Final Total Maximum Daily Load for Fecal Coliform 7 Stream Segments within the Cane Run Watershed, Fayette and Scott Counties, Kentucky

Photo of Cane Run of North Elkhorn Creek (KDOW)

July 2013

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July 2013

Kentucky Department for Environmental Protection

Division of Water

Frankfort, Kentucky

This report has been approved for release

Sandra L. Gruzesky, Director
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7/12/13
Date

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AC/TC	Ratio of Atypical Coliform to Typical Coliform Bacteria
AWQA	Agricultural Water Quality Authority
AWQP	Agricultural Water Quality Plan
BAE	Biosystems and Agricultural Engineering
BMP	Best Management Practices
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
cfu	Colony Forming Units
CPP	Continuing Planning Process
CWA	Clean Water Act
DMR	Discharge Monitoring Report
DWS	Drinking Water Supply
EPA	United States Environmental Protection Agency
ERTL	Environmental Research Training Laboratory
FOCR	Friends of Cane Run
GM	Geometric Mean
GMWSS	Georgetown Municipal Water and Sewer Service
GNIS	Geographic Names Information System
HSPF	Hydrologic Simulation Program Fortran
HUC	Hydrologic Unit Code
KAR	Kentucky Administrative Regulations
KDEP	Kentucky Department for Environmental Protection
KDOW	Kentucky Division of Water
KEEC	Kentucky Energy and Environment Cabinet
KGS	Kentucky Geological Survey
KNDOP	Kentucky No-Discharge Operating Permit

KPDES	Kentucky Pollution Discharge Elimination System
KRWW	Kentucky River Watershed Watch
KWRRI	Kentucky Water Resources Research Institute
KYTC	Kentucky Transportation Cabinet
LA	Load Allocations
LFUCG	Lexington Fayette Urban County Government
mgd	Million Gallons per Day
MHP	Mobile Home Park
ml	Milliliter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
NGO	Non-Governmental Organization
NHD	National Hydrography Dataset
OWTS	On Site Wastewater Treatment System
PCR	Primary Contact Recreation
PRIDE	Personal Responsibility in a Desirable Environment
RM	River Mile
SCR	Secondary Contact Recreation
SDWA	Safe Drinking Water Act
SSA	Sanitary Sewer Assessment
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWS	Sanitary Wastewater System
TMDL	Total Maximum Daily Load
UK	University of Kentucky
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UT	Unnamed Tributary
WBP	Watershed Based Plan
WLA	Waste Load Allocation
WMB	Watershed Management Branch
WQC	Water Quality Criteria
WWTP	Waste Water Treatment Plant

TMDL SYNOPSIS

S.1 Impaired Waterbodies

State: Kentucky
Major River Basin: Kentucky River
USGS HUC8: 05100205
Counties: Fayette and Scott
Pollutant of Concern: Fecal Coliform, *E. coli*
Impaired Use: Primary Contact Recreation, Secondary Contact Recreation
Suspected Sources: Livestock (Grazing or Feeding Operations), Managed Pasture Grazing, Package Plant or Other Permitted Small Flows Discharges, Unspecified Urban Stormwater

Table S.1 Impaired Waterbodies Addressed in this TMDL Document

Waterbody and Segment (GNIS[1] Number)	County	Support Status	Pollutant	Suspected Source(s)
Cane Run 0.0 to 3.0 (KY488799_01)	Scott	PCR (Nonsupport), SCR (Partial Support)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Managed Pasture Grazing, Package Plant or Other Permitted Small Flows Discharges, Unspecified Urban Stormwater
Cane Run 3.0 to 9.6 (KY488799_02)	Scott	PCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Package Plant or Other Permitted Small Flows Discharges
Cane Run 9.6 to 17.4 (KY488799_03)	Fayette	PCR (Nonsupport), SCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Unspecified Urban Stormwater
UT to Cane Run at 6.13 RM[2] 0.0 to 3.5 (KY488799-6.13_01)	Scott	PCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations)
UT to Cane Run at 10.8 RM 0.0 to 2.4 (KY488799-10.8_01)	Scott	PCR (Nonsupport)	*E. coli*	Livestock (Grazing or Feeding Operations)

Waterbody and Segment (GNIS[1] Number)	County	Support Status	Pollutant	Suspected Source(s)
UT to Cane Run at 12.9 RM 0.0 to 2.1 (KY488799-12.9_01)	Scott	PCR (Nonsupport)	*E. coli*	Agriculture, Unspecified Urban Stormwater
UT to Cane Run at 15.6 RM 0.0 to 0.9 (KY488799-15.6_01)	Scott	PCR (Nonsupport)	*E. coli*	Unspecified Urban Stormwater

[1] GNIS = Geographic Names Information System.
[2] RM = River Mile.

S.2 TMDL Target (Numeric or Narrative)

Table S.2 TMDL Targets by Impaired Waterbody

Waterbody and River Mile (GNIS[1] Number)	TMDL Target[3]
Cane Run 0.0 to 3.0 (KY488799_01)	180 fecal coliform colonies/100ml expressed as a 30-day geometric mean as well as 360 colonies/100ml which must be met in at least 80% of all observations within a 30-day period (incorporating an implicit Margin of Safety)
Cane Run 3.0 to 9.6 (KY488799_02)	
Cane Run 9.6 to 17.4 (KY488799_03)	
UT to Cane Run at 6.13 RM[2] 0.0 to 3.5 (KY488799-6.13_01)	
UT to Cane Run at 10.8 RM 0.0 to 2.4 (KY488799-10.8_01) [4]	
UT to Cane Run at 12.9 RM 0.0 to 2.1 (KY488799-12.9_01) [4]	
UT to Cane Run at 15.6 RM 0.0 to 0.9 (KY488799-15.6_01) [4]	

[1] GNIS = Geographic Names Information System.
[2] RM = River Mile.
[3] The TMDL Targets reflect the fecal coliform WQCs minus an implicit MOS.
[4] Segments impaired for *E. coli* received allocations in terms of fecal coliform because the model was calibrated using fecal coliform data, and Kentucky has a dual standard for both fecal coliform and *E. coli* as shown in Section 2.1, thus development of TMDLs using the fecal coliform criterion are sufficient to provide TMDLs for *E. coli*-listed segments and vice versa.

S.3 TMDL Equation and Calculations:

According to EPA (1991), a TMDL calculation is performed as follows:

$$TMDL = WLA + LA + MOS$$
(Equation S.1)

The WLA has three components:

$$WLA = SWS\text{-}WLA + MS4\text{-}WLA + Future\ Growth\text{-}WLA$$
(Equation S.2)

Definitions:
TMDL: the WQC, expressed as a load.
MOS: the Margin of Safety, which can be an implicit or explicit additional reduction applied to sources of pollutants that accounts for uncertainties in the relationship between effluent limits and water quality. For this report, the MOS is implicit .
TMDL Target: the TMDL minus the MOS.
WLA: the Wasteload Allocation, which is the allowable loading of pollutants into the stream from KPDES-permitted sources, such as Sanitary Wastewater Systems (SWSs) and Municipal Separate Storm Sewer Systems (MS4s).
SWS-WLA: the WLA for KPDES-permitted sources which have discharge limits for pathogen indicators (including wastewater treatment plants, package plants and home units, which are referred to as Sanitary Wastewater Systems, or SWSs).
Future Growth-WLA: the allowable loading for future KPDES-permitted sources, including new SWSs, expansion of existing SWSs, new storm water sources, and growth of existing storm water sources (such as MS4s). Also includes the allocation for KPDES-permitted sources that existed but were not known at the time the TMDL was written.
Remainder: the TMDL minus the MOS and minus the SWS-WLA (also equal to Future Growth-WLA plus the MS4-WLA and the LA).
MS4-WLA: the WLA for KPDES-permitted Municipal Separate Storm Sewer Systems (MS4 permittees can include cities, counties, roads and right-of-ways owned by the Kentucky Transportation Cabinet (KYTC), universities and military bases).
LA: the Load Allocation, which is the allowable loading of pollutants into the stream from sources not permitted by KPDES and from natural background.
Seasonality: yearly factors that affect the relationship between pollutant inputs and the ability of the stream to meet its designated uses.
Critical Condition: the time period when the pollutant conditions are expected to be at their worst.
Critical Flow: the flow(s) used to calculate the TMDL as a load.
Existing Conditions: the load that exists in the watershed at the time of TMDL development (i.e., sampling) and is causing the impairment.
Load: concentration * flow * conversion factor.
Concentration: colonies per 100 milliliters (colonies/100ml).
Flow (i.e., stream discharge): cubic feet per second (cfs).

Conversion Factor: the value that converts the product of concentration and flow to load (in units of colonies/day); it is derived from the calculation of the following components: (28.31685L/ft^3 * 86400seconds/day * 1000ml/L)/(100ml) and is equal to 24,465,758.4.

Calculation Procedure:

1) The MOS, if an explicit value, is calculated and subtracted from the TMDL first, giving the TMDL Target;
2) The SWS-WLA is calculated and subtracted from the TMDL Target, leaving the Remainder;
3) The Future Growth-WLA is calculated and subtracted from the Remainder;
4) If there is a MS4 present upstream of the impaired segment, the MS4-WLA is subtracted from the Remainder based on percent developed landcover within the MS4 permitted boundary, leaving the LA.

TMDL calculations for individual impaired waterbodies are shown in TableS.3. SWSs with discharges to Cane Run have SWS-WLAs as described in Table S.4.

Table S.3 Final TMDL Allocations

Subwatershed	TMDL (fecal coliform colonies/ day) (1)	SWS-WLA (fecal coliform colonies/ day) (2)	MS4 Permittee	MS4-WLA (fecal coliform colonies/ day) (3)	Future Growth-WLA (fecal coliform colonies/ day)	LA (fecal coliform colonies/ day)
Cane Run 0.0 to 3.0	2.17E+12	0	Georgetown/ KYTC	2.83E+08	4.35E+10	2.12E+12
Cane Run 3.0 to 9.6	4.91E+12	0	Lexington/ Georgetown/ KYTC	1.98E+09	1.48E+11	4.76E+12
UT(4) to Cane Run at 6.13 RM(5) 0.0 to 3.5	1.36E+12	5.68E+08	None	0.00E+00	4.08E+10	1.32E+12
Cane Run 9.6 to 17.4	2.23E+12	0	Lexington/ KYTC	1.29E+10	1.11E+11	2.10E+12
UT to Cane Run at 10.8 RM 0.0 to 2.4	1.19E+12	0	Lexington/ KYTC	6.43E+07	2.38E+10	1.17E+12
UT to Cane Run at 12.9 RM 0.0 to 2.1	4.79E+11	0	Lexington/ KYTC	1.58E+09	2.40E+10	4.53E+11

Subwatershed	TMDL (fecal coliform colonies/ day) [1]	SWS-WLA (fecal coliform colonies/ day) [2]	MS4 Permittee	MS4-WLA (fecal coliform colonies/ day) [3]	Future Growth-WLA (fecal coliform colonies/ day)	LA (fecal coliform colonies/ day)
UT to Cane Run at 15.6 RM 0.0 to 0.9	1.40E+11	0	Lexington/ KYTC	7.01E+09	7.00E+09	1.26E+11

(1) In the event that compliance with the WQC is determined using *E. coli* concentrations as opposed to fecal coliform concentrations, the final fecal coliform allocations can be converted to *E. coli* by multiplying by the figure (240/400) for instantaneous values, or by the figure (130/200) for the 30-day geometric mean value, assuming 5 or more samples are taken within a 30-day period. Note that these relationships only demonstrate how to convert the TMDL allocations from terms of fecal coliform to terms of *E. coli* based on the relationship between the fecal coliform WQC and the *E. coli* WQC: The actual relationship between fecal coliform and *E. coli* instream has been defined in Section 2.2.4.1 of the Modeling Report based on sampling data. However, the relationship given in Section 2.2.4.1 of the Modeling Report is an estimate, and will not be used to convert *E. coli* to fecal coliform (or vice versa) to demonstrate compliance.

The TMDL is defined as the sum of the Wasteload Allocations (WLAs), Load Allocations (LAs) and a Margin of Safety (MOS, which in this case is implicit). However, sources of bacteria change over time and the output of existing sources changes with time. Allocation shifts can be made between the sources within the WLA, and between sources within the LA after the TMDL is approved, but not between the LA and WLA without TMDL revision, public notice and EPA approval.

(2) WLAs for the Sanitary Wastewater Systems (SWSs, e.g., Wastewater Treatment Plants (WWTPs)) discharging to a listed segment are equal to their permit limit times their design flow. These values were derived using the fecal coliform Water Quality Criterion (WQC) of 200 colonies/100ml calculated as a geometric mean using 5 or more samples collected within a 30-day period so the allocated load is in units of colonies/day. See Table S.4 for allocations for individual SWSs. According to 401 KAR 10:031, individual SWSs may be permitted to discharge either fecal coliform or *E. coli;* currently all SWSs in the Cane Run watershed are permitted in terms of *E. coli*. However, the SWSs were modeled as discharging fecal coliform so their output was consistent with the monitoring protocol used to develop the TMDL.

Although Concentrated Animal Feeding Operations (CAFOs) receive their allocations within the WLA, there are no permitted CAFOs present in the watershed. Any future CAFO cannot legally discharge to surface water, and therefore receives a WLA of zero. The only exception is holders of a CAFO Individual Permit can discharge during a 25-year or greater storm event.

(3) Municipal Separate Storm Sewer Systems (MS4s) receiving aggregated MS4-WLAs include the City of Lexington (Permit Number KYS000002), the City of Georgetown (Permit Number KYG200040) and the Kentucky Transportation Cabinet (KYTC, Permit Number KYS000003).

(4) UT = Unnamed Tributary.

(5) RM = River Mile.

Table S.4 SWS-WLAs

Facility	KPDES Permit	Receiving Waterbody	Design Discharge (mgd[1])	Permit Limit (fecal coliform colonies/ 100ml) [2]	Wasteload Allocation (fecal coliform colonies/day)
Spindletop MHP	KY0081213	UT to Cane Run at 6.13 RM 0.0 to 3.5	0.030	200	2.27E+08
Ponderosa MHP	KY0081221	UT to Cane Run at 6.13 RM 0.0 to 3.5	0.016	200	1.21E+08
Maple Grove MHP	KY0083321	UT to Cane Run at 6.13 RM 0.0 to 3.5	0.029	200	2.20E+08

(1) mgd = millions of gallons per day.

(2) While all Sanitary Wastewater System (SWS) facilities were modeled as discharging fecal coliform at the monthly geometric mean of 200 colonies/100ml, since the TMDL was begun in 2002 KDOW has been in the process of switching active permit holders from reporting in terms of fecal coliform to instead reporting in terms of *E. coli* when their permits became due for reissuance, therefore all facilities in the Cane Run watershed now report in terms of *E. coli*. However, it was necessary to report the WLA for all SWSs in terms of fecal coliform so their allocations were consistent with the monitoring protocol used to develop the TMDL. Although the WLA is in terms of fecal coliform, this does not change the permit limits for any given facility.

S.4 Translation of WLAs into Permit Limits

Draft S.4 Translation of WLAs into Permit Limits

WLAs for Sanitary Wastewater Systems (SWSs) were given in Table S.3. SWS-WLAs will be translated into KPDES SWS permit limits as an *E. coli* effluent gross limit of 130 colonies/100ml as a monthly average and 240 colonies/100ml as a maximum weekly average or as a fecal coliform effluent gross limit of 200 colonies/100ml as a monthly average and 400 colonies/100ml as a maximum weekly average.

KPDES permits for Municipal Separate Storm Sewer Systems (MS4) must also contain conditions that are consistent with the MS4-WLA [40 CFR 122.44(d)(1)(vii)(B)]. Because of the varying flow conditions associated with MS4 discharges and the fact that the MS4-WLA was set under a single modeling scenario, permit conditions should provide for an adaptive iterative approach via Best Management Practices (BMPs) outlined in the Stormwater Quality Management Plan (SWQMP) and implemented to the Maximum Extent Practicable (MEP).

Because MS4 loading inputs vary over time and with flow, the MS4-WLA values shown in the TMDL Summary Tables represent only one possible allocation scenario. The computed MS4-WLA should be viewed in this broader context of varying load and varying flow when evaluating the MS4's fractional contribution to total in-stream bacteria concentration. Consideration of stream assimilative capacity, use of pollutant trading or offset scenarios, MS4 pollutant load input variations for dry and wet weather, and BMP implementation and performance are some of the variables to consider when setting compliance goals.

The MS4 permit requires that upon completion of a TMDL for a receiving water to which the MS4 discharges, the SWQMP must be revised to identify specific, measureable, and enforceable actions to be taken, in the context of MEP, in the MS4's effort to attain the MS4-WLA identified in the TMDL.

While not all MS4 permits within the watershed currently call for monitoring as a requirement of the MS4 permittee based on an approved TMDL, KDOW plans to issue future MS4 permits in watersheds with approved TMDLs that will require MS4s to develop and implement a monitoring program to measure the effectiveness of the actions taken toward meeting the MS4-WLA and to direct the MS4 to adaptive management approaches to implementing the TMDL; all permits will provide that actions taken by the MS4 toward meeting the MS4-WLA must meet the standard of MEP. Accordingly, future MS4 permit conditions should require the permittee to propose, as part of its SWQMP, structural and/or non-structural BMPs to attain MS4-WLA to the MEP. The SWQMP shall also include an adaptive, iterative approach that can be evaluated over multiple MS4 permit terms to ensure reasonable progress toward achieving the MS4-WLA.

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act (CWA) requires states to identify waterbodies within their boundaries that have been assessed and are not currently meeting their designated uses (401 KAR 10:026 and 10:031) and that require the development of a Total Maximum Daily Load (TMDL). States must establish a priority ranking for such waters, taking into account their intended uses and the severity of the pollutant. Section 303(d) also requires that states provide a list of this information called the 303(d) list. This list is submitted to the U.S. Environmental Protection Agency (EPA) during even-numbered years and each submittal replaces the previous list. The 2010-303(d) information for Kentucky can be found in the *2010 Integrated Report to Congress on the Condition of Water Resources in Kentucky Volume II. 303(d) List of Surface Waters* (Kentucky Division of Water (KDOW), 2011a) and can be obtained at: http://water.ky.gov.

States are also required to develop TMDLs for the pollutants that cause each waterbody to fail to meet its designated uses. The TMDL process establishes the allowable amount (i.e., load) of the pollutant the waterbody can naturally assimilate while continuing to meet the Water Quality Criteria (WQC) for each designated use. The pollutant load must be established at a level necessary to implement the applicable WQC with seasonal variations and a Margin of Safety (MOS) that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. This load is then divided among different sources of the pollutant in a watershed. Information from EPA on TMDLs can be found at: http://www.epa.gov/owow/tmdl.

In order to separate the watershed and general source information from the technical details of the modeling effort, a separate Modeling Report has been provided following the References Section of this portion of the report (hereafter referred to as the narrative portion of the report to distinguish it from the Modeling Report).

1.1 Location

The Cane Run watershed is contained within parts of Fayette and Scott counties in central Kentucky as shown in Figure 1.1. Major highways that traverse the watershed include I-64 and I-75. The part of the watershed within Fayette County drains highly urbanized areas of Lexington. The part of the watershed in Scott County drains the southern part of Georgetown.

1.2 Hydrologic Information

Cane Run is a third order stream which originates in central Fayette County and flows north to discharge into the North Elkhorn Creek 44.3 km (27.9 miles) upstream of its confluence with Elkhorn Creek. Elkhorn Creek runs northwest to discharge into the Kentucky River: Therefore, Cane Run is part of the Kentucky River Watershed, United States Geological Survey (USGS) HUC (Hydrologic Unit Code) 05100205 (USGS, 2004).

The mainstem of Cane Run is approximately 17.4 miles long and drains an area of approximately 44.6 square miles (mi^2) (28,500 acres); however, only 41.3 mi^2 (26,456 acres) are normally drained by surface runoff due to karst effects, see Section 1.3. The average gradient is 12.4 feet/mile. Elevations for Cane Run range from 975 ft above mean sea level (msl) in the headwaters in Lexington to 760 ft above msl at the confluence with the North Elkhorn Creek.

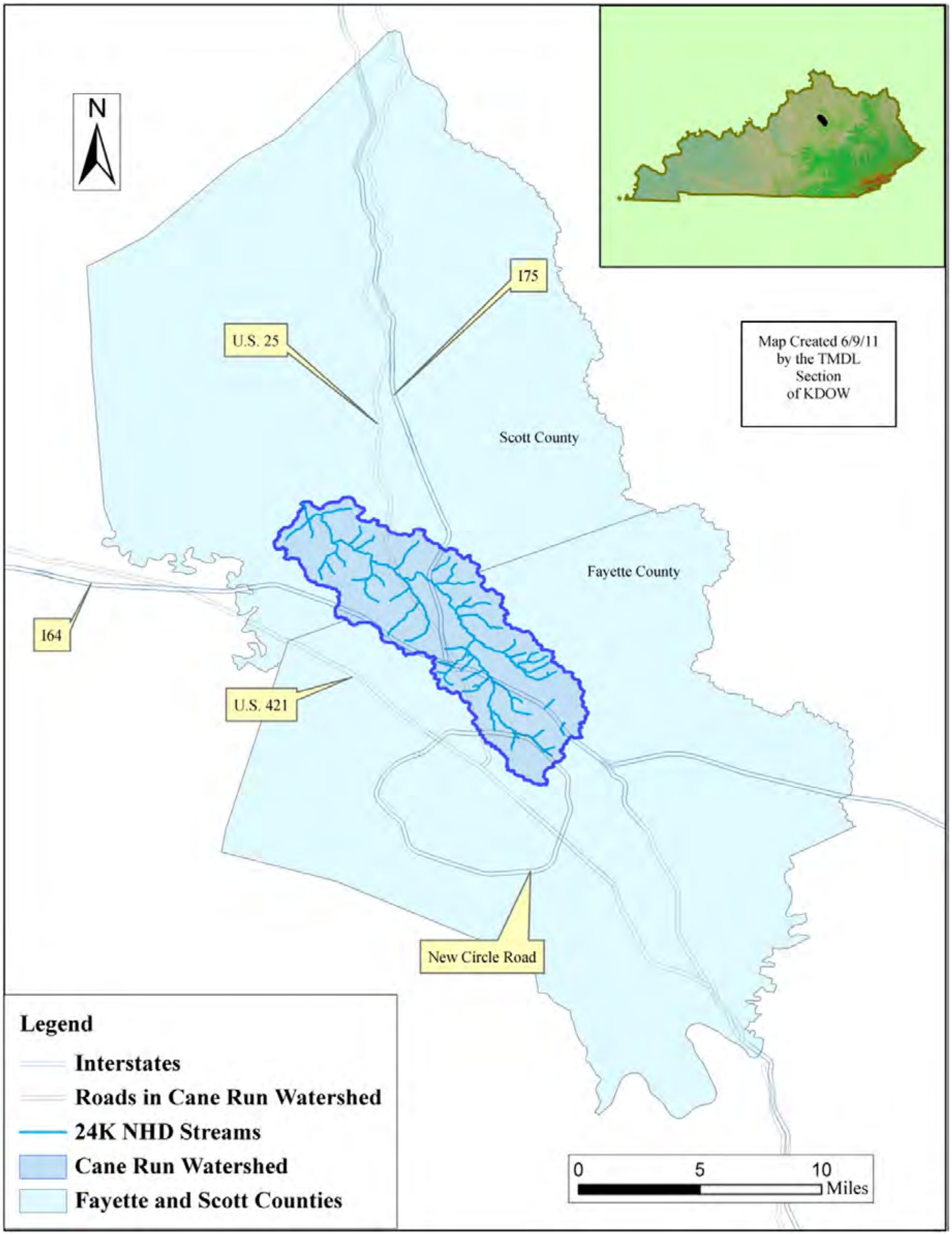

Figure 1.1 Cane Run Watershed Location

1.3 Catchment Delineation

In order to assess the sources and associated pathogen loadings in the Cane Run watershed, a Hydrologic Simulation Program Fortran (HSPF, Bicknell et al., 1997) computer model of the watershed was developed using stream data from the National Hydrography Dataset (NHD, USGS, 2003a). The modeling is complicated by the karst nature of the watershed; the Royal Spring karst basin and the Cane Run surface water basin overlap considerably, see Figure 1.2. In particular a large part of the surface water flow in the upper part of the watershed enters karst conduits near the site of the former USGS gaging station 03288200 Cane Run near Donerail, which was located on Berea Road; see Figure 1.3 (USGS, 2003b) during the time of this study, although it was moved in 2012. From there the lost surface water flows underground until it exits at Royal Spring in Georgetown. Swallets (i.e., the point where a losing or sinking stream enters the subsurface; this can be a single feature or a sizeable losing reach of stream (Personal Communication, Rob Blair, 2011a)) and large sinkholes are present within the Royal Spring karst basin, draining surface flow to the karst aquifer during most of the year. As a result, the USGS Cane Run near Donerail gauging station showed no flows except during periods of heavy rainfall during this study. Therefore, flow is only available as surface runoff in Cane Run immediately downstream of the Royal Spring karst basin during the wetter parts of the year. The Kentucky Geological Survey (KGS, 2003) conducted tracer studies and delineated the ground water basins for major springs in the area. Royal Spring is the water supply for the City of Georgetown.

For the purposes of modeling and determining the associated TMDLs, the entire watershed was initially subdivided into two separate areas: the part of Cane Run above River Mile (RM) 6.8, and the part of Cane Run below RM 6.8. The part of the watershed above RM 6.8 may also be referred to as Royal Spring karst basin. These areas were then subdivided into several catchments: eight catchments in the part of Cane Run above RM 6.8 and six catchments in the part of Cane Run below RM 6.8 (see Figure 1.4). Two additional catchments were defined for the part of Cane Run above RM 6.8 to facilitate modeling the karst system (i.e., K1 and K2), since flow normally exits these basins into the adjacent parts of the North Elkhorn Creek watershed, and does not appear in the Cane Run part of the watershed. Loads from the two karst catchments apply only when rainfall events exceed a certain level (see Section 4.5.2.2 of the Modeling Report for further discussion). For the purposes of modeling the part of Cane Run above RM 6.8 (i.e., the Royal Spring karst basin) an additional catchment (i.e., K3) has been added to accommodate the karst contributions to Royal Spring that lie external to the surface topography boundary of the upper watershed, but this catchment was only used to model the karst flow; it was not included in TMDL development since there is no bacteria-impaired waterbody in that catchment.

During TMDL loading and reduction calculations, separate TMDLs and associated load allocations were developed for each catchment except K3: Although the individual catchments are defined in Figure 1.4, the loading from an individual catchment may or may not represent the loading to an impaired segment, see Figure 1.5; therefore, the term ‘subwatershed’ is used to represent the upstream area of impaired segments in the document (most subwatersheds include multiple catchments, with the exception of the Unnamed Tributary (UT) of Cane Run at RM 10.8, whose subwatershed is identical with catchment U4).

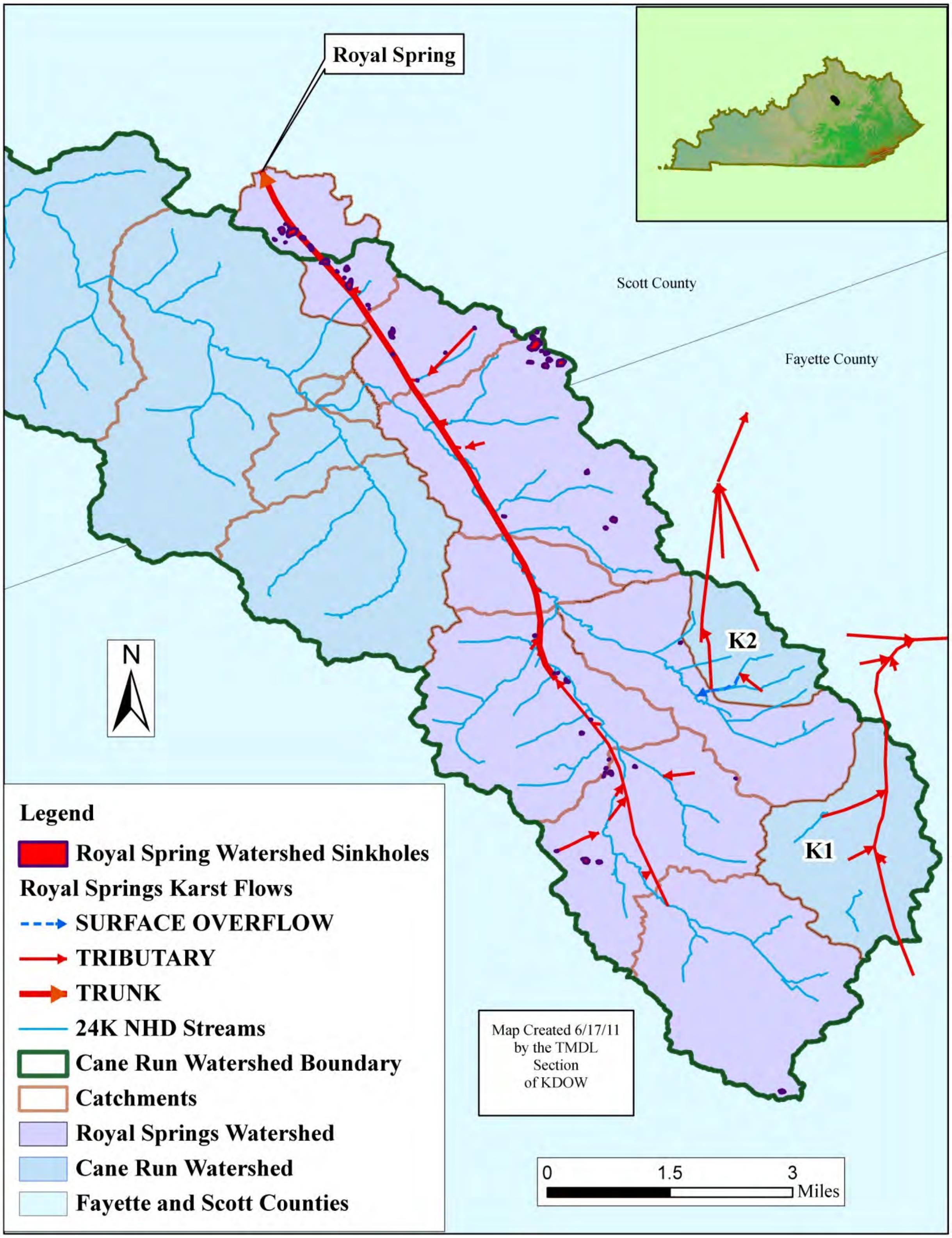

Figure 1.2 Cane Run Surface Water and Royal Spring Ground Water Basins

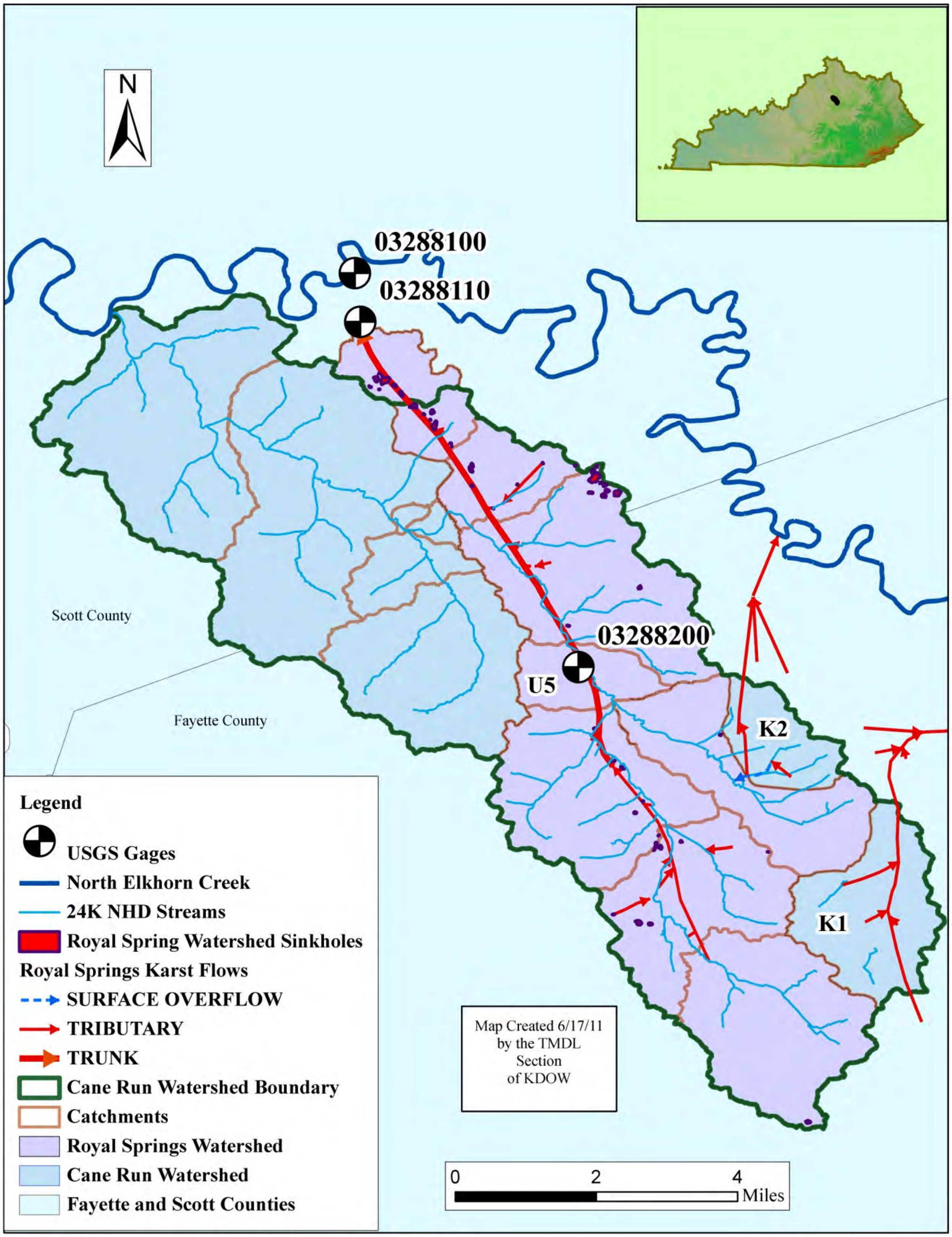

Figure 1.3 Cane Run Surface Water and Royal Spring Ground Water Basins with USGS Gaging Stations

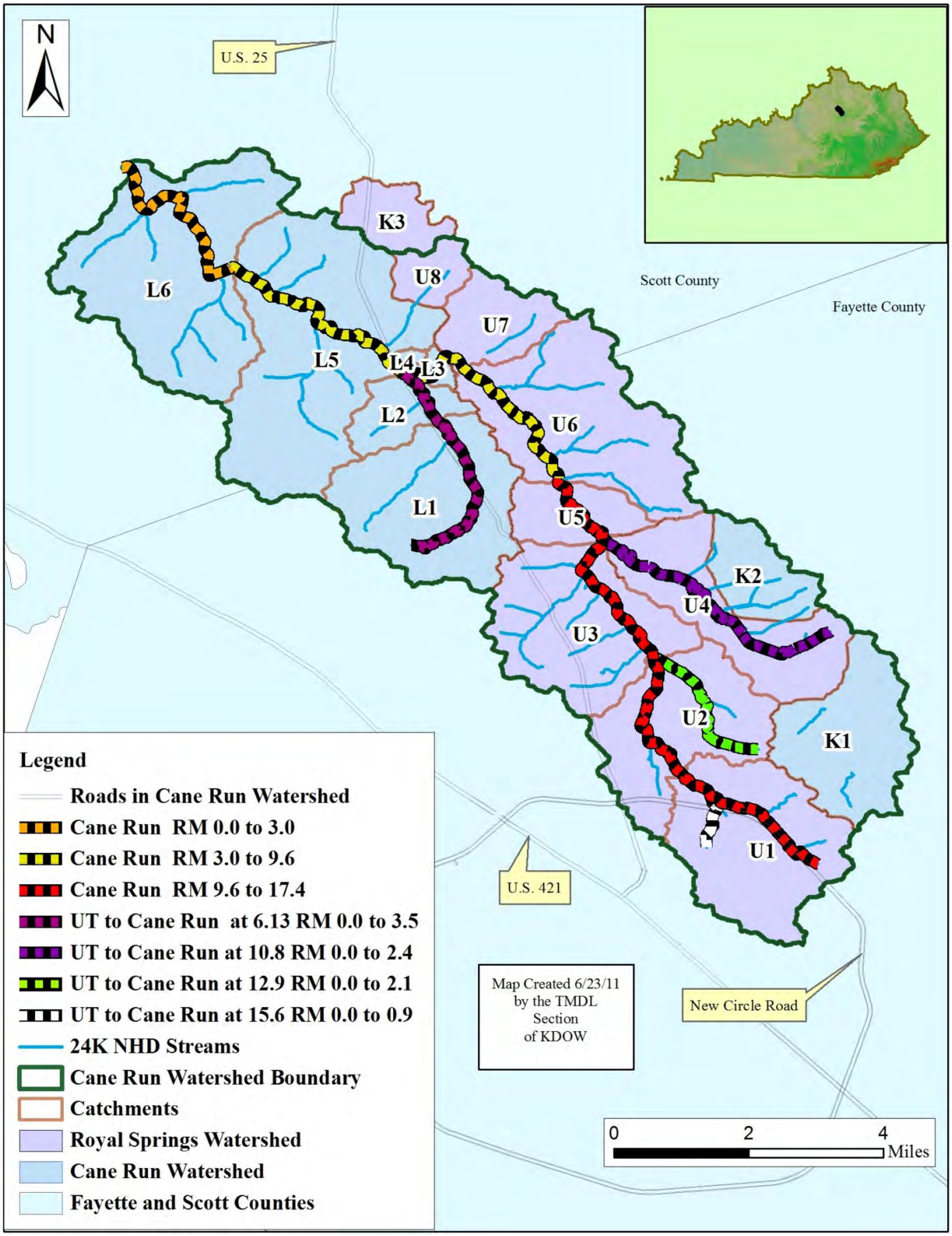

Figure 1.4 Cane Run Catchment Delineation

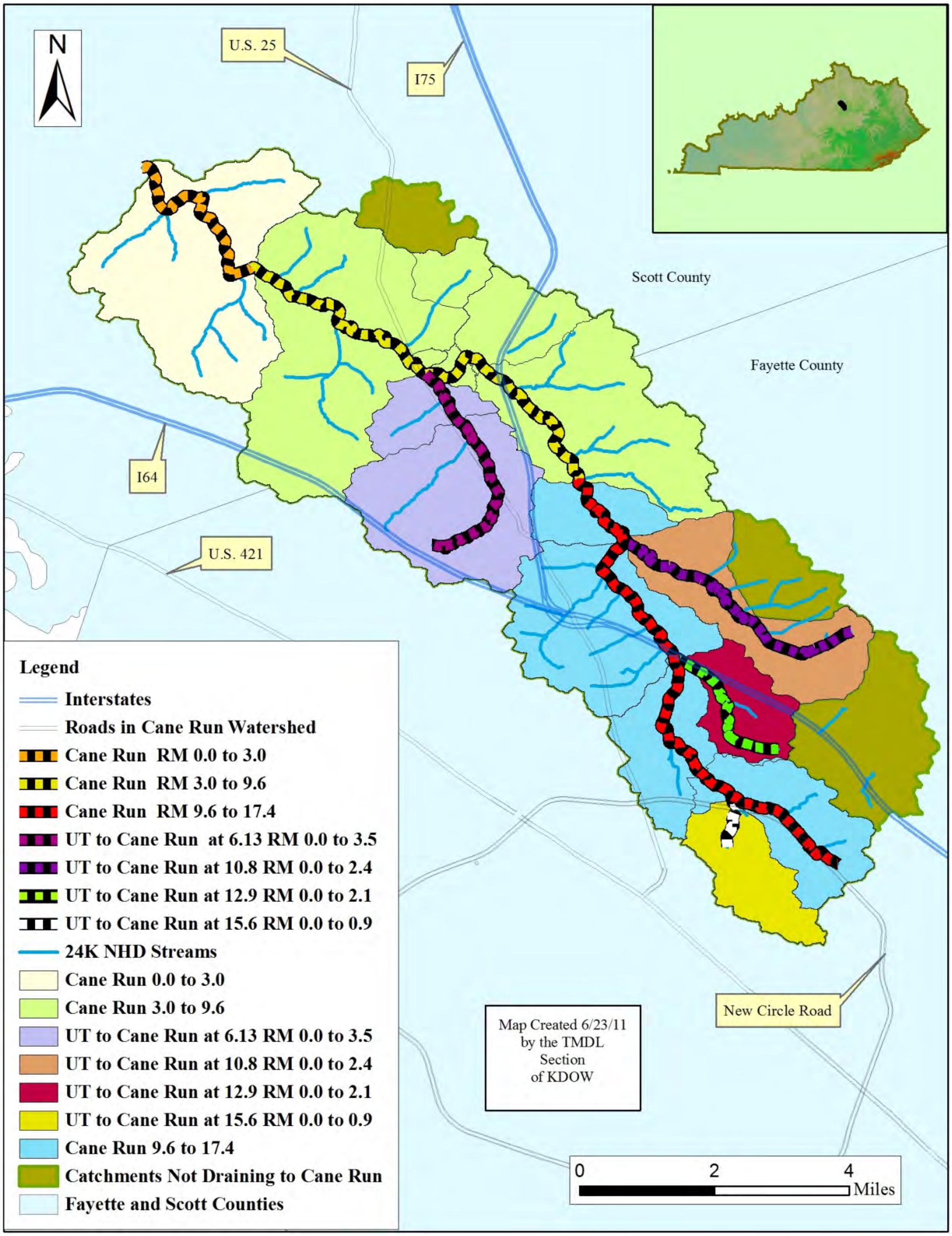

Figure 1.5 Cane Run Subwatersheds

1.4 Geologic Information

The Cane Run watershed is in the Inner Bluegrass physiographic region. According to KGS (2011) the area is underlain with the Lexington limestone formation of the Ordovician age. The Lexington formation is thinly-bedded shale limestone and is phosphatic in content. The Tanglewood member is exposed in the largest area of the basin and is likely responsible for contributing phosphorus to ground water and surface water. Karst features like sinkholes and springs also dominate the geology. There are also moderate amounts of shale and alluvium deposits in the region. The relief of the Cane Run watershed ranges from nearly level to gently rolling and undulating hills.

1.5 Soils Information

The Cane Run watershed is dominated by nearly level to strongly sloping silt loam and silty clay loam. The area is comprised mostly of the Maury and Lowell soils series. The Maury series are deep, well-drained soils formed from weathered phosphatic limestone. Permeability for this series is moderate to moderately rapid. The Lowell series are deep, well drained to moderately drained soils formed from weathered interbedded limestone and calcareous shale. Permeability for this series is moderately slow. The McAfee soil series are moderately deep to deep, well-drained soils formed from weathered phosphatic limestone. Permeability for this series is moderate to moderately low (Soil Surveys of Fayette and Scott Counties, USDA, 1968, 1977).

