TOTAL MAXIMUM DAILY LOAD (TMDL)

For

pH

In

Straight Fork Creek

Located in the

South Fork of the Cumberland River Watershed

(HUC 05130104)

Anderson, Campbell, Fentress, Morgan, Pickett, & Scott Counties, Tennessee

FINAL

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TDEC

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LIST OF ABBREVIATIONS

AMD	Acid Mine Drainage
CCC	Criteria Continuous Concentration
CFR	Code of Federal regulations
CFS	Cubic Feet per Second
CMC	Criteria Maximum Concentration
DEM	Digital Elevation Model
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
GIS	Geographic Information System
HUC	Hydrologic Unit Code
ITRC	Instream Total Recoverable Concentration
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
NHD	National Hydrography Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
RM	River Mile
TDEC	Tennessee Department of Environment & Conservation
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WCS	Watershed Characterization SYstem
WLA	Waste Load Allocation

SUMMARY SHEET

Total Maximum Daily Load (TMDL) for pH in South Fork of the Cumberland River Watershed (05130104)

<u>Impaired Waterbody Information</u>

State: Tennessee
Counties: Campbell and Scott
Watershed: South Fork of the Cumberland River (HUC 05130104)
Constituents of Concern: pH

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN05130104044 – 0500	STRAIGHT FORK CREEK	7.2

Designated Uses:

The designated use classifications for waterbodies in the South Fork of the Cumberland River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004*:

The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

TMDL Scope:

Waterbodies identified on the Final 2006 303(d) list as impaired due to pH.

Portions of the South Fork of the Cumberland River Watershed are located in Kentucky. This TMDL only addresses the portion of the South Fork of the Cumberland River Watershed located in Tennessee.

Monitoring data was unavailable for Straight Fork Creek. Additional monitoring is recommended to either confirm impairment or allow for delisting.

Analysis/Methodology:

Net alkalinity was used as a surrogate for pH. The net alkalinity TMDL for impaired waterbodies in the Straight Fork Creek Subwatershed was developed using a load duration curve methodology to assure compliance with the target net alkalinity of 10.8 mg/L (see Appendices B & C), which will provide a pH within the criteria range of 6.0 – 9.0. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow regime represented by these existing loads.

Critical Conditions:

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

Seasonal Variation:

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

Margin of Safety (MOS):

Implicit (conservative modeling assumptions).

Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Straight Fork Creek Subwatershed (HUC 051301040105)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS	WLAs	LAs
			[lbs/day]	[lbs/day]	[lbs/day]	[lbs/day/ac]
Straight Fork Creek	TN05130104044 – 0500	Net Alkalinity	58.1 x Q	NA[a]	58.1 x Q_2	{(4.83×10^{-3}) x Q} – {(4.83×10^{-3}) x Q_2}

Notes: NA = Not Applicable.
NR = No Reduction Required
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Point Sources; because Q_2 is driven by rainfall and the drainage area for Q_2 (35.7 acres) << the drainage area for Q (12,000 acres), Q_2 << Q.

a. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.5).

pH TOTAL MAXIMUM DAILY LOAD (TMDL)
STRAIGHT FORK CREEK SUBWATERSHED
in the
SOUTH FORK OF THE CUMBERLAND RIVER WATERSHED (HUC 05130104)

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 meeting designated uses. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991a).

2.0 WATERSHED DESCRIPTION

The South Fork of the Cumberland River Watershed (HUC 05130104) is located in middle and eastern Tennessee and Kentucky (Figure 1). This document addresses only the portion of the watershed located in Tennessee. The South Fork of the Cumberland River Watershed falls within two Level III ecoregions (Southwestern Appalachians and Central Appalachians) and contains three Level IV subecoregions (USEPA, 1997) as shown in Figure 2:

- **Cumberland Plateau (68a)** tablelands and open low mountains are about 1000 feet higher than the Eastern Highland Rim (71g) to the west, and receive slightly more precipitation with cooler annual temperatures than the surrounding lower-elevation ecoregions. The plateau surface is less dissected with lower relief compared to the Cumberland Mountains (69d) or the Plateau Escarpment (68c). Elevations are generally 1200-2000 feet, with the Crab Orchard Mountains reaching over 3000 feet. Pennsylvanian-age conglomerate, sandstone, siltstone, and shale is covered by well-drained, acid soils of low fertility. Bituminous coal that has been extensively surface and underground mined underlies the region. Acidification of first and second order streams is common. Stream siltation and mine spoil bedload deposits continue as long-term problems in these headwater systems. Pockets of severe acid mine drainage persist.
- **Plateau Escarpment (68c)** is characterized by steep, forested slopes and high velocity, high gradient streams. Local relief is often 1000 feet or more. The geologic strata include Mississippian-age limestone, sandstone, shale, and siltstone, and Pennsylvanian-age shale, siltstone, sandstone, and conglomerate. Streams have cut down into the limestone, but the gorge talus slopes are composed of colluvium with huge angular, slabby blocks of sandstone. Vegetation community types in the ravines and gorges include mixed oak and chestnut oak on the upper slopes, mesic forests on the middle and lower slopes (beech-tulip poplar, sugar maple-basswood-ash-buckeye), with hemlock along rocky streamsides and river birch along floodplain terraces.

- The **Cumberland Mountains (69d)**, in contrast to the sandstone-dominated Cumberland Plateau (68a) to the west and southwest, are more highly dissected, with narrow-crested steep slopes, and younger Pennsylvanian-age shales, sandstones, siltstones, and coal. Narrow, winding valleys separate the mountain ridges, and relief is often 2000 feet. Cross Mountain, west of Lake City, reaches 3534 feet in elevation. Soils are generally well-drained, loamy, and acidic, with low fertility. The natural vegetation is a mixed mesophytic forest, although composition and abundance vary greatly depending on aspect, slope position, and degree of shading from adjacent land masses. Large tracts of land are owned by lumber and coal companies, and there are many areas of stripmining.

The South Fork of the Cumberland River Watershed, located in Anderson, Campbell, Fentress, Morgan, Pickett, and Scott Counties, Tennessee, has a drainage area of approximately 976 square miles (mi^2) in Tennessee. The entire watershed, including portions of Tennessee and Kentucky, drains approximately 1,374 square miles. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the South Fork of the Cumberland River Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the South Fork of the Cumberland River Watershed and the Straight Fork Creek Subwatershed is summarized in Table 1 and Figure 3.

