TOTAL MAXIMUM DAILY LOAD (TMDL)

For

Metals

In the

Wolf River Watershed (HUC 08010210)

Shelby County, Tennessee

FINAL

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TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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LIST OF ABBREVIATIONS

CCC	Criteria Continuous Concentration
CDC	Concentration Duration Curve
CFR	Code of Federal regulations
CFS	Cubic Feet per Second
CMC	Criteria Maximum Concentration
DEM	Digital Elevation Model
DWR	Division of Water Resources
EPA	Environmental Protection Agency
GIS	Geographic Information System
HUC	Hydrologic Unit Code
ITRC	Instream Total Recoverable Concentration
LA	Load Allocation
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 Metals in Wolf River Watershed (08010210)

Impaired Waterbody Information

State: Tennessee
Counties: Shelby
Watershed: Wolf River (HUC 08010210)
Constituents of Concern: metals (arsenic and lead)

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN08010210001 – 0100	HARRINGTON CREEK	16.5
TN08010210001 – 1000	WOLF RIVER	12.8
TN08010210023 – 0100	UNNAMED TRIB TO FLETCHER CREEK	23.1
TN08010210023 – 1000	FLETCHER CREEK	10.7
TN08010210032 – 1000	CYPRESS CREEK	8.6

Designated Uses:

The designated use classifications for waterbodies in the Wolf River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. The Wolf River from mile 6.7 to the Mississippi state line is also classified for industrial water supply and navigation.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, 2011 Version* for recreation use classification (most stringent):

Toxic Substances:

The waters shall not contain toxic substances, whether alone or in combination with other substances, that will render the waters unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish, or will propose toxic conditions that will adversely affect man, animal, aquatic life, or wildlife. Human health criteria have been derived to protect the consumer from consumption of contaminated fish and water. The water and organisms criteria should only be applied to those waters classified for both recreation and domestic water supply. The criteria for recreation are as follows:

Compound	Water & Organisms Criteria * (ug/L)	Organisms Only Criteria (ug/L)
Arsenic (c)	10.0	10.0

(c) 10-5 risk level is used for all carcinogenic pollutants.

* These criteria are for protection of public health due to consumption of water and organisms and should only be applied to these waters designated for both recreation and domestic water supply.

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, 2011 Version* for fish and aquatic life use classification (most stringent):

Toxic Substances:

The waters shall not contain substances or a combination of substances including disease - causing agents which, by way of either direct exposure or indirect exposure through food chains, may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), physical deformations, or restrict or impair growth in fish or aquatic life or their offspring. References on this subject include, but are not limited to: Quality Criteria for Water (Section 304(a) of Public Law 92-500 as amended); Federal Regulations under Section 307 of Public Law 92-500 as amended. The following criteria are for the protection of fish and aquatic life:

Compound	Criterion Maximum Concentration ug/l (CMC)	Criterion Continuous Concentration ug/l (CCC)
Lead**	65	2.5

** Criteria for these metals are expressed as dissolved and are a function of total hardness (mg/L). Hardness-dependent metals criteria may be calculated from the following (values displayed above correspond to a total hardness of 100 mg/l and may have been rounded):

$$\text{CMC (dissolved)} = \exp\{m_A[\ln(\text{hardness})]+b_A\}\ (\text{CF})$$

$$\text{CCC (dissolved)} = \exp\{m_C[\ln(\text{hardness})]+b_C\}\ (\text{CF})$$

Chemical	m_A	b_A	m_C	b_C	Freshwater Conversion Factors (CF)	
					CMC	CCC
Lead	1.273	-1.460	1.273	-4.705	1.462-[(ln hardness)(0.145712)]	1.462-[(ln hardness)(0.145712)]

If criteria are hardness-dependent, the Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) shall be based on the actual stream hardness. When an ambient hardness of less than 25 mg/l is used to establish criteria for cadmium or lead, the hardness dependent conversion factor (CF) shall not exceed one. When ambient hardness is greater than 400 mg/l, criteria shall be calculated according to one of the following two options: (1) calculate the criterion using a default Water Effects Ratio (WER) of 1.0 and a hardness of 400 mg/l in the hardness based equation; or (2) calculate the criterion using a WER and the actual ambient hardness of the surface water in the hardness based equation. For information concerning metals translation and site-specific criteria, see 1200-4-3-.02 (9).

TMDL Scope:

Waterbodies identified on the Draft 2012 303(d) list as impaired by metals (arsenic and lead).

Analysis/Methodology:

The metals TMDLs for impaired waterbodies in the Wolf River Watershed were developed using a mass balance approach. For arsenic, the water quality criterion for recreational use was used as the target concentration. For lead, (a hardness-dependent metal), equation-based target concentrations were derived. The target concentration for each metal was used to develop a flow-based TMDL. 10% of the TMDL was reserved for a margin of safety. The remaining 90% of the TMDL was available for Waste Load Allocations and Load Allocations. The TMDLs, WLAs, and LAs for each metal are summarized in the following tables.

Critical Conditions:

Expression of water quality criteria and TMDLs as an equation accounts for all conditions, including variance in flow and hardness.

Seasonal Variation:

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

Margin of Safety (MOS):

Implicit (conservative modeling assumptions) and explicit (10% of the water quality criteria for each individual metal for each impaired subwatershed).

Summary of TMDLs and MOS expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210)

HUC-12 Subwatershed (08010210__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS
				[lbs/day]	[lbs/day]
0307	Fletcher Creek	TN08010210023 – 1000	Arsenic	$5.39 \times 10^{-2} \times Q$	$5.39 \times 10^{-3} \times Q$
	Unnamed Trib to Fletcher Creek	TN08010210023 – 0100			
0308 (DA)	Cypress Creek	TN08010210032 – 1000	Lead	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-3}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-4}) \times Q$
0308 (DA)	Harrington Creek	TN08010210001 – 0100	Arsenic	$5.39 \times 10^{-2} \times Q$	$5.39 \times 10^{-3} \times Q$
0308	Wolf River	TN08010210001 – 1000	Lead	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-3}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-4}) \times Q$

Notes: Q = Mean Daily In-stream Flow (cfs).
H = Hardness (mg/L as $CaCO_3$)
TSS = Total Suspended Solids (mg/L)

Summary of WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210)

HUC-12 Subwatershed (08010210__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	Constituent	PLRG	WLAs*	LAs (SW)
				[%]	[lbs/day/ac]	[lbs/day/ac]
0307	Fletcher Creek	TN08010210023 – 1000	Arsenic	16.7	$8.79 \times 10^{-6} \times Q$	$2.36 \times 10^{-7} \times Q$
	Unnamed Trib to Fletcher Creek	TN08010210023 – 0100		20.6	$7.28 \times 10^{-6} \times Q$	$2.36 \times 10^{-7} \times Q$
0308 (DA)	Cypress Creek	TN08010210032 – 1000	Lead	8.6	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (4.72 \times 10^{-7}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (4.25 \times 10^{-7}) \times Q$
0308 (DA)	Harrington Creek	TN08010210001 – 0100	Arsenic	47.4	$6.43 \times 10^{-6} \times Q$	$6.43 \times 10^{-6} \times Q$
0308	Wolf River	TN08010210001 – 1000	Lead	50.3	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (1.05 \times 10^{-8}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (9.26 \times 10^{-9}) \times Q$

Notes: Q = Mean Daily In-stream Flow (cfs).
H = Hardness (mg/L as $CaCO_3$)
TSS = Total Suspended Solids (mg/L)
PLRG = Percent Load Reduction Goal to achieve TMDL.

* WLA term represents loading from regulated MS4s. TMSPs are considered to be in compliance with provisions of the TMDL (WLA) if they are covered under the *Tennessee Storm Water Multi-Section General Permit* (TMSP) for Industrial Activities and satisfy all conditions of the permit including meeting benchmark permit limits.

METALS TOTAL MAXIMUM DAILY LOAD (TMDL)
WOLF RIVER WATERSHED (HUC 08010210)

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 Wolf River Watershed is located in Mississippi and Southwestern Tennessee (ref.: Figure 1). This TMDL addresses only impaired waterbodies in Tennessee. For the purposes of TMDL development, waters flowing into Tennessee from Mississippi are assumed to meet Tennessee water quality standards at the state line. The Wolf River Watershed lies within three Level III ecoregions (Southeastern Plains, Mississippi Alluvial Plain, and Mississippi Valley Loess Plains) and contains three Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- The **Southeastern Plains and Hills (65e)** contain several north-south trending bands of sand and clay formations. Tertiary-age sand, clay, and lignite are to the west, and Cretaceous-age fine sand, fossiliferous micaceous sand, and silty clays are to the east. With elevations reaching over 650 feet, and more rolling topography and more relief than the Loess Plains (74b) to the west, streams have increased gradient, generall sandy substrates, and distinctive faunal characteristics for west Tennessee. The natural vegetation type is oak-hickory forest, grading into oak-hickory-pine to the south.
- The **Northern Holocene Meander Belts (73a)** within Tennessee is a relatively flat region of Quaternary alluvial deposits of sand, silt, clay, and gravel. It is bounded distinctly on the east by the Bluff Hills (74a), and on the west by the Mississippi River. Average elevations are 200-300 feet with little relief. Most of the region is in cropland, with some areas of deciduous forest. Soybeans, cotton, corn, sorghum, and vegetables are the main crops. The natural vegetation consists of Southern floodplain forest (oak, tupelo, bald cypress). The two main distinctions in the Tennessee portion of the ecoregion are between areas of loamy, silty, and sandy soils with better drainage, and areas of more clayey soils of poor drainage that may contain wooded swamp-land and oxbow lakes. Waterfowl, raptors, and migratory songbirds are relatively abundant in the region.

- The **Loess Plains (74b)** are gently rolling, irregular plains, 250-500 feet in elevation, with loess up to 50 feet thick. The region is a productive agricultural area of soybeans, cotton, corn, milo, and sorghum crops, along with livestock and poultry. Soil erosion can be a problem on the steeper, upland Alfisol soils; bottom soils are mostly silty Entisols. Oak-hickory and southern floodplain forests are the natural vegetation types, although most of the forest cover has been removed for cropland. Some less-disturbed bottomland forest and cypress-gum swamp habitats still remain. Several large river systems with wide floodplains, the Obion, Forked Deer, Hatchie, Loosahatchie, and Wolf, cross the region. Streams are low-gradient and murky with silt and sand bottoms, and most have been channelized.

The Wolf River watershed includes parts of Fayette, Hardeman, and Shelby counties in Tennessee. The Tennessee portion of the Wolf River Watershed, HUC 08010210, has approximately 1026 miles of streams and drains approximately 569 square miles. The entire Wolf River Watershed drains approximately 819 square miles.

Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from approximately 2001. Although changes in the land use of the Wolf River watershed have occurred since 2001 as a result of rapid development, this is the most current land use data available. Table 1 summarizes land use for the Wolf River watershed, as shown in Figure 3. Predominant land use in the Tennessee portion of the Wolf River Watershed is forest (42.6%) followed by agriculture (30.8%) and urban (25.4%).

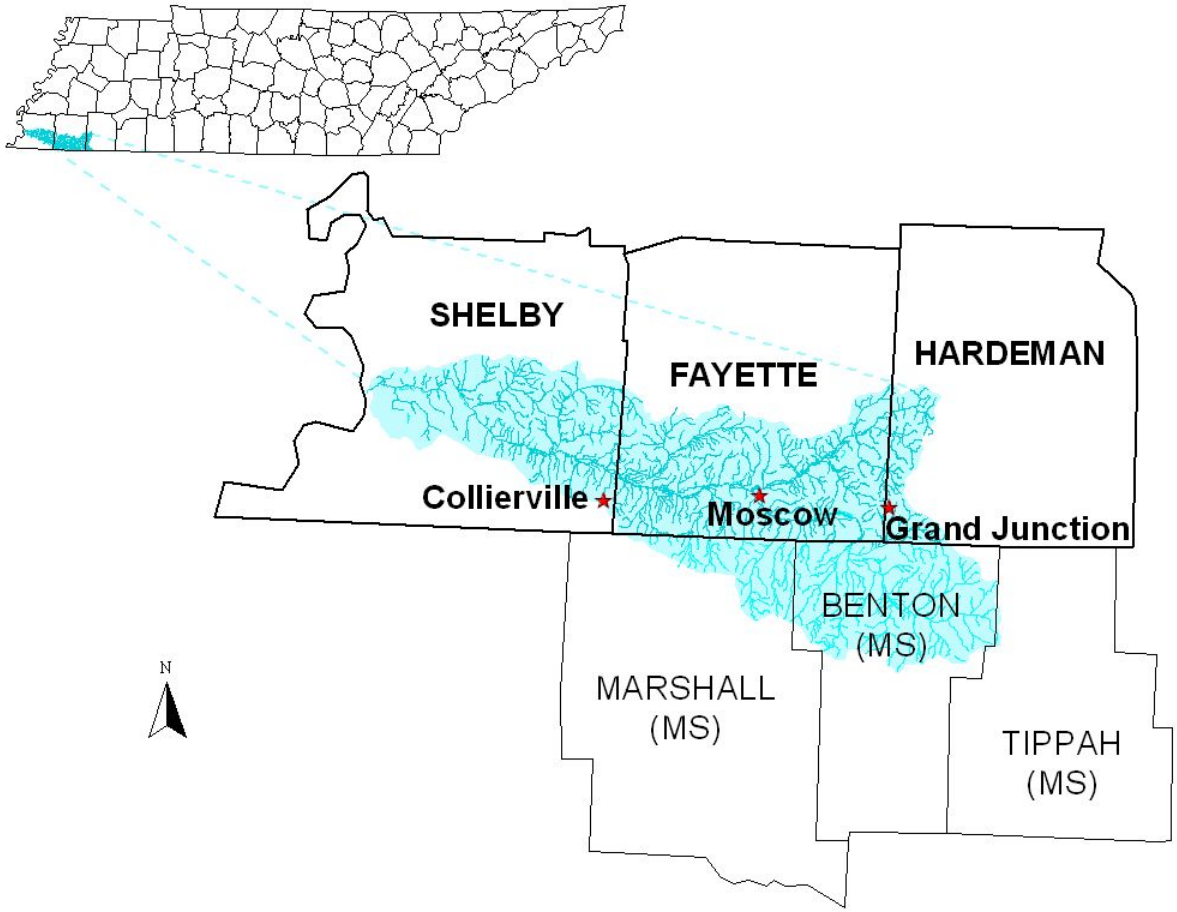

Figure 1 Location of Wolf River Watershed

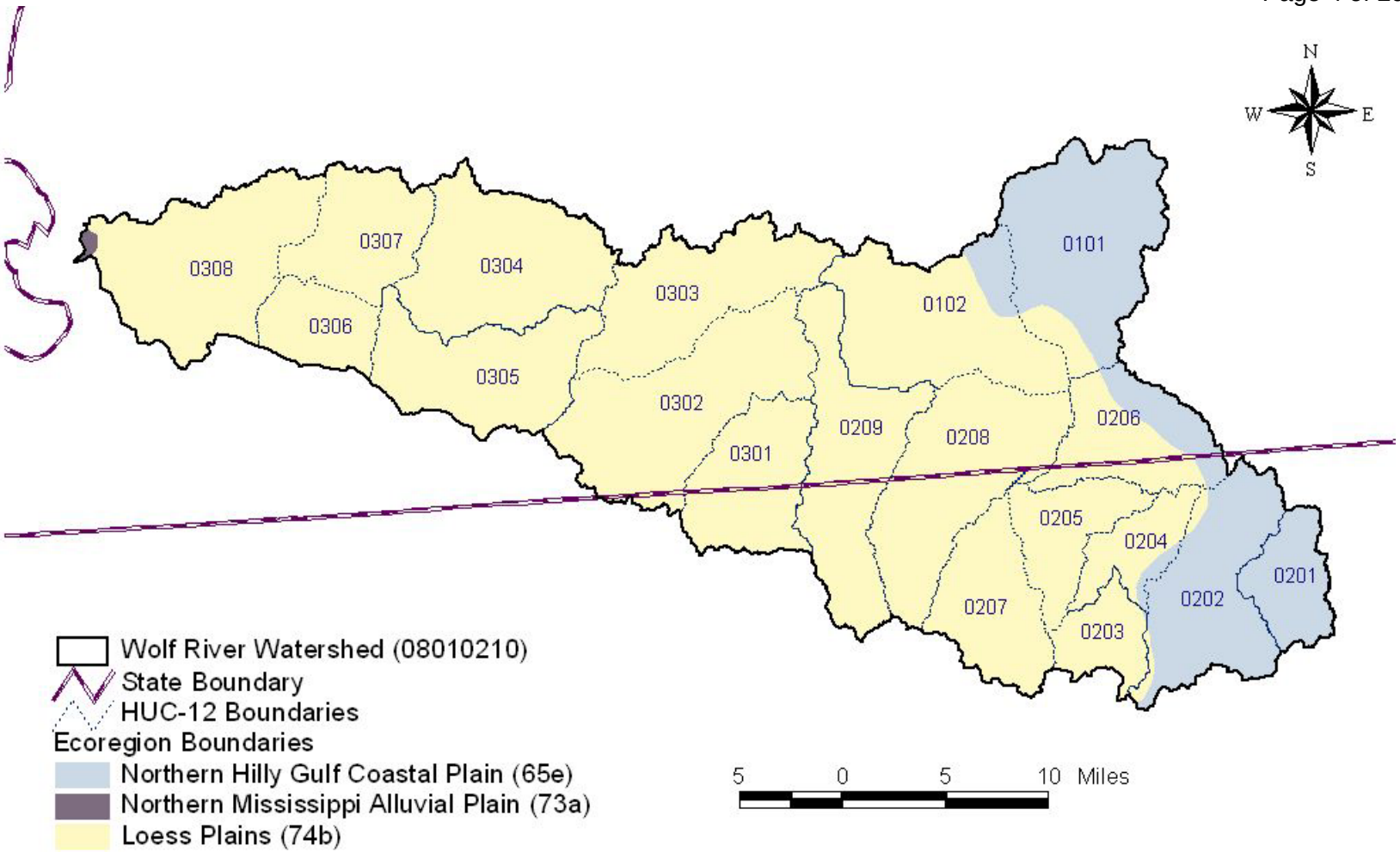

Figure 2 Wolf River Watershed Ecoregion Designation

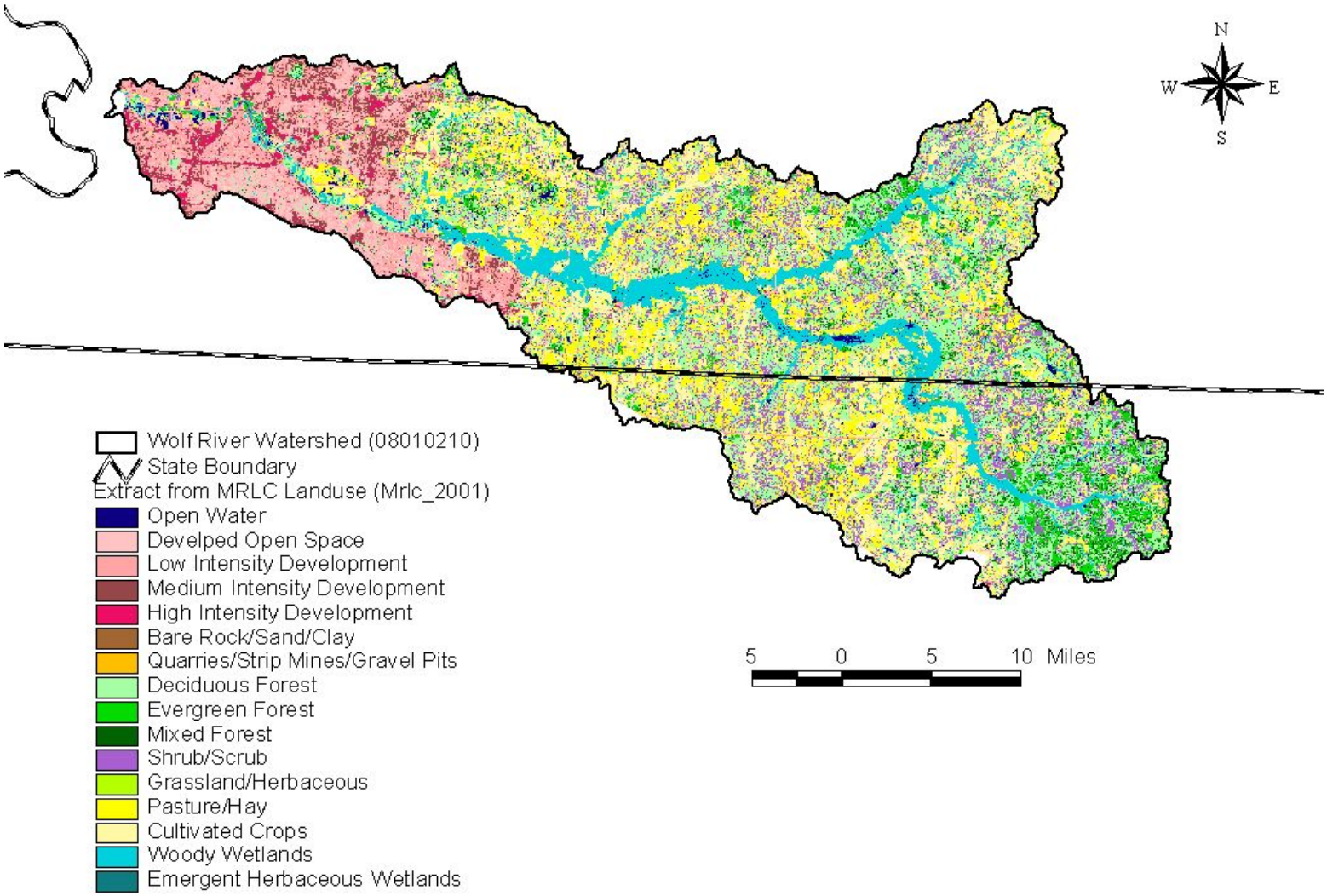

Figure 3 Wolf River Watershed Land Use Distribution

Table 1. MRLC Land Use Distribution – Wolf River Watershed (08010210)

Land use	Wolf River Watershed (TN & MS)		Wolf River Watershed (TN only)	
	[acres]	[%]	[acres]	[%]
Open Water	5,242	1.0	4,115	1.1
Developed Open Space	43,977	8.4	39,366	10.8
Low Intensity Development	33,441	6.4	31,791	8.7
Medium Intensity Development	16,878	3.2	16,715	4.6
High Intensity Development	4,613	0.9	4,588	1.3
Barren Land (Rock/Sand/Clay)	0	0.0	0	0.0
Deciduous Forest	104,518	19.9	63,400	17.4
Evergreen Forest	20,128	3.8	9,322	2.6
Mixed Forest	16,301	3.1	8,376	2.3
Shrub/Scrub	64,262	12.3	36,999	10.2
Grassland/Herbaceous	1,992	0.4	1,347	0.4
Pasture/Hay	74,011	14.1	50,181	13.8
Cultivated Crops	93,615	17.9	62,126	17.1
Woody Wetlands	43,086	8.2	34,340	9.4
Emergent Herbaceous Wetlands	2,201	0.4	1,529	0.4
Subtotal – Urban	98,909	18.9	92,460	25.4
Subtotal – Agriculture	167,626	32.0	112,307	30.8
Subtotal – Forest	252,488	48.2	155,313	42.6
Total	**524,265**	**100.0**	**364,196**	**100.0**

Note: A spreadsheet was used for this calculation and values are approximate due to rounding.

3.0 PROBLEM DEFINITION

The State of Tennessee's Draft 2012 303(d) list (TDEC, 2012) was on Public Notice in July and August 2012. The list identified several waterbodies in the Wolf River Watershed as not supporting designated use classifications due, in part, to metals (arsenic and lead). An excerpt from the Draft 2012 303(d) list is presented in Table 2. Waterbodies included on the 303(d) list are shown in Figure 4.

The designated use classifications for the Wolf River and their tributaries include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. The Wolf River from mile 6.7 to the Mississippi state line is also classified for industrial water supply and navigation. Assessment information for waterbodies impaired due to metals in the Wolf River Watershed is available in the EPA/TDEC Assessment Database (ADB) and is referenced to the waterbody IDs in Table 2. ADB information may be accessed at: http://tnmap.tn.gov/wpc/default.aspx?resetSession=true .

The major concerns regarding metal contamination are toxicity to fish and aquatic life, plus the danger it poses to people who come in contact with the water or eat fish from the contaminated waterbody. The precipitation of metals in streams can also affect habitat. Occasionally, metals are elevated in streams and rivers due to natural conditions. However, it is relatively rare for waterbodies to violate criteria for metals simply based on natural conditions.

3.1 Effects of Arsenic

Arsenic is a ubiquitous, naturally occurring element. Arsenic may exist in both an organic and inorganic form, either in the trivalent (arsenite) or pentavalent (arsenate) oxidation state. Arsenite tends to predominate under reducing conditions and arsenate tends to predominate under oxidizing conditions. Trivalent forms of arsenic (inorganic and organic) are more toxic to humans and aquatic organisms and are usually only present under anaerobic conditions (ODEQ, 2001). Webb (1966) found that arsenite is approximately 60 times more toxic to humans than arsenate. With few exceptions, inorganic arsenic is more toxic than organic arsenic.

Some arsenic species have an affinity for clay mineral surfaces and organic matter, and this can affect their environmental behavior. Methylation and demethylation reactions are also important transformations controlling the mobilization and subsequent distribution of arsenicals. Transport and partitioning of arsenic in water depends on the chemical form of the arsenic and on interactions with other materials present. Arsenic may be adsorbed from water on to clays, iron oxides, aluminum hydroxides, manganese compounds, and organic material. (WHO, 2001)

Arsenic compounds cause acute and chronic effects in individuals, populations and communities at concentrations ranging from a few micrograms per liter, depending on species, time of exposure, and end-points measured. These effects include lethality, inhibition of growth, photosynthesis and reproduction, and behavioral effects. (WHO, 2001) Arsenic-contaminated environments are characterized by limited species abundance and diversity. If levels of arsenate are high enough, only species that exhibit resistance may be present. (Brooks, 2000)

Arsenic has long been known because of its acute and long-term toxicity. The EPA has classified arsenic as a known carcinogen. Sources of human exposure to arsenic compounds may include air, soil, water and food. Dietary sources may include dairy products, meat, poultry and fish, fruits and vegetable and grain products. However, the greatest potential hazard is in the consumption of water containing high concentrations of inorganic arsenite (Webb, 1966).