1.6 Landcover Information

Landcover is based on landcover mapping, a process which assigns categorical rather than specific uses based on the digitization and sorting of returns from radar or lidar. Landcover is a surrogate indicator for the type of landuse, but they are not equivalent: for instance, strip mines and areas denuded by forest fire can both show up as barren land, etc.

The geology in the Cane Run watershed, with its phosphorus rich soils, is conducive to agriculture. The watershed consists of 76% agricultural area (which, for purposes of this analysis, included Cropland, Pastureland and Forest), and 24% urban area. The urban area ranges from residential to commercial and industrial tracts. These values were derived using the BASINS 3.1 database (EPA, 2004). Figure 1.6 shows a map of landcover based on Anderson Level II Landcover Categories (Anderson, 1972). Categories include:

1. Residential;
2. Commercial and Services;
3. Transportation, Communications, and Utilities, and;
4. Mixed Urban or Built Up.

Industrial and Commercial Complexes are considered within the category of Commercial and Services.

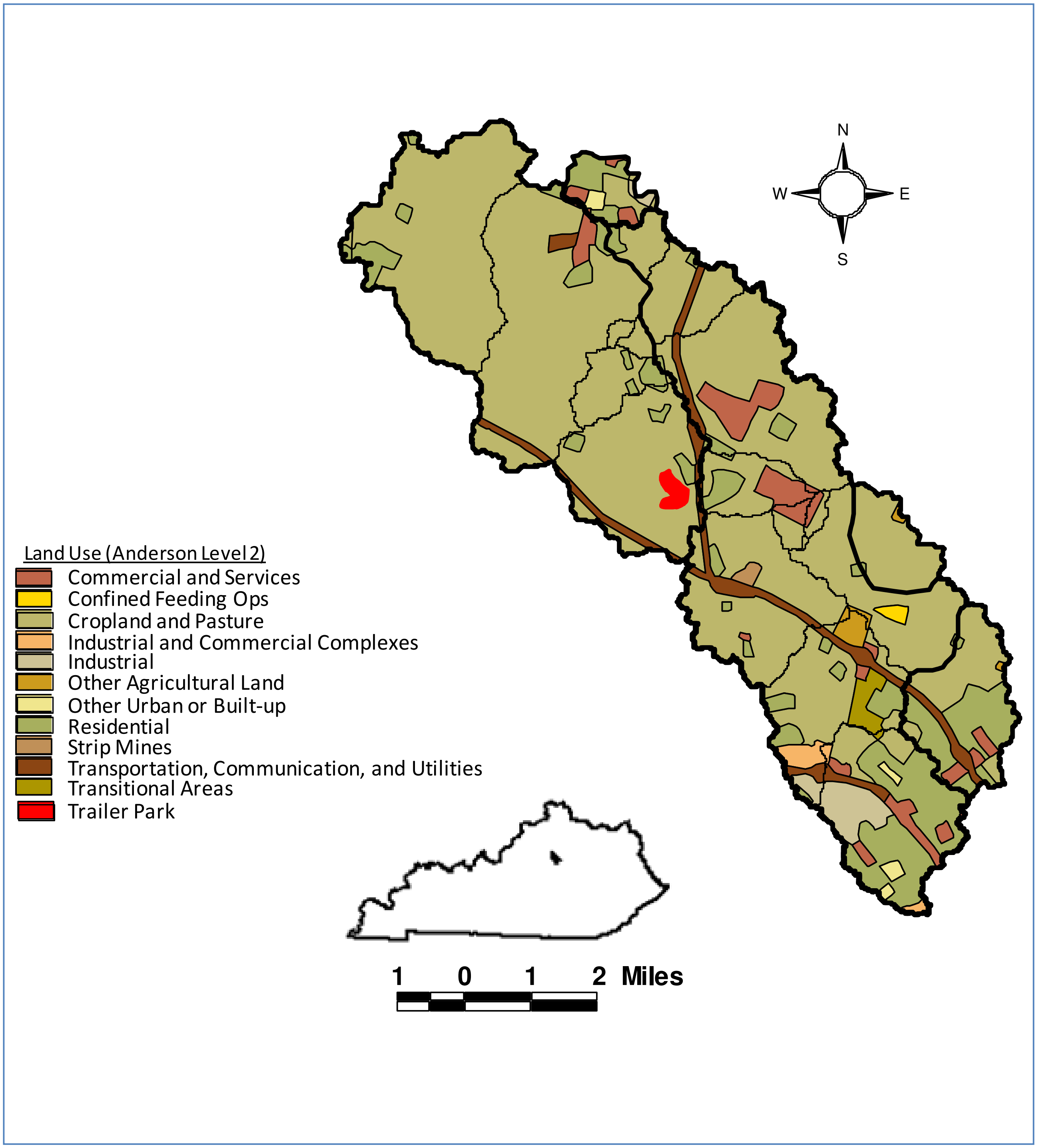

Figure 1.6 Anderson Level 2 Landcover Map of Cane Run Watershed

2.0 PROBLEM DEFINITION

Cane Run was listed as impaired for the Primary Contact Recreation (PCR) designated use due to pathogens on the Kentucky Division of Water's (KDOW's) 1998 303(d) list. The term 'pathogens' is a designation for pathogen indicators, which for the sake of brevity may be referred to simply as pathogens (KDOW, 2011b), or bacteria. Since that time, the listing was changed from pathogens to fecal coliform, and additional segments on the Cane Run mainstem have been added to subsequent 303(d) lists. Further, the UT of Cane Run at RM 6.13 was also listed as impaired for fecal coliform, initially in the 2002 303(d) list; see Table 2.1 for the listing history of these segments.

Table 2.1 Initial 303(d) Listings and Listing Changes in the Cane Run Watershed

Stream	Initial River Miles, 1998	2002 River Miles	2008 River Miles	2010 River Miles
Cane Run Creek	10.0 to 17.4	3.0 to 9.6	3.0 to 9.6	0.0 to 3.0
		9.6 to 17.4	9.6 to 17.4	3.0 to 9.6
				9.6 to 17.4
UT of Cane Run at 6.05	Not Listed	0.0 to 3.5	No change (but the RM now is 6.13)	No Change

Additional data submitted to KDOW after finalization of the 2010 303(d) list has resulted in the assessment of three more UTs as impaired for fecal coliform, see Section 2.2.4.1 for these data. Some of the streams in the watershed are also impaired for the Secondary Contact Recreation (SCR) designated use (KDOW, 2008, 2011a); the final list of all segments included in this TMDL document is shown in Table 2.2. Figure 2.1 shows these impaired stream segments.

Table 2.2 All Impaired Waterbodies Addressed in this TMDL Document

Waterbody and Segment (GNIS[(1)] Number)	Listing Year[(2)]	County	Support Status	Use Impairment(s)	Suspected Source(s)
Cane Run 0.0 to 3.0 (KY488799_01)	2010	Scott	PCR (Nonsupport), SCR (Partial Support)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Managed Pasture Grazing, Package Plant or Other Permitted Small Flows Discharges, Unspecified Urban Stormwater
Cane Run 3.0 to 9.6 (KY488799_02)	2002	Scott	PCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Package Plant or Other Permitted Small Flows Discharges
Cane Run 9.6 to 17.4 (KY488799_03)	1998	Fayette	PCR (Nonsupport), SCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Unspecified Urban Stormwater

Waterbody and Segment (GNIS[1] Number)	Listing Year[2]	County	Support Status	Use Impairment(s)	Suspected Source(s)
UT to Cane Run at RM 6.13 0.0 to 3.5 (KY488799-6.13_01)	2002	Scott	PCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations)
UT to Cane Run at RM 10.8 0.0 to 2.4 (KY488799-10.8_01)	N/A	Fayette	PCR (Nonsupport),	*E. coli*[3]	Livestock (Grazing or Feeding Operations)
UT to Cane Run at RM 12.9 0.0 to 2.1 (KY488799-12.9_01)	N/A	Fayette	PCR (Nonsupport),	*E. coli*[3]	Agriculture, Unspecified Urban Stormwater
UT to Cane Run at RM 15.6 0.0 to 0.9 (KY488799-15.6_01)	N/A	Fayette	PCR (Nonsupport),	*E. coli*[3]	Unspecified Urban Stormwater

(1) GNIS = Geographic Names Information System.

(2) Waterbodies with a Listing Year of N/A (i.e., 'Not Applicable') have not yet been listed on the 303(d); they were found to be impaired by sampling submitted with this study. This TMDL report constitutes the public notice required to list these waterbodies as impaired. Upon approval of this TMDL, they will be listed in Category 4A of Kentucky's Integrated Report, Approved TMDLs.

(3) Segments impaired for *E. coli* received allocations in terms of fecal coliform because the model was calibrated using fecal coliform data, and Kentucky has a dual standard for both fecal coliform and *E. coli* as shown in Section 2.1, thus development of TMDLs using the fecal coliform criterion are sufficient to provide TMDLs for *E. coli*-listed segments and vice versa.

2.1 Target Identification

The goal of the TMDL process is to achieve a numeric fecal coliform loading within the assimilative capacity of the impaired waterbody under study that allows it to meet its designated uses (i.e., PCR and in some cases SCR). KDOW currently uses fecal coliform and *Escherichia coli* (*E. coli*) as indicators of the likelihood of bacteria impairment. The PCR Water Quality Criteria are in effect from May 1 through October 31. For this designated use, 401 KAR 10:031 Section 7(1)(a) states that:

[The] Fecal coliform content or Escherichia coli content shall not exceed 200 colonies per 100 ml or 130 colonies per 100 ml respectively as a geometric mean based on not less than five (5) samples taken during a thirty (30) day period. Content also shall not exceed 400 colonies per 100 ml in twenty (20) percent or more of all samples taken during a thirty (30) day period for fecal coliform or 240 colonies per 100 ml for Escherichia coli. These limits shall be applicable during the recreation season of May 1 through October 31.

The geometric mean (GM, or geomean) of data series of n observations (i.e., y_1, y_2, y_3 …. y_n) is defined as:

$$GM = \sqrt[n]{y_1 . y_2 . y_3 ... y_n}$$

(Equation 1)

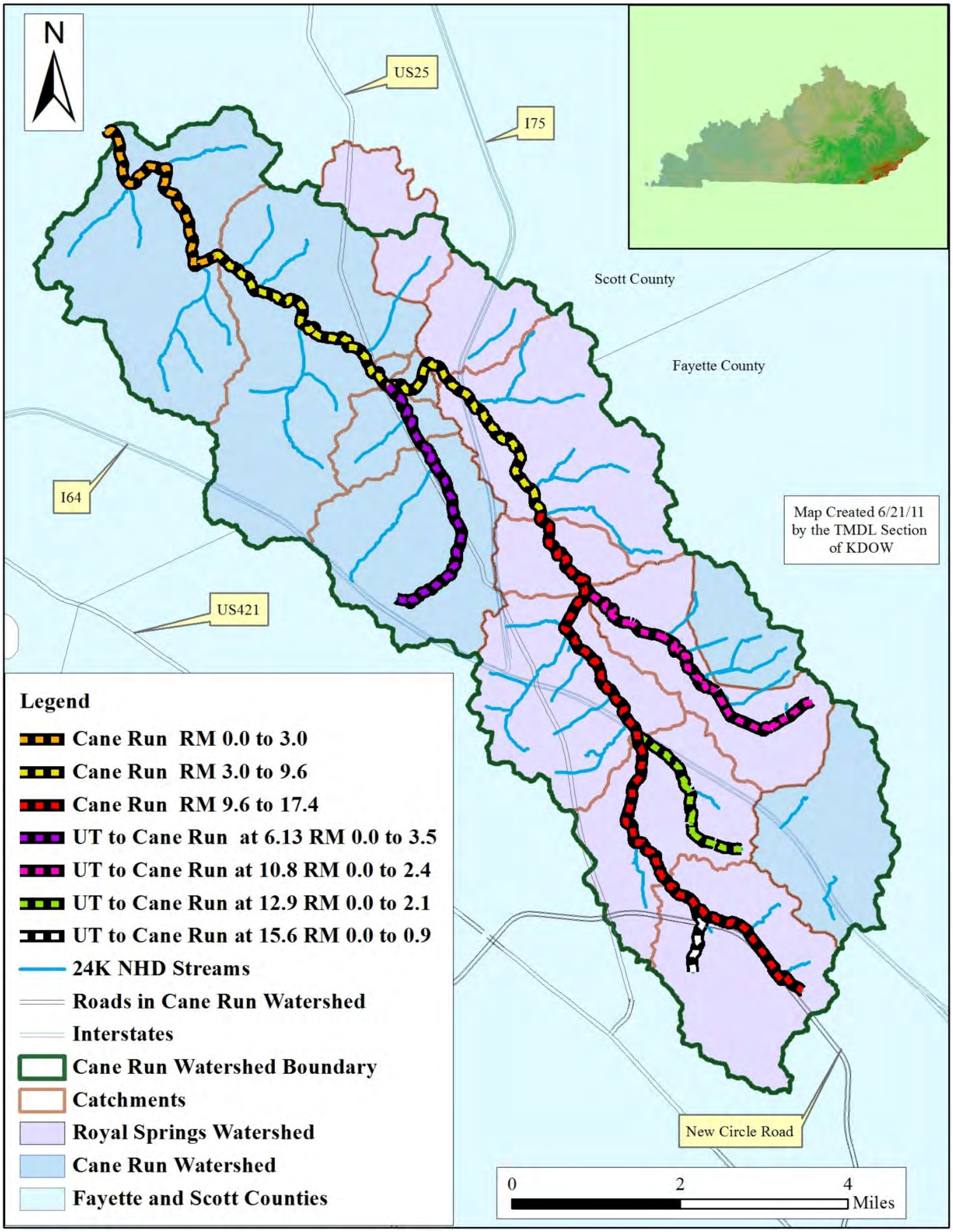

Figure 2.1 Cane Run Watershed Impaired Streams

Most segments were not analyzed for *E. coli*, and the model was created using fecal coliform to be consistent with the original sampling protocol, thus the fecal coliform WQC was used. The instream fecal coliform WQC for this TMDL is a geometric mean of 200 colonies/100ml (which also may be written as colony forming units, or cfu/100ml) which must be based on 5 or more samples taken within a 30-day period and a maximum of 400 colonies/100ml, which shall not be exceeded in 20% or more of all samples taken within a 30-day period.

SCR is protected for the entire year. 401 KAR 10:031 Section 7(2)(a) states:

Fecal coliform content shall not exceed 1000 colonies per 100 ml as a monthly geometric mean based on not less than five (5) samples per month; nor exceed 2000 colonies per 100 ml in twenty (20) percent or more of all samples taken during the month.

Because Kentucky has a dual standard for the PCR designated use, development of TMDLs using the *E. coli* criterion are sufficient to provide TMDLs for fecal coliform-listed segments and vice versa (i.e., development of fecal coliform TMDLs will protect the PCR use regardless of whether a segment is impaired for *E. coli*, fecal coliform, or both). Additionally, because the instantaneous limit is lower for PCR than for SCR (400 colonies/100ml versus 2000 colonies/100ml), development of TMDLs for the PCR season also protects waterbodies impaired for the SCR use due to fecal coliform. Likewise, Kentucky Pollutant Discharge Elimination System (KPDES) permit holders who are permitted to discharge bacteria into the surface waters of the Commonwealth may be given discharge limits in units of fecal coliform or *E. coli*, either of which protect the PCR use and allow the facility to meet the requirements of 401 KAR 10:031. After determining the TMDLs for each stream catchment and each impaired segment, load reductions were applied until all Cane Run streams met both the PCR (and thus the SCR) WQCs.

Royal Spring is the water supply source for the City of Georgetown. Public drinking water suppliers have Water System Numbers, the Georgetown Municipal Water and Sewer Service's (GMWSS's) number is KY1050157. Although fecal coliform bacteria are present in the upper part of the Cane Run watershed and thus are transported to Royal Spring, this report only addresses the PCR and SCR designated uses; in the context of 401 KAR 10:031, bacteria do not impair for the Drinking Water Supply (DWS) designated use. This is because bacteria are removed by drinking water facility treatments, and public drinking water suppliers are regulated under the Safe Drinking Water Act (SDWA). See http://water.ky.gov/DrinkingWater/Pages/default.aspx for a description of Kentucky's SDWA program. From this website, Georgetown's latest coliform/microbial sample results can be accessed for their water distribution system, http://dep.gateway.ky.gov/DWW/ (KDOW, 2011c). A search of this database on 11/19/11 showed no coliform bacteria indicated anywhere in the water supply system during the preceding two years.

2.2 Water Quality Assessment

2.2.1 USGS Streamflow Gaging Stations

There is one USGS streamflow gaging station located in the Cane Run watershed and two other USGS stations located nearby, one at Royal Spring and one on North Elkhorn Creek, as shown in Figure 1.3 (http://nwis.waterdata.usgs.gov/ky/nwis/); all three were used for flow analysis of Cane Run streams, see Table 2.3 for the duration of data collection at these gages.

Table 2.3 USGS Streamflow Gaging Stations

Station ID	Station Description	Duration
03288200	Cane Run near Donerail	1997 – 2012
03288110	Royal Spring, Georgetown	1997 - present
03288100	North Elkhorn, Georgetown	1992 - present

In addition, since GMWSS uses Royal Spring as a drinking water supply source for Georgetown, GMWSS keeps water withdrawal data on file with KDOW. Monthly and annual total withdrawal data are available in units of millions of gallons per day (mgd).

2.2.2 LFUCG Sampling

The Lexington Fayette Urban County Government (LFUCG, or Lexington) has been performing fecal coliform sampling in Cane Run in support of its KPDES storm water permit since 1993. LFUCG's sampling network includes five monitoring stations within the Cane Run watershed; see Table 2.4 and Figure 2.2.

Table 2.4 LFUCG Water Quality Monitoring Stations and Sampling Data, 1996 to 2003

Station ID	Latitude	Longitude	Station Description	Sampling Dates	Fecal Coliform Geometric Mean (colonies/ 100 ml)	Number of Samples
CR-L1	38.0781	-84.49809	Nandino Blvd	Dec-01 to Apr-02	4,240	9
CR-L2	38.0723	-84.46554	Silver Lane	Nov-01 to Dec-01	2,711	6
CR-S1	38.07949	-84.49192	Lexmark	May-96 to Jun-02	5,755	7
CR-S2	38.09183	-84.50142	Cold Stream Farm	May-96 to Oct-96	36,037	3
CR-S3	38.16897	-84.55482	US-25	May-98 to Nov-03	629	13

2.2.3 Georgetown Municipal Water and Sewer Service Sampling

GMWSS collected fecal coliform data at RM 6.0 of Cane Run from 2002 through 2005, see Table 2.5.

Table 2.5 Georgetown Municipal Water and Sewer Service Sampling Data at RM 6.0 of Cane Run, 2002 to 2005

Year	Annual Fecal Coliform Geomean (colonies/100 ml)
2002	237
2003	468
2004	no data
2005	75

2.2.4 University of Kentucky Sampling

The University of Kentucky (UK) has three separate departments that have sampled the Cane Run watershed for bacteria; sampling began in 2002 and continued intermittently until 2010.

2.2.4.1 Department of Biosystems and Agricultural Engineering Sampling

The UK Department of Biosystems and Agricultural Engineering (BAE) collected *E. coli* at 14 different monitoring sites from 2008 to 2010 (Tables 2.6, 2.7). As shown in Figure 2.3, all of the sites were located in the upper part of the watershed. The *E. coli* results associated with the BAE sites are provided in Appendix A2. Data from these sites was also used to assess three UTs (at RMs 10.8, 12.9 and 15.6) as impaired for bacteria for this report.

An estimate of the equivalent fecal coliform values may be obtained from the following relationship (Ormsbee and Akasapu, 2010):

$$E.\ coli = 1.44*(\text{Fecal Coliform})^{0.8093}$$

(Equation 2)

or

$$\text{Fecal Coliform} = (E.\ coli/1.44)^{(1/0.8093)}$$

(Equation 3)

The fecal coliform equivalencies for the collected *E. coli* data are shown in Table 2.8. These data were used to validate the model which was calibrated using the 2001-2002 Kentucky Water Resources Research Institute (KWRRI) dataset, see Section 2.2.4.2.

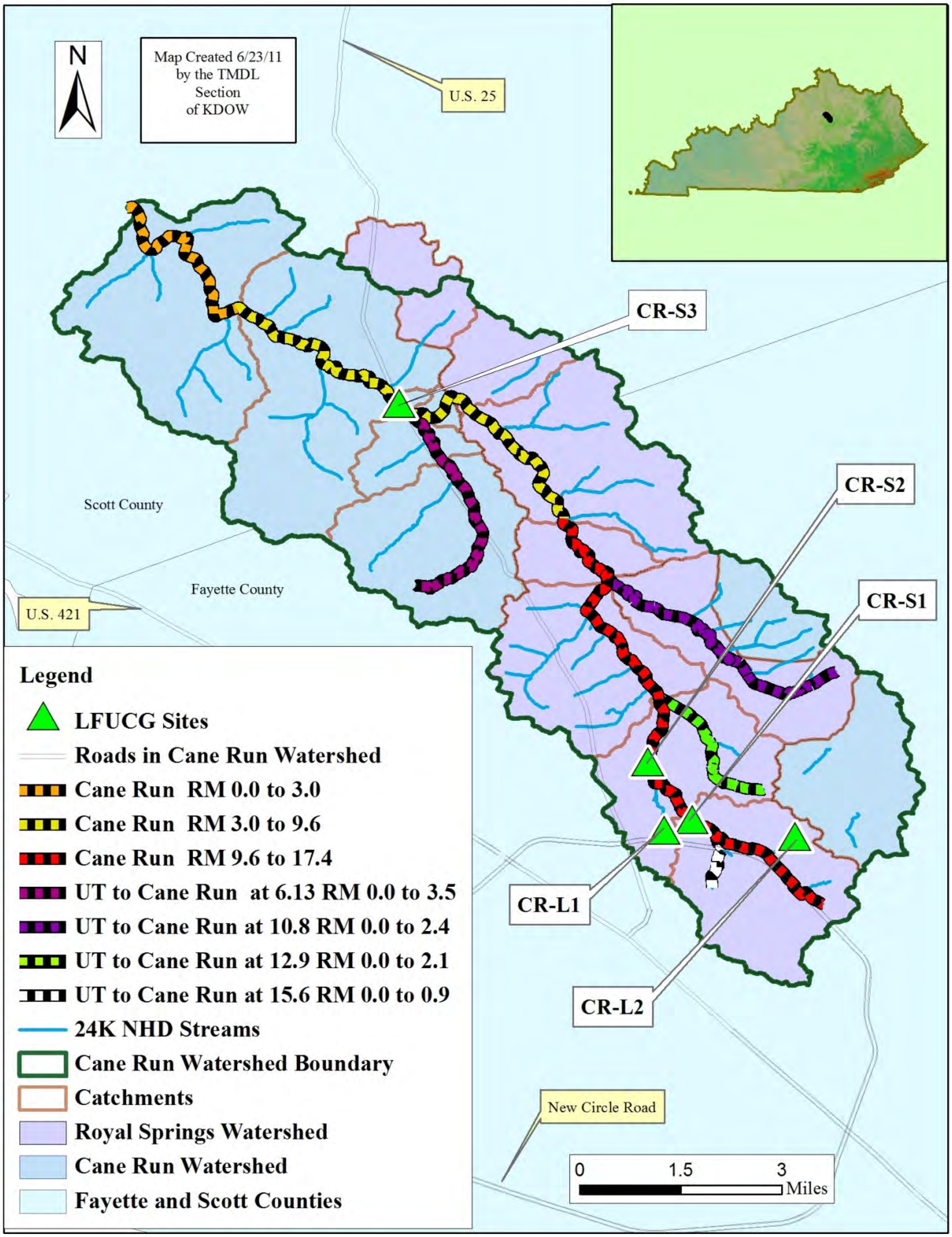

Figure 2.2 Location of LFUCG Monitoring Stations

Table 2.6 Biosystems and Agricultural Engineering Sampling Site Locations, 2008 to 2010

Longitude	Latitude	Description	Station ID
-84.486667	38.070317	Lexmark Main Campus - Left Branch	CR01
-84.491817	38.1015	Coldstream Research Park	CR05
-84.499083	38.105867	Upstream I-75	CR06
-84.497267	38.12345	UK Farm - Bridge Main Drive from Ironworks	CR08
-84.517033	38.1388	Berea Road	CR11
-84.538967	38.167117	Bridge at Lisle Road	CR12
-84.502905	38.09122	between Highland Park and Citation	CR04
-84.485661	38.11555	UK Farm - Downstream Newtown Pike, Fasig Tipton	CR07
-84.482233	38.073833	Lexmark Park West	CR02
-84.485212	38.075548	Lexmark Park below subdivision	CR14
-84.487429	38.064183	Loudon Ave	CR13
-84.492517	38.080083	Newtown Pike	CR03
-84.506541	38.128848	UK Farm below lake	CR09
-84.511883	38.128441	UK Farm Confluence	CR10

Table 2.7 Biosystems and Agricultural Engineering *E. coli* Sampling Data, 2008 to 2010

Station ID	Station Description	*E. Coli* Geomean (colonies/100 ml)	Number of Samples
CR01	Lexmark Park West	1,969	45
CR02	Lexmark Park East	4,728	20
CR03	Newtown Pike	2,438	24
CR04	Highlands	9,608	45
CR05	Coldstream Park	475	46
CR06	UK Farm South I-75	2,484	16
CR07	UK Farm below Fasig-Tipton	1,061	45
CR08	UK Farm	607	44
CR09	UK Farm below Lake	387	39
CR10	UK Farm above Confluence	835	10
CR11	Berea Road	498	13
CR12	Lisle Road	425	34
CR13	Loudon Avenue	10,552	34
CR14	Lexmark below Subdivision	1,395	17

Table 2.8 Biosystems and Agricultural Engineering Fecal Coliform Equivalents, 2008 to 2010

Station ID	Station Description	Fecal Coliform Geometric Mean (colonies/100 ml)	Number of Samples
CR01	Lexmark Park West	7,494	45
CR02	Lexmark Park East	22,124	20
CR03	Newtown Pike	9,759	24
CR04	Highlands	53,138	45
CR05	Coldstream Park	1,293	46
CR06	UK Farm South I-75	9,990	16
CR07	UK Farm below Fasig-Tipton	3,491	45
CR08	UK Farm	1,750	44
CR09	UK Farm below Lake	1,005	39
CR10	UK Farm above Confluence	2,598	10
CR11	Berea Road	1,370	13
CR12	Lisle Road	1,128	34
CR13	Loudon Avenue	59,665	34
CR14	Lexmark below Subdivision	4,895	17

2.2.4.2 KWRRI Sampling

KWRRI collected instream samples on a weekly basis from June through September of 2002 to determine the location and magnitude of potential pathogen sources. A list and description of the sites is provided in Table 2.9. A map of the sampled sites is provided in Figure 2.4. The pathogen results obtained are shown in Appendix A1. Histograms of the resultant geometric means for fecal coliform for all the stations are provided in Figures 2.5 through 2.7. No data were collected at site C2 because of the lack of any flow at the site during the study.

Table 2.9 UK-KWRRI Water Quality Monitoring Stations, 2002

Site	Latitude	Longitude	Stream	RM	Description	Number of Samples
C0	38.08066	-84.49257	Cane Run	15.1	Newtown Pike Road	10
C1	38.10572	-84.49857	Cane Run	12.9	I-75 bridge across Cane Run	10
C2	38.13857	-84.51704	Cane Run	9.9	Berea Road	10
C3	38.16736	-84.53901	Cane Run	7.2	Lisle Road at Cane Run Bridge	10
C4	38.1563	-84.5452	UT to Cane Run at 6.13	0.9	Lisle Road	10
C5	38.16877	-84.55481	Cane Run	5.9	Lexington Road	10
C6	38.20956	-84.61127	Cane Run	0.0	Paynes Depot Road	10
C7	38.18912	-84.58908	Cane Run	3.0	Frankfort Road	10

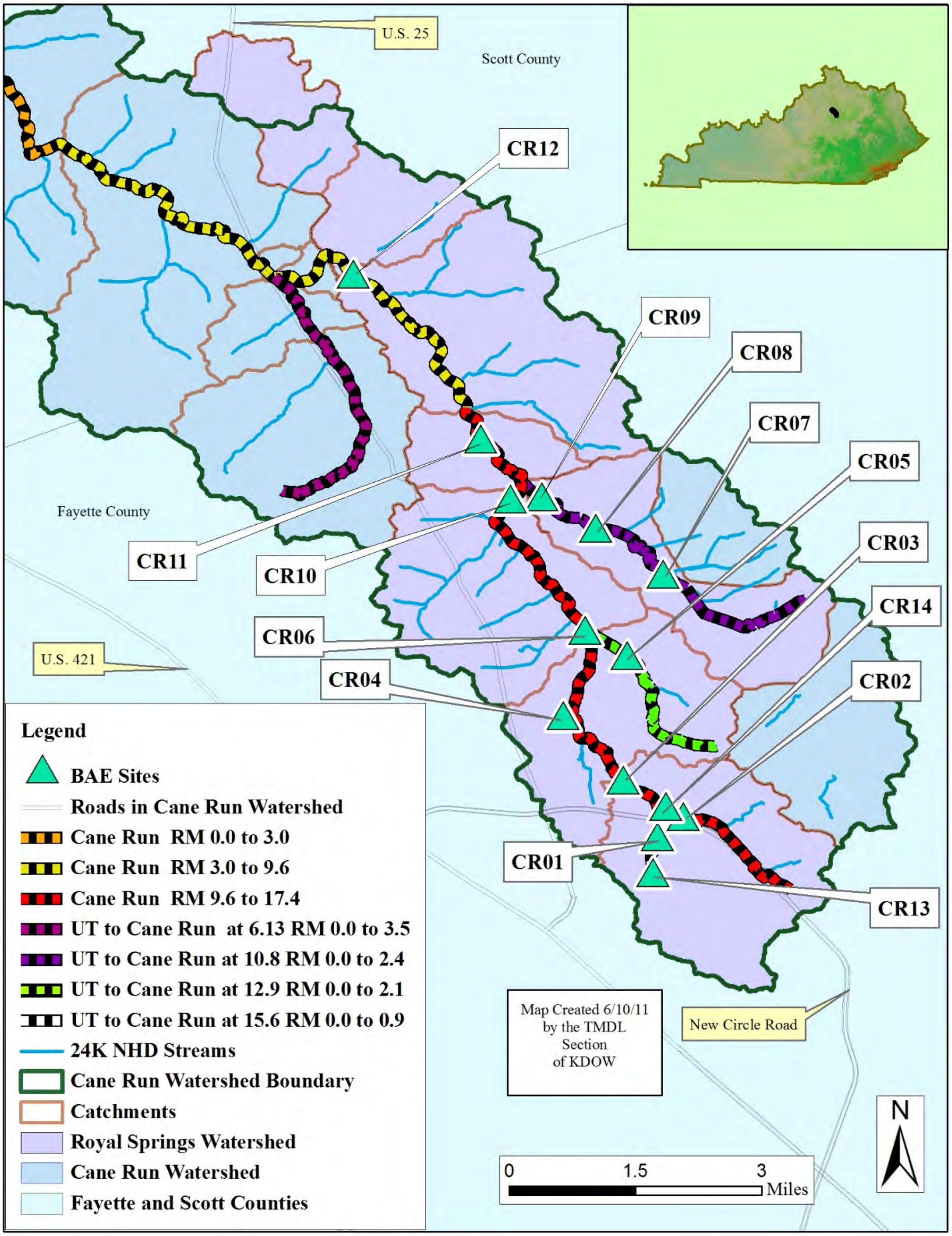

Figure 2.3 UK Biosystems and Agricultural Engineering Monitoring Stations

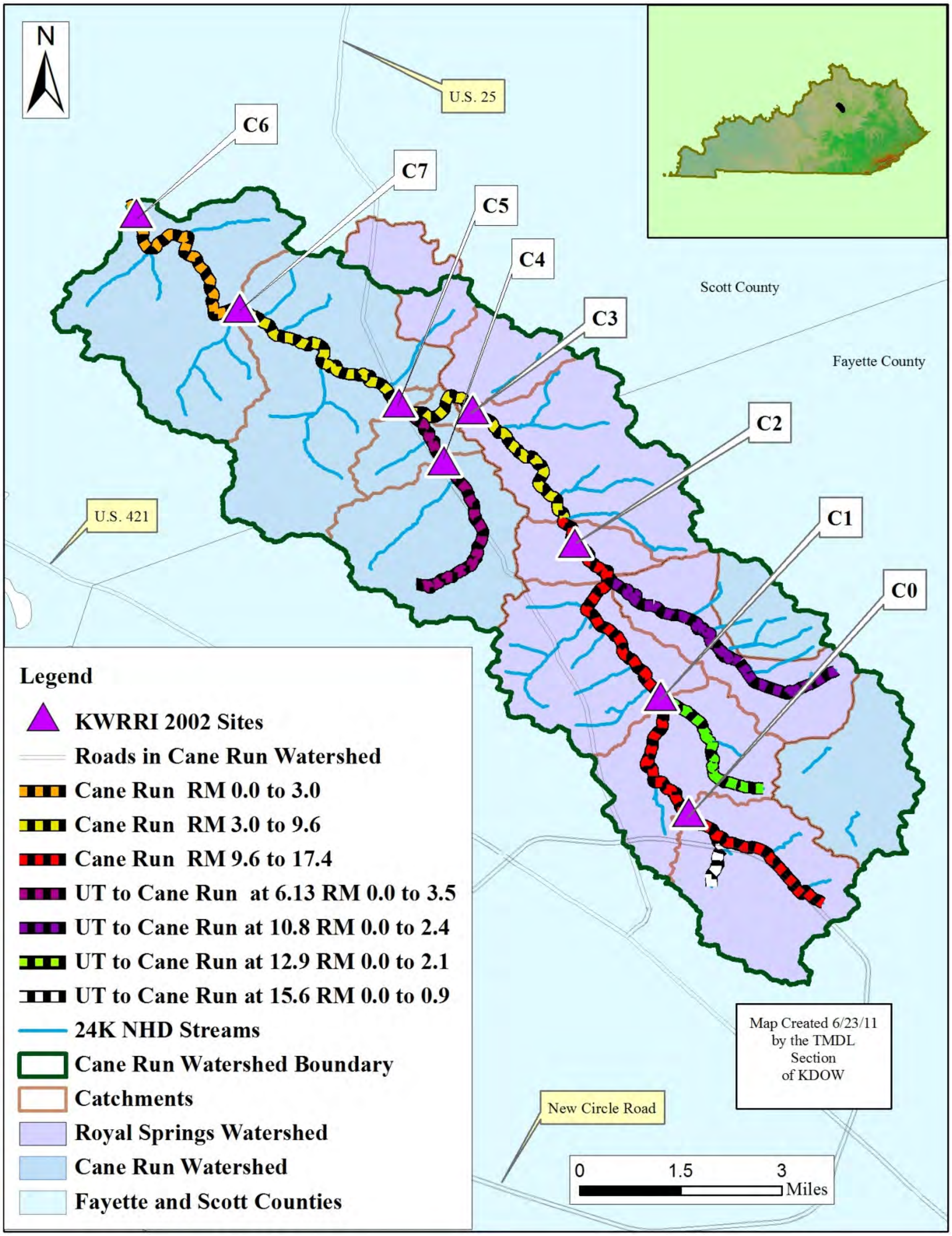

Figure 2.4 Cane Run Watershed KWRRI Sampling Sites

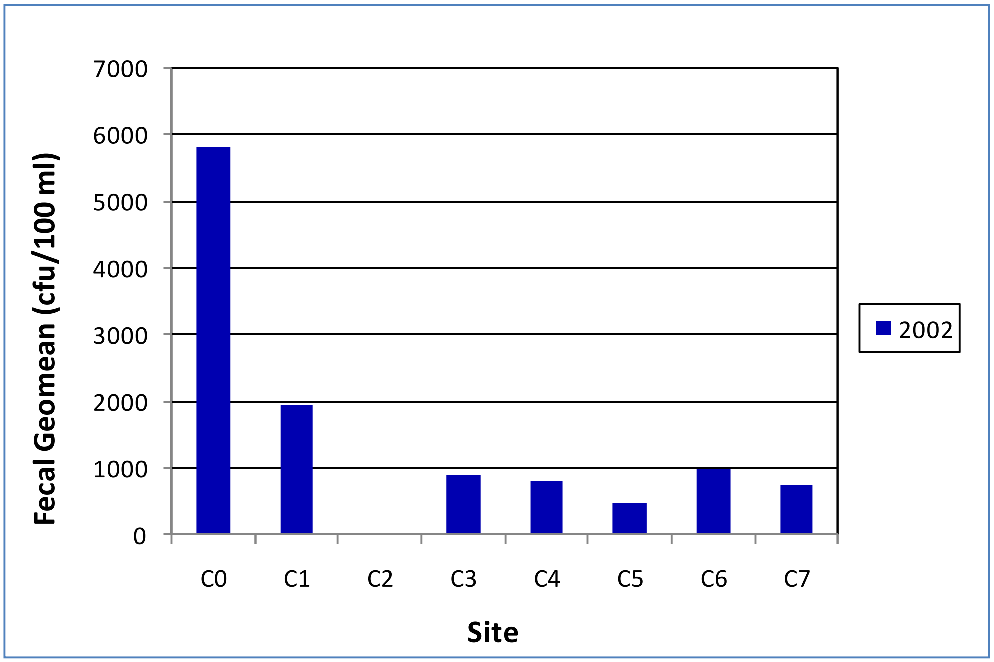

Figure 2.5 Fecal Coliform Geometric Means for Days Sampled in 2002, Cane Run

In an attempt to differentiate the likely source of the pathogen loads to Cane Run, the sample results were divided between wet and dry days. Based on a statistical analysis of historical rainfall and runoff data for the project area, wet days were characterized as days in which the sum of the current and previous two day rainfall totals were in excess of 0.3 inches. These results are shown in Figures 2.6 and 2.7. No data were available for site C2 on either wet or dry days (due to surface flow entering the subsurface), and no data were available at sites C0 and C1 on dry days. For sites with flow on both wet and dry days, the pathogen loads during wet events are significantly higher than during dry events.

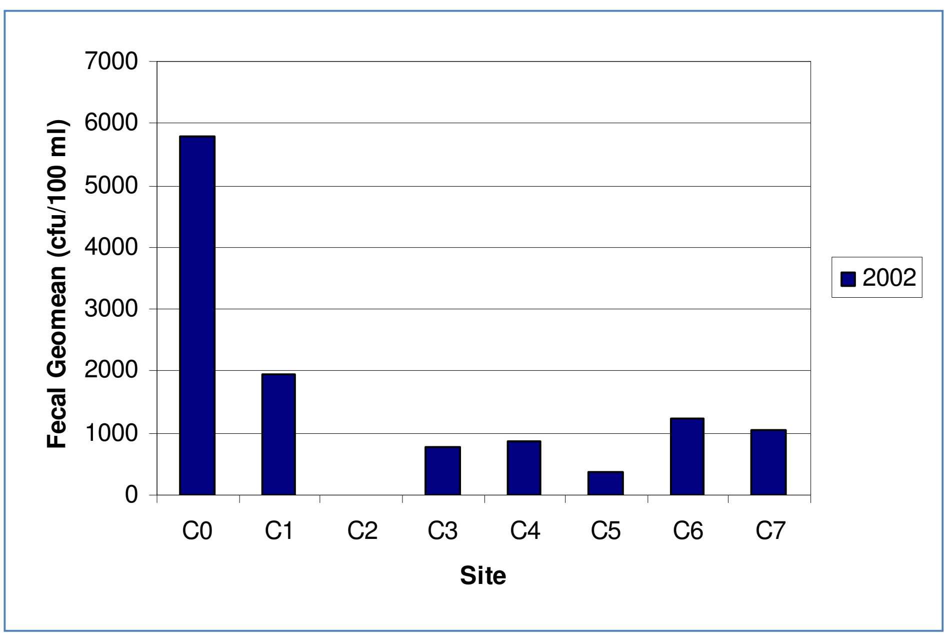

Figure 2.6 Fecal Coliform Geometric Means for Wet Days Sampled in 2002, Cane Run

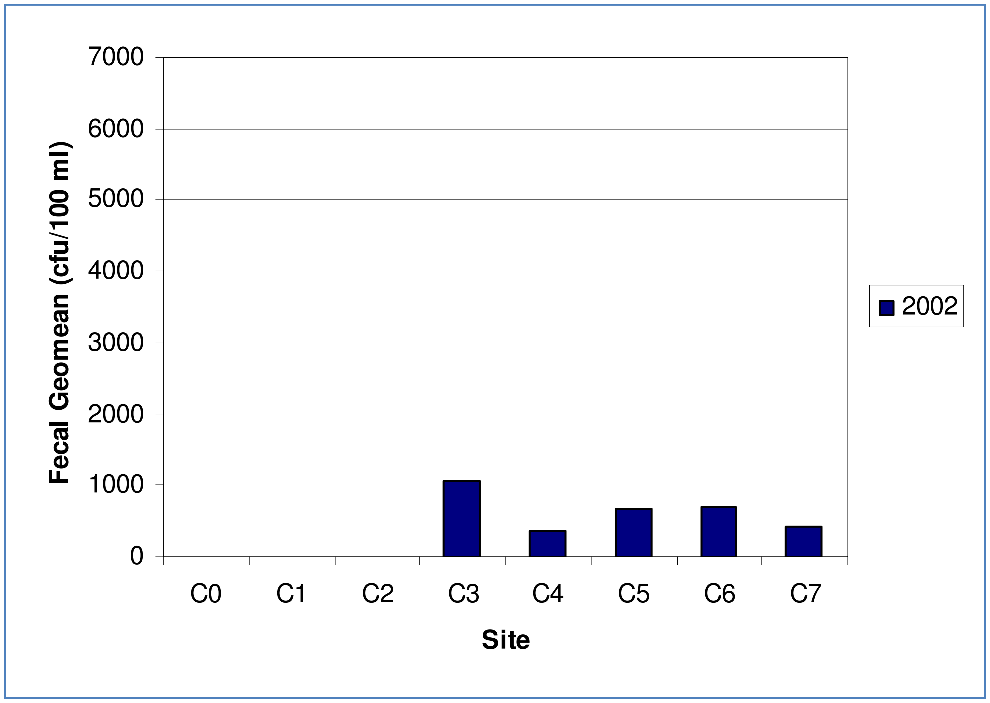

Figure 2.7 Fecal Coliform Geometric Means for Dry Days Sampled in 2002, Cane Run

2.2.4.3 ERTL Sampling

In 2005, the city of Georgetown contracted with Dr. Gail Brion at the UK Environmental Research Training Laboratory (ERTL) to conduct a study within the Cane Run watershed in an attempt to identify and rank potential sources of fecal contamination into the Royal Springs water supply (Brion, 2005). The study employed several different pathogen indicator species including total and atypical coliforms, *E. coli* and F+coliphage. Eight different sampling sites were established, see Table 2.10 and Figure 2.8, which shows the Royal Springs watershed, not the entire Cane Run watershed. Each site was sampled weekly during the period of March 2nd, 2005 to May 11th, 2005. The geometric means of the *E. coli* values for each site are shown in Table 2.9. Based on an analysis of the results, the study came to the following conclusions: 1) untreated sewage is entering surface water at the Highland Springs and IBM (now Lexmark) sites, and thus into the water supply for Georgetown, and; 2) there is an unknown source of human sewage in the spring system. Brion (2005) added that further study is required to identify the source or sources of the sewage so that a remediation plan can be developed.