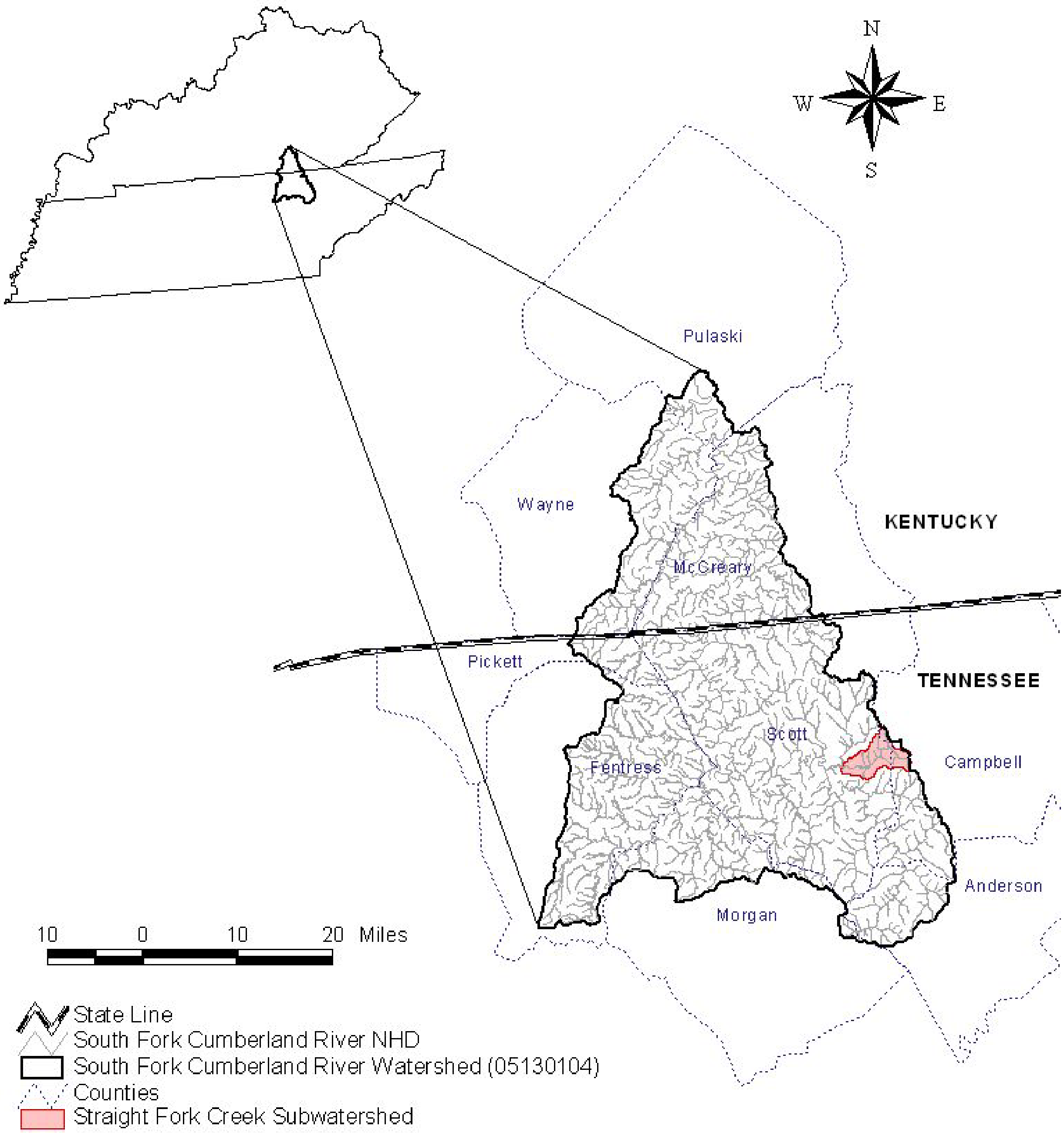

Figure 1 Location of South Fork of the Cumberland River Watershed

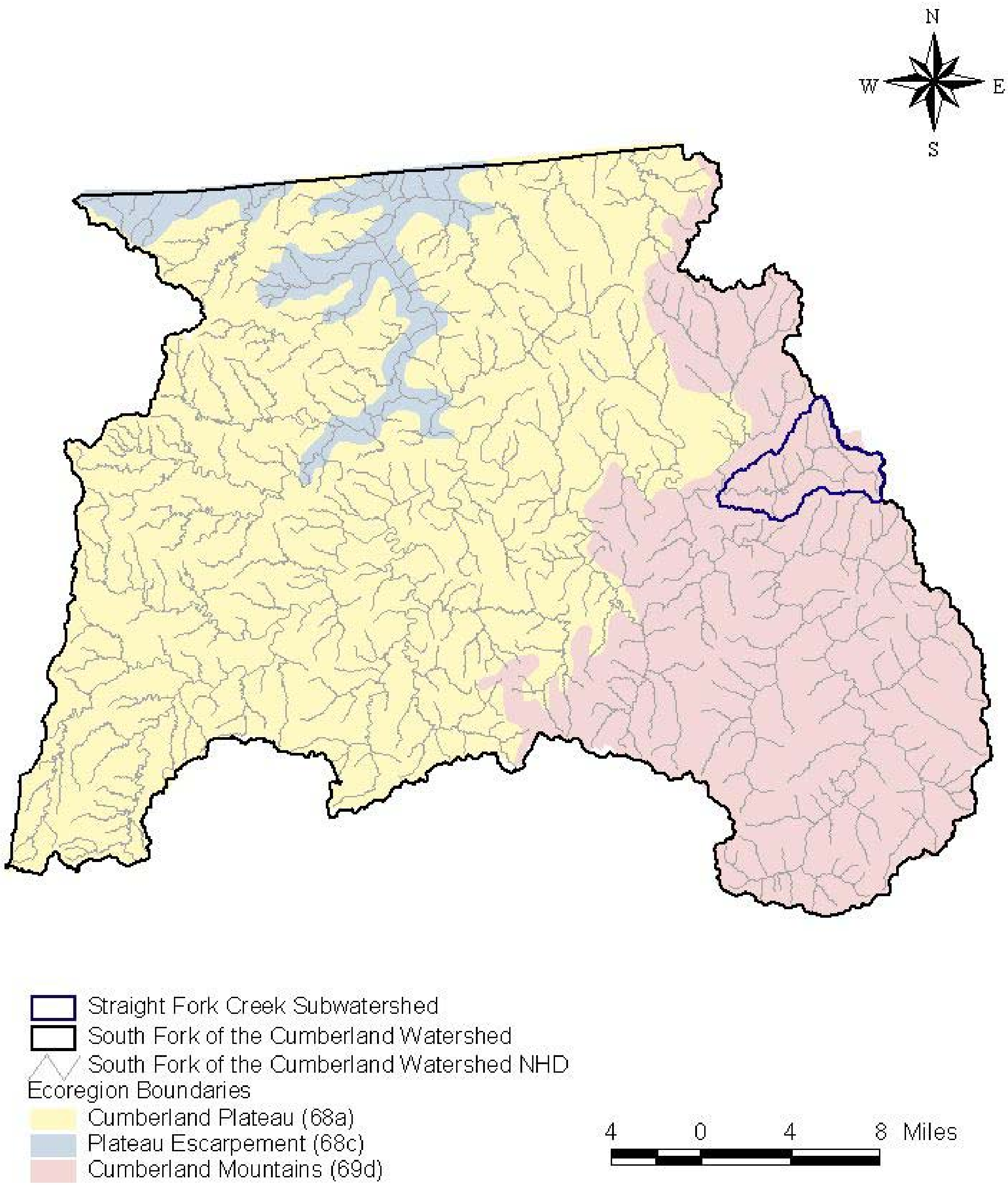

Figure 2 South Fork of the Cumberland River Watershed Ecoregion Designation

Table 1. MRLC Land Use Distribution – South Fork of the Cumberland River Watershed (Tennessee portion) and Straight Fork Creek Subwatershed

Land use	Straight Fork Creek Subwatershed (051301040105)		S. Fork Cumberland River Watershed (TN only) (05130104)	
	[acres]	[%]	[acres]	[%]
Deciduous Forest	9,403.1	72.1	1,337,729	56.3
Emergent Herbaceous Wetlands	0	0	486	0.0
Evergreen Forest	562.4	4.67	262,555	11.0
High Intensity Commercial/Industrial/ Transportation	46.7	0.39	9,661	0.4
High Intensity Residential	0	0	1,523	0.1
Low Intensity Residential	85.2	0.71	16,272	0.7
Mixed Forest	1,554.1	12.91	473,331	19.9
Open Water	2.0	0.02	36,375	1.5
Other Grasses (Urban/recreational)	55.8	0.46	12,268	0.5
Pasture/Hay	236.9	1.97	172,190	7.2
Quarries/Strip Mines/Gravel Pits	0	0	2,258	0.1
Transitional	59.4	0.49	42,195	1.8
Row Crops	33.6	0.28	5,983	0.3
Woody Wetlands	0	0	4,850	0.2
Total	12,039.1	100.0	2,377,676	100.0

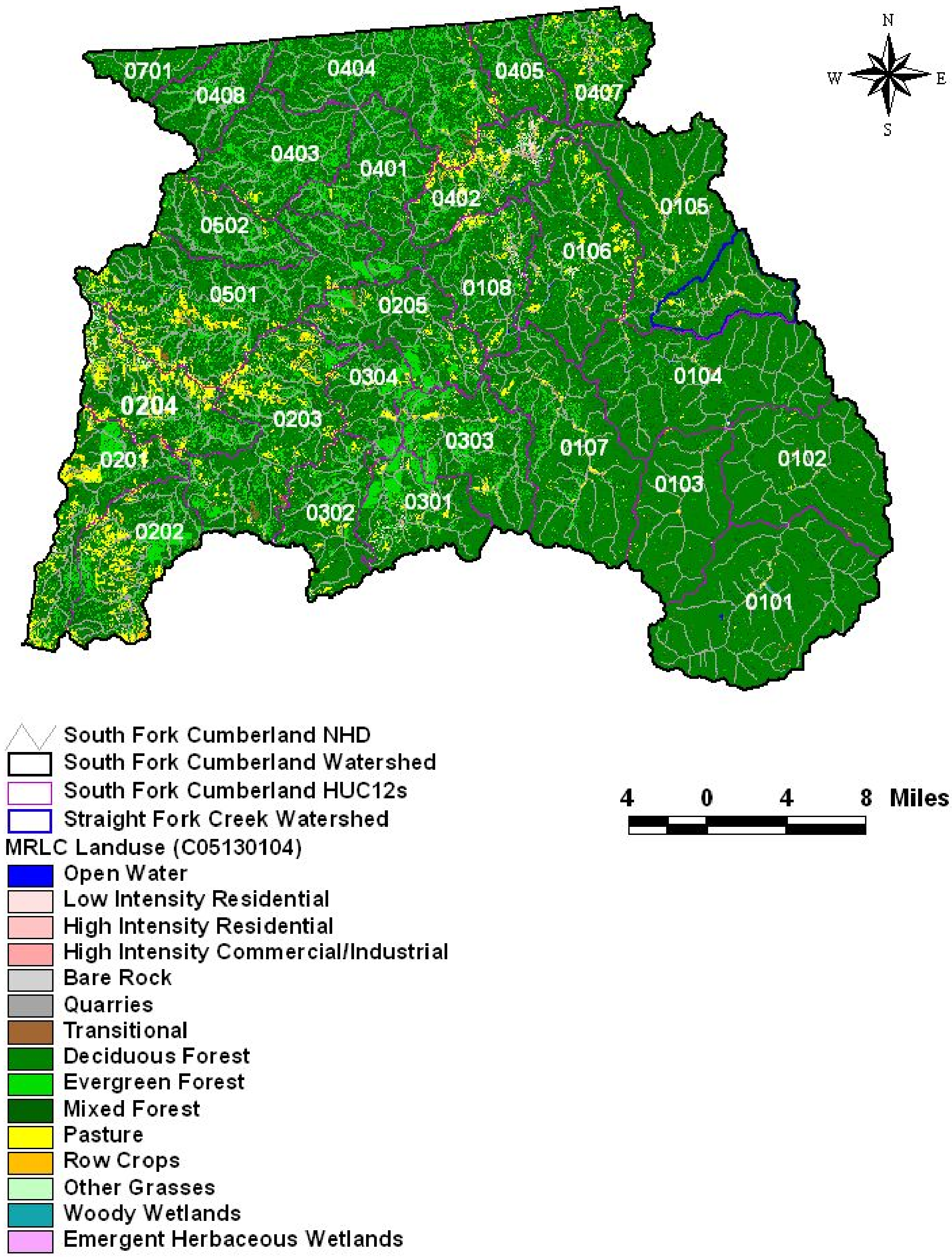

Figure 3 South Fork of the Cumberland River Watershed Land Use Distribution

3.0 PROBLEM DEFINITION

The State of Tennessee's final 2006 303(d) list (TDEC, 2006) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2006. The list identified several waterbodies in the South Fork of the Cumberland River Watershed as not supporting designated use classifications due, in part, to pH associated with abandoned mines and resource extraction. Information regarding formation of acid mine drainage (AMD) is contained in Appendix A. An excerpt from the 2006 303(d) list is presented in Table 2. There is one permitted mine in the Straight Fork Creek portion of the South Fork of the Cumberland River Watershed. Impaired segments in the South Fork of the Cumberland River Watershed are shown in Figure 4. The designated use classifications for Straight Fork Creek includes fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Table 2 2006 303(d) List – South Fork of the Cumberland River Watershed

Waterbody ID	Impacted Waterbody	County	Miles/Acres Impaired	Cause	Pollutant Source
TN05130104 044 – 0500	Straight Fork Creek	Scott	25.4	pH Other Anthropogenic Substrate Alterations	Abandoned Mining

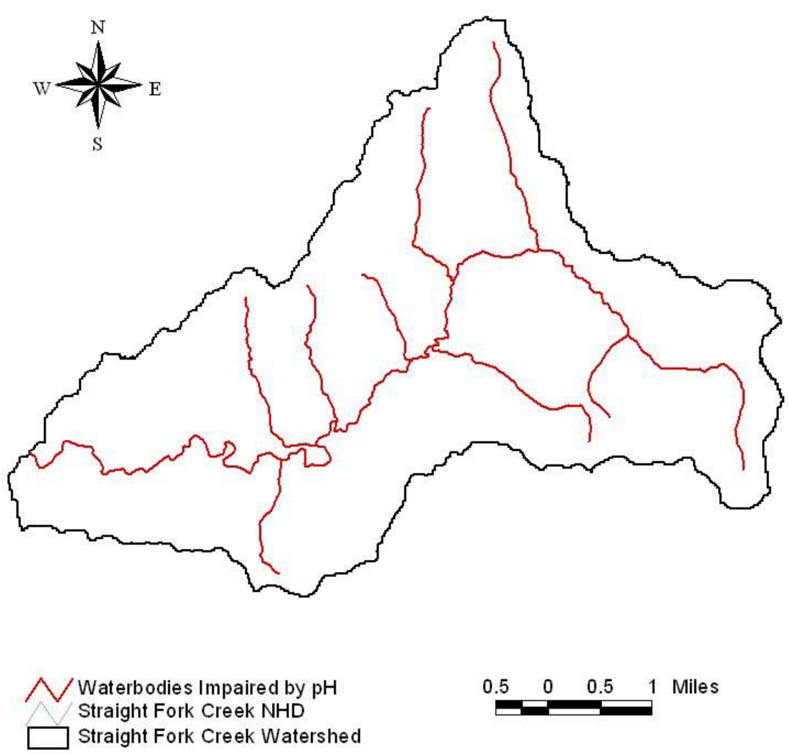

Figure 4 Straight Fork Creek Subwatershed pH-Impaired Segments

4.0 TARGET IDENTIFICATION

The allowable instream range of pH for the South Fork of the Cumberland River Watershed, is established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, January, 2004 (Revised)* (TDEC, 2004) for applicable use classifications. The Fish & Aquatic Life criteria pH range for “all other wadeable streams” of 6.0 to 9.0 is the most stringent for the waterbodies covered by this TMDL. The criteria were approved by the Environmental Protection Agency (EPA) in September 2004.

