United States Environmental Protection Agency, Region IV
Natural Resources Conservation Service
Tennessee Department of Agriculture
Friends of Murfreesboro Greenway
The Nature Conservancy
Cumberland River Compact
Stones River Watershed Association

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in subwatersheds that contain waterbodies impaired due to low dissolved oxygen or nutrients. A draft copy was sent to the following entities:

Metro Nashville/Davidson County (TNS068047)
City of LaVergne, Tennessee (TNS075418)
City of Murfreesboro, Tennessee (TNS075469)
City of Smyrna, Tennessee (TNS075779)
Rutherford County, Tennessee (TNS075647)
Wilson County, Tennessee (TNS075809)
Tennessee Dept. of Transportation (TNS077585)

5) Letters were sent to WWTFs located in the Stones River Watershed that would potentially be affected by Stage II or Stage III low dissolved oxygen/nutrient TMDLs, advising them of the proposed Stage I TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. Letters were sent to the following facilities:

Bill Rice Ranch (TN0057975)
Lascassas Elementary School (TN0067245)
Murfreesboro-Sinking Creek STP (TN0022586)
Smyrna STP (TN0020541)
LaVergne Collection System (SOP-88061)

No formal 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:

Bruce R. Evans, P.E., Watershed Management Section
e-mail: Bruce.Evans@state.tn.us

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

Nutrients and Water Quality

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
(Jarman Branch)

Example of Stream Assessment – Jarman Branch at RM 0.3 (6 pages)

STREAM SURVEY FORM

assessment reflects High Flow condition

STREAM SURVEY INFORMATION

Support Status: *(PS)*

STREAM: *Jarman Crk*
STREAM LOCATION: *Hwy 96*
STATION NUMBER: *JARMA 000.3 RU* *(Previous site exists)*
COUNTY: *Rutherford*
MAJOR BASIN: *ST WS*
WBID#/HUC: *TN05130203029*
WBID NAME: *Bradley Crk*
LAT/LONG DEC: *35.929167 / -86.280000*
USGS QUAD: *315NE (Cascassas, TN)*
Drainage: *Bradley (RM 2.4) → E.F. ST (19.0)*
ECOLOGICAL SUBREGION: *71i (FNB)* *(35°55'45" N*
OBJECTIVES: *WSSS* *86° 16' 48" W)*

12/05/02 KB

ASSESSORS: *A M Goodhue*
DATE: *TH 04/04/02*
TIME: *5:20 - 6:00 pm*
STREAM MILE: *0.3 RM*
STREAM ORDER: *1st*
ADB SEGMENT:
3Q20: *?*
ELEVATION (ft): *560'-570'*
GAZETTEER PAGE: *p 38*
Field # *Bradley (A)*

SAMPLES COLLECTED — METERS USED: *Hydrolab Mini IV*

pH	*8.25 / 8.17*	SU
~~CONDUCTIVITY~~ *Temp.*	*14.60 / 14.54*	UMHOS
~~TEMPERATURE~~ *Cond.*	*378.1 / 377.4*	C

DISSOLVED OXYGEN	*9.67 / 9.57*	PPM
TIME	*5:30 / 5:35*	
OTHERS *Batt.*	*35.0% / 33.8%*	

Previous 48 hours Precip: UNKNOWN NONE *(LITTLE)* MODERATE HEAVY FLOODING
Ambient Weather: *(SUNNY)* CLOUDY BREEZY RAIN SNOW Current Temp: *48°F (sunset)*
CHEMICAL SAMPLES COLLECTED: *None @ Present / =ST029 JAR0.3 u, d, land use*
Photographs: Slides Prints *(Digital)* *(Photo #s)*: *#9 d/s, #10 u/s, #11 u/s land use= Housing developm. starting*
BIOLOGICAL ASSESSMENT: *(Benthics)* Fish Algae Other:
Type of benthic sample: *(BIORECON)* SQ KICK SQ BANK DENDY SURBER OTHER:
Taxa List Attached? *(Yes)* / No Specimens collected ? *(Y)* or N Sample Log Numbers: *N0204004*

WATERSHED CHARACTERISTICS — App. % of watershed observed: *40%*

UPSTREAM SURROUNDING LAND USE: (estimated %)

PASTURE	*70-90%*	URBAN		RESID/*rec*	*15-10%*
Row Crops		INDUSTRY		OTHER	
FOREST	*0-15%*	MINING			

NOTES: *Housing Development starting in upper WS @ this reach ...*

IMPACTS OBSERVED AND POSSIBLE SOURCES — Describe causes, nature, and rate magnitude

General land use = agriculture w/ pasture - but recent Housing development beginning.

OVERALL ASSESSMENT & SUMMARY: *[Prev WSSS = 07/24/97 (PS) / HAB=106 (AMG)]*

This stream winds through a field/pasture lands area w/ no riparian... a new Housing development has begun off RDB u/s of Hwy 96 w/ a drainage culvert under subdiv. rd (where drainage leads to Jarman Crk = runoff)... no flow through culvert @ subdiv. area presently... there is High sediment + excessive sometimes floating algae in areas. i.e. d/s Hwy 96 is a slow run, deep pool, Bedrock substrate area w/ some riparian on LDB + RDB, but Highly turbid pools + grass/macrophyte HABitat ... numerous fish were observed... Macroinvert. = EPT/TOT/INT: 4/16/2 ... all EPT observed were rare in abundance... @ this time, for F+A life, support status = (PS)

BIORECON Score= *FNB (Not Avail)* Time = *25"*	Habitats = *2.0 riffle + 2.0 grass*	
EPT Families (+ add. taxa) = *4*	Total Families (+ add. taxa) = *16*	Intolerant Taxa = *2*
EPA Habitat Assessment Completed ? *✓*	SCORE = *103*	GRADIENT : *(HIGH)* LOW

revised 8-10-98

STREAM SURVEY FORM

PHYSICAL STREAM CHARACTERISTICS | **Length of stream reach assessed =** 100'

SURROUNDING LAND USE (facing downstream) :

ESTIMATE %	RDB	LDB		RDB	LDB		RDB	LDB
PASTURE	50-80	70-88	URBAN			RESID.	40-20	
CROPS			INDUSTRY			ROAD	15	15
FOREST	0-10	0-10	MINING			School OTHER		10-20

% CANOPY COVER: Estimated: u/s = Open(0-10) ✓   Partly Shaded(11-45)   d/s Mostly Shaded(46-80)   Shaded(>80)

Measured: ______ U/S______ D/S______ LB______ RB______

BANK HEIGHT (m): 0.2' - 1.0'   **HIGH WATER MARK** (m): 3.0'(+)

SEDIMENT DEPOSITS: NONE   SLIGHT   MODERATE   (EXCESSIVE)   BLANKET

TYPE: SLUDGE   MUD Shallow   SAND   SILT ✓   NONE   OTHER________   Contaminated   Y or N

TURBIDITY CLEAR   (SLIGHT)   (MODERATE)   (HIGH)   (OPAQUE)

ALGAE PRESENT? NONE   SLIGHT   (MODERATE) / (CHOKING algae)   TYPE   micro + macro algae

AQUATIC VEGET. ROOTED   FLOATING   TYPE

RAPID PERIPHYTON ASSESS : % Filamentous =   % Colonizable Substrate =
% Direct Sunlight =   Mean Thickness Rank =

WATER QUALITY COMMENTS:(oil sheen, odor, colors, etc) areas of very High sediment + ~~Hook stat~~ Choking algae

SUBSTRATE (%) Bedrock (Visual estimates)

	RIFFLES	RUN	POOL
BOULDER (> 10")	0-5 %	~ %	0-10 %
COBBLE (2.5-10")	5-10 %	~ %	0-10 %
GRAVEL (0.1-2.5")	10-20 %	~ %	0-10 %
BEDROCK	40-50 %	80-95 %	40-50 %
SAND (gritty)	10-20 %	0-5 %	15-20 %
SILT (fine)	10-20 %	10-20 %	15-30 %
CLAY (slick)	— %	— %	%
DETRITUS (CPOM)	~ %	~ %	≈ %
MUCK-MUD (FPOM)	0-5 %	0-5 %	0-5 %
MARL (shell frags.)	— %	— %	— %

	RIFFLE	RUN	POOL
DEPTH (m)	2.0"-4.0"	2.0"-6.0"	2.0'(+)
WIDTH (m)	2-3'	4-8'	4-10'
REACH LENGTH (m)	4-8'	8'-15'(+)	4-8'

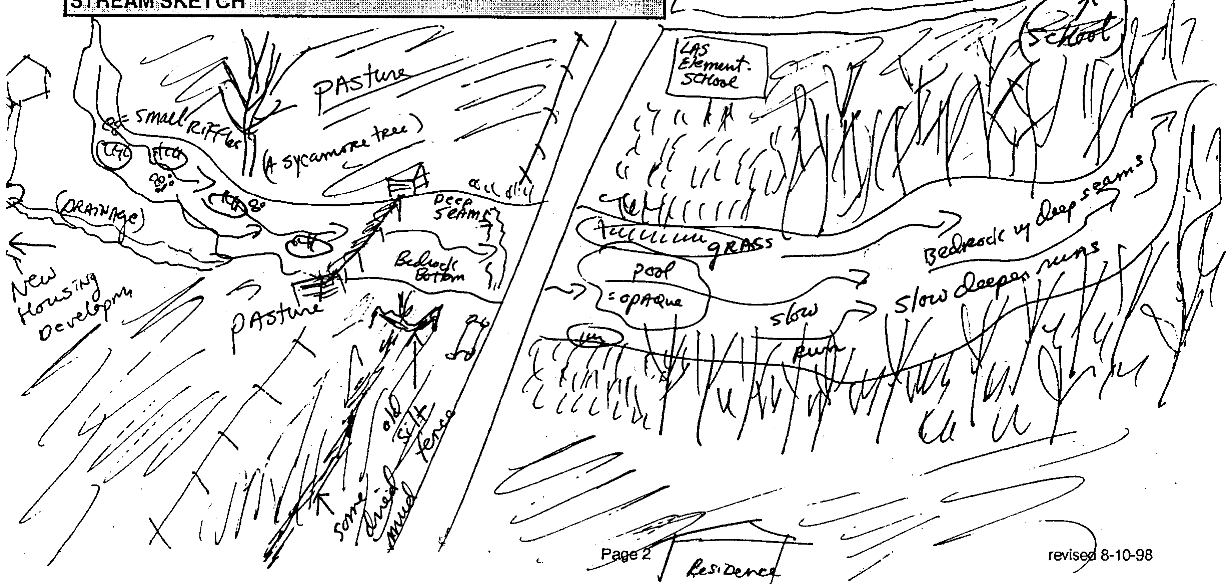
Staff Gauge/Bench Ht: ________
VELOCITY (FS) ________
FLOW (CFS) ________
HABITAT ASSESSMENT SCORE #:
RR # ________ GP # ________

Gradient (sample reach): Flat   (Low)   Moderate   High   Cascade

Size (stream width) : 5-15'   V. Small (<1.5m)   (Small (1.5-3m)) / (Med (3-10m))   Large (10-25m)   Very Lrg (>25m)

HABITAT QUALITY COMMENTS: (bank erosion, riparian, pool/riffle variety, etc) high sediment w/ no riparian u/s as small stream winds through pasture + Housing dev. starting..

STREAM SKETCH



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

STREAM NAME JAeman Crk(A)	LOCATION Hwy 96
STATION #____ RIVERMILE____	STREAM CLASS
LAT ____ LONG ____	RIVER BASIN ST WS
STORET # TN029	AGENCY WPC
INVESTIGATORS AMG	
FORM COMPLETED BY AMG	DATE 08/04/02 TH TIME 6:15 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 8	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 11	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 5	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 19	20 (19) 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

(54)

Total= (see comments on SS Form) + Back

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 16	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 13	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 8 (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE 8 (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 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 (1) 0
SCORE 1 (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 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 (1) 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 (1) 0

(49)

Total Score 103

{assessment reflects High Flow period}

BIORECON FIELD SHEET

STATION NUMBER: JARMA 000.3 RU
STREAM NAME: Jarman = [BRADLEY(F)]
STREAM LOCATION: Hwy 96

ASSESSORS: A M Goodhue
DATE: TH 04/04/02 TIME 5:40-5:45 pm (collect) 5:45-6:10 pm pick
ECOREGION: 71i (FNB)
LOG #: N0204004

FIELD OBSERVATION OF MACROBENTHOS

Indicate estimated abundance (EA):
1 = rare (1-3 organisms) 3 = abundant (10-49 organisms)
2 = common (4-9 organisms) 4 = dominant (>50 organisms)

Time Interval [25+] [ ] [ ] [ ] [ ]
EPT [4] [ ] [ ] [ ] [ ]
Total Taxa [16] [ ] [ ] [ ] [ ]

Habitats Sampled:	Riffle	Macrophytes	Pool/Run Rock	Woody debris/snag	Leaf Packs	Sediment	Undercut Banks	Other
Percent habitat in reach								
# Jabs per habitat	2.0	2.0						

Taxa		EA/NO
Ephemeroptera		
Baetidae		
Heptageniidae		
Isonychia		
Caenidae	(NF.) ✓	✓ R/C
Ephemerellidae		
Leptophlebiidae	✓	✓ R
Trichoptera		
Hydropsychidae		
Philopotamidae		
Rhyacophilidae		
Leptoceridae	✓	✓ R
Plecoptera		
Leuctriform		
Perlidae		
Perlodidae	✓	✓ R