Arsenic has effects on widely different organ systems in the body. It has produced serious effects on humans after both oral and inhalation exposure, it has many end-points, and exposure is widespread all over the world. Ingestion of large doses of arsenic may lead to acute symptoms within 30-60 min, but the effects may be delayed when the arsenic is taken with food. Acute gastrointestinal syndrome is the most common presentation of acute arsenic poisoning. (WHO, 2001)

Incidents of continuous or repeated oral exposure to arsenic have been described. Symptoms, mainly from the gastrointestinal tract and skin, were observed among 220 patients studied among 447 who had been exposed to arsenic in soy sauce at a level of 100 mg/L for 2-3 weeks; the estimated daily dose of arsenic was 3 mg. In a mass poisoning in Japan, where 12,000 infants were fed with milk powder inadvertently contaminated with arsenic at a level of 15-24 mg/kg, leading to an estimated daily dose of 1.3-3.6 mg for a period of varying duration, 130 of the infants died. Chronic skin effects of arsenic, including pigmentation changes, hyperkeratosis, and skin cancer, from medicinal use, but also from drinking-water, were reported as early as the 19th century. A large number of case series on arsenical skin cancer after exposure via drinking water were published from Argentina, Chile, Mexico, and Taiwan in the early 1900s. (WHO, 2001)

A peculiarity of arsenic carcinogenicity is that the information mainly comes from experience with exposed humans; it has been unusually difficult to find any animal models (WHO, 2001).

3.2 Effects of Lead

Lead has been shown to have effects on many biochemical processes. Dissolved chemical forms of lead are extremely toxic when present in high concentrations in an aquatic environment. Chronic toxicity occurs when lead is bioconcentrated in aquatic species over a period of time and when it is stored in internal organs (Prosi, 1989). Lead is known to bioaccumulate in algae, macrophytes and benthic organisms, in particular in biota feeding primarily on particulate matter. In communities of aquatic invertebrates, some populations are more sensitive than others, and community structure may be adversely affected by lead contamination. Early development stages are more vulnerable than adult stages. However, populations of invertebrates from polluted areas can show more tolerance to lead than those from non-polluted areas (UNEP, 2008).

In humans, lead can result in a wide range of biological effects depending upon the level and duration of exposure. Effects at the subcellular level, as well as effects on the overall functioning of the body, have been noted and range from inhibition of enzymes to the production of marked morphological changes and death. Such changes occur over a broad range of doses. Children are usually more vulnerable to the effects of lead than adults. Lead does not appear to have deleterious effects on skin, muscle or the immune system. Except in the case of rats, lead does not appear to be related to the development of tumors. (WHO, 1995).

Table 2 Draft 2012 303(d) List – Wolf River Watershed

Waterbody ID	Impacted Waterbody	County	Miles/Acres Impaired	Cause	Pollutant Source
TN08010210001 – 0100	Harrington Creek	Shelby	16.5	Arsenic Total Phosphorus Low dissolved oxygen Escherichia coli	Discharges from MS4 area
TN08010210001 – 1000	Wolf River (Mississippi River to Fletcher Creek)	Shelby	12.8	Total Phosphorus Mercury Lead Chlordane PCBs Dioxin Loss of biological integrity due to siltation Escherichia coli	Atmospheric Deposition Discharges from MS4 area RCRA Hazardous Waste Site Channelization Contaminated sediments
TN08010210023 – 0100	Unnamed Trib to Fletcher Creek	Shelby	23.1	Arsenic Alteration in stream-side or littoral vegetative cover Physical Substrate Habitat Alterations Escherichia coli	Discharges from MS4 area
TN08010210023 – 1000	Fletcher Creek	Shelby	10.7	Arsenic Low dissolved oxygen Total Phosphorus Physical Substrate Habitat Alterations Escherichia coli	Pasture Grazing Discharges from MS4 area Channelization
TN08010210032 – 1000	Cypress Creek	Shelby	8.6	PCBs Aldrin Dieldrin Endrin DDT Chlordane Lead Low dissolved oxygen Total Phosphorus Physical Substrate Habitat Alterations Escherichia coli	Contamined Sediment Collection System Failure Discharges from MS4 area Channelization

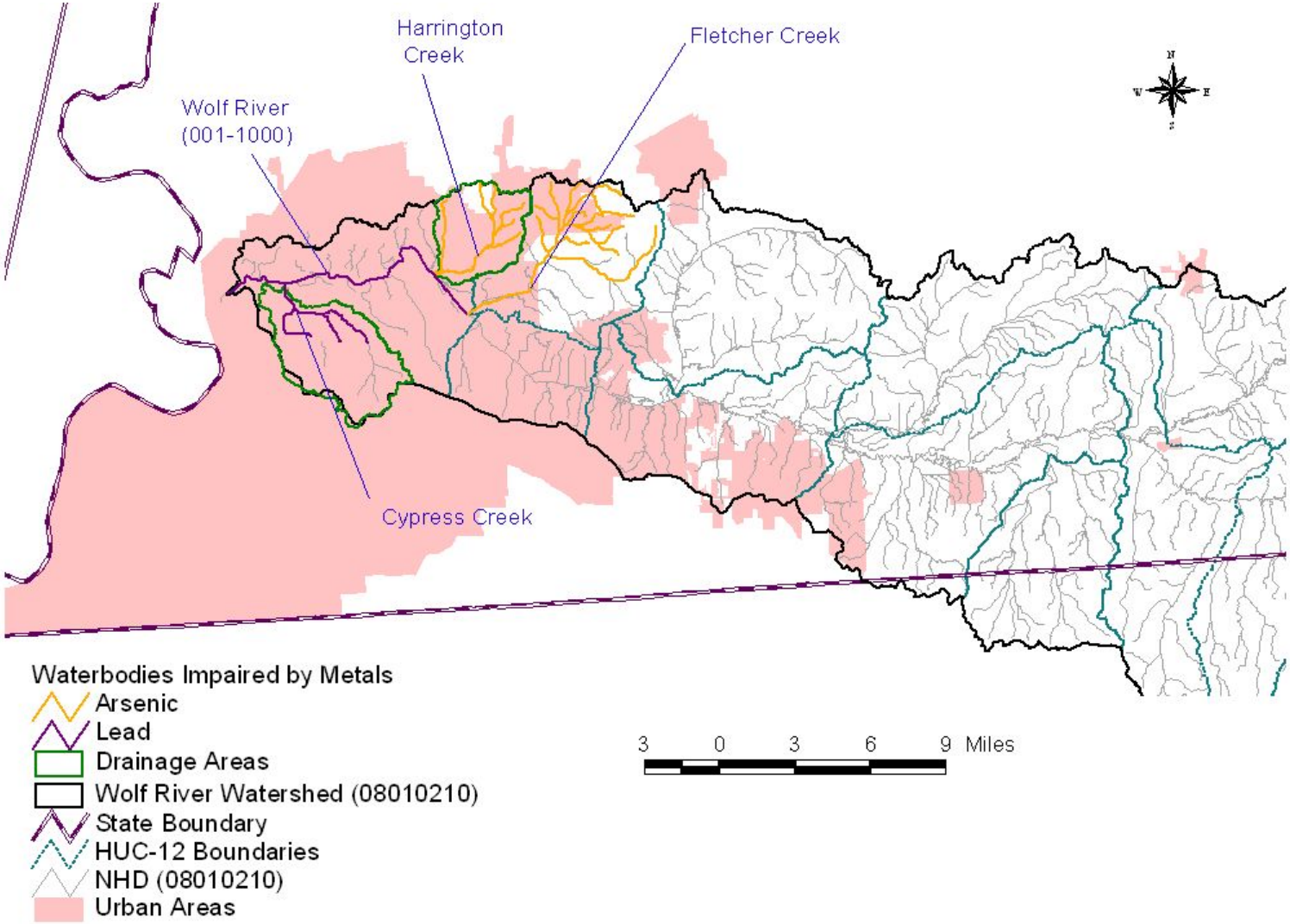

Figure 4 Wolf River Watershed Metal-Impaired Segments

4.0 TARGET IDENTIFICATION

Numeric water quality criteria for each metal and designated use, as stated in the *State of Tennessee Water Quality Standards*, are summarized in Table 3. Where multiple criteria are applicable to a specific waterbody, the most protective criterion will be used.

Table 3 Numeric Metals Criteria for Each Designated Use Classification

Metal (Total Recoverable)	Designated Use Classification	Criteria [µg/l]
Arsenic	Recreation (Organisms Only)	10
Arsenic (III)	Fish & Aquatic Life (CCC)	150
Arsenic (III)	Fish & Aquatic Life (CMC)	340
Lead	Fish & Aquatic Life (CCC)	2.5 [a]
Lead	Fish & Aquatic Life (CMC)	65 [a]

[a] Criteria for these metals are expressed as dissolved and are a function of total hardness (mg/L). Values displayed above correspond to a total hardness of 100 mg/L and may have been rounded.

In accordance with the guidance in *Technical Support Document For Water Quality-based Toxics Control* (USEPA, 1991b), fish & aquatic life criteria are interpreted to mean that the 1-hour average exposure should not exceed the Criterion Maximum Concentration (CMC) and the 4-day average exposure should not exceed the Criterion Continuous Concentration (CCC). Excursions of CMCs & CCCs should not exceed a frequency of once every three years.

For hardness-dependent metals, the following equations are used to calculate the dissolved criteria under the specific sampling conditions:

$$\text{CMC (dissolved)} = \exp\{m_A[\ln(\text{hardness})]+b_A\}\ (\text{CF})$$
$$\text{CCC (dissolved)} = \exp\{m_C[\ln(\text{hardness})]+b_C\}\ (\text{CF})$$

For lead, the values in Table 4 are substituted for the variables in the equations above. The measured hardness was applied in the equations to calculate the sample specific target criteria for the dissolved metals.

Table 4 Variables in Metals Criteria for Hardness-Dependent Metals

Chemical	m_A	b_A	m_C	b_C	Freshwater Conversion Factors (CF)	
					CMC	CCC
Lead	1.273	-1.460	1.273	-4.705	1.462-[(ln hardness)(0.145712)]	1.462-[(ln hardness)(0.145712)]

As stated in *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, 2011 Version, General Considerations*:

> All fish and aquatic life metals criteria are expressed as total recoverable, except cadmium, copper, lead, nickel, silver, and zinc which are expressed as dissolved. Translators will be used to convert the dissolved fraction into a total recoverable permit limit. One of three approaches to metals translation will be used: (1) translator is the same as the conversion factor, (2) translator is based on relationships derived from STORET data, or (3) a site-specific translator is developed. Where available, a site-specific translator is preferred. For assessing whether criteria for cadmium, copper, lead, nickel, silver, and zinc are exceeded by ambient water quality conditions, the dissolved criteria will also be translated in order to allow direct comparison to the ambient data, if total recoverable.

Since monitoring data for lead in the Wolf River watershed are in the form of total recoverable metal, a metals translator will be required. There was insufficient data available to develop a site-specific metals translator for the Wolf River watershed. Therefore, option 2 above was selected. The methods and partition coefficients contained in *The Metals Translator: Guidance for Calculating A Total Recoverable Permit Limit From a Dissolved Criterion,* (USEPA, 1996) will be used to convert the dissolved metals criteria to a total recoverable metals criteria, which can then be compared to the measured total metal concentration. A complete explanation of the development of water quality criteria for hardness-dependent metals is provided in Appendix B. Target values for lead for each sampling date and monitoring station were calculated using the measured hardness and TSS for the same sampling date and monitoring location. Results are provided in Table B-1.

For lead, the equation for the chronic (CCC) criteria is more conservative than the equation for the acute (CMC) criteria. Therefore, the target criteria for lead will be calculated using the equation for the chronic criteria.

As explained in Section 3.1, arsenic can exist in several forms. Arsenic(III) is a subset of Total Arsenic. Since the recreation criteria is expressed as total arsenic and is more stringent than the fish & aquatic life criteria, the recreation criteria is more conservative than the fish & aquatic life criteria. Therefore, the target criteria for arsenic will be 10 μg/L.

5.0 WATER QUALITY ASSESSMENT AND DIFFERENCE FROM TARGET

Water quality monitoring of the Wolf River Watershed was conducted by Division of Water Resources (DWR) personnel from the Memphis Environmental Field Office (EFO) during the period from 2/11/03 through 3/29/11. Several monitoring stations were located on or near impaired segments in the Wolf River Watershed (see Figure 5).

- HUC-12 08010210_0307:
    - FLETC001.4SH – Fletcher Creek, at Sycamore View Rd.
    - FLETC005.2SH – Fletcher Creek, at Appling Rd.
    - FLETC4.4T0.2SH – Unnamed Trib to Fletcher Creek, at Reese Rd.
- HUC-12 08010210_0308:
    - CYPRE001.2SH – Cypress Creek, at North Watkins St.
    - CYPRE001.82/1.84SH – Cypress Creek, at Evergreen St.
    - CYPRE004.8SH – Cypress Creek, at Summer Ave.
    - HARRI001.8SH – Harrington Creek, at Raleigh-Lagrange Rd.
    - WOLF000.7SH – Wolf River, at Second Street
    - WOLF001.5SH – Wolf River, at Hwy 51 bridge near mouth
    - WOLF009.3SH – Wolf River, at Austin Peay Hwy 14

The metals data collected at each monitoring site (ref: Appendix B) in the Wolf River Watershed are tabulated and compared to the appropriate targets in Table 5. For lead, the target criteria for each combination of sampling date and sampling location was calculated using the measured hardness and TSS for that sampling date and location.

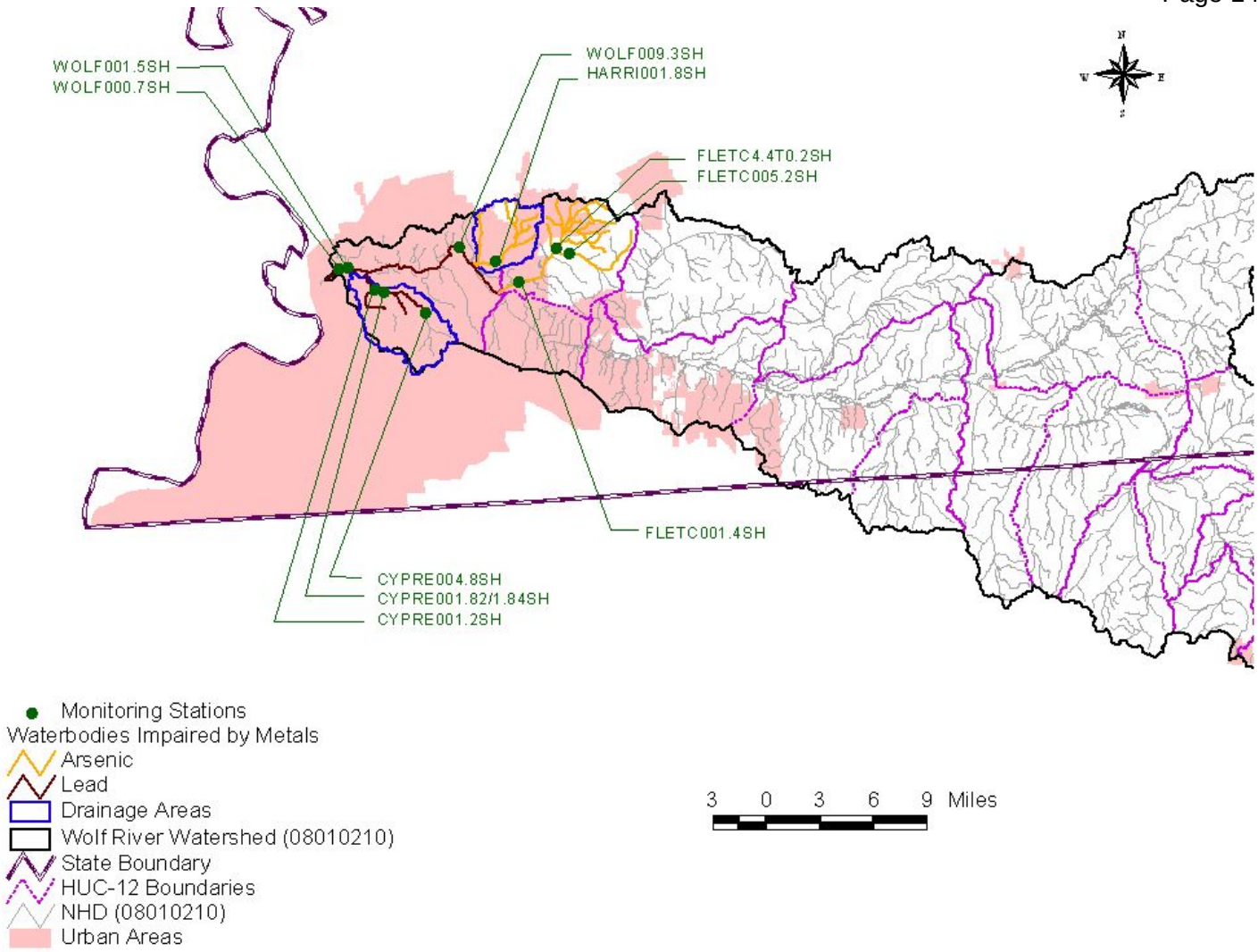

Figure 5 Wolf River Watershed Monitoring Stations

Table 5 Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	Parameter	Data Pts.	Target (μg/L)	Min. (μg/L)	Avg. (μg/L)	Max. (μg/L)	No. Exceed. Target
CYPRE001.2SH	2008 – 2011	Lead	17	4.48-25.8 [a]	ND	2.67	11	1
CYPRE001.82SH	2010 – 2011		6	4.79-14.9 [a]	0.45	1.50	4.8	1
CYPRE001.84SH	2010 – 2011		6	4.98-13.6 [a]	0.51	1.45	4.7	0
CYPRE004.8SH	2008 – 2011		18	4.33-10.5 [a]	ND	1.10	6.4	1
FLETC001.4SH	2008 – 2009	Arsenic	11	10	3.7	7.59	15	2
FLETC005.2SH	2008 – 2009		12	10	3.5	7.08	15	2
FLETC4.4T0.2SH	2008 – 2009	Arsenic	12	10	3.2	8.3	18	3
HARRI001.8SH	2003 – 2009	Arsenic	23	10	4	8.90	19	7
WOLF000.7SH	2008 – 2011	Lead	15	2.04-4.96 [a]	0.22	1.81	4.3	3
WOLF001.5SH	2003 – 2008		25	1.72-5.74 [a]	ND	3.08	11	9
WOLF009.3SH	2003 – 2009		22	1.27-5.91 [a]	ND	2.49	9	6

a Target value varies depending on hardness and TSS.

6.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of individual sources, or source categories, of 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

6.1.1 NPDES Regulated Individual and Tennessee Multi-Sector Permits

Stormwater discharges from regulated industrial facilities are authorized under NPDES Permit No. TNR050000, Tennessee Stormwater Multi-Sector General Permit (TMSP) for Industrial Activities (TDEC, 2009). Operators of point source discharges of storm water associated with industrial activity, that discharge into waters of the State of Tennessee, represented by multiple industry sectors identified in the permit, are authorized to discharge storm water runoff in accordance with storm water pollution prevention plan requirements, effluent limitations, and monitoring and reporting requirements, from the subject facilities to waters of the State of Tennessee. As of January 1, 2013, there were twelve (12) facilities with active coverage under the TMSP in sectors M (8), C (1), K2 (1), and N (2). (See Table 6 and Figure 6.) There is also one (1) facility covered under an individual stormwater permit. All twelve facilities are located in HUC-12 0308. Since their discharge is precipitation driven, the contribution of these facilities will be a function of their total acreage and the concentration of stormwater runoff. The total area of the facilities (321.52 acres) is less than 3% of the Cypress Creek drainage area. If these facilities meet their benchmark permit limits, their contributions will be insignificant. However, if any of these facilities are not meeting the benchmark concentrations in their permits, they may be potential sources. The WLAs for these facilities are to meet their benchmark limits.

6.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

MS4s may discharge stormwater runoff to waterbodies in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. These systems convey urban runoff from construction sites, roads, municipal operations such as garages, schools, storage facilities, golf courses, etc.; and residential, commercial, and industrial properties. Phase I of the EPA storm water program requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. The only Phase I MS4 entity in the Wolf River Watershed is the City of Memphis (TNS068276).

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, 2010). At present, there are five (5) permitted Phase II MS4s in the Wolf River Watershed: the cities of

Bartlett, Collierville, Germantown, and Lakeland, and Shelby County. Collierville and Germantown do not discharge to metal-impaired waterbodies.

Table 6 NPDES Permitted Facilities of Interest in the Wolf River Watershed

NPDES Permit No.	Facility	Size (acres)	Receiving Stream
TN0078964	Mid South Auto Recycling, LLC	14	Wolf River, RM3.2
TNR050578	Mid-Town Auto Parts & Salvage, Inc.	32.7	Kilowatt Lake to Wolf River
TNR050639	Warford Auto Parts LLC	99	Workhouse Bayou to Wolf River
TNR051057	Velsicol Chemical, LLC	68	Cypress Creek
TNR051478	Worley Brother's Iron and Metal dba Complete Auto Parts	6.5	Cypress Creek
TNR051479	Mr. Complete Chrysler Recycled	2	Cypress Creek
TNR053315	Sims Metal Management Memphis, LLC	32.93	Wolf River
TNR054429	NexAir, LLC	7	Cypress Creek
TNR055941	Dixie Waste Paper Company, Inc.	1.5	Cypress Creek via MS4
TNR056003	Memphis Auto Parts & Truck Salvage	5	Cypress Creek via MS4
TNR056500	McKenzie Auto Parts, Inc.	23.89	Cypress Creek
TNR056533	BP's Lane Avenue Auto Parts, Inc.	6	Cypress Creek
TNR058643	Worley Brothers Scrap Iron & Metal	23	Wolf River

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.

For information regarding storm water permitting in Tennessee, see the TDEC website:

http://www.state.tn.us/environment/wpc/stormh2o/.

In the Draft 2012 303(d) List (ref.: Table 2), discharges from MS4 areas was identified as the source of metals in several impaired waterbodies in the watershed. This TMDL will consider discharges from MS4 areas as one of the primary sources of metals contamination in the Wolf River watershed.

6.2 Non-point Sources

6.2.1 Superfund Sites

There is one Superfund facility located in the Wolf River Watershed that may have contributed to metals impairment in the past. The Ross Metals Superfund site (TND096070396) is located in Fayette County and covers approximately 14 acres on a 200-acre parcel of land owned by Ross Metals, Inc. Ross Metals operated as a secondary lead smelter from 1979 to 1992. Site operations resulted in lead-contaminated surface soils located throughout most of the site, as well as lead-contaminated subsurface soil located in isolated portions of the site. Ground water and surface water were also affected. EPA began the cleanup of the site in 2001. Activities included demolition of on-Site buildings, excavation of contaminated soil, off-Site disposal of excavated materials, and re-vegetation of landfill areas and wetlands. Site restoration activities were completed in November 2003. The 2004 Remedial Action Report indicated that remediation activities were monitored to ensure that cleanup levels were achieved and all the source material at the Site was removed to the cleanup goals set forth in the ROD. Therefore, the Ross Metals Superfund site should no longer be a source of metals. For more information regarding the Ross Metals Superfund site, see: http://www.epa.gov/region4/waste/npl/npltn/rossmetn.htm.

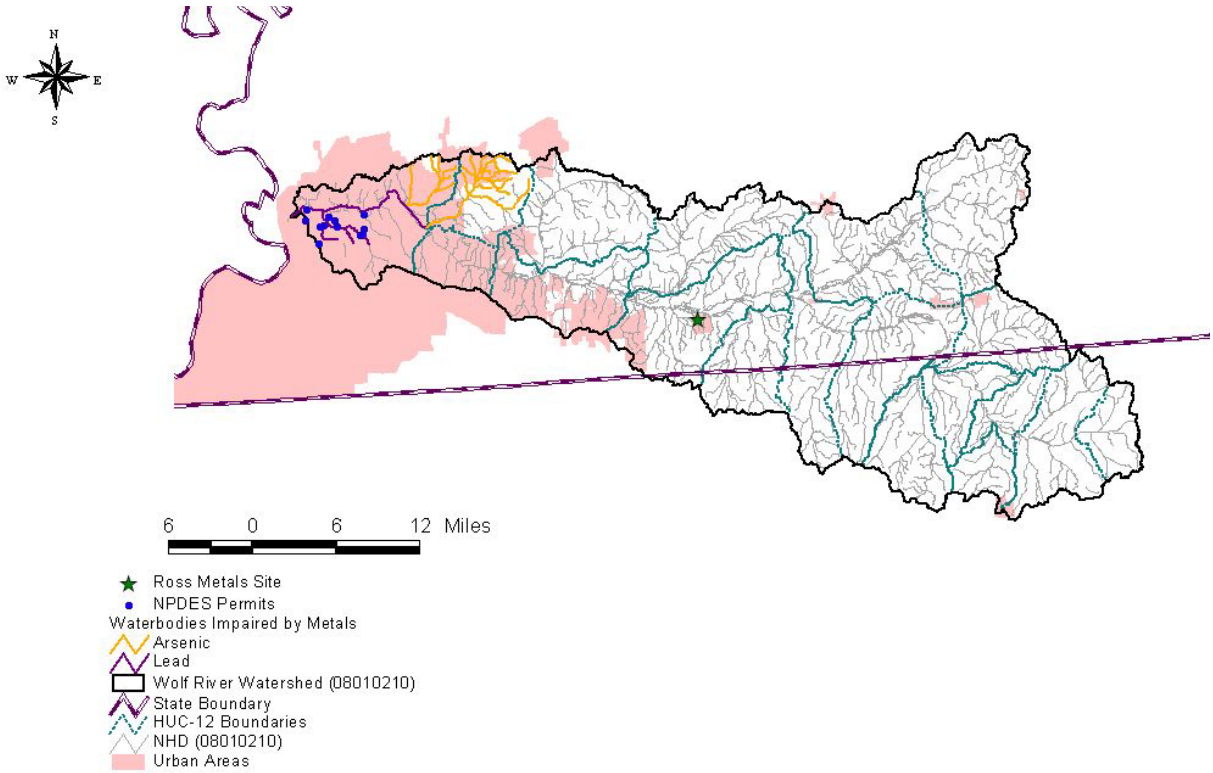

Figure 6 NPDES and RCRA Sites of Interest in the Wolf River Watershed

6.2.2 Potential Sources of Arsenic

Arsenic is the main constituent of more than 200 mineral species (WHO, 2001). In nature, arsenic-bearing minerals undergo oxidation and release arsenic to water. Nationally, approximately 21 percent of stream and river samples collected by the USGS in a 1969 study had arsenic concentrations above 10 μ/L (Welch et al 1988). No information was given as to the suspected source of surface water arsenic, other than to note that it is "unusual to find high arsenic concentrations in river water without a significant contribution of arsenic from geothermal water or mineralized areas". Edwards (1994) reported that a random survey of raw drinking water sources in the United States resulted in an average arsenic concentration of 4 μg/L.

Historic use of arsenic-containing pesticides is suspected as a source that may be contributing to the elevated arsenic levels. In 1983, arsenical pesticides were one of the largest classes of biocontrol agents in the USA (WHO, 2001). Only very limited quantities of arsenic-containing pesticides are still manufactured and used under strict limitations in the U.S. However, arsenic has proven to be a problem in suburban areas where subdivisions have crept out on to former agricultural land where pesticides containing lead arsenate were applied (Hodel, 2002). Litter from poultry fed organic arsenic additives is another possible anthropogenic source.