According to the Pennsylvania Department of Environmental Protection (PDEP, 1998), the “acidity or net alkalinity of a solution, not the pH, is probably the best single indicator of the severity of AMD.” In order to facilitate analysis of existing pollutant loads and load reductions required to restore the South Fork of the Cumberland River Watershed to fully supporting all of its designated use classifications, net alkalinity will be used as a surrogate parameter for TMDL development. For the purposes of this TMDL, the following terms are defined:

Acidity	The quantitative capacity of a water to react with a strong base to a designated pH. Expressed as milligrams per liter calcium carbonate.
Total Alkalinity	A measure of the ability of water to neutralize acids. Expressed as milligrams per liter calcium carbonate.
Net Alkalinity	The total alkalinity minus the acidity. Expressed as milligrams per liter calcium carbonate.

Since there is no specified numerical criterion for net alkalinity, a net alkalinity of 10.8 mg/l $CaCO_3$, was selected as the numerical target for this TMDL based on analysis of all available monitoring data for Tennessee (see Appendix B). In order to characterize net alkalinity (as $CaCO_3$) over the range of flow conditions encountered in the watershed, the target net alkalinity (as $CaCO_3$) is expressed by means of a target load duration curve. The target load duration curve, developed in Appendix C, is shown in Figure 5. In order to meet Tennessee Water Quality Standards for pH, this TMDL requires that net alkalinity (as $CaCO_3$) loads of streams in the South Fork of the Cumberland River Watershed meet, or exceed, the loads per unit area specified in the target load duration curve.

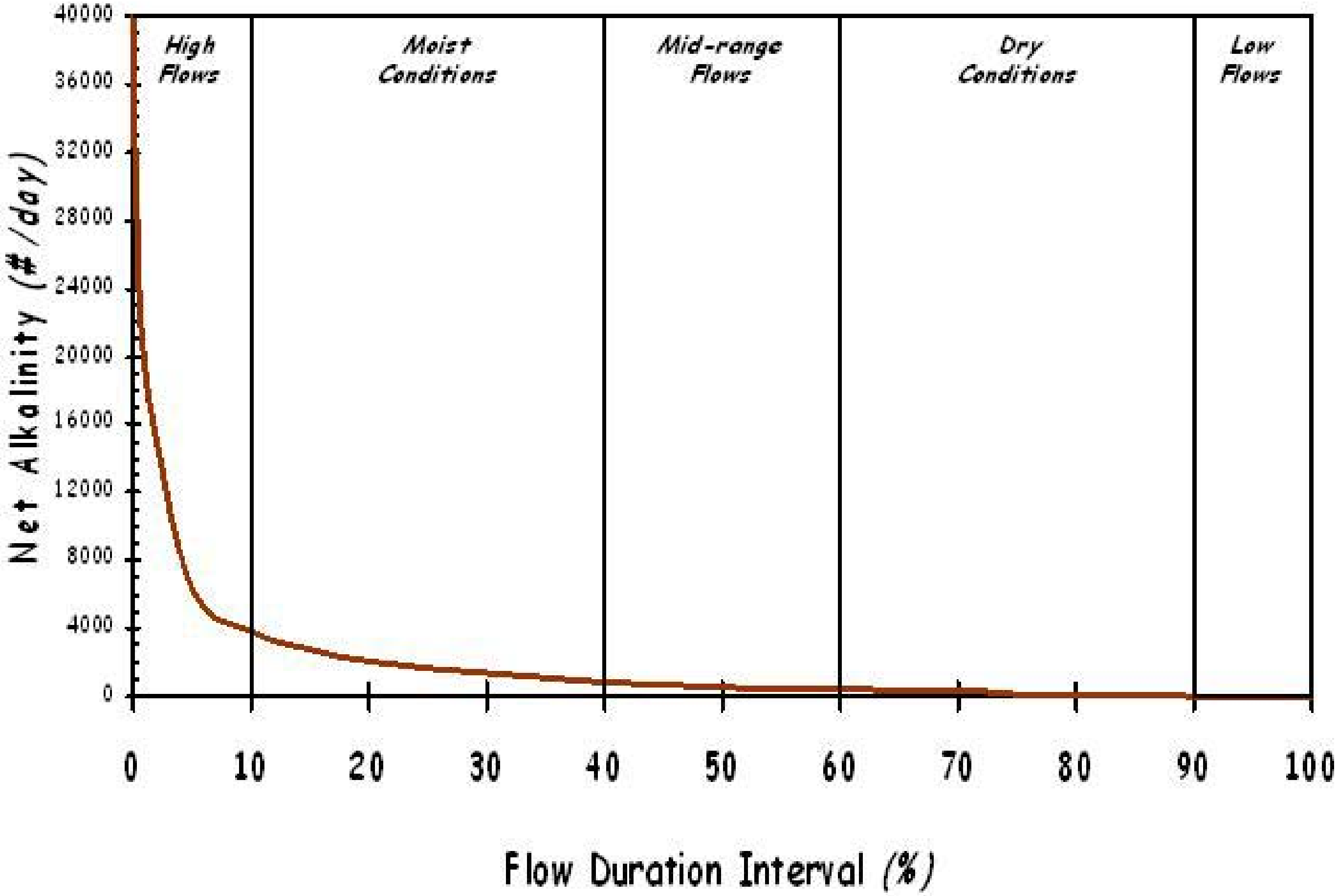

Figure 5 Target Net Alkalinity Load Duration Curve

5.0 WATER QUALITY ASSESSMENT AND DIFFERENCE FROM TARGET

Water quality monitoring of the South Fork of the Cumberland River Watershed was conducted by Division of Water Pollution Control (DWPC) personnel from the Cookeville Environmental Field Office (EFO) during the period from 6/28/04 through 10/11/04. Only one monitoring station is located on Straight Fork Creek (see Figure 6). However, no pH or metals water quality data was collected.

- STRAI001.9SC – Straight Fork Creek, at Shiloh Rd. bridge

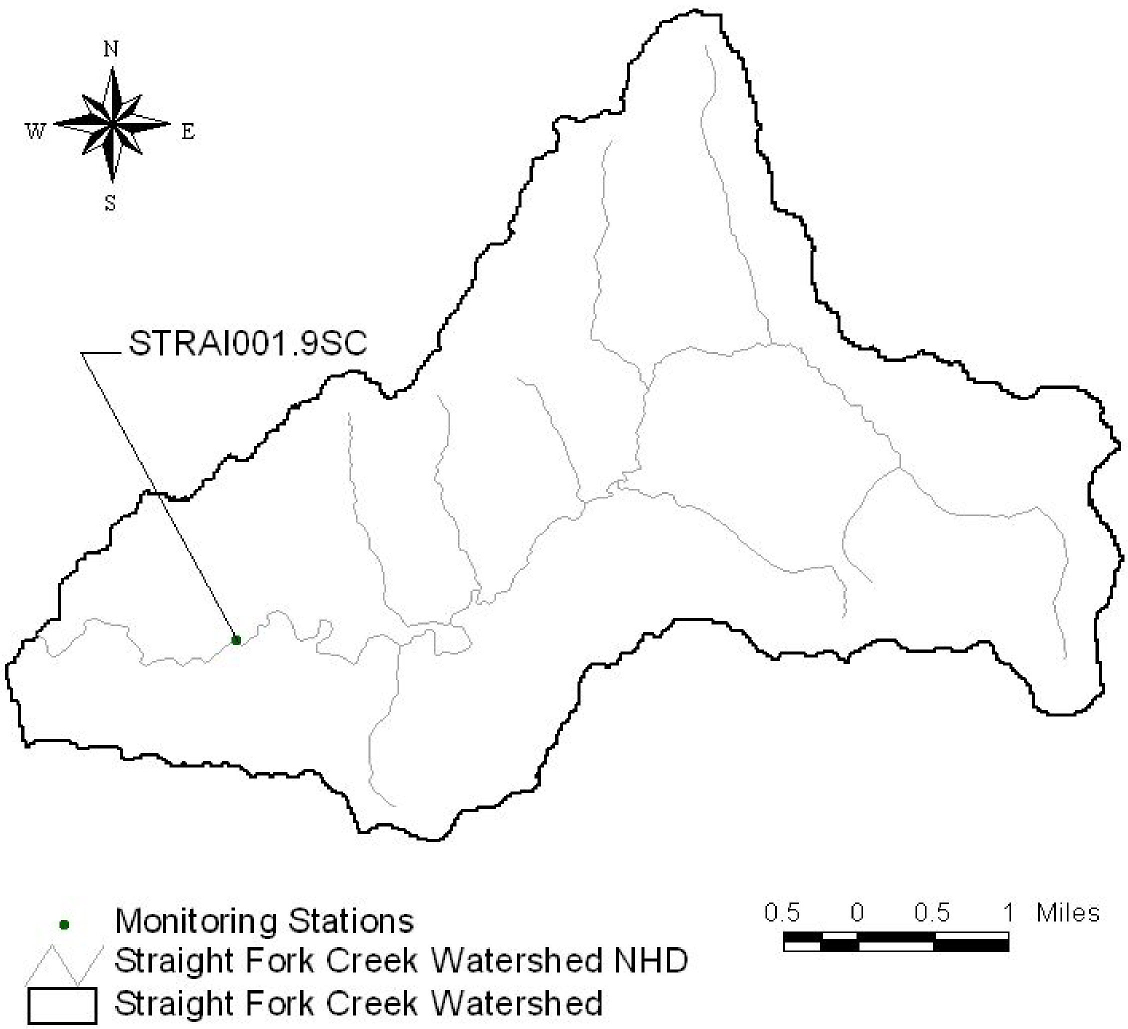

Figure 6 Straight Fork Creek Subwatershed Monitoring Stations

6.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of individual sources, or source categories, of low pH and high metals in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point or non-point sources. A point source can be defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Non-point sources include all other sources of pollution.