Table 2.10 Brion Study Sampling Site Description and *E. coli* Geomeans

Site Name	Description	*E. coli* Geomean (colonies/100 ml)	Number of Samples
Highland Springs	A small creek which flows past an older subdivision north of the city of Lexington and into a swallet.	454	5
IBM (Lexmark)	A medium sized creek that has signs posted warning of potential human sewage contamination in urban Lexington.	243	5
Barton Springs	An agriculturally impacted stream that disappears into a large swallet found on the property of the Kentucky Horse Park near a large manure pile.	40	5
Newtown Exchange	A confluence of two streams influenced by urban runoff that flows under a bridge and disappears into a swallet.	20	5
Spindletop	A stream with swallets in the creek bottom located behind the UK Asphalt Research Facility and beside a pressurized sewer main, an area impacted by a variety of land uses.	20	5
Pristine Spring	A very small spring-swallet combination on the Kentucky Horse Park property that collects drainage from a flat agricultural pasture that quickly disappears into a swallet a few feet away.	13	5
Georgetown WTP	Inlet water from the spring coming into the water treatment plant.	30	5
Retention Pond	A water feature at the entrance to the Kentucky Horse Park.	18	5

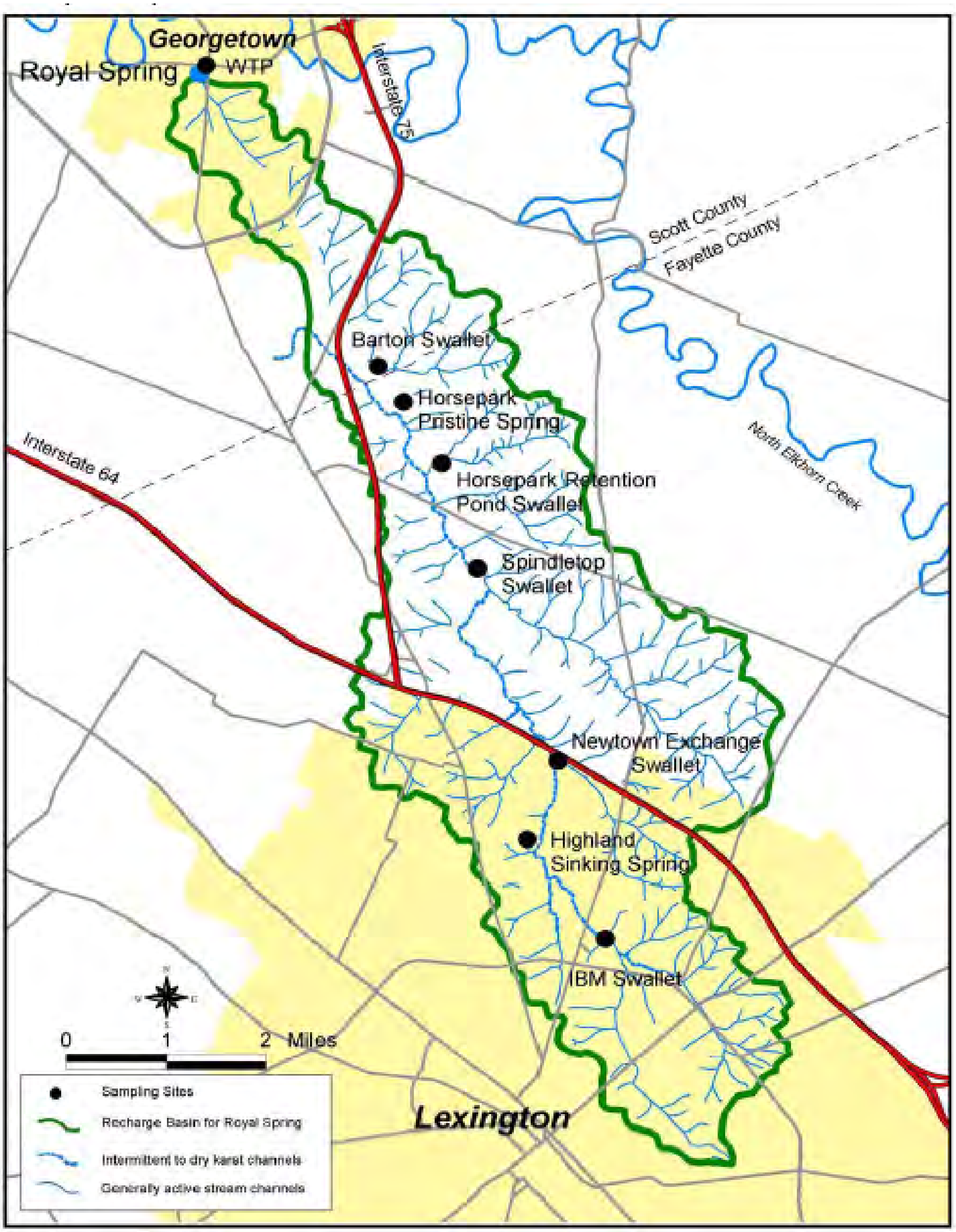

Figure 2.8 Cane Run Watershed Brion 2005 Sampling Sites

3.0 SOURCE ASSESSMENT

According to EPA (1991) the three components of the TMDL are the Wasteload Allocation (WLA), the Load Allocation (LA) and the MOS. The MOS is either an implicit or explicit portion of the TMDL that is reserved to account for any uncertainty in the relationship between effluent limitations and the water quality of the receiving waterbody, see Section 4.1 for further explanation. The sum of these allocations (including the MOS) may not result in an exceedance of the WQC(s) for that waterbody, see Section 4.2 for a discussion of the MOS. Therefore, any source which receives a final allocation must be accounted for within this framework. Existing pathogen sources for the impaired streams within the Cane Run watershed may be subdivided into four primary sources (future sources are discussed in Section 5.6.3 of the Modeling Report):

1) KPDES-permitted point sources, also known as Sanitary Wastewater Systems (SWSs), which are part of the WLA;
2) KPDES-Permitted Municipal Separate Storm Sewer System (MS4) sources (e.g., the developed areas within the boundary of any MS4 permit holder), which are part of the WLA;
3) Non-permitted illegal point sources (which receive no allocation), and;
4) Non-permitted nonpoint sources (i.e., nonpoint sources such as agriculture and non-developed areas within an MS4, and all lands outside an MS4 that are not accounted for above), which are part of the LA.

As stated, any sources from developed land within an MS4 permitted area were assigned to the WLA portion of the TMDL and any sources from non-developed land within an MS4 area were assigned to the LA portion of the TMDL. Illegal non-KPDES permitted nonpoint sources such as failing septic systems are also present in the watershed, but these were accounted for in number 3 above, illegal point sources, and receive an allocation of zero. The complete distribution of sources and their impact on the final TMDL for the impaired streams is shown in Figure 3.1.

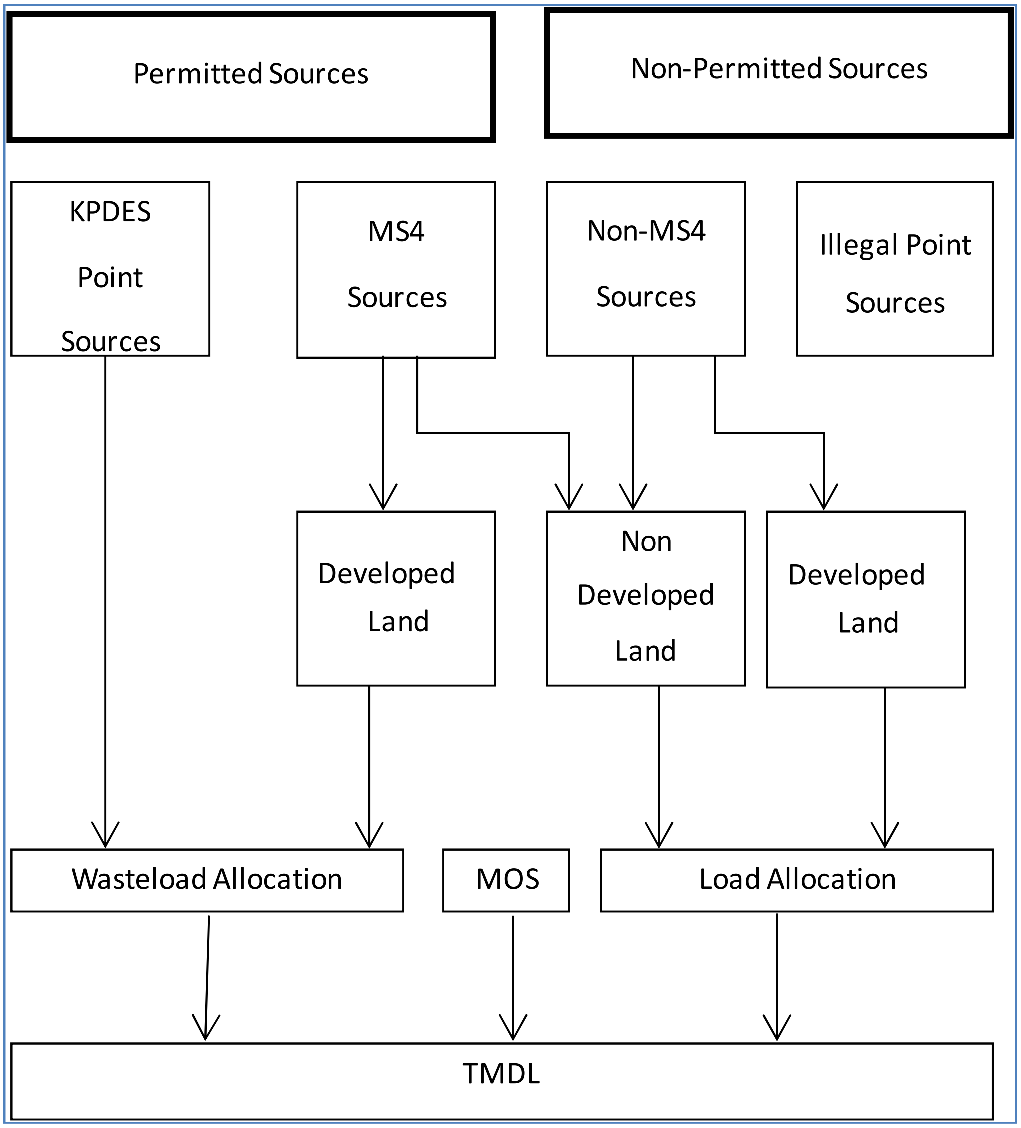

Figure 3.1 Source Assessment

3.1 Assessment of Point Sources

3.1.1 Sanitary Wastewater Systems

Sanitary Wastewater Systems (SWSs) include all facilities with a KPDES-permitted discharge limit for bacteria, including Wastewater Treatment Plants (WWTPs), Sewage Treatment Plants (STPs), package plants and home units. There are three active SWS facilities in the Cane Run watershed; all three are package plants treating influent from Mobile Home Parks (MHPs). Estimates of effluent loads were derived using the discharge permit limits, historical Discharge Monitoring Reports (DMRs, KDOW, 2003), and information on treatment type, see Table 3.1. However, for bacteria TMDLs, all SWSs are modeled at their permit limits for flow and bacteria concentration, see Section 5.2.1 of the Modeling Report. A map showing the relative locations of these facilities is provided in Figure 3.2. SWSs are also responsible for their collection systems: The locations of sanitary sewer lines and lift stations within the Cane Run watershed are shown in Figure 3.3 (KIA, 2010a, 2010b). The collection system within Fayette County serves the Town Branch WWTP (permit number KY0021491) and the collection system within Scott County serves the Georgetown STP (permit number KY0020150), neither of which have a surface water discharge to the Cane Run watershed, so they do not receive SWS-WLAs in this TMDL. Any discharge from their collection systems is an illegal source and thus receives an allocation of zero.

Table 3.1 Sanitary Wastewater Systems in the Cane Run Watershed

Facility	KPDES Permit	Receiving Waterbody	Design Discharge (mgd)	Permit Limit (Colonies/ 100ml)	2003 Historical Geomean (Colonies/100ml)
Spindletop MHP	0081213	UT to Cane Run at 6.13	0.030	200	75
Ponderosa MHP	0081221	UT to Cane Run at 6.13	0.016	200	10
Maple Grove MHP	0083321	UT to Cane Run at 6.13	0.029	200	21

Two of these facilities, Spindletop and Ponderosa, are currently in receivership with Franklin Circuit Court due to actions stemming from multiple violations of 401 KAR Chapter 5 during 2005, 2006, 2008 and 2011 (Agreed Order DOW-33003-039, Civil Action 09-CI-851). The court has appointed an Independent Administrator to bring these facilities back into compliance.

3.1.2 Non-Permitted (Illegal) Point Sources

Three different potential non-permitted point sources of fecal coliform Cane Run have been identified. By definition, all of these sources are illegal and will not be included in the final TMDL allocation. These are:

1. Failing Onsite Wastewater Treatments Systems (OWTSs, e.g., septic systems);
2. Straight pipes, and;
3. Sanitary Sewer Overflows (SSO)s.

3.1.2.1 Failing Onsite Wastewater Treatment Systems

OWTSs include those wastewater systems in which wastewater discharges from a house or commercial facility are processed through a biological treatment facility (e.g., septic tank) before the treated effluent is dispersed through a network of buried drainage pipes for subsequent infiltration and adsorption. Such systems can fail when the septic tank becomes full of solids, there is short-circuiting of the flow through the tank, or the field lines become clogged. Failure, malfunctioning of field lines and lack of maintenance may cause septic systems to release wastewater with high levels of fecal coliform into surface water and groundwater. EPA (2002a) states that properly functioning OWTSs can remove fecal coliform with an efficiency between 99% and 99.9%, after fecal coliform losses are accounted for in the soil column. Failing OWTSs are assumed to have a removal efficiency of zero.

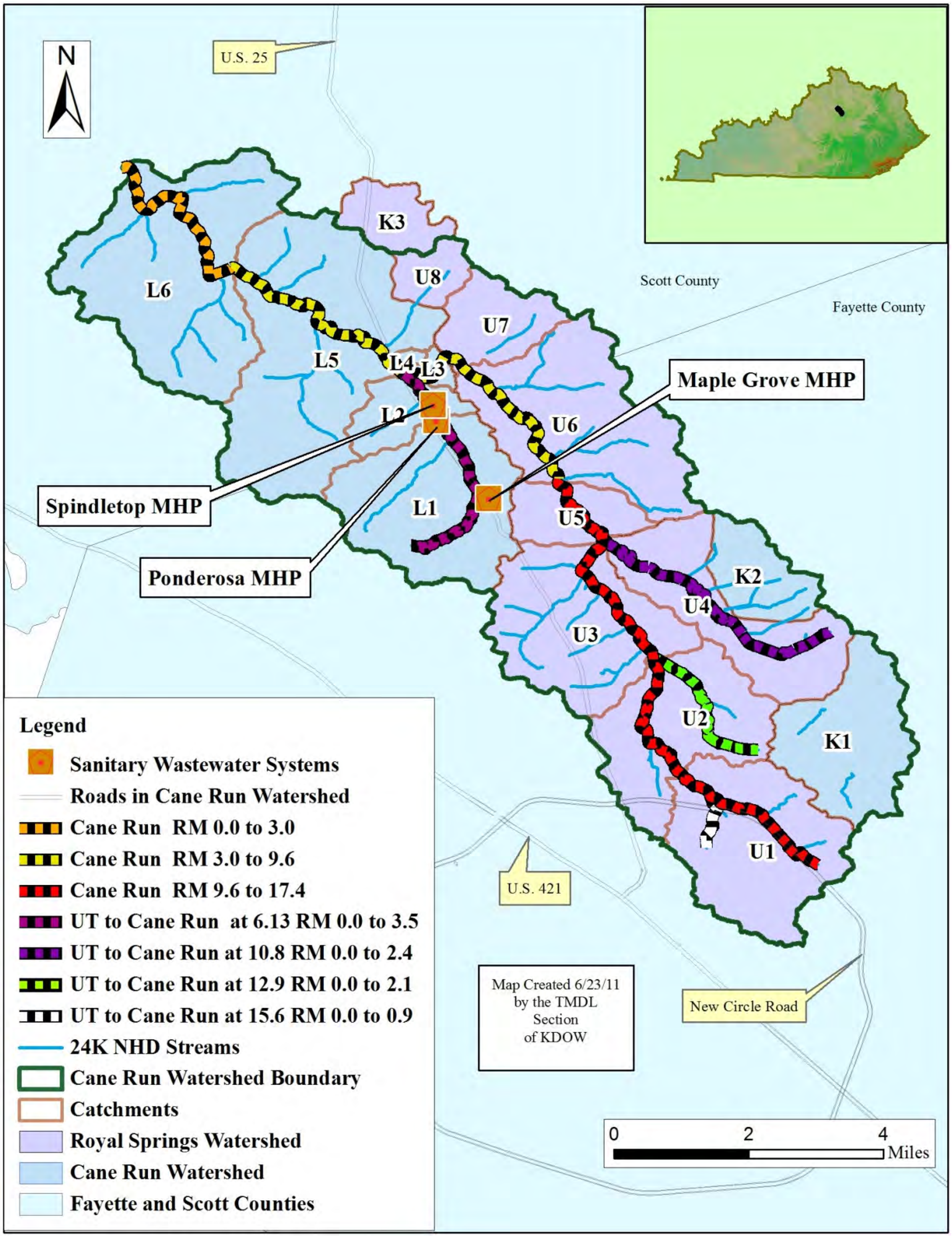

Figure 3.2 Map of Sanitary Wastewater Systems in the Cane Run Watershed

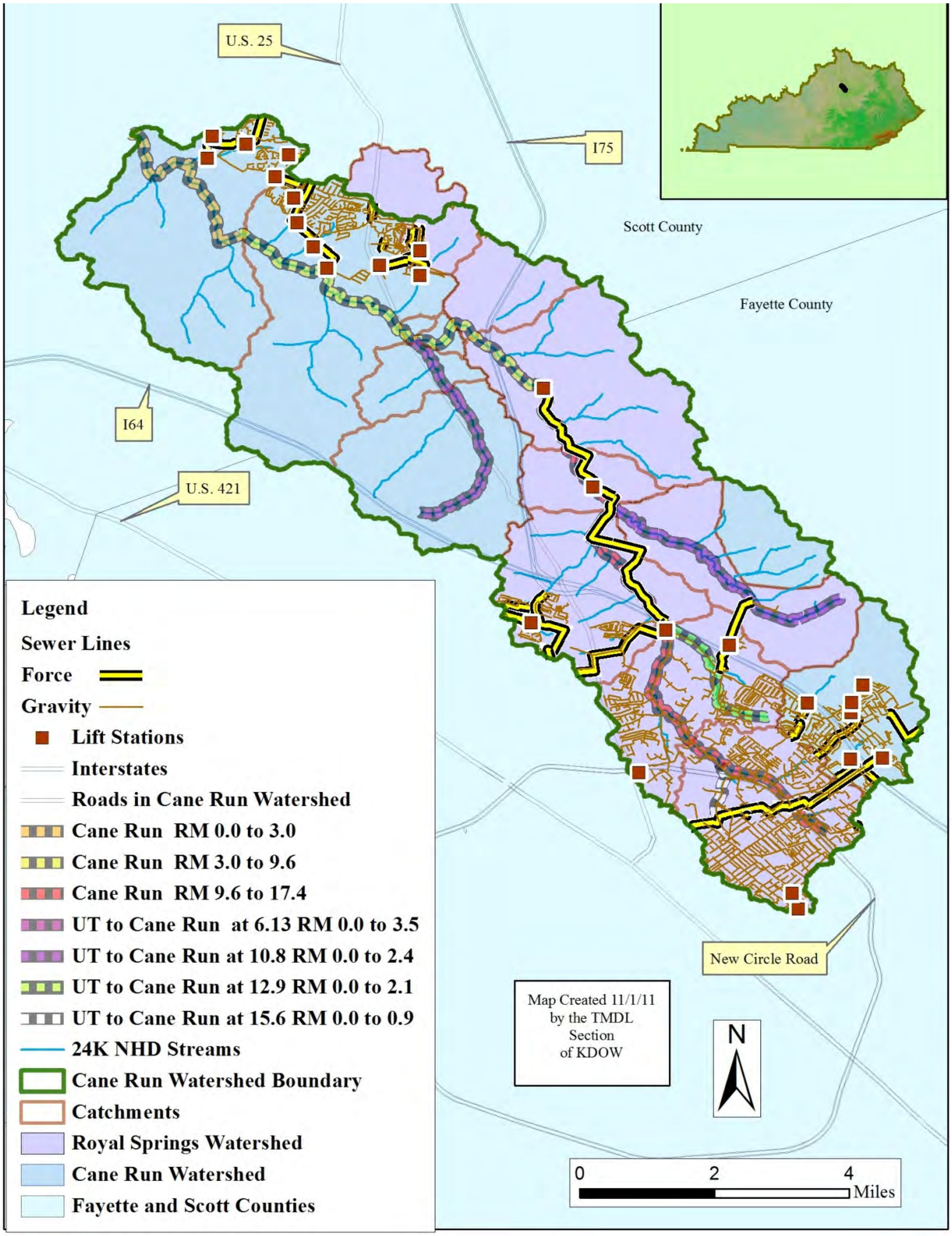

Figure 3.3 Map of Sanitary Sewer Lines and Lift Stations in the Cane Run Watershed

3.1.2.2 Straight Pipes

Straight pipes include those "wastewater systems" in which a pipe from a home or business is connected directly to a receiving waterbody. Based on a preliminary survey of the area and based on conversations with local health officials and county extension agents, some straight pipes are suspected to exist within the watershed that ultimately discharge into Cane Run, although the exact number and location are unknown. While straight pipes technically meet the definition of a point source as defined by 401 KAR 5:002, they are a non-permitted source for load allocation purposes within a TMDL, and receive an allocation of zero.

3.1.2.3 Sanitary Sewer Overflows

SWS dischargers are responsible for their wastewater collection system as well as the discharge from their outfalls. Sewage in the Fayette County part of the Cane Run watershed is typically collected by gravity systems and is then pumped via force mains into the adjacent Town Branch watershed where it flows to the Town Branch SWS (KY0021491). Georgetown pumps its sewage to The Georgetown STP #1 (KY0020150) outside of the Cane Run watershed (located on North Elkhorn Creek upstream of the Cane Run confluence). The locations of the major sanitary sewer lines and lift stations located within the Cane Run watershed are shown in Figure 3.3. Publically owned sanitary sewer infrastructure problems are known to exist in some of the subdivisions of north Lexington, including Green Acres/Hollow Creek (in Catchment U1), Highlands (in catchment U2) and Winburn (in catchment K1 and U2) (LFUCG Sewer System Assessments 2011). Many of these problems are attributable to the advanced age and deterioration of the system in these older neighborhoods. Age and deterioration negatively impact the public and private sanitary sewer systems equally so it can be assumed that the privately owned sanitary lateral lines in these areas are also compromised. LFUCG's past experience has found that many of the sanitary lateral lines in pre-1975 era neighborhoods such as these have laterals constructed of clay pipe or tarred cardboard tubing, which are easily compromised structurally and are often not maintained unless there is a service failure (blockage) that impacts the customer (personal communication, Charles Martin, 2013). SSOs also exist to a lesser extent in the Scott County portion of the Cane Run watershed, see Section 4.5.2.2 of the Modeling Report. Cross-connections, leaking sewer lines and SSOs are illegal sources and must be eliminated.

3.2 Nonpoint Sources

Nonpoint sources were assumed to include 1) wildlife, 2) livestock, 3) instream cattle, and 4) urban runoff from developed land. These four sources were assumed to occur both inside and outside MS4 areas. Only the load from urban runoff from developed land within the MS4 area is part of the WLA; all other sources are part of the LA. Descriptions of each of these sources are provided below.

3.2.1 Wildlife

The wildlife in the Cane Run watershed is represented by ducks, migratory geese, deer, beavers, and raccoons. These sources were explicitly modeled in non-developed areas, and implicitly modeled in developed areas; see Section 4.6.1 of the Modeling Report for details.

3.2.2 Livestock

The manure on pastureland deposited by livestock (grazing cattle, horses, etc.) is washed off and delivered to larger streams through intermittent streams, surface water flows, interflows, and groundwater flows. All grazing livestock were assumed to be pastured throughout the day within a watershed area. Grazing livestock deposit manure directly onto pastureland, which is carried to nearby streams and sinkholes by precipitation runoff. For the purposes of modeling, the fraction of the total daily fecal coliform load from livestock was aggregated and treated as a daily fecal coliform load for each watershed, which then experienced build-up during dry periods and subsequent runoff during wet periods.

When not grazing, animals may be confined to stalls or other confined spaces. In such instances, any generated manure or muck is typically collected into piles (which may or may not be effectively managed) or deposited in remote parts of a farm, sometimes in sinkholes. In some instances the associated manure may be used onsite as fertilizer. In recent years, a few horse farms in the Cane Run watershed have begun composting their horse muck prior to application as fertilizer (Oldfield, 2002).

3.2.3 Livestock Instream Sources

Cattle stand in streams to lose excess heat, especially when no shade is available; therefore instream fecal sources include direct deposition of manure from livestock. The land slopes, geographic terrain, and topography of the Cane Run watershed are such that cattle can access the intermittent streams that run through the pastureland.

3.2.4 Urban Runoff from Developed Land

Analysis using BASINS 3.1 shows approximately 24% of the total watershed landcover is developed. Developed land fecal coliform loading includes loadings from domestic animals and other sources (e.g., wildlife in the urban environment).

Although runoff from developed land was modeled as a nonpoint source, the loading to the streams needed to be divided between MS4 areas and non-MS4 areas, as loading from developed MS4 areas belongs in the WLA, and loading from developed non-MS4 areas belongs in the LA. MS4s are KPDES-permitted sources which are defined in 401 KAR 5:002. EPA has categorized MS4s into three categories: small, medium, and large. The medium and large categories are regulated under the Phase I Storm Water program. Large systems, such as the cities of Lexington and Louisville, have populations in excess of 250,000. Medium systems have populations in excess of 100,000 but less than 250,000; however, there are currently no medium-sized systems in Kentucky. Phase I systems have five-year permitting cycles and have annual reporting requirements. The small MS4 category includes all MS4s not covered under Phase I. Since this category covers a large number of systems, only a select group are regulated under the Phase II rule, either being automatically included based on population (i.e., having a total population over 10,000 or a population per square mile in excess of 1000) or on a case-by-case basis due to the potential to cause adverse impact on surface water. Water quality monitoring is not a requirement of Phase II MS4s, unless the waterbody has an approved TMDL and the MS4 causes or contributes to the impairment for which the TMDL was written. A WLA is assigned to all MS4 permit holders, which can include cities, counties, the Kentucky Transportation Cabinet (KYTC), universities and military bases.

In the Cane Run watershed, there are three MS4 permit holders: The City of Lexington (Permit Number KYS000002), Georgetown (Permit Number KYG200040) and KYTC (Permit Number KYS000003). The current boundaries of the MS4s in the Cane Run watershed are shown in Figure 3.4. KYTC does not have boundaries shown because it is responsible for the roads and right-of-ways it owns within the boundaries of other MS4 permittees. The University of Kentucky is not a MS4 permit holder in the Cane Run watershed: While UK and owns property within the Cane Run watershed, an area called the North Farm, UK's permitted MS4 boundary does not include the North Farm since it is an agricultural facitlity; instead the permit applies to the downtown campus area only, which is not located within the Cane Run watershed. The procedure for allocating loads to MS4 and LA sources for the impaired streams is described in Section 4.1. For a list of storm water improvements made by the various MS4 permit holders, see Section 5.0

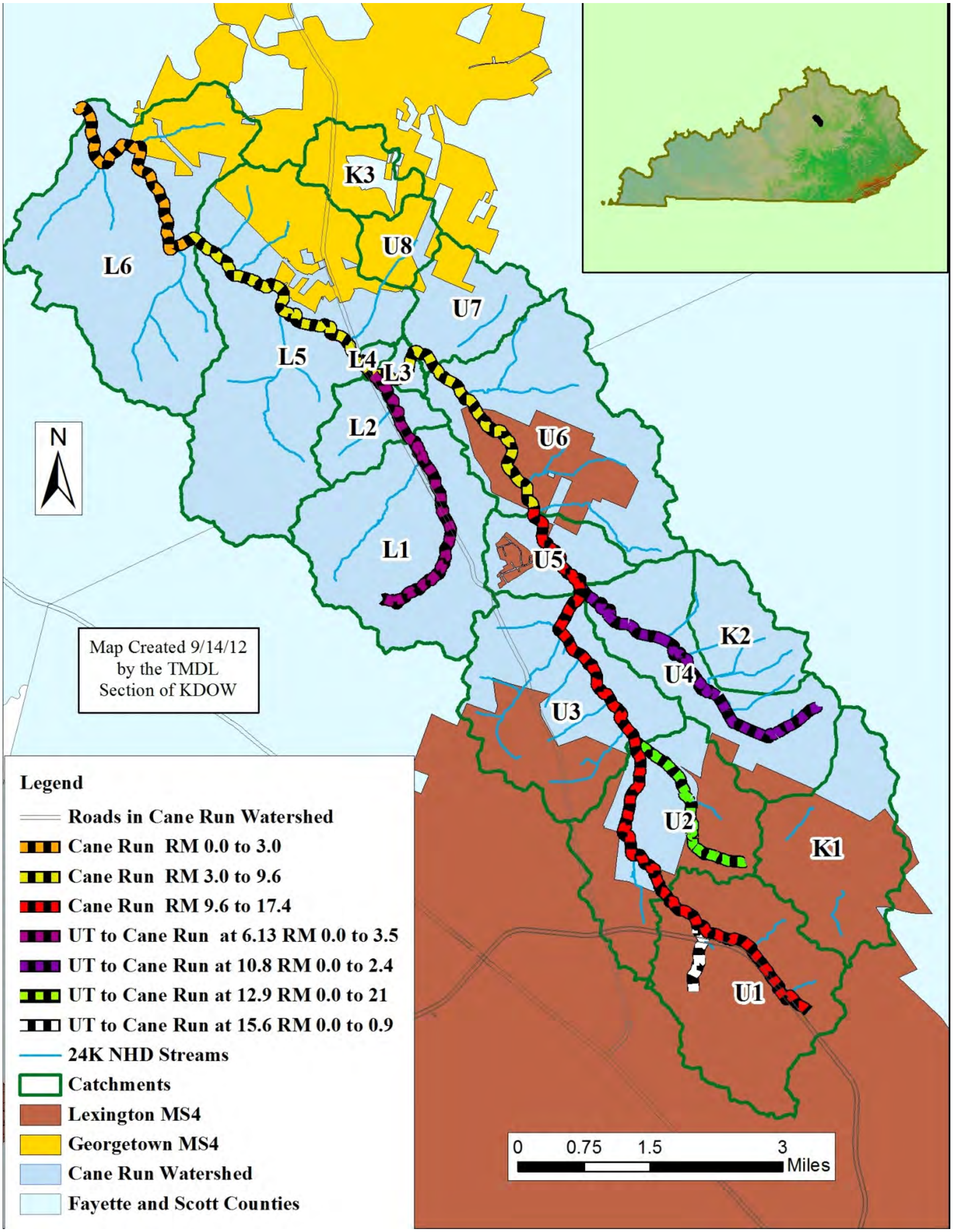

Figure 3.4 Current MS4 Boundaries in the Cane Run Watershed

4.0 TMDL ALLOCATIONS

TMDL definitions are presented in Section 4.1, the MOS in 4.2, and final TMDL tables are presented in Sections 4.3 and 4.4.

4.1 TMDL Definitions

According to EPA (1991), a TMDL calculation is performed as follows:

$$TMDL = WLA + LA + MOS$$
(Equation 4)

The WLA has three components:

$$WLA = SWS\text{-}WLA + MS4\text{-}WLA + Future\ Growth\text{-}WLA$$
(Equation 5)

Definitions:
TMDL: the WQC, expressed as a load.
MOS: the Margin of Safety, which can be an implicit or explicit additional reduction applied to sources of pollutants that accounts for uncertainties in the relationship between effluent limits and water quality. For this report, the MOS is implicit.
TMDL Target: the TMDL minus the MOS.
WLA: the Wasteload Allocation, which is the allowable loading of pollutants into the stream from KPDES-permitted sources, such as SWSs and MS4s.
SWS-WLA: the WLA for KPDES-permitted sources which have discharge limits for pathogen indicators (including wastewater treatment plants, package plants and home units).
Future Growth-WLA: the allowable loading for future KPDES-permitted sources, including new SWSs, expansion of existing SWSs, new storm water sources, and growth of existing storm water sources (such as MS4s). Also includes the allocation for KPDES-permitted sources that existed but were not known at the time the TMDL was written.
Remainder: the TMDL minus the MOS and minus the SWS-WLA (also equal to Future Growth-WLA plus the MS4-WLA and the LA).
MS4-WLA: the WLA for KPDES-permitted MS4s; MS4 permittees can include cities, counties, roads and right-of-ways owned by the Kentucky Transportation Cabinet (KYTC), universities and military bases.
LA: the Load Allocation, which is the allowable loading of pollutants into the stream from sources not permitted by KPDES and from natural background.
Seasonality: yearly factors that affect the relationship between pollutant inputs and the ability of the stream to meet its designated uses.
Critical Condition: the time period when the pollutant conditions are expected to be at their worst.
Critical Flow: the flow(s) used to calculate the TMDL as a load.
Existing Conditions: the load that exists in the watershed at the time of TMDL development (i.e., sampling) and is causing the impairment.
Load: concentration * flow * conversion factor.
Concentration: colonies per 100 milliliters (colonies/100ml).
Flow (i.e., stream discharge): cubic feet per second (cfs).

Conversion Factor: the value that converts the product of concentration and flow to load (in units of colonies per day); it is derived from the calculation of the following components: (28.31685L/ft^3 * 86400seconds/day * 1000ml/L)/(100ml) and is equal to 24,465,758.4.

Calculation Procedure:

1) The MOS, if an explicit value, is calculated and subtracted from the TMDL first, giving the TMDL Target;
2) The SWS-WLA is calculated and subtracted from the TMDL Target, leaving the Remainder;
3) The Future Growth-WLA is calculated and subtracted from the Remainder;
4) If there is a MS4 present upstream of the impaired segment, the MS4-WLA is subtracted from the Remainder based on percent land use, leaving the LA.

See the Modeling Report for descriptions of the above calculations. The remainder of this Section presents the results of those calculations.

4.2 Margin of Safety

An implicit MOS was incorporated into the modeling effort by imposing a slightly positive bias in the model's water quality calibration, including overestimating the contribution of both point- and nonpoint sources. This provides an implicit MOS approximately equal to 10%, see Appendices D and E for graphical representations.

4.3 Sanitary Wastewater System WLAs

There are three permitted SWSs in the Cane Run watershed. Since these facilities are permitted to operate at or below the WQC, no reduction is necessary for these sources. The SWS-WLAs for these facilities are summarized in Table 4.1.

Table 4.1 Sanitary Wastewater System WLAs

Facility	KPDES Permit	Design Discharge (mgd$^{(1)}$)	Waterbody	Wasteload Allocation (colonies/day)
Spindletop MHP	KY0081213	0.030	UT to Cane Run at 6.13	2.27E+08
Ponderosa MHP	KY0081221	0.016	UT to Cane Run at 6.13	1.21E+08
Maple Grove MHP	KY0083321	0.029	UT to Cane Run at 6.13	2.20E+08

(1) mgd = millions of gallons per day.

4.4 TMDL Summary

Table 4.2 represents the final TMDL allocations for all modeled sources in the Cane Run watershed. See the Modeling Report for additional discussion on TMDL calculations.

Table 4.2 Final TMDL Allocations

Subwatershed	TMDL (fecal coliform colonies/ day) (1)	SWS-WLA (fecal coliform colonies/ day) (2)	MS4 Permittee	MS4-WLA (fecal coliform colonies/ day) (3)	Future Growth-WLA (fecal coliform colonies/ day)	LA (fecal coliform colonies/ day)
Cane Run 0.0 to 3.0	2.17E+12	0	Georgetown/ KYTC	2.83E+08	4.35E+10	2.12E+12
Cane Run 3.0 to 9.6	4.91E+12	0	Lexington/ Georgetown/ KYTC	1.98E+09	1.48E+11	4.76E+12
UT(4) to Cane Run at 6.13 RM(5) 0.0 to 3.5	1.36E+12	5.68E+08	None	0.00E+00	4.08E+10	1.32E+12
Cane Run 9.6 to 17.4	2.23E+12	0	Lexington/ KYTC	1.29E+10	1.11E+11	2.10E+12
UT to Cane Run at 10.8 RM 0.0 to 2.4	1.19E+12	0	Lexington/ KYTC	6.43E+07	2.38E+10	1.17E+12
UT to Cane Run at 12.9 RM 0.0 to 2.1	4.79E+11	0	Lexington/ KYTC	1.58E+09	2.40E+10	4.53E+11
UT to Cane Run at 15.6 RM 0.0 to 0.9	1.40E+11	0	Lexington/ KYTC	7.01E+09	7.00E+09	1.26E+11

(1) In the event that compliance with the WQC is determined using *E. coli* concentrations as opposed to fecal coliform concentrations, the final fecal coliform allocations can be converted to *E. coli* by multiplying by the figure (240/400) for instantaneous values, or by the figure (130/200) for the 30-day geometric mean value, assuming 5 or more samples are taken within a 30-day period. Note that these relationships only demonstrate how to convert the TMDL allocations from terms of fecal coliform to terms of *E. coli* based on the relationship between the fecal coliform WQC and the *E. coli* WQC: The actual relationship between fecal coliform and *E. coli* instream has been defined in Section 2.2.4.1 of the Modeling Report based on sampling data. However, the relationship given in Section 2.2.4.1 of the Modeling Report is an estimate, and will not be used to convert *E. coli* to fecal coliform (or vice versa) to demonstrate compliance.

The TMDL is defined as the sum of the Wasteload Allocations (WLAs), Load Allocations (LAs) and a Margin of Safety (MOS, which in this case is implicit). However, sources of bacteria change over time, and the output of existing sources changes with time. Allocation shifts can be made between the sources within the WLA, and between sources within the LA after the TMDL is approved, but not between the LA and WLA without TMDL revision, public notice and EPA approval.

(2) WLAs for the Sanitary Wastewater Systems (SWSs, e.g., Wastewater Treatment Plants (WWTPs)) discharging to a listed segment are equal to their permit limit times their design flow. These values were derived using the fecal coliform Water Quality Criterion (WQC) of 200 colonies/100ml calculated as a geometric mean using 5 or more samples collected within a 30-day period so the allocated load is in units of colonies/day. See Table S.4 for allocations for individual SWSs. According to 401 KAR 10:031, individual SWSs may be permitted to discharge either fecal coliform or *E. coli;* currently all SWSs in the Cane Run watershed are permitted in terms of *E. coli*. However, the SWSs were modeled as discharging fecal coliform so their output was consistent with the monitoring protocol used to develop the TMDL.

Although Concentrated Animal Feeding Operations (CAFOs) receive their allocations within the WLA, there are no permitted CAFOs present in the watershed. Any future CAFO cannot legally discharge to surface water, and therefore receives a WLA of zero. The only exception is holders of a CAFO Individual Permit can discharge during a 25-year or greater storm event.

(3) Municipal Separate Storm Sewer Systems (MS4s) receiving aggregated MS4-WLAs include the City of Lexington (Permit Number KYS000002), the City of Georgetown (Permit Number KYG200040) and the Kentucky Transportation Cabinet (KYTC, Permit Number KYS000003).

(4) UT = Unnamed Tributary.

(5) RM = River Mile.

5.0 IMPLEMENTATION

Section 303(e) of the CWA and 40 CFR Part 130, Section 130.5, require states to have a Continuing Planning Process (CPP) composed of several parts specified in the Act and the regulation. The CPP provides an outline of agency programs and the available authority to address water issues. Under the CPP umbrella, the Watershed Management Branch (WMB) of KDOW will provide technical support and leadership with developing and implementing watershed plans to address water quality and quantity problems and threats. Developing watershed plans enables more effective targeting of limited restoration funds and resources, thus improving environmental benefit, protection and recovery. Pollutant trading may be a viable management strategy to consider for meeting the TMDL load reduction goals. In addition, several organizations that are already active in the watershed are listed below, including Non-Governmental Organizations (NGOs), governments and UK.

5.1 Non-Governmental Organizations

5.1.1 Bluegrass PRIDE

In addition to management activities associated with the local governments in each of the impacted counties, TMDL implementation in the region, especially associated with nonpoint source issues, may be facilitated by Bluegrass Personal Responsibility in a Desirable Environment (PRIDE). Bluegrass PRIDE was established in the fall of 2001 to monitor the status of water quality in the Bluegrass Region of Central Kentucky and provide funding and programs to help improve the quality of life of its citizens as well as the quality of the environment. More information about Bluegrass PRIDE can be found at http://www.kentuckypride.com/.

5.1.2 Kentucky River Watershed Watch

Kentucky River Watershed Watch (KRWW) performs annual volunteer sampling throughout the Kentucky River Basin, including Cane Run. See Appendix F for KRWW sampling locations in the Cane Run watershed and bacteria monitoring data. More information about KRWW can be found at http://www.uky.edu/OtherOrgs/KRWW.

5.1.3 Friends of Cane Run Inc.

Friends of Cane Run, Inc. (FOCR) was organized as a non-profit educational group in the spring of 2007 to promote sound water resource management practices and conservation; promote an interest in, and a study of the streams, rivers, lakes and other water resources of the central Kentucky area; collect scientific information regarding water quality; and disseminate information regarding water resources and water quality. The group conducts focused water quality sampling in the Cane Run watershed and is currently exploring ways to characterize and improve the water quality in the watershed. More information is available at http://kywater.net/canerun.

5.2 Governments

5.2.1 Lexington-Fayette Urban County Government

Lexington must meet the terms and conditions of both its MS4 permit and its KDPES discharge permit for the Town Branch SWS (Town Branch's collection system extends into the Cane Run watershed). Lexington entered into a Consent Decree with EPA, the Department of Justice and the Kentucky Energy and Environment Cabinet (KEEC) in the US Eastern District Court regarding SSOs, storm water and cross-connections: The Consent Decree was final in 2008, but due to an appeal it was entered in January of 2011. The Consent Decree requires Lexington to enact a Stormwater Quality Management Fee. The fee took effect on January 1, 2010, and Lexington has awarded several Stormwater Quality Projects Incentive Grants, which are funded using 10% of the revenue generated by the Stormwater Quality Management Fee. The program provides financial assistance to projects to reduce storm water runoff, improve water quality, and/or educate the public. The LFUCG Division of Water Quality administers the program, but projects are identified, managed, and implemented by citizens. Projects are selected for implementation by the LFUCG Water Quality Fees Board, which is an official LFUCG citizen board appointed by the mayor. During Fiscal Year 2011 the budget is $1.5 million, and it will be $1.2 million for Fiscal Year 2012 (Personal Communications, Susan Plueger, LFUCG, 3/11/2011 and 4/11/2011). While this program funds projects in different watersheds across Lexington, a list of the approved projects that are in the Cane Run watershed or that may affect it is included in Appendix G.