Taxa		EA/NO
Isopoda	✓	✓ VA/D
Amphipoda		
Decapoda - Cambaridae (N.C.)	✓	✓ R
Gastropoda PLANORBIDAE	✓	✓ R
Ancylidae		
Physidae	✓	✓ C
Pleuroceridae	✓	✓ 10+
Bivalvia-Corbicula	✓	✓
Sphaeridae		
Diptera		
Simuliidae		
Tabanidae		
Tipulidae		
Chironomidae - Red		
Non-Red	✓	✓
Tanypodinae		
Oligochaeta Lumbricul.	✓	✓
Corixidae	✓	✓
Hemiptera Belostomatidae	✓	✓

Taxa		EA/NO
Odonata		
Calopterygidae		
Argia		
Boyeria		
Coleoptera		
Elmidae		
Dytiscidae	✓	✓
Psephenidae		
Dryopidae		
Haliplidae	✓	✓
Lepidoptera		
Megaloptera - Sialidae		
Corydalidae		
OTHER		
Porifera (sponges)		
Hydracarina (mites)		
Platyhelminthes (flatworms)		
Hirudinea (leeches)		

TAXA RICHNESS 16
OF EPT 4
OF INTOLERANTS (1-3) 2

NOTES: - fish observed
Heavy sediment

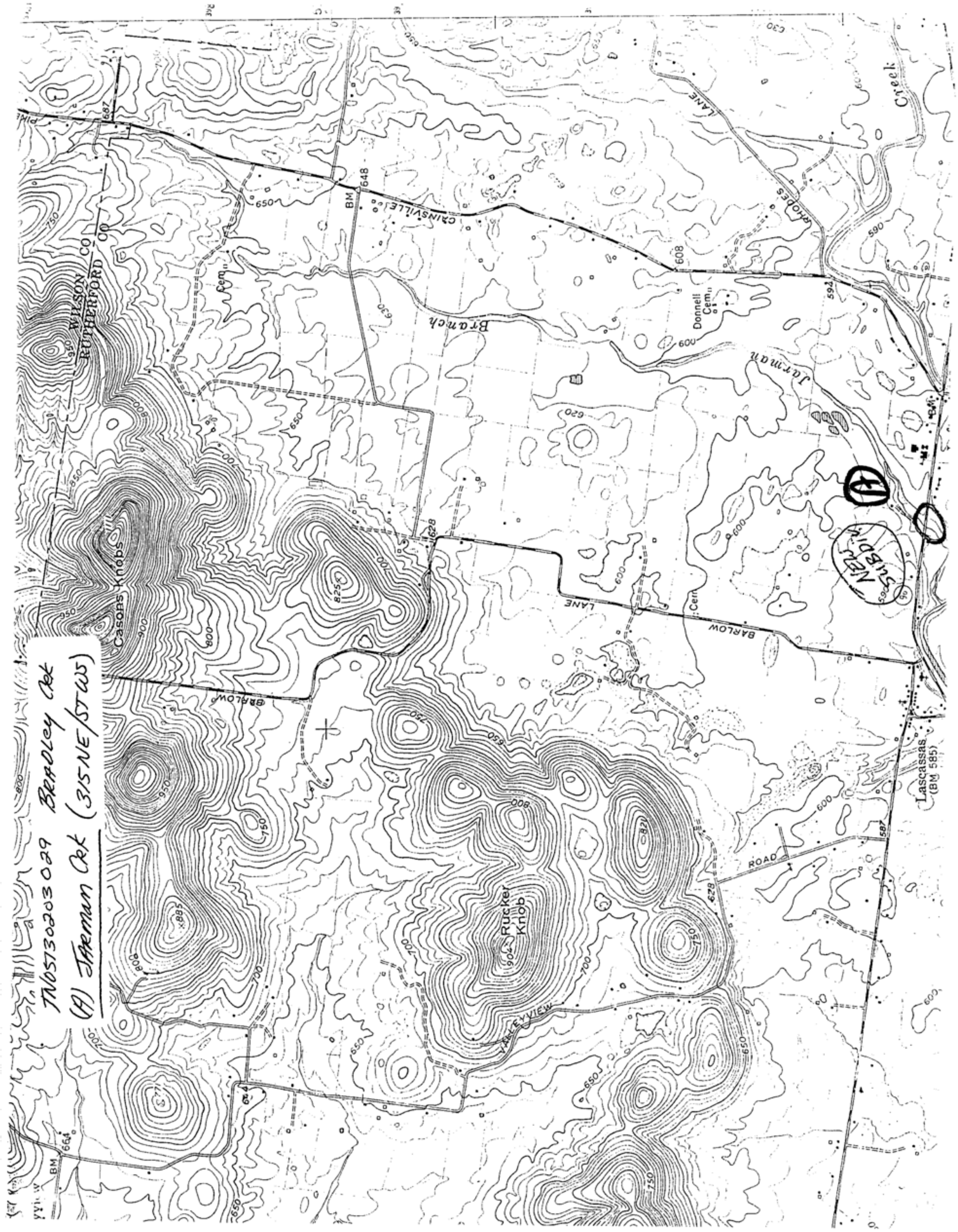

TN05130203029 Bradley Crk
(A) Jarman Crk (315NE/STWS)
WILSON CO
RUTHERFORD CO
Casons Knobs
Rucker Knob
Lascassas
(BM 585)
Jarman
Branch
Creek
Donnell Cem
BARLOW
LANE
ROAD
New Subdiv

Figure B-1 Jarman Branch at RM 0.3 – Upstream View

APPENDIX C

Land Use Distribution in Impaired Subwatersheds & Waterbody Drainage Areas

Table C-1 2001 MRLC Land Use Distribution of Impaired Subwatersheds & Drainage Areas

Land Use	Impaired Subwatershed (05130203____)							
	0106		0201		McCrory Creek DA		Hurricane Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00	0	0.00	0	0.00
Open Water	3	0.01	59	0.16	19	0.33	4	0.04
Developed Open Space	821	3.24	2,241	5.90	1,614	27.79	1,107	11.76
Low Intensity Development	158	0.62	835	2.20	1,054	18.15	1,933	20.52
Medium Intensity Development	11	0.04	197	0.52	357	6.15	982	10.43
High Intensity Development	0	0.00	2	0.01	181	3.12	659	7.00
Bare Rock	1	0.01	79	0.21	1	0.02	2	0.02
Deciduous Forest	4,369	17.23	7,974	20.98	1,141	19.65	1,996	21.20
Evergreen Forest	3,115	12.28	3,555	9.35	258	4.43	345	3.66
Mixed Forest	1,557	6.14	1,846	4.86	396	6.82	559	5.94
Shrub/Scrub	960	3.79	1,751	4.61	137	2.35	238	2.53
Grassland/Herbaceous	358	1.41	692	1.82	57	0.98	213	2.27
Pasture/Hay	12,066	47.58	15,755	41.45	540	9.30	1,313	13.94
Row Crops	1,904	7.51	2,933	7.72	38	0.66	54	0.58
Woody Wetlands	36	0.14	90	0.24	13	0.23	11	0.12
Emergent Herbaceous Wetland	0	0.00	1	0.00	0	0.00	0	0.00
Subtotal – Urban	990	3.90	3,275	8.62	3,207	55.22	4,681	49.71
Subtotal - Agriculture	13,970	55.09	18,688	49.17	578	9.96	1,367	14.52
Subtotal - Forest	10,398	41.00	15,988	42.06	2,003	34.49	3,365	35.73
Total	**25,360**	**100.00**	**38,010**	**100.00**	**5,808**	**100.00**	**9,417**	**100.00**

Table C-1 (Contd.) 2001 MRLC Land Use Distribution of Impaired Subwatersheds & Drainage Areas

Land Use	Impaired Subwatershed (05130203____)			
	Bear Branch DA		Unnamed Tributary to Lytle Creek DA	
	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00
Open Water	0	0.00	0	0.00
Developed Open Space	189	10.51	13	10.84
Low Intensity Development	588	32.63	28	23.93
Medium Intensity Development	128	7.11	41	34.77
High Intensity Development	6	0.33	33	28.04
Bare Rock	0	0.00	0	0.00
Deciduous Forest	49	2.72	2	1.50
Evergreen Forest	55	3.05	0	0.00
Mixed Forest	19	1.06	0	0.00
Shrub/Scrub	39	2.17	0	0.00
Grassland/Herbaceous	4	0.21	0	0.00
Pasture/Hay	629	34.93	0	0.00
Row Crops	95	5.28	0	0.00
Woody Wetlands	0	0.00	1	0.93
Emergent Herbaceous Wetland	0	0.00	0	0.00
Subtotal – Urban	912	50.59	116	97.57
Subtotal - Agriculture	725	40.21	0	0.00
Subtotal - Forest	166	9.21	3	2.43
Total	**1,802**	**100.00**	**119**	**100.00**

APPENDIX D

Water Quality Monitoring Data in Impaired Waterbodies

Table D-1 Water Quality Monitoring Data for Selected Stations in Stones River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen *	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
BEAR000.8RU	9/12/06	1215	6.22	<0.03	0.62	0.14	0.76	<0.01	22.68	0.75
	10/10/06	1125	9.18	<0.03	<0.15	0.43	0.51	0.02	17.57	1.33
	1/22/07	1050	14.32	<0.03	<0.15	1.1	1.18	<0.01	11.03	5.98
	3/6/07	1135	13.93	<0.03	<0.15	1.4	1.48	<0.007	13.51	3.95
JARMA000.3RU	7/31/02	1031				2.20		0.470		
	8/7/02	1030				0.61		0.053		78.71

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Stones River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen *	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
HURRI003.7RU	10/2/06	1315	11.35						20.28	150
HURRI004.2RU	7/31/02	0816				0.36		0.309		
	8/7/02	0835				0.12		0.148		
	10/9/06	1305	10.81						18.75	1.06
	10/11/06	1225	9.63						20.14	3.01
	10/18/06	1250	10.2						19.96	5.08
	10/23/06	1215	12.87						12.27	2.33
	10/25/06	1318	14.06						11.8	1.27
	10/31/06	1235	9.70						16.77	4.71
	1/8/07	1300	10.77						11.07	41.82
	1/10/07	1230	14.04	<0.03	<0.15	0.77	0.85		8.2	14.93
	1/17/07	0840	11.93	<0.03	<0.15	0.72	0.80		6.48	15.64
	1/23/07	1315	14.73	<0.03	<0.15	0.66	0.74		8.85	
	1/25/07	1250	15.14	<0.03	<0.15	0.20	0.28		8.16	11.64
	1/30/07	1155	16.51	<0.03	<0.15	0.41	0.49		5.16	5.83
	6/4/07	1305	10.12						27.14	
	6/5/07	1200	6.54						25.7	
	6/11/07	1305	8.54						23.25	
	6/12/07	1320	12.21						26.13	
	6/19/07	1215	5.61						24.2	
	6/25/07	1245	7.87						27.05	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Stones River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen *	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
LYTLE1T0.1RU	10/11/01	1220	6.76	0.09	0.37	0.42	0.79	0.050	18.89	
	11/28/01	1420	5.52	0.05	0.17	0.60	0.77	0.038	17.59	
	12/4/01	1245	7.65	0.03	<0.10	0.78	0.83	0.007	16.24	
	1/3/02	1340	7.04	<0.02	0.11	1.06	1.17	0.059	8.30	
	2/12/02	1215	7.93	<0.02	<0.10	1.34	1.39	0.03	13.58	
	3/19/02	1130	8.82	<0.02	<0.10	0.44	0.49	0.03	14.77	
	4/18/02	1405		<0.02	<0.10	1.10	1.15	<0.004		
	5/20/02	1235		<0.02	0.16	0.66	0.82	<0.004	18.68	
	6/25/02	1245	5.93	<0.02	0.96	0.57	1.53	<0.004	22.64	
	7/31/02	1121				0.36		0.075		
	9/6/06	1128		<0.03	1.0	0.55	1.55	<0.01	20.27	2.29
	9/11/06	1115		<0.1	<0.5	0.33	0.58	<0.01	21.02	2.36
	9/13/06	1045						<0.01	20.22	2.09
	9/21/06	1052	5.42	<0.03	<0.15	0.4	0.48	0.03	16.70	2.12
	9/25/06	1034	4.59	0.19	<0.15	0.18	0.26	0.04	18.41	5.82
	9/26/06	1145	5.16	<0.03	<0.15	0.57	0.65	0.03	17.75	4.06
	9/28/06	1105	**3.35**	<0.03	<0.15	0.57	0.65	0.04	18.92	3.87
	5/8/07	1130	8.52	<0.03	<0.15	0.52	0.6	0.04	19.42	
	5/9/07	1130	6.87	<0.03	<0.15	0.41	0.49	<0.02J	18.04	
	5/15/07	1130	7.01	<0.03	<0.15	0.40	0.48	<0.007	18.79	
	5/16/07	1239	5.68						18.52	
	5/23/07	1045	6.80						19.29	
	5/24/07	1126	7.75	<0.03	<0.15	0.28	0.36	<0.03	19.97	
	5/29/07	1052	6.72						19.44	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Stones River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen *	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
MCCRO001.5DA	10/24/01	1400	3.88	<0.02	<0.10	0.55	0.60	0.014	19.19	2.08
	11/15/01	1245	7.03	0.02	<0.10	0.39	0.44	0.078	10.30	0.64
	12/6/01	1220	9.73	<0.02	0.58	1.60	2.18	0.265	13.79	6.20
	1/24/02	1130	10.12	0.02	0.29	0.99	1.28	0.623	12.60	
	3/26/02	1120	10.47	0.03	<0.10	0.87	0.92	0.440	13.11	45
	4/23/02	1250	7.45	0.02	<0.10	0.83	0.88	0.080	15.55	3.95
	5/16/02	1236	9.65	<0.02	<0.10	1.14	1.19	0.140	16.78	11.56
	6/19/02	1150	7.88	<0.02	0.03	0.71	0.74	0.141	20.13	0.70
	10/1/06	1330	5.92						17.36	0.62
	10/12/06	1300	6.07						15.62	1.21
	10/17/06	1335	8.46						15.87	7.45
	10/19/06	1305	6.70						17.66	1.92
	10/26/06	1320	7.56						11.62	1.42
	10/30/06	1320	8.68						14.53	
	11/2/06	1320	8.95						12.14	3.60
	5/10/07	1320	8.43						19.79	
	5/15/07	1300	7.90						19.72	
	5/22/07	1230	7.95						17.81	
	5/29/07	1325	6.41						21.17	
	5/31/07	1320	6.37						20.97	