6.1 Point Sources

There is one facility in the Straight Fork Creek Watershed that has an NPDES permit authorizing the discharge of wastewater due to mine operations. This facility is a coal mining operation, is located in the impaired subwatershed, and discharges to a tributary of Straight Fork Creek (see Table 3 & Figure 7). The permit limits for discharges from these facilities are in accordance with the effluent limitations specified in 40 CFR §434.35 and are given in Table 4.

Table 3 NPDES Permitted Coal Mines in Impaired Subwatersheds

NPDES Permit No.	Facility	Size (acres)	Receiving Stream
TN0079120	National Coal Corp. Deep Mine #11	35.7	Simpson Branch

Table 4 NPDES Permit Limits

Constituent	Monthly Average	Daily Max
Iron, total	3.0 mg/L	6.0 mg/L
Manganese, total	2.0 mg/L	4.0 mg/L
Total Suspended Solids	35.0 mg/L	70.0 mg/L
Settleable Solids	NA	0.5 mg/L
pH	6.5 to 9.0 Standard Units at all times	

6.2 Non-point Sources

There are a number of abandoned surface mining sites in the South Fork of the Cumberland River Watershed that are susceptible to the formation of acid mine drainage as discussed in Appendix A. In the 2006 303(d) List (ref.: Table 2), abandoned mining was identified as the source of low pH in several impaired waterbodies in the watershed.

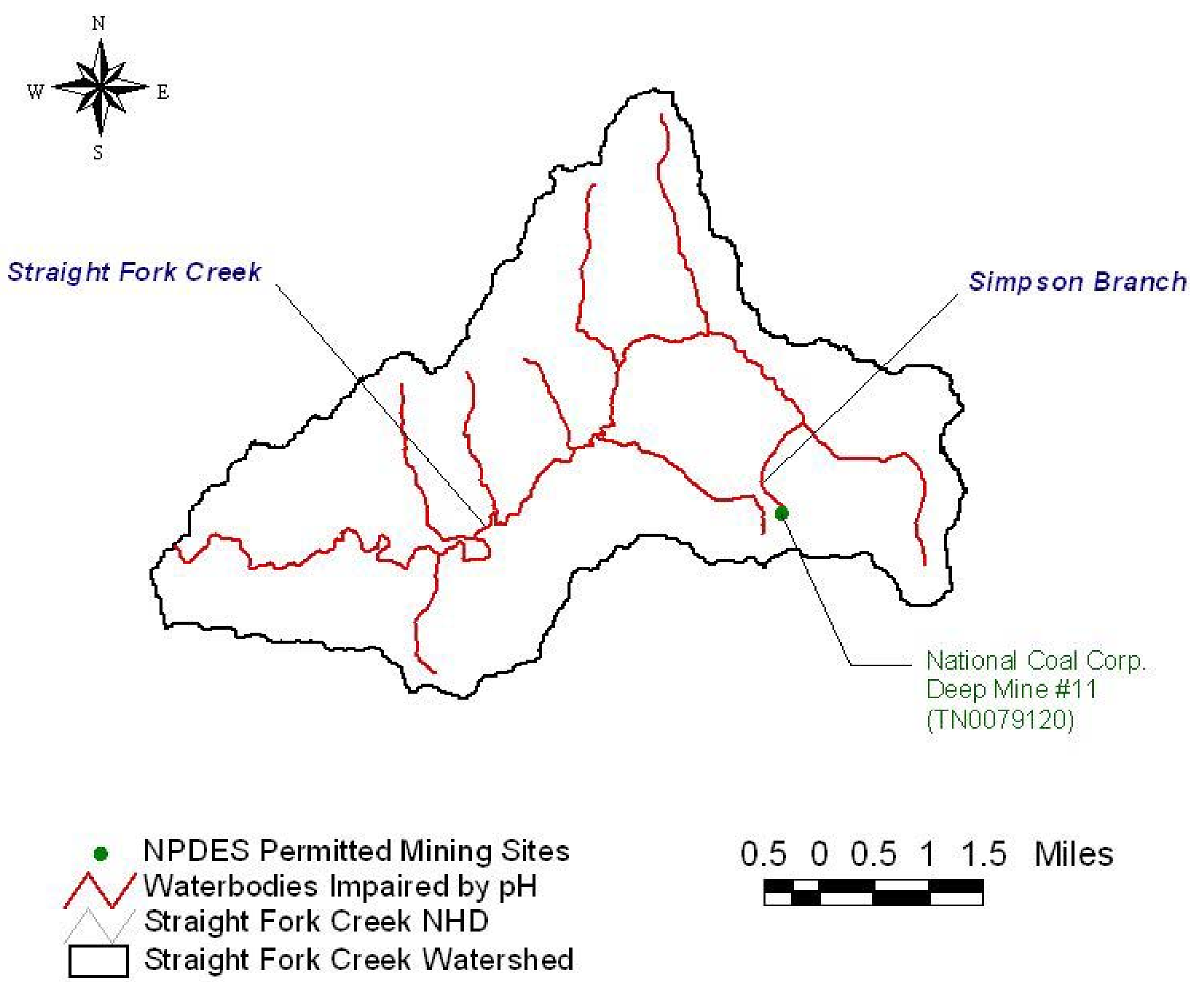

Figure 7 NPDES Permitted Mines in the Straight Fork Creek Subwatershed

7.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

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

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

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

7.1 Expression of TMDLs, WLAs, & LAs

In this document, the TMDL for each constituent is a daily load expressed as a function of mean daily flow (daily loading function). WLAs & LAs are also expressed as daily loading functions in lbs/day/acre. For implementation purposes, corresponding percent load reduction goals (PLRGs) to decrease constituent loads to TMDL target levels are also expressed.

7.2 TMDL Analysis Methodology

TMDLs for the South Fork of the Cumberland River Watershed were developed using load duration curves for analysis of impaired waterbodies. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow zone represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and daily loading functions were expressed for TMDLs, WLAs, LAs, and MOS.

7.3 TMDL Representation

In general, waterbodies become impaired due to excessive loading of particular pollutants that result in concentrations that violate instream water quality standards. A TMDL establishes the maximum load that can be assimilated by the waterbody, without violating standards, and allocates portions of this load to point and non-point sources. This normally involves reductions in loading from existing levels, with WLAs & LAs of zero load reduction as the ideal.

The use of net alkalinity as a surrogate parameter, however, requires a different approach. Existing levels of net alkalinity in impaired subwatersheds may be negative, while target values are positive. The concept of a "maximum net alkalinity load" does not appropriately represent the desired target condition with respect to AMD caused impairment. Net alkalinity targets can be achieved by reducing acidity, increasing total alkalinity, or some combination of both.

7.4 Critical Conditions and Seasonal Variation

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

The ten-year period from January 1, 1996 to December 31, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions and seasonal variation are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies.

7.5 Margin of Safety

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

For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions. These include: 1) the use of a 10-year continuous simulation that incorporates a wide range of meteorological events, 2) the use of the load duration curve, which addresses pollutant loading over the entire range of flow, and 3) the use of a positive net alkalinity target of 10.8 mg/L based on analysis of all available monitoring data for Tennessee (see Appendix B).

7.6 Determination of Total Maximum Daily Loads

Daily loading functions were calculated for impaired segments in the South Fork of the Cumberland River Watershed using LDCs to evaluate compliance with the maximum target concentrations according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subsequent subwatersheds are shown in Table 5. Note that for net alkalinity, the TMDL represents the minimum loading rather than the maximum loading.

7.7 Determination of WLAs, & LAs

WLAs and LAs were determined according to the procedures in Appendix C. These allocations represent the available loading after application of the explicit MOS. For waterbodies with no active mining operations, there is no WLA and the LA for pH is equal to the TMDL for pH. The TMDLs, WLAs, and LAs for net alkalinity in the Straight Fork Creek Subwatershed are summarized in Table 5.

Table 5. TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Straight Fork Creek Subwatershed (HUC051301040105)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	PLRG	TMDL	Explicit MOS	WLAs	LAs
			[%]	[lbs/day]	[lbs/day]	[lbs/day]	[lbs/day/ac]
Straight Fork Creek	TN05130104044 – 0500	Net Alkalinity	NA	58.1 x Q	NA[a]	58.1 x Q_2	{(4.83 x 10^{-3}) x Q} – {(4.83 x 10^{-3}) x Q_2}

Notes: NA = Not Applicable.
NR = No Reduction Required
PLRG = Percent Load Reduction Goal
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Point Sources; because Q_2 is driven by rainfall and the drainage area for Q_2 (35.7 acres) << the drainage area for Q (12,000 acres), Q_2 << Q.

a. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.5).

8.0 IMPLEMENTATION PLAN

Monitoring conducted in 2000 thru 2004 has identified a number of waterbodies in the South Fork of the Cumberland River Watershed as impaired due to low pH. This condition is a result of AMD from land disturbance caused by past coal mining activities. Acid mine drainage has one or more of four major components: high acidity (low pH < 6 or alkalinity < 20 mg/L), high metal concentrations (> 500 μg/L), elevated sulfate levels (> 74 mg/L), and excessive suspended solids and/or siltation.

Required LAs will be implemented in several steps to reduce acidity and/or increase total alkalinity so as to result in an increase of instream net alkalinity. In order to meet Tennessee Water Quality Standards for pH, this TMDL requires that net alkalinity (as $CaCO_3$) loads of streams in the South Fork of the Cumberland River Watershed meet, or exceed, the daily loading functions specified in Table 5.

Step 1: Conduct water quality testing for Straight Fork Creek to confirm its status as impaired by pH. No monitoring data was available.

Step 2: Conduct additional water and minespoil testing to identify specific AMD sites and delineate actual areas of acid production at each site.

Step 3: Once sites have been identified, remediation plans will be developed utilizing primarily passive treatment schemes (versus treatment by chemical addition) to provide a long-term solution to stream impairment. Remediation measures that have proved successful include, but are not limited to:

- Regrading of spoil
- Isolation of acid producing material from water contact
- Anoxic limestone drains
- Constructed wetlands.

The Abandoned Mine Lands Section of the DWPC has expertise in the development of AMD remediation plans and has completed a number of reclamation projects on abandoned mines in the Tennessee coalfield. A number of these projects have included measures designed to remediate acid production caused by land disturbance due to past mining. One reclamation project was completed at the Three Sisters site in the North Chickamauga Creek subwatershed in 2000 at a cost of $95,000.