Also under the Consent Decree, Lexington is responsible for completing Sanitary Sewer Assessment (SSA) Reports and Remedial Measures Plans for three groups of watersheds. The SSA Report summarizes the results of the Sanitary Sewer Assessment, Pump Station Evaluation, Capacity Assessment, and Hydraulic Model to identify problem areas in the sewer system and WWTPs. The SSA Report for Group 1 watersheds (West Hickman, East Hickman, and Wolf

Run) was submitted to EPA and KDOW on April 13, 2011. The SSA Report for Group 2 watersheds (Cane Run and Town Branch) was submitted on October 14, 2011. The SSA Report for Group 3 watersheds (North Elkhorn and South Elkhorn) was submitted on April 20th, 2012. The Remedial Measures Plans have specific measures and schedules that, when implemented, will result in adequate capacity in LFUCG's sanitary sewer system and WWTPs, such that recurring SSOs, unpermitted bypasses, overloading at the WWTP, and WWTP KPDES permit noncompliance will be eliminated. The Remedial Measures Plan for Group 1 watersheds was submitted to EPA and KDOW on October 13, 2011. The Remedial Measures Plan for Group 2 watersheds was submitted on April 18th of 2012. The Remedial Measures Plan for Group 3 watersheds is due to be submitted around October 2012 but within 6 months after the SSA Report for Group 3 watersheds is submitted. In addition, there are required sewer remediation projects listed separately in the Consent Decree (i.e., projects not identified during the SSA process and included in the Remedial Measures Plan) because the need for them was already apparent at the time the Consent Decree was written.

5.2.2 Georgetown Government

Like Lexington, Georgetown must meet the terms and conditions of both its MS4 permit and its KPDES discharge permit for the Georgetown STP #1 on North Elkhorn Creek (the collection system for this SWS extends into the Cane Run watershed). The Georgetown MS4 program has instituted a recharge requirement for its new construction projects beginning in 2003; detention basins or other Best Management Practices (BMPs) must be put in place that will collect a 1" rainfall (approximately an 80th percentile storm event) from the watershed area upstream of the construction area and allow the entire amount to infiltrate to groundwater, providing a water quantity and water quality benefit. The newer subdivisions in the Georgetown MS4 area that drain to Cane Run were built to this standard, including Payne's Crossing, the Bradford Subdivision, McClelland Springs (all located north of the US460 bypass, on the west side of town), as well as the Stonecrest Subdivision (located south of the US460 bypass). Construction for these projects was completed after the 2002 KWRRI sampling event. Also, the Suffoletta Aquatics Center (located along the US460 bypass, recently completed) has a retention basin with a mechanical BMP, a Vortecs® unit which circulates storm water, drawing down the cleaner water from the center of the circulation pattern while allowing oil and grease, as well as sediment, to remain and settle on the outside (Personal Communication, Eric Larson, City of Georgetown, 2011).

5.2.3 Kentucky Horse Park

The Kentucky Horse Park is owned by the Commonwealth of Kentucky, and is administered by the Tourism, Arts and Heritage Cabinet. It is located in the headwaters of the Cane Run watershed, adjacent to UK's North Farm Area, http://kyhorsepark.com/. The Kentucky Horse Park recently partnered with UK, the Bluegrass Partnership for a Green Community and M2D Design to install a riparian buffer restoration project on 500 linear feet of an unnamed tributary to Cane Run on Horse Park property; the work was completed in the spring of 2010. Several volunteer groups assisted with site preparation and planting (Personal Communication, Sarah Wightman, 2011). The Horse Park is considering plans to create further riparian restoration projects at other streams within the Park boundaries. See Figure 5.1 for photograph of the riparian buffer restoration project.

Figure 5.1 Riparian Buffer Restoration Project at the Kentucky Horse Park

5.3 University of Kentucky

UK owns the North Farm, which includes Spindletop, Main Chance Farm and the Coldstream Research Farm. The North Farm is permitted under Kentucky's No Discharge Operating Permit (KNDOP) program, permit number 067047596, for the waste handling area (Personal Communication, Steve Higgins, 2011, Sarah Wightman, 2011).

The North Farm has an Agricultural Water Quality Plan (AWQP) as of April, 2011; this plan is kept onsite, and UK has also signed a statement attesting to the Agricultural Water Quality Authority (AWQA) that the plan has been developed; this statement is on file at the Fayette County Conservation District. The AWQP includes a Nutrient Management Plan for crops and livestock, which requires that gross solids (i.e., manure) be collected and hauled offsite for composting. Horse and dairy manure are blended together to make the resultant wastestream more stackable and thus easier to transport. Creech Services currently holds the contract for transporting the North Farm's manure.

The Nutrient Management Plan also addresses runoff from the dairy area by changing the surrounding drainage system; now 'clean' storm water is diverted from running onto the dairy operation's production area, this has had the effect of creating large amounts of excess capacity in the dairy's existing holding ponds. UK published a paper on this BMP and approached the AWQA on its applicability to other farms; this resulted in the AWQA adding the BMP (runoff controls) to the approved list of BMPs for dairy operations (Higgins, Wightman, 2010).

Another recent BMP is the creation of no-mow zones along riparian areas and drainage ditches across the North Farm, including almost all of the 'blue-line' streams (i.e., those that appear on a 1:24,000-scale USGS topographic map). UK has planted approximately 5000 trees in the no-mow zones, which are nominally 50 feet wide. This required that animals be fenced off from the streams, including the provision of alternate water supplies, which has happened in all the paddocks save one. Flowers growing in the no-mow area have proven beneficial for UK's entomology program, which collects specimens drawn to the flowers, and for the Audubon Society, whose members bird watch in these areas now that bird species such as the owl have re-colonized.

Additional BMPs already in place or ongoing include the following:

1. Gully erosion projects;
2. Reinforced stream crossings (for both animals and equipment, some of which were used for the 2010 World Equestrian Games endurance races and other races since);
3. A fertilizer take-back program,
4. A pesticide take-back program (one day per year which has been held since 2008; in its first and most successful year, the program collected approximately 8000 pounds of pesticide, some of which had been in circulation for over 30 years);
5. A pervious concrete wash stall for horses;
6. Downsizing the dairy cow herd from 140 to 105 animals to reduce stocking density in support of the Nutrient Management Plan (excess animals are kept offsite and used to repopulate the North Farm's herd);
7. An awareness-raising effort for onsite staff which involved mapping most of the farming operations, no-mow zones, sinkholes, etc., and;
8. Invasive species removal in riparian zones (including eradication efforts for Canadian Thistle, Bull Thistle, Bush Honeysuckle, Poison Hemlock and Giant Ragweed populations).

In addition, UK's BAE holds a 2007 319 Grant from EPA through KDOW to write a Watershed Based Plan (WBP) for the Cane Run watershed. Project partners include the City of Lexington, Bluegrass PRIDE, KRWW, Bluegrass Partnership for a Green Community, Fayette and Scott County Public Schools, Cane Run Watershed Council, FOCR, Lexmark, Inc., Kentucky Department of Transportation, Bluegrass Rain Garden Alliance, neighborhood associations, and the Kentucky Horse Park. The plan contains a summary of water quality monitoring, a source delineation and a draft BMP plan to address impairments from bacteria as well as other pollutants, including sediment, nutrients, etc. (BAE, 2011). The WBP report was approved by KDOW on 10/25/11.

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MODELING REPORT

Total Maximum Daily Load for Fecal Coliform 7 Stream Segments within the Cane Run Watershed, Fayette and Scott Counties, Kentucky

Photo of Cane Run (KDOW)

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UNBRIDLED SPIRIT

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LIST OF ACRONYMS

ASAE	American Society of Agricultural Engineers
BIT	Bacterial Indicator Tool
CAFO	Confined Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
cfu	Colony Forming Units
CWA	Clean Water Act
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
GM	Geometric Mean
GNIS	Geographic Names Information System
HSPF	Hydrologic Simulation Program Fortran
HUC	Hydrologic Unit Code
KAR	Kentucky Administrative Regulations
KASS	Kentucky Agricultural Statistics Service
KDEP	Kentucky Department for Environmental Protection
KDOW	Kentucky Division of Water
KGS	Kentucky Geological Survey
KPDES	Kentucky Pollution Discharge Elimination System
KWRRI	Kentucky Water Resources Research Institute
KYTC	Kentucky Transportation Cabinet
LA	Load Allocations
LFUCG	Lexington Fayette Urban County Government
LIRPB	Long Island Regional Planning Board
MAE	Mean Absolute Error
mgd	Million Gallons per Day
MHP	Mobile Home Park
ml	Milliliter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NHD	National Hydrography Dataset
NLCD	National Landcover Database
NOAA	National Oceanic and Atmospheric Administration
NSE	Nash-Sutcliffe Coefficient, or Nash-Sutcliffe Efficiency

OWTS	Onsite Wastewater Treatment System
PCR	Primary Contact Recreation
R	Pearson's Correlation Coefficient
R^2	Coefficient of Determination
RM	River Mile
RMSE	Root Mean Square Error, or Root Mean Square Deviation
RSR	Ratio of the RMSE to the SD
SCR	Secondary Contact Recreation
SD	Standard Deviation
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWS	Sanitary Wastewater System
TMDL	Total Maximum Daily Load
TNTC	Too Numerous To Count
UK	University of Kentucky
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UT	Unnamed Tributary
WBP	Watershed-Based Plan
WLA	Wasteload Allocation
WQC	Water Quality Criteria
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act (CWA) requires states to identify waterbodies within their boundaries that have been assessed and are not currently meeting their designated uses (401 KAR 10:026 and 10:031) and that require the development of a Total Maximum Daily Load (TMDL). States must establish a priority ranking for such waters, taking into account their intended uses and the severity of the pollutant. Section 303(d) also requires that states provide a list of this information called the 303(d) list. States are also required to develop TMDLs for the pollutants that cause each waterbody to fail to meet its designated uses. The TMDL process establishes the allowable amount (i.e., load) of the pollutant the waterbody can naturally assimilate while continuing to meet the Water Quality Criteria (WQC) for each designated use. The pollutant load must be established at a level necessary to implement the applicable WQC with seasonal variations and a Margin of Safety (MOS) that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. This load is then divided among different sources of the pollutant in a watershed. Information from the U.S. Environmental Protection Agency (EPA) on TMDLs can be found at: http://www.epa.gov/owow/tmdl.

This Modeling Report describes all modeling, assumptions and calculations that result in the determination of the existing conditions and TMDL allocations needed for the impaired waterbodies in this document. This modeling information was placed in a separate portion of the report to streamline the narrative portion of the report; however, while they are given separate titles, together the narrative and modeling portions of the report (in addition to the attached appendices) constitute the TMDL submittal for the affected waterbodies and are to be placed in the TMDL administrative record as one document. However, although these separately titled portions of the report are part of the same TMDL submittal, some of the information from the narrative portion of the report was repeated within the Modeling Report to provide context for the modeling discussion. The exception is the sampling tables and figures in Section 2.0 of the narrative portion of the report; these were not reproduced in the Modeling Report due to their number and size.

1.1 Catchment Delineation

In order to assess the sources and associated pathogen loadings in the Cane Run watershed, a Hydrologic Simulation Program Fortran (HSPF) (Bicknell et al., 1997) computer model of the watershed was developed, using stream data from the National Hydrography Dataset (NHD, USGS, 2003a). The modeling is complicated by the karst nature of the watershed; the Royal Spring karst basin and the Cane Run surface water basin overlap considerably, see Figure 1.1. In particular a large part of the surface water flow in the upper part of the watershed enters karst conduits near the site of the former USGS gaging station 03288200 Cane Run near Donerail, which was located on Berea Road; see Figure 1.3 (USGS, 2003b) during the time of this study, although it was moved in 2012. From there it flows underground until it exits at Royal Spring in Georgetown. Swallets (i.e., the point where a losing or sinking stream enters the subsurface; this can be a single feature or a sizeable losing reach of stream (Personal Communication, Rob Blair, 2011a)) and large sinkholes are present within the Royal Spring karst basin, draining surface flow to the karst aquifer during most of the year. As a result, the Cane Run near Donerail gauging station showed no flows except during periods of heavy rainfall during this study. Therefore, flow is only available as surface runoff in Cane Run immediately downstream of the Royal Spring karst basin during the wetter parts of the year. The Kentucky Geological Survey (KGS, 2003) conducted tracer studies and delineated the ground water basins for major springs in the area. Royal Spring is the water supply for the City of Georgetown.

For the purposes of modeling and determining the associated TMDLs, the entire watershed was initially subdivided into two separate areas: the part of Cane Run above River Mile (RM) 6.8, and the part of Cane Run below RM 6.8. The part of the watershed above RM 6.8 may also be referred to as Royal Spring karst basin. These areas were then subdivided into several catchments: eight catchments in the part of Cane Run above RM 6.8 and six catchments in the part of Cane Run below RM 6.8 (see Figure 1.3). Two additional catchments were defined for the part of Cane Run above RM 6.8 to facilitate modeling the karst system (i.e., K1 and K2), since flow normally exits these basins into the adjacent parts of the North Elkhorn Creek watershed, and does not appear in the Cane Run part of the watershed. Loads from the two karst catchments apply only when rainfall events exceed a certain level, see Section 4.5.2.2. For the purposes of modeling the part of Cane Run above RM 6.8 (i.e., the Royal Spring karst basin) an additional catchment (i.e., K3) has been added to accommodate the karst contributions to Royal Spring that lie external to the surface topography boundary of the upper watershed, but this catchment was only used to model the karst flow; it was not included in TMDL development since there is no bacteria-impaired waterbody in that catchment.

During TMDL loading and reduction calculations, separate TMDLs and associated load allocations were developed for each catchment except K3: Although the individual catchments are defined in Figure 1.3, the loading from an individual catchment may or may not represent the loading to an impaired segment, see Figure 1.4; therefore, the term ‘subwatershed’ is used to represent the upstream area of impaired segments in the document (most subwatersheds include multiple catchments, with the exception of the Unnamed Tributary (UT) of Cane Run at RM 10.8, whose subwatershed is identical with catchment U4).

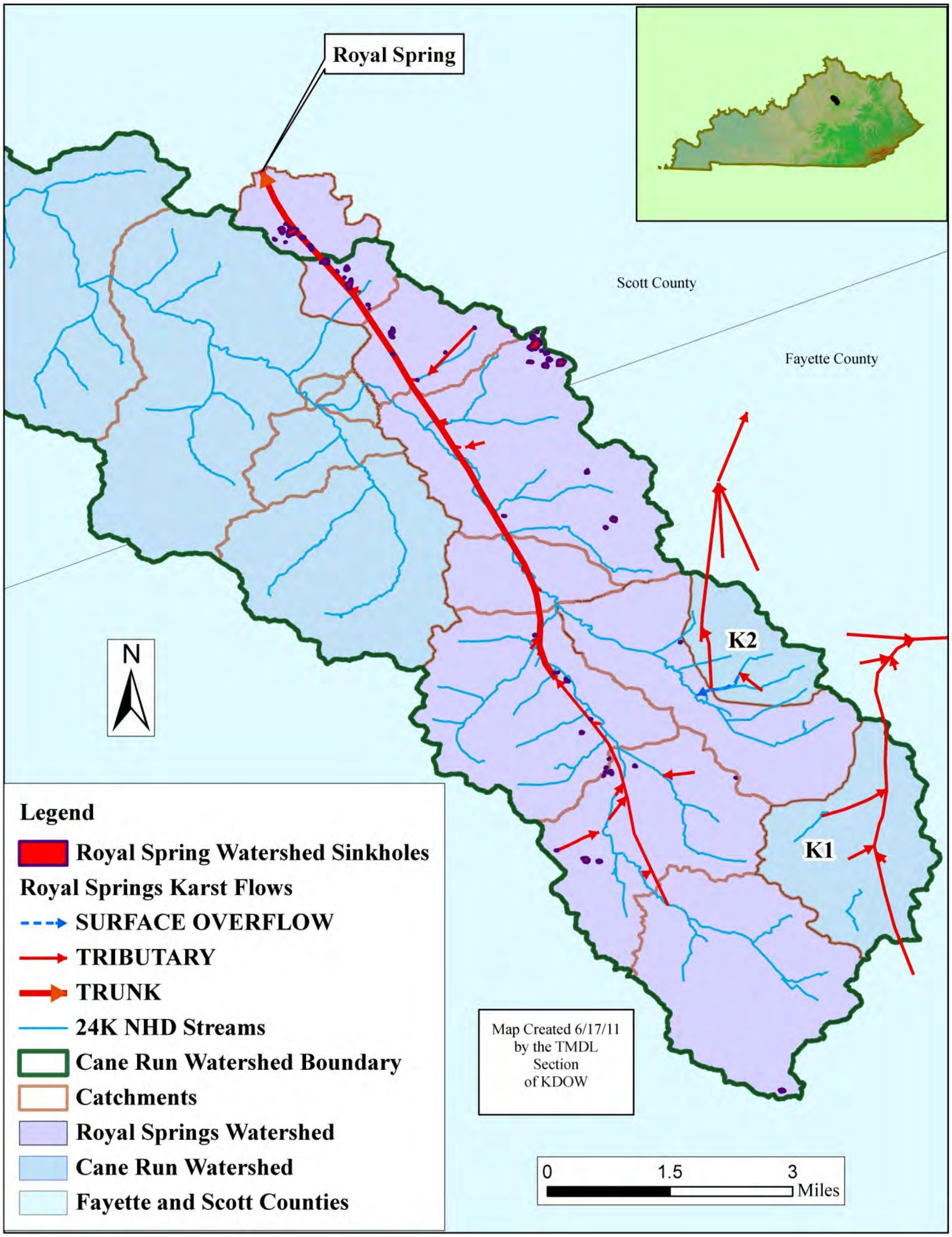

Figure 1.1 Cane Run Surface Water and Royal Spring Ground Water Basins

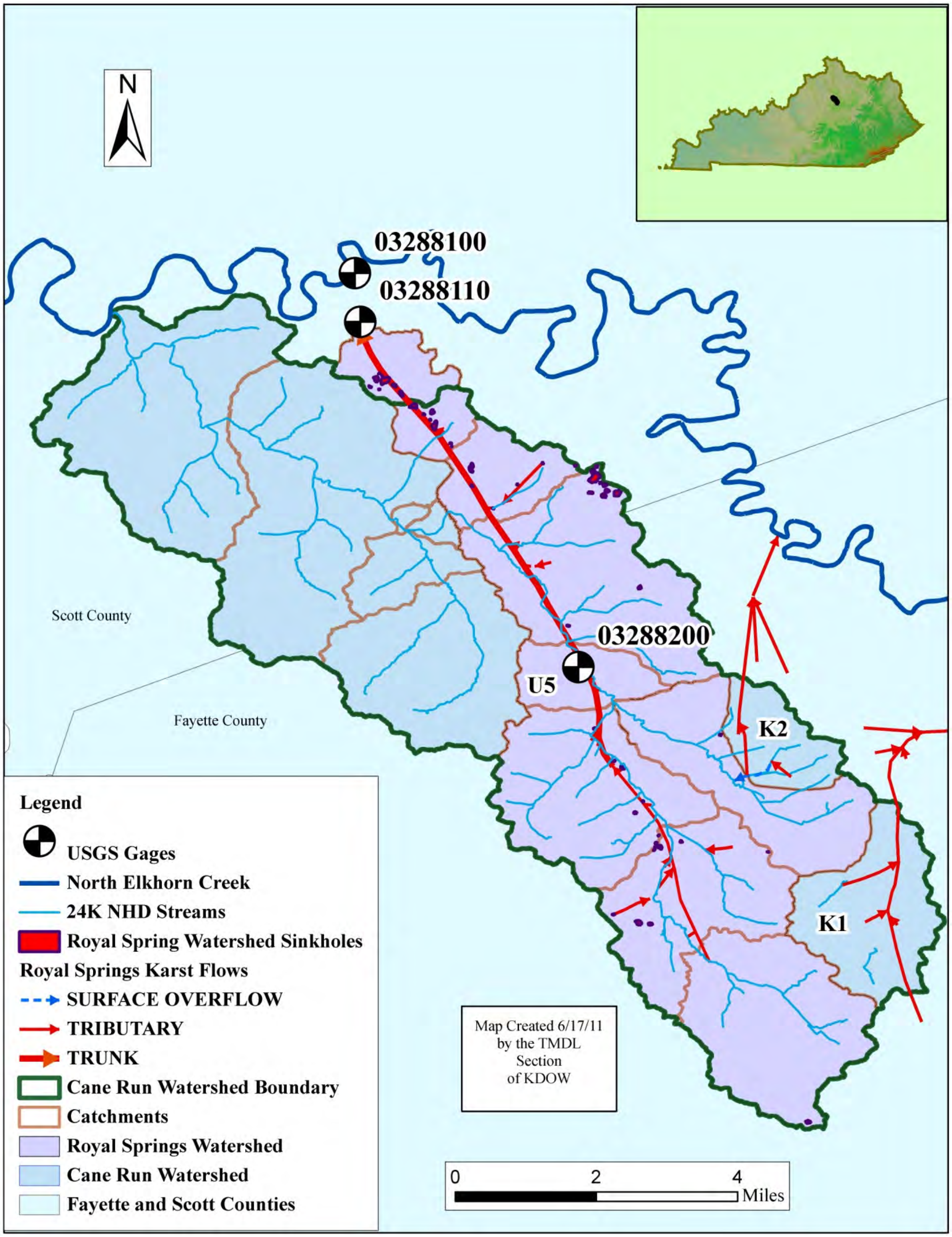

Figure 1.2 Cane Run Surface Water and Royal Spring Ground Water Basins with USGS Gaging Stations

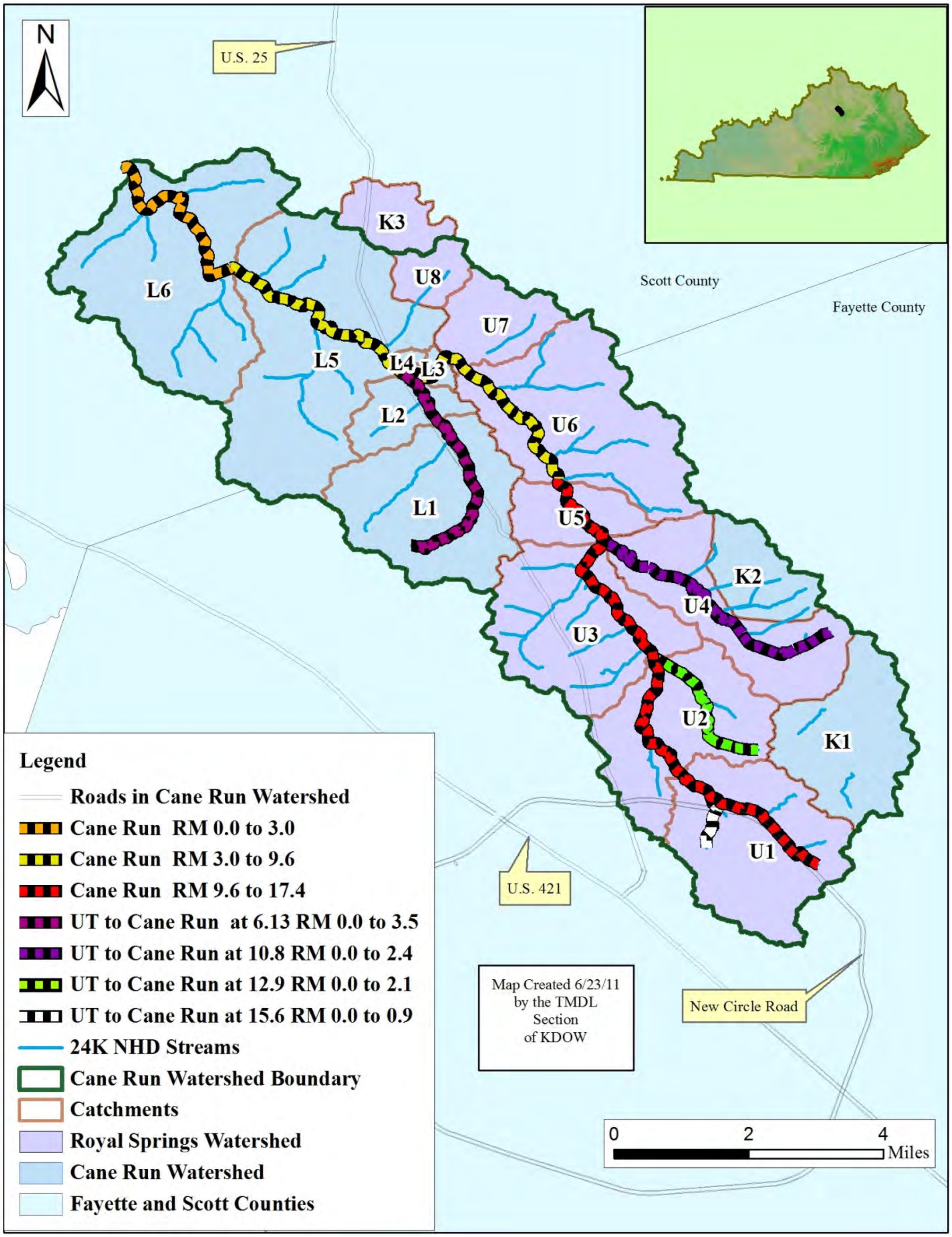

Figure 1.3 Cane Run Catchment Delineation

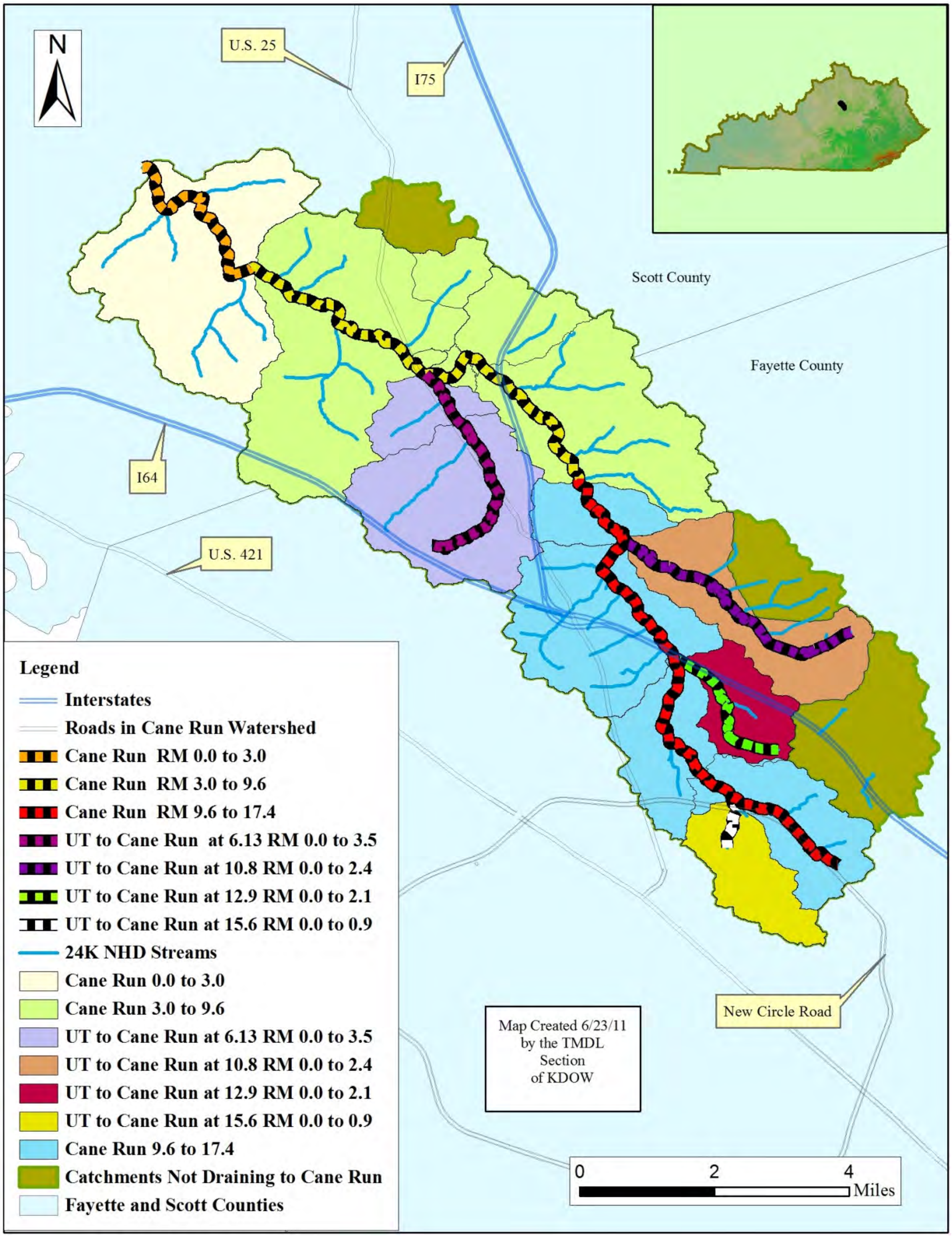

Figure 1.4 Cane Run Subwatersheds

1.2 Landcover Information

Landcover is based on landcover mapping, a process which assigns categorical rather than specific uses based on the digitization and sorting of returns from radar or lidar. Landcover is a surrogate indicator for the type of landuse, but they are not equivalent: for instance, strip mines and areas denuded by forest fire can both show up as barren land, etc.

The geology in the Cane Run watershed, with its phosphorus rich soils, is conducive to agricultural purposes. The watershed consists of 76% agricultural area (which, for purposes of this analysis, included Cropland, Pastureland and Forest), and 24% urban area. The urban area ranges from residential to commercial and industrial tracts. A detailed breakdown of the landcover distributions for each catchment is provided in Tables 1.1, through 1.5. These values were derived using the BASINS 3.1 database (EPA, 2004). Figure 1.5 shows a map of landcover based on Anderson Level II Landcover Categories (Anderson, 1972). However, since the EPA (2001a) Bacterial Indicator Tool (BIT) has components for determining initial loadings based on BIT landcover categories, Table 1.6 provides the relationship between the two category systems. Categories include:

1. Residential;
2. Commercial and Services;
3. Transportation, Communications, and Utilities, and;
4. Mixed Urban or Built Up.

Industrial and Commercial Complexes are considered within the category of Commercial and Services.

Table 1.1 MS4 and Development Distribution in Cane Run Watershed

Catchment	Total Catchment Area (acres)	Agriculture/Non-Developed (acres)			Developed (acres)		
		MS4	Non-MS4	Total	MS4	Non-MS4	Total
Cane Run 0.0 to 3.0							
L6	3831	467	3128	3595	0	236	236
Cane Run 3.0 to 9.6							
L3	113	0	102	102	0	11	11
L4	68	0	68	68	0	0	0
L5	4359	675	3251	3926	289	144	433
U6	2935	0	2353	2353	0	582	582
U7	905	120	690	810	9	86	95
U8	366	268	54	322	44	0	44
UT to Cane Run (at RM 6.13) 0.0 to 3.5							
L1	2606	0	2226	2226	0	380	380
L2	636	0	521	521	0	115	115
Cane Run 9.6 to 17.4							

Catchment	Total Catchment Area (acres)	Agriculture/Non-Developed (acres)			Developed (acres)		
		MS4	Non-MS4	Total	MS4	Non-MS4	Total
U1	2623	325	0	325	2298	0	2298
U2	2147	1173	162	1335	812	0	812
U3	2546	1011	1197	2208	115	223	338
U4	1903	161	1552	1713	0	190	190
U5	795	0	439	439	0	356	356
Royal Spring							
K3	623	66	99	165	440	18	458

Table 1.2 General Landcover in Cane Run Watershed (acres)

Catchment	Total	Developed	Cropland	Pastureland	Forest
Cane Run 0.0 to 3.0					
L6	3831	236	1198	2397	0
Cane Run 3.0 to 9.6					
L3	113	11	34	68	0
L4	68	0	23	45	0
L5	4359	433	1309	2617	0
U6	2935	582	1177	1176	0
U7	905	95	405	405	0
U8	366	44	161	161	0
UT to Cane Run (at RM 6.13) 0.0 to 3.5					
L1	2606	380	742	1484	0
L2	636	115	174	347	0
Cane Run 9.6 to 17.4					
U1	2623	2298	157	168	0
U2	2147	812	571	764	0
U3	2546	338	1075	1133	0
U4	1903	190	857	856	0
U5	795	356	220	219	0
Royal Spring					
K3	623	458	83	82	0

Table 1.3 Fraction of Non-Developed Land that is Within and Outside the MS4 Boundary

Catchment	Non-Developed Land, Acres			Non-Developed Land, Fraction	
	Within MS4 Boundary	Outside MS4 Boundary	Total	Within MS4 Boundary	Outside MS4 Boundary
Cane Run 0.0 to 3.0					
L6	467	3128	3595	13%	87%
Cane Run 3.0 to 9.6					
L3	0	102	102	0%	100%
L4	0	68	68	0%	100%
L5	675	3251	3926	17.2%	82.8%
U6	0	2353	2353	0%	100%
U7	120	690	810	14.8%	85.2%
U8	268	54	322	83.2%	16.8%
UT to Cane Run (at RM 6.13) 0.0 to 3.5					
L1	0	2226	2226	0%	100%
L2	0	521	521	0%	100%
Cane Run 9.6 to 17.4					
U1	325	0	325	100%	0%
U2	1173	162	1335	87.9%	12.1%
U3	1011	1197	2208	45.8%	54.2%
U4	161	1552	1713	9.4%	90.6%
U5	0	439	439	0%	100%
Royal Spring					
K3	66	99	165	40%	60%

Table 1.4 Fraction of Developed Land that is Within and Outside the MS4 Boundary

Catchment	Developed Land, acres			Developed Land, Fraction	
	Within MS4 Boundary	Outside MS4 Boundary	Total	Within MS4 Boundary	Outside MS4 Boundary
Cane Run 0.0 to 3.0					
L6	0	236	236	0%	100%
Cane Run 3.0 to 9.6					
L3	0	11	11	0%	100%
L4	0	0	0		
L5	289	144	433	66.7%	33.3%
U6	0	582	582	0%	100%
U7	9	86	95	9.5%	90.5%
U8	44	0	44	100%	0%
UT to Cane Run (at RM 6.13) 0.0 to 3.5					
L1	0	380	380	0%	100%
L2	0	115	115	0%	100%
Cane Run 9.6 to 17.4					
U1	2298	0	2298	100%	0%
U2	812	0	812	100%	0%
U3	115	223	338	34.0%	66.0%
U4	0	190	190	0%	100%
U5	0	356	356	0%	100%
Royal Spring					
K3	440	18	458	96.1%	3.9%

Table 1.5 Types of Developed Landcover in the Cane Run Watershed (acres)

Catchment	Commercial and Services	Mixed Urban	Residential	Transportation, Communication, and Utilities	Total
Cane Run 0.0 to 3.0					
L6	0	0	236	0	236
Cane Run 3.0 to 9.6					
L3	2	1	4	4	11
L4	0	0	0	0	0
L5	113	0	191	130	434

Catchment	Commercial and Services	Mixed Urban	Residential	Transportation, Communication, and Utilities	Total
U6	349	0	116	116	581
U7	0	0	19	76	95
U8	11	0	19	13	43
UT to Cane Run (at RM 6.13) 0.0 to 3.5					
L1	0	0	76	304	380
L2	0	0	115	0	115
Cane Run 9.6 to 17.4					
U1	299	506	1402	92	2299
U2	146	65	284	317	812
U3	125	0	85	128	338
U4	17	16	143	14	190
U5	0	0	128	228	356
Royal Spring					
K3	0	0	458	0	458

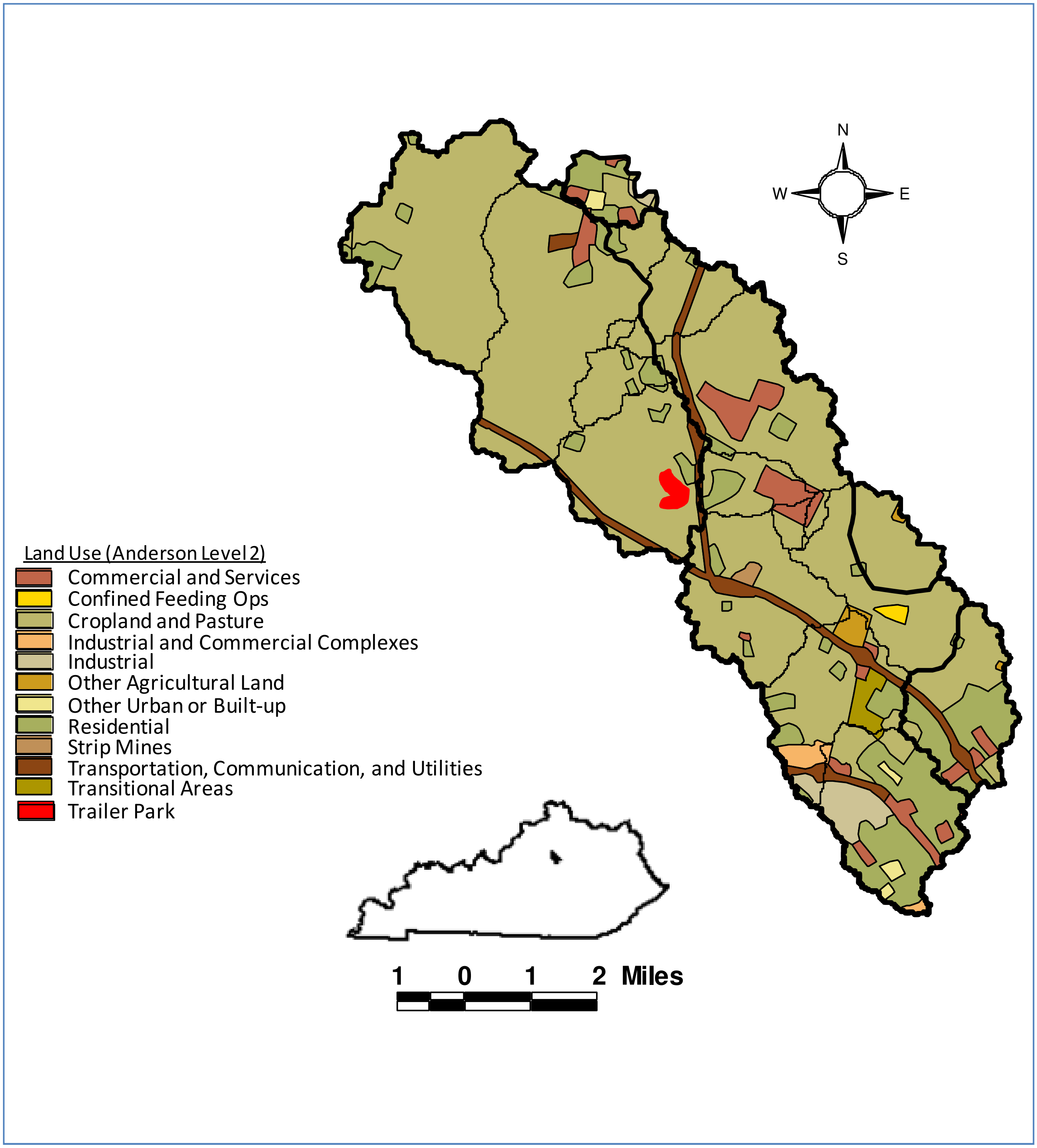

Figure 1.5 Anderson Level 2 Landcover Map of Cane Run Watershed

Table 1.6 Relationship Between Anderson Level II Landcover Categories and BIT Landcover Categories

Anderson Landcover Category	Level II Class	BIT Landcover Category
Residential	11	Residential
Commercial and Services	12	Commercial and Services
Industrial	13	Commercial and Services
Transportation	14	Trans., Comm., and Utilities
Industrial and Commercial	15	Commercial and Services
Mixed Urban or Built-up Land	16	Mixed Urban or Built-Up
Other Urban or Built-up land	17	Mixed Urban or Built-Up
Cropland and Pasture	21	50% Cropland
Cropland and Pasture	21	50% Pasture
Confined Feeding Operations	23	Cropland
Other Agricultural Land	24	Pasture
Deciduous Forest Land	41	Forest
Mixed Forest Land	43	Forest
Quarries	75	Commercial and Services
Transitional Areas	76	Commercial and Services

2.0 PROBLEM DEFINITION

The Kentucky Division of Water's (KDOW's) 2010 303(d) list of waters for Kentucky (KDOW, 2011a) shows four streams in the Cane Run watershed do not support the Primary Contact Recreation (PCR) use due to pathogen indicators, which for the sake of brevity may be referred to as pathogens (KDOW, 2011b) or bacteria, specifically fecal coliform. Some of these streams are also impaired for Secondary Contact Recreation (SCR). In addition, three streams (UT to Cane Run at 10.8 RM 0.0 to 2.4, UT to Cane Run at 12.9 RM 0.0 to 2.1, and UT to Cane Run at 15.6 RM 0.0 to 0.9) which did not appear on the 2010 303(d) list, were also found to be impaired for bacteria and so were included in this study. The impairments are illustrated in Figure 2.1, and are presented in tabular form in Table 2.1.