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Stones River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen *	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
WFSTO032.1RU	6/27/05	1100		0.03	<0.1	0.12	0.17	<0.004		
	7/6/05	1020		0.01	0.43	0.02	0.45	0.02		
WFSTO032.3RU (Former ECO71I09)	5/1/96	0900	10.6	<0.02	0.22	0.26	0.48	0.02	13.00	
	9/3/96	0940	4.75	0.05	0.23	0.30	0.53	0.053	20.44	
	9/4/96	0900	5.04	<0.02	<0.1	0.35	0.40	0.032	20.35	
	9/5/96		3.8	0.03	0.17	0.32	0.49	0.032	20.52	
	11/25/96	1015	9.26	<0.02	<0.1	0.88	0.93	0.015	13.36	
	11/26/96	1010	9.5	<0.02	<0.1	0.50	0.55	0.055	10.95	30.13
	11/27/96	1400	10.96	<0.02	<0.1	0.78	0.83	0.029	10.12	
	2/6/97	1245	11.81	<0.02	<0.1	0.58	0.63	0.024	10.11	26.06
	4/23/97	1300	10.3	<0.02	0.38	0.25	0.63	<0.004	14.99	60.89
	10/1/97	1130	9.09	<0.02	<0.1	1.41	1.46	0.023	17.98	1.21
	11/13/97	1000	10.13	<0.02	<0.1	0.98	1.03	<0.004	8.53	2.88
	2/25/98	1330	12.16	<0.02	<0.1	0.64	0.69	<0.004	13.13	
	4/27/98	1300	11.65	<0.02	<0.1	0.37	0.42	<0.004	15.39	10.36
	9/1/98	1000	9.09	<0.02	<0.1	0.39	0.44	0.02	21.78	0.97
	12/2/98	1145	9.16	<0.02	<0.1	0.017	0.067	0.06	11.26	1.20
	2/16/99	1200		<0.02	<0.1	0.75	0.80	0.01	12.00	14.60
	6/3/99	1000	4.78	0.07	0.37	0.34	0.71	0.02	21.64	0.29
	1/11/00	0845	8.78	<0.02	<0.1	2.76	2.81	<0.004	9.77	12.86
	4/19/00	1100	12.2	<0.02	0.11	0.81	0.92	0.009	14.30	15.55

Table D-1 (Contd.) Water Quality Monitoring Data for Selected Stations in Stones River Watershed

Monitoring Station	Date	Time	DO	NH3 (as N)	TKN	NO2-NO3	Total Nitrogen *	Total Phosphorus	Temp	Flow
			[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[°C]	[cfs]
WFSTO032.3RU (Former ECO71I09)	7/25/00	1030	2.9	0.02	1.22	0.03	1.25	0.302	21.4	
	10/17/00	1145	2.53	<0.02	0.89	0.14	1.03	0.174	14.79	
	6/11/01	1040	7.87	<0.02	0.21	0.88	1.09	0.04	18.65	2.2
	10/11/01	1000	6.27	<0.02	<0.1	0.47	0.52	0.036	16.16	0.98
	11/28/01	1055	7.28	<0.02	0.18	0.56	0.74	0.014	15.10	5.34
	12/4/01	0950	10.09	<0.02	<0.1	1.25	1.30	0.026	12.35	9.55
	1/3/02	1030	12.51	<0.02	0.14	0.99	1.13	0.033	4.96	2.88
	2/12/02	0925	10.38	0.13	<0.1	0.67	0.72	0.03	8.04	15.75
	3/19/02	0925	9.91	<0.02	<0.1	0.61	0.66	0.04	13.5	83.99
	4/18/02	1010	9.75	<0.02	<0.1	0.41	0.46	<0.004	18.70	5.46
	5/20/02	1010		<0.02						
	6/25/02	0945	6.23	0.07	1.19	0.15	1.34	0.023	23.08	2.12
	6/14/05	1330		0.09	0.34	0.35	0.69	0.02		
	6/23/05	1005		<0.02	0.49	<0.01	0.50	0.03		

* For all stations, total nitrogen data corresponds to sum of NO3+NO2 plus TKN for each sample data.

APPENDIX E

Development of Nutrient & $CBOD_5$ TMDLs, WLAs, & LAs – Annual Loading

DEVELOPMENT OF STAGE I NUTRIENT & $CBOD_5$ TMDLS

Nutrient and $CBOD_5$ target concentrations for Level IV ecoregions 71g, 71h, & 71i were used to develop Stage I nutrient TMDLs for the Stones River watershed using the procedure outlined below.

E.1 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	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
	ECO71I16	West Fork Stones River	Stones	05130203

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 April 30, 2005.

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.

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 target concentration (ref. Section 5.2) was applied to each daily flow at each ecoregion reference site to generate daily total nitrogen loads.

5. The average annual total nitrogen loads for each ecoregion reference site were calculated by summing the daily loads for the 10-year period and dividing by 10.

6. The average annual total nitrogen loads, on a unit area basis, were calculated for each ecoregion reference site by dividing the average annual loads (Step 5) by the corresponding reference site drainage areas. Average annual total nitrogen loads per unit area are shown in Table E-2 for each ecoregion reference site.

7. The average annual total nitrogen load per unit area for Level IV ecoregion 71g was determined by calculating the geometric mean of annual total nitrogen loads per unit area (Step 6) of the three ecoregion 71g reference sites. The target average annual total nitrogen loads per unit area for Level IV ecoregions 71h (3 sites) & 71i (5 sites) were determined in a similar manner.

8. Steps 4 through 7 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 Annual Nutrient & $CBOD_5$ Loads for Ecoregion Reference Sites

Ecoregion Reference Site	Total Nitrogen	Total Phosphorus	$CBOD_5$
	[lbs/ac/yr]	[lbs/ac/yr]	[lbs/ac/yr]
ECO71G03	2.6564	0.0770	5.7749
ECO71G04	3.2069	0.0930	6.9715
ECO71G10	3.3567	0.0973	7.2972
ECO71H03	6.1941	0.5105	12.7625
ECO71H06	3.6276	0.2990	7.4745
ECO71H09	3.7022	0.3051	7.6281
ECO71I10	4.5860	0.9719	9.1113
ECO71I12	4.6096	0.9769	9.1582
ECO71I14	5.3153	1.1264	10.5601
ECO71I15	4.3824	0.9287	8.7067
ECO71I16	3.5439	0.7510	7.0408

Table E-3 Target Nutrient & $CBOD_5$ Loads for Level IV Ecoregions 71g, 71h, & 71i

Level IV Ecoregion	Total Nitrogen	Total Phosphorus	$CBOD_5$
	[lbs/ac/yr]	[lbs/ac/yr]	[lbs/ac/yr]
71g	3.0580	0.0886	6.6477
71h	4.3653	0.3598	8.9945
71i	4.4500	0.9431	8.8411

E.2 Development of Nutrient TMDLs

Note: The following procedure describes development of the annual loading portion of nutrient and $CBOD_5$ TMDLs. Calculations for Subwatershed 051302030201 (West Fork Stones River) are shown. The process for other subwatersheds and drainage areas is similar.

9. Since Subwatershed 051302030201 is approximately 4% in ecoregion 71h and 96% in ecoregion 71i, target nutrient loads for the subwatershed as a whole were based on an area-weighted combination of the ecoregion target loads:

$$TMDL_{0201} = (TL_{71h})\ (A_{71h}) + (TL_{71i})\ (A_{71i})$$

where: $TMDL_{0201}$ = TMDL for Subwatershed 0201 [lbs/yr]
TL_{71h} = Target load for ecoregion 71h [lbs/acre/yr]
A_{71h} = Area of Subwatershed 0106 in ecoregion 71h [acres]
TL_{71i} = Target load for ecoregion 71i [lbs/acre/yr]
A_{71i} = Area of Subwatershed 0106 in ecoregion 71i [acres]

As an example, for total nitrogen:

$$TMDL_{0201} = (4.3653\ \text{lbs/ac/yr})\ (1{,}626\ \text{ac}) + (4.4500\ \text{lbs/ac/yr})\ (36{,}384\ \text{ac})$$

$$TMDL_{0201} = 169{,}007\ \text{lbs/yr}$$

For total phosphorus:

$$TMDL_{0201} = (0.3598\ \text{lbs/ac/yr})\ (1{,}626\ \text{ac}) + (0.9431\ \text{lbs/ac/yr})\ (36{,}384\ \text{ac})$$

$$TMDL_{0201} = 34{,}899\ \text{lbs/yr}$$

For $CBOD_5$:

$$TMDL_{0201} = (8.9945\ \text{lbs/ac/yr})\ (1{,}626\ \text{ac}) + (8.8411\ \text{lbs/ac/yr})\ (36{,}384\ \text{ac})$$

$$TMDL_{0201} = 336{,}300\ \text{lbs/yr}$$

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

The annual loading portion of TMDLs for impaired HUC-12 subwatersheds and waterbody drainage areas are summarized in Table E-4. $CBOD_5$ TMDLs were only developed for subwatersheds with low dissolved oxygen specifically identified as a cause of impairment and/or subwatersheds containing impaired waterbodies with measured diurnal dissolved oxygen concentrations that drop below 5 mg/l.

E.3 Development of Waste Load Allocations (WLAs) & Load Allocations (LAs)

Note: The following procedure describes development of the annual loading portion of nutrient and $CBOD_5$ 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 Stages II & III and are not included in this document.

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:

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

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

Expanding the terms:

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

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

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

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

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/yr]
LA_{NPS} = LA for nonpoint sources on a unit area basis [lbs/ac/yr]
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:

$$\Sigma[(WLA_{MS4})\ (A_{MS4})] + \Sigma[(LA_{NPS})\ (A_{NPS})] = (LA_{NPS})\ [(\Sigma\ A_{MS4}) + (\Sigma\ A_{NPS})]$$

$$= (LA_{NPS})\ (A_{subw})$$

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 0201 is shown as an example. Calculations for total phosphorus & $CBOD_5$ are similar.

<u>Total Nitrogen in Subwatershed 0201</u>

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

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 E-4 & C-1 and noting that WLA_{CAFO} = 0:

$$LA_{NPS} = \frac{[(0.95)\ (169{,}007\ \text{lbs/yr})] - (0)}{(38{,}010\ \text{ac})}$$

therefore:

$$LA_{NPS} = WLA_{MS4} = 4.2241\ \text{lbs/ac/yr}$$

The annual loading portion of stage I nutrient WLAs for MS4s & CAFOs, and LAs for nonpoint sources are summarized in Table E-4 for total nitrogen, Table E-5 for total phosphorus, and Table E-6 for $CBOD_5$. WLAs for MS4s apply only to MS4 discharges into impaired subwatersheds and drainage areas. WLAs for CAFOs apply to existing and future entities.