The Mining Section issues NPDES permits for discharges of wastewater from coal and non-coal mines and, where applicable, Mining Law permits to non-coal facilities in Tennessee. This section of the DWPC has worked with a number of permitted mine sites, offering considerable technical advice in the remediation of problems similar to those found in the South Fork of the Cumberland River Watershed.

Step 4: Conduct follow-on water quality testing of impaired waterbodies in the Straight Fork Creek Subwatershed to verify the effectiveness of remediation measures. Parameters should include flow, pH, acidity, and total alkalinity.

9.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pH TMDL for the South Fork of the Cumberland River Watershed will be placed on Public Notice for a 35-day period and comments solicited. Steps that will be taken in this regard include:

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

3) Letters were sent to NPDES-permitted mines located in pH- or metal-impaired subwatersheds or drainage areas in the South Fork of the Cumberland River Watershed, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. A letter was sent to the following entities:

   National Coal Corp., Deep Mine #11 (TN0079120)

10.0 FURTHER INFORMATION

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

www.state.tn.us/environment/wpc/tmdl.htm

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

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APPENDIX A

Acid Mine Drainage

Acid Mine Drainage Formation

The following information regarding acid mine drainage formation was taken from the U.S. Department of Interior, Office of Surface Mining (OSM) website at www.osmre.gov/amdform.htm. The first section on the Chemistry of Pyrite Weathering is reproduced below. Discussion of subsequent sections can be found on the OSM website.

The formation of acid drainage is a complex geochemical and microbially mediated process. The acid load ultimately generated from a minesite is primarily a function of the following factors:

- Chemistry
- Microbiological Controls
- Depositional environment
- Acid/base balance of the overburden
- Lithology
- Mineralogy
- Minesite hydrologic conditions

Chemistry of Pyrite Weathering

A complex series of chemical weathering reactions are spontaneously initiated when surface mining activities expose spoil materials to an oxidizing environment. The mineral assemblages contained in the spoil are not in equilibrium with the oxidizing environment and almost immediately begin weathering and mineral transformations. The reactions are analogous to "geologic weathering" which takes place over extended periods of time (i.e., hundreds to thousands of years) but the rates of reaction are orders of magnitude greater than in "natural" weathering systems. The accelerated reaction rates can release damaging quantities of acidity, metals, and other soluble components into the environment. The pyrite oxidation process has been extensively studied and has been reviewed by Nordstrom (1979). For purposes of this description, the term "pyrite" is used to collectively refer to all iron disulfide minerals.

The following equations show the generally accepted sequence of pyrite reactions:

$2\ FeS_2 + 7\ 0_2 + 2\ H_2O \rightarrow\rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+$ (Equation 1)

$4\ Fe^{2+} + O_2 + 4\ H^+ \rightarrow 4\ Fe^{3+} + 2\ H_2O$ (Equation 2)

$4\ Fe^{3+} + 12\ H_2O \rightarrow 4\ Fe(OH)_3 + 12\ H^+$ (Equation 3)

$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$ (Equation 4)

In the initial step, pyrite reacts with oxygen and water to produce ferrous iron, sulfate and acidity. The second step involves the conversion of ferrous iron to ferric iron. This second reaction has been termed the "rate determining" step for the overall sequence.

The third step involves the hydrolysis of ferric iron with water to form the solid ferric hydroxide (ferrihydrite) and the release of additional acidity. This third reaction is pH dependent. Under very acid conditions of less than about pH 3.5, the solid mineral does not form and ferric iron remains in solution. At higher pH values, a precipitate forms, commonly referred to as “yellowboy.”

The fourth step involves the oxidation of additional pyrite by ferric iron. The ferric iron is generated by the initial oxidation reactions in steps one and two. This cyclic propagation of acid generation by iron takes place very rapidly and continues until the supply of ferric iron or pyrite is exhausted. Oxygen is not required for the fourth reaction to occur.

The overall pyrite reaction series is among the most acid-producing of all weathering processes in nature.

APPENDIX B

Development of Target Net Alkalinity

Since there is no numerical criterion for net alkalinity, all available monitoring data for the State of Tennessee was examined in an effort to develop a target net alkalinity.

Of the available monitoring data for waterbodies that are not impaired for pH, 47 data points existed for which numerical values for both acidity and total alkalinity were available. (See Figure B-1.) The highest calculated net alkalinity that fell outside of the desired pH range of 6.0 to 9.0 was 10.78 mg/L as $CaCO_3$ at a pH of 9.1. Therefore, a net alkalinity of 10.8 was selected as the target net alkalinity.

Analysis was then expanded to include monitoring data for waterbodies that are not impaired for pH and for which both total alkalinity and acidity were analyzed, but for which either acidity or total alkalinity, but not both, was not detected. (See Figure B-2.) For the purpose of calculating net alkalinity, the analyte concentrations were estimated to be one half of the appropriate detection limit (10 mg/L for total alkalinity and 1 mg/L for acidity). Of the 211 data points, only 3 points (or 1.4%) exceeded the target net alkalinity value of 10.8 mg/L $CaCO_3$ but were not within the required pH range.

Available monitoring data for waterbodies that are included on the 303(d) List as impaired for pH were also compared to the target net alkalinity. Of 41 data points for which numerical values for both acidity and total alkalinity were available, only 2 points (or 4.9%) exceeded the target net alkalinity value of 10.8 mg/L $CaCO_3$ but was not within the required pH range. These data points were for North Suck Creek on 5/21/2005 (pH 5.14, net alkalinity 16.9) and South Suck Creek on 9/9/2004 (pH 5.2, net alkalinity 29.96). When analysis was expanded to include data points for which both acidity and total alkalinity were analyzed, but for which either acidity or total alkalinity, but not both, was not detected, only 3 points (or 2.0%) exceeded the target net alkalinity value of 10.8 mg/L $CaCO_3$ but were not within the required pH range. These data points were the previously mentioned points for North and South Suck Creek and a data point for North Suck Creek on 3/22/2005 (pH 5.8, net alkalinity 18.5).

Therefore, based on analysis of all available monitoring data for the State of Tennessee, selection of a target net alkalinity of 10.8 mg/L as $CaCO_3$ should provide a pH within the criteria of 6.0 to 9.0 standard pH units for waterbodies with a designated use of Fish & Aquatic Life.

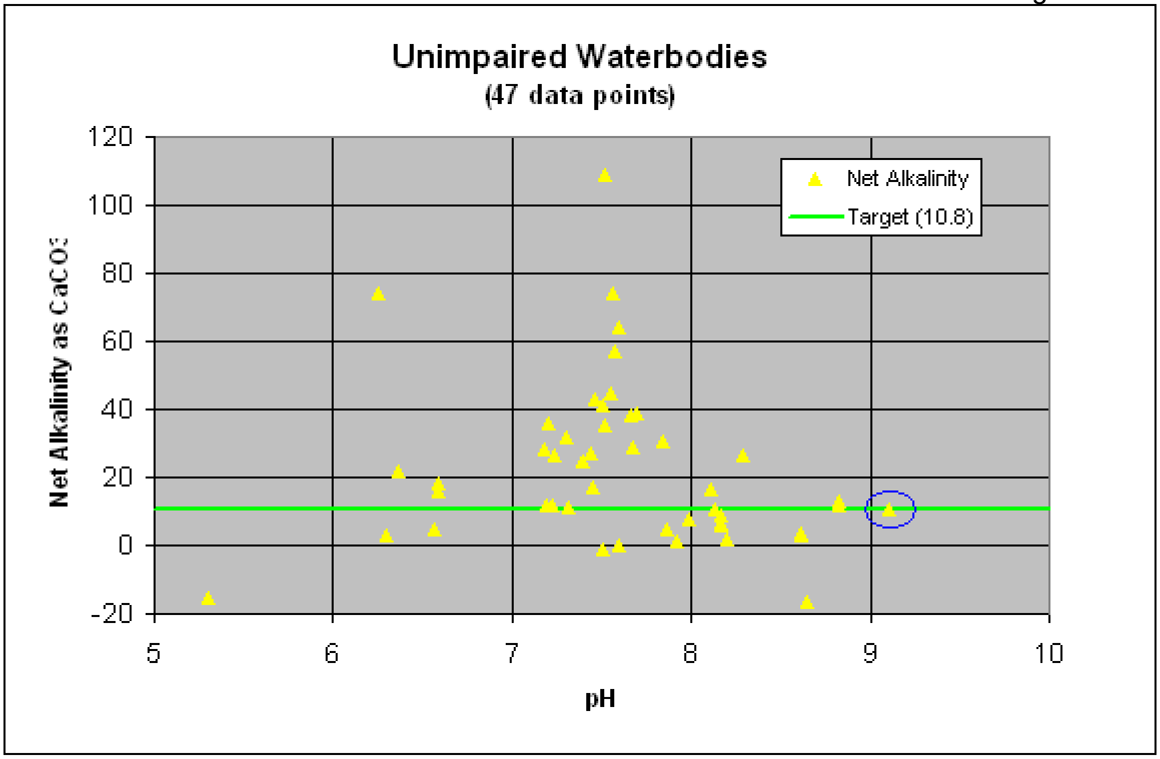

Figure B-1 pH and Net Alkalinity for Unimpaired Waterbodies in Tenneessee
(no non-detects for either acidity or total alkalinity)