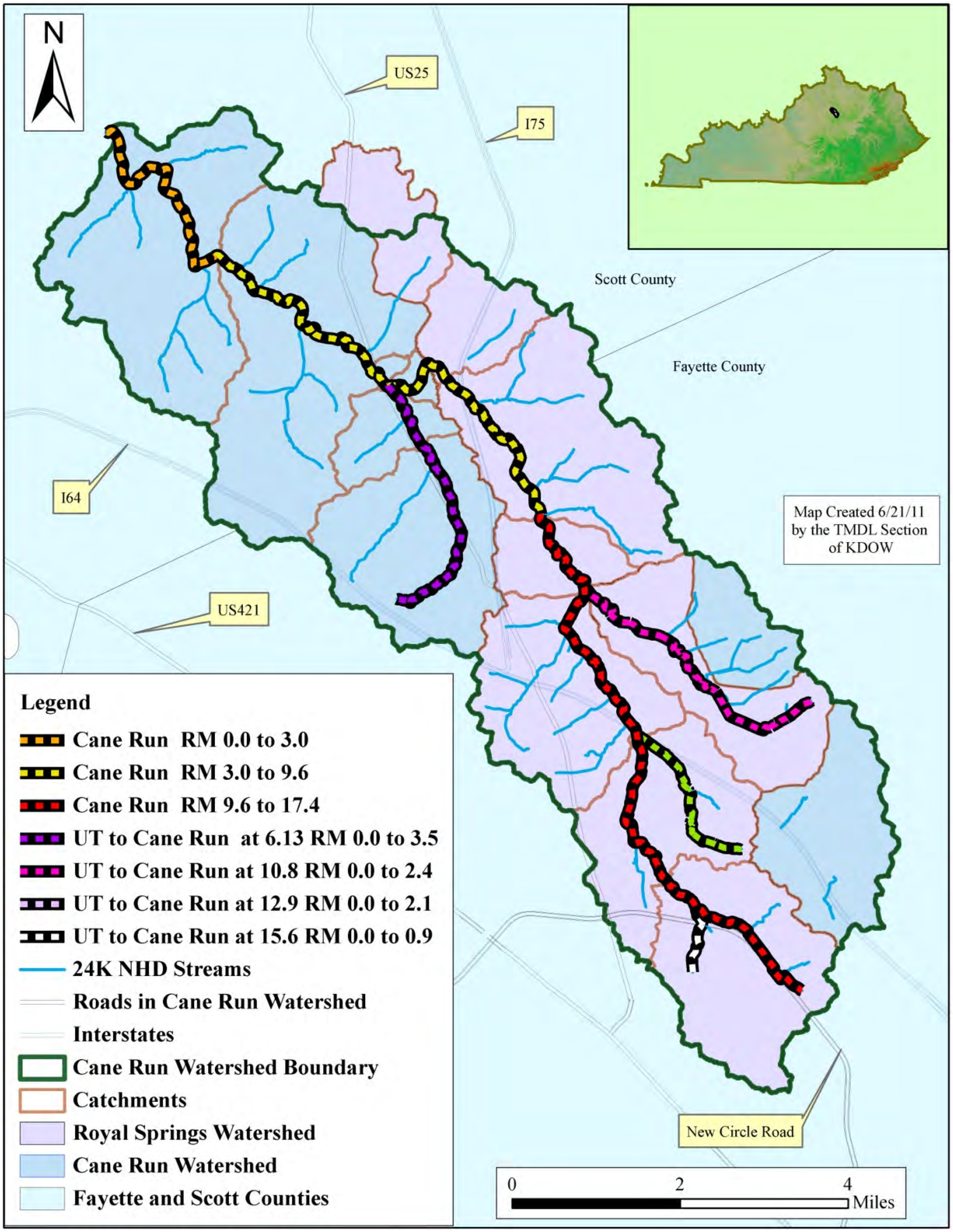

Figure 2.1 Cane Run Watershed Impaired Streams

Table 2.1 Impaired Waterbodies Addressed in this TMDL Document

Waterbody and Segment (GNIS[1] Number)	Listing Year[2]	County	Support Status	Use Impairment(s)	Suspected Source(s)
Cane Run 0.0 to 3.0 (KY488799_01)	2010	Scott	PCR (Nonsupport), SCR (Partial Support)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Managed Pasture Grazing, Package Plant or Other Permitted Small Flows Discharges, Unspecified Urban Stormwater
Cane Run 3.0 to 9.6 (KY488799_02)	2002	Scott	PCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Package Plant or Other Permitted Small Flows Discharges
Cane Run 9.6 to 17.4 (KY488799_03)	1998	Fayette	PCR (Nonsupport), SCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations), Unspecified Urban Stormwater
UT to Cane Run at 6.13 RM 0.0 to 3.5 (KY488799-6.13_01)	2002	Scott	PCR (Nonsupport)	Fecal Coliform	Livestock (Grazing or Feeding Operations)
UT to Cane Run at 10.8 RM 0.0 to 2.4 (KY488799-10.8_01)	N/A	Scott	PCR (Nonsupport)	*E. coli*[3]	Livestock (Grazing or Feeding Operations)
UT to Cane Run at 12.9 RM 0.0 to 2.1 (KY488799-12.9_01)	N/A	Scott	PCR (Nonsupport)	*E. coli*[3]	Agriculture, Unspecified Urban Stormwater
UT to Cane Run at 15.6 RM 0.0 to 0.9 (KY488799-15.6_01)	N/A	Scott	PCR (Nonsupport)	*E. coli*[3]	Unspecified Urban Stormwater

(1)GNIS = Geographic Names Information System.

(2) Waterbodies with a Listing Year of N/A (i.e., ‘Not Applicable’) have not yet been listed on the 303(d); they were found to be impaired by sampling submitted with this study. This TMDL report constitutes the public notice required to list these waterbodies as impaired. Upon approval of this TMDL, they will be listed in Category 4A of Kentucky’s Integrated Report, Approved TMDLs.

(3) Segements impaired for *E. coli* received allocations in terms of fecal coliform because the model was calibrated using fecal coliform data, and Kentucky has a dual standard for both fecal coliform and *E. coli* as shown in Section 2.1, thus development of TMDLs using the fecal coliform criterion are sufficient to provide TMDLs for *E. coli*-listed segments and vice versa.

2.1 Target Identification

The goal of the TMDL process is to achieve a numeric fecal coliform loading within the assimilative capacity of the impaired waterbody under study that allows it to meet its designated uses (i.e., PCR and in some cases SCR). KDOW currently uses fecal coliform and Escherichia Coli (*E. coli*) as indicators of the likelihood of bacteria impairment. The PCR Water Quality Criteria are in effect from May 1 through October 31. For this designated use, 401 KAR 10:031 Section 7(1)(a) states that:

[The] Fecal coliform content or Escherichia coli content shall not exceed 200 colonies per 100 ml or 130 colonies per 100 ml respectively as a geometric mean based on not less than five (5) samples taken during a thirty (30) day period. Content also shall not exceed 400 colonies per 100 ml in twenty (20) percent or more of all samples taken during a thirty (30) day period for fecal coliform or 240 colonies per 100 ml for Escherichia coli. These limits shall be applicable during the recreation season of May 1 through October 31.

The geometric mean (GM, or geomean) of data series of n observations (i.e., y_1, y_2, y_3 …. y_n) is defined as:

$$GM = \sqrt[n]{y_1 . y_2 . y_3 ... y_n}$$

(Equation 1)

Most segments were not analyzed for *E. coli*, and the model was created using fecal coliform to be consistent with the original sampling protocol, thus the fecal coliform WQC was used. The instream fecal coliform WQC for this TMDL is a geometric mean of 200 colonies/100ml (which also may be written as colony forming units, or cfu/100ml) which must be based on 5 or more samples taken within a 30-day period and a maximum of 400 colonies/100ml, which shall not be exceeded in 20% or more of all samples taken within a 30-day period.

SCR is protected for the entire year. 401 KAR 10:031 Section 7(2)(a) states:

Fecal coliform content shall not exceed 1000 colonies per 100 ml as a monthly geometric mean based on not less than five (5) samples per month; nor exceed 2000 colonies per 100 ml in twenty (20) percent or more of all samples taken during the month.

Because Kentucky has a dual standard for the PCR designated use, development of TMDLs using the *E. coli* criterion are sufficient to provide TMDLs for fecal coliform-listed segments and vice versa (i.e., development of fecal coliform TMDLs will protect the PCR use regardless of whether a segment is impaired for *E. coli*, fecal coliform, or both). Additionally, because the instantaneous limit is lower for PCR than for SCR (400 colonies/100ml versus 2000 colonies/100ml), development of TMDLs for the PCR season also protects waterbodies impaired for the SCR use due to fecal coliform. Likewise, Kentucky Pollutant Discharge Elimination System (KPDES) permit holders who are permitted to discharge bacteria into the surface waters of the Commonwealth may be given discharge limits in units of fecal coliform or *E. coli*, either of which protect the PCR use and allow the facility to meet the requirements of 401 KAR

10:031. After determining the TMDLs for each stream catchment and each impaired segment, load reductions were applied until all Cane Run streams met both the PCR (and thus the SCR) WQCs.

2.2 USGS Streamflow Gaging Stations

There is one USGS streamflow gaging station located in the watershed and two other USGS stations located nearby, one at Royal Spring and one on North Elkhorn Creek, as shown in Figure 1.2 (http://nwis.waterdata.usgs.gov/ky/nwis/); all three were used for flow analysis of Cane Run streams, see Table 2.2 for the duration of data collection at these gages.

Table 2.2 USGS Streamflow Gaging Stations

Station ID	Station Description	Duration
03288200	Cane Run near Donerail	1997 – 2012
03288110	Royal Spring, Georgetown	1997 - present
03288100	North Elkhorn, Georgetown	1992 - present

3.0 SOURCE ASSESSMENT

Sections 3.1 and 3.2 discuss the sources used to model the fecal coliform inputs to the streams in the Cane Run watershed.

3.1 Point Sources

KPDES-permitted point sources receive Wasteload Allocations (WLAs) within the TMDL framework. These sources include Sanitary Wastewater Systems (SWSs); Municipal Separate Storm Sewer Systems (MS4s) are also KPDES-permitted sources, but they are respond to precipitation events like non-point sources, see Sections 3.2.4 and 4.6.4. Also, there are illegal point sources which are not KPDES-permitted, such as straight pipes and failing septic systems.

3.1.1 Sanitary Wastewater Systems

SWSs include all facilities with a KPDES-permitted discharge limit for bacteria, including Wastewater Treatment Plants (WWTPs), Sewage Treatment Plants (STPs), package plants and home units. There are three active SWS facilities in the Cane Run watershed; all three are package plants treating influent from Mobile Home Parks (MHPs). Initial estimates of effluent loads were derived using the discharge permit limits, historical Discharge Monitoring Reports (DMRs, EPA, 2003), and information on treatment type, see Table 3.1. A map showing the relative locations of these facilities is provided in Figure 3.1. SWSs are also responsible for their collection systems: Figure 3.2 shows the locations of the sewer lines and lift stations within the Cane Run watershed (KIA, 2002a, 200b). The collection system within Fayette County serves the Town Branch WWTP (KPDES Permit Number KY0021491) and the collection system within Scott County serves the Georgetown STP #1 (KPDES Permit Number KY0020150), neither of which discharge to the Cane Run watershed, so they do not receive SWS-WLAs in this TMDL.

Table 3.1 Sanitary Wastewater Systems in the Cane Run Watershed

Facility	KPDES Permit	Receiving Waterbody	Design Discharge (mgd)	Permit Limit (Colonies/ 100ml)	2003 Historical Geomean (Colonies/100ml)
Spindletop MHP	KY0081213	UT to Cane Run at 6.13	0.030	200	75
Ponderosa MHP	KY0081221	UT to Cane Run at 6.13	0.016	200	10
Maple Grove MHP	KY0083321	UT to Cane Run at 6.13	0.029	200	21

3.1.2 Non-Permitted (Illegal) Point Sources

Three different potential non-permitted point sources of fecal coliform Cane Run have been identified. By definition, all of these sources are illegal and will not be included in the final TMDL allocation. These are:

1. Failing Onsite Wastewater Treatment Systems (OWTSs, e.g., septic systems). However, failing systems do receive the same allocation as a properly functioning OWTSs;
2. Straight pipes, and;
3. Sanitary Sewer Overflows (SSOs).

3.1.2.1 Failing Onsite Wastewater Treatment Systems

OWTSs include those wastewater systems in which wastewater discharges from a house or commercial facility are processed through a biological treatment facility (e.g., septic tank) before the treated effluent is dispersed through a network of buried drainage pipes for subsequent infiltration and adsorption. Such systems can fail when the septic tank becomes full of solids, there is short-circuiting of the flow through the tank, or the field lines become clogged. Failure, malfunctioning of field lines and lack of maintenance may cause septic systems to release wastewater with high levels of fecal coliform into surface water and groundwater. EPA (2002a) states that properly functioning OWTSs can remove fecal coliform with efficiency between 99% and 99.9%, after fecal coliform losses are accounted for in the soil column. Failing OWTSs are assumed to have a removal efficiency of zero.

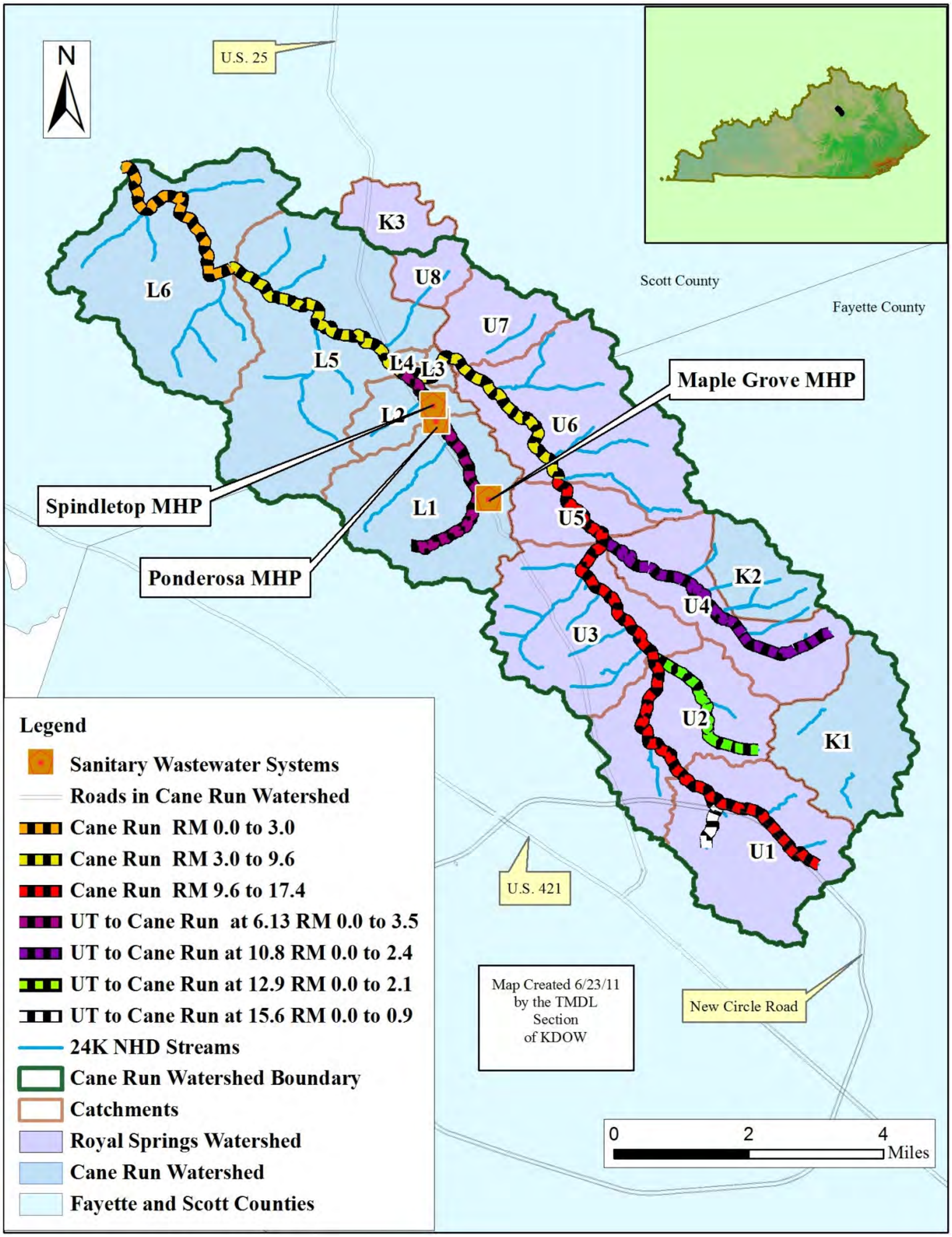

Figure 3.1 Map of Sanitary Wastewater Systems in the Cane Run Watershed

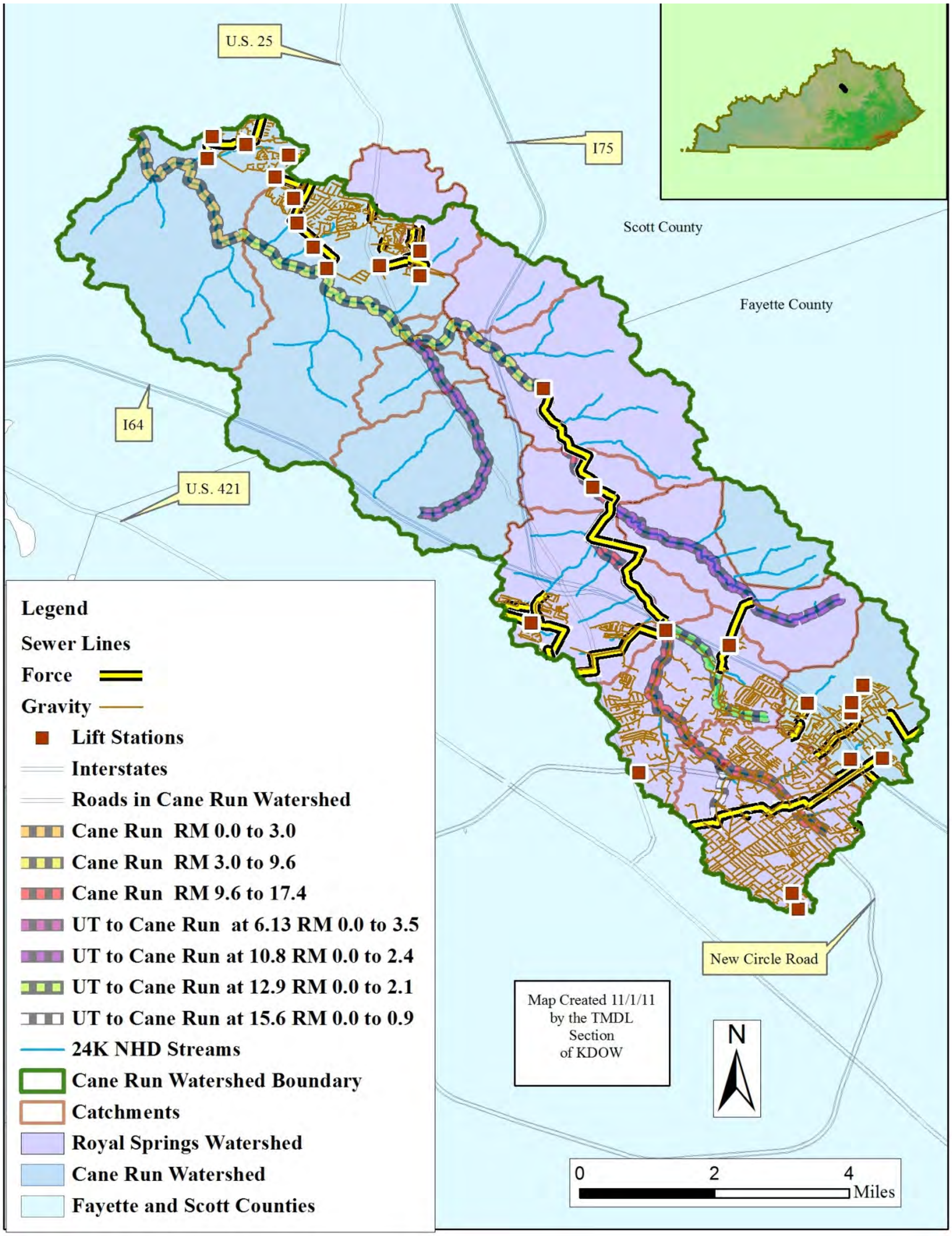

Figure 3.2 Map of Sanitary Sewer Lines and Lift Stations

Based on a preliminary survey of the area, and conversations with local health officials and county extension agents, failing septic systems are known to exist in the Cane Run watershed. For modeling purposes, the total estimated number of failing septic systems was aggregated and treated as a single source for each catchment. The estimated number of failing septic systems per catchment is provided in Table 3.2. Due to the lack of relevant sewage disposal survey data in the 2000 census data, these estimates were obtained using 1990 census tract data on sewage disposal – Data Set STF3: Table H024 (septic tank or cesspool) which were then proportionally revised using the ratio of the 2000 to 1990 populations for each census tract (http://factfinder.census.gov). For the purposes of this study, it was assumed that 2.5% of the septic systems were failing (EPA, 2001a). To effect a conservative estimate, fractional numbers were rounded up to the nearest integer.

3.1.2.2 Straight Pipes

Straight pipes include those "wastewater systems" in which a pipe from a home or business is connected directly to a receiving waterbody. Based on a preliminary survey of the area and based on conversations with local health officials and county extension agents, some straight pipes are suspected to exist within the watershed that ultimately discharge into Cane Run, although the exact number and location are unknown. While straight pipes technically meet the definition of a point source as defined by 401 KAR 5:002, they are a non-permitted source for allocation purposes within a TMDL. For modeling purposes, the total estimated number of straight pipes were aggregated and treated as a single source for each catchment. The estimated number of straight pipes per catchment is provided in Table 3.2. These estimates were obtained using 1990 census tract data on sewage disposal – Data Set STF3: Table H024 (other means) which were then proportionally revised using the ratio of the 2000 to 1990 populations for each census tract (http://factfinder.census.gov). For the purposes of this study, an assumption was made that 100% of those housing units with a sewage disposal characteristic of "other means" were associated with straight pipes.

Table 3.2 Estimated Number of Failing OWTSs and Straight Pipes by Catchment

Catchment	Failing OWTS	Straight Pipes
Cane Run 0.0 to 3.0		
L6	4	4
Cane Run 3.0 to 9.6		
L3	0	1
L4	0	1
L5	4	34
U6	3	3
U7	1	8
U8	0	3
UT to Cane Run (at RM 6.13) 0.0 to 3.5		
L1	3	3
L2	1	5

Catchment	Failing OWTS	Straight Pipes
Cane Run 9.6 to 17.4		
U1	3	8
U2	2	0
U3	3	2
U4	2	7
U5	1	1
Royal Spring		
K3	1	0

3.1.2.3 Sanitary Sewer Overflows

SWS dischargers are responsible for their wastewater collection systems as well as the discharge from their outfalls. Sewage in the Fayette County part of the Cane Run watershed is typically collected by gravity systems and is then pumped via force mains into the adjacent Town Branch watershed where it flows to the Town Branch SWS. Georgetown pumps its sewage to STP #1, outside of the Cane Run watershed (located on North Elkhorn Creek downstream of the Cane Run confluence). The locations of the major sanitary sewer lines and lift stations located within the Cane Run watershed are shown in Figure 3.2. Publically owned sanitary sewer infrastructure problems are known to exist in some of the subdivisions of north Lexington, including Green Acres/Hollow Creek (in Catchment U1), Highlands (in catchment U2) and Winburn (in catchment K1 and U2) (LFUCG Sewer System Assessments 2011). Many of these problems are attributable to the advanced age and deterioration of the system in these older neighborhoods. Age and deterioration negatively impact the public and private sanitary sewer systems equally so it can be assumed that the privately owned sanitary lateral lines in these areas are also compromised. LFUCG's past experience has found that many of the sanitary lateral lines in pre-1975 era neighborhoods such as these have laterals constructed of clay pipe or tarred cardboard tubing, which are easily compromised structurally and are often not maintained unless there is a service failure (blockage) that impacts the customer (personal communication, Charles Martin, 2013). SSOs also exist to a lesser extent in the Scott County portion of the Cane Run watershed, see Section 4.5.2.2. Cross-connections, leaking sewer lines and SSOs are illegal sources and must be eliminated.

3.2 Nonpoint Sources

Modeled nonpoint sources included 1) wildlife, 2) livestock, 3) instream cattle, and 4) urban runoff from developed land. These four sources were assumed to occur both inside and outside of MS4 areas. Only the load from urban runoff from developed land within the MS4 area is part of the WLA; all other sources are part of the Load Allocation (LA). Descriptions of each of these sources are provided below.

3.2.1 Wildlife

The wildlife in the Cane Run watershed is represented by ducks, migratory geese, deer, beavers, and raccoons. EPA's BIT provides a population density for each kind of animal for a particular landcover (EPA, 2001a). These densities are shown in Table 3.3. The number of acres associated with each non-developed landcover in each catchment (see Table 1.2) was multiplied by the corresponding population densities for each animal then aggregated to generate the wildlife population by catchment as shown in Table 3.4.

Table 3.3 Animal Population per Acre (EPA's Bacterial Indicator Tool, 2001)

	Ducks	Geese	Deer	Beaver	Raccoons
Cropland	0.015625	0.0078125	0.0078125	0.0015625	0.0078125
Pastureland	0.015625	0.0078125	0.0078125	0.0015625	0.0078125
Forest	0.031250	0.0156250	0.0156250	0.0031250	0.0156250

Table 3.4 Wildlife Population per Catchment

Catchment	Ducks	Geese	Deer	Beavers	Raccoons
Cane Run 0.0 to 3.0					
L6	56	28	28	6	28
Cane Run 3.0 to 9.6					
L3	2	1	1	0	1
L4	1	1	1	0	1
L5	61	31	31	6	31
U6	37	18	18	4	18
U7	13	6	6	1	6
U8	5	3	3	1	3
UT to Cane Run (at RM 6.13) 0.0 to 3.5					
L1	35	17	17	3	17
L2	8	4	4	1	4
Cane Run 9.6 to 17.4					
U1	5	3	3	1	3
U2	21	10	10	2	10
U3	35	17	17	3	17
U4	27	13	13	3	13
U5	7	3	3	1	3
Royal Spring					
K3	3	1	1	0	1

3.2.2 Grazing and Confined Livestock

Countywide estimates of the number of livestock were obtained from the Kentucky Agricultural Statistics Service (KASS, 2002) database and were distributed to each catchment based on the number of animals in each county and the total number of acres of forest and pastureland in each catchment (see http://www.nass.usda.gov/census/census02/volume1/ky/index2.htm).

The University of Kentucky's (UK's) College of Agriculture provided actual livestock numbers on UK's North Farm, which lies within catchments U2, U3, U4, and U5. The UK data correlated well with the Kentucky Agricultural Database for horse and cattle values, but identified additional numbers of goats and chickens. Therefore the 30 goats and the 2,772 chickens on UK's farm were added to catchments U2, U3, U4, and U5 based on the fraction of UK's farm land contained within each catchment. An estimate of the number of livestock in each catchment is provided in Table 3.5.

The manure on pastureland deposited by livestock (grazing cattle, horses, etc.) is washed off and delivered to larger streams through intermittent streams and surface water flows. All grazing livestock are assumed to be pastured for grazing throughout the day within a watershed area. For the purposes of modeling, the fraction of the total daily fecal load from livestock was aggregated and treated as a daily fecal load for each watershed, which then experienced build-up during dry periods and subsequent runoff during wet periods.

When not grazing, animals may be confined in stalls or other confined spaces. In such instances, any generated manure or muck is typically collected into piles (which may or may not be effectively managed) or deposited in remote parts of a farm, sometimes in sinkholes. In some instances the associated manure may be used onsite as fertilizer. In recent years, a few horse farms in the Cane Run watershed have begun composting their horse muck prior to application as fertilizer (Oldfield, 2002). For the purposes of modeling, all manure and muck associated with confined spaces were assumed to be evenly distributed over the pastureland. This provided a conservative loading estimate for each catchment.

Table 3.5 Livestock Population Estimates per Catchment (Kentucky Agricultural Statistics, 2001-2002)

Catchment	Hogs	Beef Cattle	Dairy Cattle	Chickens	Horses	Sheep	Goats
Cane Run 0.0 to 3.0							
L6	1	548	61	15	88	7	4
Cane Run 3.0 to 9.6							
L3	0	10	1	1	3	0	0
L4	0	7	1	0	2	0	0
L5	1	511	57	15	100	7	0
U6	5	326	36	19	223	2	1
U7	0	122	14	3	19	2	5
U8	1	48	5	1	8	1	0

Catchment	Hogs	Beef Cattle	Dairy Cattle	Chickens	Horses	Sheep	Goats
UT to Cane Run (at RM 6.13) 0.0 to 3.5							
L1	0	120	13	3	19	2	4
L2	0	51	6	2	12	1	0
Cane Run 9.6 to 17.4							
U1	0	32	4	2	30	0	0
U2	2	130	14	241	122	1	3
U3	8	216	24	940	202	1	11
U4	7	165	18	1398	154	0	15
U5	5	43	5	234	40	0	4
Royal Spring							
K3	1	69	8	2	11	1	0

3.2.3 Livestock Instream Sources

Cattle stand in streams to lose excess heat, especially when no shade is available; therefore instream fecal sources include direct deposition of manure, and manure from overland flow and intermittent streams. The land slopes, geographic terrain, and topography of the Cane Run watershed are such that cattle can access the intermittent streams that run through the pastureland within a watershed area. For the purposes of modeling it was assumed that grazing cattle spend 2.2% of their time standing in the stream (EPA, 2002b). For modeling purposes, the total estimated number of stream deposits was aggregated and treated as a single source for each stream reach modeled in the analysis.

3.2.4 Urban Runoff from Developed Land

Analysis using BASINS 3.1 indicates approximately 24% of the total watershed landcover is developed. Urban fecal loading consists of loadings from domestic animals and other sources. The number of acres for various developed landcovers per catchment is provided in Table 1.3. Specific loadings for each catchment were obtained using the EPA Bacterial Indicator Tool (EPA, 2001a).

Although runoff from developed land was modeled as a nonpoint source, the loading to the streams needed to be divided between MS4 areas and non-MS4 areas, as loading from developed MS4 areas belongs in the WLA, and loading from developed non-MS4 areas belongs in the LA. MS4s are KPDES-permitted sources which are defined in 401 KAR 5:002. EPA has categorized MS4s into three categories: small, medium, and large. The medium and large categories are regulated under the Phase I Storm Water program. Large systems, such as the cities of Lexington and Louisville, have populations in excess of 250,000. Medium systems have populations in excess of 100,000 but less than 250,000; however, there are currently no medium-sized systems in Kentucky. Phase I systems have five-year permitting cycles and have annual reporting requirements. The small MS4 category includes all MS4s not covered under Phase I. Since this category covers a large number of systems, only a select group are regulated under the

Phase II rule, either being automatically included based on population (i.e., having a total population over 10,000 or a population per square mile in excess of 1000) or on a case-by-case basis due to the potential to cause adverse impact on surface water. Water quality monitoring is not a requirement of Phase II MS4s, unless the waterbody has an approved TMDL and the MS4 causes or contributes to the impairment for which the TMDL was written. A WLA is assigned to all MS4 permit holders, which can include cities, counties, the Kentucky Transportation Cabinet (KYTC), universities and military bases.

In the Cane Run watershed, there are three MS4 permit holders: The City of Lexington (or Lexington Fayette Urban County Government (LFUCG), Permit Number KYS000002), Georgetown (Permit Number KYG200040) and the KYTC (Permit Number KYS000003). The current boundaries of the MS4s in the Cane Run watershed are shown in Figure 3.3. KYTC does not have boundaries shown because it is responsible for the roads and right-of-ways it owns within the boundaries of other MS4 permittees. The procedure for allocating loads to MS4 and LA sources for the impaired streams is described in Section 5.1.1.

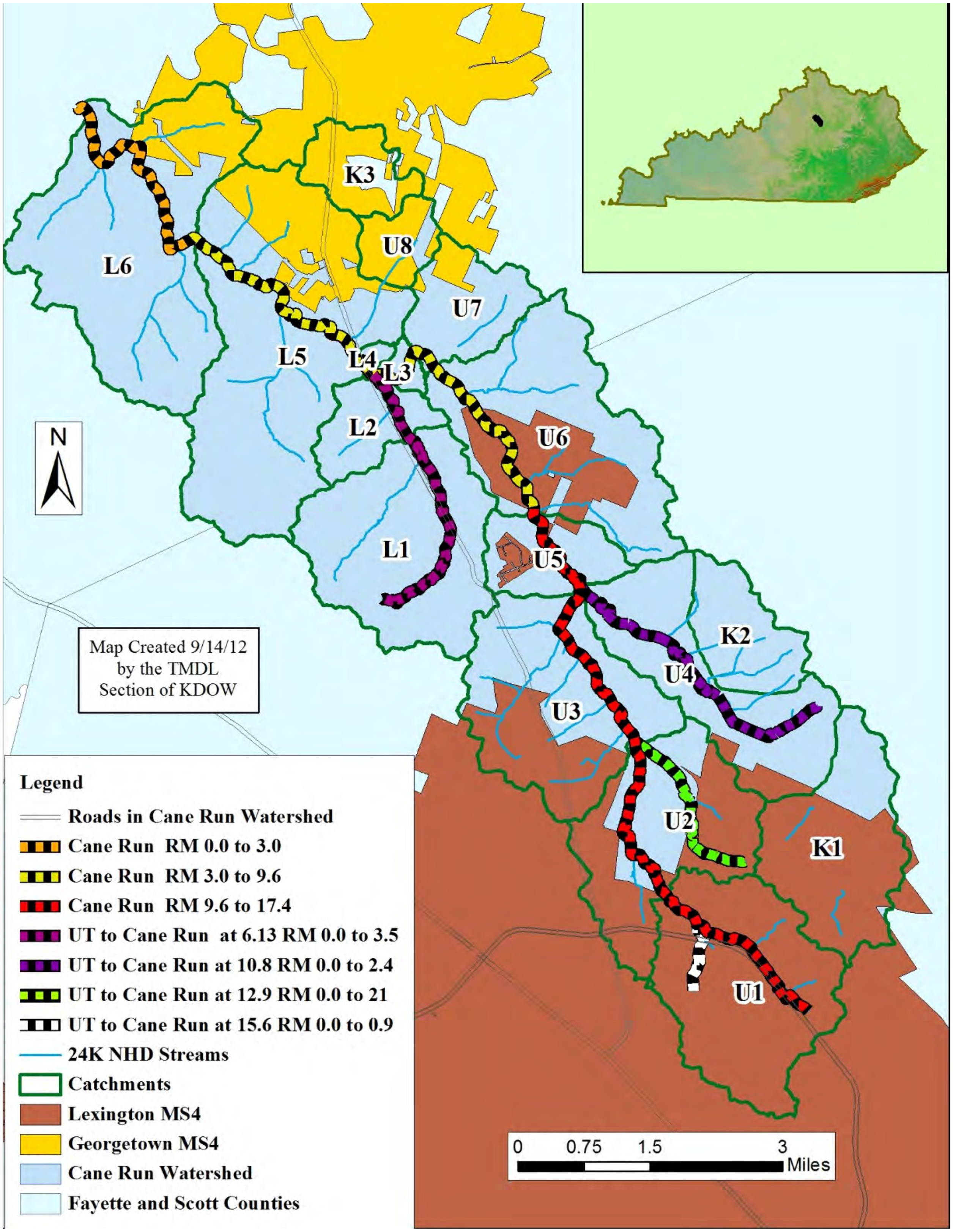

Figure 3.3 Current MS4 Boundaries in the Cane Run Watershed

4.0 MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

This Section discusses the basic TMDL terms introduced in Section 3.0 (such as the LA, WLA and MOS) as they relate to model setup (further definitions are provided in Section 5.1.1) as well as assigning pathogen loading rates to each of the sources described in Section 3.0.

4.1 Modeling Framework Selection

The model chosen for TMDL development must link the sources to the endpoint. It must therefore be able to determine the TMDL (i.e., the maximum amount of a pollutant a stream can assimilate without violating the WQC), the inputs from the various sources of that pollutant, and final loading allocations (i.e., the LA, WLA and MOS, if explicit) that will allow the impaired waterbody to meet the TMDL. The units of load measurement are typically mass of pollutant per unit time (i.e., mg/hr, lbs/day). In the case of fecal coliform, the load is typically expressed in terms of colonies/day. The link can be established though a range of techniques, from qualitative assumptions to sophisticated modeling. Ideally, the linkage is supported by monitoring data that allow the TMDL developer to associate waterbody responses to flow and loading conditions. In this section, the selection of the modeling tools, setup, and model application are discussed.

EPA guidance (2001b) allows TMDLs to be based on either steady state or dynamic water quality models. Steady state models provide predictions for only a single set of environmental conditions. For permitting purposes, steady-state models are applicable for a single "critical" environmental condition that represents an extremely low assimilative capacity. For point source discharges to riverine systems, critical environmental conditions typically correspond to low flows such as the 7Q10 (i.e., the 7-day, 10-year low flow). The assumption behind steady state modeling is that permit limits that are protective of water quality during critical conditions will be protective for the large majority of environmental conditions. However, it is often inappropriate when modeling to attempt to define a single critical stream flow for wet weather problems that is analogous to the critical (low flow) condition traditionally used with continuous point source discharges. Furthermore, even when continuous simulation is used for point source discharges, it is often still appropriate to examine the model-generated data (receiving water concentrations) in terms of frequency and duration rather than examining concentrations at a single critical flow.

Continuous simulation usually generates daily or hourly values of stream flow and pollutant concentrations. With a well-calibrated model, the simulated stream flows and pollutant concentrations should be representative of real-world conditions. Continuous simulation, as well as other dynamic modeling approaches, explicitly considers the variability in all model inputs and defines effluent limits in compliance with the associated WQC. This is achieved through selecting a critical time period for which load allocations create the most stressful situation. Thus the critical period for TMDL development corresponds to the "worst case" scenario of environmental conditions in the waterbody for which the TMDL for the pollutant will continue to satisfy the WQC (EPA, 2001b). This critical time period is also known as the Critical Condition.

4.2 Critical Period

The Critical Condition for streams impaired by nonpoint sources generally occurs during periods of wet weather and high surface runoff (especially with an antecedent dry period that allows pollutant buildup prior to the runoff event), while the Critical Condition for streams impaired by point sources generally occurs during periods of dry weather and low surface runoff. Because fecal coliform inputs are attributed to both point and nonpoint sources in the Cane Run watershed, the Critical Condition used for the modeling and evaluation of stream response was represented by a multi-year period. Ideally, a USGS flow gage within the watershed with data recorded for many years before sampling took place would be used to analyze the Critical Condition. However, there is only one USGS gauging station with flow observation from 1997 available in the Cane Run watershed, and a statistical analysis of flow showed a good correlation with flows at the South Elkhorn station at Midway (USGS gaging station ID 03289300), which has recorded flow data since 1983.

Therefore, in order to select a critical period for analysis, historical flows from the USGS South Elkhorn Creek gaging station at Midway (Station 03289300, USGS 2003b) were analyzed for the 21-year period from 1983 to 2003. For each year in the analysis period a six-month total flow is shown in Figure 4.1 along with the associated 25% and 75% flow values for all years in the dataset. The six-month total flow is the sum of the daily average flows for all days in May through October (i.e., the PCR season).

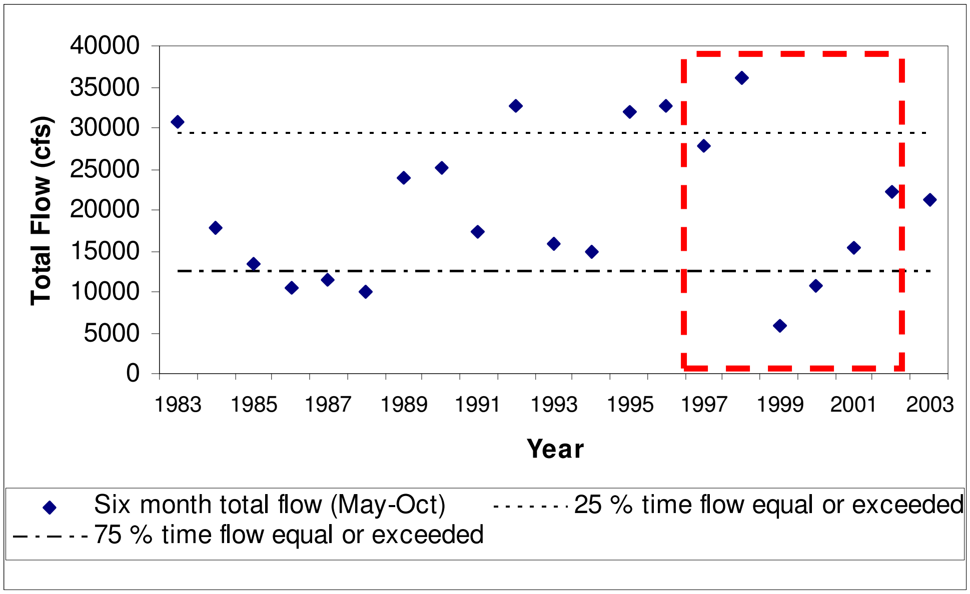

Figure 4.1 Critical Period Assessment Using South Elkhorn Creek Flow Data Observed at Midway

Instead of using the entire 21-year series, a shorter time series from 1997 to 2002 was used to develop the TMDL for Cane Run. Examination of Figure 4.1 and Table 4.1 reveals that this six-year time series captures the same basic range of flows as the 21-year series as well as the extremes of the 21-year series and thus should be sufficient for capturing a range of conditions associated with both wet and dry weather.

Table 4.1 Critical Period Assessment: Comparing Periods 1983 to 1996 and 1997 to 2002

Probability of exceedances	1983 – 1996	1997 – 2002
75%	28.6	16.7
50%	78.6	66.7
25%	42.9	50.0

4.3 Model Selection

In order to model the origin and transport of bacteria through a stream system, some type of hydrologic model is needed. In the current study, this was accomplished using the windows version of HSPF (WinHSPF, Duda, et. al., 2001) along with the BASINS Version 3.1 (EPA, 2004) modeling environment. BASINS is a multipurpose environmental analysis software system for use by regional, state and local agencies in performing watershed and water quality based studies. A Geographic Information System (GIS) provides the integrating framework for BASINS and allows for the display and analysis of a wide variety of landscape information such as landcovers, monitoring stations, point source discharges, and stream descriptions. BASINS is useful in incorporating both point and nonpoint sources, while including instream transport and visualization. BASINS also provides a data download capability which is organized using

USGS Hydrologic Unit Codes (HUCs, USGS 2004). The current version of BASINS no longer requires ArcView. Instead, the program works with the MapWindow platform which is public domain. After the initial geoprocessing through BASINS, the WinHSPF model was used to build an HSPF model for the stream system. The WinHSPF model simulates both point source and nonpoint source loads.

4.4 Model Setup

The Cane Run TMDL model includes the lowest 303(d)-listed section of the creek, as well as all the evaluated drainage areas within the entire basin. The watershed was divided into 14 catchments (plus 3 karst catchments) in an effort to isolate the major stream reaches. This subdivision allowed the relative contribution of point and nonpoint sources to be addressed within each catchment.

4.5 Point Source Representation

4.5.1 KPDES-Permitted Point Sources

KPDES-permitted sources such as SWSs were represented in the model using a total discharge and an associated fecal coliform concentration. Although a historic geometric mean was calculated for 2003 DMR data, for the purposes of modeling the permitted facilities shown in Table 3.1, a conservative fecal coliform effluent concentration of 200 colonies/100ml was assumed. This is equal to the current allowable discharge geometric mean limit but is significantly higher than historically observed values. Because the permit limit of 200 colonies/100ml is higher than historical observations, this provides an implicit MOS, see Section 4.9. Fecal coliform loadings from KPDES-permitted point sources are shown in Table 4.2. A more comprehensive presentation of SWS DMRs including measurements, numeric violations and overdue DMR reports for these facilities can be found in Appendix H.