Approximately 90 percent of industrial arsenic in the U.S. is currently used as a wood preservative, but arsenic is also used in paints, dyes, metals, drugs, soaps, and semi-conductors. (USEPA, 2011) Arsenic has been used in manufactured wood products, like particleboard and treated lumber, to prevent rot and provide weather resistance. A study of anthropogenic sources of arsenic and copper in a small (0.91 mi^2), densely populated suburban watershed in Virginia (Rice, 2002) found that over 50% of the arsenic in a small (< 30 ac.) recreational lake was attributable to pressure treated lumber and that urbanization of the watershed was a major cause of increasing arsenic concentrations in the lake sediments. Atmospheric deposition was found to be an insignificant source (< 3%) of arsenic to the lake.

Arsenic associated with unregulated urban runoff can come from erosion of natural deposits and runoff from roads and parking lots. (USEPA, 2011) A study under EPA's National Urban Runoff Project indicated that arsenic concentrations in stormwater runoff ranged from 1 to 51 μg/L in different areas of the United States.

6.2.3 Potential Sources of Lead

Specific sources identified for lead include building siding and atmospheric deposition. The soil serves as a great reservoir of lead, and a major source of lead in urban soils is fallout of engine exhaust from vehicles burning leaded gasoline (Hodel, 2002). Although banned since 1986, the burning of leaded gasoline for more than 60 years has left a legacy of lead embedded in soils in urban areas, especially near roads with heavy and congested automobile traffic. Another source of lead in urban soils is lead-based paints. Although mostly banned since 1978, lead-based paints still remain on walls and other fixtures of old houses, buildings, and equipment. Unsafe removal of lead-based paint, such as scraping, sanding, and especially sandblasting, can easily release lead particles and dust that is then deposited on nearby soils or other surfaces. Illegally or improperly discarded or dumped batteries of automobiles, trucks, boats, and motorcycles can also be sources of lead in the soil. Its long natural life and history of use has ensured that lead is and will remain a common contaminant in urban areas for years to come.

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

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

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (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) and, for hardness-dependent metals, hardness and TSS (total suspended solids). WLAs & LAs are also expressed as daily loading functions in lbs/day/acre. In order to facilitate implementation, corresponding percent load reduction goals (PLRGs) to decrease constituent loads to TMDL target levels are also expressed.

7.2 Critical Conditions and Seasonal Variation

The critical condition for precipitation-induced non-point source metals loading is usually 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. This condition is represented in the TMDL analyses.

For hardness-dependent metals, hardness and TSS are also factors in determining critical conditions. A lower measured hardness results in toxicity at a lower metals concentration. The use of an equation-based metals criteria and an equation-based TMDL accounts for the variance in hardness.

The flow zone with the most exceedances was determined at each monitoring site using Concentration Duration Curves as described in Appendix D. A Concentration Duration Curve (CDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by monitoring data) and the portion of the waterbody flow zone represented by these data.

The ten-year period from January 1, 2001 to December 31, 2010 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Seasonal variation is accounted for in the analyses by using the entire period of flow and water quality data available for the impaired waterbodies. In the Wolf River subwatersheds, water quality data have been collected during most flow ranges.

7.3 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative modeling 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 lead TMDLs, an implicit MOS was incorporated through the use of the chronic criteria (see Appendix B).

For development of all metals TMDLs, an explicit MOS, equal to 10% of the water quality target (ref.: Section 4.0), was utilized for determination of WLAs and LAs.

7.4 Determination of Total Maximum Daily Loads

Daily loading functions were derived for impaired segments in the Wolf River Watershed using water quality criteria, ambient hardness and TSS, and average daily flow according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subsequent subwatersheds are shown in Table 7.

7.5 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. The WLAs and LAs for arsenic and lead in the Wolf River Watershed are summarized in Table 8.

Table 7. TMDLs and MOS expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210)

HUC-12 Subwatershed (08010210__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS
				[lbs/day]	[lbs/day]
0307	Fletcher Creek	TN08010210023 – 1000	Arsenic	$5.39 \times 10^{-2} \times Q$	$5.39 \times 10^{-3} \times Q$
	Unnamed Trib to Fletcher Creek	TN08010210023 – 0100			
0308 (DA)	Cypress Creek	TN08010210032 – 1000	Lead	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-3}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-4}) \times Q$
0308 (DA)	Harrington Creek	TN08010210001 – 0100	Arsenic	$5.39 \times 10^{-2} \times Q$	$5.39 \times 10^{-3} \times Q$
0308	Wolf River	TN08010210001 – 1000	Lead	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-3}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-4}) \times Q$

Notes: Q = Mean Daily In-stream Flow (cfs).
H = Hardness (mg/L as $CaCO_3$)
TSS = Total Suspended Solids (mg/L)

Table 8. WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210)

HUC-12 Subwatershed (08010210__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	Constituent	PLRG	WLAs*	LAs (SW)
				[%]	[lbs/day/ac]	[lbs/day/ac]
0307	Fletcher Creek	TN08010210023 – 1000	Arsenic	16.7	$8.79 \times 10^{-6} \times Q$	$2.36 \times 10^{-7} \times Q$
	Unnamed Trib to Fletcher Creek	TN08010210023 – 0100		20.6	$7.28 \times 10^{-6} \times Q$	$2.36 \times 10^{-7} \times Q$
0308 (DA)	Cypress Creek	TN08010210032 – 1000	Lead	8.6	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (4.72 \times 10^{-7}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (4.25 \times 10^{-7}) \times Q$
0308 (DA)	Harrington Creek	TN08010210001 – 0100	Arsenic	47.4	$6.43 \times 10^{-6} \times Q$	$6.43 \times 10^{-6} \times Q$
0308	Wolf River	TN08010210001 – 1000	Lead	50.3	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (1.05 \times 10^{-8}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (9.26 \times 10^{-9}) \times Q$

Notes: Q = Mean Daily In-stream Flow (cfs).
H = Hardness (mg/L as $CaCO_3$)
TSS = Total Suspended Solids (mg/L)
PLRG = Percent Load Reduction Goal to achieve TMDL.

* WLA term represents loading from regulated MS4s. TMSPs are considered to be in compliance with provisions of the TMDL (WLA) if they are covered under the *Tennessee Storm Water Multi-Section General Permit* (TMSP) for Industrial Activities and satisfy all conditions of the permit including meeting benchmark permit limits.

8.0 IMPLEMENTATION PLAN

Monitoring conducted in 1996 thru 2011 has identified a number of waterbodies in the Wolf River Watershed as impaired due to metals. This condition is primarily the result of discharges from urban areas.

Individual metal load reduction goals were calculated for impaired segments to evaluate compliance with the target concentrations according to the procedure in Appendix D. The load reductions were calculated at each monitoring site within the drainage area for which monitoring data was available. The load reductions for the Wolf River Watershed are also summarized in Table 8. Required load reductions will be implemented in several steps to reduce the concentration of metals (arsenic and lead).

8.1 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For present and future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs are and will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Program (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2010) and the individual MS4 permits (TDOT - TNS077585 and Memphis – TNS068276) require SWMPs to include minimum control measures. The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

For guidance on the six minimum control measures for MS4s regulated under Phase I or Phase II, a series of fact sheets are available at: http://cfpub1.epa.gov/npdes/stormwater/swfinal.cfm .

For further information on Tennessee's *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems*, see:
http://www.tn.gov/environment/wpc/stormh2o/finals/tns000000_ms4_phase_ii_2010.pdf .

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs.

Each MS4 having a waterbody within their jurisdiction that is listed as impaired due to metals must conduct water quality testing for metals. Monitoring must include sampling at least one location on the most impaired stream segment for each constituent located within the MS4 jurisdiction. (The most impaired segment should be the segment with the most exceedances based on the data included in Appendix B of the TMDL and summarized in Table 5.) Whenever possible, testing should be done at existing ambient monitoring stations to allow for continuity. Sampling must be conducted on at least a quarterly basis and parameters must include flow (if practicable), hardness, TSS, and either lead or arsenic (depending on the specific metal that is the source of impairment). Sampling should be conducted following implementation of one or more BMPs and should continue until the waterbody is no longer impaired for metals.

In keeping with the watershed approach, DWR recommends that monitoring and implementation strategies begin in the headwaters and work toward the mouth of the waterbody. Given the location of impaired waterbodies relative to MS4 jurisdiction, DWR suggests BMP implementation and monitoring of Harrington Creek and the Unnamed Trib to Fletcher Creek be conducted by the City

of Bartlett. DWR suggests that the City of Memphis focus their attention on headwaters of Fletcher Creek other than the Unnamed Trib and the mainstem of the Wolf River (segment 001-1000). Given the limited area of the Wolf River watershed under the jurisdiction of the City of Lakeland and Shelby County, TDEC does not suggest any activities at this time.

8.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of metals loading from nonpoint sources 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. 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.

Management measures to reduce metals loading from urban nonpoint sources are similar to those recommended for MS4s (Sect. 8.1). Specific categories of urban nonpoint sources include stormwater and illicit discharges.

> Stormwater: BMPs are typically designed to remove sediment and other pollutants. Metals in stormwater runoff are, however, often attached to particulate matter. Therefore, treatment systems that remove sediment may also provide reductions in metals concentrations.
>
> Illicit discharges: Removal of illicit discharges to storm sewer systems may be an effective means of reducing metals loading to receiving waters (ENSR, 2005). These include intentional illegal connections from commercial or residential buildings.

Two additional urban nonpoint source resource documents provided by EPA are:

National Management Measures to Control Nonpoint Source Pollution from Urban Areas (http://www.epa.gov/owow/nps/urbanmm/index.html) helps citizens and municipalities in urban areas protect bodies of water from polluted runoff that can result from everyday activities. The scientifically sound techniques it presents are among the best practices known today. The guidance will also help states to implement their nonpoint source control programs and municipalities to implement their Phase II Storm Water Permit Programs (Publication Number EPA 841-B-05-004, November 2005).

The Use of Best Management Practices (BMPs) in Urban Watersheds (http://www.epa.gov/nrmrl/pubs/600r04184/600r04184chap1.pdf) is a comprehensive literature review on commonly used urban watershed Best Management Practices (BMPs) that heretofore was not consolidated. The purpose of this document is to serve as an information source to individuals and agencies/municipalities/watershed management groups/etc. on the existing state of BMPs in urban stormwater management (Publication Number EPA/600/R-04/184, September 2004).

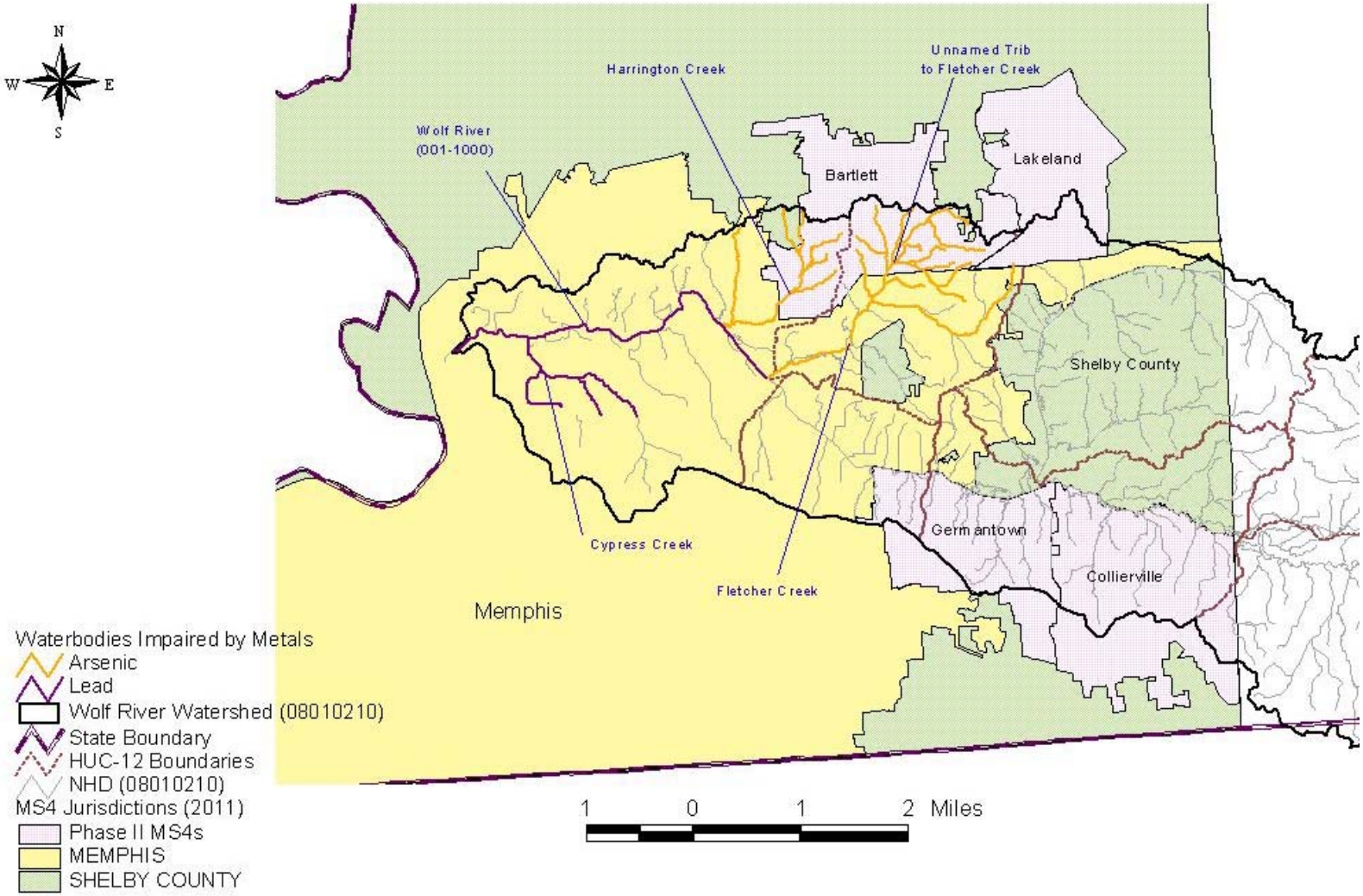

Figure 7 Metal-Impaired Waterbodies and MS4s in the Wolf River Watershed

9.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed metals TMDL for the Wolf River Watershed were 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 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 facilities located in metal-impaired subwatersheds or drainage areas in the Wolf River Watershed, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the TMDL document would be provided on request. A letter was sent to the following facilities:

   Mid South Auto Recycling, LLC (TN0078964)
   Mid-Town Auto Parts & Salvage, Inc. (TNR050578)
   Warford Auto Parts LLC (TNR050639)
   Velsicol Chemical, LLC (TNR051057)
   Worley Brother's Iron and Metal dba Complete Auto Parts (TNR051478)
   Mr. Complete Chrysler Recycled (TNR051479)
   Sims Metal Management Memphis, LLC (TNR053315)
   NexAir, LLC (TNR054429)
   Dixie Waste Paper Company, Inc. (TNR055941)
   Memphis Auto Parts & Truck Salvage (TNR056003)
   McKenzie Auto Parts, Inc. (TNR056500)
   BP's Lane Avenue Auto Parts, Inc. (TNR056533)
   Worley Brothers Scrap Iron & Metal (TNR058643)

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in metals-impaired subwatersheds. A draft copy was sent to the following entities:

   City of Bartlett, Tennessee (TNS075698)
   City of Lakeland, Tennessee (TNS077526)
   City of Memphis MS4, Tennessee (TNS068276)
   Shelby County (TNS075663)
   Tennessee Dept. of Transportation (TNS077585)

5) A letter was sent to identified water quality partners in the Wolf River Watershed advising them of the proposed metals TMDLs, stating the document's availability on the TDEC website, and inviting comments. These partners included:

Natural Resources Conservation Service
Tennessee Department of Agriculture
Tennessee Water Sentinels
United States Army Corps of Engineers
United States Fish and Wildlife Service
United States Geological Survey
Wolf River Conservancy

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:

http://www.tn.gov/environment/wpc/tmdl/

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

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APPENDIX A

Land Use Distribution in the Wolf River Watershed

Table A-1 2001 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Land Use	0307 (Fletcher Creek)		Cypress Creek DA (in 0308)		Harrington Creek DA (in 0308)		0308 (Wolf River segment 001_1000)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00	0	0.00	0	0.00
Open Water	53	0.26	2	0.02	4	0.05	869	2.15
Developed Open Space	5,840	28.35	3,579	31.32	1,846	24.45	12,163	30.05
Low Intensity Development	5,871	28.50	4,054	35.48	2,767	36.65	12,712	31.40
Medium Intensity Development	4,863	23.60	2,313	20.24	1,959	25.95	6,800	16.80
High Intensity Development	942	4.57	1,119	9.79	329	4.36	2,703	6.68
Bare Rock	2	0.01	0	0.00	0	0.00	6	0.01
Deciduous Forest	593	2.88	247	2.16	239	3.17	1,562	3.86
Evergreen Forest	315	1.53	0	0.00	59	0.78	699	1.73
Mixed Forest	300	1.46	8	0.07	166	2.20	246	0.61
Shrub/Scrub	294	1.42	0	0.00	66	0.87	599	1.48
Grassland/Herbaceous	1	0.01	0	0.00	0	0.00	9	0.02
Pasture/Hay	507	2.46	22	0.19	11	0.14	348	0.86
Row Crops	810	3.93	43	0.38	63	0.83	744	1.84
Woody Wetlands	198	0.96	39	0.34	40	0.53	947	2.34
Emergent Herbaceous Wetland	12	0.06	0	0.00	0	0.00	71	0.18
Subtotal – Urban	17,516	85.02	11,063	96.83	6,900	91.4	34,378	84.93
Subtotal - Agriculture	1,316	6.39	65	0.57	73	1.0	1,092	2.70
Subtotal – Forest	1,715	8.33	294	2.57	570	7.6	4,138	10.23
Total	**20,600**	**100.00**	**11,424**	**100.0**	**7,547**	**100.0**	**40,477**	**100.00**

APPENDIX B

TDEC Water Quality Monitoring Data
and
Development of Water Quality Criteria
for
Hardness-Dependent Metals

The Draft 2012 303(d) list (TDEC, 2012) identified several waterbodies in the Wolf River watershed as not fully supporting designated use classifications due, in part, to metals associated with discharges from MS4 areas. Two of the designated use classifications for the listed segments in the Wolf River watershed (fish and aquatic life and recreation) have numerical criteria for metals. Water quality criteria for applicable use classifications are established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, 2011 Version* (TDEC, 2011).

Water quality criteria for the fish & aquatic life use classification contain two expressions of allowable magnitude: a Criteria Maximum Concentration (CMC) to protect against short-term (acute) effects and a Criteria Continuous Concentration (CCC) to protect against long-term (chronic) effects. In accordance with the guidance in *Technical Support Document For Water Quality-based Toxics Control* (USEPA, 1991b), fish & aquatic life criteria are interpreted to mean that the 1-hour average exposure should not exceed the CMC and the 4-day average exposure should not exceed the CCC. Excursions of CMCs & CCCs should not exceed a frequency of once every three years.

CMCs & CCCs for certain metals (including cadmium, chromium, copper, lead, nickel, and zinc) are a function of water hardness (as $CaCO_3$). In the toxicity tests used to derive metals criteria for aquatic life, some fraction of the metal was dissolved and some fraction bound to particulate matter. The criteria concentrations resulting from these tests were expressed as total recoverable metal. In consideration of the premise that the dissolved fraction of metal more closely approximates the biologically available fraction, conversion factors were developed to predict how different the criteria would be if they had been based on measurements of the dissolved concentrations in the toxicity tests used to develop criteria.

As effluents from point and nonpoint source discharges mix with receiving water, the chemical properties of the mixture will determine the fraction of metal that is dissolved and the fraction that is in particulate form. Factors that influence the dissolved to total recoverable metal ratio include temperature, hardness, pH, concentration of binding sites (such as total suspended solids), and concentrations of other materials that compete for binding sites. Instream criteria (CMCs & CCCs) can be related to effluent discharges through the use of metals translators.

Lead criteria, as well as the instream total recoverable concentrations (ITRCs) required to comply with these criteria, were calculated for each sample date in accordance with *State of Tennessee Water Quality Standards* using the methodology described in *The Metals Translator: Guidance For Calculating A Total Recoverable Permit Limit From a Dissolved Criterion*, EPA 823-B-96-007, June 1996 (USEPA 1996) (see Table 4).

As stated in Section 4, the equation for the chronic criteria is more conservative than the equation for the acute criteria. Therefore, only the chronic criteria will be calculated.

Fish & aquatic life criteria and ITRCs for lead were calculated using the following procedure:

1) The total recoverable Criterion Continuous Concentration (CCC_{TR}) at laboratory conditions is calculated using the equation:

$$CCC_{TR} = \exp\{m_C\ [\ln(\text{hardness})] + b_C\}$$

for lead:

$$CCC_{TR} = \exp\{1.273\ [\ln(\text{hardness})] - 4.705\}$$

for sampling event at WOLF009.3SH on 6/2/09:

$$CCC_{TR} = \exp\{1.273\ [\ln(22.0)] - 4.705\} = 0.46\ \mu g/l$$

2) The dissolved Criterion Continuous Concentration (CCC_{DIS}) at laboratory conditions is calculated by applying the Chronic Conversion Factor (CCF):

$$CCC_{DIS} = (CCC_{TR})\ (CCF)$$

for lead:

$$CCF = 1.462 - \{[\ln(\text{hardness})][0.145712]\}$$

*For lead, if the ambient hardness is less than 25, a conversion factor of 1.0 is used.

therefore:

$$CCC_{DIS} = (0.46)\ (1.0) = 0.46\ \mu g/l$$

3) The metals translator is defined as the fraction of total recoverable metal in the downstream water, after mixing with effluents, that is dissolved. The metals translator is calculated using the equation:

$$\text{Translator} = \frac{1}{1 + \{\ [K_{po}]\ \ [TSS^{(1+a)}\ ]\ [10^{-6}]\ \}}$$

for lead:

$$\text{Translator}_{Cu} = \frac{1}{1 + \{\ [2.80 \times 10^{6}]\ [77^{(1\ -\ 0.8)}\ ]\ [10^{-6}]\ \}} = 0.13$$

4) The instream total recoverable concentration (ITRC) that corresponds to the dissolved criterion is expressed as:

$$ITRC = (\text{Water Quality Criterion})_{dissolved}\ \ (1/\text{Translator})$$

The ITRC is calculated by applying the translator to the CCC_{DIS}:

$$ITRC_{chronic} = \frac{CCC_{DIS}}{\text{Translator}}$$

for lead:

$$ITRC_{chronic} = \frac{0.46}{0.13} = 3.55\ \mu g/l$$

5) The observed value for the sample date (2.5 μg/l) is less than the chronic ITRC. Therefore, there is no exceedance of water quality criteria on this date.

The results of the calculations for instream total recoverable criteria and comparison to measured values for lead are presented along with TDEC monitoring data in Table B-1.