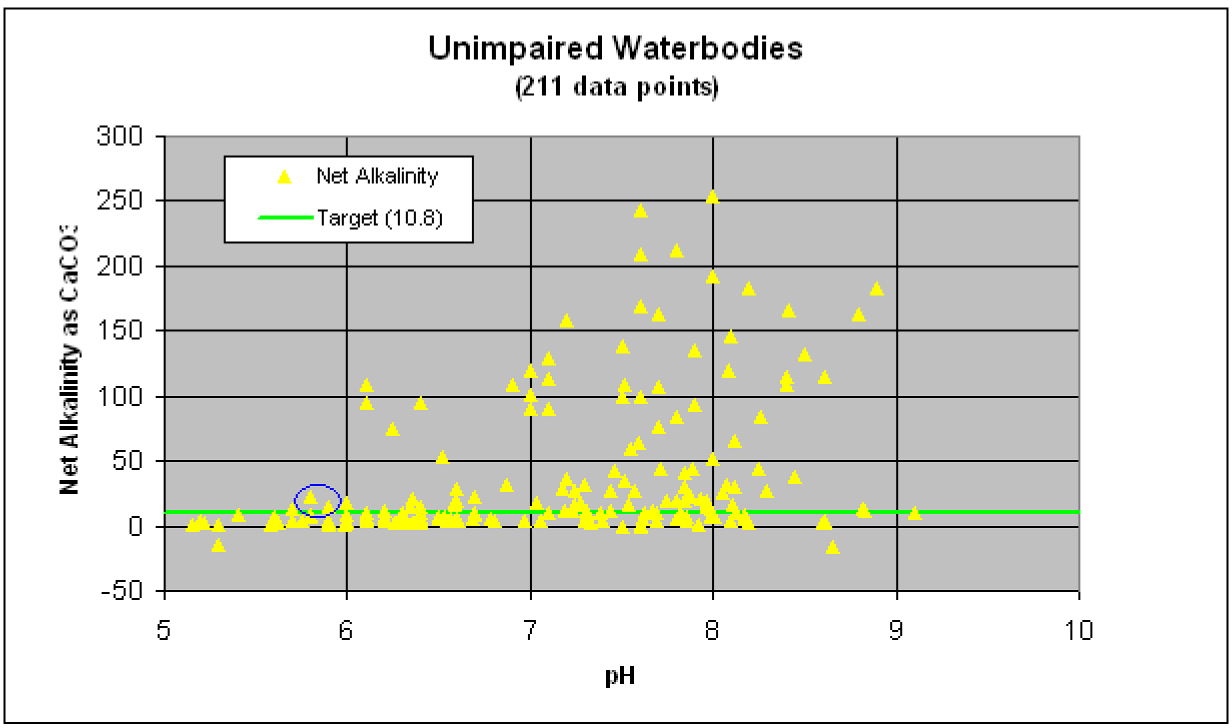

Figure B-2 pH and Net Alkalinity for Unimpaired Waterbodies in Tenneessee
(acidity or total alkalinity was not detected; 0.5 x detection limit used for non detects)

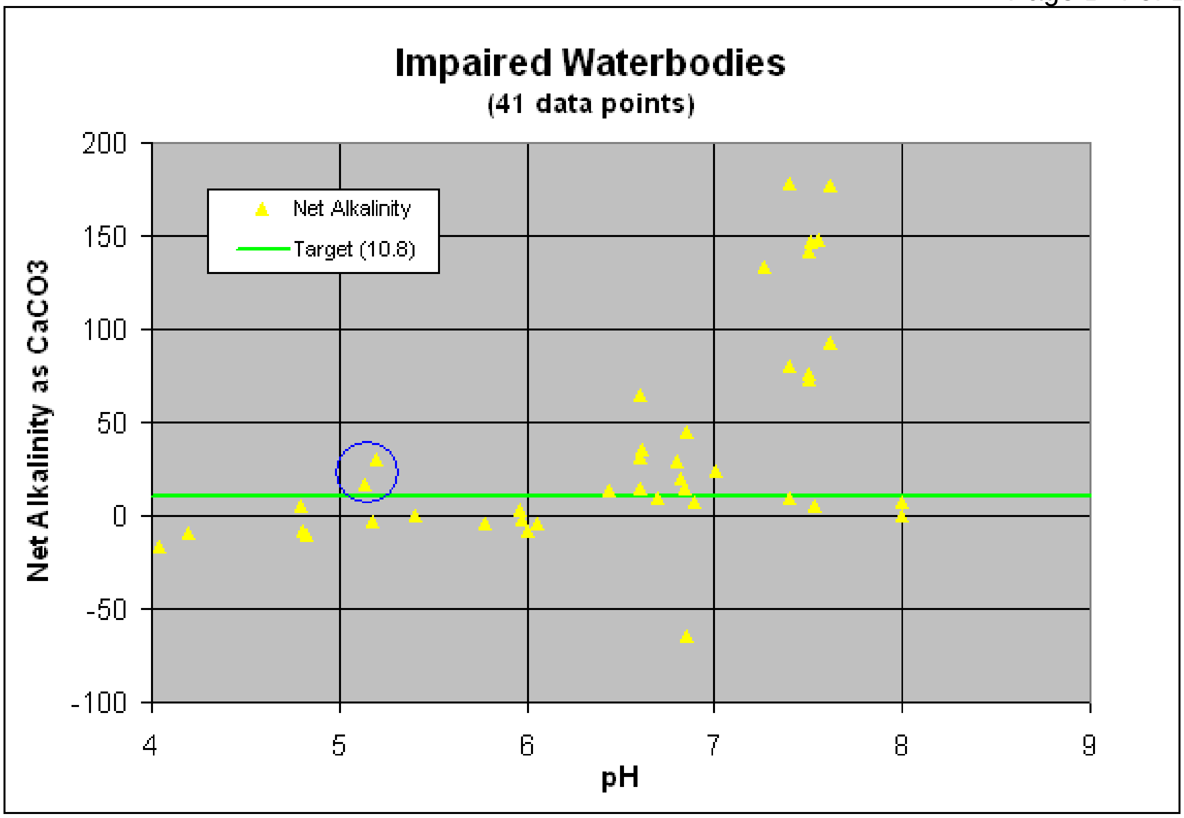

Figure B-3 pH and Net Alkalinity for Impaired Waterbodies in Teneessee
(no non-detects for either acidity or total alkalinity)

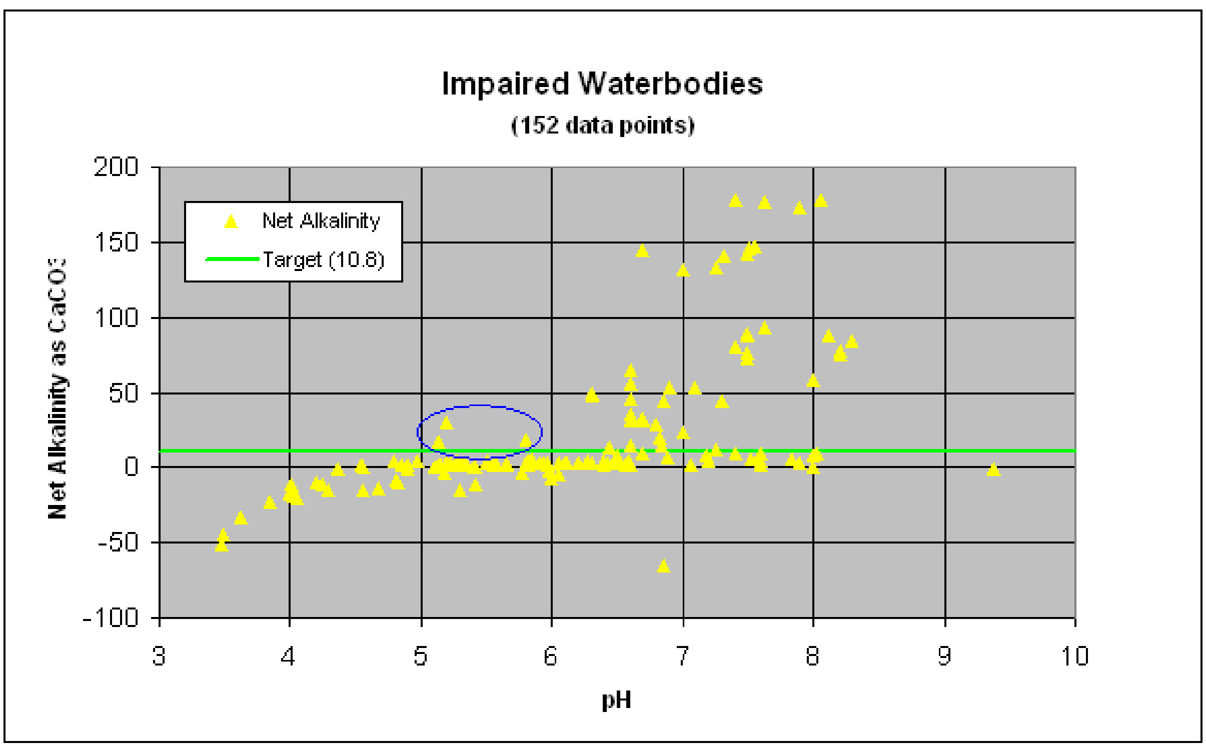

Figure B-4 pH and Net Alkalinity for Impaired Waterbodies in Teneessee
(acidity or total alkalinity was not detected; 0.5 x detection limit used for non detects)

APPENDIX C

Load Duration Curve Development
and
Determination of Daily Loading

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

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

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) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

Net alkalinity TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Straight Fork Creek Subwatershed using Load Duration Curves (LDCs). Daily Loads for TMDLs, WLAs, and LAs are expressed as a function of daily mean in-stream flow (daily loading function).

C.1 Development of Flow Duration Curves

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

Flow duration curves for pH-impaired waterbodies in the Straight Fork Creek Subwatershed were derived from LSPC hydrologic simulations based on parameters derived from calibration at USGS Station No. 03408500, located on New River at New River, Tennessee, in the South Fork of the Cumberland River watershed (see Appendix D for details of calibration). For example, a flow-duration curve for Straight Fork Creek was constructed using simulated daily mean flow for the period from 10/1/95 through 9/30/05. This flow duration curve is shown in Figure C-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time).

C.2 Development of Load Duration Curves

When a water quality target concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. The target net alkalinity load duration curve for the Straight Fork Creek Subwatershed was developed from the flow duration curve for Straight Fork Creek developed in Section C.1. The net alkalinity target concentration of 10.8 mg/L was applied to each of the ranked flows used to generate the flow duration curve and the results were plotted. The net alkalinity target load corresponding to each ranked daily mean flow is:

Target Load = (10.8) x (Q) x (UCF)

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

The target net alkalinity load duration curve is presented in Figures C-2 and C-3. Figure C-2 is presented in semi-log scale format while Figure C-3 is presented in non-log scale format. Because the calculated net alkalinity of the Straight Fork Creek Subwatershed can be negative and negative values cannot be plotted on a log or semi-log scale format, the non-log scale format will be used for net alkalinity load duration curves in this TMDL.

Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into four zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-70%), and low flows (70-100%). Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left on the LDC (representing zones of higher flow) generally reflect potential nonpoint source contributions (Stiles, 2003).

C.3 Development of WLAs, LAs, and MOS

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

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

C.4 Daily Load Calculations

Each of the terms in the equation above can be derived sequentially:

TMDL = (Target Concentration) x (Q) x (UCF)

where: Target Concentration = water quality criterion
Q = daily mean flow
UCF = the required unit conversion factor

For Straight Fork Creek:

TMDL = (10.8 mg/L) x (Q) x (UCF)

TMDL = 58.1 x Q (lbs/day)

By rearranging the equation in section C.3 and expressing on a unit area basis:

Σ LAs = (TMDL – MOS – Σ WLAs) / DA

where: DA = waterbody drainage area (acres)

When permitted point sources exist, the applicable WLA must be calculated:

WLA = {(Permit Limit) x (Q_2) x (UCF)}

where: Q_2 = daily mean flow for combined point sources
UCF = the required unit conversion factor

WLA = (10.8 mg/L x Q_2 x UCF)

WLA = 58.1 x Q_2 (lbs/day)

Finally, the LA must be calculated. (The MOS in the equation is zero because an implicit MOS was incorporated through the use of conservative modeling assumptions.):

LA = {(58.1 x Q) – (0) – (58.1 x Q_2)} / (12,039.1)

LA = {(4.83×10^{-3}) x Q} – {(4.83×10^{-3}) x Q_2} (lbs/day/ac)

TMDLs, WLAs, & LAs for the Straight Fork Creek Subwatershed are summarized in Table C-1.