Table 4.2 Sanitary Wastewater System Loads

Facility	KPDES Permit	Design Discharge (mgd)	2003 Historical DMR Geomean (colonies/100 ml)	Geomean Permit Limit (colonies/ 100 ml)	Modeled Loading (colonies/day)
Spindletop MHP	KY0081213	0.030	75	200	2.27E+08
Ponderosa MHP	KY0081221	0.016	10	200	1.21E+08
Maple Grove MHP	KY0083321	0.029	21	200	2.20E+08

4.5.2 Non-Permitted (Illegal) Point Sources

4.5.2.1 Failing Septic Systems and Straight Pipes

Two types of non-permitted (illegal) point sources within the watershed include failing OWTSs and straight pipes. For the purposes of modeling, the assumed daily discharge from an individual straight pipe was 200 gallons and the assumed fecal concentration was 10^6 colonies/100ml (Geldreich, E.E., 1978). The assumed daily discharge from an individual failing OWTS was 70 gallons per person with an assumed fecal coliform concentration of 10^4 colonies/100ml (Horsley & Whitten, 1996, EPA, 2001b). Using county statistics and Tiger census data, it was found that the watershed contained an estimated 1,073 septic systems with 16,469 people documented as being served by the means of septic systems (http://factfinder.census.gov). Based on these data, the loading values in the model incorporated a factor of 15.35 persons served by each failing OWTS.

For modeling purposes, the total estimated number of failing OWTSs and straight pipes was aggregated and treated as a single source for each catchment modeled in the analysis. For the purposes of this study, it was assumed that 2.5% of the OWTSs were failing (EPA, 2001a) and that 100% of those housing units with a sewage disposal characteristic of "other means" were associated with straight pipes. The resulting catchment loads for straight pipes and failing OWTSs are shown in Table 4.3.

Table 4.3 Loads from Failing OWTSs and Straight Pipes

Catchment	Failing OWTS (colonies/day)	Straight Pipes (colonies/day)	Total
Cane Run 0.0 to 3.0			
L6	1.63E+09	3.03E+10	3.19E+10
Cane Run 3.0 to 9.6			
L3	0.00E+00	7.57E+09	7.57E+09
L4	0.00E+00	7.57E+09	7.57E+09
L5	1.63E+09	2.57E+11	2.59E+11
U6	1.22E+09	2.27E+10	2.39E+10
U7	4.07E+08	6.06E+10	6.10E+10
U8	0.00E+00	2.27E+10	2.27E+10
UT to Cane Run (at RM 6.13) 0.0 to 3.5			
L1	1.22E+09	2.27E+10	2.39E+10
L2	4.07E+08	3.79E+10	3.83E+10
Cane Run 9.6 to 17.4			
U1	1.22E+09	6.06E+10	6.18E+10
U2	8.10E+08	0.00E+00	8.10E+08
U3	1.22E+09	1.51E+10	1.63E+10
U4	8.10E+08	5.30E+10	5.38E+10
U5	4.07E+08	7.57E+09	7.98E+09
Royal Spring			
K3	4.07E+08	0.00E+00	4.07E+08

4.5.2.2 Sanitary Sewer Overflows

Lexington: SSOs explain the large loads of fecal coliform observed in the headwaters sampling stations of Cane Run (i.e., sites C0 and C1) observed during UK KWRRI's 2002 wet weather sampling (see Figure 2.6 of the TMDL portion of this report). For the modeling effort, location and volume estimates documented by Lexington during 2007 and 2008 were used to reconstruct the loading from SSOs (Personal Communication, Chandramouli Viswanathan, 2011), including manholes with overflows in catchments U1, U2 and K1. Inspection of the data showed that SSOs occurred when the flow in Cane Run within catchment U1 exceeded 30 cubic feet per second (cfs), and this value was therefore used as a threshold for the initiation of SSOs.

Next it was necessary to determine the amount of flow in the Cane Run system that is available to carry SSO loads from Lexington. Simply summing the flows from the former Cane Run near Donerail gage and the Royal Springs gage is not appropriate since part of the flow at Royal Springs is from catchment K3 and other karst features that do not drain north Lexington. Thus it was necessary to determine what percentage of flow at Royal Spring is from Lexington; then, summing Lexington's karst flow to Royal Springs (underflow) plus Cane Run's stream channel flow (overflow) and in the vicinity of the USGS Cane Run near Donerail station (catchment U5) yields the total flow leaving the Lexington catchments (U1, U2 and K1), which is the flow that is available to carry SSO loads. This calculation was only performed for wet weather events; otherwise there is no overflow, since Cane Run loses 100% of its flow to the karst system in the vicinity of Donerail under base flow (i.e., non-storm flow) conditions, and also because SSOs are mostly a wet weather phenomenon and were treated as such for modeling purposes. Therefore, to determine the division between underflow and overflow, runoff curves were generated for both basins (Royal Spring underflow and surface overflow at Donerail) and the predicted runoff was determined using five storm events coupled with an area relationship between the two basins; according to best fit of these data, 55% of the flow at Royal Springs comes from Cane Run. Thus, 55% of the recorded flow at the spring's USGS gage was available to carry SSO loads from Lexington. Adding this flow to the wet weather flows at Donerail gives the total flow available to carry SSO loads.

On 12/13/2007, the 30 cfs flow value (i.e., the SSO threshold) in catchment U1 was exceeded, and both flow data at KWRRI sampling station C2 (i.e., from the USGS Gage Cane Run near Donerail) and loading data from SSOs in the upstream area of U1 were available (see Table 4.4), as were flow data from the USGS Royal Springs gage. Therefore these data were used to simulate SSOs.

To distribute this load to catchments U1, U2, K1 and K2, the flows at these catchments needed to be determined. Flow for station C2 was 235 cfs, and flow at Royal Springs was 374 cfs. Because 55% of the flow at Royal Springs is attributable to losses to the underground karst system which are not expressed surficially at C2, 55% of the flow at Royal Springs plus the flow at C2 was the total average runoff from the watershed above C2 (i.e., from Lexington) on that day, or 440.7 cfs. Disaggregating this flow based on area allowed the flow in U1 to be calculated as 73.83 cfs.

The estimated load in the upstream area of U1 from SSOs for that day was 1,420,220 gallons (by summing the SSO data in Table 4.4); multiplying this times a fecal coliform concentration of 1,000,000 colonies/100ml for untreated sewage (Geldreich, 1978) produces a total load of 5.38E+13 colonies/day. Since the flow at U1 for that day was 73.83 cfs, dividing the load by the flow produces a load for each cfs-day of 7.28E+11 colonies/cfs-day (in other words, each incremental cfs of stream flow carried an incremental load of 7.28E+11 colonies during that day). Disaggregating the total runoff from the watershed above C2 (440.7 cfs) to other modeled stream reaches in catchments U2, K1 and K2 (SSOs and excess stormflow from catchments K1 and K2 both drain to U4, so all of the SSO loading from K1 and K2 was modeled as entering the Cane Run system in catchment U4) allows the load for that day to be determined for U2 and U4 as well.

A time-series SSO loading was creating by following this procedure (multiplying the cfs in catchments U1, U2, K1 and K2 by 7.28E+11 colonies/cfs-day) for all days when runoff exceeded 30 cfs in catchment U1. It was determined that an antecedent rainfall of 0.5 inches (recorded at the UK Agricultural Weather Center precipitation gage at Spindletop Farm, located in Catchment U5, http://wwwagwx.ca.uky.edu/data.shtml) was needed on dry days to produce SSOs, although if prior rainfalls had elevated the soil moisture content, a value as low as 0.3 inches of precipitation could initiate SSOs.

Table 4.5 shows the average daily load from SSOs by catchment which was extracted from the time-series loading from 1997-2006 (this range was selected because it is the same as the range of the model runs shown in Appendices C and D). Of course, SSOs did not occur on a majority of days; these values are provided to illustrate the magnitude of SSO loadings relative to other sources in the watershed, whose loading figures are provided in terms of colonies/day in other tables in Section 4.0. Figure 4.2 shows the daily average SSO loading by year for all catchments combined compared to the annual rainfall for 1997 through 2006.

Georgetown: While Lexington is a known source of SSOs, it is also possible that SSOs also occurred from the City of Georgetown, which has sewer and storm sewer infrastructure present in catchments L5, L6 and U8; if SSOs were present in the Georgetown portion of the watershed during the 2002 UK KWRRI sampling, this could explain or partly explain the rise in fecal coliform levels at UK KWRRI sampling sites C6 and C7 (see Figure 2.6 of the TMDL portion of this report): While the levels at C6 and C7 are not as high as those at sites C0 and C1 (which show large loads coming from the headwaters (Lexington) portion of the watershed), nevertheless there is an increase above that of sites C3, C4 and C5, which lie between Lexington's sewer infrastructure and Georgetown's. Therefore KDOW queried the Not/Com (Notification and Complaints) database and TEMPO database for wastewater releases: TEMPO replaced Not/Com in late 2002 as the Kentucky Department for Environmental Protection's (KDEP's) incident database. While it is not always possible to extract location information from Not/Com as latitude/longitude information was not routinely entered, TEMPO does routinely record these location data.

For the 2002 UK KWRRI sampling period, Not/Com recorded SSOs to North Elkhorn Creek and Eagle Creek, but not to Cane Run; therefore the increases in fecal coliform levels at sites C6 and

C7 may be due to other sources, possibly including other urban runoff. Of course, it is always possible that undocumented SSO releases occurred, or that a SSO listed as entering North Elkhorn Creek did so after first entering Cane Run. TEMPO returned six SSO reports in the Georgetown portion of the Cane Run watershed from 2002 through 2010, see Table 4.6. However, these releases were smaller and less frequent than those known to occur in Lexington; therefore, the SSO modeling was confined to the Lexington sewer infrastructure.

Table 4.4 12/13/07 SSO Reports in Catchment U1

Overflow Source	Estimated Release (gallons)	Address
Manhole ID#CR4_14	9,000	1502 Russell Cave Rd.
Manhole ID#CR4_15	9,000	1502 Russell Cave Rd.
Sharon Village Pump Station	133,320	1985 Haggard Ct.
Thoroughbred Acres Pump Station	524,800	619 Parkside Dr.
Lower Cane Run Pump Station	738,100	1760 McGrathiana Pky
Winburn Pump Station	6,000	1985 Russell Cave Rd.

Table 4.5 SSO Loads by Catchment

Catchment(s)	SSO Load (colonies/day)
U1	3.17E+12
K1+K2+U4	5.34E+12
U2	2.59E+12

Table 4.6 Georgetown SSO Reports

Date	Incident Description
12/19/2002	Bypass from Pump Station 20 (Southgate); 60,000 gallons.
2/15/2006	Overflow at privately owned grinder pump stations located behind businesses along US 25 near the US 460 bypass; 200-300 gallons.
2/6/2008	Bypass due to rain event at Spindletop MHP; reported as stormwater only, no solids.
3/23/2008	Report of sewer overflows, clogged sewer lines, SSO from manholes, Ponderosa MHP bypassing, similar issues at Spindletop MHP.
5/2/2010	Manhole overflow at the Spindletop MHP; 200 GPM tapering to 75 GPM, 5/2/10-5/4/10.
9/13/2010	Overflow at privately owned grinder pump stations located behind businesses along US 25 near the US 460 bypass.

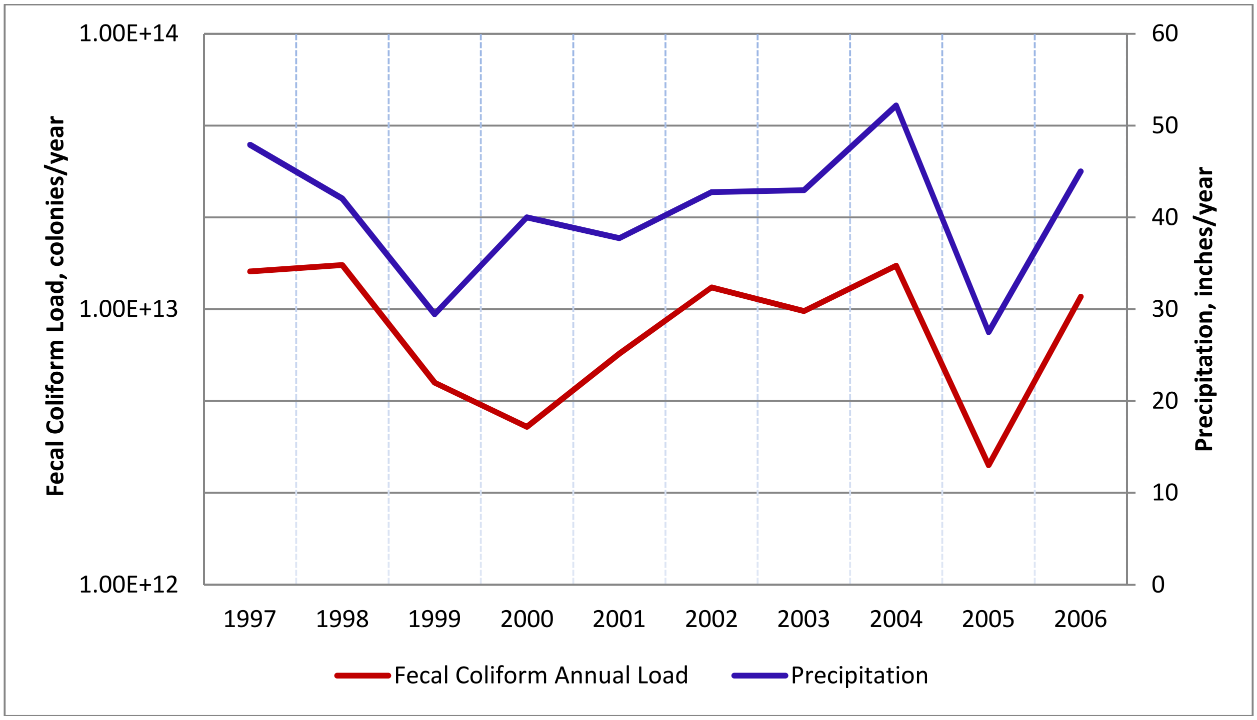

Figure 4.2 Modeled SSO Loads and Precipitation for the Cane Run Watershed, 1997-2006

4.6 Nonpoint Source Representation

Several different types of nonpoint sources of fecal coliform were considered in the model. These included instream loads from livestock, loads from grazing livestock, land application of manure from dairy cattle, wildlife, and urban areas. The BIT was used to estimate loads as a function of both physical and demographic data associated with each catchment. Separate unit loading factors were determined for the major nonpoint source categories which were then aggregated into a total unit load per catchment. When modeling sources which deposit fecal matter on the land surface, the maximum storage of fecal coliform bacteria was approximated at 1.8 times the daily deposition rate (Horsley and Witten, 1996).

4.6.1 Wildlife

In Section 3.2.1, the estimated wildlife population in the Cane Run watershed was determined. Fecal loading rates from ducks, geese, deer, beaver, and raccoons are shown in Table 4.7 based on the American Society of Agricultural Engineers (ASAE, 1998), the Long Island Regional Planning Board (LIRPB, 1998), and best professional judgment as per the BIT (EPA, 2001a). The total wildlife load in each catchment was calculated by multiplying the population of each animal in Table 3.4 by the animal's unit loading in Table 4.7 and aggregating these values by catchment. The total wildlife load for each catchment is shown in Table 4.8.

Table 4.7 Wildlife Unit Fecal Load

Fecal Coliform (colonies/animal/day)	
Duck	2.43E+09
Goose	4.90E+10
Deer	5.00E+08
Beaver	2.50E+08
Raccoon	1.25E+08

Table 4.8 Wildlife Loads (colonies/day)

Catchment	Ducks	Geese	Deer	Beavers	Raccoons	Total
Cane Run 0.0 to 3.0						
L6	1.36E+11	1.37E+12	1.40E+10	1.50E+09	3.50E+09	1.53E+12
Cane Run 3.0 to 9.6						
L3	4.86E+09	4.90E+10	5.00E+08	0.00E+00	1.25E+08	5.45E+10
L4	2.43E+09	4.90E+10	5.00E+08	0.00E+00	1.25E+08	5.21E+10
L5	1.48E+11	1.52E+12	1.55E+10	1.50E+09	3.88E+09	1.69E+12
U6	8.99E+10	8.82E+11	9.00E+09	1.00E+09	2.25E+09	9.84E+11
U7	3.16E+10	2.94E+11	3.00E+09	2.50E+08	7.50E+08	3.30E+11
U8	1.22E+10	1.47E+11	1.50E+09	2.50E+08	3.75E+08	1.61E+11
UT to Cane Run (at RM 6.13) 0.0 to 3.5						
L1	8.51E+10	8.33E+11	8.50E+09	7.50E+08	2.13E+09	9.29E+11
L2	1.94E+10	1.96E+11	2.00E+09	2.50E+08	5.00E+08	2.18E+11
Cane Run 9.6 to 17.4						
U1	1.22E+10	1.47E+11	1.50E+09	2.50E+08	3.75E+08	1.61E+11
U2	5.10E+10	4.90E+11	5.00E+09	5.00E+08	1.25E+09	5.48E+11
U3	8.51E+10	8.33E+11	8.50E+09	7.50E+08	2.13E+09	9.29E+11
U4	6.56E+10	6.37E+11	6.50E+09	7.50E+08	1.63E+09	7.11E+11
U5	1.70E+10	1.47E+11	1.50E+09	2.50E+08	3.75E+08	1.66E+11
Royal Spring						
K3	7.29E+09	4.90E+10	5.00E+08	0.00E+00	1.25E+08	5.69E+10

4.6.2 Land Application of Manure

There are no permitted Concentrated Animal Feeding Operations (CAFOs, as defined by 40 CFR 122.23(b)) in the Cane Run watershed. Nonetheless, small confined feeding operations are present. Application of waste produced by animals such as hogs, cattle, chickens, and horses during confinement is applied as manure in agriculture and pasture lands. The application of manure for different animals is handled using the BIT (EPA, 2001a), which gives the loading parameters shown in Table 4.9 (ASAE, 1998; LIRPB, 1978; Metcalf and Eddy, 1991; NCSU, 1994). The fecal load produced by a given animal due to manure application can be estimated by the product of the number of animals, the animal's fecal production rate, the fraction of time the animal is confined, and the fraction of applied manure that becomes available for runoff, see Table 4.9. The loads for each kind of animal in each catchment are shown in Table 4.10.

Table 4.9 Livestock Load Parameters

	Hog	Beef Cow	Dairy Cow	Chicken	Horse	Sheep	Goat
Fraction of Applied Manure Available For Runoff	0.600	0.625	0.625	0.360	0.625	N/A	N/A
Average Fraction of Time Animal is Confined	1.0	0.3	1.0	1.0	0.2	0.0	0.0
Average Fraction of Time Animal is in Pasture	0.0	0.7	0.0	0.0	0.8	1.0	1.0
Animal Fecal Unit Load (colonies/day)	8.90E+09	3.75E+09	3.75E+09	1.36E+08	4.18E+08	1.20E+10	1.20E+10

Table 4.10 Confined Livestock Loads (Land Application of Manure, colonies/day)

Catchment	Hogs	Beef Cattle	Dairy Cattle	Chickens	Horses	Total
Cane Run 0.0 to 3.0						
L6	5.34E+09	3.85E+11	1.43E+11	7.34E+08	4.60E+09	5.39E+11
Cane Run 3.0 to 9.6						
L3	0.00E+00	7.03E+09	2.34E+09	4.90E+07	1.57E+08	9.58E+09
L4	0.00E+00	4.92E+09	2.34E+09	0.00E+00	1.04E+08	7.36E+09
L5	5.34E+09	3.59E+11	1.34E+11	7.34E+08	5.22E+09	5.04E+11
U6	2.67E+10	2.29E+11	8.44E+10	9.30E+08	1.16E+10	3.53E+11
U7	0.00E+00	8.58E+10	3.28E+10	1.47E+08	9.92E+08	1.20E+11
U8	5.34E+09	3.37E+10	1.17E+10	4.90E+07	4.18E+08	5.12E+10
UT to Cane Run (at RM 6.13) 0.0 to 3.5						
L1	0.00E+00	8.44E+10	3.05E+10	1.47E+08	9.92E+08	1.16E+11
L2	0.00E+00	3.58E+10	1.41E+10	9.79E+07	6.27E+08	5.06E+10
Cane Run 9.6 to 17.4						
U1	0.00E+00	2.25E+10	9.37E+09	9.79E+07	1.57E+09	3.35E+10

Catchment	Hogs	Beef Cattle	Dairy Cattle	Chickens	Horses	Total
U2	1.07E+10	9.14E+10	3.28E+10	1.18E+10	6.37E+09	1.53E+11
U3	4.27E+10	1.52E+11	5.62E+10	4.60E+10	1.05E+10	3.07E+11
U4	3.74E+10	1.16E+11	4.22E+10	6.84E+10	8.04E+09	2.72E+11
U5	2.67E+10	3.02E+10	1.17E+10	1.15E+10	2.09E+09	8.22E+10
Royal Spring						
K3	5.34E+09	4.85E+10	1.87E+10	9.79E+07	5.74E+08	7.32E+10

4.6.3 Grazing Livestock (Including Cattle in Streams)

The model assumes that the manure produced by grazing livestock is evenly spread on pastureland throughout the year. The number of livestock per county is based upon the 2001-2002 Census of Agriculture data from KASS. This county livestock count was used to estimate the number of livestock on a catchment scale by multiplying the county livestock figures by the area of the county within the catchment boundaries. This assumes livestock are uniformly distributed throughout the county.

The associated fecal loadings for different kinds of livestock (i.e., cattle, horses, etc.) were obtained using the BIT (EPA, 2001a). Beef cattle were assumed to spend 97.8 % of their unconfined time grazing in pasture while spending the remaining 2.2% of their unconfined time in the streams. Therefore the fecal load from beef cattle due to their time grazing in pasture is the product of the number of beef cattle, the fecal production rate of beef cattle, and the fraction of time beef cattle are unconfined times 0.978. The fecal load from beef cattle in streams is the product of the number of beef cattle, the fecal production rate of beef cattle, and the fraction of time beef cattle are unconfined times 0.022. Other livestock animals are assumed not to be in the streams and therefore their load is not divided between grazing time and instream time.

The loads due to the unconfined time of livestock are shown below in Table 4.11; this includes both grazing and instream time. Table 4.12 shows the grazing and instream loads separated. Table 4.13 shows the total of all livestock loads (confined loads (i.e., manure) plus unconfined loads (i.e., grazing and instream loads)).

Table 4.11 Unconfined Livestock Loads (Grazing Plus Instream Loads, colonies/day)

Catchment	Horses Grazing	Sheep Grazing	Goats Grazing	Beef Cattle Grazing	Beef Cattle Instream	Total
Cane Run 0.0 to 3.0						
L6	2.94E+10	8.40E+10	4.80E+10	1.41E+12	3.16E+10	1.60E+12
Cane Run 3.0 to 9.6						
L3	1.00E+09	0.00E+00	0.00E+00	2.57E+10	5.77E+08	2.73E+10
L4	6.68E+08	0.00E+00	0.00E+00	1.80E+10	4.04E+08	1.91E+10

Catchment	Horses Grazing	Sheep Grazing	Goats Grazing	Beef Cattle Grazing	Beef Cattle Instream	Total
L5	3.34E+10	8.40E+10	0.00E+00	1.31E+12	2.95E+10	1.46E+12
U6	7.45E+10	2.40E+10	1.20E+10	8.37E+11	1.88E+10	9.66E+11
U7	6.35E+09	2.40E+10	6.00E+10	3.13E+11	7.04E+09	4.10E+11
U8	2.67E+09	1.20E+10	0.00E+00	1.23E+11	2.77E+09	1.40E+11
UT to Cane Run (at RM 6.13) 0.0 to 3.5						
L1	6.35E+09	2.40E+10	4.80E+10	3.08E+11	6.93E+09	3.93E+11
L2	4.01E+09	1.20E+10	0.00E+00	1.31E+11	2.94E+09	1.50E+11
Cane Run 9.6 to 17.4						
U1	1.00E+10	0.00E+00	0.00E+00	8.21E+10	1.85E+09	9.40E+10
U2	4.08E+10	1.20E+10	3.60E+10	3.34E+11	7.51E+09	4.30E+11
U3	6.75E+10	1.20E+10	1.32E+11	5.54E+11	1.25E+10	7.78E+11
U4	5.15E+10	0.00E+00	1.80E+11	4.24E+11	9.53E+09	6.77E+11
U5	1.34E+10	0.00E+00	4.80E+10	1.10E+11	2.48E+09	1.74E+11
Royal Spring						
K3	3.68E+09	1.20E+10	0.00E+00	1.77E+11	3.98E+09	1.97E+11

Table 4.12 Breakdown of Unconfined Loads (Grazing vs. Instream)

Catchment	Total	Grazing	Instream
Cane Run 0.0 to 3.0			
L6	1.60E+12	1.57E+12	3.16E+10
Cane Run 3.0 to 9.6			
L3	2.73E+10	2.67E+10	5.77E+08
L4	1.91E+10	1.87E+10	4.04E+08
L5	1.46E+12	1.43E+12	2.95E+10
U6	9.66E+11	9.48E+11	1.88E+10
U7	4.10E+11	4.03E+11	7.04E+09
U8	1.40E+11	1.38E+11	2.77E+09
UT to Cane Run (at RM 6.13) 0.0 to 3.5			
L1	3.93E+11	3.86E+11	6.93E+09
L2	1.50E+11	1.47E+11	2.94E+09
Cane Run 9.6 to 17.4			

Catchment	Total	Grazing	Instream
U1	9.40E+10	9.21E+10	1.85E+09
U2	4.30E+11	4.23E+11	7.51E+09
U3	7.78E+11	7.66E+11	1.25E+10
U4	6.77E+11	6.68E+11	9.53E+09
U5	1.74E+11	1.71E+11	2.48E+09
Royal Spring			
K3	1.97E+11	1.93E+11	3.98E+09

Table 4.13 Total Livestock Loads (Manure Plus Grazing and Instream Cattle, colonies/day)

Catchment	Confined Total	Unconfined Total	Total
Cane Run 0.0 to 3.0			
L6	5.39E+11	1.60E+12	2.14E+12
Cane Run 3.0 to 9.6			
L3	9.58E+09	2.73E+10	3.69E+10
L4	7.36E+09	1.91E+10	2.64E+10
L5	5.04E+11	1.46E+12	1.96E+12
U6	3.53E+11	9.66E+11	1.32E+12
U7	1.20E+11	4.10E+11	5.30E+11
U8	5.12E+10	1.40E+11	1.92E+11
UT to Cane Run (at RM 6.13) 0.0 to 3.5			
L1	1.16E+11	3.93E+11	5.09E+11
L2	5.06E+10	1.50E+11	2.01E+11
Cane Run 9.6 to 17.4			
U1	3.35E+10	9.40E+10	1.27E+11
U2	1.53E+11	4.30E+11	5.83E+11
U3	3.07E+11	7.78E+11	1.09E+12
U4	2.72E+11	6.77E+11	9.49E+11
U5	8.22E+10	1.74E+11	2.56E+11
Royal Spring			
K3	7.32E+10	1.97E+11	2.70E+11

4.6.4 Developed Landcover

Analysis using BASINS 3.1 shows the Cane Run watershed includes approximately 24% urban landcover, including the KPDES-permitted MS4 areas. In the model, fecal coliform from sources such as domestic pets in the urban area are assumed to build up during dry periods and then wash off during wet periods. For the purposes of this TMDL, fecal coliform buildup rates for urban areas were determined using EPA's BIT (EPA, 2001a), which references Horner (1992). For fecal modeling, the urban buildup area is classified into four groups, which are 1) commercial and services, 2) mixed urban or build-up, 3) residential and 4) transportation-communication-utilities. The fecal accumulation rates for each group are provided in Table 4.14. The fecal loads from developed landcover in a catchment can be estimated by summing the products of the number of acres for each urban landcover and its fecal loading rate. The resulting loads for each catchment are shown in Table 4.15.

Table 4.14 Developed Landcover Unit Fecal Loads (Horner, 1992)

Developed Landcover	Fecal Load (colonies/acre/day)
Commercial/Services	6.21E+06
Mixed Developed	1.13E+07
Residential	1.67E+07
Trans/Comm/Util	2.00E+05

Table 4.15 Developed Land Loads

Catchment	Commercial and Services	Mixed Urban	Residential	Trans, Comm, Util	Total
Cane Run 0.0 to 3.0					
L6	0.00E+00	0.00E+00	3.94E+09	0.00E+00	3.94E+09
Cane Run 3.0 to 9.6					
L3	1.24E+07	1.13E+07	6.68E+07	8.00E+5	9.15E+07
L4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
L5	7.02E+08	0.00E+00	3.19E+09	2.60E+07	3.92E+09
U6	2.17E+09	0.00E+00	1.94E+09	2.32E+07	4.13E+09
U7	0.00E+00	0.00E+00	3.17E+08	1.52E+07	3.32E+08
U8	6.83E+07	0.00E+00	3.17E+08	2.60E+06	3.88E+08
UT to Cane Run (at RM 6.13) 0.0 to 3.5					
L1	0.00E+00	0.00E+00	1.27E+09	6.08E+07	1.33E+09
L2	0.00E+00	0.00E+00	1.92E+09	0.00E+00	1.92E+09
Cane Run 9.6 to 17.4					
U1	1.86E+09	5.72E+09	2.34E+10	1.84E+07	3.10E+10
U2	9.07E+08	7.35E+08	4.74E+09	6.34E+07	6.45E+09
U3	7.76E+08	0.00E+00	1.42E+09	2.56E+07	2.22E+09

Catchment	Commercial and Services	Mixed Urban	Residential	Trans, Comm, Util	Total
U4	1.06E+08	1.81E+08	2.39E+09	2.80E+06	2.68E+09
U5	0.00E+00	0.00E+00	2.14E+09	4.56E+07	2.19E+09
Royal Spring					
K3	0.00E+00	0.00E+00	7.65E+09	0.00E+00	7.65E+09

4.7 Model Calibration Process

Before using the WinHSPF model for determination of the loading to the Cane Run watershed as well as the magnitude and distribution of the associated load reductions, the computer model was calibrated for hydrology and water quality. The outlet points of the catchments were determined using a 10-meter resolution Digital Elevation Model (DEM) dataset provided by BASINS. The general modeling process is illustrated in Figure 4.3.

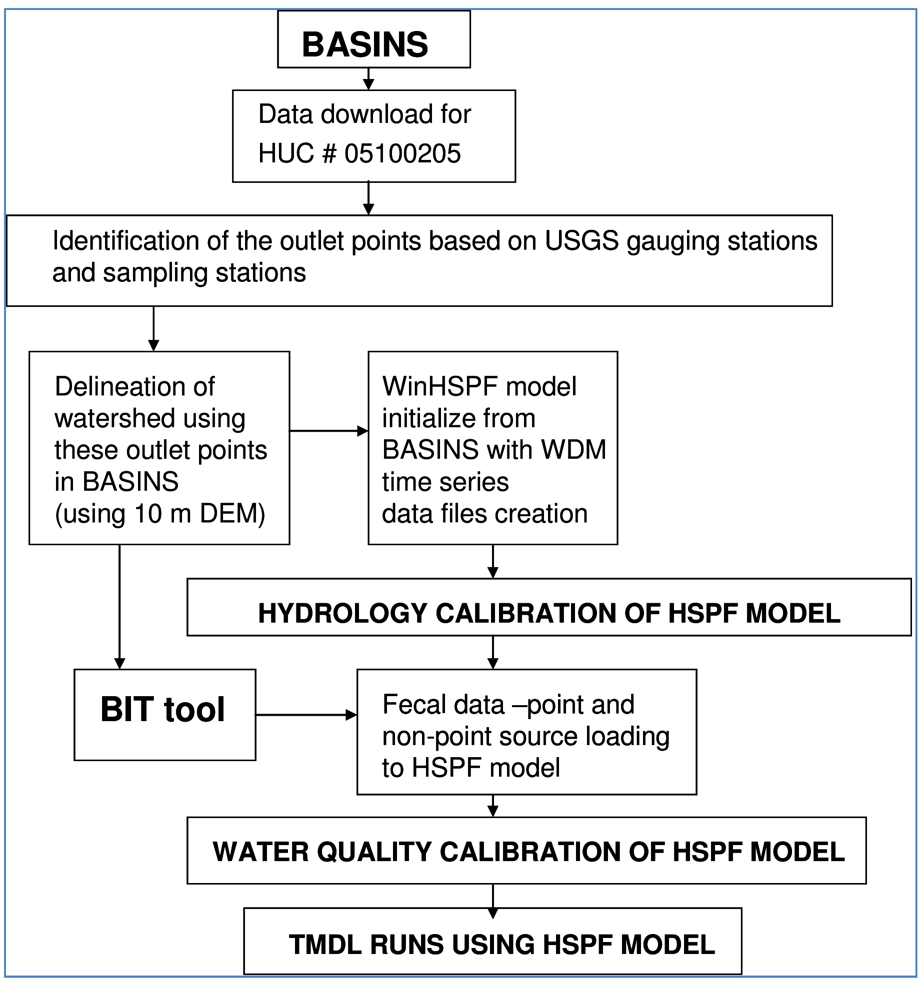

Figure 4.3 Overall Modeling Process

4.7.1 Cane Run Watershed Modeling: Basic Assumptions

Under normal flow conditions, all of the runoff from the upper part of the watershed is diverted from the lower part of the watershed through one of three different karst systems, the underflow of the mainstem of Cane Run to Royal Spring in Georgetown, and the drainage into an adjacent watershed from catchments K1 and K2 (see Figure 4.4 and 4.5). The most significant diversion is associated with the groundwater recharge area that discharges to Royal Spring. Based on observed flow data at the former USGS gauging station at Berea Road (Cane Run near Donerail, which is in the same location as UK KWRRI sampling site C2), all groundwater and storm water flows upstream of the station are diverted except during periods of high rainfall, when part of the flow appears to bypass the karst features (most likely due to surcharging) and then continue to flow downstream of the station.

In order to properly model the karst aquifer conditions in the Cane Run watershed, detailed karst flow data would be required. The groundwater flow paths within the watershed have been previously identified through dye trace vector studies and current research is underway to better characterize the main karst conduit in the watershed; however, detailed flows through the individual sinkholes are not currently monitored, and hence not available for modeling. As a result, the daily discharges measured at three USGS gauging stations (USGS 03288200 on Cane Run near Donerail, USGS 03288110 at Royal Spring, Georgetown, and USGS 03288100 on North Elkhorn at Georgetown) are the only long-term flow observations available to model the Cane Run watershed's hydrology.

For the purposes of modeling the karst flow within the watershed, two separate HSPF models were developed. The flows measured at USGS station 03288110 (Royal Spring) were assumed to reflect karst contributions from catchments U1-U8 and K3. Catchments K1 and K2 were assumed to drain into the adjacent portion of the North Elkhorn Creek watershed (i.e., out of the Cane Run watershed). The flows measured at the former USGS station 03288200 (Cane Run near Donerail, at sampling site C2) were assumed to reflect surface water contributions from catchments U1-U5 during high rainfall events. Estimates of additional surface water contributions from U6-U8 were generated by multiplying the flows at USGS station 03288200 by a ratio equivalent to the sum of the areas of catchments U6-U8 divided by the sum of the areas of catchments U1-U5. Estimates of surface water flows from catchments L1-L6 were obtained using USGS station 03288100 (North Elkhorn at Georgetown).

4.7.2 Hydrologic Calibration

The hydrologic calibration for Cane Run Watershed was accomplished in two steps: 1) the part of Cane Run above RM 6.8 calibration, followed by 2) the part of Cane Run below RM 6.8 calibration.

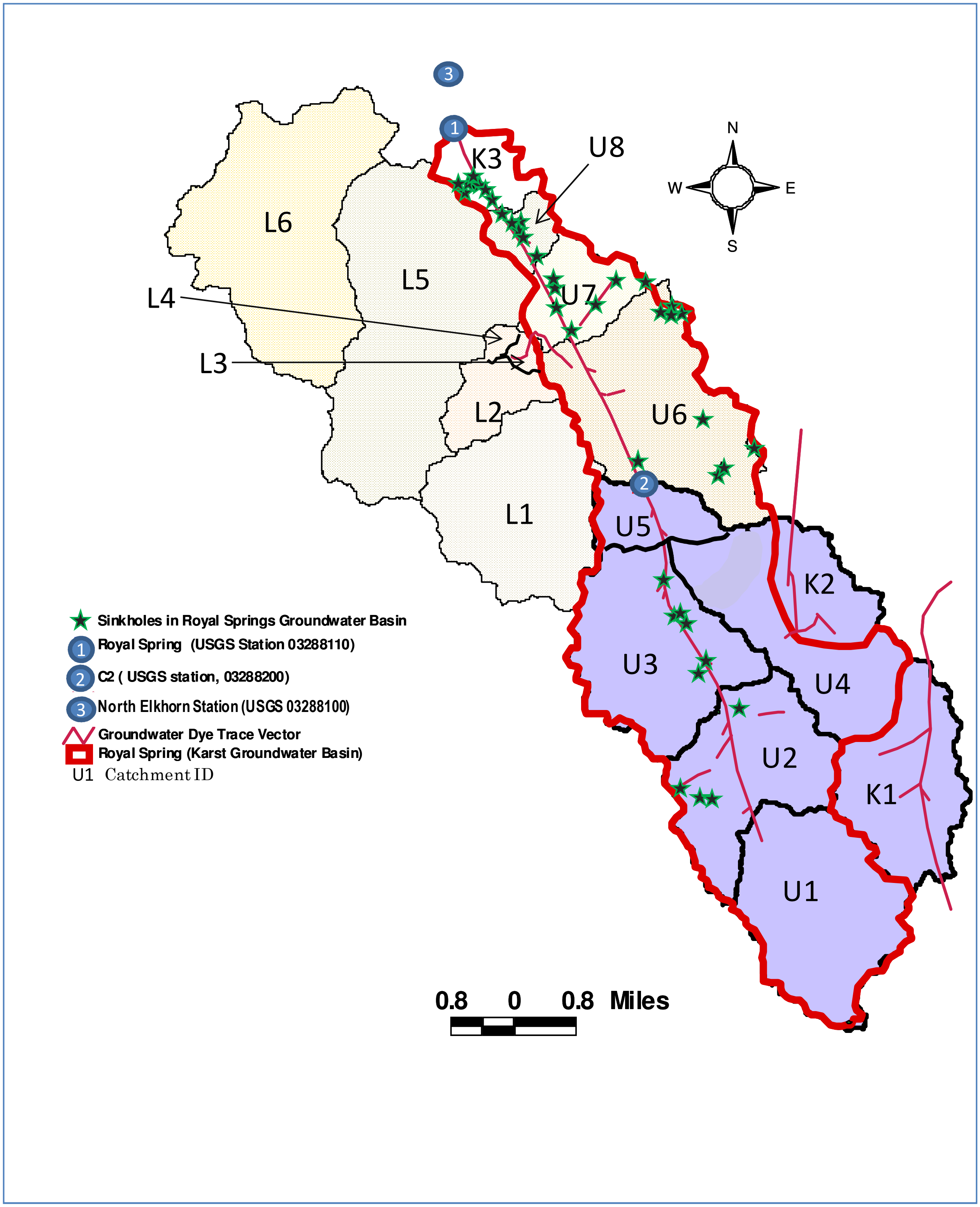

Figure 4.4 Cane Run Surface Water and Royal Springs Ground Water Basins

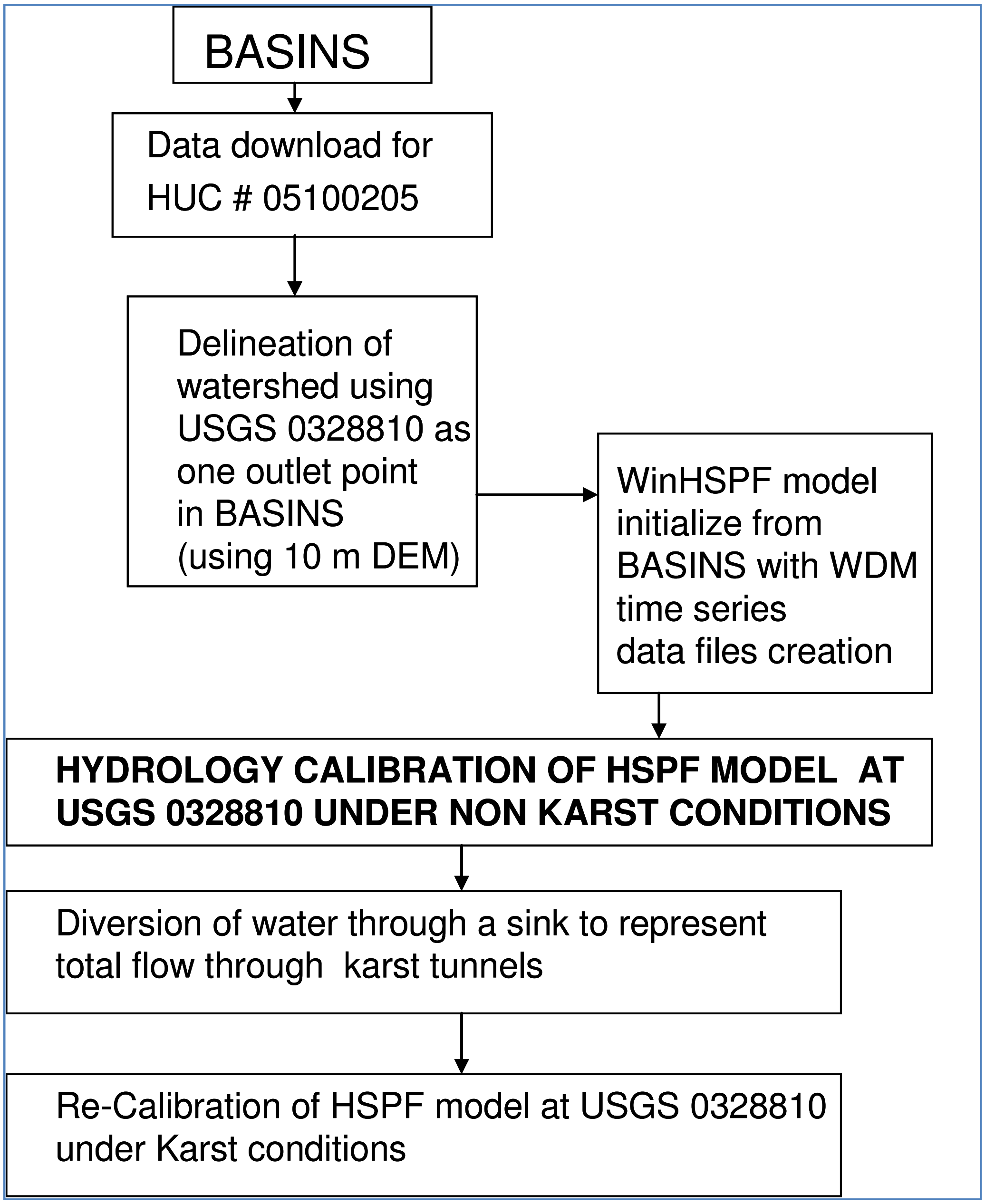

Figure 4.5 Hydrology Calibration for Cane Run Model for Non-Karst and Karst Conditions

4.7.2.1 Upper Basin Calibration (Cane Run above RM 6.8)

In the first step, a HSPF computer model was developed for the upper part of the Cane Run watershed (i.e., catchments U1-U8) as well as catchment K3, which was used to account for the flow to Royal Spring. This model was calibrated using the karst flows obtained from the Royal Spring gaging station plus the estimated surface water flows from catchments U1-U8. The latter flows were obtained using the surface water flows observed at the former USGS Station USGS 03288200 (Cane Run near Donerail, at sampling cite C2) which were then adjusted to account for additional surface water flows from basins U6-U8 as discussed previously. Because the two upper karst catchments (i.e., K1 and K2) normally divert flows into the adjacent portion of the North Elkhorn Creek watershed, the area associated with these catchments was not included as part of the hydrologic model calibration. However, since the fecal loads associated with the homes in K1 and K2 are pumped via force mains and the potential exists for such wasteloads to contribute to stream impairments through SSOs, fecal loads associated with catchments K1 and K2 were included in the water quality calibration of the model, see Section 4.5.2.2.