Table B-1 Monitoring Data and Calculations for Hardness-Dependent Metals

Station ID	Date	TSS	Hardness (as $CaCO_3$)	Lead				Arsenic
				CCC_{TR}	CCC_{DIS}	$ITRC_{Chr}$	Observed Value	Observed Value
		[mg/l]	[mg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]
CYPRE001.2SH	7/1/08	10	105	3.39	2.65	14.43	1.9	14
	8/5/08	5	100	3.18	2.52	12.24	0.7	
	9/2/08	5	100	3.18	2.52	12.24	1.3	4.3J
	10/9/08	5	60	1.66	1.44	6.99	2.8	7.4
	12/2/08	5	200	7.69	5.31	25.80	11.0	2.1J
	1/6/09	13	35	0.84	0.79	4.48	**4.9**	5.3
	2/4/09	5	110	3.59	2.79	13.58	1.4	4.2J
	3/4/09	5	100	3.18	2.52	12.24	2.5	3.2J
	4/8/09	5	160	5.79	4.18	20.34	0.5	4.0J
	5/7/09	5	79	2.36	1.95	9.46	3.7	5.6
	6/2/09	17	160	5.79	4.18	24.82	1.3	6.9
	10/13/10	5	110	3.59	2.79	13.58	0.8	2.4J
	11/17/10	12					2.7	2.0J
	12/14/10	5	84	2.55	2.08	10.12	1.5	3.7J
	1/19/11	10	71	2.06	1.73	9.41	4.4	3.0J
	2/17/11	5	110	3.59	2.79	13.58	1.1	2.1J
	3/15/11	14	48	1.25	1.12	6.45	2.8	3.1J
	Average	*7.7*	*102*	3.27	2.57	13.4	2.67	
CYPRE001.82SH	10/13/10	5	94	2.94	2.35	11.44	0.5	1.8J
	11/17/10	5					1.1	1.8J
	12/14/10	5	120	4.01	3.07	14.92	0.5	1.8Jz
	1/19/11	13	79	2.36	1.95	11.04	1.9	2.6J
	2/17/11	5	85	2.59	2.11	10.25	0.3	1.7J
	3/15/11	16	36	0.87	0.81	4.79	**4.8**	3.0J
	Average	*8.2*	*82.8*	2.50	2.05	10.78		

Table B-1 (cont'd) Monitoring Data and Calculations for Hardness-Dependent Metals

Station ID	Date	TSS	Hardness (as $CaCO_3$)	Lead				Arsenic
				CCC_{TR}	CCC_{DIS}	$ITRC_{Chr}$	Observed Value	Observed Value
		[mg/l]	[mg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]
CYPRE001.84SH	10/13/10	5	88	2.70	2.19	10.65	0.5	1.5U
	11/17/10	5					1.1	1.8J
	12/14/10	5	110	3.59	2.79	13.58	0.6	2.1Jz
	1/19/11	5	75	2.21	1.84	8.94	1.6	2.4J
	2/17/11	5	85	2.59	2.11	10.25	0.3	1.6J
	3/15/11	17	37	0.90	0.84	4.98	4.7	3.3J
	Average	*7*	*79*	2.36	1.95	9.98		
CYPRE004.8SH	7/1/08	5	56	1.52	1.33	6.48	1.6	3.6J
	8/5/08	11	58	1.59	1.38	7.65	1.2	5.1
	9/2/08	5	61	1.70	1.46	7.12	1.1	2.0J
	10/9/08	5	56	1.52	1.33	6.48	0.8	5.1
	11/4/08	5	56	1.52	1.33	6.48	0.5	1.2J
	12/2/08	5	64	1.80	1.54	7.50	1.4	0.94J
	1/6/09	20	43	1.09	0.99	6.06	**6.4**	6.5
	2/4/09	5	39	0.96	0.89	4.33	0.4	0.97J
	3/4/09	5	51	1.35	1.20	5.84	0.6	2.8J
	4/8/09	5	44	1.12	1.02	4.95	0.5	2.2J
	5/7/09	5	87	2.66	2.16	10.51	1.2	8.1
	6/2/09	11	71	2.06	1.73	9.55	0.8	4.4J
	10/13/10	5	53	1.42	1.25	6.09	0.8	1.5U
	11/17/10	5					0.7	0.94J
	12/14/10	5	48	1.25	1.12	5.46	0.2	1.7J
	1/19/11	5	48	1.25	1.12	5.46	0.3	0.82U
	2/17/11	5	44	1.12	1.02	4.95	0.3	0.82U
	3/15/11	5	56	1.52	1.33	6.48	1.1	3.1J
	Average	*6.5*	*55*	1.49	1.31	6.62	1.10	

Table B-1 (cont'd) Monitoring Data and Calculations for Hardness-Dependent Metals

Station ID	Date	TSS	Hardness (as $CaCO_3$)	Lead				Arsenic
				CCC_{TR}	CCC_{DIS}	$ITRC_{Chr}$	Observed Value	Observed Value
		[mg/l]	[mg/l]	[μg/l]	[μg/l]	[μg/l]	[μg/l]	[μg/l]
FLETC001.4SH	8/12/08	5	44	1.12	1.02	4.95	0.8	15
	9/2/08	13	37	0.90	0.84	4.77	2.1	6.8
	10/9/08	57	42	1.05	0.97	7.05	4.3	11
	11/4/08	14	41	1.02	0.94	5.41	2.3	6.5
	12/2/08	5	42	1.05	0.97	4.70	1.5	6.6
	1/6/09	44	27	0.60	0.59	4.11	3.3	7.3
	2/4/09	21	54	1.45	1.28	7.86	1.8	3.7J
	3/4/09	17	48	1.25	1.12	6.66	2.1	4.6J
	4/8/09	5	54	1.45	1.28	6.22	1.7	6.1
	5/7/09	20	41	1.02	0.94	5.74	2.8	7.9
	6/2/09	21	48	1.25	1.12	6.90	0.7	8.0
	Average	*20.2*	*43.5*	1.10	1.00	6.14		
FLETC005.2SH	7/1/08	5	86	2.63	2.13	10.38	0.5	5.8
	8/12/08	40	70	2.02	1.70	11.68	0.3	7.3
	9/4/08	57	30	0.69	0.66	4.84	1.7	15
	10/9/08	5	36	0.87	0.81	3.96	2.3	11
	11/4/08	5	55	1.49	1.31	6.35	0.7	6.2
	12/2/08	5	55	1.49	1.31	6.35	0.6	4.4J
	1/6/09	110	31	0.72	0.69	5.63	4.0	8.0
	2/4/09	21	53	1.42	1.25	7.70	1.3	3.9J
	3/10/09	5	64	1.80	1.54	7.50	0.6	3.5J
	4/8/09	5	67	1.91	1.62	7.89	1.8	6.1
	5/7/09	5	39	0.96	0.89	4.33	2.1	8.3
	6/10/09	24	65	1.84	1.57	9.87	0.9	5.5
	Average	23.4	54.2	1.46	1.28	8.03		

Table B-1 (cont'd) Monitoring Data and Calculations for Hardness-Dependent Metals

Station ID	Date	TSS	Hardness (as $CaCO_3$)	Lead				Arsenic
				CCC_{TR}	CCC_{DIS}	$ITRC_{Chr}$	Observed Value	Observed Value
		[mg/l]	[mg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]
FLETC4.4T0.2SH	7/1/08	21	64	1.80	1.54	9.49	1.8	17
	8/12/08	5	52	1.38	1.23	5.97	0.7	18
	9/4/08	194	31	0.72	0.69	6.22	**8.5**	13
	10/9/08	44	39	0.96	0.89	6.21	3.6	10
	11/4/08	18	51	1.35	1.20	7.19	3.2	6.4
	12/2/08	20					2.9	5.9
	1/6/09	150	30	0.69	0.66	5.73	4.6	8.3
	2/4/09	23	52	1.38	1.23	7.66	2.4	3.4J
	3/10/09	15	55	1.49	1.31	7.59	1.6	3.2J
	4/8/09	16	64	1.80	1.54	9.07	2.4	4.2J
	5/7/09	5	40	0.99	0.92	4.46	2.5	5.2
	6/10/09	12	54	1.45	1.28	7.17	0.9	5.0
	Average	43.6	48.4	1.26	1.13	7.87		
HARRI001.8SH	6/30/03	10	68	1.95	1.65	8.97	1U	8
	8/4/03	10	54	1.45	1.28	6.95	1U	13
	9/3/03	12	37	0.90	0.84	4.71	1	11
	10/1/03	5	52	1.38	1.23	5.97	4	9
	11/3/03	5	64	1.80	1.54	7.50	1U	6
	12/3/03	15	53	1.42	1.25	7.28	2	7
	1/7/04	36	47	1.22	1.10	7.38	2	7
	2/4/04	14	57	1.56	1.36	7.80	2	4
	3/2/04	35	44	1.12	1.02	6.83	3	10
	4/7/04	5	72	2.09	1.76	8.54	1U	5
	5/5/04	17	59	1.63	1.41	8.37	1	9
	6/2/04	16	48	1.25	1.12	6.59	1U	14

Table B-1 (cont'd) Monitoring Data and Calculations for Hardness-Dependent Metals

Station ID	Date	TSS	Hardness (as $CaCO_3$)	Lead				Arsenic
				CCC_{TR}	CCC_{DIS}	$ITRC_{Chr}$	Observed Value	Observed Value
		[mg/l]	[mg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]
HARRI001.8SH (cont'd)	8/5/08	5	57	1.56	1.36	6.60	0.74J	19
	9/2/08	13	50	1.32	1.17	6.67	**12**	7.8
	10/9/08	33	28	0.63	0.61	4.08	2.8J	14
	11/4/08	5	59	1.63	1.41	6.86	2.1J	7.8
	12/2/08	5	54	1.45	1.28	6.22	0.30U	4.2J
	1/6/09	46	30	0.69	0.66	4.66	3.9	9.6
	2/4/09	18	52	1.38	1.23	7.35	2.1J	6.3
	3/4/09	27	46	1.18	1.07	6.86	2.2J	5.5
	4/8/09	5	63	1.77	1.52	7.38	1.4J	7.8
	5/7/09	13	46	1.18	1.07	6.08	2.9J	9.7
	6/2/09	12	61	1.70	1.46	8.20	0.64J	10
	Average	*5.0*	*52.3*	1.39	1.23	6.00		
WOLF000.7SH	11/4/08	13	23	0.49	0.49	2.78	0.68	1.5J
	12/2/08	10	19	0.38	0.38	2.09	1.9	1.4J
	1/6/09	32	26	0.57	0.57	3.73	3.3	3.4J
	2/4/09	15	19	0.38	0.38	2.23	0.77	1.5J
	3/4/09	38	17	0.33	0.33	2.27	**2.6**	2.2J
	4/8/09	11	19	0.38	0.38	2.12	1.9	2.4J
	5/7/09	78	23	0.49	0.49	3.77	**4.3**	4.4j
	6/2/09	22	33	0.78	0.74	4.58	0.22	3.7J
	9/23/09	82	29	0.66	0.64	4.96	3.4	4.6J
	12/15/09	52	15	0.28	0.28	2.04	**2.7**	1.6J
	3/23/10	35	22	0.46	0.46	3.10	**4.0**	2.6J
	6/29/10	10	31	0.72	0.69	3.75	2.2	2.9J
	9/8/10	41	29	0.66	0.64	4.40	1.7	3.0J
	12/8/10	12	19	0.38	0.38	2.15	0.6	1.7J
	3/29/11	5	26	0.57	0.57	2.75	0.3	0.86J
	Average	*30.4*	*23.3*	0. 50	0.50	3.28	**1.81**	

Table B-1 (cont'd) Monitoring Data and Calculations for Hardness-Dependent Metals

Station ID	Date	TSS	Hardness (as $CaCO_3$)	Lead				Arsenic
				CCC_{TR}	CCC_{DIS}	$ITRC_{Chr}$	Observed Value	Observed Value
		[mg/l]	[mg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]
WOLF001.5SH	2/11/03	45	18	0.36	0.36	2.51	2.0	1U
	5/27/03	15	21	0.44	0.44	2.54	**3.0**	3
	6/30/03	47	33	0.78	0.74	5.21	2.0	2
	8/4/03	512	21	0.44	0.44	4.69	**11.0**	10
	9/3/03	188	27	0.60	0.59	5.30	**8.0**	9
	10/1/03	50	20	0.41	0.41	2.92	2.0	3
	11/3/03	41	20	0.41	0.41	2.82	1.0	1U
	12/3/03	13	19	0.38	0.38	2.18	0.5	1
	1/7/04	15	18	0.36	0.36	2.08	1.0	1
	2/4/04	3	19	0.38	0.38	1.72	**2.0**	2
	3/2/04	308	21	0.44	0.44	4.28	**8.0**	8
	4/7/04	15	19	0.38	0.38	2.23	1.0	2
	5/5/04	21	20	0.41	0.41	2.52	1.0	3
	6/2/04	47	23	0.49	0.49	3.45	2.0	4
	10/25/04	63	15	0.28	0.28	2.11	3.0	3
	2/8/05	64	33	0.78	0.74	5.49	2.0	3
	9/21/05	54	23	0.49	0.49	3.54	3.0	2
	1/31/06	75	14	0.26	0.26	1.99	1.0	3
	5/24/06	13	19	0.38	0.38	2.18	**4.0**	2
	10/10/06	26	19	0.38	0.38	2.45	1.0	2
	1/17/07	47	18	0.36	0.36	2.53	**9.0**	3
	4/11/07	19	17	0.33	0.33	2.02	**4.0**	2
	7/25/07	20	41	1.02	0.94	5.74	0.5	2
	11/28/07	25	16	0.31	0.31	1.95	1.0	2
	2/5/08	140	19	0.38	0.38	3.27	1.0	4
	Average	*66.5*	*21.8*	0.44	0.44	3.42	3.4	3.08

Table B-1 (cont'd) Monitoring Data and Calculations for Hardness-Dependent Metals

Station ID	Date	TSS	Hardness (as $CaCO_3$)	Lead				Arsenic
				CCC_{TR}	CCC_{DIS}	$ITRC_{Chr}$	Observed Value	Observed Value
		[mg/l]	[mg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]
WOLF009.3SH	6/30/03	19	23	0.49	0.49	2.96	1.0	2
	8/4/03	376	24	0.52	0.52	5.26	**9.0**	10
	10/1/03	25	12	0.21	0.21	1.35	1.0	2
	11/3/03	27	15	0.28	0.28	1.82	0.5	1U
	12/3/03	22	17	0.33	0.33	2.07	2.0	2
	1/7/04	24	16	0.31	0.31	1.94	1.0	3
	2/4/04	24	13	0.24	0.24	1.49	1.0	2
	3/2/04	204	18	0.36	0.36	3.27	**5.0**	4
	4/7/04	26	17	0.33	0.33	2.12	1.0	2
	5/5/04	45	16	0.31	0.31	2.16	0.5	3
	6/2/04	114	20	0.41	0.41	3.37	3.0	3
	8/5/08	54	15	0.28	0.28	2.05	1.5	2.2J
	9/2/08	26	17	0.33	0.33	2.12	1.0	1.9J
	10/9/08	180	19	0.38	0.38	3.42	**5.2**	4.3J
	11/4/08	10	14	0.26	0.26	1.42	0.7	0.98j
	12/2/08	5	14	0.26	0.26	1.27	0.7	1.2J
	1/6/09	178	30	0.69	0.66	5.91	**6.9**	5.7
	2/4/09	22	14	0.26	0.26	1.61	1.2	1.2J
	3/4/09	62	16	0.31	0.31	2.28	**2.5**	1.9
	4/8/09	33	18	0.36	0.36	2.38	1.7	2.1J
	5/7/09	260	19	0.38	0.38	3.65	**6.8**	4.1J
	6/2/09	77	22	0.46	0.46	3.55	1.7	2.9J
	Average	*82.4*	*17.7*	0.35	0.35	2.72	**2.49**	

APPENDIX C

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:

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

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (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.

Individual metal TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Wolf River Watershed. Daily Loads for TMDLs, WLAs, and LAs are expressed as a function of daily mean in-stream flow (daily loading function), hardness, and total suspended solids (TSS).

C.1 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:

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

Expanding the terms:

$$TMDL = [\Sigma\ WLAs]_{MS4} + [\Sigma\ WLAs]_{TMSP} + [\Sigma\ LAs]_{SW} + MOS$$

For metals TMDLs in the Wolf River watershed, WLA terms include:

- $[WLA]_{MS4}$ = the allowable metal load for discharges from MS4s. Loading from these sources is the result of buildup/wash-off processes associated with storm events.
- $[WLA]_{TMSP}$ = the allowable metal loading from TMSPs. Loading from these sources is the result of buildup/wash-off processes associated with storm events. Industrial facilities are considered to be in compliance with provisions of the TMDL (WLA) if they are covered under the *Tennessee Storm Water Multi-Sector General Permit* (TMSP) for Industrial Activities and satisfy all conditions of the permit including meeting benchmark permit limits.

For metals TMDLs in the Wolf River watershed, LA terms include:

- $[LA]_{SW}$ = the allowable metal loading from nonpoint sources indirectly going to surface waters from all land use areas (except areas covered by an MS4 permit) as a result of the buildup/wash-off processes associated with storm events (i.e., precipitation induced).

The expression relating TMDLs to precipitation-based point and nonpoint sources may be simplified to:

$$TMDL - MOS = [\Sigma WLA]_{MS4} + [\Sigma LA]_{SW}$$

WLAs for MS4s and LAs for precipitation-based nonpoint sources are equal on a per unit area basis and may be expressed as the daily allowable load per unit area (acre) resulting from a decrease in in-stream concentrations to TMDL target values minus MOS:

$$WLA_{MS4} = LA_{SW} = \{TMDL - MOS\} / DA$$

Where: DA = waterbody drainage area (acres)

As stated in Section 7.3, an explicit MOS, equal to 10% of the water quality targets (ref.: Section 4.0), was utilized for determination of the percent load reductions necessary to achieve the WLAs and LAs.

C.2 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 (μg/l)
Q = daily mean flow (ft^3/sec)
UCF = the required unit conversion factor
= 5.3944×10^{-3} (lb-sec-L)/(μg-day-ft^3)

Using Harrington Creek as an example for arsenic:

$$TMDL_{Harrington\ Creek} = (10\ \mu g/L) \times (Q) \times (UCF)$$

$$\mathbf{TMDL_{Harrington\ Creek} = 5.39 \times 10^{-2} \times Q\ (lbs/day)}$$

$$MOS_{Harrington\ Creek} = TMDL \times 0.10$$

$$\mathbf{MOS_{HarringtonCreek} = 5.39 \times 10^{-3} \times Q\ (lbs/day)}$$

Using the equation in section C.1:

$$\Sigma\ LAs = \Sigma\ WLAs = (TMDL - MOS) / DA$$

$$LA_{Harrington\ Ck} = WLA_{Harrington\ Ck} = \{(5.39 \times 10^{-2} \times Q) - (5.39 \times 10^{-3} \times Q)\} / (7{,}548\ ac)$$

$$\mathbf{LA_{Harrington\ Ck} = WLA_{HarringtonCk} = (6.43 \times 10^{-6}) \times Q\ (lbs/day/acre)}$$

Since lead is a hardness-dependent metal, the target concentration is an equation. As developed in Appendix B:

$$\text{Target Concentration} = ITRC_{chronic} = CCC_{DIS} / \text{Translator}$$

$$= (CCC_{TR} / \text{Translator}) \times CCF$$

$$= \{Exp[1.273(\ln H) - 4.705] \times [1 + (2.8)(TSS^{0.2})]\} \times \{1.462 - [(\ln H)(0.145712)]\}$$

where: H = ambient hardness (mg/l)
TSS = ambient total suspended solids (mg/l)

Therefore:

$$\mathbf{TMDL = \{Exp[1.273(\ln H) - 4.705] \times [1 + (2.8)(TSS^{0.2})]\} \times \{1.462 - [(\ln H)(0.145712)]\} \times (Q) \times (5.39\times10^{-3})\ (lbs/day)}$$

$$MOS = TMDL \times 0.10$$

$$\mathbf{MOS = \{Exp[1.273(\ln H) - 4.705] \times [1 + (2.8)(TSS^{0.2})]\} \times \{1.462 - [(\ln H)(0.145712)]\} \times (Q) \times (5.39\times10^{-4})\ (lbs/day)}$$

Using the equation in section C.1 and using Wolf River (segment 001-1000) as an example:

$$\Sigma\ LAs = \Sigma\ WLAs = (TMDL - MOS) / DA = (TMDL \times 0.90) / DA$$

$$LA_{001\text{-}1000} = WLA_{001\text{-}1000} = \{Exp[1.273(\ln H) - 4.705] \times [1 + (2.8)(TSS^{0.2})]\} \times \{1.462 - [(\ln H)(0.145712)]\} \times (Q) \times (5.39\times10^{-3})\ (0.90) / (524{,}265\ \text{acres})$$

$$\mathbf{LA_{001\text{-}1000} = WLA_{001\text{-}1000} = \{Exp[1.273(\ln H) - 4.705] \times [1 + (2.8)(TSS^{0.2})]\} \times \{1.462 - [(\ln H)(0.145712)]\} \times (Q) \times (9.26\times10^{-9})\ (lbs/day/acre)}$$

TMDLs, WLAs, & LAs for impaired waterbodies in the Wolf River Watershed are summarized in Tables C-1 and C-2.

Table C-1. TMDLs and MOS expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210)

HUC-12 Subwatershed (08010210__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	Constituent	TMDL	Explicit MOS
				[lbs/day]	[lbs/day]
0307	Fletcher Creek	TN08010210023 – 1000	Arsenic	$5.39 \times 10^{-2} \times Q$	$5.39 \times 10^{-3} \times Q$
	Unnamed Trib to Fletcher Creek	TN08010210023 – 0100			
0308 (DA)	Cypress Creek	TN08010210032 – 1000	Lead	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-3}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-4}) \times Q$
0308 (DA)	Harrington Creek	TN08010210001 – 0100	Arsenic	$5.39 \times 10^{-2} \times Q$	$5.39 \times 10^{-3} \times Q$
0308	Wolf River	TN08010210001 – 1000	Lead	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-3}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (5.39 \times 10^{-4}) \times Q$

Notes: Q = Mean Daily In-stream Flow (cfs).
H = Hardness (mg/L as $CaCO_3$)
TSS = Total Suspended Solids (mg/L)

Table C-2. WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210)

HUC-12 Subwatershed (08010210__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	Constituent	PLRG	WLAs*	LAs (SW)
				[%]	[lbs/day/ac]	[lbs/day/ac]
0307	Fletcher Creek	TN08010210023 – 1000	Arsenic	16.7	$8.79 \times 10^{-6} \times Q$	$2.36 \times 10^{-7} \times Q$
	Unnamed Trib to Fletcher Creek	TN08010210023 – 0100		20.6	$7.28 \times 10^{-6} \times Q$	$2.36 \times 10^{-7} \times Q$
0308 (DA)	Cypress Creek	TN08010210032 – 1000	Lead	8.6	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (4.72 \times 10^{-7}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (4.25 \times 10^{-7}) \times Q$
0308 (DA)	Harrington Creek	TN08010210001 – 0100	Arsenic	47.4	$6.43 \times 10^{-6} \times Q$	$6.43 \times 10^{-6} \times Q$
0308	Wolf River	TN08010210001 – 1000	Lead	50.3	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (1.05 \times 10^{-8}) \times Q$	$\{Exp[1.273(\ln H) – 4.705] \times [1+(2.8)(TSS^{0.2})]\} \times \{1.462 – [(\ln H)(0.145712)\} \times (9.26 \times 10^{-9}) \times Q$

Notes: Q = Mean Daily In-stream Flow (cfs).
H = Hardness (mg/L as $CaCO_3$)
TSS = Total Suspended Solids (mg/L)
PLRG = Percent Load Reduction Goal to achieve TMDL.

* WLA term represents loading from regulated MS4s. TMSPs are considered to be in compliance with provisions of the TMDL (WLA) if they are covered under the *Tennessee Storm Water Multi-Section General Permit* (TMSP) for Industrial Activities and satisfy all conditions of the permit including meeting benchmark permit limits.

APPENDIX D

Duration Curve Development

D.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 Windows version of Hydrologic Simulation Program - Fortran (WinHSPF).

Flow duration curves for most metals-impaired waterbodies in the Wolf River Watershed were derived from WinHSPF hydrologic simulations based on parameters derived from calibration at USGS Station No. 07031692, located on Fletcher Creek at Sycamore View Road in Memphis, Tennessee (see Appendix E for details of calibration). Flow duration curves for segments of Wolf River were derived from an area ratio of the flow at USGS Station No. 07031740, located on the Wolf River at Hollywood St in Memphis, TN. For example, a flow-duration curve for Wolf River at RM 9.3 was constructed for the period from 1/1/01 through 12/31/10 (RM 9.3 corresponds to the location of monitoring station WOLF009.3SH). This flow duration curve is shown in Figure D-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). The flow duration curve for other impaired waterbodies was derived using a similar procedure.

D.2 Development of Concentration Duration Curves

Pollutant monitoring data, plotted on a Concentration Duration Curve (CDC), provides a visual depiction of stream water quality over the entire range of flow as well as the frequency and magnitude of any exceedances. 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 duration curve (representing zones of higher flow) generally reflect potential nonpoint source contributions (Stiles, 2003).

Concentration duration curves for specific monitoring locations in the Wolf River watershed were developed. Using the flow duration curves developed in D.1, the “percent of days the flow was exceeded” (PDFE) was determined for each sampling event. Each sample concentration was then plotted according to the PDFE. The resulting lead concentration duration curve for Wolf River at mile 9.3 is shown in Figure D-2.

Example – 1/6/09 sampling event:
Modeled Flow = 4,240 cfs
PDFE = 4.5%

CDCs for other metals and other impaired waterbodies were derived in a similar manner and are shown in Figures D-3 through D-11.

D.3 Calculation of Percent Load Reduction Goals (PLRGs) and Determination of Critical Flow Zones

In order to facilitate implementation, corresponding percent reductions in loading required to decrease existing, in-stream loads to TMDL target levels (percent load reduction goals) were calculated. As a result, critical flow zones were determined and subsequently verified by secondary analyses. The following example is from Wolf River at Mile 9.3.

1. For cases where the measured concentration exceeded the target criteria at a particular PDFE, the reduction required to reduce the sample concentration to the target criteria was calculated.

   Example – 1/6/09 sampling event:
   Target Concentration = 5.91 μg/L
   Measured Concentration = 6.9 μg/L
   Reduction to Target = 14.4%

2. The CDC for Wolf River was analyzed to determine the frequency with which observed daily water quality concentrations exceed the target criteria under five flow conditions (low, dry, mid-range, moist, and high). Observation of the plot illustrates that the exceedances occurred under both high flow and moist conditions indicating that the Wolf River watershed may be impacted by nonpoint sources.

3. For each flow zone, the mean of the observed percent exceedances of individual concentrations relative to their respective target criteria (at their respective PDFEs) was calculated. Each negative percent exceedance was assumed to be equal to zero.

Date	Sample Conc. (μg/ mL)	Flow (cfs)	Target Criteria (μg/ mL)	Percent Reduction
5/7/09	6.8	4,873	3.65	46.3
1/6/09	6.9	4,240	5.91	14.4
Percent Load Reduction Goal (PLRG) for High Flow Conditions (Mean)				**30.3**

4. The PLRGs calculated for each of the flow zones were compared and the PLRG of the greatest magnitude indicates the flow zone for prioritizing implementation actions for Wolf River at RM9.3.

Example – ***High Flow Zone Percent Load Reduction Goal = 30.3***
Moist Conditions Flow Zone Percent Load Reduction Goal = 14.3
Mid-Range Flow Zone Percent Load Reduction Goal = NR
Dry Conditions Flow Zone Percent Load Reduction Goal = NR
Low Flow Zone Percent Load Reduction Goal = NR

Therefore, the flow zone for prioritization of Wolf River implementation activities is the High Flow Zone and subsequently actions targeting predominantly nonpoint source controls.

A summary of flow zones for prioritization of implementation activities for all metal impaired waterbodies in the Wolf River Watershed is presented in Table D-1.

Table D-1. Summary of Flow Zones and Locations for Prioritization of Implementation Activities for Metal Impaired Waterbodies in the Wolf River Watershed.

Waterbody ID	Arsenic	Lead
UT to Fletcher Creek [b]	Low flow	
Fletcher Creek [b]	High flow (RM5.2)	
Cypress Creek [b]		High flow (RM4.8)
Harrington Creek [b]	Low flow (RM1.8)	
Wolf River (001-1000) [a]		High flow (RM1.5)

* Shaded areas indicate waterbody not listed and no exceedances occurred.
[a] Waterbody(ies) with 5 flow zones.
[b] Waterbody(ies) with 4 flow zones.

5. Due to the frequently limited availability of sampling data and subsequent randomness of distribution of samples by flow zone, the determination of the priority flow zone by PLRG calculation often has a high degree of uncertainty. Therefore, secondary analyses were conducted to verify or supplement the determination of the priority flow zones. For each flow zone, the percent of samples that exceed the TMDL target levels was calculated. For Wolf River at RM9.3:

Flow Zone	Number of Samples	Samples > Target µg/mL	% > Target µg/mL
High	***2***	***2***	***100.0***
Moist	3	2	66.7
Mid-Range	1	0	0.0
Dry	3	0	0.0
Low	2	0	0.0

The priority flow zone for Wolf River implementation activities is confirmed as the high flow zone. If a different flow zone were indicated, both zones would receive equal emphasis for implementation prioritization.

6. Lastly, emphasis (priority) should be placed on recent data versus historical data. If data from multiple watershed cycles is available, analysis of recent data (current cycle) versus the entire period of record, or previous cycles, may identify different priority areas for implementation. The following example is from Wolf River at RM9.3.

Zone	Previous Cycle (2003-2007)			Most Recent (2008-2012)		
	# of samples	% Red.	% Exc.	# of samples	% Red.	% Exc.
High	0	NA	NA	2	**30.3**	**100**
Moist	6	**12.7**	**33.3**	3	14.3	66.7
Mid-Range	2	NR	0	1	NR	0
Dry	3	NR	0	3	NR	0
Low	0	NA	NA	2	NR	0

In this case, the priority flow zone for implementation activities for the most recent cycle is not the same zone as the previous cycle indicated. Therefore, the flow zone from analysis of the most recent data would have emphasis for implementation prioritization.

Percent load reduction goals for other metals and other impaired waterbodies were derived in a similar manner and are shown in Tables D-2 through D-10.

PLRGs for impaired waterbodies in the Wolf River Watershed are summarized in Table D-11.