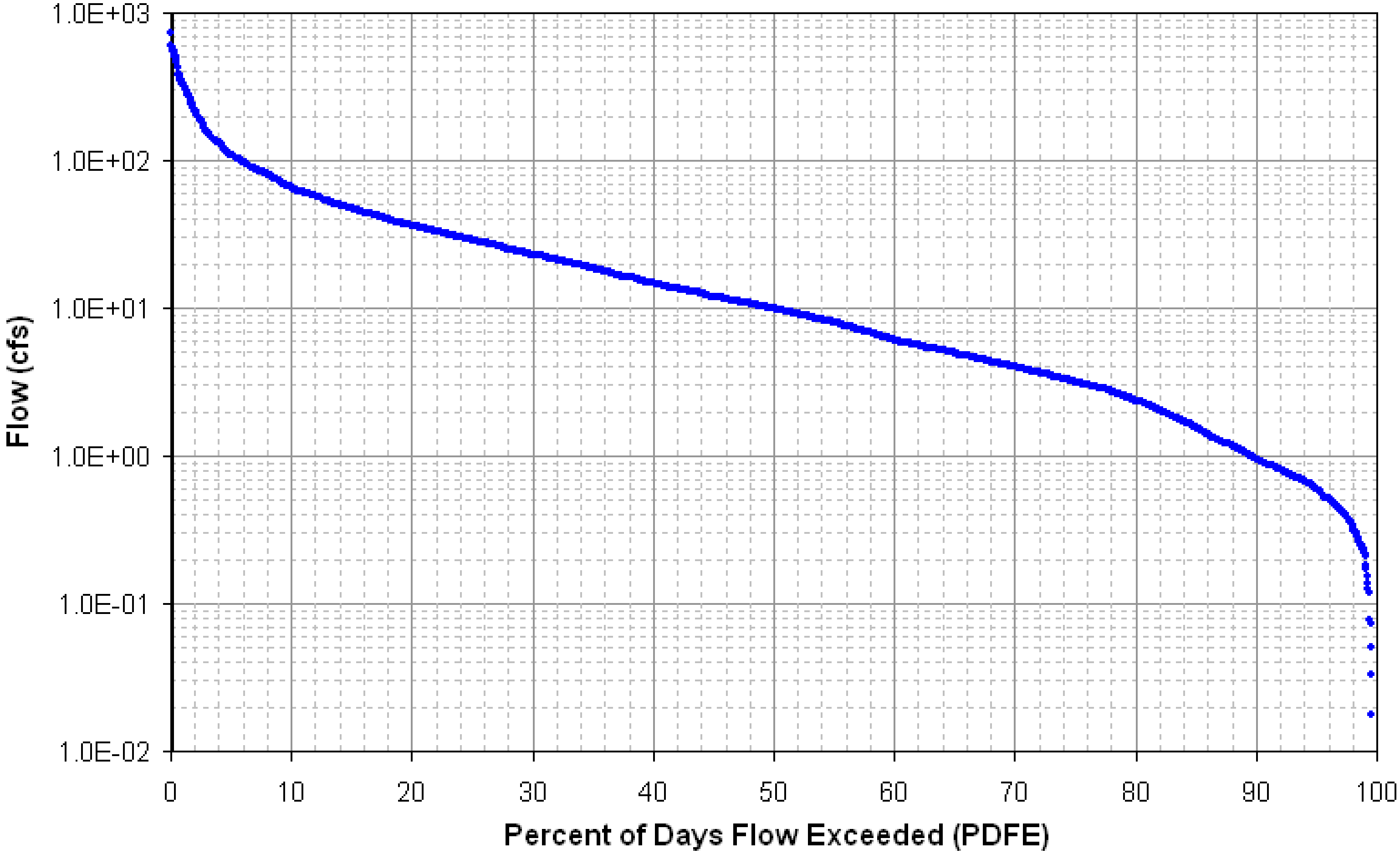

Figure C-1 Flow Duration Curve for Straight Fork Creek

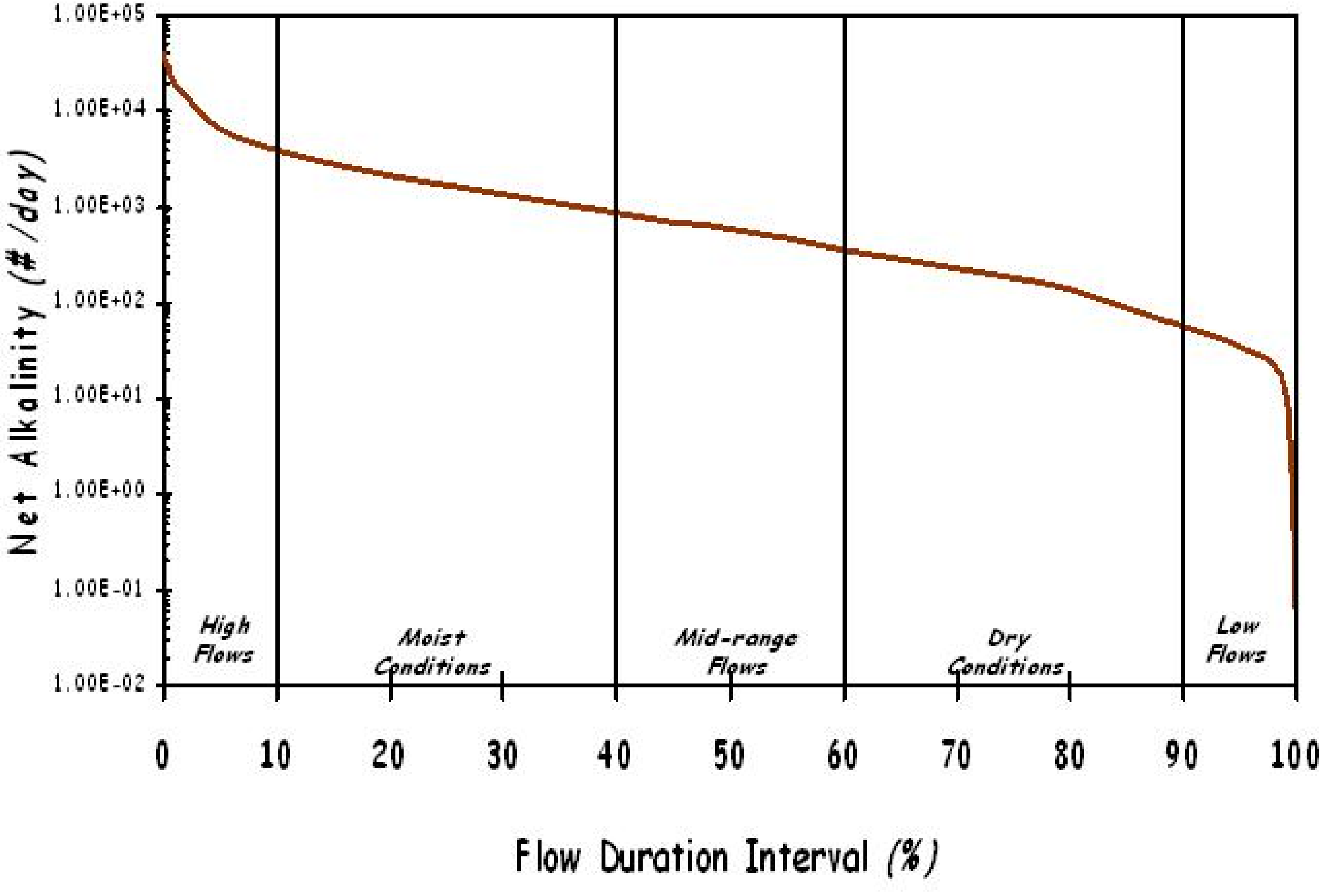

Figure C-2 Target Net Alkalinity Load Duration Curve (semi-log-scale)

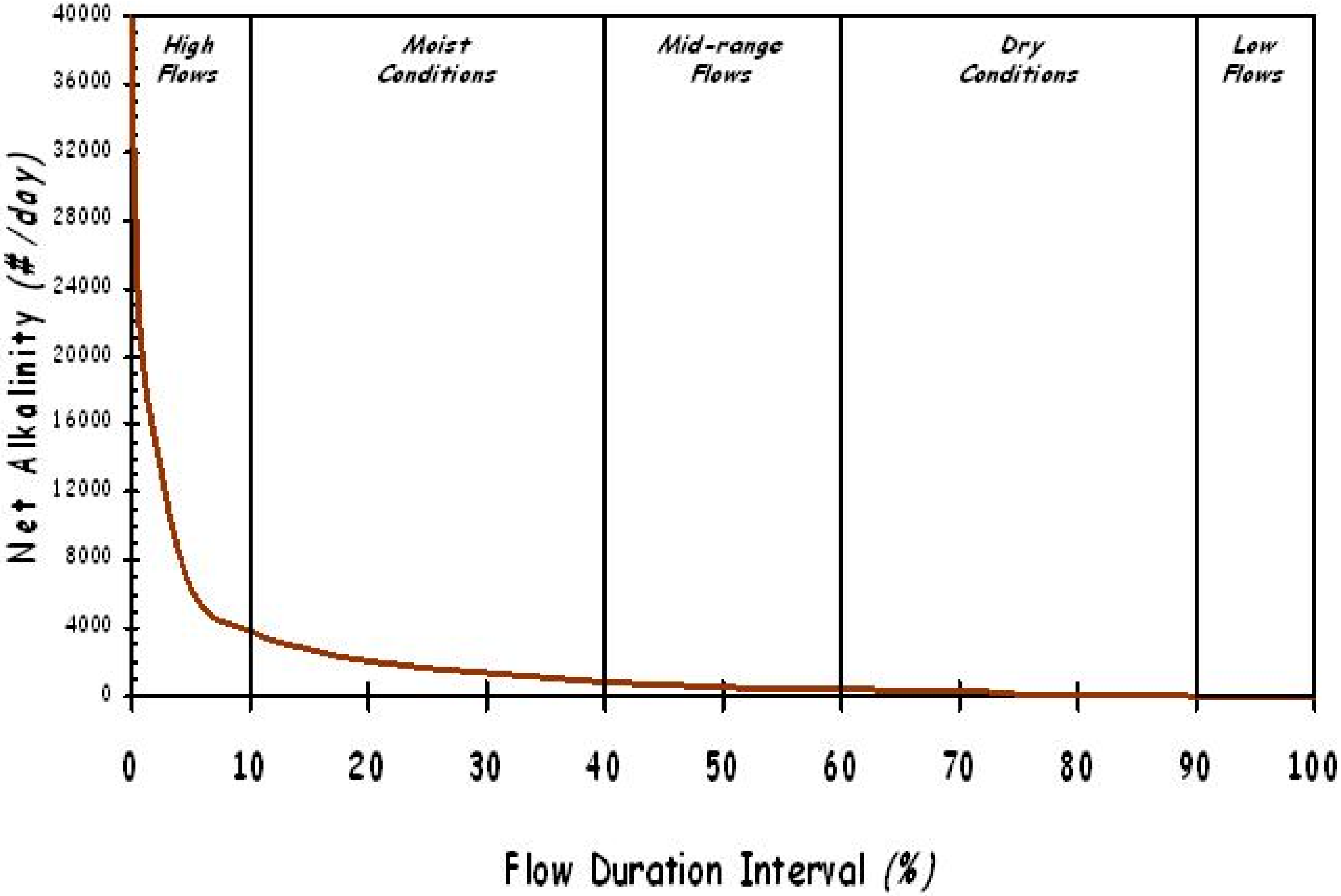

Figure C-3 Target Net Alkalinity Load Duration Curve (non-log scale)