The hydrologic calibration for the upper basin involved initial estimates and subsequent adjustment of the appropriate HSPF model parameters such as infiltration index capacity (INFILT), lower zone evapotranspiration parameter (LZETP), lower zone soil moisture storage (LZSN), fraction of groundwater flow to deep recharge (DEEPFR), etc., as described in BASINS Technical Note 6 Estimating Hydrology and Hydraulic Parameters for HSPF (EPA, 2000) to reproduce the observed streamflow at USGS station 03288110 (Royal Springs) plus the area ratio-adjusted flows from USGS gaging station 03288200 (Cane Run near Donerail). Daily rainfall data from the Spindletop meteorological station were used to represent rainfall in the watershed. The daily rainfall data were then disaggregated to hourly data using the hourly rainfall data obtained from the regional National Oceanic and Atmospheric Administration (NOAA, 2002) weather station at the Bluegrass Airport in Lexington. The hydrologic calibration was performed using observed streamflow values from 1997 to 2002.

Observed flow hydrographs and simulated flow hydrographs were compared on each simulation and the essential parameters were tuned in different trials. The best-tuned hydrologic model was used for TMDL modeling. Summary comparisons are provided for the Royal Spring USGS gaging station using a plot of the residual series (i.e., a graph of the simulated minus the observed stream flows plotted as points), a flow duration curve and a visualization of the deviation of the annual volumes (a bar graph of the predicted annual stream flows minus the observed annual flows), see Figures 4.6 through 4.8. In general, the residual plot reveals the absence of model bias. The annual volume deviation plot reveals the absence of any persistent model bias. The hydrologic model showed good calibration, as determined by a mean annual volumetric deviation less than 10% and a maximum observed deviation of 15% in 2004.

Plots of the observed and calibrated hydrographs, as well as scatter diagrams for each year of the simulation period, are shown in Appendix B. The predicted hydrographs matched the observed hydrographs fairly closely. In addition, the best-fit line through the scatter plots yielded a line with a fairly high correlation coefficient for most years, as well as a slope fairly close to one. The latter observation confirms that the resulting calibration is fairly free of any model parameter bias as a function of the magnitude of the flows.

4.7.2.2 Lower Basin Calibration (Cane Run below RM 6.8)

Once the upper watershed model was calibrated, the model parameters associated with catchments L1-L6 were then obtained. This was accomplished by first estimating the surface runoff associated with these catchments. This was done by apportioning a fraction of the observed flows at USGS Station 03288100 (North Elkhorn at Georgetown) equivalent to the ratio of the sum of the areas of catchments L1-L6 to the total watershed area upstream of USGS Station 03288100.

The hydrologic calibration for the lower basin involved initial estimates and subsequent adjustment of the appropriate HSPF model parameters such as infiltration index capacity (INFILT), lower zone evapotranspiration parameter (LZETP), lower zone soil moisture storage (LZSN), fraction of groundwater flow to deep recharge (DEEPFR) etc., as described in BASINS Technical Note 6 Estimating Hydrology and Hydraulic Parameters for HSPF (EPA, 2000) to reproduce the apportioned fraction of the observed streamflow at USGS station 03288100. Daily rainfall data from the Spindletop meteorological station were used to represent rainfall in the watershed. The daily rainfall data were then disaggregated to hourly data using the hourly rainfall data obtained from the regional NOAA weather station at the Bluegrass Airport in Lexington. The hydrologic calibration was performed using observed streamflow values from 1997 to 2002.

Observed flow hydrographs and simulated flow hydrographs were compared on each simulation and the essential parameters were tuned in different trials (the best-tuned hydrologic model was used for TMDL modeling). Comparisons between the observed and predicted values at the outlet of Cane Run watershed as synthesized from the flows at USGS gaging station 03288100 (North Elkhorn at Georgetown) are provided in Figures 4.9 through 4.11, including a plot of the residual series, a flow duration curve, and a visualization of the deviation of the annual volumes. In general, the residual plot reveals the absence of model bias. The annual volume deviation plot reveals the absence of any persistent model bias; the calibration was good, with a mean annual volumetric deviation of 10% and a maximum observed deviation of 15% in 2003.

Plots of the observed and calibrated hydrographs, as well as scatter diagrams for each year of the simulation period, are shown in Appendix B. The predicted hydrographs matched the observed hydrographs fairly closely. In addition, the best-fit line through the scatter plots yielded a line with a fairly high correlation coefficient for most years, as well as a slope fairly close to one. The latter observation confirms that the resulting calibration is fairly free of any model parameter bias as a function of the magnitude of the flows.

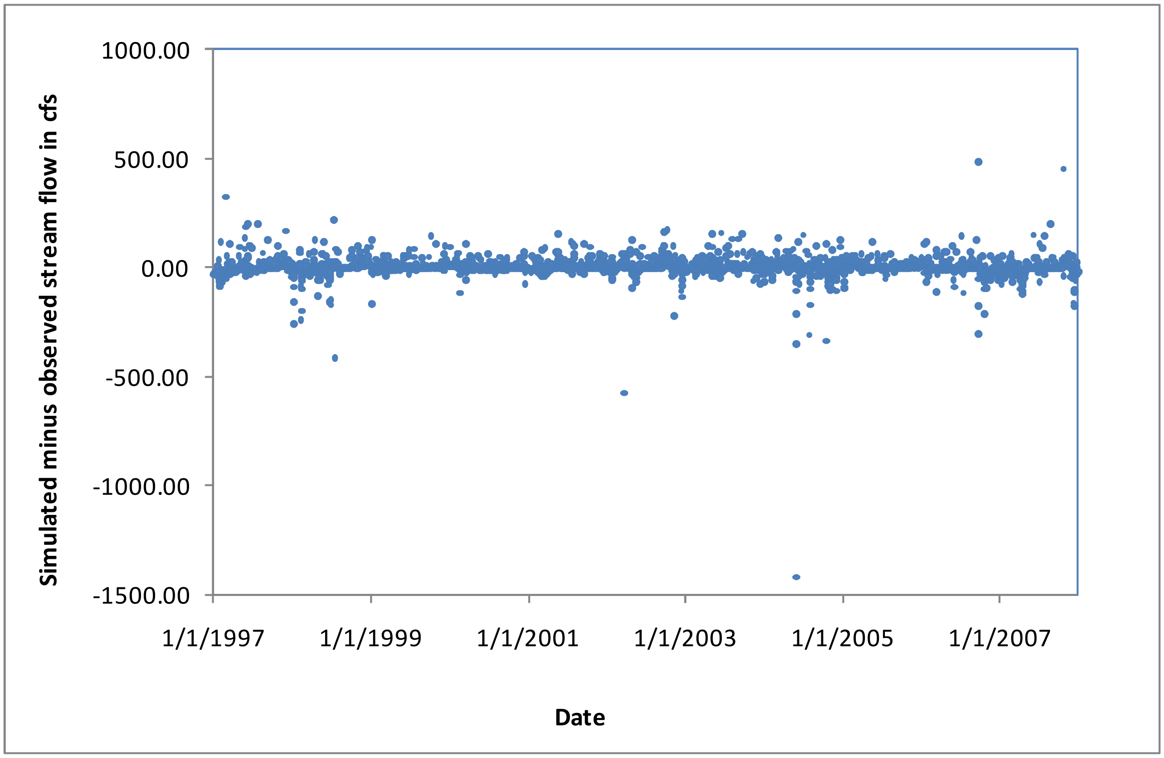

Figure 4.6 Residual Series for Cane Run at Royal Spring

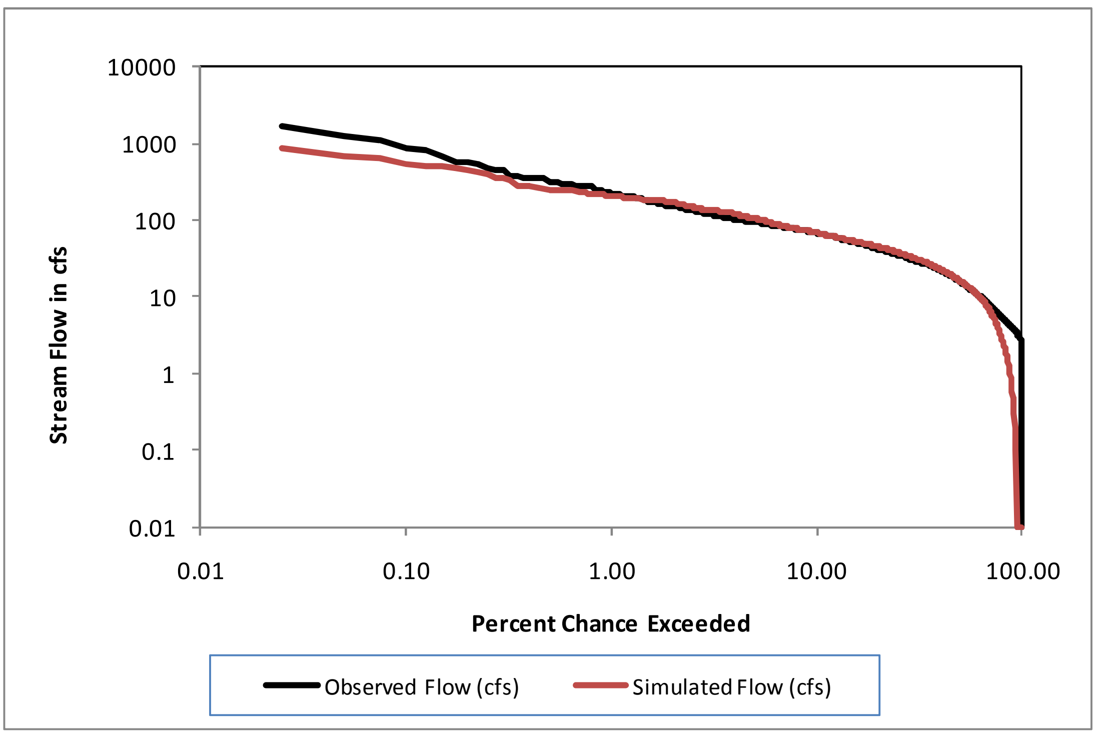

Figure 4.7 Flow Duration Curves for Cane Run at Royal Spring

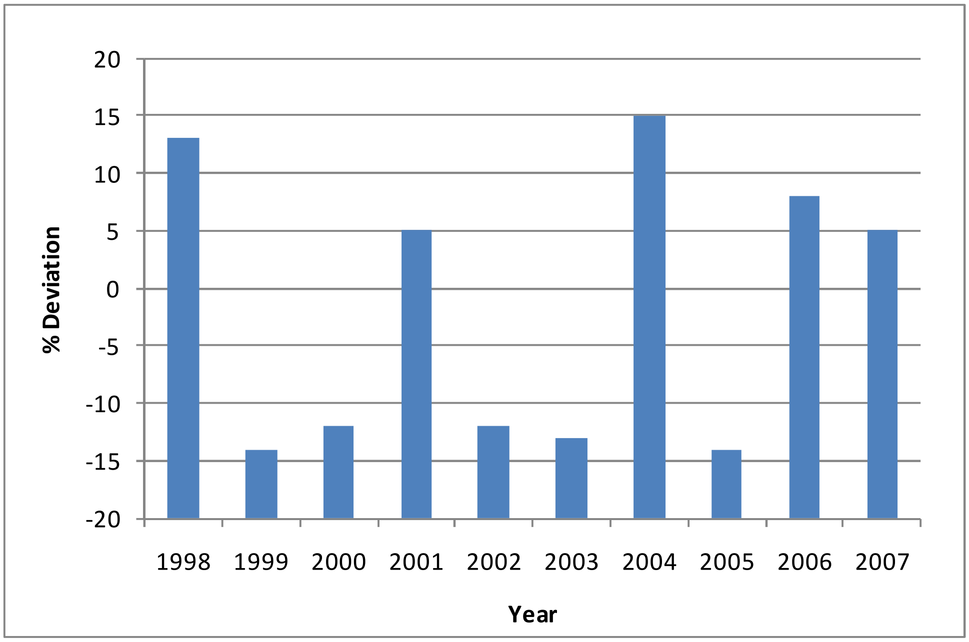

Figure 4.8 Annual Hydrograph Volume Deviations for Cane Run at Royal Spring

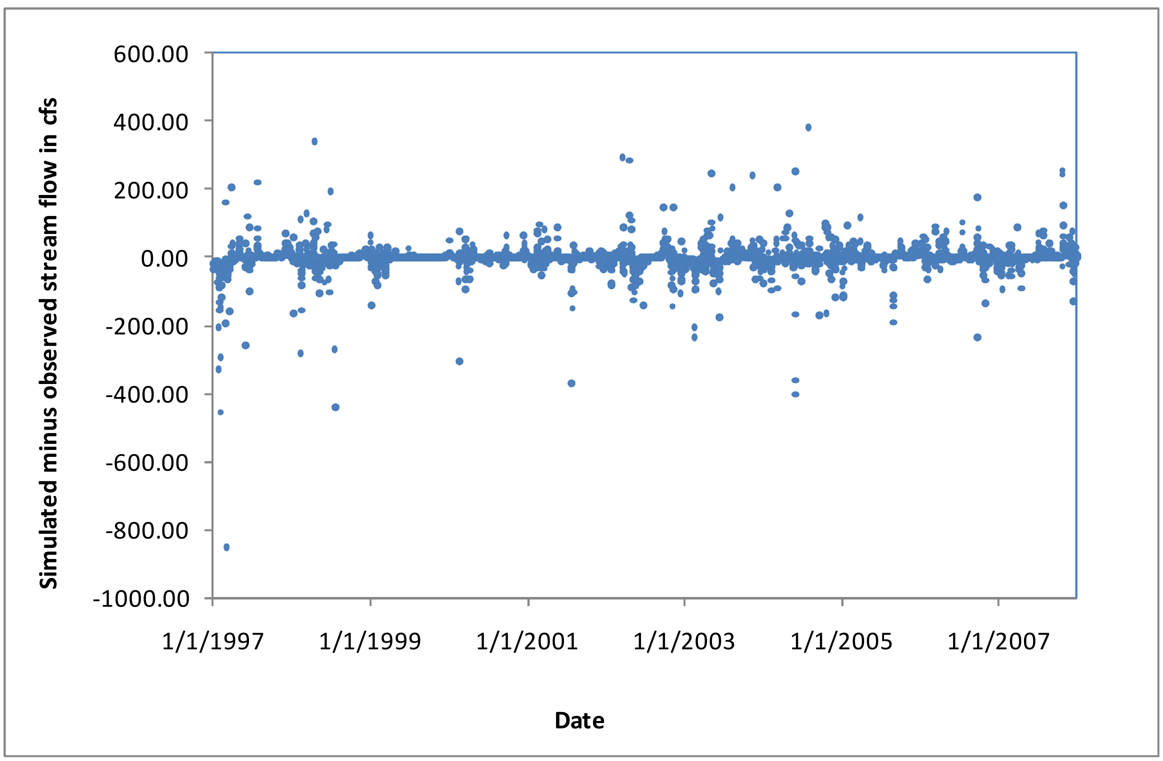

Figure 4.9 Residual Series for Cane Run at North Elkhorn

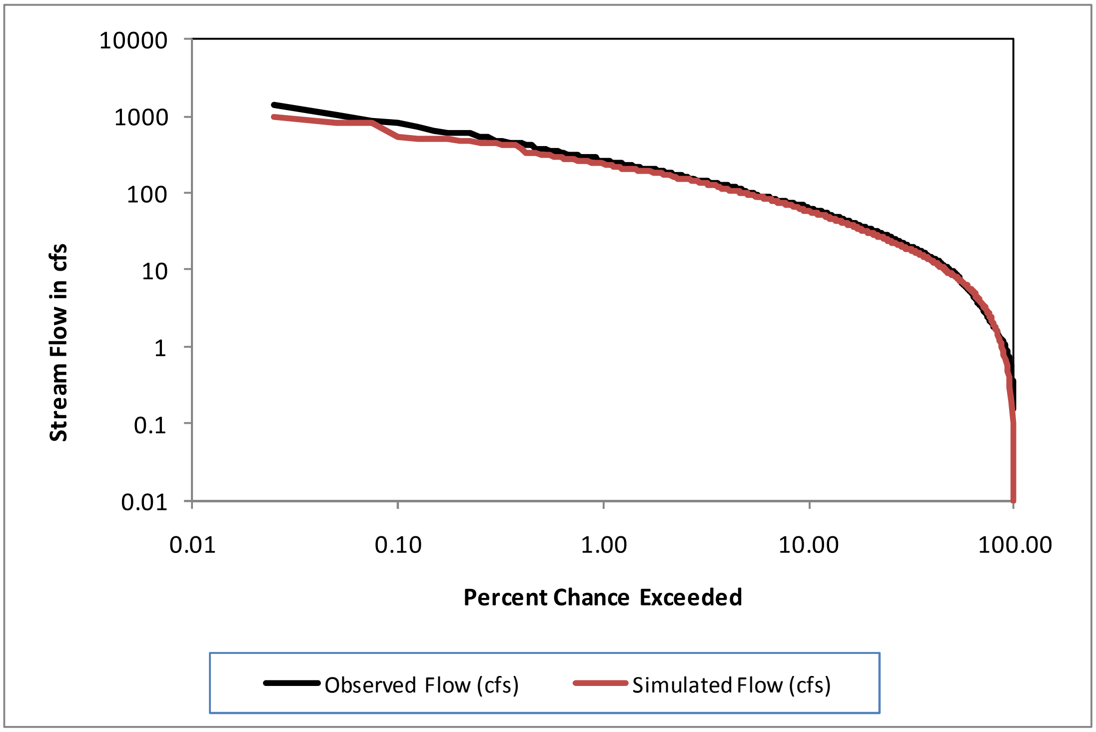

Figure 4.10 Flow Duration Curves for Cane Run at North Elkhorn

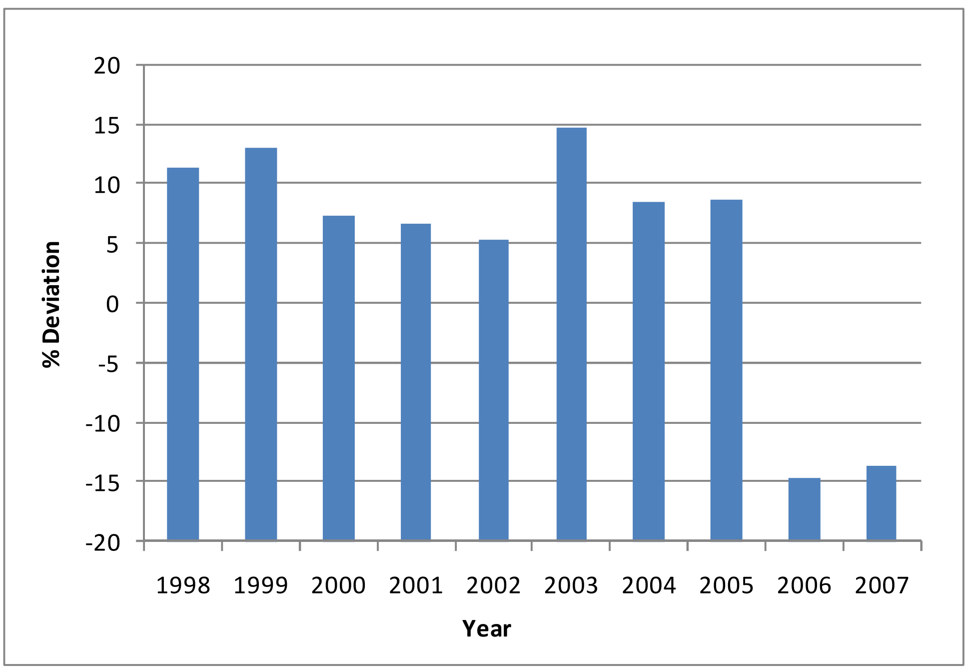

Figure 4.11 Annual Hydrograph Volume Deviations for Cane Run at North Elkhorn

4.7.3 Water Quality Calibration

Once the HSPF models were calibrated hydrologically, an attempt was made to calibrate the water quality parameters of the model (e.g. loading accumulation rates (ACCUM), decay rates

(FSTDEC), and storage limit (SQOLIM) etc.) to match the observed instream fecal coliform concentrations from 2002. Plots of the observed and calibrated fecal coliform concentrations for 2002 are shown in Appendix C. Due to the high variability of instream fecal coliform concentration, model performance associated with the replication of individual daily fecal loads was evaluated using a log differential range of 0.5. An attempt was made to calibrate the model so that the daily difference between observed and predicted fecal loads was within a value of 0.5 of the differences of the logarithms of the actual values. This is parallels the procedure found in EPA, 1986. The results of these comparisons are shown in Appendix C. The predicted values tend to fall within these bounds for the majority of days and the majority of stations. In general, deviations outside the limits typically occur when the predicted value is above the upper limit, thus providing for a more conservative analysis, which provides an implicit MOS. In addition to comparing the predicted and observed results for a given day, a comparison was also made between the observed values and the geometric mean of five days of predicted values centered on the date of the observed data point. This analysis was conducted to account for any variability of model performance as influenced by variations due to timing effects associated with hydrologic errors. The log difference of 0.5 criterion was satisfied for the vast majority of the time for all of the sites.

4.8 Model Application

Once the model was calibrated, it was used to determine the TMDL of the impaired streams as well as the load reductions needed to bring the streams into regulatory compliance. The TMDL load reduction is accomplished by systematically reducing the associated loading functions or loading rates until both the 30-day geometric mean criterion and the 400 colonies/100 ml (for 80% or more of all data in a 30-day period) criterion are met. Plots of the pre- and post-reduction geometric mean fecal coliform model results for the period from 1997 through 2007 are shown in Appendix D. Plots of the post-reduction fecal coliform results for the period from 1997 through 2007 are shown in Appendix E. Results of the pre-reduction conditions associated with the existing loads reveal numerous violations. Results from the post-reduction conditions show compliance with both WQCs. The specific allocations strategy required to meet this condition are discussed Section 5.0, and a more detailed look at model performance can be found in Section 6.0.

4.9 Margin of Safety

The MOS takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality, and is part of the TMDL development process (Section 303(d)(1)(C) of the Clean Water Act). There are two basic methods for incorporating the MOS (EPA, 1991):

(a) Implicitly incorporate the MOS using conservative model assumptions to develop allocations, or
(b) Explicitly reserve a portion of the total TMDL as the MOS, using the remainder for allocations.

An implicit MOS was incorporated into the modeling effort by imposing a slightly positive bias in the model's water quality calibration, including overestimating the contribution of both point- and nonpoint sources. This provides an implicit MOS approximately equal to 10%, see Appendices D and E for graphical representations.

5.0 TMDL, WASTELOAD AND LOAD ALLOCATIONS

5.1 TMDL

Sources that receive TMDL allocations can be divided into two categories, KPDES-permitted SWS facilities, and other sources that are calculated based on landcover (illegal loads receive no allocation). Allocations to wildlife, livestock and developed areas are computed based on landcover. Developed areas are then subdivided into MS4 and LA areas. Figure 5.1 shows a hypothetical catchment divided by a MS4 boundary and by developed/non-developed landcover. Referring to Figure 5.1, the load attributed to developed landcover within the MS4 area for a given catchment (i.e., the part of the loading that is the MS4-WLA) will be the total developed landcover load for the watershed multiplied by the fraction A/(A + B), where A = acres of MS4 developed land, B = acres of non-MS4 developed land, C = acres of MS4 non-developed land, D = acres of non-MS4 non-developed land, A+B = total developed land, and C+D = total non-developed land.

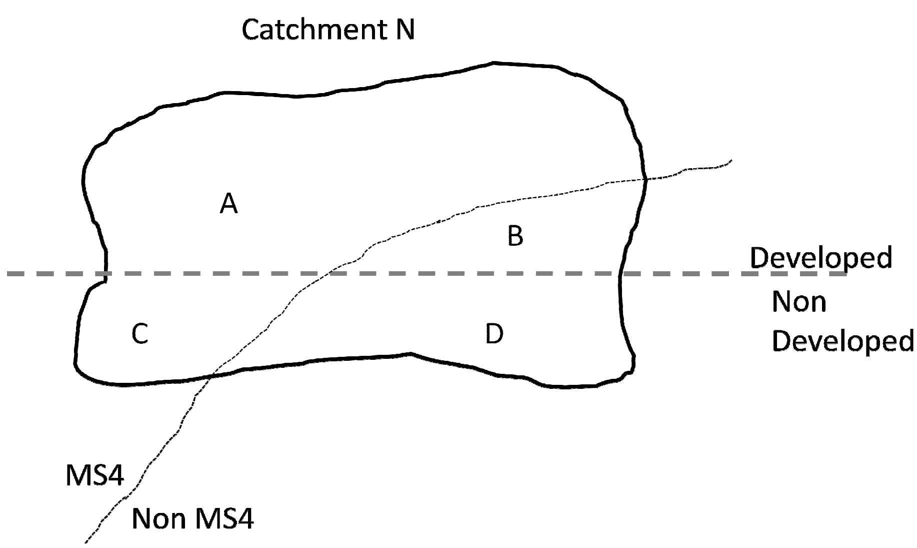

Figure 5.1 Hypothetical Catchment Showing Regulatory Landcover Subdivision

Once the HSPF model for Cane Run was developed and calibrated, all illegal loads were eliminated. Then the loads associated with the remaining sources were reduced until the instream WQCs were satisfied. The sum of the resulting allowable WLAs and LAs for all modeled sources is equal to the TMDL for each impaired segment. After the HSPF model determined the required allocations, the resulting TMDLs are shown in Table 5.9. However, these figures were then further modified, see Section 5.6.

5.1.1 TMDL Definitions

According to EPA (1991), a TMDL calculation is performed as follows:

$$TMDL = WLA + LA + MOS$$
(Equation 4)

The WLA has three components:

$$WLA = SWS\text{-}WLA + MS4\text{-}WLA + Future\ Growth\text{-}WLA$$
(Equation 5)

Definitions:
TMDL: the WQC, expressed as a load.
MOS: the Margin of Safety (MOS), which can be an implicit or explicit additional reduction applied to sources of pollutants that accounts for uncertainties in the relationship between effluent limits and water quality. For this report, the MOS is implicit.
TMDL Target: the TMDL minus the MOS.
WLA: the Wasteload Allocation, which is the allowable loading of pollutants into the stream from KPDES-permitted sources, such as SWSs and MS4s.
SWS-WLA: the WLA for KPDES-permitted sources which have discharge limits for pathogen indicators (including wastewater treatment plants, package plants and home units, which are referred to as Sanitary Wastewater Systems, or SWSs).
Future Growth-WLA: the allowable loading for future KPDES-permitted sources, including new SWSs, expansion of existing SWSs, new storm water sources, and growth of existing storm water sources (such as MS4s). Also includes the allocation for KPDES-permitted sources that existed but were not known at the time the TMDL was written.
Remainder: the TMDL minus the MOS and minus the SWS-WLA (also equal to Future Growth-WLA plus the MS4-WLA and the LA).
MS4-WLA: the WLA for KPDES-permitted Municipal Separate Storm Sewer Systems (MS4 permittees can include cities, counties, roads and right-of-ways owned by the Kentucky Transportation Cabinet (KYTC), universities and military bases).
LA: the Load Allocation, which is the allowable loading of pollutants into the stream from sources not permitted by KPDES and from natural background.
Seasonality: yearly factors that affect the relationship between pollutant inputs and the ability of the stream to meet its designated uses.
Critical Condition: the time period when the pollutant conditions are expected to be at their worst.
Critical Flow: the flow(s) used to calculate the TMDL as a load.
Existing Conditions: the load that exists in the watershed at the time of TMDL development (i.e., sampling) and is causing the impairment.
Load: concentration * flow * conversion factor.
Concentration: colonies per 100 milliliters (colonies/100ml).
Flow (i.e., stream discharge): cubic feet per second (cfs).
Conversion Factor: the value that converts the product of concentration and flow to load (in units of colonies/day); it is derived from the calculation of the following components: (28.31685L/ft^3 * 86400seconds/day * 1000ml/L)/(100ml) and is equal to 24,465,758.4.

Calculation Procedure:

1) The MOS, if an explicit value, is calculated and subtracted from the TMDL first, giving the TMDL Target;
2) The SWS-WLA is calculated and subtracted from the TMDL Target, leaving the Remainder;
3) The Future Growth-WLA is calculated and subtracted from the Remainder;
4) If there is a MS4 present upstream of the impaired segment, the MS4-WLA is subtracted from the Remainder based on percent developed landcover within the MS4 permitted boundary, leaving the LA.

5.2 WLA Sources

5.2.1 SWS-WLAs

There are three permitted SWSs in the Cane Run watershed. For the purposes of modeling, these facilities were assumed to operate at their permitted discharge limits. As a result, the WLA for these facilities are summarized in Table 5.1. Since these facilities are permitted to operate at or below the WQC, no reduction is necessary for these sources.

Table 5.1 SWS-WLAs

Facility	KPDES Permit	Catchment	Waterbody	Wasteload Allocation (colonies/day)
Spindletop MHP	KY0081213	L2	Cane Run	2.27E+08
Ponderosa MHP	KY0081221	L2	Cane Run	1.21E+08
Maple Grove MHP	KY0083321	L1	Cane Run	2.20E+08

The WLAs for the individual SWSs sums to 5.68E+8 colonies/day, all of which is applied to the UT to Cane Run at 6.13 RM 0.0 to 3.5, since both catchments L1 and L2 are located in (and wholly comprise) this subwatershed.

5.2.2 Initial MS4-WLA

The total existing load from developed landcover per catchment is shown in Table 4.15. The fraction of that existing load which occurs in developed land inside the MS4 boundary (see Table 1.4) appears in the fourth column of Table 5.2, which is the initial MS4 existing wasteload. After TMDL reductions, the initial MS4-WLA is reported in the fifth column of Table 5.2. Graphically, the fraction of the total developed landcover load for a given catchment attributed to non-MS4 developed lands is A/(A + B) (see Figure 5.1).

The remaining Total Developed Landcover Load not allocated to the MS4-WLA (because it comes from developed land outside the MS4 boundary) is allocated to the LA in Section 5.3.3.

Table 5.2 Initial MS4-WLA

Catchment	Total Developed Landcover Load	Fraction of Developed Land Within the MS4 Boundary	Existing Developed Landcover Load Within the MS4 Boundary (colonies/day)	MS4-WLA (colonies/day)
Cane Run 0.0 to 3.0				
L6	3.94E+09	0%	0.00E+00	0.00E+00
Cane Run 3.0 to 9.6				
L3	9.15E+07	0%	0.00E+00	0.00E+00
L4	0.00E+00		0.00E+00	0.00E+00
L5	3.92E+09	66.70%	2.62E+09	7.86E+08
U6	4.13E+09	0%	0.00E+00	0.00E+00
U7	3.32E+08	9.50%	3.15E+07	1.58E+07
U8	3.88E+08	100%	3.88E+08	1.94E+08
UT to Cane Run (at RM 6.13) 0.0 to 3.5				
L1	1.33E+09	0%	0.00E+00	0.00E+00
L2	1.92E+09	0%	0.00E+00	0.00E+00
Cane Run 9.6 to 17.4				
U1	3.10E+10	100%	3.10E+10	1.55E+10
U2	6.45E+09	100%	6.45E+09	3.23E+09
U3	2.22E+09	34.00%	7.55E+08	3.78E+08
U4	2.68E+09	0%	0.00E+00	0.00E+00
U5	2.19E+09	0%	0.00E+00	0.00E+00
Royal Spring				
K3	7.65E+09	96.10%	7.35E+09	3.68E+09

These are the initial MS4-WLA values; they have been modified by post-modeling analysis, see Section 5.6.

5.3 Load Allocations

Load allocations were assigned to the following sources: 1) wildlife (both inside and outside of the MS4 boundaries), 2) runoff loads generated from livestock (both inside and outside the MS4 boundaries), including loads from grazing deposits, manure application, and instream deposits, and 3) urban runoff from developed lands outside of the MS4 area (including loads from domestic pets). The load allocations for each of the individual sources are described below.

5.3.1 Load Allocations for Wildlife

The total wildlife load for each catchment is shown in Table 4.8, which is calculated for non-developed areas. Wildlife received a zero percent reduction, see Table 5.3 for the final wildlife LA. The wildlife load attributed to non-developed land within the MS4 boundary for a catchment is the product of the fraction C/(C + D) and the total wildlife load for the catchment, see Figure 5.1. Similarly, the wildlife load attributed to non-developed land outside the MS4 boundary for a given catchment is the product of the fraction D/(C + D) and the total wildlife load for that catchment. The fractions of non-developed land within and outside the MS4 boundary for each catchment are reported in Table 1.3. See Table 5.4 for the final wildlife LA by catchment both within and outside the MS4 boundary.

Table 5.3 Wildlife LA for Wildlife Sources by Catchment

Catchment	Existing Conditions Total (colonies/day)	LA (colonies/day)
Cane Run 0.0 to 3.0		
L6	1.53E+12	1.53E+12
Cane Run 3.0 to 9.6		
L3	5.45E+10	5.45E+10
L4	5.21E+10	5.21E+10
L5	1.69E+12	1.69E+12
U6	9.84E+11	9.84E+11
U7	3.30E+11	3.30E+11
U8	1.61E+11	1.61E+11
UT to Cane Run (at RM 6.13) 0.0 to 3.5		
L1	9.29E+11	9.29E+11
L2	2.18E+11	2.18E+11
Cane Run 9.6 to 17.4		
U1	1.61E+11	1.61E+11
U2	5.48E+11	5.48E+11
U3	9.29E+11	9.29E+11
U4	7.11E+11	7.11E+11
U5	1.66E+11	1.66E+11
Royal Spring		
K3	5.69E+10	5.69E+10

Table 5.4 Wildlife LA for Land Within and Outside the MS4 Boundary by Catchment

Catchment	Fraction of Non-Developed Land Within the MS4 Boundary	Fraction of Non-Developed Land Outside the MS4 Boundary	Load Allocations from Non-Developed Land Within the MS4 Boundary (colonies/day)	Load Allocations From Non-Developed Land Outside the MS4 Boundary (colonies/day)
Cane Run 0.0 to 3.0				
L6	13.0%	87.0%	1.99E+11	1.33E+12
Cane Run 3.0 to 9.6				
L3	0%	100%	0.00E+00	5.45E+10
L4	0%	100%	0.00E+00	5.21E+10
L5	17.2%	82.8%	2.91E+11	1.40E+12
U6	0%	100%	0.00E+00	9.84E+11
U7	14.8%	85.2%	4.88E+10	2.81E+11
U8	83.2%	16.8%	1.34E+11	2.70E+10
UT to Cane Run (at RM 6.13) 0.0 to 3.5				
L1	0%	100%	0.00E+00	9.29E+11
L2	0%	100%	0.00E+00	2.18E+11
Cane Run 9.6 to 17.4				
U1	100.0%	0.0%	1.61E+11	0.00E+00
U2	87.9%	12.1%	4.82E+11	6.63E+10
U3	45.7%	54.3%	4.25E+11	5.04E+11
U4	9.4%	90.6%	6.68E+10	6.44E+11
U5	0%	100%	0.00E+00	1.66E+11
Royal Spring				
K3	40%	60%	2.28E+10	3.41E+10

5.3.2 Load Allocations for Livestock

In model runs, all loads associated with cattle deposits instream are expected to be eliminated first. For informational purposes, allocated livestock loads (i.e., the LA column of Table 5.5) were then split into non-developed land within the MS4 boundary and non-developed land outside the MS4 boundary based on the same fractions as described for wildlife above (i.e., the fractions reported in Table 1.3) since all livestock load is also assumed to originate from non-developed land, see Table 5.6.

Table 5.5 Livestock LA for Livestock Sources by Catchment

Catchment	Existing Conditions Total (colonies/day)	LA (colonies/day)
Cane Run 0.0 to 3.0		
L6	2.14E+12	6.42E+11
Cane Run 3.0 to 9.6		
L3	3.69E+10	1.11E+10
L4	2.64E+10	7.92E+09
L5	1.96E+12	5.87E+11
U6	1.32E+12	6.60E+11
U7	5.30E+11	2.65E+11
U8	1.92E+11	9.61E+10
UT to Cane Run (at RM 6.13) 0.0 to 3.5		
L1	5.09E+11	1.53E+11
L2	2.01E+11	6.03E+10
Cane Run 9.6 to 17.4		
U1	1.27E+11	6.35E+10
U2	5.83E+11	2.91E+11
U3	1.09E+12	5.43E+11
U4	9.48E+11	4.75E+11
U5	2.56E+11	1.28E+11
Royal Spring		
K3	2.70E+11	1.35E+11

Table 5.6 Livestock LA for Land Within and Outside the MS4 Boundary by Catchment

Catchment	Fraction of Non-Developed Land Within the MS4 Boundary	Fraction of Non-Developed Land Outside the MS4 Boundary	Load Allocations for Non-Developed Land Within the MS4 Boundary (colonies/day)	Load Allocations for Non-Developed Land Outside the MS4 Boundary (colonies/day)
Cane Run 0.0 to 3.0				
L6	13.0%	87.0%	8.35E+10	5.59E+11
Cane Run 3.0 to 9.6				
L3	0%	100%	0.00E+00	1.11E+10
L4	0%	100%	0.00E+00	7.92E+09
L5	17.2%	82.8%	1.01E+11	4.86E+11
U6	0%	100%	0.00E+00	6.60E+11
U7	14.8%	85.2%	3.93E+10	2.26E+11
U8	83.2%	16.8%	8.00E+10	1.61E+10
UT to Cane Run (at RM 6.13) 0.0 to 3.5				
L1	0%	100%	0.00E+00	1.53E+11
L2	0%	100%	0.00E+00	6.03E+10
Cane Run 9.6 to 17.4				
U1	100.0%	0.0%	6.35E+10	0.00E+00
U2	87.9%	12.1%	2.56E+11	3.54E+10
U3	45.8%	54.2%	2.49E+11	2.94E+11
U4	9.4%	90.6%	4.46E+10	4.30E+11
U5	0%	100%	0.00E+00	1.28E+11
Royal Spring				
K3	40.0%	60.0%	5.40E+10	8.10E+10

5.3.3 Load Allocations for Developed Lands Outside the MS4 Boundary

The total existing load from developed landcover per catchment is shown in Table 4.15. The fraction of that existing load which occurs in developed land outside the MS4 boundary (see Table 1.4) appears in the third column of Table 5.7, and the existing load was calculated in the fourth column. Graphically, the fraction of the total developed landcover load for a given catchment attributed to non-MS4 developed lands is B/(A + B), see Figure 5.1.

Table 5.7 LA for Developed Land Outside the MS4 Boundary

Catchment	Total Developed Landcover Load (colonies/day)	Fraction of Developed Land Outside the MS4 Boundary	Existing Developed Landcover Load Outside the MS4 Boundary (colonies/day)	LA (colonies/day)
Cane Run 0.0 to 3.0				
L6	3.94E+09	100%	3.94E+09	1.18E+09
Cane Run 3.0 to 9.6				
L3	9.15E+07	100%	9.15E+07	2.75E+07
L4	0.00E+00		0.00E+00	0.00E+00
L5	3.92E+09	33.30%	1.30E+09	3.91E+08
U6	4.13E+09	100%	4.13E+09	2.07E+09
U7	3.32E+08	90.50%	3.01E+08	1.50E+08
U8	3.88E+08	0%	0.00E+00	0.00E+00
UT to Cane Run (at RM 6.13) 0.0 to 3.5				
L1	1.33E+09	100%	1.33E+09	3.99E+08
L2	1.92E+09	100%	1.92E+09	5.76E+08
Cane Run 9.6 to 17.4				
U1	3.10E+10	0%	0.00E+00	0.00E+00
U2	6.45E+09	0%	0.00E+00	0.00E+00
U3	2.22E+09	66.00%	1.46E+09	7.32E+08
U4	2.68E+09	100%	2.68E+09	1.34E+09
U5	2.19E+09	100%	2.19E+09	1.10E+09
Royal Spring				
K3	7.65E+09	3.90%	3.01E+08	1.50E+08

5.4 Illegal Sources

No allocations were given to illegal sources such as straight pipes, failing septic systems or SSOs. The separate existing loads due to straight pipes and failing septic systems are shown in Table 4.3, and the loads from SSOs are shown in Table 4.5. All illegal loads from these tables and the associated reductions of 100% are shown in Tables 5.8.

Table 5.8 Illegal Sources

	Straight Pipes, Failing OWTS		SSOs		
Catchment	**Existing Load (colonies/day)**	**Wasteload Allocation (colonies/day)**	**Existing Load (colonies/day)**	**Wasteload Allocation (colonies/day)**	**Percent Reduction (colonies/day)**
Cane Run 0.0 to 3.0					
L6	3.19E+10	0	0	0	100
Cane Run 3.0 to 9.6					
L3	7.57E+09	0	0	0	100
L4	7.57E+09	0	0	0	100
L5	2.59E+11	0	0	0	100
U6	2.39E+10	0	0	0	100
U7	6.10E+10	0	0	0	100
U8	2.27E+10	0	0	0	100
UT to Cane Run (at RM 6.13) 0.0 to 3.5					
L1	2.39E+10	0	0	0	100
L2	3.83E+10	0	0	0	100
Cane Run 9.6 to 17.4					
U1	6.18E+10	0	3.17E+12	0	100
U2	8.10E+08	0	2.59E+12	0	100
U3	1.63E+10	0	0	0	100
U4	5.38E+10	0	5.34E+12[(1)]	0	100
U5	7.98E+09	0	0	0	100
Royal Spring					
K3	4.07E+08	0	0	0	100

[(1)] Includes loads from catchments K1 and K2.

5.5 Initial TMDL Calculations

Summing the final columns (i.e., the allowable loads, not the existing conditions) from Tables 5.1 (SWS-WLA), 5.2 (Initial MS4-WLA), 5.3 (Wildlife LA), 5.5 (Livestock LA), and 5.7 (Developed Land LA) gives the TMDL column of Table 5.9, Initial TMDL Allocations by Catchment.

The values for the individual catchments were summed, where appropriate, to give Table 5.10, Initial TMDL Values by Subwatershed. However, while the initial TMDL values are presented in these two tables, they are not the final allocations for the watershed; see Section 5.6, Post-Modeling Analysis.