Table E-4 Summary of Stage I Total Nitrogen TMDLs, WLAs, & LAs - Annual Loading

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL	WLA		LA
				MS4s [a]	CAFOs [b]	
			[lbs/yr]	[lbs/ac/yr]	[lbs/yr]	[lbs/ac/yr]
0106	Jarman Branch	TN05130203029-0100	112,695	4.2206	0	4.2206
	Unnamed Tributary to Bradley Creek	TN05130203029-0200				
	Unnamed Tributary to Bradley Creek	TN05130203029-0300				
0201	West Fork Stones River	TN05130203018-7000	169,007	4.2241	0	4.2241
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	25,354	4.1470	0	4.1470
		TN05130203001-0150				
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	41,786	4.2110	0	4.2110
	Hurricane Creek	TN05130203036-1000				
Bear Branch DA	Bear Branch	TN05130203023-0310	8,019	4.2275	0	4.2275
Unnamed Trib. to Lytle Ck. DA [c]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	534	4.2275	0	4.2275

Notes:
a. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
b. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
c. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Table E-5 Summary of Stage I Total Phosphorus TMDLs, WLAs, & LAs - Annual Loading

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL	WLA		LA
				MS4s [a]	CAFOs [b]	
			[lbs/yr]	[lbs/ac/yr]	[lbs/yr]	[lbs/ac/yr]
0106	Jarman Branch	TN05130203029-0100	22,655	0.8485	0	0.8485
	Unnamed Tributary to Bradley Creek	TN05130203029-0200				
	Unnamed Tributary to Bradley Creek	TN05130203029-0300				
0201	West Fork Stones River	TN05130203018-7000	34,899	0.8722	0	0.8722
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	2,090	0.3418	0	0.3418
		TN05130203001-0150				
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	7,760	0.7820	0	0.7820
	Hurricane Creek	TN05130203036-1000				
Bear Branch DA	Bear Branch	TN05130203023-0310	1,699	0.8959	0	0.8959
Unnamed Trib. to Lytle Ck. DA [c]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	113	0.8959	0	0.8959

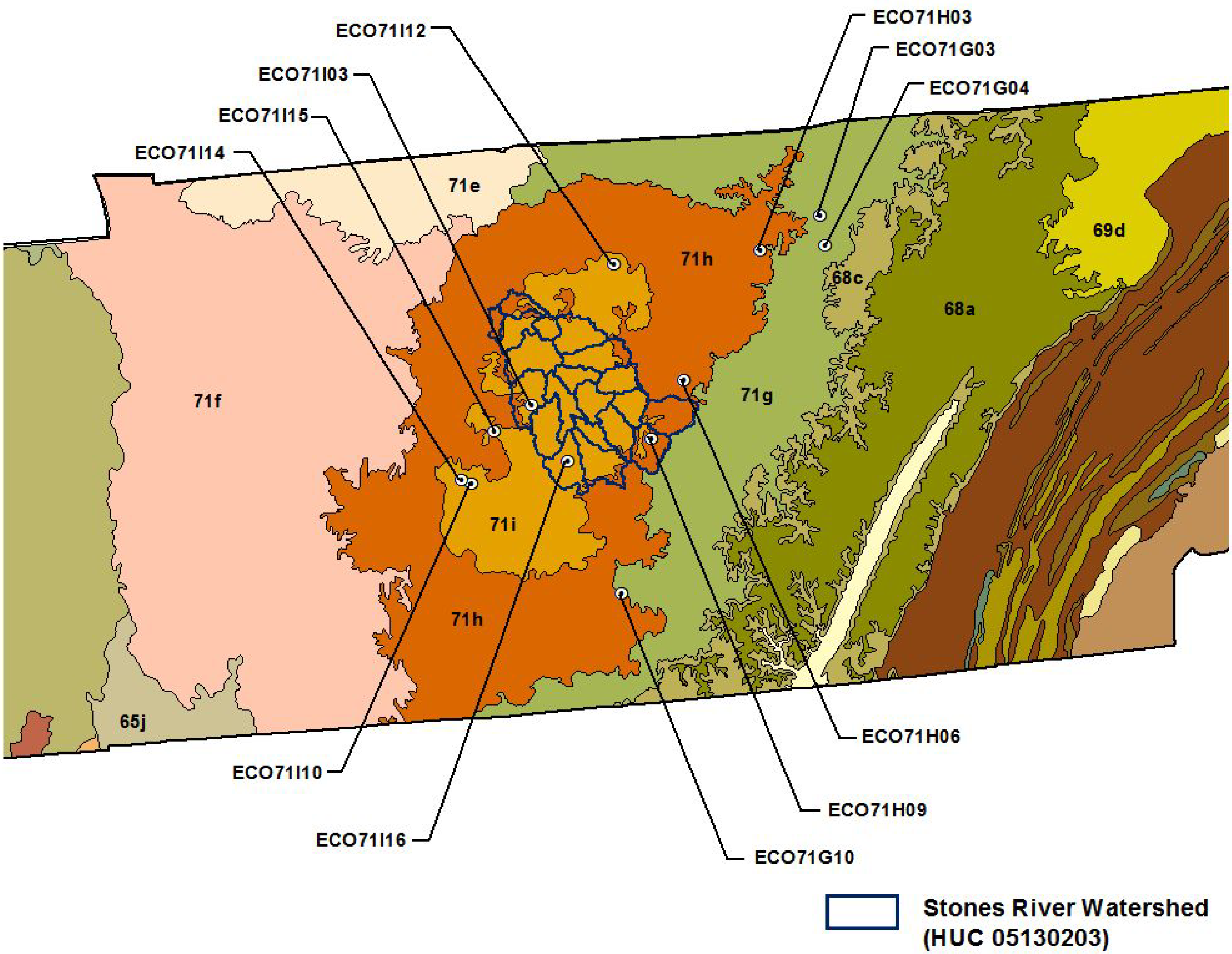
Notes:
a. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
b. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
c. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

Table E-6 Summary of Stage I $CBOD_5$ TMDLs, WLAs, & LAs - Annual Loading

HUC-12 Subwatershed (05130203__) or Drainage Area	Impaired Waterbody	Waterbody ID	TMDL	WLA		LA
				MS4s [a]	CAFOs [b]	
			[lbs/yr]	[lbs/ac/yr]	[lbs/yr]	[lbs/ac/yr]
0106	Jarman Branch	TN05130203029-0100	224,597	8.4115	0	8.4115
	Unnamed Tributary to Bradley Creek	TN05130203029-0200				
	Unnamed Tributary to Bradley Creek	TN05130203029-0300				
0201	West Fork Stones River	TN05130203018-7000	336,300	8.4053	0	8.4053
McCrory Ck. DA	McCrory Creek	TN05130203001-0100	NA [c]	NA [c]	0	NA [c]
		TN05130203001-0150				
Hurricane Ck. DA	W. Branch Hurricane Ck.	TN05130203036-0200	83,642	8.4290	0	8.4290
	Hurricane Creek	TN05130203036-1000				
Bear Branch DA	Bear Branch	TN05130203023-0310	NA [c]	NA [c]	0	NA [c]
Unnamed Trib. to Lytle Ck. DA [d]	Unnamed Tributary to Lytle Creek	TN05130203022-0100	1,061	8.3990	0	8.3990

Notes:
a. WLA applies to permitted discharges in the subwatershed or drainage area indicated.
b. WLAs for CAFOs are applicable to existing and future permittees in subwatersheds indicated.
c. NA = Not applicable (low dissolved oxygen not listed as a cause for waterbody impairment or no low diurnal dissolved oxygen measurements).
d. Drainage area for Unnamed Tributary to Lytle Creek estimated at 120 acres.

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



APPENDIX F

Development of Daily Expression of Annual Loads

One of the options discussed in *Options for Expressing Daily Loads in TMDLs* (USEPA 2007) is the use of statistical analysis to identify a daily maximum load. The statistical approach selected to derive daily load expressions for Stage I TMDLs, WLAs, & LAs in the Stones River watershed was based on a procedure described in the *Technical Support Document for Water Quality-based Toxics Control* (TSD)(USEPA 1991a). Using the methodologies described in Appendix E of the TSD document, allowable daily maximum concentrations for total nitrogen (TN) and total phosphorus (TP) were calculated from monitoring data collected at Level IV ecorgion reference sites (71 h & 71i). The 99.7th percentile daily maximum value was selected as the appropriate expression of the annual average loads developed in Appendix E of this (TMDL) document. The two referenced documents should be consulted for a more detailed description of these procedures.

F.1 Daily Maximum Concentrations for Total Nitrogen Based on the Lognormal Distribution

Analysis to determine daily maximum concentration for total nitrogen was based on the premise that ambient water quality data are often lognormally distributed. The logarithmic transformation of a random variable X, Y = ln(X) results in a random variable Y that is normally distributed. Since total nitrogen was not directly measured at ecoregion reference sites, TN concentrations were computed as the sum of nitrite+ nitrate (NO_2+NO_3) and total Kjeldahl nitrogen (TKN) concentrations. Only values based on <u>detected</u> NO_2+NO_3 and TKN measurements were used for daily maximum concentration calculations.

The following equations are excerpted from Table E-1 of the Technical Support Document (TSD) with all measurements greater than the detection limit (based on the lognormal distribution):

$X_{99.7}$ = 99.7th percentile daily maximum concentration
= $\exp[\mu_y + 2.778\ \sigma_y]$

where:

x_i = daily pollutant measurement i

y_i = $\ln(x_i)$

k = sample size of data set

μ_y = $\Sigma(y_i) / k \qquad 1 \le I \le k$

σ_y^2 = $\Sigma[(y_i - \mu_y)^2] / (k - 1) \qquad 1 \le I \le k$

E(x) = $\exp(\mu_y + 0.5\sigma_y^2)$

V(x) = $\exp(2\mu_y + \sigma_y^2)\ [\exp(\sigma_y^2) - 1]$

cv(x) = $[\exp(\sigma_y^2) - 1]^{½}$

Total nitrogen data and calculated daily maximum concentrations for reference sites in Level IV ecoregions 71h & 71i are shown in Tables F-1 & F-2.

F.2 Daily Maximum Concentrations for Total Phosphorus Based on the Delta-Lognormal Distribution

Since total phosphorus (TP) was measured directly at ecoregion reference sites, with a number of values reported as below a detection level, calculation of daily maximum concentrations based on the delta-lognormal distribution was considered appropriate. The Technical Support Document (TSD) describes the delta-lognormal distribution as follows:

> The delta-lognormal distribution is a generalization of the lognormal distribution. The delta-lognormal distribution may be used when the data contain a mixture of nondetect values and values above the detection limit and can be used to model nondetects in water quality-based limits. In delta-lognormal procedures, nondetect values are weighted in proportion to their occurrence in the data. The values above the detection limit are assumed to be lognormally distributed values.

The following equations are excerpted from Table E-1 of the TSD with some measurements less than the detection limit (based on the delta-lognormal distribution):

$X_{99.7}$ = 99.7th percentile daily maximum concentration

= D $\qquad \delta \geq 0.997$

= $\exp[\mu_y + 2.778\ \sigma_y]$ $\qquad \delta < 0.997$

with $Z^* = \Phi^{-1}\ [(0.997 - \delta) / (1 - \delta)]$ $\qquad$ (Φ^{-1} is the mathematical notation for Z scores)

where:

x_i	=	daily pollutant measurement i
k	=	sample size of data set
D	=	detection limit
r	=	number of nondetects
k - r	=	number of detects
y_i	=	$\ln(x_i)$
δ	=	r / k
μ_y	=	$\Sigma(y_i) / (k - r)$ $\quad r+1 \leq i \leq k$ (excludes values $\leq$ D from sum)
σ_y^2	=	$\Sigma[(y_i - \mu_y)^2] / (k - r - 1)$ $\quad r+1 \leq i \leq k$
E(x)	=	$\delta D + (1 - \delta) \exp(\mu_y + 0.5\sigma_y^2)$
V(x)	=	$(1 - \delta)\exp(2\mu_y + \sigma_y^2)\ [\exp(\sigma_y^2) - (1 - \delta)] + \delta\ (1 - \delta)\ D\ [D - 2\exp(2\mu_y + \sigma_y^2)]$

Total phosphorus data and calculated daily maximum concentrations for reference sites in Level IV ecoregions 71h & 71i are shown in Tables F-3 & F-4.

F.3 Daily Maximum Concentrations for $CBOD_5$

Since $CBOD_5$ data was not routinely collected at ecoregion reference sites, an instream $CBOD_5$ concentration of 7.5 mg/l was selected as an appropriate daily maximum concentration. This value is based on five times the $CBOD_5$ target concentration specified in Section 5.2.

F.4 Determination of Daily Expression of Annual Average Loads

Daily expression of annual average loads for impaired subwatersheds and drainage areas were determined according to the following procedure:

1. Area-weighted daily maximum concentrations were calculated for each impaired subwatershed based on the amount of subwatershed area within each Level IV ecoregion.

$$DMC_{subw} = \frac{(DMC_{71h})\ (A_{71h}) + (DMC_{71i})\ (A_{71i})}{A_{subw}}$$

where:
DMC_{subw} = Daily maximum concentration for the subwatershed [mg/l]
DMC_{71h} = Daily maximum concentration for Level IV ecoregion 71h [mg/l]
DMC_{71i} = Daily maximum concentration for Level IV ecoregion 71i [mg/l]
A_{71h} = Subwatershed area in 71h [acres]
A_{71i} = Subwatershed area in 71i [acres]
A_{subw} = Total subwatershed area [acres]

2. Daily maximum loads were calculated for the impaired subwatershed:

$$DML_{subw} = (DMC_{subw} \times UCF) \times Q$$

where:
DML_{subw} = Daily maximum load for the subwatershed [lbs/day]
UCF = Unit conversion factor
Q = Stream flow at the subwatershed pour point [cfs]

Daily maximum loads for subwatersheds and drainage areas are expressed as a function of stream flow (Q)

3. As noted in Appendix E, Section E.3, WLAs for MS4s are considered to be equal to LAs for nonpoint sources on a per unit area basis. Likewise, the daily expressions of the annual average loads on a per unit area for these allocations are also considered to be equal.

$$DML_{MS4} = DML_{NPS} = \frac{DML_{subw}}{A_{subw}} \times Q$$

Total nitrogen (TN) calculations for Subwatershed 051302030201 (West Fork Stones River) are shown as an example. The procedure for TP and $CBOD_5$ in other impaired subwatersheds and drainage areas is similar.