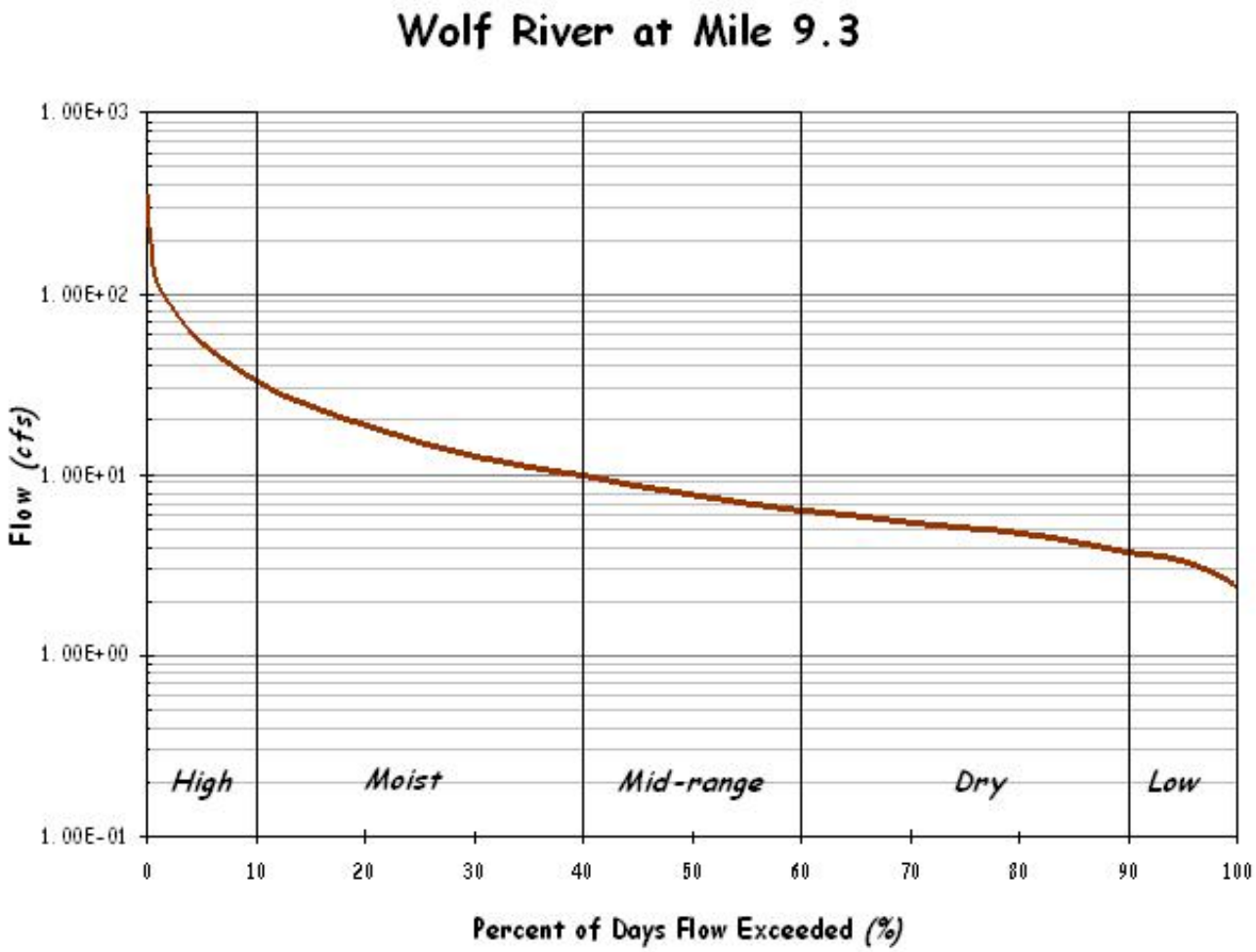


Figure D-1 Flow Duration Curve for Wolf River at RM9.3

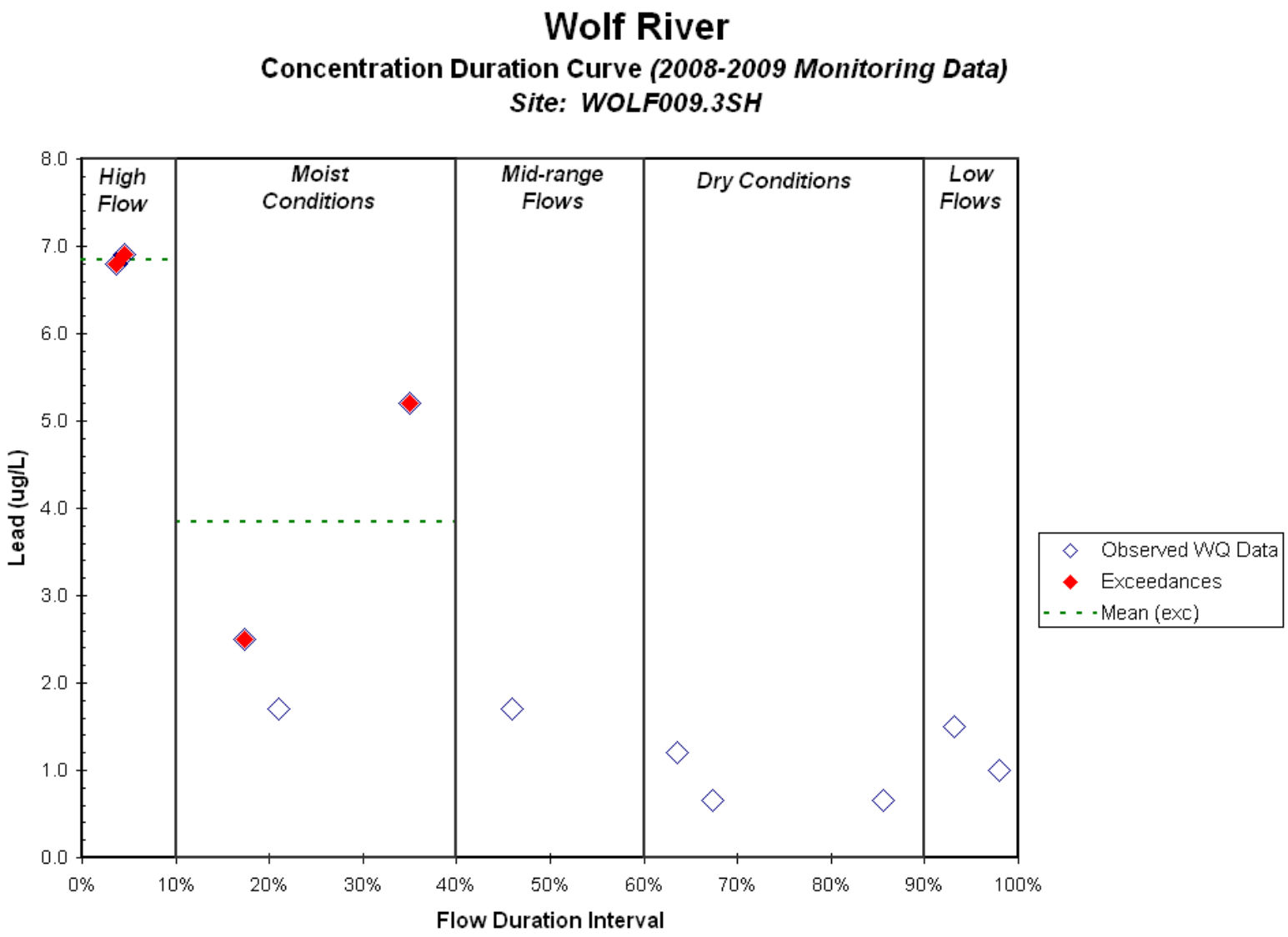


Figure D-2 Lead Concentration Duration Curve for Wolf River at RM9.3

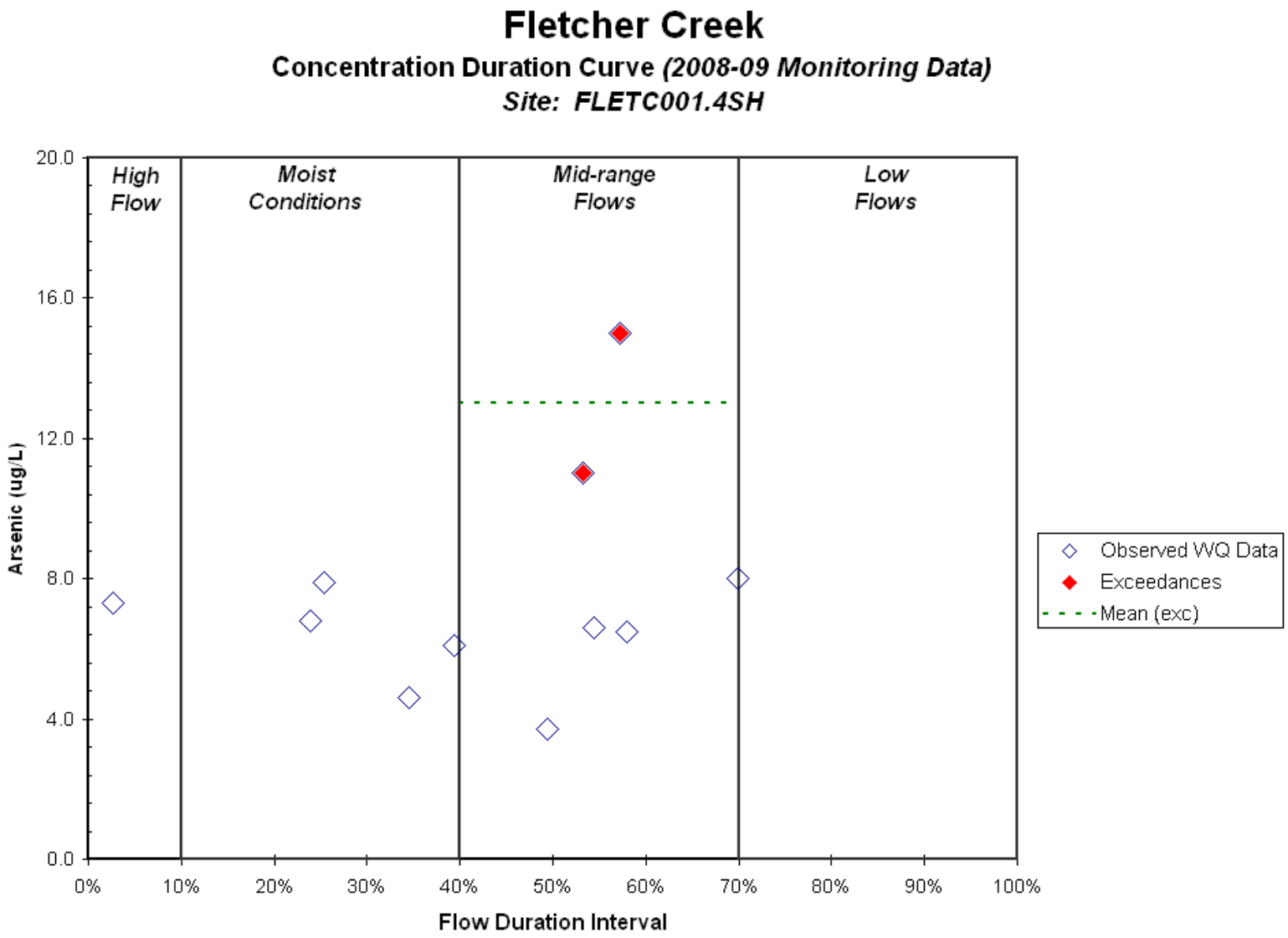


Figure D-3 Arsenic Concentration Duration Curve for Fletcher Creek at Mile 1.4

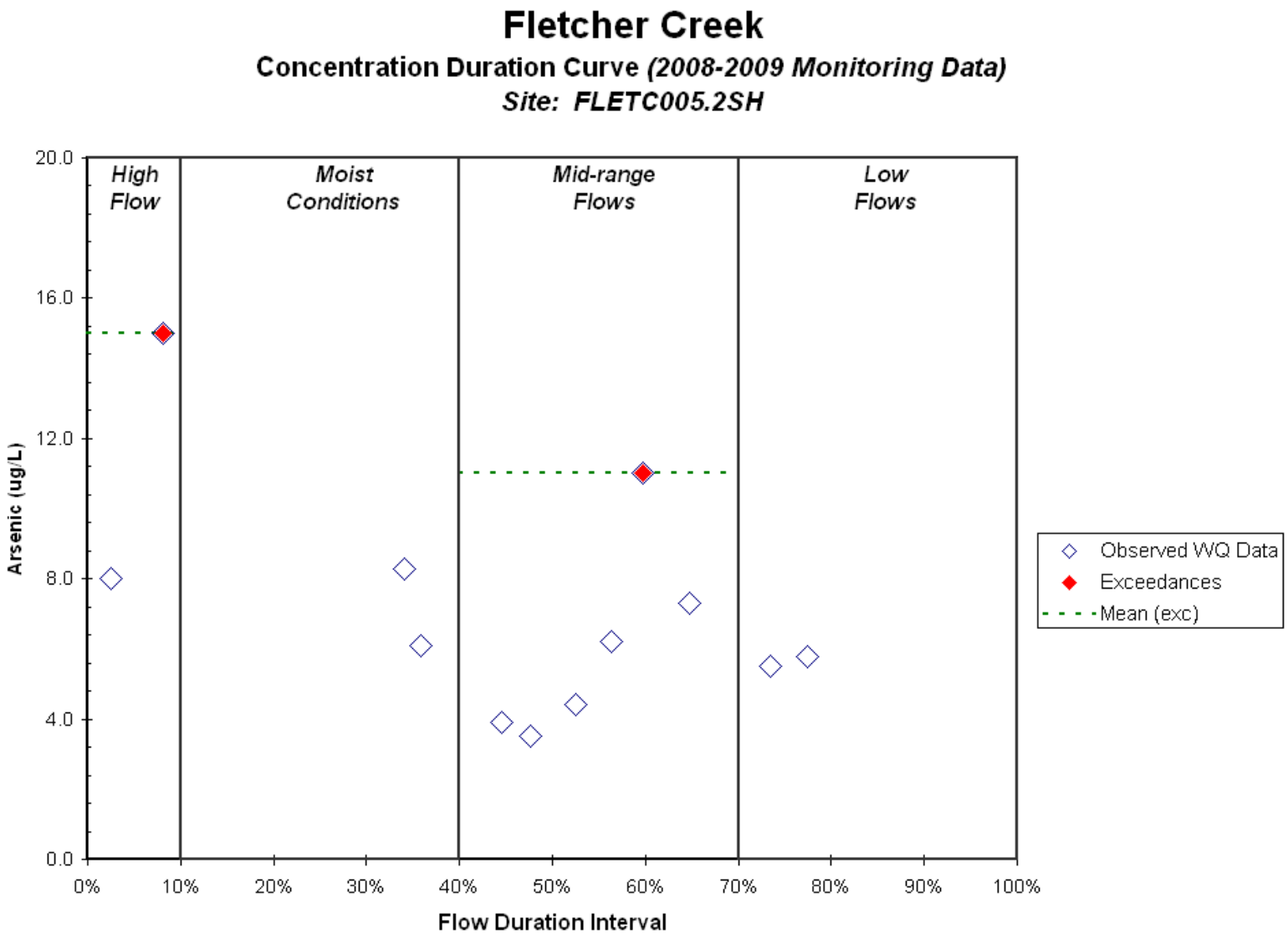


Figure D-4 Arsenic Concentration Duration Curve for Fletcher Creek at Mile 5.2

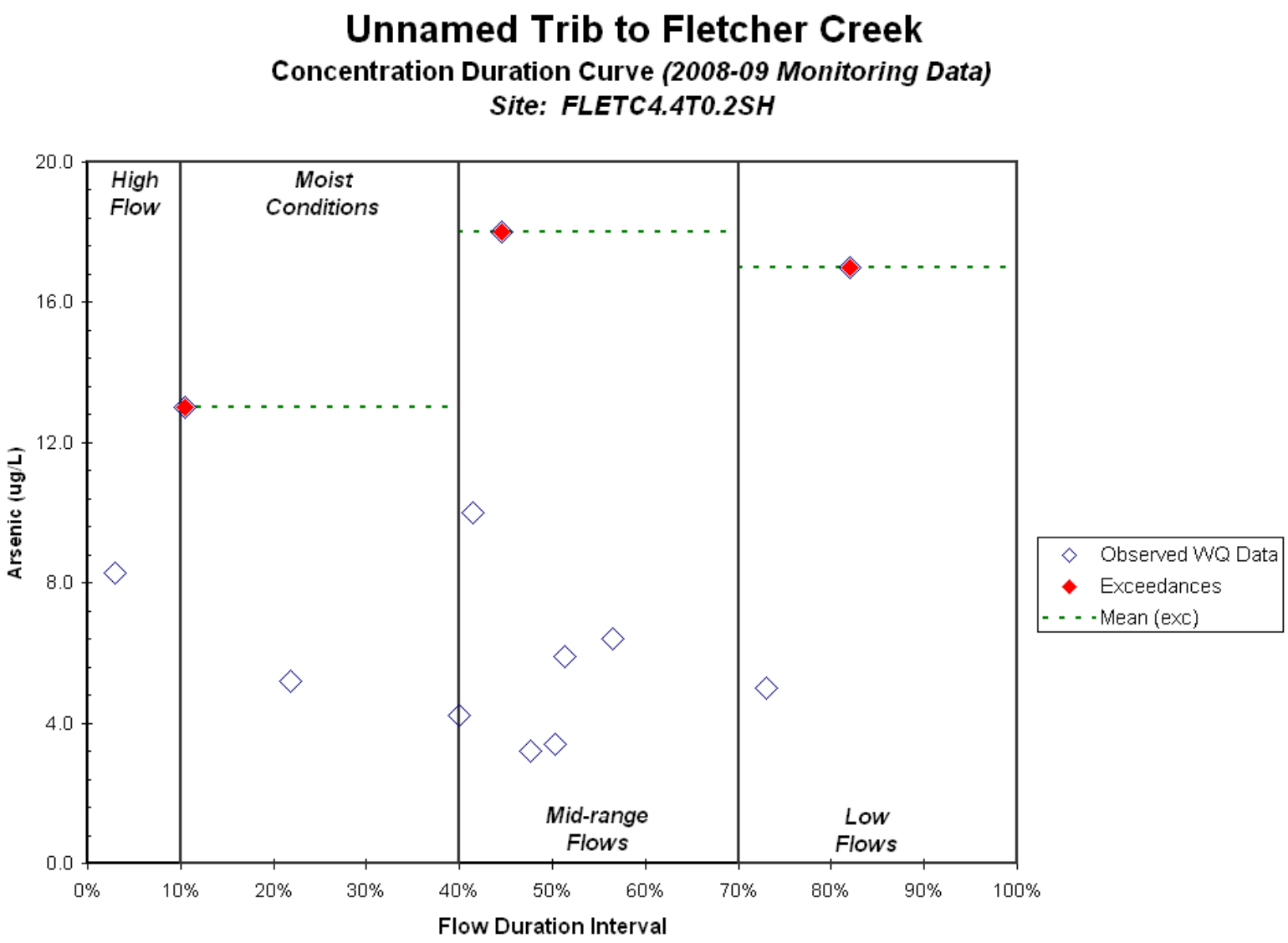


Figure D-5 Arsenic Concentration Duration Curve for Unnamed Tributary to Fletcher Creek at Mile 0.2