Table C-1. TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Straight Fork Creek Subwatershed (HUC051301040105)

Impaired Waterbody Name	Impaired Waterbody ID	Constituent	PLRG	TMDL	Explicit MOS	WLAs	LAs
			[%]	[lbs/day]	[lbs/day]	[lbs/day]	[lbs/day/ac]
Straight Fork Creek	TN05130104044 – 0500	Net Alkalinity	NA	58.1 x Q	NA[a]	58.1 x Q_2	{(4.83×10^{-3}) x Q} – {(4.83×10^{-3}) x Q_2}

Notes: NA = Not Applicable.
NR = No Reduction Required
PLRG = Percent Load Reduction Goal
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Point Sources; because Q_2 is driven by rainfall and the drainage area for Q_2 (35.7 acres) << the drainage area for Q (12,000 acres), Q_2 << Q.

a. For development of net alkalinity TMDLs, an implicit MOS was incorporated through the use of conservative modeling assumptions (see Section 7.5).

APPENDIX D

Hydrodynamic Modeling Methodology

D.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for TMDL analyses of pH- and metal-impaired waters in the South Fork of the Cumberland River Watershed. LSPC is a watershed model capable of performing flow routing through stream reaches. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program – Fortran (HSPF).

D.2 Model Set Up

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

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

An important factor influencing model results is the precipitation data contained in the meteorological data file used in the simulation. Weather data from the Knoxville meteorological station were available for the time period from January 1980 through December 2005. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (10/1/95 – 9/30/05) used for TMDL analysis.

D.3 Model Calibration

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

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

The results of the hydrologic calibration for New River at New River, Tennessee, USGS Station 03408500, are shown in Table D-1 and Figures D-1 and D-2.

Table D-1 Hydrologic Calibration Summary: New River, USGS 03408500

				381.96	sq. m
	Simulation Name:	3408500	**Simulation Period:**		
		New River @ New River	**Watershed Area (ac):**	244456.93	
	Period for Flow Analysis				
	Begin Date:	**07/01/98**	**Baseflow PERCENTILE:**	2.5	
	End Date:	**06/30/04**	*Usually 1%-5%*		
	Total Simulated In-stream Flow:	**130.26**	Total Observed In-stream Flow:	**137.03**	
	Total of highest 10% flows:	**71.67**	Total of Observed highest 10% flows:	**74.48**	
	Total of lowest 50% flows:	**8.23**	Total of Observed Lowest 50% flows:	**7.91**	
	Simulated Summer Flow Volume (months 7-9):	**15.86**	Observed Summer Flow Volume (7-9):	**10.63**	
	Simulated Fall Flow Volume (months 10-12):	**18.27**	Observed Fall Flow Volume (10-12):	**19.77**	
	Simulated Winter Flow Volume (months 1-3):	**60.40**	Observed Winter Flow Volume (1-3):	**65.07**	
	Simulated Spring Flow Volume (months 4-6):	**35.73**	Observed Spring Flow Volume (4-6):	**41.55**	
	Total Simulated Storm Volume:	**128.87**	Total Observed Storm Volume:	**136.42**	
	Simulated Summer Storm Volume (7-9):	**15.52**	Observed Summer Storm Volume (7-9):	**10.48**	
	Errors (Simulated-Observed)		*Recommended Criteria*	Last run	
	Error in total volume:	**-4.94**	10		
	Error in 50% lowest flows:	**4.04**	10		
	Error in 10% highest flows:	**-3.78**	15		
***	Seasonal volume error - Summer:	**49.15**	30		
	Seasonal volume error - Fall:	**-7.63**	30		
	Seasonal volume error - Winter:	**-7.18**	30		
	Seasonal volume error - Spring:	**-14.00**	30		
	Error in storm volumes:	**-5.54**	20		
	Error in summer storm volumes:	**48.04**	50		

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

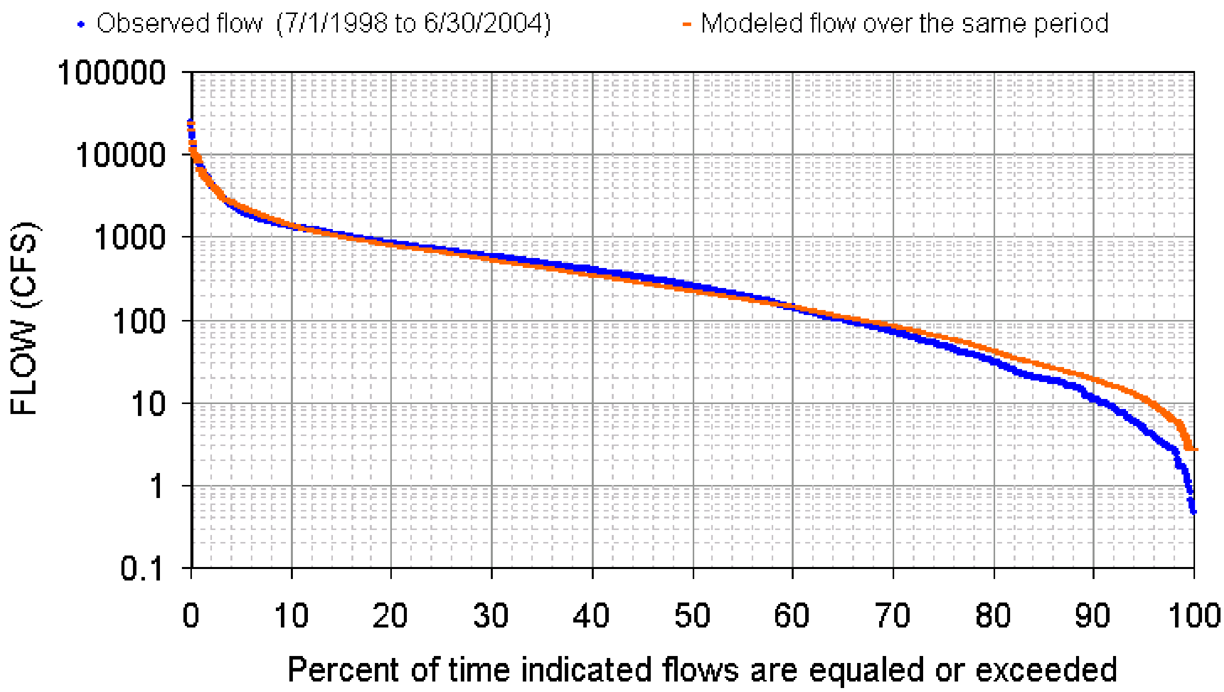

Figure D-1. Hydrologic Calibration: New River, USGS 03408500

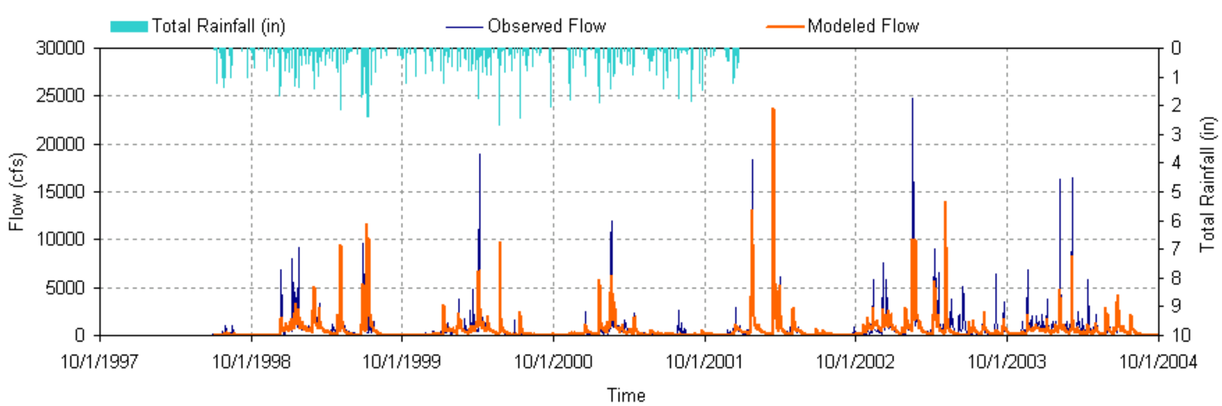

Figure D-2. 7-Year Hydrologic Comparison: New River, USGS 03408500

APPENDIX E

Public Notice Announcement

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

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOADS (TMDLs) FOR pH IN THE STRAIGHT FORK CREEK SUBWATERSHED SOUTH FORK CUMBERLAND RIVER WATERSHED (HUC 05130104), TENNESSEE

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

Straight Fork Creek is listed on Tennessee's Final 2006 303(d) list as not supporting designated use classifications due, in part, to low pH associated with abandoned mines. The TMDL utilizes Tennessee's general water quality criteria, net alkalinity (as $CaCO_3$) as a surrogate for pH, USGS continuous record station flow data, in-stream water quality monitoring data, a calibrated dynamic water quality model, load duration curves, and an appropriate Margin of Safety (MOS) to establish loadings of net alkalinity (as $CaCO_3$) which will result in the attainment of water quality standards for pH.

The proposed Straight Fork Creek pH TMDL may be downloaded from the Department of Environment and Conservation website:

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

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

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

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

Persons wishing to comment on the proposed TMDL are invited to submit their comments in writing no later than November 12, 2007 to:

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

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

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