Total Nitrogen in Subwatershed 0201

Step 1:

$$DMC_{subw} = \frac{(2.3043 \text{ mg/l})\ (1{,}626 \text{ ac}) + (4.1584 \text{ mg/l})\ (36{,}384 \text{ ac})}{(38{,}010 \text{ ac})} = 4.079 \text{ mg/l}$$

Step 2:

$$DML_{subw} = [(4.079 \text{ mg/l}) \times (5.3944 \text{ lb-L-sec/mg-cu.ft.-day}) \times Q$$

$$DML_{subw} = (2.200 \times 10^{3} \text{ lb-sec/cu.ft.-day}) \times Q \quad [\text{lbs/day}]$$

Step 3:

$$DML_{MS4} = DML_{NPS} = \frac{(2.200 \times 10^{1} \text{ lb-sec/cu.ft.-day})}{(38{,}010 \text{ ac})} \times Q$$

$$DML_{MS4} = DML_{NPS} = (5.789 \times 10^{-4}) \times Q \quad [\text{lbs/ac/day}]$$

Daily expression of TN, TP, & $CBOD_5$ annual average loads for impaired subwatersheds and drainage areas are summarized in Table F-5

Table F-1 Ecoregion 71h Total Nitrogen Monitoring Data & Statistics

Station ID	Date	TN [mg/l]	LN(TN)
ECO71H03	8/20/97	0.84	-0.1744
	11/10/97	0.49	-0.7133
	2/16/05	0.88	-0.1278
	3/16/05	0.88	-0.1273
	4/14/05	0.59	-0.5276
ECO71H06	5/12/97	0.37	-0.9943
	4/13/98	0.88	-0.1278
	11/16/98	1.82	0.5988
	11/19/02	0.32	-1.1394
	3/17/03	0.43	-0.8440
	4/7/03	0.52	-0.6539
ECO71H09	4/13/98	0.58	-0.5447
	11/16/98	0.71	-0.3425
	10/30/01	0.81	-0.2107
	10/17/06	0.98	-0.0202
k (number of data points)		15	
Minimum reported value [mg/l]		0.32	
Maximum reported value [mg/l]		1.82	
μ(y) (average of data set)			-0.3966
s(y) (std deviation of data set)			0.4433
t(y) (variance of data set)			0.1965
E(X*) (daily average)			0.7420
V(X*) (variance)			0.1195
Daily Maximum Limits (99.7th %tile)		**2.3043**	

Table F-2 Ecoregion 71i Total Nitrogen Monitoring Data & Statistics

Station ID	Date	TN [mg/l]	LN(TN)
ECO71I10	5/20/96	0.58	-0.5447
	9/5/96	0.371 [b]	-0.9925
	2/10/97	0.64	-0.4463
	4/28/97	0.185 [a]	-01.6878
	10/9/97	0.254 [a]	-1.3713
	12/2/98	0.447	-0.8052
	6/8/99	0.63	-0.4620
	11/9/99	0.49	-0.7133
	1/25/00	3.55	1.2669
	4/6/00	0.60	-0.5108
	4/12/00	0.56	-0.5798
	7/12/00	1.14	0.1310
	8/20/03	0.29	-1.2379
	9/16/03	0.29	-1.2379
ECO71I12	4/19/00	0.69	-0.3711
	7/19/00	0.62	-0.4780
	5/7/01	0.69	-0.3711
	8/25/04	1.52	0.4187
	9/8/04	1.04	0.0392
	9/20/04	1.891	0.6371
	9/28/04	1.779	0.5761
	10/5/04	1.171	0.1579
	11/15/04	0.881	-0.1267
	1/13/05	1.010	0.0100
	3/30/05	0.554 [a]	-0.5901
	4/6/05	0.810	-0.2107
	6/22/05	0.68	-0.3857
ECO71I14	7/11/00	0.484 [a]	-0.7249
	5/9/01	0.29	-1.2379
	9/12/01	0.19	-1.6607
	10/28/02	0.62	-0.4780
	8/20/03	0.31	-1.1712
	9/16/03	0.76	-0.2744
ECO71I115	5/3/00	0.70	-0.3567
	7/13/00	0.72	-0.3285
	10/31/00	1.21	0.1906
	5/9/01	0.68	-0.3857
	12/12/01	1.24	0.2151
	1/29/02	1.09	0.0862
	6/11/02	1.08	0.0770
	8/3/06	0.84	-0.1744
	9/19/06	0.63	-0.4620
	5/7/07	1.40	0.3365
	6/26/07	0.91	-0.0943

Table F-2 (Contd.) Ecoregion 71i Total Nitrogen Monitoring Data & Statistics

ECO71I16	9/9/04	0.83	-0.1863
	9/22/04	1.27	0.2390
	1/22/07	1.50	0.4055
	2/15/07	2.010	0.6981
	6/26/07	0.241	-1.4231
k (number of data points)		49	
Minimum reported value [mg/l]		0.185	
Maximum reported value [mg/l]		3.55	
μ(y) (average of data set)			-0.3387
s(y) (std deviation of data set)			0.6349
t(y) (variance of data set)			0.4031
E(X*) (daily average)			0.8719
V(X*) (variance)			0.3374
Daily Maximum Limits (99.7th %tile)		**4.1584**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.
b. Value shown is geometric mean of measurements collected on three consecutive days.

Table F-3 Ecoregion 71h Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO71H03	4/29/96	0.34	-1.0788
	8/29/96	0.022 [b]	-38259
	11/27/96	0.049 [c]	-3.0184
	2/3/97	0.035	-3.3524
	5/6/97	0.004U	
	8/20/97	0.04	-3.2189
	11/10/97	0.03	-3.5066
	2/3/98	0.004U	
	5/4/98	0.03	-3.5066
	9/17/98	0.013 [a]	-4.3702
	11/18/98	0.020 [a]	-3.9120
	6/2/99	0.014 [a]	-4.2586
	9/5/00	0.02	-3.9120
	10/16/00	0.167	-1.7898
	1/30/01	0.03	-3.5066
	12/15/04	0.017	-4.0745
	1/12/05	0.06	-2.8134
	2/16/05	0.01	-4.6052
	3/16/05	0.004U	
	4/14/05	0.03	-3.5066
	5/24/05	0.03	-3.5066
	7/14/05	0.02U	
ECO71H06 [d]	4/22/96	0.031	-3.4738
	8/21/96	0.033 [b]	-3.4031
	11/14/96	0.031 [b]	-3.4632
	2/4/97	0.037	-3.2968
	5/12/97	0.004U	
	8/20/97	0.004U	
	12/8/97	0.02	-3.9120
	2/12/98	0.022	-3.8167
	4/13/98	0.004U	
	8/31/98	0.004U	
	2/9/99	0.02	-3.9120
	6/11/99	0.01	-4.6052
	8/5/02	0.019 [a]	-3.9510
	9/25/02	0.008 [a]	-4.8606
	10/8/02	0.052 [a]	-2.9573
	11/19/02	0.003 [a]	-5.7565
	1/27/03	0.004U [a]	
	2/11/03	0.005	-5.2983
	3/17/03	0.060 [a]	-2.8134
	4/7/03	0.024 [a]	-3.7093
	5/8/03	0.039 [a]	-3.2511
	6/12/03	0.006 [a]	-5.0633
	9/9/04	0.026	-3.6497
	9/16/04	0.024	-3.7297
	9/23/04	0.036	-3.3242
	7/31/07	0.010 [a]	-4.6052
	8/15/07	0.006 [a]	-5.0673
	9/4/07	0.029 [a]	-3.5458
	10/24/07	0.010 [a]	-4.6052
	11/6/07	0.011 [a]	-4.4700

Table F-3 (Contd.) Ecoregion 71h Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO71H09	5/1/96	0.035 [a]	-3.3627
	8/21/96	0.107 [b]	-2.2368
	11/14/96	0.086 [b]	-2.4506
	2/4/97	0.04	-3.2189
	4/30/97	0.004U	
	8/19/97	0.059	-2.8302
	12/8/97	0.007	-4.9618
	2/12/98	0.056	-2.8824
	4/13/98	0.038	-3.2702
	8/31/98	0.04	-3.2189
	11/16/98	0.21	-1.5606
	2/9/99	0.09	-2.4079
	6/11/99	0.04	-3.2189
	10/30/01	0.060	-2.8134
	11/6/01	0.034	-3.3814
	12/3/01	0.058	-2.8473
	1/10/02	0.083	-2.4889
	2/14/02	0.06	-2.8134
	3/12/02	0.06	-2.8134
	4/22/02	0.004U	
	5/29/02	0.004U	
	6/12/02	0.06	-2.8134
	7/24/06	0.094 [a]	-2.3665
	8/21/06	0.049 [a]	-3.0161
	9/13/06	0.030 [a]	-3.5066
	10/17/06	0.141 [a]	-1.9610
	11/28/06	0.045 [a]	-3.1073
	12/2/06	0.045 [a]	-3.1073
	1/10/07	0.090 [a]	-2.4079
	2/6/07	0.065 [a]	-2.7363
	3/8/07	0.040 [a]	-3.2189
	4/11/07	0.116 [a]	-2.1525
	5/22/07	0.059 [a]	-2.8275
	6/12/07	0.095 [a]	-2.3553
k (number of data points)		86	
Minimum reported value [mg/l]		0.003	
Maximum reported value [mg/l]		0.340	
D (detection limit) [mg/l]		0.004	
k - r (number of detects)		74	
r (number of nondetects)		12	
d (ratio of nondetects/total, delta)		0.1395	
μ(y) (average of detects)			-3.3873
s(y) (std deviation of detects)			0.8855
t(y) (variance of detects)			0.7481
E(X*) (daily average)			0.0436
V(X*) (variance)			0.0028
z*99.7 (adjusted Z-score, 99.7th %tile)			2.7683
Daily Maximum Limits (99.7th %tile)		**0.3922**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.
b. Value shown is geometric mean of measurements collected on three consecutive days.
c. Value shown is geometric mean of measurements collected on four consecutive days.
d. Value of 8.86 reported for ECO71ho6 on 11/16/98 was not considered in the statistical analysis.

Table F-4 Ecoregion 71i Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO71i10	01-25-2000	0.02	-3.9120
	01-06-2000	0.1	-2.3026
	04-06-2000	0.11	-2.2073
	04-12-2000	0.165	-1.8018
	07-12-2000	0.13	-2.0402
	05-30-2001	0.12	-2.1203
	09-11-2001	0.16	-1.8326
	05-20-1996	0.09	-2.4079
	09-05-1996	0.175 [b]	-1.7401
	11-21-1996	0.040 [b]	-3.2191
	02-10-1997	0.03	-3.5066
	04-28-1997	0.004U [a]	
	10-09-1997	0.134 [a]	-2.0087
	11-13-1997	0.09	-2.4079
	02-25-1998	0.08	-2.5257
	04-27-1998	0.04	-3.2189
	12-02-1998	0.32	-1.1394
	02-16-1999	0.09	-2.4079
	06-08-1999	0.11	-2.2073
	11-09-1999	0.24	-1.4271
	08-20-2003	0.079	-2.5383
	09-16-2003	0.108	-2.2256
	10-28-2003	0.004U	
	12-16-2003	0.082	-2.5010
	01-14-2004	0.043	-3.1466
	04-27-2004	0.057	-2.8647
	05-19-2004	0.066	-2.7181
ECO71i12	01-03-2000	0.06	-2.8134
	04-19-2000	0.06	-2.8134
	07-19-2000	0.1	-2.3026
	11-02-2000	0.004U	
	05-07-2001	0.09	-2.4079
	08-25-2004	0.006 [a]	-5.0980
	09-08-2004	0.010 [a]	-4.6025
	09-20-2004	0.117	-2.1456
	09-28-2004	0.157	-1.8515
	10-05-2004	0.084	-2.4769
	10-25-2004	0.022 [a]	-3.8038
	11-15-2004	0.008 [a]	-4.8057
	12-15-2004	0.012 [a]	-4.4588
	01-13-2005	0.018 [b]	-3.9912
	02-24-2005	0.008 [b]	-4.8788
	03-30-2005	0.006 [a]	-5.0809
	04-06-2005	0.007 [a]	-5.0295
	05-25-2005	0.026 [a]	-3.6492
	06-22-2005	0.008 [a]	-4.8788

Table F-4 (Contd.) Ecoregion 71i Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO71i14	01-26-2000	0.008	-4.8283
	04-11-2000	0.004U	
	07-11-2000	0.059 [a]	-2.8275
	05-09-2001	0.06	-2.8134
	09-12-2001	0.04	-3.2189
	08-20-2003	0.026	-3.6497
	09-16-2003	0.07	-2.6593
	10-28-2002	0.08	-2.5257
	12-16-2003	0.023	-3.7723
	01-14-2004	0.012	-4.4228
	04-27-2004	0.005	-5.2983
	05-19-2004	0.058	-2.8473
ECO71i15	01-24-2000	0.17	-1.7720
	05-03-2000	0.11	-2.2073
	07-13-2000	0.16	-1.8326
	10-31-2000	0.92	-0.0834
	05-09-2001	0.25	-1.3863
	10-09-2001	0.211	-1.5559
	11-08-2001	0.153	-1.8773
	12-12-2001	0.142	-1.9519
	01-29-2002	0.19	-1.6607
	02-21-2002	0.12	-2.1203
	03-18-2002	0.39	-0.9416
	04-10-2002	0.07	-2.6593
	05-23-2002	0.131	-2.0326
	06-11-2002	0.22	-1.5141
	07-18-2006	0.31	-1.1712
	08-03-2006	0.32	-1.1394
	09-19-2006	0.29	-1.2379
	10-11-2006	0.39	-0.9416
	11-07-2006	0.24	-1.4271
	12-20-2006	0.16	-1.8326
	01-23-2007	0.16	-1.8326
	02-12-2007	0.1	-2.3026
	03-13-2007	0.12	-2.1203
	04-25-2007	0.24	-1.4271
	05-07-2007	0.16	-1.8326
	06-26-2007	0.31	-1.1712

Table F-4 (Contd.) Ecoregion 71i Total Phosphorus Monitoring Data & Statistics

Station ID	Date	TP [mg/l]	LN(TP)
ECO71i16	09-03-2004	0.004U	
	09-09-2004	0.010 [b]	-4.6539
	09-16-2004	0.037	-3.2968
	09-22-2004	0.038	-3.2702
	07-20-2006	0.010U [a]	
	08-24-2006	0.36	-1.0217
	09-12-2006	0.010U [a]	
	10-10-2006	0.007 [a]	-4.9517
	11-30-2006	0.008 [a]	-4.8362
	12-19-2006	0.008 [a]	-4.8362
	01-22-2007	0.013 [a]	-4.3349
	02-15-2007	0.005 [a]	-5.3051
	03-06-2007	0.007 [a]	-4.9388
	04-11-2007	0.02	-3.9120
	05-01-2007	0.020 [a]	-3.9120
	06-26-2007	0.027 [a]	-3.6066
k (number of data points)		100	
Minimum reported value [mg/l]		0.004	
Maximum reported value [mg/l]		0.920	
D (detection limit) [mg/l]		0.004	
k - r (number of detects)		93	
r (number of nondetects)		7	
d (ratio of nondetects/total, delta)		0.0700	
μ(y) (average of detects)			-2.8095
s(y) (std deviation of detects)			1.2660
t(y) (variance of detects)			1.6028
E(X*) (daily average)			0.1251
V(X*) (variance)			0.0676
z*99.7 (adjusted Z-score, 99.7th %tile)			2.7690
Daily Maximum Limits (99.7th %tile)		**2.0060**	

Notes: a. Value shown is geometric mean of multiple measurements on sample date.
b. Value shown is geometric mean of measurements collected on three consecutive days.