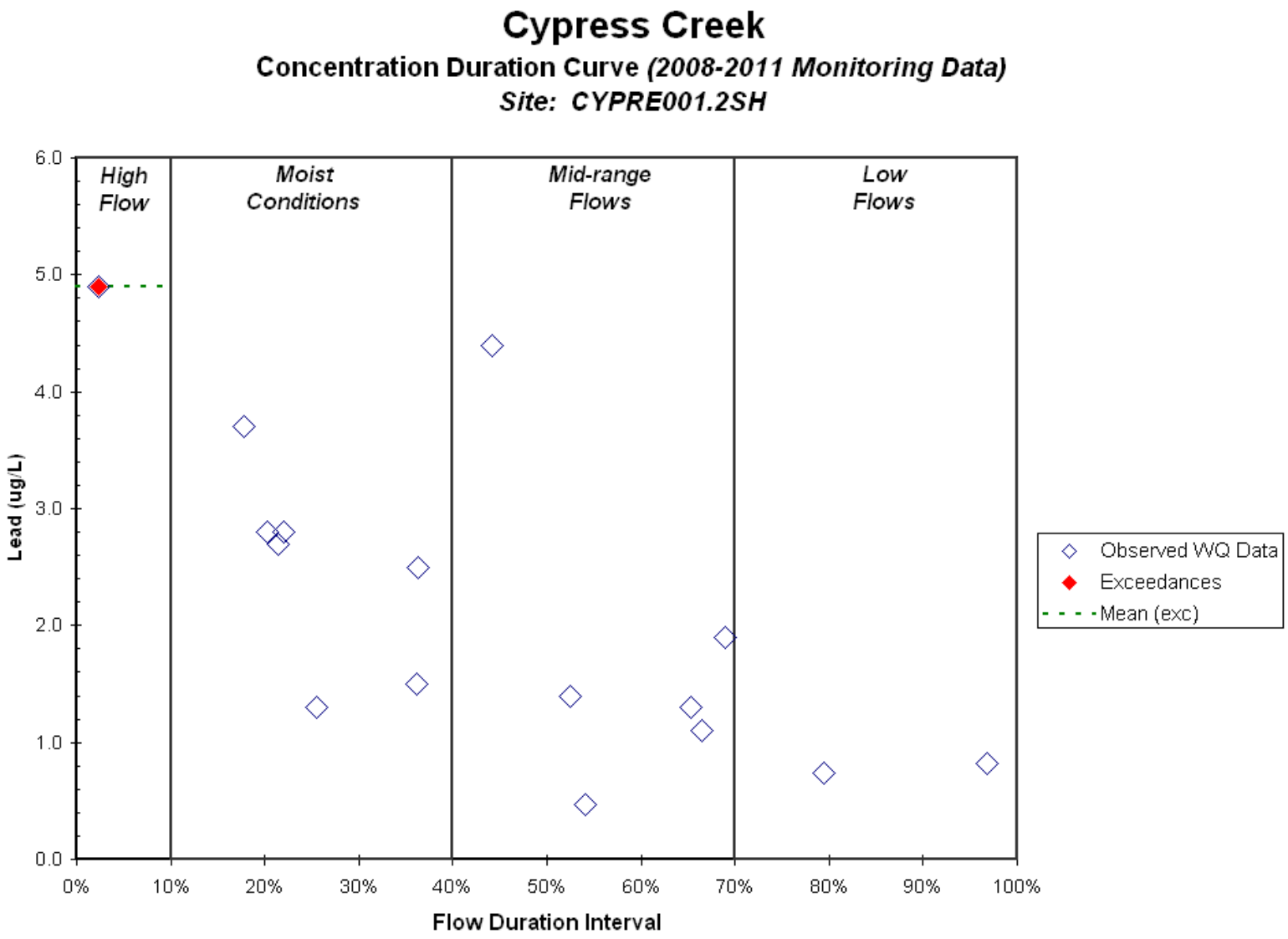


Figure D-6 Lead Concentration Duration Curve for Cypress Creek at Mile 1.2

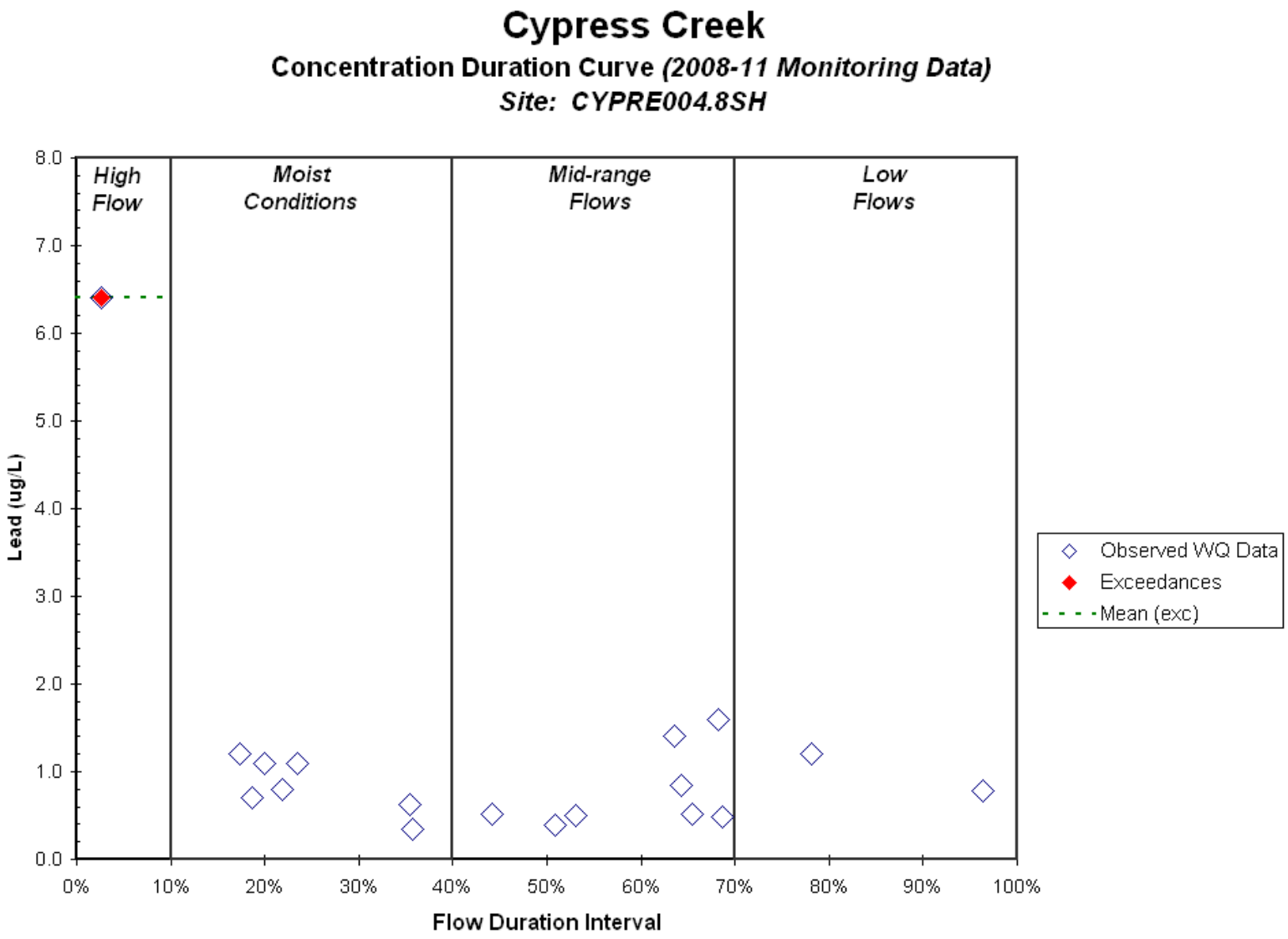


Figure D-7 Lead Concentration Duration Curve for Cypress Creek at Mile 4.8

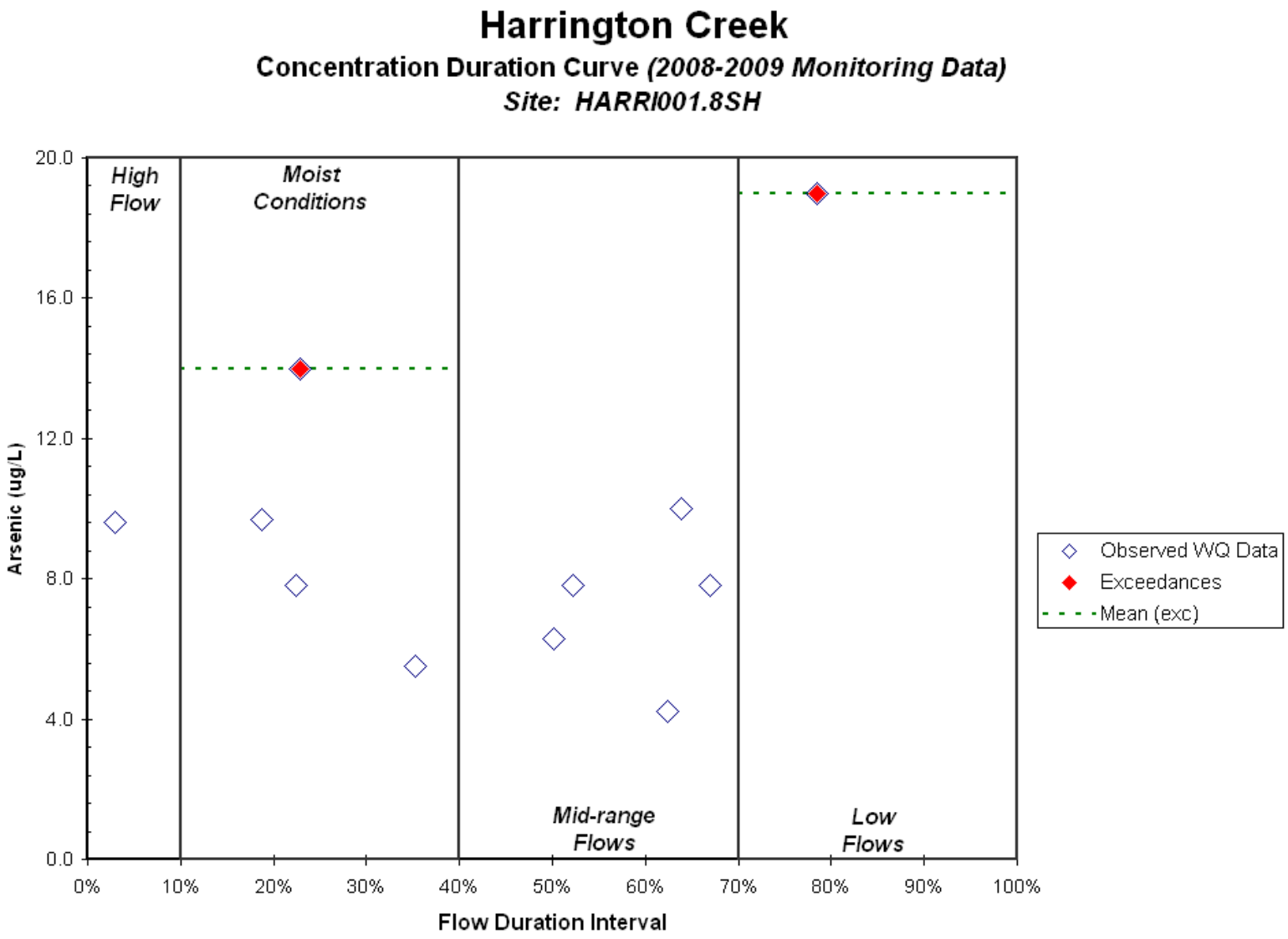


Figure D-8 Arsenic Concentration Duration Curve for Harrington Creek at Mile 1.8

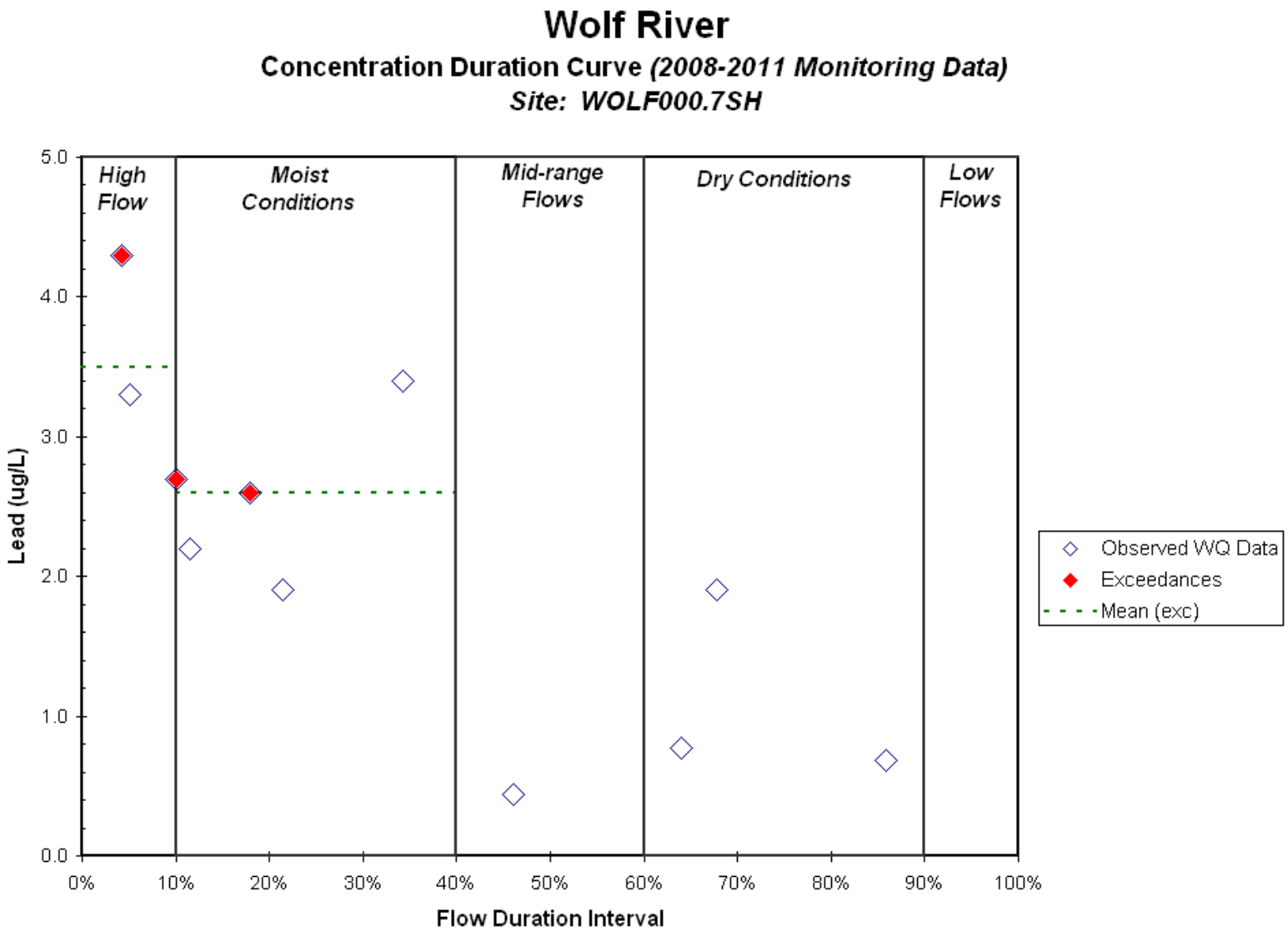


Figure D-9 Lead Concentration Duration Curve for Wolf River at Mile 0.7

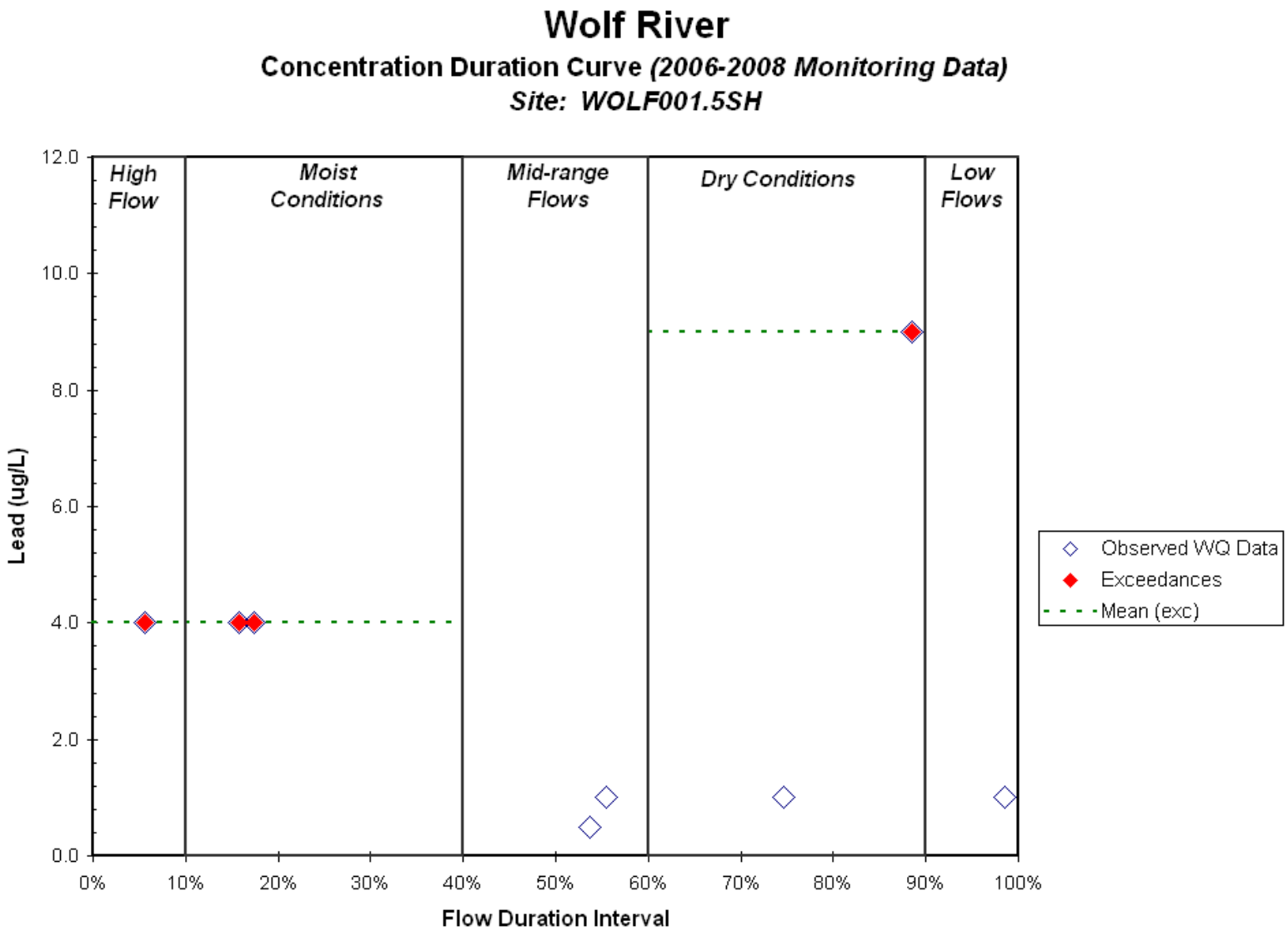


Figure D-10 Lead Concentration Duration Curve for Wolf River at Mile 1.5

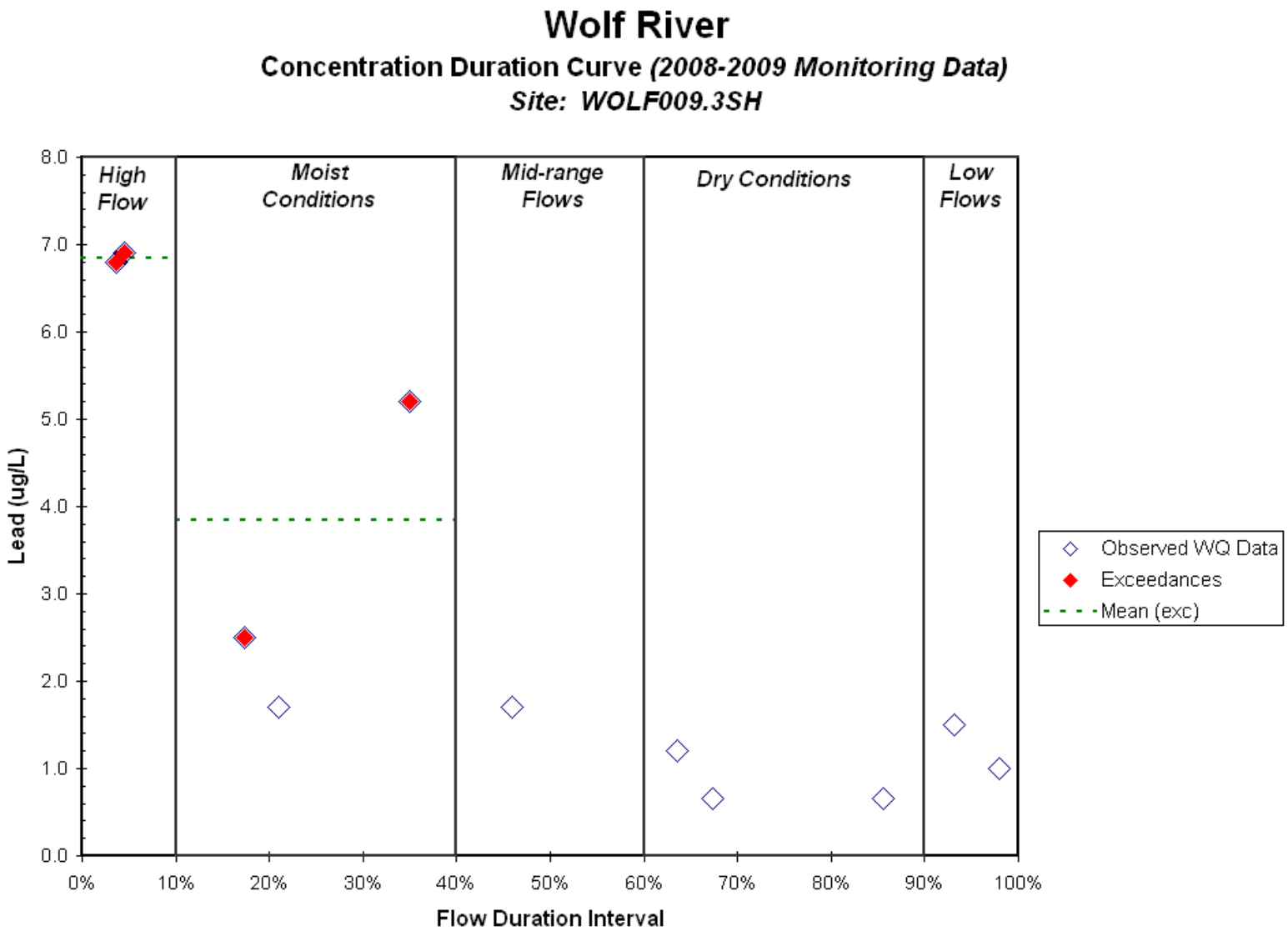


Figure D-11 Lead Concentration Duration Curve for Wolf River at Mile 9.3

Table D-2. Calculated Load Reduction Based on Daily Loading – Fletcher Creek at RM1.4 – Arsenic

Sample Date	Flow Regime	Flow	PDFE	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[lb/day]	[%]	[%]
1/6/09	High Flow	548	2.6%	7.3	2.16E+01	NR	**NR**
9/2/08	Moist Conditions	19.5	23.9%	6.8	7.14E-01	NR	
5/7/09		17.9	25.4%	7.9	7.63E-01	NR	
3/4/09		12.2	34.5%	4.6	3.02E-01	NR	
4/8/09		10.3	39.4%	6.1	3.40E-01	NR	**NR**
2/4/09	Mid-Range Flows	7.10	49.4%	3.7	1.42E-01	NR	
10/9/08		5.96	53.3%	11	3.53E-01	**9.1**	
12/2/08		5.59	54.4%	6.6	1.99E-01	NR	
8/12/08		4.60	57.3%	15	3.72E-01	**33.3**	
11/4/08		4.41	58.0%	6.5	1.55E-01	NR	
6/2/09		1.54	69.9%	8	6.64E-02	NR	**7.1**

Note: NR = No reduction required

Table D-3. Calculated Load Reduction Based on Daily Loading – Fletcher Creek at RM5.2 – Arsenic

Sample Date	Flow Regime	Flow	PDFE	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[lb/day]	[%]	[%]
1/6/09	High Flow	179	2.5%	8	7.74E+00	NR	
9/4/08		55.2	8.1%	15	4.47E+00	**33.3**	**16.7**
5/7/09	Moist Conditions	2.89	34.0%	8.3	1.29E-01	NR	
4/8/09		2.72	35.9%	6.1	8.96E-02	NR	**NR**
2/4/09	Mid-Range Flows	2.05	44.5%	3.9	4.31E-02	NR	
3/10/09		1.81	47.6%	3.5	3.43E-02	NR	
12/2/08		1.48	52.5%	4.4	3.51E-02	NR	
11/4/08		1.23	56.3%	6.2	4.12E-02	NR	
10/9/08		0.97	59.7%	11	5.74E-02	**9.1**	
8/12/08		0.64	64.8%	7.3	2.50E-02	NR	**1.5**
6/10/09	Low Flow	0.27	73.5%	5.5	8.11E-03	NR	
7/1/08		0.15	77.5%	5.8	4.77E-03	NR	**NR**

Note: NR = No reduction required

Table D-4. Calculated Load Reduction Based on Daily Loading – UT to Fletcher Creek at RM0.2 – Arsenic

Sample Date	Flow Regime	Flow	PDFE	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[lb/day]	[%]	[%]
1/6/09	High Flow	152	2.9%	8.3	6.81E+00	NR	**NR**
9/4/08	Moist Conditions	33.4	10.5%	13	2.35E+00	**23.1**	
5/7/09		8.56	21.9%	5.2	2.40E-01	NR	
4/8/09		3.86	39.9%	4.2	8.75E-02	NR	**7.7**
10/9/08	Mid-Range Flows	3.61	41.5%	10	1.95E-01	NR	
8/12/08		3.13	44.6%	18	3.04E-01	**44.4**	
3/10/09		2.66	47.6%	3.2	4.59E-02	NR	
2/4/09		2.32	50.3%	3.4	4.25E-02	NR	
12/2/08		2.16	51.3%	5.9	6.89E-02	NR	
11/4/08		1.52	56.5%	6.4	5.23E-02	NR	**7.4**
6/10/09	Low Flow	0.36	73.0%	5	9.63E-03	NR	
7/1/08		0.14	82.0%	17	1.27E-02	**41.2**	**20.6**

Note: NR = No reduction required

Table D-5. Calculated Load Reduction Based on Daily Loading – Cypress Creek at RM1.2 – Lead

Sample Date	Flow Regime	Flow	PDFE	Target Concentration	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[μg/ml]	[lb/day]	[%]	[%]
1/6/09	High Flow	211	2.4%	4.5	4.9	5.56E+00	**8.6**	**8.6**
5/7/09	Moist Conditions	15.6	17.7%	9.5	3.7	3.12E-01	NR	
3/15/11		1.16	44.1%	9.4	4.4	1.87E-01	NR	
11/17/10		10.8	21.3%		2.7	1.57E-01	NA	
10/9/08		10.3	21.8%	7.0	2.8	1.55E-01	NR	
9/2/08		7.30	25.3%	12.2	1.3	5.12E-02	NR	
12/14/10		2.47	35.9%	10.1	1.5	1.99E-02	NR	
3/4/09		2.46	36.0%	12.2	2.5	3.32E-02	NR	**NR**
1/19/11	Mid-Range Flows	1.16	44.1%	9.4	4.4	2.74E-02	NR	
2/4/09		0.64	52.2%	13.6	1.4	4.83E-03	NR	
4/8/09		0.60	53.8%	20.3	0.47	1.52E-03	NR	
12/2/08		0.36	64.4%	25.8	11	2.14E-02	NR	
6/2/09		0.34	65.1%	24.8	1.3	2.41E-03	NA	
2/17/11		0.33	66.4%	13.6	1.1	1.93E-03	NR	
7/1/08		0.28	68.6%	14.4	1.9	2.87E-03	NR	**NR**
8/5/08	Low Flow	0.15	79.4%	12.2	0.74	6.11E-04	NR	
10/12/10		0.001	96.6%	13.6	0.82	4.42E-06	NR	**NR**

Note: NR = No reduction required
NA = Not applicable; target concentration could not be determined due to lack of hardness and/or TSS data, or lack of flow data

Table D-6. Calculated Load Reduction Based on Daily Loading – Cypress Creek at RM4.8 – Lead

Sample Date	Flow Regime	Flow	PDFE	Target Concentration	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[μg/ml]	[lb/day]	[%]	[%]
1/6/09	High Flow	106	2.7%	6.1	6.4	3.65E+00	**5.4**	**5.4**
5/7/09	Moist Conditions	8.59	17.3%	10.5	1.2	5.56E-02	NR	
11/17/10		7.41	18.6%		0.71	2.84E-02	NA	
3/15/11		6.53	19.9%	6.5	1.1	3.87E-02	NR	
10/9/08		5.21	21.6%	6.5	0.79	2.22E-02	NR	
9/2/08		4.52	23.2%	7.1	1.1	2.68E-02	NR	
3/4/09		1.14	35.2%	5.8	0.62	3.82E-03	NR	
12/14/10		1.10	35.4%	5.5	0.35	2.08E-03	NR	**NR**
1/19/11	Mid-Range Flows	0.52	44.2%	5.5	0.51	1.42E-03	NR	
2/4/09		0.36	50.6%	4.3	0.39	7.55E-04	NR	
4/8/09		0.33	52.8%	5.0	0.5	8.79E-04	NR	
12/2/08		0.20	63.5%	7.5	1.4	1.53E-03	NR	
6/2/09		0.20	64.2%	9.6	0.84	8.88E-04	NR	
2/17/11		0.19	65.4%	5.0	0.51	5.14E-04	NR	
7/1/08		0.16	67.9%	6.5	1.6	1.38E-03	NR	
11/4/08		0.16	68.4%	6.5	0.48	4.07E-04	NR	**NR**
8/5/08	Low Flow	0.10	78.1%	7.6	1.2	6.15E-04	NR	
10/12/10		0.002	96.1%	6.1	0.78	8.42E-06	NR	**NR**

Note: NR = No reduction required
NA = Not applicable; target concentration could not be determined due to lack of hardness and/or TSS data or lack of flow data

Table D-7. Calculated Load Reduction Based on Daily Loading – Harrington Creek at RM1.8 – Arsenic

Sample Date	Flow Regime	Flow	PDFE	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[lb/day]	[%]	[%]
1/6/09	High Flow	174	2.9%	9.6	9.01E+00	NR	**NR**
5/7/09	Moist Conditions	11.9	18.8%	9.7	6.22E-01	NR	
9/2/08		8.05	22.4%	7.8	3.39E-01	NR	
10/9/08		7.74	22.9%	14	5.84E-01	**28.6**	
3/4/09		1.77	35.3%	5.5	5.25E-02	NR	**7.1**
2/4/09	Mid-Range Flows	0.57	50.1%	6.3	1.92E-02	NR	
4/8/09		0.50	52.2%	7.8	2.12E-02	NR	
12/2/08		0.33	62.4%	4.2	7.41E-03	NR	
6/2/09		0.30	63.8%	10	1.61E-02	NR	
11/4/08		0.25	67.0%	7.8	1.06E-02	NR	**NR**
8/5/08	Low Flow	0.14	78.4%	19	1.39E-02	**47.4**	**47.4**

Note: NR = No reduction required

Table D-8 Calculated Load Reduction Based on Daily Loading – Wolf River at RM0.7 – Lead

Sample Date	Flow Regime	Flow	PDFE	Target Concentration	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[μg/ml]	[lb/day]	[%]	[%]
3/15/11	High Flow	21,453	0.4%	2.75	0.66	7.64E+01	NR	
5/7/09		5,108	4.3%	3.77	**4.3**	1.18E+02	**12.4**	
1/6/09		4,444	5.1%	3.73	3.3	7.91E+01	NR	
12/15/09		2,758	10.0%	2.04	**2.7**	4.02E+01	**24.5**	**9.2**
3/23/10	Moist Conditions	2,452	11.5%	3.10	2.2	2.91E+01	NR	
3/4/09		1,675	17.9%	2.27	**2.6**	2.35E+01	**12.8**	
4/8/09		1,430	21.4%	2.12	1.9	1.47E+01	NR	
9/23/09		885	34.3%	4.96	3.4	1.62E+01	NR	**3.2**
6/2/09	Mid-Range Flows	664	46.1%	4.58	0.44	1.58E+00	NR	
12/8/10		518	58.3%	2.15	0.51	1.42E+00	NR	**NR**
2/4/09	Dry Conditions	470	64.0%	2.23	0.77	1.95E+00	NR	
12/2/08		443	67.8%	2.09	1.9	4.54E+00	NR	
6/29/10		337	84.4%	3.75	0.59	1.07E+00	NR	
11/4/08		326	85.9%	2.78	0.68	1.20E+00	NR	**NR**
9/8/10	Low Flow	274	93.5%	4.40	1.7	2.51E+00	NR	**NR**

Note: NR = No reduction required

Table D-9 Calculated Load Reduction Based on Daily Loading – Wolf River at RM1.5 – Lead

Sample Date	Flow Regime	Flow	PDFE	Target Concentration	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[μg/ml]	[μg/ml]	[lb/day]	[%]	[%]
1/31/06	High Flow	4130	5.0%	1.99	4	8.91E+01	**50.3**	**50.3**
2/5/08	Moist Conditions	1820	15.3%	3.27	4	3.93E+01	**18.1**	
1/17/07		1700	16.9%	2.53	4	3.67E+01	**36.8**	**27.5**
4/11/07	Mid-Range Flows	550	53.6%	2.02	0.5	1.48E+00	NR	
11/28/07		533	55.2%	1.95	1	2.88E+00	NR	**NR**
5/24/06	Dry Conditions	398	74.0%	2.18	1	2.15E+00	NR	
10/10/06		299	88.3%	2.45	9	1.45E+01	**72.8**	**36.4**
7/25/07	Low Flow	222	98.5%	5.74	1	1.20E+00	NR	**NR**

Note: NR = No reduction required

Table D-10 Calculated Load Reduction Based on Daily Loading – Wolf River at RM9.3 – Lead

Sample Date	Flow Regime	Flow	PDFE	Target Concentration	Observed Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions
		[cfs]	[%]	[µg/ml]	[µg/ml]	[lb/day]	[%]	[%]
5/7/09	High Flow	4873	3.6%	3.65	6.8	1.79E+02	**46.3**	
1/6/09		4240	4.5%	5.91	6.9	1.58E+02	**14.4**	**30.3**
3/4/09	Moist Conditions	1598	17.4%	2.28	2.5	2.16E+01	**8.7**	
4/8/09		1364	21.0%	2.38	1.7	1.25E+01	NR	
10/9/08		825	35.0%	3.42	5.2	2.31E+01	**34.2**	**14.3**
6/2/09	Mid-Range Flows	634	45.9%	3.55	1.7	5.81E+00	NR	**NR**
2/4/09	Dry Conditions	448	63.5%	1.61	1.2	2.90E+00	NR	
12/2/08		423	67.3%	1.27	0.66	1.51E+00	NR	
11/4/08		311	85.6%	1.42	0.65	1.09E+00	NR	**NR**
8/5/08	Low Flow	263	93.1%	2.05	1.5	2.13E+00	NR	
9/2/08		221	98.0%	2.12	1	1.19E+00	NR	**NR**

Note: NR = No reduction required

Table D-11. Summary of PLRGs for Metal Impaired Waterbodies in the Wolf River Watershed.