Table F-5 Daily Expression of Annual Average Loads for Impaired Subwatersheds & Drainage Areas

HUC-12 Subwatershed (05130203__) or Drainage Area	Total Nitrogen			Total Phosphorus			$CBOD_5$		
	Daily Maximum Conc.	Daily Maximum Load		Daily Maximum Conc.	Daily Maximum Load		Daily Maximum Conc.	Daily Maximum Load	
	[mg/l]	[lbs/day]	[lbs/ac/day]	[mg/l]	[lbs/day]	[lbs/ac/day]	[mg/l]	[lbs/day]	[lbs/ac/day]
0106	3.999	2.157×10^{1} * Q	8.505×10^{-4} * Q	1.868	1.008×10^{1} * Q	3.972×10^{-4} * Q	7.5	4.046×10^{1} * Q	1.595×10^{-3} * Q
0201	4.079	2.200×10^{1} * Q	5.789×10^{-4} * Q	1.937	1.045×10^{1} * Q	2.749×10^{-4} * Q	7.5	4.046×10^{1} * Q	1.064×10^{-3} * Q
McCrory Creek DA	2.304	1.243×10^{1} * Q	2.140×10^{-3} * Q	0.392	2.116×10^{0} * Q	3.643×10^{-4} * Q	7.5	4.046×10^{1} * Q	6.966×10^{-3} * Q
Hurricane Creek DA	3.777	2.038×10^{1} * Q	2.161×10^{-3} * Q	1.674	9.031×10^{0} * Q	9.580×10^{-4} * Q	7.5	4.046×10^{1} * Q	4.292×10^{-3} * Q
Bear Branch DA	4.158	2.243×10^{1} * Q	1.245×10^{-2} * Q	2.006	1.082×10^{1} * Q	6.005×10^{-3} * Q	7.5	4.046×10^{1} * Q	2.245×10^{-2} * Q
Unnamed Tributary To Lytle Creek DA	4.158	2.243×10^{1} * Q	1.869×10^{-1} * Q	2.006	1.082×10^{1} * Q	9.018×10^{-2} * Q	7.5	4.046×10^{1} * Q	3.371×10^{-1} * Q

APPENDIX G

Estimation of Required Reductions in Nutrient Loading

DEVELOPMENT OF LOAD DURATION CURVES & ESTIMATION OF REQUIRED REDUCTIONS IN NUTRIENT & $CBOD_5$ LOADING

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

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 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).

Flow duration curves were developed for impaired waterbodies in the Stones River watershed using simulated daily mean flow data from LSPC models constructed for each waterbody at an appropriate water quality monitoring station. Due to the small size of the drainage area for the unnamed tributary to Lytle Creek, an adequate LSPC model of the waterbody could not be constructed. Model setup and calibration are summarized in Appendix G. Load duration curves were developed from the FDCs using target nutrient concentrations, nutrient monitoring data, and flows measured at the time of sample collection. LDCs could not be constructed for Jarman Creek or the unnamed tributaries to Bradley Creek due to the lack of adequate monitoring data. Estimated load reductions required to meet TMDL targets were then calculated from the LDCs according to the procedure described below (Bear Branch is shown, other waterbodies are similar).

1. A flow-duration curve for Bear Branch at water quality monitoring station BEAR000.8RU (~RM 0.8) was constructed using simulated daily mean flow for the period from 10/1/97 through 9/30/07. 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).

2. A target load-duration curve was generated for Bear Branch at the water quality monitoring station by applying the target nitrogen concentration for Level IV ecoregion 71i (ref.: Section 5.2) to each of the 3,652 ranked flows:

   $(\text{Target Load})_{\text{Bear Branch}} = (\text{TN})_{71i} \times (Q_{Sim}) \times (\text{UCF})$

   where: Q_{Sim} = Simulated daily mean flow
   UCF = the required unit conversion factor

   Note: For drainage areas that are located within more than one Level IV ecoregion, area-weighted target values were calculated.

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

4. Using the flow duration curve developed in Step 1, the "percent of days the flow was exceeded" (PDFE) was determined, based on the measured flow for each sampling event. Each sample load was then plotted on the load duration curve developed in Step 2 according to the PDFE. The resulting curve is shown in Figure G-1.

5. 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.

6. Steps 2 through 5 were repeated for total phosphorus. The load duration curve for total phosphorus is shown in Figure G-2. Sample loads, target loads, PDFEs, and approximate required reductions in nutrient loading for Bear Branch are summarized in Table G-1.

Load duration curves for McCrory Creek, West Fork Stones River, and Hurricane Creek are shown in Figures G-3 through G-7. Sample loads, target loads, PDFEs, and approximate required reductions in nutrient loading for these waterbodies are tabulated in Tables G-2 through G-4.

Load reductions for the unnamed tributary to Lytle Creek were approximated from sample and target concentrations and are shown in Table G-5.

Figure G-1 Total Nitrogen Load Duration Curve – Bear Branch at BEAR000.8RU

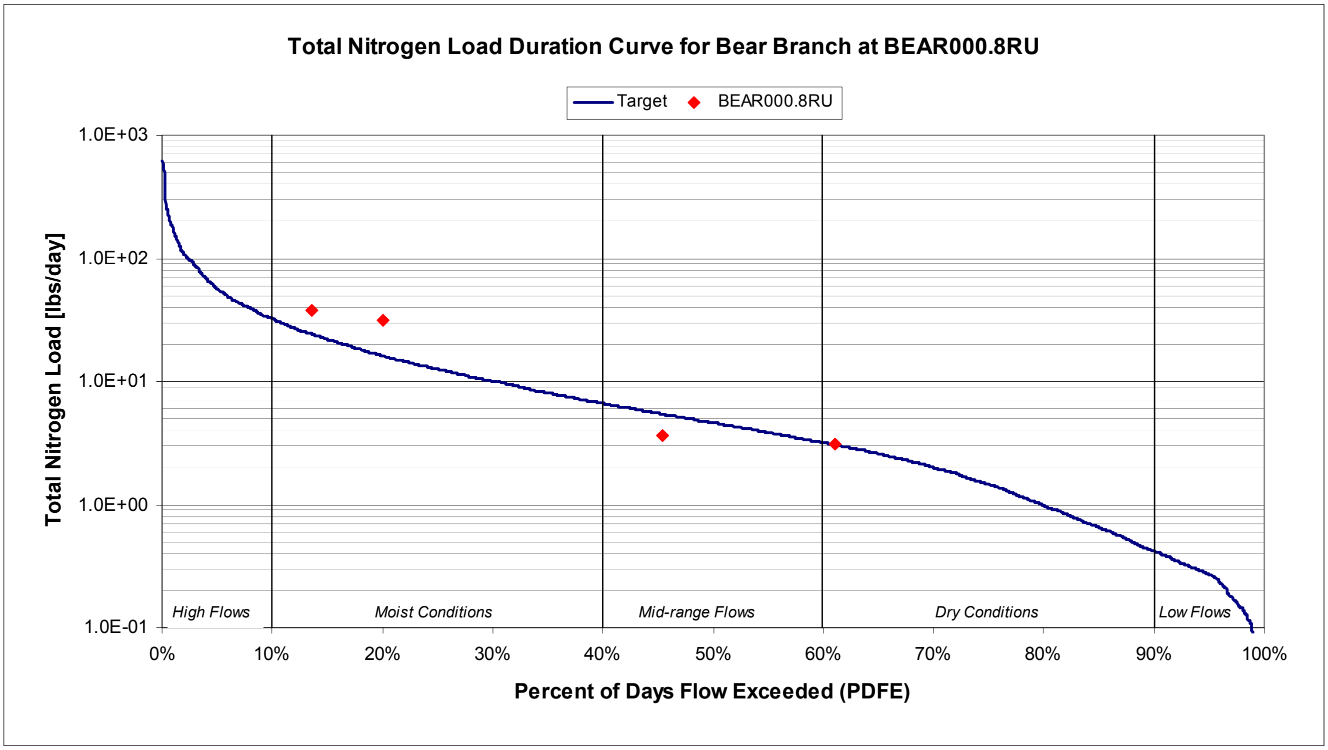


Figure G-2 Total Phosphorus Load Duration Curve – Bear Branch at BEAR000.8RU

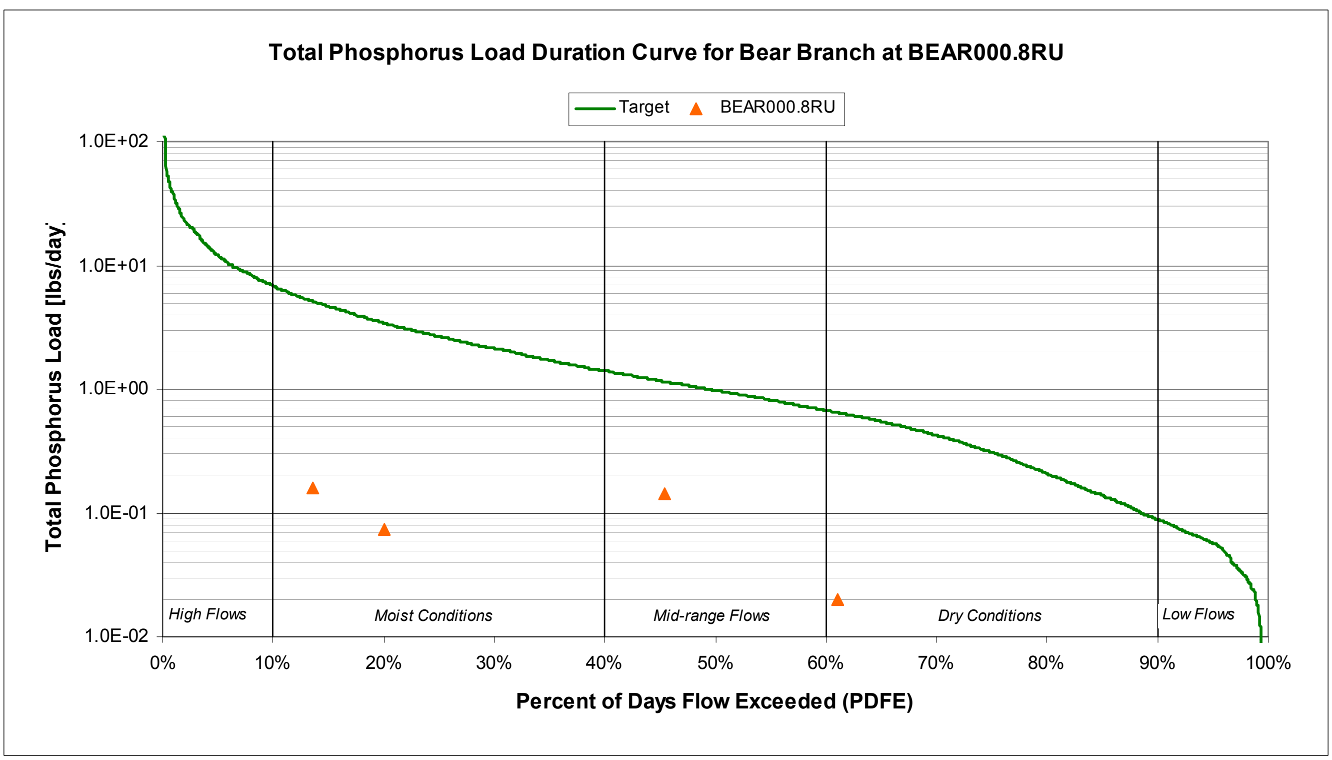


Figure G-3 Total Nitrogen Load Duration Curve – McCrory Creek at MCCRO001.5DA

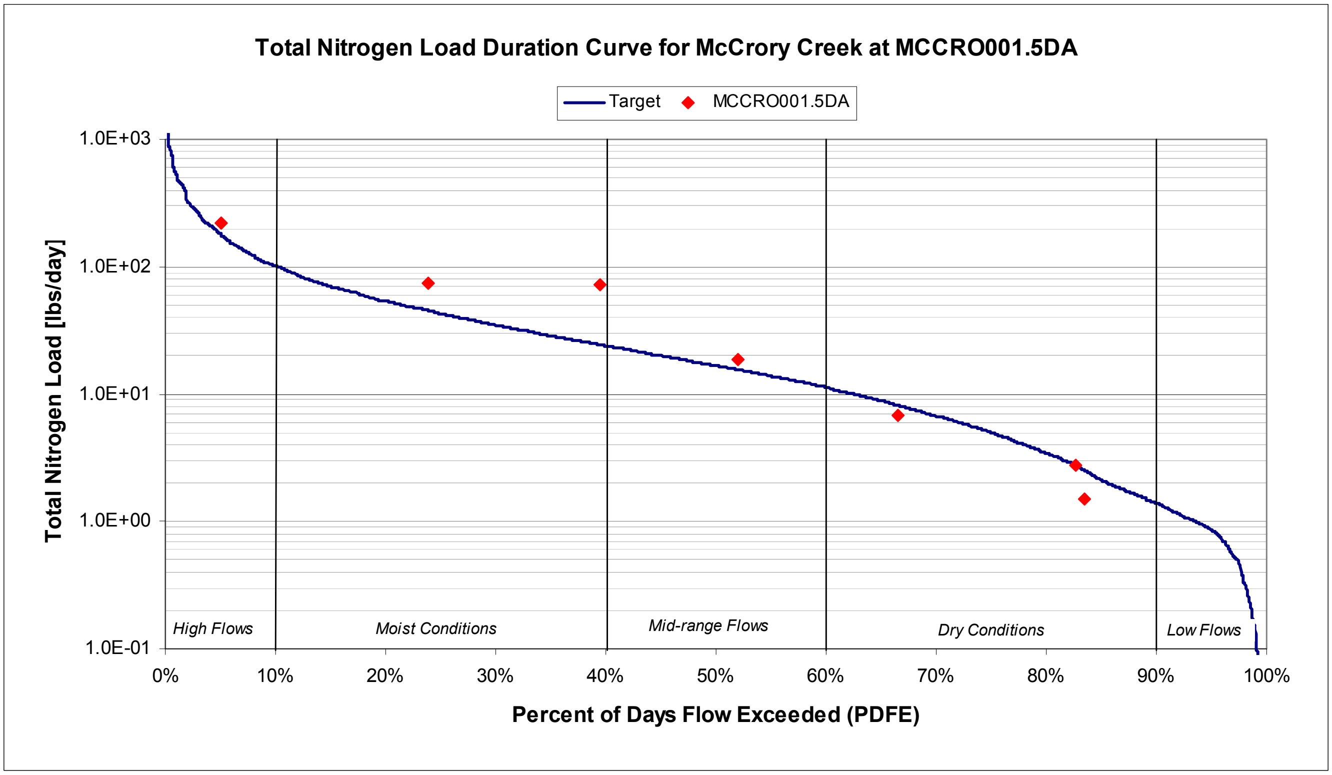


Figure G-4 Total Phosphorus Load Duration Curve – McCrory Creek at MCCRO001.5DA

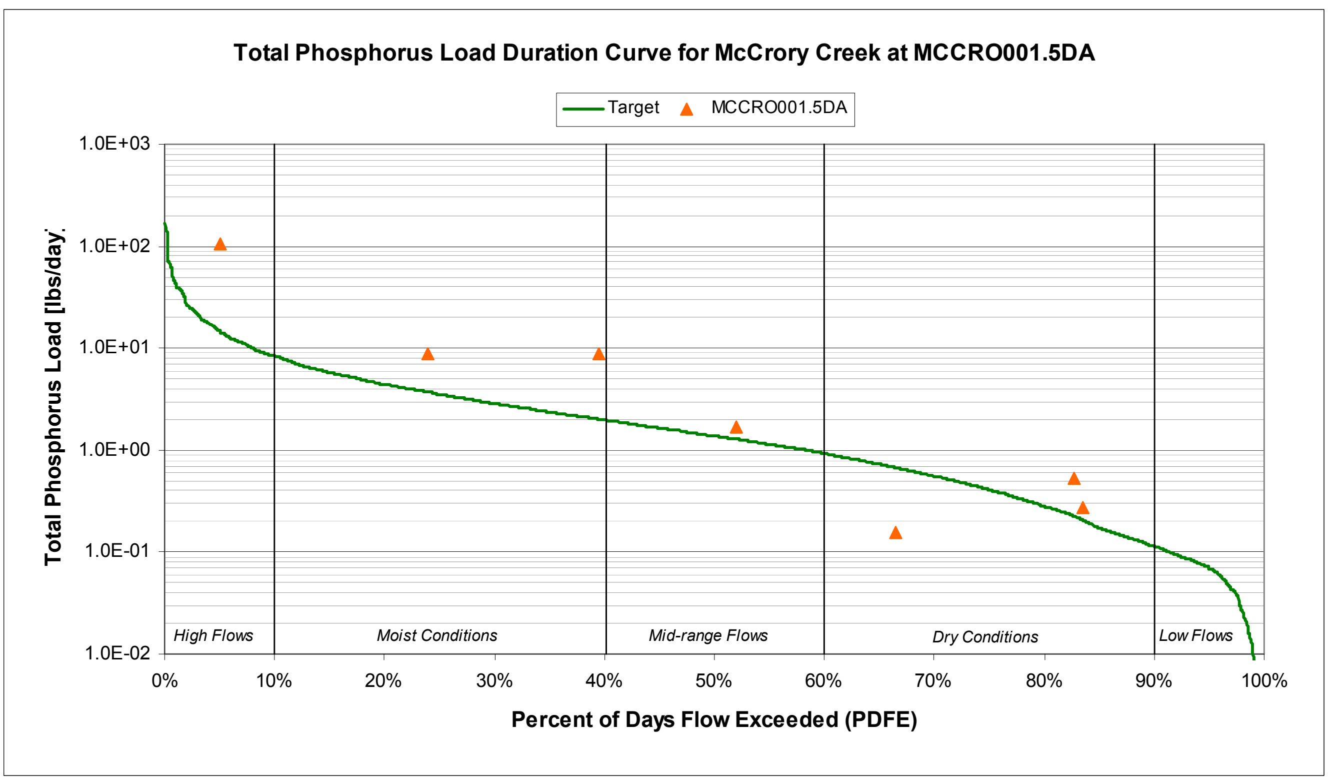


Figure G-5 Total Nitrogen Load Duration Curve – W.F. Stones River at WFSTO032.3RU

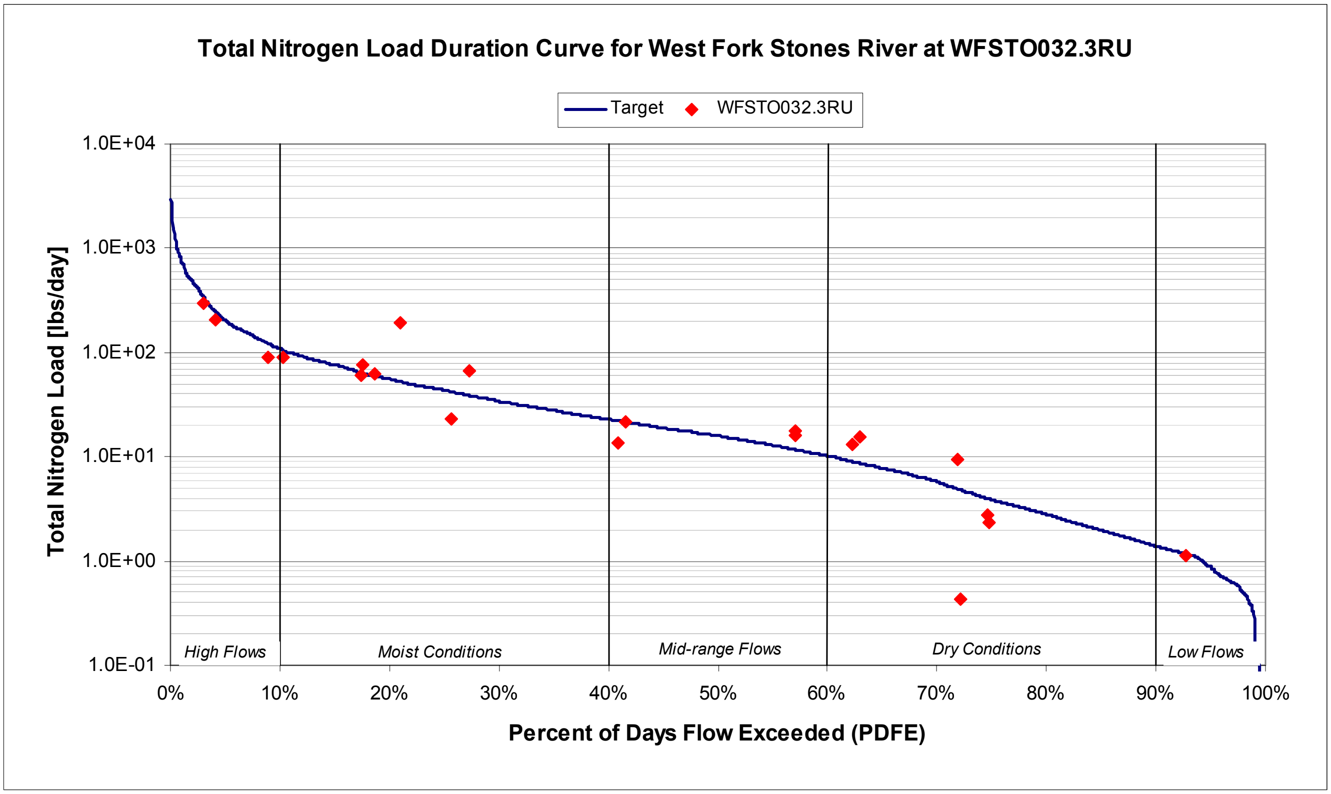


Figure G-6 Total Phosphorus Load Duration Curve – W.F. Stones River at WFSTO032.3RU