Waterbody ID	Arsenic	Lead
UT to Fletcher Creek	20.6	
Fletcher Creek	16.7	
Cypress Creek		8.6
Harrington Creek	47.4	
Wolf River (001-1000)		50.3

* Shaded areas indicate waterbody not listed.

APPENDIX E

Hydrodynamic Modeling Methodology

E.1 Model Selection

The Windows version of Hydrologic Simulation Program - Fortran (HSPF) was selected for flow simulation of metals-impaired waters in the subwatersheds of the Wolf Watershed. HSPF is a watershed model capable of performing flow routing through stream reaches.

E.2 Model Set Up

The Wolf 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 WinHSPF 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 Wolf 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 used for the simulation. Weather data from multiple meteorological stations were available for the time period from January 1970 through December 2010. 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 (1/1/01 – 12/31/10) used for TMDL analysis. Weather data from the Memphis meteorological station was used for hydrologic calibration.

E.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. Two USGS continuous record stations located in the Wolf River Watershed with a sufficiently long and recent historical record were selected as a basis of the hydrology calibration. These USGS stations were selected based on similarity of drainage area, Level IV ecoregion, land use, and topography. Station 07031692 is located on Fletcher Creek at Sycamore View Road in Memphis, TN, within Level IV ecoregion 74B and has a drainage area of 30.5 square miles. Calibration parameters determined for station 07031692 were used for all impaired waterbodies except the Wolf River.

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 Fletcher Creek, USGS Station 07031692, are shown in Table E-1 and Figures E-1 and E-2.

Station 07031740 is located on the Wolf River at Hollywood St. in Memphis, TN, within Level IV ecoregion 74B, but also including portions in ecoregion 65E, and has a drainage area of 788 square miles. Flow at monitoring stations along the Wolf River was determined by calculating the ratio of the drainage area at the monitoring station to the drainage area for the gaging station and applying that ratio to the observed flow at the gaging station.

Table E-1 Hydrologic Calibration Summary: Fletcher Creek, USGS 07031692

			31.0302234	
	Simulation Name:	USGS07031692	**Simulation Period:**	
			Watershed Area (ac):	19865.70
	Period for Flow Analysis			
	Begin Date:	**10/01/96**	**Baseflow PERCENTILE:**	2.5
	End Date:	**09/30/06**	*Usually 1%-5%*	
	Total Simulated In-stream Flow:	**267.38**	Total Observed In-stream Flow:	**254.66**
	Total of highest 10% flows:	**214.47**	Total of Observed highest 10% flows:	**216.72**
	Total of lowest 50% flows:	**4.87**	Total of Observed Lowest 50% flows:	**3.55**
	Simulated Summer Flow Volume (months 7-9):	**40.22**	Observed Summer Flow Volume (7-9):	**36.37**
	Simulated Fall Flow Volume (months 10-12):	**81.11**	Observed Fall Flow Volume (10-12):	**82.01**
	Simulated Winter Flow Volume (months 1-3):	**86.36**	Observed Winter Flow Volume (1-3):	**81.95**
	Simulated Spring Flow Volume (months 4-6):	**59.69**	Observed Spring Flow Volume (4-6):	**54.32**
	Total Simulated Storm Volume:	**267.24**	Total Observed Storm Volume:	**254.27**
	Simulated Summer Storm Volume (7-9):	**40.19**	Observed Summer Storm Volume (7-9):	**36.27**
	Errors (Simulated-Observed)		*Recommended Criteria*	Last run
	Error in total volume:	**5.00**	10	
***	Error in 50% lowest flows:	**37.39**	10	
	Error in 10% highest flows:	**-1.04**	15	
	Seasonal volume error - Summer:	**10.59**	30	
	Seasonal volume error - Fall:	**-1.10**	30	
	Seasonal volume error - Winter:	**5.39**	30	
	Seasonal volume error - Spring:	**9.88**	30	
	Error in storm volumes:	**5.10**	20	
	Error in summer storm volumes:	**10.79**	50	

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

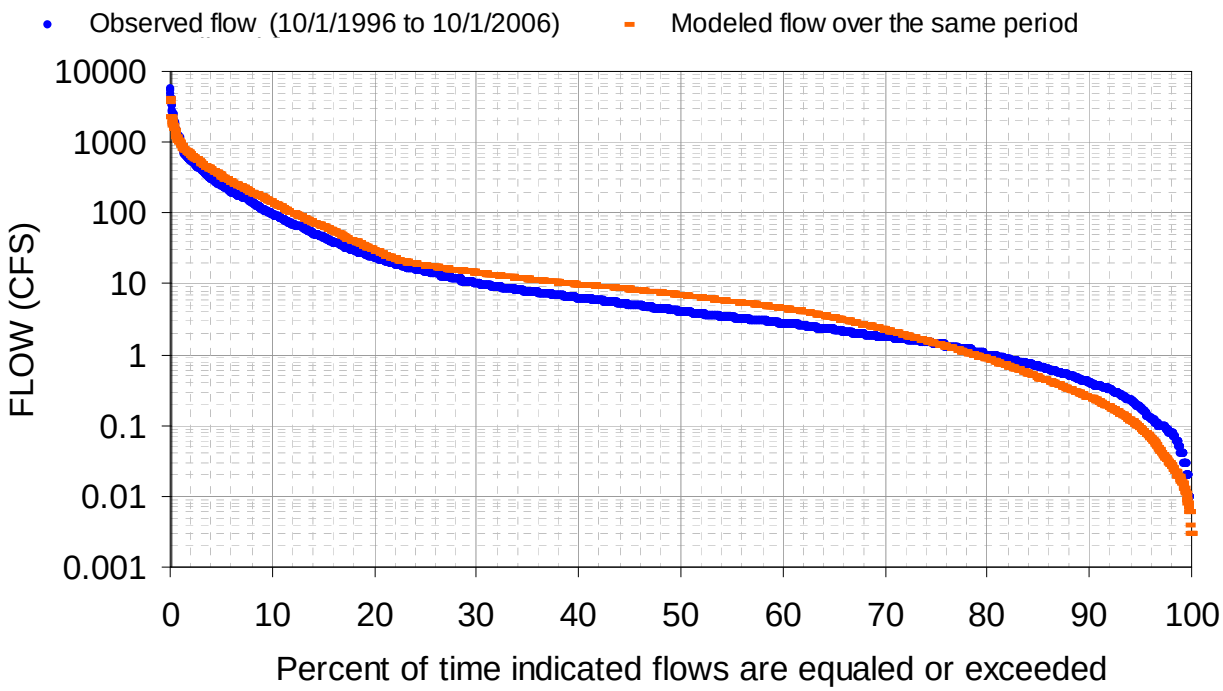


Figure E-1. Hydrologic Calibration: Fletcher Creek, USGS 07031692

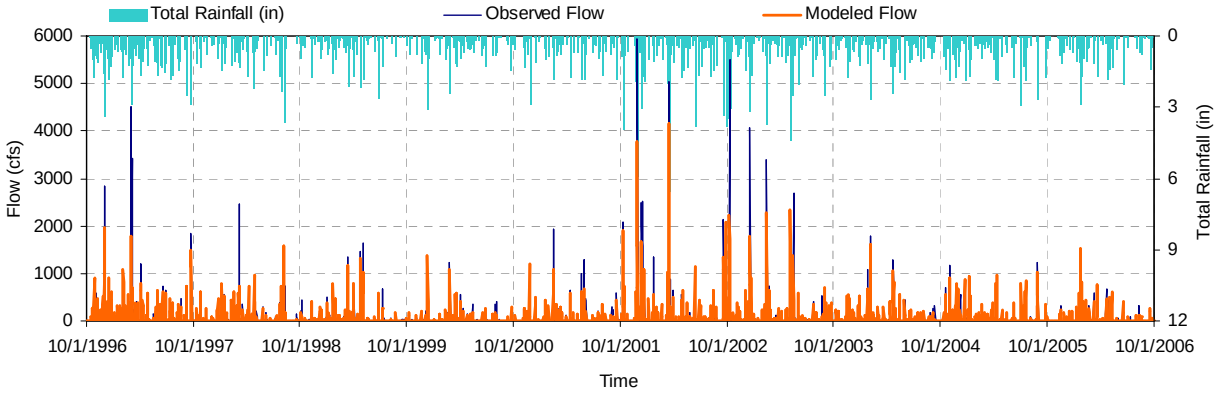


Figure E-2. 10-Year Hydrologic Comparison: Fletcher Creek, USGS 07031692

APPENDIX F

Public Notice Announcement

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

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR METALS IN WOLF RIVER WATERSHED (HUC 08010210), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for metals (arsenic, copper, and lead) in the Wolf River watershed, located in western Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

A number of waterbodies in the Wolf River watershed are listed on Tennessee's Draft 2012 303(d) list as not supporting designated use classifications due, in part, to discharges from MS4 areas. The TMDL utilizes Tennessee's general water quality criteria, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, site specific water quality monitoring data, a calibrated hydrologic model, load duration curves, and an appropriate Margin of Safety (MOS) to establish allowable loadings of pathogens which will result in the reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of metals (arsenic and lead) loading on the order of 8.6-30.3% in the listed waterbodies.

The Wolf River Metals TMDL may be downloaded from the Department of Environment and Conservation website:

http://www.tennesse.gov/environment/wpc/tmdl/

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

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

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

Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than March 4, 2013 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.

APPENDIX G

Public Comments Received

RECEIVED
MAR 04 2013

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
ENVIRONMENTAL DIVISION
FACILITIES ENVIRONMENTAL COMPLIANCE OFFICE
SUITE 300, JAMES K. POLK BUILDING
505 DEADERICK STREET
NASHVILLE, TENNESSEE 37243-1402
(615) 741-4732

JOHN C. SCHROER
COMMISSIONER

BILL HASLAM
GOVERNOR

March 1, 2013

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

Re: Comments on Proposed Metals Total Maximum Daily Load for the Wolf River Watershed

TDEC has recently issued a draft document for public comment presenting a proposed Total Maximum Daily Load (TMDL) for Metals in the Wolf River Watershed (HUC 08010210). In Section 6.1.2 of that document, the Tennessee Department of Transportation (TDOT) Municipal Separate Storm Sewer System (MS4), regulated under Permit TNS077585, is listed as a point source for the pollutant loading that is the subject of the TMDL. Inclusion as a point source will trigger requirements in the TDOT MS4 Permit that could include stormwater effluent monitoring, in-stream monitoring, and the implementation of control measures at discharge points. TDOT does not believe that the inclusion of its MS4 as a point source for the pollutant loading which is the subject of this TMDL is appropriate and requests that the document be modified to remove the TDOT MS4 as a point source. The following discussion relates specifically to the potential for lead contamination, as arsenic contamination has not been attributed to roadway stormwater runoff (see for example: http://environment.fhwa.dot.gov/ecosystems/ultraurb/uubmp2.asp#s221 or http://www.michigan.gov/documents/MDOT_MS4_MDOT_Hwy_SW_Runoff_Study_91946_7.pdf).

The rationale for this request includes the following points:

1. The TMDL document bases inclusion of discharges from roadways as a contributor to lead contamination on two cited documents (i.e. Davis, 2001 and Novotny, 1981). The conclusions of both these documents are based on research performed in the 1980's and 1990's. The major source of lead contamination on and around roadways during the 1980's and 1990's is widely recognized to be overwhelmingly attributed to the use of leaded gasoline and the resulting airborne deposition of lead contaminants from vehicle exhaust (see for example: http://yosemite.epa.gov/R10/airpage.nsf/webpage/Leaded+Gas+Phaseout)
However, the use of lead additives in gasoline was banned in the United States in 1996, and this major source of lead contamination for roadway stormwater run-off was completely eliminated. Any research on contaminants in the stormwater discharges from roadways performed in the 1980's and 1990's would reflect the contribution from leaded gasoline and thus not be valid for application to present day conditions.

2. The reference Davis, 2001(entitled: Loading Estimates of Lead, Copper, Cadmium, and Zinc in Urban Runoff from Specific Sources) cited as a basis for the inclusion of discharges from roadways as a contributor to lead contamination did not actually sample stormwater discharges from roadways, but exposed "simulated" stormwater to various materials, such as automobile brakes and wheels, tires, and used oil. Figure 3 of this document (entitled: Estimated Contributions of Various Sources of Metals in Urban Commercial Stormwater Runoff) indicates that that the lead contribution from brake wear was 1% of the total lead contamination observed, the lead contribution from tire wear was 1% of the total lead contamination observed, and the lead contribution from oil was 0% of the total lead contamination observed. Thus, this study appears to indicate that the sources of lead contamination that would be expected to be deposited directly on roadways constitute a very small and insignificant portion of the overall lead pollutant loading in an urban environment.

3. The TDOT MS4 Program has been acquiring and analyzing actual samples of stormwater runoff from state highways in Tennessee over the past two years. These samples have been acquired from a variety of highway scenarios across the State, ranging from high traffic volume interstate highways in urban commercial areas to low traffic volume highways in rural agricultural areas. The sampling sites were selected to ensure that the runoff was exclusively from the TDOT MS4 and was minimally impacted from non-roadway runoff. The TDOT MS4 is only accountable for contamination that originates within its boundaries. A recent U.S. Supreme Court decision (*Los Angeles County Flood Control District v. Natural Resources Defense Council, et al.*, No. 11-460 (U.S. 2013)) has found that a MS4 cannot be held responsible for stormwater contaminants that originated off its jurisdiction.

   To date, a total of 288 stormwater samples from the TDOT MS4 have been evaluated for dissolved lead. Of these 288 analyses, only 130 (45%) detected the presence of dissolved lead above the laboratory detection limit. The overall average value of dissolved lead observed in these samples (not including non-detects) is 2.35μg/l. The maximum level of dissolved lead observed in any sample was 29.0 μg/l. Typical values of hardness observed in these samples ranged from 30 mg/l to 220 mg/l. The average value for Total Suspended Solids for these samples was 43.7 mg/l. These results are below the Criterion Maximum Concentration for lead of 65μg/l specified in the TMDL document. Based on these results, the stormwater discharge from the TDOT MS4 would be expected to be a negligible contributor to the lead contamination observed in this watershed.

4. The subject TMDL affects a total of five impaired stream segments in the Wolf River Watershed. Those five stream segments include designated portions of:

   - Harrington Creek (TN0801021001 - 0100)
   - Wolf Creek (Mississippi River to Fletcher Creek TN0801021001 - 1000)
   - Unnamed Tributary to Fletcher Creek (TN08010210023 - 0100)
   - Fletcher Creek (TN08010210023 - 1000)
   - Cypress Creek (TN08010210032 - 1000)

   Data from TDOT's outfall mapping program has determined that the TDOT MS4 has point source discharges to these five stream segments at approximately 614 locations. The total area within the TDOT MS4 that drains to these 614 point source outfalls is calculated to be 347.6 acres. However, the total drainage area of the five impaired stream segment watersheds is 107,371.1 acres. The TDOT MS4 drainage area contributing to these stream segments is less than 3.5% of the overall impaired watershed drainage areas and thus, the TDOT MS4 appears to be a negligible contributor to this hydrologic system. Numerous sources in the literature (see for example:

www.epa.gov/athens/publications/LindaNWQMC.doc) have found that impervious areas within a watershed do not significantly impact water quality until the impervious area exceeds 10% of the watershed area. The TDOT MS4 drainage area value of 3.5% is the total drainage area of the TDOT Right-of-Way, including both the impervious roadway and any adjacent pervious shoulders, ditches, swales, and vegetated areas. Thus, the actual effective impervious area of the TDOT MS4 would be expected to be significantly lower than 3.5%.

From this evaluation of actual stormwater runoff from the TDOT MS4, and the potential contribution of the TDOT MS4 to the proposed TMDL Watershed, the stormwater runoff from the TDOT MS4 has been shown to contain minimal concentrations of lead (and arsenic) and to be a negligible contributor to the hydrologic regime of the subject watershed. Based on this information, TDOT respectfully requests that this draft TMDL document be revised to remove the TDOT MS4 as a possible source for the subject contamination.

If you have any questions, or require additional information or documentation, please call me at 615-741-4732 or email me at Barry.Brown@tn.gov. Additionally, TDOT has not been receiving the notices of the availability of draft TMDL documents for review in a timely manner. We request that in the future, if possible, these notices be emailed directly to Barry.Brown@tn.gov and mcramer@ensafe.com to facilitate our ability to perform a thorough review on behalf of TDOT.

Sincerely,

Barry C. Brown
Director, Environmental Compliance Office
TDOT Environmental Division

Cc:
Jim Ozment, TDOT
John Nichols, TDOT
Project Files

City of Memphis
TENNESSEE

A C WHARTON, JR. - Mayor
GEORGE M. LITTLE - Chief Administrative Officer
DIVISION OF PUBLIC WORKS
DWAN L. GILLIOM - Director

Storm Water Program

March 4, 2013

Ms. Vicki Steed
Watershed Management Section
Tennessee Department of Environment and Conservation
Division of Water Pollution
401 Church Street
L&C Annex, Seventh Floor
Nashville, Tennessee 37243

Subject: Draft of Proposed Total Maximum Daily Load for Metals
Wolf River Watershed (HUC 08010210); January 21, 2012

Dear Ms. Steed:

The City of Memphis respectfully submits the attached comments to the referenced document for your consideration. Please do not hesitate to contact me at 901-636-4345 to discuss.

Sincerely,

Bobby D. Allen, P.E.
Stormwater Program Manager
City of Memphis

2714 Union Avenue Extended, Suite 625 • Memphis, Tennessee 38112 • (901) 636-4349

Comments on Draft Proposed Total Maximum Daily Load for Metals for the Wolf River Watershed (HUC 08010210) dated January 28, 2013

1. Development of TMDL Ignored Appropriate Averaging Period Associated with Water Quality Standard

The TMDL for arsenic and lead were developed using a mass balance approach with the allowable mass based on the flow in the river multiplied by the applicable water quality standard:

> Daily loading functions were derived for impaired segments in the Wolf River Watershed using water quality criteria, ambient hardness and TSS, and average daily flow according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subsequent subwatersheds are shown in Table 7.

(Draft TMDL at 21)

a. Arsenic

The applicable water quality standard for arsenic is 10 µg/L (Recreation, organism only). This water quality standard was established to protect human health from the carcinogenic effects of arsenic on consumption of fish over an extended period of time (70 years) (See Tennessee Water Quality Standards Chapter 1200-04-03-.03(l) – cancer risk from fish consumption based on a consumption rate averaged over a 70 year lifetime.). However, the TMDL was set so that the load limit cannot be exceeded any single day for the purpose of assessing the adequacy of the MS4 BMPs.

$$TMDL = (10\ \mu g/L) \times (Q,\ ft^3/sec) \times (5.39 \times 10^{-3}\ lb\text{-}sec\text{-}L/\mu g\text{-}day\text{-}ft^3)$$

(Draft TMDL Table 7 at 22)

Consequently, any time the water quality in the stream exceeds the water quality standard, it is presumed to be an exceedance of the standard as indicated in the Implementation Plan with the TMDL:

> Each MS4 having a waterbody within their jurisdiction that is listed as impaired due to metals must conduct water quality testing for metals. Monitoring must include sampling at least one location on the most impaired stream segment for each constituent located within the MS4 jurisdiction. (The most impaired segment

> should be the segment with the most exceedances based on the data included in Appendix B of the TMDL and summarized in Table 5.) [1]

(Draft TMDL at 23)

A review of Table 5 (Draft TMDL at 15) indicates that individual monitoring data in excess of 10 µg/L is considered an exceedance although the arithmetic average concentration for each of the four monitoring stations is less than the arsenic criterion. This would suggest that these streams are in compliance with the carcinogenic arsenic criterion if the averaging period is appropriately considered.

Moreover, a review of the water quality monitoring data included in Appendix B of the draft TMDL for Fletcher Creek and Harrington Creek indicates that the summary in Table 5 is incorrect, particularly for Harrington Creek – Table 5 indicates 35 data points with an average concentration of 9.53 µg/L and 11 exceedances. Appendix B only includes 23 data points with an average of 8.90 µg/L and 5 exceedances of the criterion concentration. A revised summary of the data in Appendix B is proved in the table below.

Monitoring Station	Data Points	Average (µg/L)	Maximum (µg/L)	Observations >10 µg/L
FLETC001.4SH	11	7.59	15	2
FLETC005.2SH	12	7.08	15	2
FLETC4.4T0.2SH	12	8.30	18	3
HARRI001.8SH	23	8.90	19	5

In fact, the load can vary significantly from day to day and still meet the instream target long term average concentration as discussed in the EPA Technical Support Document for Water Quality-based Toxics Control, EPA-505/2-90-001 (the "TSD"; EPA, 1991).

> The duration of the averaging period for the WLA should be selected to be consistent with the assumptions used to derive the water quality criteria. Two categories of pollutants should be recognized: carcinogens and noncarcinogens. The human health criteria for carcinogens are derived assuming lifetime exposure. The upper-bound risk is directly proportional to the lifetime arithmetic mean dose. The criteria thus apply to the ambient water concentrations averaged over a 70-year period.

(TSD at 88)

[1] The exceedances identified in Table 5 of the draft TMDL are associated with daily excursions of the arsenic criterion.

Based on the averaging period associated with the carcinogenic arsenic criterion, the data presented in Appendix B of the TMDL reflects that these streams are not impaired for arsenic. Consequently, there is no need for a TMDL. However, if TDEC determines that the available data suggests that the criterion is threatened and a TMDL is still necessary, the allowable loading from the MS4s must account for the criterion averaging period and the intermittent nature of the discharges.

b. Lead

The draft TMDL for lead was based on the chronic criterion to provide an implicit margin of safety (TMDL at 21) and this criterion is a function of the ambient hardness. The chronic criterion only applies to the dissolved form of lead. Consequently, the TMDL used a translator based on partitioning with the suspended solids in the receiving water. The resulting TMDL is a complex equation to determine the chronic criterion expressed as the total recoverable form of the metal multiplied by the river flow. (See, Draft TMDL Table 7 at 22).

As with arsenic, this TMDL is expressed as a single day, not-to-exceed limit, but it ignores the averaging period associated with the chronic criterion. The chronic criterion averaging period is 4 days as noted in the draft TMDL.

> In accordance with the guidance in Technical Support Document For Water Quality-based Toxics Control (USEPA, 1991b), fish & aquatic life criteria are interpreted to mean that the 1-hour average exposure should not exceed the Criterion Maximum Concentration (CMC) and the 4-day average exposure should not exceed the Criterion Continuous Concentration (CCC).

(Draft TMDL at 11)

If the averaging period is taken into consideration, the TMDL would increase. The allowable loading from the MS4s must account for the criterion averaging period and the intermittent nature of the discharge.

2. Dissolved Translator for Lead

The Tennessee water quality standard for lead is expressed as the dissolved form of the metal. (See, Chapter 1200-4-3 of the Tennessee Water Quality Standards; also see Draft TMDL at 12):

> All fish and aquatic life metals criteria are expressed as total recoverable, except cadmium, copper, lead, nickel, silver, and zinc which are expressed as dissolved. Translators will be used to convert the dissolved fraction into a total recoverable permit limit. One of three approaches to metals translation will be used: (1) translator is the same as the conversion factor, (2) translator is based on relationships derived from STORET data, or (3) a site-specific translator is developed. Where available, a site-specific translator is preferred. For assessing

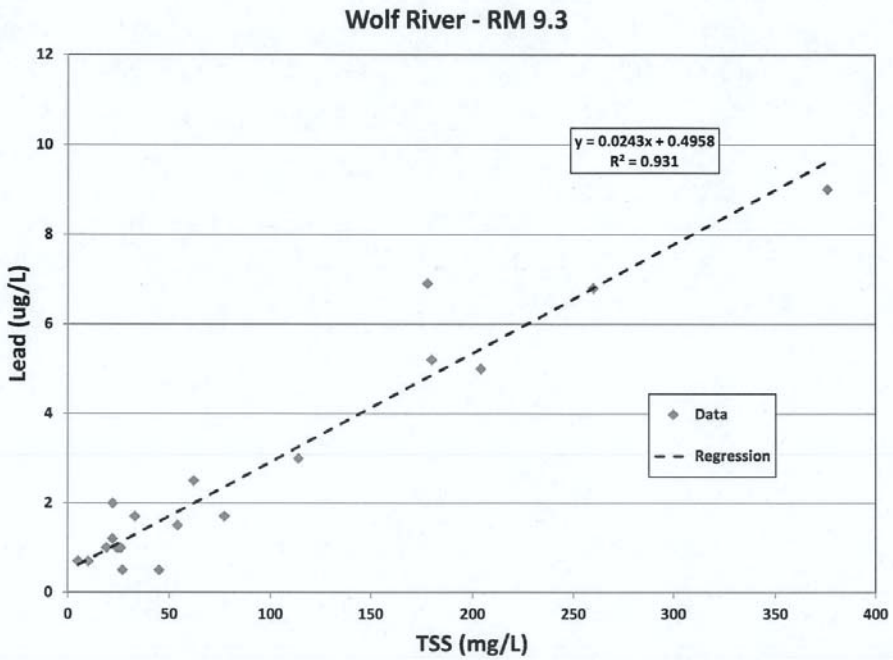
> whether criteria for cadmium, copper, lead, nickel, silver, and zinc are exceeded by ambient water quality conditions, the dissolved criteria will also be translated in order to allow direct comparison to the ambient data, if total recoverable.