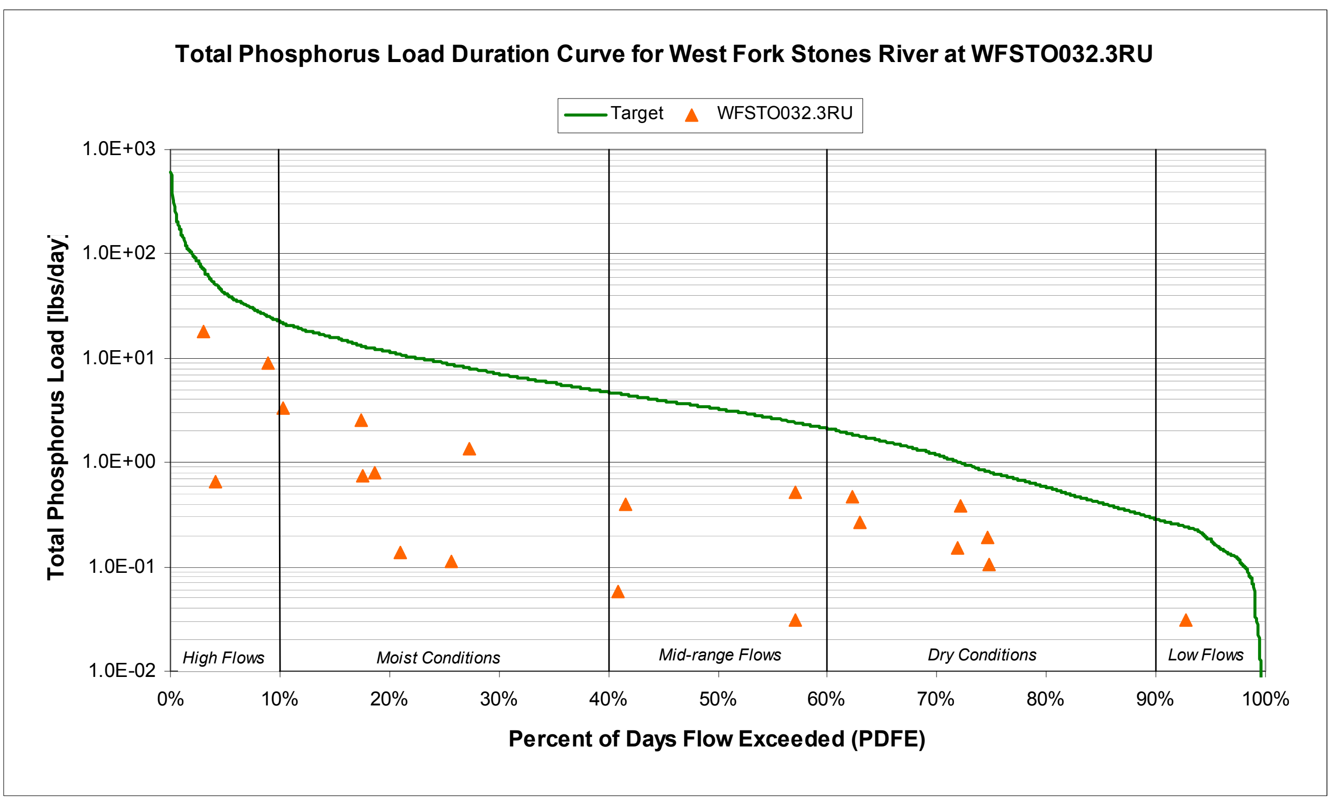


Figure G-7 Total Nitrogen Load Duration Curve – Hurricane Creek at HURRI004.2RU

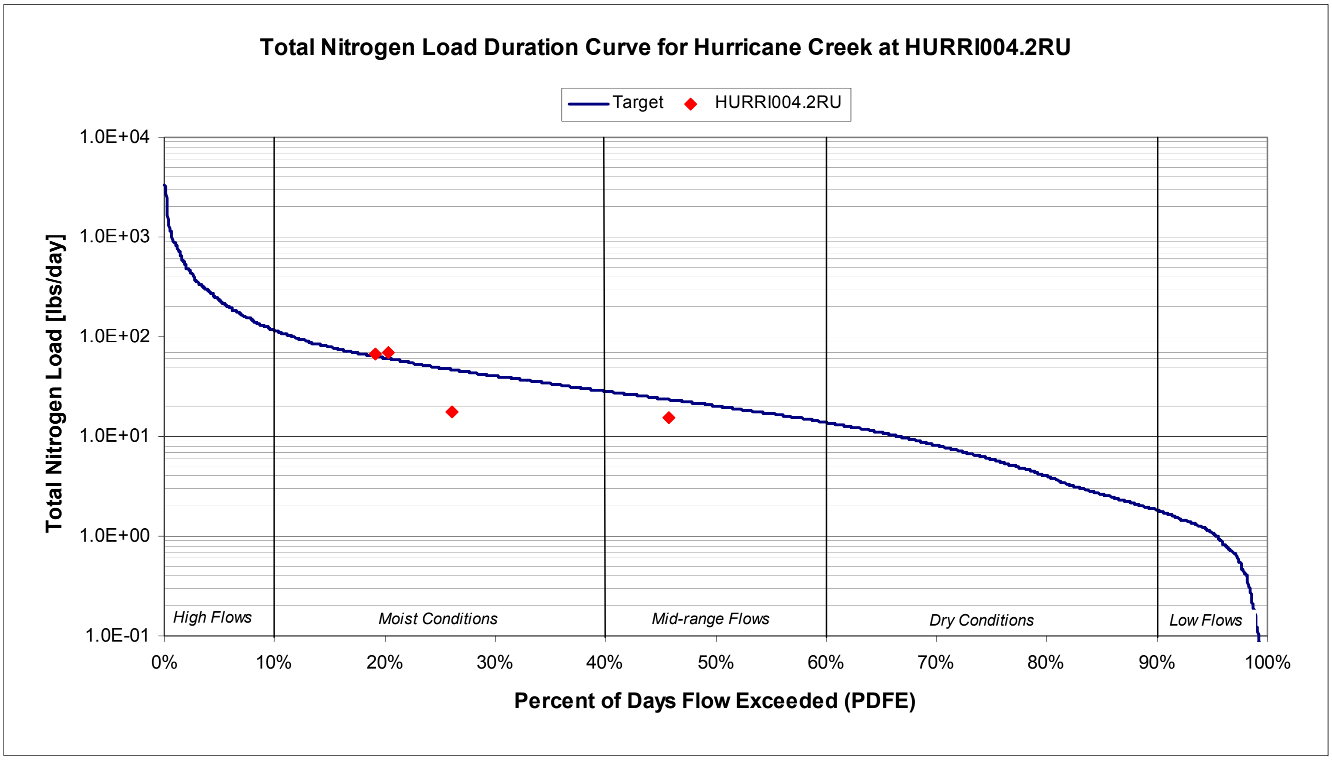


Table G-1 Determination of Overall Required Nutrient Load Reduction for Bear Branch

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	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]	[%]
9/26/06	0.75	61.1	0.76	3.07	3.05	0.7	0.005	0.02	0.65	NR
10/10/06	1.33	45.4	0.51	3.66	5.41	NR	0.020	0.14	1.15	NR
1/22/07	5.98	13.6	1.18	38.04	24.29	36.1	0.005	0.16	5.15	NR
3/6/07	3.95	20.1	1.48	31.52	16.07	49.0	0.004	0.07	3.41	NR
					Geometric Mean →	**10.5**			**Geometric Mean →**	**NR**

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

Table G-2 Determination of Overall Required Nutrient Load Reduction for Hurricane Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	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]	[%]
1/10/07	14.93	20.3	0.85	68.42	60.32	11.8	ND	—	—	—
1/17/07	15.64	19.2	0.80	67.45	63.14	6.4	ND	—	—	—
1/25/07	11.64	26.1	0.28	17.57	46.98	NR	ND	—	—	—
1/30/07	5.83	45.7	0.49	15.40	23.53	NR	ND	—	—	—
					Geometric Mean →	**8.7**			**Geometric Mean →**	—

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

Table G-3 Determination of Overall Required Nutrient Load Reduction for McCrory Creek

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	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]	[%]
10/24/01	2.08	66.5	0.60	6.73	8.16	NR	0.014	0.16	0.67	NR
11/15/01	0.64	83.5	0.44	1.52	2.52	NR	0.078	0.27	0.21	23.1
12/6/01	6.20	39.5	2.18	72.87	24.33	66.6	0.265	8.86	2.01	77.4
3/26/02	45.00	5.1	0.92	223.2	176.47	20.9	0.44	106.7	14.54	86.4
4/23/02	3.95	52.0	0.88	18.74	15.50	17.2	0.08	1.70	1.28	25.0
5/16/02	11.56	23.9	1.19	74.16	45.39	38.8	0.14	8.72	3.74	57.1
6/19/02	0.70	82.7	0.74	2.79	2.75	1.6	0.141	0.53	0.23	57.5
					Geometric Mean →	**17.3**			**Geometric Mean →**	**48.3**

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

Table G-4 Determination of Overall Required Nutrient Load Reduction for W.F. Stones River (Headwaters)

Sample Date	Flow	PDFE (Approx.)	Total Nitrogen				Total Phosphorus			
			Sample Concen. [a]	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]	[%]
11/26/96	30.13	8.9	0.55	89.34	122.65	NR	0.055	8.93	25.38	NR
2/6/97	26.06	10.3	0.63	88.51	105.43	NR	0.024	3.37	21.81	NR
4/23/97	60.89	4.1	0.63	206.81	247.74	NR	0.002	0.66	51.26	NR
10/1/97	1.21	71.9	1.46	9.52	4.92	48.3	0.023	0.15	1.02	NR
11/13/97	2.88	57.0	1.03	15.99	11.71	26.8	0.002	0.03	2.42	NR
4/27/98	10.36	25.6	0.42	23.46	42.09	NR	0.002	0.11	8.71	NR
9/1/98	0.97	74.8	0.44	2.30	3.94	NR	0.02	0.10	0.82	NR
12/2/98	1.20	72.1	0.07	0.43	4.88	NR	0.06	0.39	1.01	NR
2/16/99	14.60	18.7	0.80	62.97	59.31	5.8	0.01	0.79	12.27	NR
6/3/99	0.29	92.7	0.71	1.11	1.18	NR	0.02	0.03	0.24	NR
1/11/00	12.86	21.0	2.81	194.82	52.32	73.1	0.002	0.14	10.83	NR
4/19/00	15.55	17.6	0.92	77.12	63.21	18.0	0.009	0.75	13.08	NR
6/11/01	2.20	62.3	1.09	12.93	8.96	30.7	0.04	0.47	1.85	NR
10/11/01	0.98	74.6	0.52	2.75	3.98	NR	0.036	0.19	0.82	NR
11/28/01	5.34	41.5	0.74	21.30	21.71	NR	0.014	0.40	4.49	NR
12/4/01	9.55	27.3	1.30	66.93	38.83	42.0	0.026	1.34	8.03	NR
1/3/02	2.88	57.0	1.13	17.54	11.71	33.3	0.033	0.51	2.42	NR
2/12/02	15.75	17.4	0.72	61.13	63.98	NR	0.03	2.55	13.24	NR
3/19/02	83.99	3.0	0.66	298.85	338.67	NR	0.04	18.11	70.07	NR
4/18/02	5.46	40.9	0.46	13.54	22.21	NR	0.002	0.06	4.59	NR
6/25/02	2.12	63.0	1.34	15.31	8.62	43.7	0.023	0.26	1.78	NR
					Geometric Mean →	**28.2**			**Geometric Mean →**	**NR**

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

Table G-5 Estimation of Overall Required Nutrient Load Reduction for Unnamed Tributary to Lytle Creek

Sample Date	Sample Concentration		Target Concentration (71i)		Required Reduction	
	Total Nitrogen [a]	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen	Total Phosphorus
	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[%]	[%]
10/11/01	0.79	0.050	0.755	0.160	4.4	NR
11/28/01	0.77	0.038			2.0	NR
12/4/01	0.83	0.007			9.0	NR
1/3/02	1.17	0.059			35.5	NR
2/12/02	1.34	0.03			43.7	NR
3/19/02	0.49	0.03			NR	NR
4/18/02	1.15	0.002 [b]			34.4	NR
5/20/02	0.82	0.002 [b]			7.9	NR
6/25/02	1.53	0.002 [b]			50.7	NR
7/31/02	—	0.075			NR	NR
9/6/06	1.55	0.005 [b]			51.3	NR
9/11/06	0.58	0.005 [b]			NR	NR
9/13/06	—	0.005 [b]			NR	NR
9/21/06	0.48	0.03			NR	NR
9/25/06	0.26	0.04			NR	NR
9/26/06	0.65	0.03			NR	NR
9/28/06	0.65	0.04			NR	NR
5/8/07	0.60	0.04			NR	NR
5/9/07	0.49	0.010 [b]			NR	NR
5/15/07	0.48	0.004 [b]			NR	NR
5/24/07	0.36	0.015			NR	NR
			Geometric Mean →		**16.4**	**NR**

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

APPENDIX H

Development and Calibration of LSPC Model

H.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected to simulate flow for load duration curve (LDC) development for Bear Branch, Hurricane Creek, McCrory Creek, and the headwater portion of West Fork Stones River. LSPC is a dynamic watershed model, based on the Hydrologic Simulation Program – Fortran (HSPF), capable of simulating nonpoint source runoff and associated pollutant loadings and performing flow routing through stream reaches.

H.2 Model Calibration

In order to simulate flow as accurately as possible, a model must be calibrated. This involves comparison of simulated stream flow to historic stream flow data from USGS stream gaging stations for the same period of time. Since there are no continuous gaging stations with adequate periods of record on the waterbodies of interest, the USGS continuous record station located in East Fork Stones River near Lascassas, Tennessee (USGS 03427500) was selected as the basis of the hydrology calibration. This station is located in the Stones River watershed within Level IV ecoregions 71h and 71i.

The drainage area upstream of the selected USGS station was delineated and an LSPC model constructed. The delineation was performed using the Watershed Characterization System (WCS) and based on National Hydrology Dataset (NHD) stream coverage and Digital Elevation Model (DEM) data. WCS is a geographic information system (GIS) tool used to display, analyze, and compile available information to support hydrology model simulations. In addition to NHD and DEM data, this information includes land use categories, point source dischargers, soil types and characteristics, and stream characteristics. WCS has the capability to export GIS and watershed data to the LSPC model.

Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed stream flow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. An important factor influencing model results is the precipitation data used for the simulation. Meteorological data from a station in Murfreesboro, Tennessee was used for hydrologic calibration. The results of the hydrologic calibration are shown in Table H-1 and Figure H-1.

H.3 Flow Simulation for Impaired Waterbodies

The drainage areas upstream of the relevant water quality monitoring stations on Bear Branch, Hurricane Creek, McCrory Creek, and the headwater portion of West Fork Stones River were delineated and LSPC models constructed. Using the hydrologic parameter values determined during calibration (Section H.2), each impaired waterbody model was run for the period 10/1/97 through 9/30/07. Data from the Nashville International Airport weather station was used for the McCrory and Hurricane Creek simulations, while data from the Murfreesboro station was used for Bear Branch and West Fork Stones River simulations.

Table H-1 Hydrologic Calibration Summary of East Fork Stones River at USGS Station 03427500

Simulation Name:	USGS03427500	**Simulation Period:**	
		Watershed Area (ac):	166900.57
Period for Flow Analysis			
Begin Date:	**10/01/81**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/91**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**237.22**	Total Observed In-stream Flow:	**244.54**
Total of highest 10% flows:	**146.99**	Total of Observed highest 10% flows:	**156.51**
Total of lowest 50% flows:	**12.63**	Total of Observed Lowest 50% flows:	**11.57**
Simulated Summer Flow Volume (months 7-9):	**21.37**	Observed Summer Flow Volume (7-9):	**20.79**
Simulated Fall Flow Volume (months 10-12):	**69.67**	Observed Fall Flow Volume (10-12):	**68.49**
Simulated Winter Flow Volume (months 1-3):	**89.87**	Observed Winter Flow Volume (1-3):	**102.13**
Simulated Spring Flow Volume (months 4-6):	**56.30**	Observed Spring Flow Volume (4-6):	**53.12**
Total Simulated Storm Volume:	**234.84**	Total Observed Storm Volume:	**239.73**
Simulated Summer Storm Volume (7-9):	**20.78**	Observed Summer Storm Volume (7-9):	**19.59**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-2.99**	10	
Error in 50% lowest flows:	**9.13**	10	
Error in 10% highest flows:	**-6.09**	15	
Seasonal volume error - Summer:	**2.81**	30	
Seasonal volume error - Fall:	**1.72**	30	
Seasonal volume error - Winter:	**-12.01**	30	
Seasonal volume error - Spring:	**5.98**	30	
Error in storm volumes:	**-2.04**	20	
Error in summer storm volumes:	**6.09**	50	

Figure H-1 Comparison of Simulated Flow vs. Observed Flow at USGS 03427500