The Draft TMDL notes that all monitoring data for the Wolf River watershed are in the form of total recoverable metal, consequently a metals translator was required to convert the total recoverable form into the equivalent amount of dissolved metal. The draft TMDL utilized the solids partitioning translator from "The Metal Translator: Guidance for Calculating a Total Recoverable Permit Limit from a Dissolved Criterion" (USEPA, 1996) (Draft TMDL at 12). This translator is presented in Appendix B of the TMDL as:

$$Translator = \frac{1}{1 + [2.80x10^{6}][TSS^{1-0.8}][10^{-6}]}$$

This translator yields dissolved fraction of lead based on the amount of suspended solids present in the receiving water. Based on the data presented in Appendix B for the Wolf River sampling station, WOLF009.3SH, the dissolved fraction ranges from 0.098 to 0.206 for suspended solids ranging from 376 mg/L to 5 mg/L. This is a relatively narrow range for such a large difference in TSS concentrations.

If the data for this station are plotted to compare TSS concentration and lead concentration, the resulting regression suggests an extremely high correlation between the amount of lead and the amount of solids, as indicated below.



Based on this regression, it would appear that the elevated levels of lead observed in the Wolf River are most likely bound to the solids. If this is the case, the river would not exceed the chronic lead criterion and the river would not be impaired for this parameter. This TMDL should not be finalized until site-specific data are collected to either confirm that the translator equation is appropriate for use in this TMDL or define the appropriate site-specific translator.

3. Source of Contaminants Not Confirmed

As discussed in the Problem Definition for this draft TMDL, several water bodies in the Wolf River Watershed are listed in the Tennessee draft 2012 303(d) List as impaired for the metals arsenic and lead. (TMDL at 7) The Source Assessment (Draft TMDL at 16 – 19) claimed that discharges from MS4 areas are one of the primary sources of the observed contamination. However, this assessment did not include any monitoring of the MS4 discharges. The only supporting information appears to be literature articles on runoff from urban areas (e.g., Davis, 2001).

Potential sources of arsenic are discussed in the draft TMDL (at 19). Again, based on literature studies, the TMDL noted:

> [A]rsenic has proven to be a problem in suburban areas where subdivisions have crept out on to former agricultural land where pesticides containing lead arsenate were applied (Hodel, 2002).
>
> Arsenic associated with unregulated urban runoff can come from erosion of natural deposits and runoff from roads and parking lots. (USEPA, 2011)

As discussed in the TMDL, the sources of arsenic can be natural, which the MS4s would not be required to mitigate, and from suburban areas that may be beyond the service areas for the MS4s. However, the burden for remediating the impairment would be placed on the MS4s.

> The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

(TMDL at 23)

As discussed above, the evaluation method involves instream sampling of the river segment with the most exceedances. This approach is inappropriate. The TMDL should not be finalized until MS4 discharge data are collected to show that these sources are causing exceedances of the criteria, based on an appropriate averaging period, rather than being caused by uncontrolled sources beyond the MS4s. Potential sources of lead include building siding and atmospheric deposition, with urban soils serving as a great reservoir of lead (TMDL at 19). Another source of lead in urban soils is lead-based paint.

As with arsenic, the TMDL does not report any data on MS4 discharges that would support the allegation that MS4s are the primary source of contaminants. Moreover, the relationship between lead concentration and suspended solids, illustrated above, may indicate that the contaminants are present in the river bottom, which is scoured under elevated flow conditions. The TMDL should not be finalized without discharge data showing that the MS4s are significant sources causing the observed impairment.

MS4's should not be required to implement load reductions if they are not the cause of an impairment.

4. Derivation of WLAs and LAs Unsupported

The derivation procedure for the WLAs and LAs presented in Table 8 of the Draft TMDL is presented in Appendix C. Appendix C provides the following methodology:

> WLAs for MS4s and LAs for precipitation-based nonpoint sources are equal on a per unit area basis and may be expressed as the daily allowable load per unit area (acre) resulting from a decrease in in-stream concentrations to TMDL target values minus MOS:
>
> $$WLA_{MS4} = LA_{SW} = \{TMDL - MOS\} / DA$$
>
> Where: DA = waterbody drainage area (acres)

(Draft TMDL at C-2, C-3)

This methodology allocates mass based on overall drainage area. Consequently, if the MS4s serve 10% of the overall drainage area, they are allocated 10% of the available load while the bulk of the upstream drainage area is allocated 90%. This approach denies the MS4s access to the additional assimilative capacity that is available from the upstream drainage area.

This upstream load must be characterized to identify the available assimilative capacity so that this capacity can be allocated to the downstream drainage area.

5. EPA Review/Approval Unnecessary

TDEC's earlier response to comments on the draft proposed TMDL for metals for the Wolf River Watershed sets forth TDEC's belief that it can develop a TMDL for any watershed, even those that are not CWA § 303(d) listed. As discussed above, we believe TDEC's methodology inappropriately identifies a waterbody as non-attainment and that such error needs to be corrected.

If the waterbody is not listed as a CWA § 303(d) non-attainment water body, or is removed from the § 303(d) list, we request that, if TDEC decides to still undertake a TMDL, it reflect that the waterbody is an attainment water body. Furthermore, such TMDL should not be submitted for EPA approval, as EPA's approval is only required for a § 303(d) listed waterbody. (40 C.F.R. § 130.7).

6. In Paragraph 1 of Section 2.0 Watershed Description, the TMDL states the following: "*For the purposes of TMDL development, waters flowing into Tennessee from Mississippi are assumed to meet Tennessee water quality standards at the state line.*" What justification, if any, can TDEC provide to support this assumption? Does TDEC have any monitoring locations near this location or data from the State of Mississippi to validate this assumption?

7. We contend that the following statement in Section 6.1.1 is an inaccurate representation of the potential source of contamination from Point Source discharges in the watershed:

   Since their discharge is precipitation driven, the contribution of these facilities will be a function of their total acreage. These facilities will not be given a WLA because the total area of the facilities (321.52 acres) is less than 0.1% of the drainage area of the Wolf River Watershed.

   The primary driver of the Illicit Discharge Detection and Elimination program required by the City's NPDES permit is to investigate potential discharges from facilities such as those referenced here. Industrial and high-risk commercial properties (regardless of size) are the focal point of the program since they represent an acute risk of water quality contamination. This section should be revised to include justification based on an assessment of the DMRs related to these facilities rather than referencing their size relative to the total watershed area.

8. In our previous comments, we noted that it is unusual for lead to show up in water column samples. We noted that the use of "clean metals handling techniques" can eliminate these exceedances. We also noted that it is possible that lead is present in sediments that are being scoured by a lack of hydrologic controls (which could also be true for arsenic). While TDEC responded to our concerns about the sampling protocols, the potential for legacy pollutants to enter the stream were not addressed in TDEC's response to comments. What consideration, if any, was given to the potential contribution of scour from legacy sediments?

9. On page 23, paragraph 5 of Section 8.1 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s), the last sentence states the following:

   Sampling should be conducted following implementation of one or more BMPs and should continue until the waterbody is no longer impaired for metals.

   What will be the compliance criteria for determining if the waterbody is still impaired? Will it be based on one sample, a series of samples with no exceedance, or the inclusion of the waterbody on the 303d list?

City of Memphis
TENNESSEE

A C WHARTON, JR. - Mayor
GEORGE M. LITTLE - Chief Administrative Officer
DIVISION OF PUBLIC WORKS
DWAN L. GILLIOM - Director
Storm Water Program

March 11, 2013

Vicki Steed
Watershed Management Section
Tennessee Department of Environmental and Conservation
Division of Water Pollution
401 Church Street
L&C Annex, Seventh Floor
Nashville, Tennessee 37243

Subject: Supplemental Data Regarding the Draft of the Proposed Total Maximum Daily Load for Metals, Wolf River Watershed (HUC 08010201); January 28, 2013

Ms. Steed:

By letter dated March 4, 2013, the City of Memphis submitted comments to TDEC on the above referenced proposed TMDL document. As reflected in our second comment (Dissolved Translator for Lead), we provided information showing that the elevated levels of lead observed in the Wolf River are most likely bound to the solids and that the Wolf River would not be expected to exceed the chronic lead criterion. We further indicated that the TMDL should not be finalized until site-specific data are collected to either confirm that the translator equation is appropriate or to define the appropriate site-specific translator. The City has undertaken some initial sampling to address this issue and is submitting the results for TDEC's consideration regarding this important matter. The site-specific information indicates that the assumptions used in the proposed TMDL are overly-conservative and that the Wolf River is, in fact, in attainment.

The draft Wolf River TMDL establishes wasteload allocations for lead based on the assumption that lead levels in the Wolf River exceed the TDEC chronic aquatic life water quality criteria. The aquatic life criteria for lead are hardness based and apply only to the dissolved fraction of the metal. Because the metals data are only available for the total recoverable form, TDEC applied a translator to determine whether the observed concentrations of total recoverable lead represent an exceedance of the chronic criterion. This translator was based on EPA Guidance associated with situations where site-specific data is not available and utilized a partitioning coefficient and the ambient concentration of total suspended solids (TSS) to calculate the dissolved fraction of lead.

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Summary data, presented in Appendix B to the TMDL, show that the Wolf River (Station 9.3SH) has very soft water (hardness ranges from 13 – 30 mg/L with an average of 17.7 mg/L). The dissolved chronic water quality criterion for lead ranged from 0.24 – 0.66 µg/L, with an average dissolved criterion of 0.35 µg/L. The TSS translator has a relatively narrow range, 0.2 – 0.1for TSS ranging from 5 – 376 mg/L, respectively. Consequently, monitoring samples that exceed about 3.5 µg/L total recoverable lead would be predicted to exceed the dissolved criterion.

The City of Memphis operates a municipal separate storm sewer system that would be regulated under this TMDL. The City collected water samples from the Wolf River in an effort to determine whether the water quality in the river actually exceeds the dissolved lead criterion (by measuring the dissolved concentration) and to test the validity of the primary assumption upon which the dissolved translator is based (by comparing the dissolved concentration to the total lead concentration). The results of this testing are summarized in Table 1.

Table 1
Sampling Results reported by Environmental Testing & Consulting, Inc.

Test	Date	Result	Method	MQL	MDL
Total Lead	2/26 13:05	3.03	200.8	0.500	0.100
	Duplicate	3.12	200.8	0.500	0.100
	2/26 13:25	1.83	200.8	0.500	0.100
	Duplicate	2.29	200.8	0.500	0.100
Dissolved Lead	2/26 13:05	<0.100	200.8	0.500	0.100
	Duplicate	<0.100	200.8	0.500	0.100
	2/26 13:25	<0.100	200.8	0.500	0.100
	Duplicate	<0.100	200.8	0.500	0.100
Total Suspended Solids	2/26 13:05	94	2540D	2	2
	Duplicate	89	2540D	2	2
	2/26 13:25	101	2540D	2	2
	Duplicate	79	2540D	2	2

The results show that the dissolved fraction of lead was always less than the quantitation level of 0.500 µg/L. This quantitation level is higher than the expected dissolved criterion (hardness was not measured). However, all measurements were also below the method detection limit for Analytical Method 200.8 (ICP-MS), confirming that the dissolved criterion was not exceeded.

A comparison of the dissolved lead method detection level to the measured total lead concentration indicates that the dissolved fraction is less than 3.2 percent of the total recoverable metal. This dissolved fraction is significantly lower than the result obtained using the TSS partitioning method.

Together, these results reflect that the dissolved lead concentration present in the Wolf River does not exceed the TDEC chronic water quality criterion and a TMDL is not necessary for this parameter. In addition, the results indicate that the TSS partitioning method significantly over-estimates the dissolved fraction of lead present in the receiving water.

Accordingly, the City requests that the TMDL for lead not be finalized based upon, what appears to be, incorrect assumptions. The City suggests that further sampling be undertaken to confirm the appropriate total/dissolved ratio. The City is willing to coordinate efforts with TDEC to assure that appropriate data is collected.

Please do not hesitate to contact me at 901-636-4345 to discuss the next steps.

Sincerely,

Bobby D. Allen, P.E.
Stormwater Program Manager
City of Memphis

Cc: Scott Morgan (City)

TMDL for metals on the Wolf

Rick McClanahan [rmcclanahan@cityofbartlett.org]
Sent: Thursday, March 07, 2013 8:31 AM
To: Sherry Wang
Cc: Vicki Steed

Sherry
I know I am late on responding back on the TMDL's for metals in the Wolf river basin. I hope you will consider these requests. I just missed the deadline with other stuff going on but I think you need to address these comments.

The first question is why are you using the recreation levels for arsenic and not the CCC for fish and wildlife. I have lived in this area all my life and most flows are not deep enough to really canoe in and I don't think fishing is really done in these channels so I would think that the CCC for fish and wildlife would be more applicable limits. If you use them we meet the arsenic levels.

The second issue I have with the report is all the TDEC samples are located outside of Bartlett's jurisdiction with several being significantly outside our city limit boundries and yet TDEC is specifically requiring Bartlett to do multiple sampling in a years time. That is not right. All the multi sector permits are outside of Bartlett. We have no multi sector industries in our boundries and all samples are outside of our jurisdiction and yet TDEC requires Bartlett to sample 4 times a year when our MS4permit only requires us to sample once in a 5 year period per Huc for other pollutants. That's not right. In fact you cannot even determine with certainty that arsenic exists in our streams because you have no samples inside our jurisdiction. You are definitely overstepping your legal boundries as TDEC cannot show arsenic exists within our city boundries.

Any sampling requirements should be conducted by TDEC and not the local agency or if you wish to require sampling then have Memphis do it at your existing locations and not Bartlett. Any new sampling locations within the cities boundries should be done by TDEC and not the local agency until such time as you can show arsenic is a problem within our jurisdiction. Right now all you can do is to infer that arsenic is problem since no samples exist inside Bartlett's city limits.

If we have no industrial sources within Bartlett's boundry then the source must be from sources as outlined in section 6.2.2. The sources mentioned are Naturally occurring, Historic pesticide use, building materials ie. Treated wood,paints,dyes etc., and runoff from roads. Sherry, none of these sources can be controlled. As a local agency I cannot legally create any BMP's that can affect Arsenic runoff within my jurisdiction. I cannot do it politically or with any type of engineered removal process. So if I cannot impliment BMP's that EPA has tested and know lower Arsenic levels, why are you requiring me to spend tax payer's dollars to do something doomed to fail. When EPA has BMP's with good data that shows this has lowered arsenic levels by some tested percentage, maybe I can then implement it; but don't require us to spend dollars without knowing the desired outcome with test data to back it up.

Under section 8.2 you Quote "TDEC has no direct regulatory authority over most nonpoint source discharges." I must add that EPA and the local agencies also do not have regulatory authority over these same non- point sources. Stop moving these unfunded mandates down to the local agencies. If I thought there was an effective way to reduce Arsenic in our waters I would not be arguing with you over this, but I cannot control the sources outlined in Section 6.2.2 of your report and as a scientist I don't think you can either. Requiring sampling and other data is good, but not if EPA and TDEC cannot show me with really good data a process that can be implemented and really works to reduce arsenic levels.

I am as always willing to discuss this further however I think the issues addressed above need to be corrected. I also feel that until EPA and TDEC have well tested processes to address these nonpoint issues they should not

enforce TMDL's on the local agencies. Please call me if you wish to discuss this further at 901-385-6499.

Rick McClanahan
Director of Utilities
City of Bartlett

APPENDIX H

Response to Public Comments Received

Response to Comments from TDOT:

1. According to Hodel (2002), "the burning of leaded gasoline for more than 60 years has left a legacy of lead embedded in soils in urban areas, especially near roads with heavy and congested automobile traffic". "Most trace elements, especially the heavy metals, remain in the soil nearly indefinitely." If soil adjacent to roadways is still contaminated, then such soil can be either blown or washed onto the roadway and contribute to stormwater contamination.

   In another study ("White Paper: Untreated Highway Runoff in Western Washington", Herrera Environmental Consultants for the Washington State Department of Transportation, 2007), site mean concentrations in highway runoff were: total lead = 24 to 61 μg/L; dissolved lead = 3.2 μg/L; total arsenic = 2.2 to 2.6 μg/L. As noted in the footnotes, "summary statistics for lead were calculated using only data that were collected after 1990". The same source noted that "lead can be deposited on highway surfaces from other sources such as vehicle tires, paints used in rights-of-way, and atmospheric deposition near industrial areas".

2. According to Davis (2001), "the sources of metals in urban stormwater runoff are numerous and the metal release mechanisms are complex." Also from Davis, "it should be stressed that in all cases, the sampling results do not represent the total amounts of metals that may be present on the target areas, but only represent metals washed/extracted by the synthetic rain water wash under the specific conditions employed."

3. Information regarding stormwater samples from the TDOT MS4 is appreciated. Unfortunately, comparison to a CMC for lead of 65 μg/L is incorrect for two reasons:
   a. Lead is a hardness-dependent metal. Therefore, the water quality criteria is expressed as an equation. A CMC of 65 μg/L is only valid when the hardness is 100 mg/L (as specified in the associated footnote). The appropriate CMC must be calculated for each sample based on the measured hardness at the time the sample was taken. For a hardness of 30 mg/L, the calculated CMC would be 17 μg/L. For a hardness of 220 mg/L, the calculated CMC would be 151 μg/L.
   b. The TMDL is not based on the CMC, but the CCC. For a hardness of 100 mg/L, the calculated CCC is 2.5 μg/L. For a hardness of 30 mg/L, the calculated CCC would be 0.66 μg/L. For a hardness of 220 mg/L, the calculated CCC would be 5.87 μg/L. If the average dissolved lead observed in TDOT samples (not including non-detects) is 2.35 μg/L, then at least some of the samples exceeded the TMDL value.

4. Based on the 2001 NLCD (downloaded from USEPA), the Cypress Creek drainage area is 37.5% impervious. HUC-12 0308 (which includes both Cypress Creek and the 001-1000 segment of Wolf River) is 30.9% impervious. HUC-12 0307 (which includes Fletcher Creek) is 32.7% impervious. Since the impervious area in all of these watersheds exceeds 10%, impervious areas within the watersheds <u>DO</u> significantly impact water quality.

Response to Comments from Memphis MS4:

1a. Table 5 has been corrected. The tally for Harrison Creek included samples prior to 2003.

Long-term monitoring as required by the TMDL under all flow conditions will account for the criterion averaging period and the intermittent nature of discharges.

If analysis of monitoring data suggests that a waterbody on the 303(d) List is no longer impaired, delisting can be suggested. However, a TMDL is required for all waterbodies contained on the 303(d) List.

1b. Whenever multiple samples occur in a 4-day period, the average of the sample values would be compared to the water quality criteria. However, in the absence of multiple samples in a 4-day period, the individual samples are assumed to be representative of average conditions over a 4-day period and each compared to the water quality criteria. The TMDL is based on the CCC. If it were based on the CMC, the CCC could easily be exceeded while still meeting the TMDL.

2. The regression supplied does suggest a relationship between lead concentration and TSS. However, the relationship is not necessary one of cause and effect. If the chart is expanded to include all three monitoring stations (rm0.7, rm1.5, and rm9.3) on the impaired segment, the R^2 value is approximately 0.7. There are several occurrence of high TSS when the lead concentration is <u>not</u> elevated. There are also several occurrences of elevated lead concentration when the TSS is below average. We believe that the metals translator currently in use is adequate.

3. A waterbody is assessed as impaired based on monitoring of the waterbody. Monitoring of permitted discharges to a waterbody is the responsibility of the permittee. If a permittee wishes to prove that they are not a source of the impairment in question, there are two options: (a) monitor permitted discharges to show that they are not contributing to a condition of impairment; or, (b) monitor the waterbody in question as it enters and exits their jurisdiction to show that the condition of the waterbody does not change by passing through their jurisdiction.

4. WLAs and LAs are expressed on a unit area basis to allow for changing boundaries of MS4s. Just as MS4s are not responsible for sources outside of their jurisdiction, MS4s are not allowed access to assimilative capacity outside of their jurisdiction.

5. Section 303(d) of the federal Clean Water Act requires that states develop a compilation of the streams and lakes that are “water quality limited” or are expected to exceed water quality standards in the next two years and need additional pollution controls. The 303(d) List is developed biennially and is based on assessment of waterbodies using all information available at the time to determine the designated use support status of each waterbody. The State of Tennessee has organized its watersheds into five groups and bases activities within each group on a five-year watershed cycle. Thus, each HUC8-watershed is assessed once every 5 years and each 303(d) List will be updated with the results of assessment for two groups of watersheds.

Development of TMDLs is also part of the watershed cycle. Like the 303(d) List, TMDLs are developed based on all information available at the time. If additional monitoring data is available that was not available at the time of the assessment, this new data is taken into account when developing the TMDLs. Sometimes the newer data suggests that a

previously unassessed waterbody or a waterbody previously assessed as being fully supporting of designated uses is now impaired. In that case, a TMDL, WLA, and LA are developed for that waterbody and it is suggested that the waterbody be placed on the 303(d) List. Sometimes the newer data suggests that a waterbody previously on the 303(d) List is no longer impaired. In that case, a TMDL, WLA, and LA are developed (because it is currently listed as impaired), but it is suggested that the waterbody be delisted.

This TMDL document has been under development for over a year. Initial analysis was based on the Final 2010 303(d) List. TMDLs, WLAs, and LAs were developed for copper for Grays Creek and for lead for several segments of the Wolf River and for Shaws Creek and Fletcher Creek. In each case, the most recent data suggested that the waterbody was no longer impaired and delisting was recommended. When the 2012 303(d) List was developed, these waterbodies were de-listed based on the most recent data. The TMDL was also updated to refer to the Proposed Final 2012 303(d) List.

Assessment is a continuous process. The 303(d) List and a TMDL document are snapshots and are accurate as of a certain moment in time. A TMDL is required for all waterbodies contained on the 303(d) List. However, a TMDL can be developed for a waterbody that is not yet contained on the 303(d) List if data suggests that the waterbody is impaired. There are no longer any waterbodies in the Wolf River watershed that fall in this category. TMDLs developed for waterbodies that are not listed as impaired will be noted as such.

6. First, Tennessee has no jurisdiction over discharges in other States. Second, if Mississippi were contributing to the impairment, monitoring data close to the state line would confirm this. Monitoring at upstream stations (ECO74B12, WOLF018.9SH, WOLF031.8SH, and WOLF044.4FA) indicate no current impairment. Therefore, TDEC assumes that Mississippi is not contributing to the impairment of the Wolf River at segment 001-1000.

7. Industrial facilities covered under the TMSP have a benchmark concentration in their permits. If these facilities meet their benchmark permit limits, their contributions will be insignificant. Under the terms of the TMSP, facilities must monitoring stormwater runoff once per year.

8. First, as noted in the TMDL (Section 6.2.1), monitoring data collected by EPA determined that cleanup levels at the Superfund site were achieved and contamination was not migrating offsite. Second, if scour from legacy sediments (from the Superfund site) were a source, then impairment would not be limited to the segment most downstream from the Superfund site. Monitoring at other locations downstream of the Superfund site (WOLF018.9SH and WOLF031.8SH) indicate improvement since remediation of the site and no current impairment.

9. When evaluation of a waterbody is based on monitoring data, impairment is usually indicated by greater than 10% of the samples in exceedance of the single sample maximum. Therefore, improvement in water quality would be indicated by less than 10% of samples in exceedance of the water quality criteria for the parameter of concern. Documentation of the improvement is necessary for de-listing. De-listing could occur whenever the HUC8 watershed is next assessed in the watershed cycle.

Response to Supplemental Comments from Memphis MS4:

We appreciate the additional data supplied by the City of Memphis. However, unless the samples were collected under rapidly varying flow conditions, four samples in a 20-minute time period are the equivalent of one sample and three duplicates. Under steady state conditions, samples should typically be collected at least 12 hours apart. (This is similar to the sampling specification for coliform to determine the geometric mean.) While the results presented are interesting, there is insufficient data to be able to draw any conclusion.

If the City of Memphis wishes to develop a site-specific criterion for lead, there are specific requirements to follow. As stated in the General Water Quality Criteria [Chapter 1200-04-03-.02(9)]:

> Site-specific criteria studies may be conducted on any appropriate fish and aquatic life critera.
>
> a. Site-specific criteria studies based on a Water Effects Ratio (WER) calculated from the documented toxicity of a parameter in the stream in which it will be introduced may supersede the adopted criteria at a site. The Division shall approve a site-specific criteria developed by others provided that the WER methodology [Interim Guidance on Determination and Use of Water-effect Ratios for Metals (EPA-823-B-94-001)] is used, both the study plan and results are approved by the department, and the U.S. Environmental Protection Agency has concurred with the final site specific criterion value(s).
>
> b. Any site-specific criterion based on methodologies other than the WER methodology which recalculate specific criterion, such as the Resident Species Method or the Recalculation Method, must be adopted as a revision to Tennessee water quality standards into Chapter 1200-04-03, and following EPA approval, can be used for Clean Water Act purposes.

As stated in #2 above, we believe that the metals translator currently in use is adequate.

Response to Comments from City of Bartlett:

1. All waterbodies in Tennessee are designated for: fish & aquatic life, recreation, livestock watering & wildlife, and irrigation. The recreation use classification for surface water includes the safe consumption of fish and shellfish. However it is not limited to fishing. While the waterbodies in question may not be deep enough for canoeing or fishing, children will wade in anything deep enough to make a splash – especially on a hot day in the middle of summer. Since all Waters of the State are classified for more than one use, the most stringent criteria and the most protective criteria will be applicable.
2. While it is true that the sampling locations for Harrington Creek and the Unnamed Trib to Fletcher Creek are not within the boundaries of the City of Bartlett, a large portion of the drainage areas for each waterbody (61.2% for Harrington Creek and 75.7% for the Unnamed Trib) lie within the boundaries of the City of Bartlett. Therefore, it is reasonable to assume that some portion of the impairment comes from within the boundaries of the City of Bartlett. If the City of Bartlett wants to prove that the impairment does not come from within their boundaries, TDEC recommends instream sampling at the point where each waterbody exits the City of Bartlett. If there are no exceedances of the Water Quality Criterion for arsenic as the waterbody exits the City of Bartlett, then the City of Bartlett is not a source of impairment.

   The City of Bartlett has coverage to discharge stormwater under the NPDES General Permit for Small MS4s. The permit does not authorize “discharges that would cause or contribute to an in-stream exceedance of water quality standards.” (Section 1.4.g) “The MS4 shall perform analytical monitoring as part of its Stormwater Management Program, at a minimum, in streams with EPA approved TMDLs and impaired streams.” (Section 5.1) Even in impaired waterbodies without a TMDL, “MS4s that have discharges containing pollutants of concern into a receiving water which has been listed on the Section 303(d) list of impaired waters must document in the SWMP how the BMPs will control the discharge of the pollutants of concern, and must demonstrate that the discharge will not cause or contribute to an impairment”. (Section 3.1.3) “For stream segments subject to TMDLs for parameters other than siltation, habitat alteration or pathogens, where discharges from the MS4 have been identified as a source of the impairment, the MS4 shall perform analytical monitoring as prescribed in the TMDL.” (Section 5.1)