Table 5.9 Initial TMDL Allocations by Catchment

Catchment	TMDL (colonies/day)	SWS-WLA (colonies/ day)	MS4-WLA (colonies/day)	Load Allocation (colonies/day)
L6	2.17E+12	0	0.00E+00	2.17E+12
L3	6.56E+10	0	0.00E+00	6.56E+10
L4	6.00E+10	0	0.00E+00	6.00E+10
L5	2.28E+12	0	7.86E+08	2.28E+12
U6	1.65E+12	0	0.00E+00	1.65E+12
U7	5.95E+11	0	1.58E+07	5.95E+11
U8	2.57E+11	0	1.94E+08	2.57E+11
L1	1.07E+12	2.20E+08	0.00E+00	1.07E+12
L2	2.79E+11	3.48E+08	0.00E+00	2.79E+11
U1	2.40E+11	0	1.56E+10	2.24E+11
U2	8.43E+11	0	3.23E+09	8.40E+11
U3	1.47E+12	0	3.78E+08	1.47E+12
U4	1.19E+12	0	0.00E+00	1.19E+12
U5	2.95E+11	0	0.00E+00	2.95E+11
K3	1.96E+11	0	3.68E+09	1.92E+11

Table 5.10 Initial TMDL Allocations by Subwatershed

Sub-watershed	TMDL (colonies/ day)	SWS-WLA (colonies/ day)	MS4 Permittee	MS4-WLA (colonies/ day)	LA (colonies/ day)
Cane Run 0.0 to 3.0	2.17E+12	0	Georgetown/ KYTC	0	2.17E+12
Cane Run 3.0 to 9.6	4.91E+12	0	Lexington/ Georgetown/ KYTC	9.96E+08	4.90E+12
UT to Cane Run (at RM 6.13) 0.0 to 3.5	1.36E+12	5.68E+08	None	0	1.36E+12
Cane Run 9.6 to 17.4	4.04E+12	0	Lexington/ KYTC	1.91E+10	4.02E+12
Royal Spring	1.96E+11	0	Georgetown/ KYTC	3.68E+09	1.92E+11

5.6 Post-Modeling Analysis

This TMDL project was scoped prior to 2007. However, changes have since occurred in three areas:

1. New segments have been assessed as impaired for fecal coliform, segments which did not have TMDLs calculated during the modeling effort.
2. Changes have occurred in the MS4 program, including changes in the type of available landcover data, as well as the expansion of the Lexington MS4 area and the addition of other MS4 permittees, therefore KDOW now calculates the MS4-WLA differently, and;
3. KDOW now computes future growth (called the Future Growth-WLA) for TMDLs.

Also, since Royal Spring is not impaired for bacteria, its calculations were dropped, and no loading is presented for Royal Spring in Table 5.21, the final TMDL summary table.

5.6.1 Addition of Newly Assessed Segments

Three UTs were assessed in the upper part of the watershed based on data provided by BAE. Because they were assessed after completion of the modeling effort, these segments received no initial TMDL allocation in Table 5.10; further, the subwatershed areas of two of the three segments did not correspond to any existing catchment, so their load is not available by incorporating the TMDL loading from a modeled catchment or catchments on a 1:1 basis. For purposes of this discussion, the term catchment describes the modeled catchments (i.e., U1 through U8 and L1 through L6), and the term subwatershed describes the watershed area of an impaired segment; these terms are not usually synonymous, see below. Loadings from catchments, or parts thereof, were used to generate the TMDL loadings for the subwatersheds (which correspond to the impaired segments). To address these three newly assessed UTs, two different methods were used:

1. The subwatershed area of UT to Cane Run at 10.8 RM 0.0 to 2.4 is identical to catchment U4. Therefore the initial TMDL loading from catchment U4 (1.19E+12 colonies/day) was assigned to this stream's subwatershed.
2. The subwatershed areas of both UT to Cane Run at 12.9 RM 0.0 to 2.1 (which is located in catchment U2) and UT to Cane Run at RM 15.6 RM 0.0 to 0.9 (which is located in catchment U1) are fractions of their parent catchments. Therefore a proportional area calculation was used to generate the TMDL loadings for these subwatersheds: the TMDL loadings from U2 and U1 were multiplied by the proportional area of the subwatershed with respect to its parent catchment to generate the final allowable TMDL loadings for these subwatersheds, see Table 5.11.
3. The loadings calculated from all three UTs were subtracted from the initial TMDL allocation for the Cane Run 9.6 to 17.4 subwatershed (because the allowable TMDL loading is not cumulative from upstream catchments to downstream catchments: Each catchment receives a TMDL allocation based solely on its assimilative capacity, therefore subdividing Cane Run 9.6 to 17.4 into four separate subwatersheds means its allocated TMDL loading must also be subdivided): However, this recalculation of the load for Cane Run 9.6 to 17.4 has the potential to create confusion, since until this Section of the document Cane Run 9.6 to 17.4 has explicitly included all catchments from RM 9.6 to the headwaters (i.e., U1-U5, the "U" standing for "Upper"). However, after recalculation, Cane Run 9.6 to 17.4 no longer includes catchment U4, or parts of catchments U2 and U1. To differentiate between the former Cane Run 9.6 to 17.4 subwatershed and the new (smaller) subwatershed, the former will henceforth be referred to as 'Upper Cane Run,' and the revised, smaller subwatershed will be referred to by it's old nomenclature (and, necessarily, in order to meet CWA requirements) and the name of it's impaired segment, Cane Run 9.6 to 17.4. See Figure 5.2, which contrasts the areas of the former and current subwatersheds. Table 5.12 shows the procedure used to subtract the three newly assessed UT's allocated TMDL load from Cane Run 9.6 to 17.4.

Table 5.11 Proportional Area Calculations to Generate Revised TMDL Allocations for the UTs at RM 12.9 and 15.6

Subwatershed	Parent Catchment	Parent Catchment Acres (NLCD)	Subwatershed Acres (NLCD)	Proportional Area	Parent Catchment Initial TMDL (colonies/day)	Revised (Proportional) Subwatershed TMDL (colonies/day)
UT to Cane Run at RM 12.9 0.0 to 2.1	U2	2218.82	1261.86	0.569	8.43E+11	4.79E+11
UT to Cane Run at RM 15.6 0.0 to 0.9	U1	2620.47	1533.18	0.585	2.40E+11	1.40E+11

Table 5.12 Revised Initial TMDL Allocations by Subwatershed (Including Newly Impaired Segments and Recalculated Allocations) for Cane Run 9.6 to 17.4

Subwatershed	TMDL (colonies/day)
Initial Allocation Upper Cane Run	4.04E+12
UT to Cane Run at 10.8 RM 0.0 to 2.4[(1)]	1.19E+12
UT to Cane Run at 12.9 RM 0.0 to 2.1	4.79E+11
UT to Cane Run at 15.6 RM 0.0 to 0.9	1.40E+11
Revised Allocation Cane Run 9.6 to 17.4 (After Removal of Allocations for Newly Assessed UTs)	2.23E+12

(1) UT to Upper Cane at 10.8 RM 0.0 to 2.4 is identical to Catchment U4.

5.6.2 Differences in Calculation of the MS4-WLA

When the City of Lexington was designated an MS4 in 2000, its Urban Service Area was used to delineate its permitted boundary (see Figure 5.3). Therefore the TMDL loading from developed areas was partitioned by the modeling effort (to either MS4-WLA or LA) based on the Urban Service Area. However, in 2008 Lexington's MS4 storm water permit was reissued, and its MS4 boundary was expanded to include areas beyond its Urban Service Area, see Figure 5.3. Also, Georgetown now holds a MS4 permit, see Figure 5.4. KYTC is also a MS4 permit holder, for all KYTC-owned roads and right-of-ways within any of the above types of MS4. Boundary data for Figures 5.3 and 5.4 were obtained from the DOW Municipal Separate Storm Sewer layer on the Kentucky Geonet (http://kygeonet.ky.gov/geographicexplorer/) after subtracting the area of UK's North Farm, which is not covered by a MS4 permit, see Section 3.2.4 of the TMDL portion of the report. The North Farm's area was subtracted using property boundary information provided from UK's Physical Plant Division (2011).

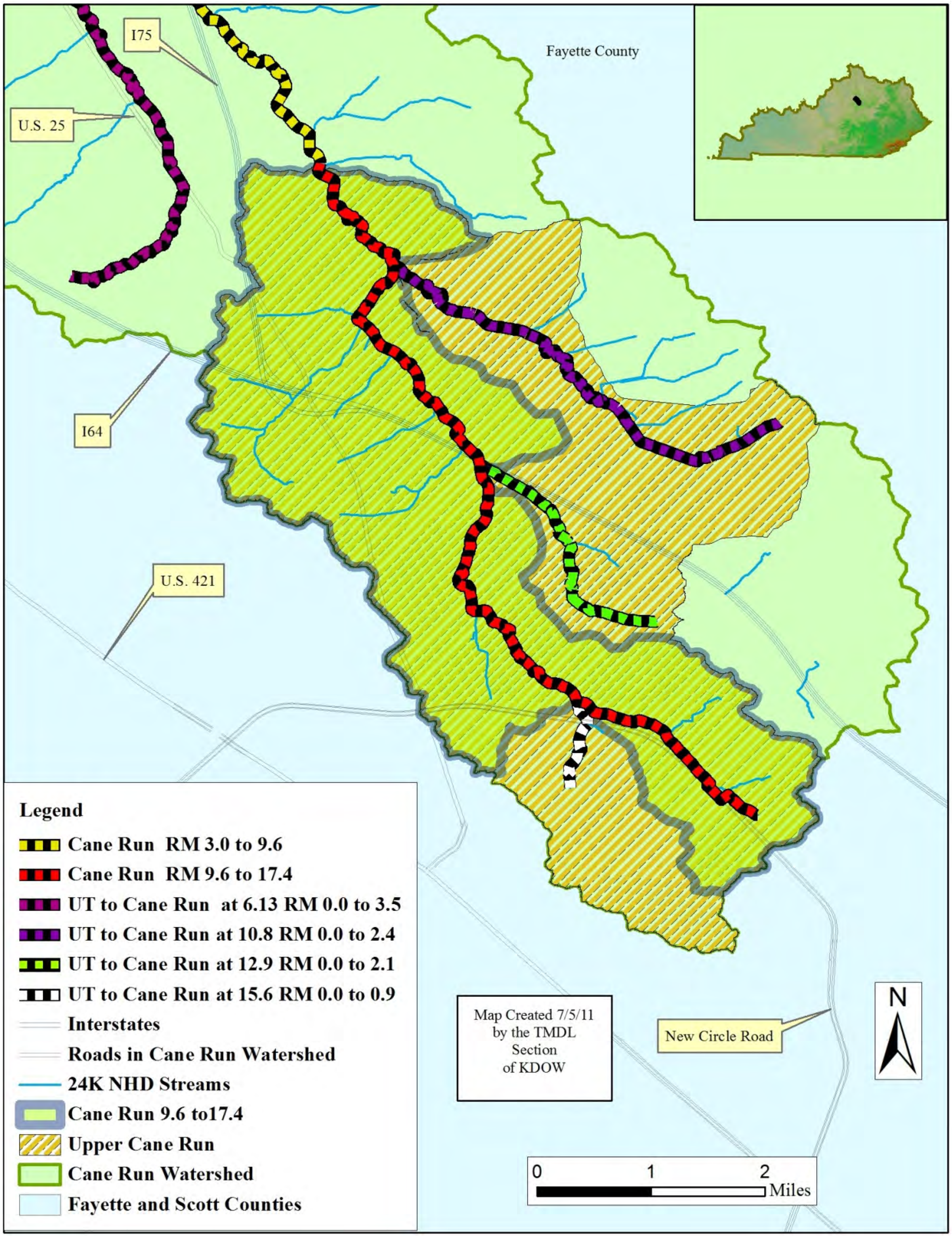

Figure 5.2 Comparison between the Upper Cane Run and Cane Run 9.6 to 17.4 Watersheds

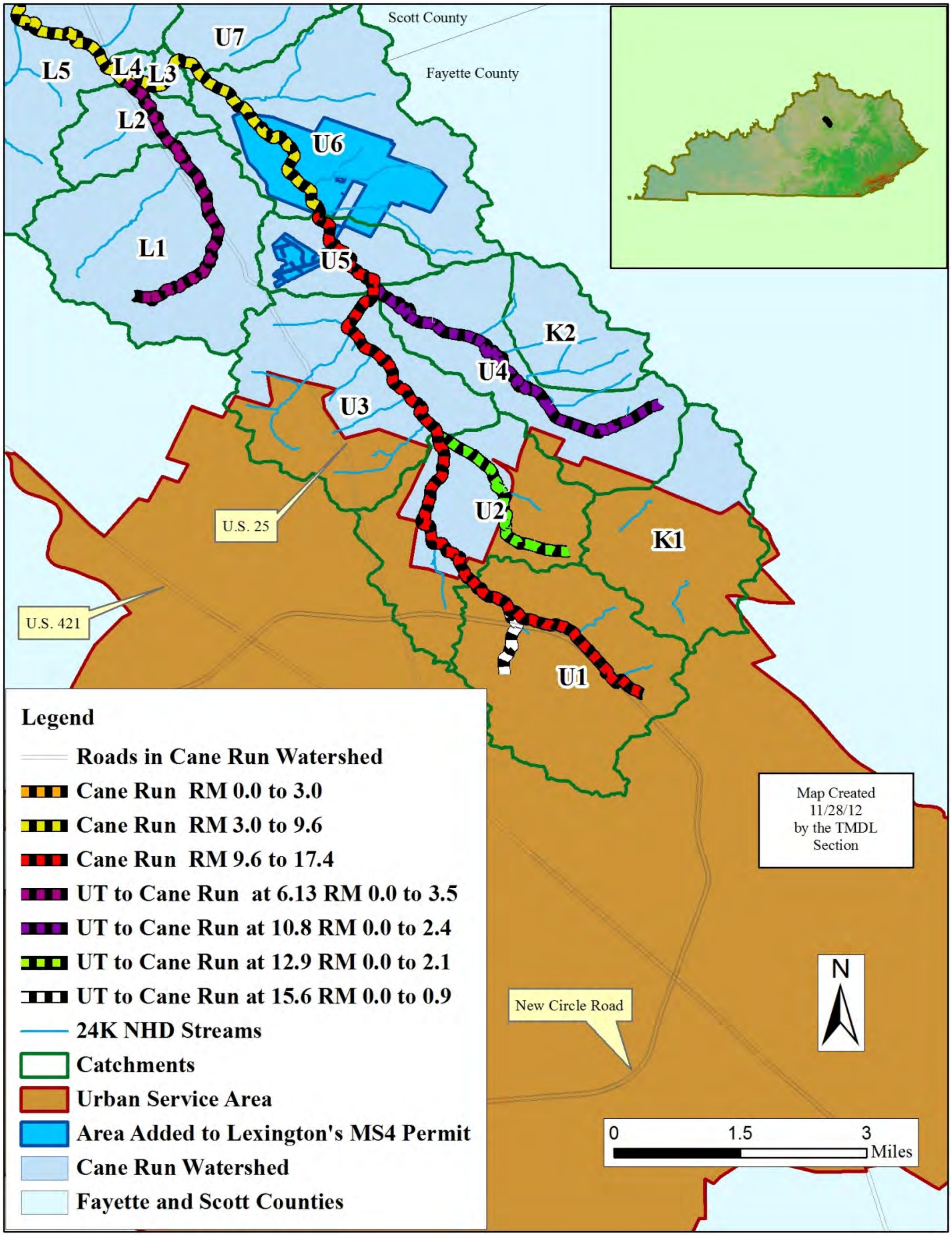

Figure 5.3 Changes to Lexington's Permitted MS4 Boundary

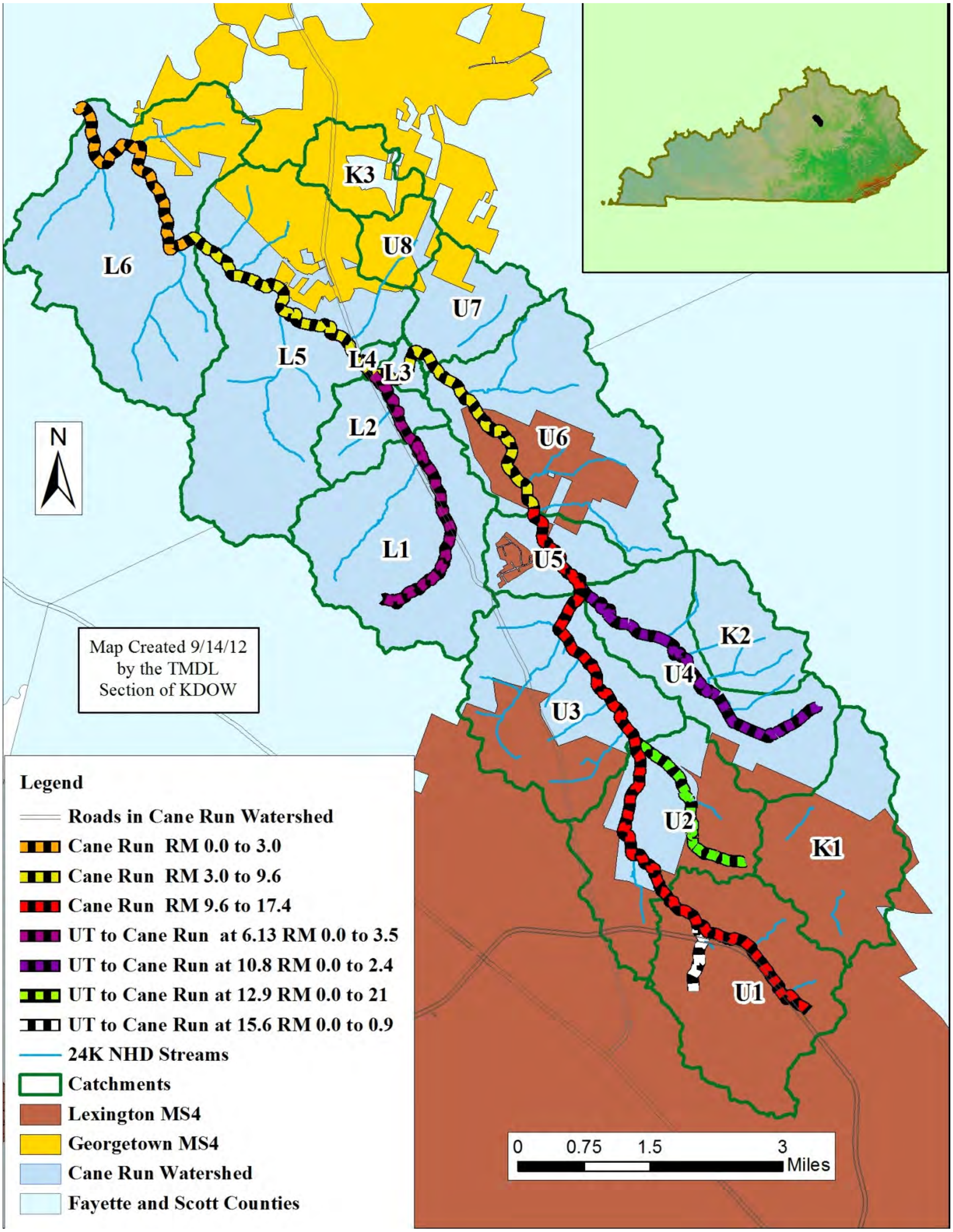

Figure 5.4 All MS4 Boundaries in the Cane Run Watershed

Another issue that affects calculation of the MS4-WLA is landcover database availability. Initially, landcover calculations were performed in BASINS 3.1; now, the 2001 National Landcover Database (NLCD, USGS 2003c) is available. The 2001 NLCD differentiates more finely than does BASINS; for instance, an area labeled in BASINS as containing a single landcover may have several within the 2001 NLCD. Also, areas BASINS shows as undeveloped are sometimes reported as developed within the 2001 NLCD. Therefore, KDOW believes the 2001 NLCD is more representative of actual conditions than the landcover data provided by BASINS. This specifically affects MS4-WLA computations and Future Growth-WLA computations, since both are based on developed area.

To account for these differences, and to ensure Lexington and Georgetown receive WLAs for the watersheds where they have developed landcover within their permitted MS4 areas (and that KYTC receives an allocation for it's roads and associated right-of-ways within any of the other MS4s), the following changes were made in the computation of the MS4-WLA, and reflected in Table 5.21, the Final TMDL Allocations:

1. The number of developed MS4 acres was recalculated for each impaired segment using the updated MS4 boundaries and the 2001 NLCD, see Table 5.13 for a comparison of developed MS4 landcover between BASINS and the 2001 NLCD using the updated boundaries.

2. No developed MS4 acres were reported for the UT to Cane Run at 6.13 RM 0.0 to 3.5 subwatershed from either BASINS or the 2001 NLCD using the revised MS4 boundaries, therefore it received no MS4-WLA.

3. For catchments or subwatersheds where BASINS returned any developed MS4 acres, the average loading per developed MS4 acre was calculated as shown in Table 5.14.

4. For catchments or subwatersheds where BASINS returned no developed MS4 acres but MS4s now exist, no initial loading per developed MS4 acre could be computed. Instead, the loading factor from the non-MS4 developed landcover was used to generate the initial loading factor in these subwatersheds as shown in Table 5.15.

5. For all subwatersheds except Cane Run 9.6 to 17.4, the average loading per developed acre in each watershed or catchment (from Table 5.14 or 5.15) was multiplied by the recalculated number of developed MS4 acres (using the 2001 NLCD and the new permitted MS4 boundaries) to generate a revised MS4-WLA for the subwatersheds as shown in Tables 5.16 and 5.17. This preserved the relative landcover mix used in the modeling effort (e.g., the ratio of industrial to commercial, etc., generated by BASINS) while simultaneously scaling the number of developed MS4 acres to reflect the 2001 NLCD and the updated MS4 boundaries. Table 5.17 shows calculations for catchments U1 and U2 separately because each of these contains (but does not comprise) an impaired subwatershed, so while the procedure was the same as that employed in Table 5.16, the column labeling was different.

6. For Cane Run 9.6 to 17.4, the revised MS4-WLA was calculated by subtracting the MS4-WLAs of the 3 newly assessed UTs from the MS4-WLA of Upper Cane Run (which was calculated in Table 5.16) as shown in Table 5.18.

Table 5.13 Developed MS4 Landcover Comparison between BASINS and the 2001 NLCD

Subwatershed	MS4 Permittee[(1)]	Total Acres (BASINS)	Developed MS4 Acres (BASINS)	% MS4 (BASINS)	Total Acres (2001 NLCD)	Developed MS4 Acres (2001 NLCD)	% MS4 (2001 NLCD)
Cane Run 0.0 to 3.0	Georgetown/ KYTC	3831	0	0%	3886.8	56.5	1.45%
Cane Run 3.0 to 9.6	Lexington/ Georgetown/ KYTC	8746	342	3.91%	8887.3	677.9	7.63%
UT to Cane Run at 6.13 RM 0.0 to 3.5	None	3242	0	0%	3256.7	0	0%
Upper Cane Run[(3)]	Lexington/ KYTC	10014	3225	32.20%	10227.0	3635.29	35.55%
UT to Cane Run at 10.8 RM 0.0 to 2.4	Lexington/ KYTC	1903	0	0%	2018.23	9.12	0.45%
UT to Cane Run at 12.9 RM 0 to 2.1	Lexington/ KYTC	N/C[(2)]	N/C	N/C	1261.86	396.53	31.42%
UT to Cane Run at 15.6 RM 0.0 to 0.9	Lexington/ KYTC	N/C	N/C	N/C	1533.18	1039.5	67.80%
Cane Run 9.6 to 17.4	Lexington/ KYTC	N/C	N/C	N/C	5413.74	2190.14	40.46%

(1) KYTC is a permittee within all other MS4s.
(2) N/C = Not Calculated.
(3) Includes Cane Run 9.6 to 17.4 as well as the three newly assessed UTs, see Section 5.6.1.

Table 5.14 Loading per Developed MS4 Acre from BASINS (colonies/day)

Watershed or Catchment	Initial (BASINS) Developed MS4-WLA (colonies/day)	Developed MS4 Acres, BASINS	Loading per Developed MS4 Acre (colonies/day)
Cane Run 3.0 to 9.6	9.96E+08	342	2.91E+06
Upper Cane Run(1)	1.91E+10	3225	5.92E+06
U2	3.23E+09	812	3.98E+06
U1	1.55E+10	2298	6.74E+06

(1) Includes Cane Run 9.6 to 17.4 as well as the three newly assessed UTs, see Section 5.6.1.

Table 5.15 Loading per Developed Non-MS4 Acre from BASINS

Watershed or Catchment	Initial (BASINS) Developed Non-MS4 Load (colonies/day)	Developed Non-MS4 Acres, BASINS	Loading per Developed Non-MS4 Acre (colonies/day)
Cane Run 0.0 to 3.0	1.18E+09	236	5.00E+06
U4(1)	1.34E+09	190	7.05E+06

(1) Catchment U4 is identical to UT to Upper Cane at 10.8 RM 0.0 to 2.4.

Table 5.16 Revised MS4-WLA for Subwatersheds Whose Area Corresponds to One or More Catchments

Sub-watershed	Loading per Developed MS4 acre (colonies/ day)	Loading per Developed Non-MS4 acre (colonies/ day)	MS4 Permittee[1]	Developed MS4 Acres (2001 NLCD)	Revised (2001 NLCD) MS4-WLA (colonies/ day)
Cane Run 0.0 to 3.0		5.00E+06	Georgetown/KYTC	56.5	2.83E+08
Cane Run 3.0 to 9.6	2.91E+06		Lexington/Georgetown/ KYTC	677.9	1.97E+09
Upper Cane Run[2]	5.92E+06		Lexington/ KYTC	3635.29	2.15E+10
UT to Cane Run at RM 10.8 0.0 to 2.4		7.05E+06	Lexington/KYTC	9.12	6.43E+07

[1] KYTC is a permittee within all other MS4s.
[2] Includes Cane Run 9.6 to 17.4 as well as the three newly assessed UTs, see Section 5.5.1.

Table 5.17 Revised MS4-WLA for Subwatersheds Contained Within Catchments U1 and U2

Catchment	Loading per MS4 Acre (colonies/ day)	MS4 Permittees[1]	Sub-watershed Developed MS4 Acres (2001 NLCD)	Sub-watershed	Revised Sub-watershed (2001 NLCD) MS4-WLA (colonies/ day)
U2	3.98E+06	Lexington/ KYTC	396.53	UT to Cane Run at 12.9 RM 0.0 to 2.1	1.58E+09
U1	6.74E+06	Lexington/ KYTC	1039.5	UT to Cane Run at 15.6 RM 0.0 to 0.9	7.01E+09

[1] KYTC is a permittee within all other MS4s.

Table 5.18 Revised MS4-WLA for Cane Run 9.6 to 17.4

Waterbody	Revised (2001 NLCD) MS4-WLA (colonies/day)
Old Allocation Upper Cane Run	2.15E+10
U4/UT to Cane Run at 10.8 RM 0.0 to 2.4	6.43E+07
UT to Cane Run at 12.9 RM 0.0 to 2.1	1.58E+09
UT to Cane Run at 15.6 RM 0.0 to 0.9	7.01E+09
New Allocation Cane Run 9.6 to 17.4 (Remove BAE UTs)	1.28E+10

5.6.3 Future Growth-WLA

The Future Growth-WLA accounts for future growth of KPDES-permitted sources (i.e., an increase in the number of WLA sources or in the loading per discharger) in order to avoid having to re-open the TMDL and change the WLA when new sources come online or increase their output. It can also account for existing sources which are later discovered to discharge the pollutant of concern, even though this fact was not known at the time the TMDL was written. Future growth is represented by a portion of the Remainder which is set aside (i.e., is not part of the LA nor is it part of the WLA for current/known sources). The amount of the Remainder set aside for future growth is determined as shown in Table 5.19 (KDOW, 2011c), which assumes that growth occurs more rapidly in developed areas (which is determined by calculating the sum of Developed Open Space, Developed Low Intensity, Developed Medium Intensity and Developed High Intensity landcover areas in the watershed area of the impaired segment) than in rural areas. The percent set aside for future growth by subwatershed is shown in Table 5.20.

Table 5.19 Percent of Remainder Set Aside for Future Growth

Percent Developed Area in the Subwatershed	Percent of Remainder Set Aside for Future Growth
≥25%	5%
≥20% – <25%	4%
≥15% – <20%	3%
≥10% – <15%	2%
≥5% – <10%	1%
<5%	0.5%

Mathematically, the Future Growth-WLA can be expressed as:

Future Growth-WLA = (TMDL – MOS – SWS-WLA) × (% of Remainder that is set aside for future growth)
(Equation 4)

Table 5.20 Future Growth Percent by Subwatershed (2001 NLCD)

Waterbody	Developed Area, 2001 NLCD (acres)	Total Area, 2001 NLCD (acres)	% Developed Area, 2001 NLCD	% of Remainder Set Aside for Future Growth
Cane Run 0.0 to 3.0	470.6	3886.8	12.1%	2%
Cane Run 3.0 to 9.6	1689.1	8887.3	19.0%	3%
UT to Cane Run at 6.13 RM 0.0 to 3.5	542.0	3256.7	16.6%	3%
Old Future Growth, Upper Cane Run	4544.4	10227.0	44.4%	5%
U4/UT to Cane Run at 10.8 RM 0.0 to 2.4	206.8	2018.2	10.2%	2%
UT to Cane Run at 12.9 RM 0.0 to 2.1	695.87	1261.9	55.1%	5%
UT to Cane Run at 15.6 RM 0.0 to 0.9	1267.7	1533.2	82.7%	5%
New Future Growth Cane Run 9.6 to 17.4 (remove newly assessed UTs)	2374.1	5413.7	43.9%	5%

5.7 Final TMDL Allocations

Table 5.21 contains the final TMDL allocations for all sources in the watershed.

Table 5.21 Final TMDL Allocations

Subwatershed	TMDL (fecal coliform colonies/ day) (1)	SWS-WLA (fecal coliform colonies/ day) (2)	MS4 Permittee	MS4-WLA (fecal coliform colonies/ day) (3)	Future Growth-WLA (fecal coliform colonies/ day)	LA (fecal coliform colonies/ day)
Cane Run 0.0 to 3.0	2.17E+12	0	Georgetown/ KYTC	2.83E+08	4.35E+10	2.12E+12
Cane Run 3.0 to 9.6	4.91E+12	0	Lexington/ Georgetown/ KYTC	1.98E+09	1.48E+11	4.76E+12
UT(4) to Cane Run at 6.13 RM(5) 0.0 to 3.5	1.36E+12	5.68E+08	None	0.00E+00	4.08E+10	1.32E+12
Cane Run 9.6 to 17.4	2.23E+12	0	Lexington/ KYTC	1.29E+10	1.11E+11	2.10E+12
UT to Cane Run at 10.8 RM 0.0 to 2.4	1.19E+12	0	Lexington/ KYTC	6.43E+07	2.38E+10	1.17E+12
UT to Cane Run at 12.9 RM 0.0 to 2.1	4.79E+11	0	Lexington/ KYTC	1.58E+09	2.40E+10	4.53E+11
UT to Cane Run at 15.6 RM 0.0 to 0.9	1.40E+11	0	Lexington/ KYTC	7.01E+09	7.00E+09	1.26E+11

(1) In the event that compliance with the WQC is determined using *E. coli* concentrations as opposed to fecal coliform concentrations, the final fecal coliform allocations can be converted to *E. coli* by multiplying by the figure (240/400) for instantaneous values, or by the figure (130/200) for the 30-day geometric mean value, assuming 5 or more samples are taken within a 30-day period. Note that these relationships only demonstrate how to convert the TMDL allocations from terms of fecal coliform to terms of *E. coli* based on the relationship between the fecal coliform WQC and the *E. coli* WQC: The actual relationship between fecal coliform and *E. coli* instream has been defined in Section 2.2.4.1 of the Modeling Report based on sampling data. However, the relationship given in Section 2.2.4.1 of the Modeling Report is an estimate, and will not be used to convert *E. coli* to fecal coliform (or vice versa) to demonstrate compliance.

The TMDL is defined as the sum of the Wasteload Allocations (WLAs), Load Allocations (LAs) and a Margin of Safety (MOS, which in this case is implicit). However, sources of bacteria change over time and the output of existing sources changes with time. Allocation shifts can be made between the sources within the WLA, and between sources within the LA after the TMDL is approved, but not between the LA and WLA without TMDL revision, public notice and EPA approval.

(2) WLAs for the Sanitary Wastewater Systems (SWSs, e.g., Wastewater Treatment Plants (WWTPs)) discharging to a listed segment are equal to their permit limit times their design flow. These values were derived using the fecal coliform Water Quality Criterion (WQC) of 200 colonies/100ml calculated as a geometric mean using 5 or more samples collected within a 30-day period so the

allocated load is in units of colonies/day. See Table S.4 for allocations for individual SWSs. According to 401 KAR 10:031, individual SWSs may be permitted to discharge either fecal coliform or *E. coli;* currently all SWSs in the Cane Run watershed are permitted in terms of *E. coli*. However, the SWSs were modeled as discharging fecal coliform so their output was consistent with the monitoring protocol used to develop the TMDL.

Although Concentrated Animal Feeding Operations (CAFOs) receive their allocations within the WLA, there are no permitted CAFOs present in the watershed. Any future CAFO cannot legally discharge to surface water, and therefore receives a WLA of zero. The only exception is holders of a CAFO Individual Permit can discharge during a 25-year or greater storm event.

(3) Municipal Separate Storm Sewer Systems (MS4s) receiving aggregated MS4-WLAs include the City of Lexington (Permit Number KYS000002), the City of Georgetown (Permit Number KYG200040) and the Kentucky Transportation Cabinet (KYTC, Permit Number KYS000003).

(4) UT = Unnamed Tributary.

(5) RM = River Mile.

6.0 ADDITIONAL MODELING DISCUSSION

Modeling inputs from the various sources in the watershed were presented in Section 3.0, basic elements of the Cane Run modeling effort were presented in Sections 4.0, and the outcomes were modified as described by the post-modeling analysis presented in Section 5.0. This section provides additional, more in-depth discussion as to the specifics of the modeling effort.

6.1 Modeling Selection, Objectives and Purpose

The model(s) used must be appropriate for the watershed being studied. Two models were selected, HSPF and BASINS.

6.1.1 HSPF

HSPF was chosen because it is a comprehensive watershed model developed by EPA for simulating water quantity and quality for a wide range of pollutants in complex watersheds. HSPF has been widely reviewed and applied throughout its long history (Hicks, 1985; Ross, 1997; Tsihrintzis, 1996; Donigian and Huber, 1991). One of the largest applications of the model was to the Chesapeake Bay Watershed, as part of the EPA's Chesapeake Bay Program's management initiative (Donigian, 1990, 1991). An extensive HSPF bibliography has been compiled to document model development and application and is available online at http://hspf.com/hspfbib.htm or http://www.aquaterra.com/resources/hspfsupport/index.php (Aqua Terra, 2011).

In HSPF, a watershed is typically characterized as a series of catchments that are linked together in a hierarchical structure through the use of connecting elements which simulate the connecting stream network. These elements are called RCHRES. Each catchment in HSPF is modeled using two separate elements: 1) an element for simulating the runoff/water quality from the pervious fraction of the catchment called PERLND, and 2) an element for simulating the runoff/water quality from the impervious fraction of the catchment called IMPLND.

Each watershed element (i.e., PERLND, IMPLND, and RCHRES) contains various numerical algorithms that are used to model the different physical process associated with the hydrology or water quality of the catchment. Each of these algorithms requires various parameter values that must be specified by the user and then adjusted during the process of model calibration. In modeling the runoff of storm water from each PERLND element, the program keeps a record or account of the movement of rainfall through several different watershed storage elements. These elements are used to model the various associated hydrologic processes; evaporation, interception, infiltration, deep percolation, surface runoff, interflow and groundwater flow. The IMPLND algorithm also includes similar elements to model surface runoff. Both elements have additional algorithms that are used to model the buildup and runoff of different pollutants (e.g., fecal coliform, total phosphorus). Once the runoff and associated water quality have been generated from both the PERLND and IMPLND, the flows and loads are transferred to the stream reach element (i.e., RCHRES) which is then used to transport or route the load downstream to the next stream segment. The various algorithms employed in HSPF include both deductive models (e.g., Manning's equation) and inductive models (linear infiltration, exponential decay functions, etc.) that have been field verified.

Ultimately, the HSPF model was selected for application in the Cane Run watershed because of the following features: 1) the model has been extensively tested and validated in the literature, 2) the ability of the model to simulate hydrologic and water quality time series, 3) the ability to simulate runoff from both urban and impervious areas as well as non-urban and pervious areas, 4) the ability simulate the build-up and runoff of bacteria, 5) the ability to accommodate independent point source time series which can be used to simulate loadings from SWSs as well as SSOs, 6) the ability to accommodate interflow and groundwater flow and pollutant loadings (e.g., from septic systems and karst conditions). While not explicitly set up to handle surface flows which enter the subsurface through karst features and subsequently reappear surficially, using three separate HSPF models to accommodate this discontinuity adequately addressed all flows in the watershed.

6.1.2 BASINS

BASINS is a multipurpose environmental analysis software system for use by regional, state and local agencies in performing watershed and water quality-based studies. A GIS interface provides the integrating framework for BASINS and allows for the display and analysis of a wide variety of landscape information such as landcover, soils, monitoring stations, point source discharges, and stream descriptions. BASINS is useful in incorporating both point and nonpoint sources, while including instream transport and visualization. While HSPF simulates nonpoint source runoff from selected watersheds as well as the transport and flow of the pollutants through stream reaches, BASINS was used to delineate the various catchments within the Cane Run watershed as well as to extract spatial data from the BASIN's soil and landcover database for use in initializing the associated HSPF model parameters. The program was also used to estimate the physical parameters of the catchments and stream elements of the watershed (e.g., catchment length, slope and roughness, as well as stream cross-sectional areas, slopes and roughness).

6.1.3 Limitations of the Chosen Models

The primary challenges of applying the HSPF model to the Cane Run watershed were the complexity of the model, the number of required model parameters, the amount of data necessary to properly characterize the system, the complicated karst features and the inherent difficulty in modeling bacteria (i.e., fecal coliform) whose high variability in the environment makes prediction of its concentrations difficult.

6.2 Data Quantity and Quality

6.2.1 Data Used in the Models

Detailed information is provided in Section 2.0 of the TMDL document and Sections 1.0 through 4.0 of the Modeling Report. Typical loading rates for fecal coliform were obtained using the BIT (EPA, 2001) following a review of the National Stormwater Quality Database at http://rpitt.eng.ua.edu/Research/ms4/Paper/Mainms4paper.html, and *Techniques for Estimating the Quantity and Quality of Storm Runoff from Urban Watersheds of Jefferson County, Kentucky* (Evaldi and Moore, 1994). Meteorological data were obtained from the UK Spindletop monitoring site (UK, 2003) and disaggregated hourly using data from the Lexington Bluegrass Airport monitoring site (NOAA, 2002).

6.2.2 Data Gaps and Extrapolations

Excepting the difficulties of modeling surface flows in karst terrane, there were no explicit gaps on the basic data used, other than the lack of extensive pathogen data for use in calibrating the model, which is typical of most HSPF applications. Two USGS gauging stations were available in the watershed during the time of the study (the former Cane Run near Donerail and Royal Springs), and one North Elkhorn Creek, along with a rainfall station at Spindletop and one in Lexington (a NOAA station which records hourly data) which together provided sufficient data to perform hydrologic calibration of the model. Pathogen data and daily discharge data from the SWSs were also available. Despite this, there were implicit challenges; first, while the main karst conduit that discharges at Royal Spring has been dye traced, many of its feeder sinkholes and swallets have not, and no information is available on the rate of loss to the subsurface as a function of rainfall and/or distance along Cane Run. Second, having a gaging station available at the outlet of Cane Run as opposed to one on North Elkhorn Creek would have allowed a more direct calibration of flows. Last, as with all such model applications to large watersheds, additional rain gages would have been useful to provide a more refined spatial distribution of rainfall, which would have likely decreased the errors associated with the hydrologic calibration.

6.2.3 Key Assumptions and Limiting Considerations

In applying any model in an effort to evaluate existing pollutant loads and possible management strategies, it must be understood that models do not completely represent reality. However, as Pease (2006) points out, while no model is completely accurate, some models are still useful. Thus, the intent of this study has been to develop a useful model, one that provides a relative estimate of the maximum load that the streams in the watershed may assimilate without violating their associated WQCs, and where this loading is exceeded, describing final allocations to bring such impaired segments into compliance. Of course, even with a well-developed and calibrated (and thus "useful") model, the validity of the model results will be highly dependent upon the validity of the following modeling assumptions:

1) The BASINs database is sufficiently robust and accurate to reflect the physical characteristics of the Cane Run watershed;
2) The spatial analysis algorithms in BASINs are sufficiently accurate to provide realistic estimates of the topographic boundaries of the catchments and the geometry of the associated stream reaches;
3) The hydrologic and water quality algorithms of HSPF are sufficient to model the runoff and pollutant loading processes of the watershed;
4) The pollutant loading and hydrologic time series are stationary processes over the period of model calibration and application;
5) Rainfall is spatially distributed in a uniform way;
6) The BIT provides accurate fecal coliform loading estimates;
7) The contributions of SSOs in the watershed have been accurately identified and modeled, and;
8) The critical period selection for the model application (i.e., 1997-2001) accurately captures the diversity of flow and load fluctuations for the system.

6.2.4 Model Parameter Estimation

Hydrology and hydraulic parameters were developed using the BASINS program along with *BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameter Estimates for HSPF, EPA-823-R00-012* (EPA, 2000). Additional guidance was obtained from the *Users Manual for an Expert System (HSPEXP) for Calibration of the Hydrologic Simulation Program – Fortran* (Lumb, 1994) and the *HPSF User's Manual: Version 12* (Bicknell, 2001). Water quality loadings and parameter values were developed using the BIT (EPA, 2001a). Calibration criteria were obtained using Table 4 from *Ambient Water Quality Criteria for Bacteria – 1986* (EPA, 1986). For more information see the Basins website, EPA (2011b) at http://water.epa.gov/scitech/datait/models/basins/index.cfm.

6.2.5 Calibration, Validation and Scenario Analysis

Water quality parameters were calibrated as described in Sections 4.7.1 and 4.7.3 of the Modeling Report. Individual hydrologic model parameters were developed for each catchment based on the associated landcover and soil types as obtained from BASINS. For the purposes of modeling, the existing landcover subcategories were grouped into three major categories: developed or built up land, agricultural land (crop land and pasture land), and forestland. The percent distribution of each landcover type per catchment was then obtained using GIS analysis of the associated landcover coverage. These percentages were then used to establish initial estimates of the hydrologic parameters for each catchment based on guidance provided from *BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameter Estimates for HSPF* (EPA, 2000). In performing the model calibration, parameter adjustments were made starting in the headwater segments and then gradually working downstream. The important hydrologic parameters for HSPF included the infiltration index capacity (INFILT), the upper and lower zone moisture storage (UZSN, LZSN) the lower zone evapotranspiration parameter (LZETP), groundwater depletion (KVARY), groundwater recession rate (AGWRC), deep groundwater percolation (DEEPER), interflow (INTFLW), interflow recession (IRC) and monthly interception (MONINTER).

Once the initial model parameter estimates were obtained, they were then adjusted to reproduce the observed streamflows at the available USGS gaging stations. Guidance from *Watershed Model Calibration and Validation: The HSPF Experience* (Donigian, 2002) was used in establishing calibration targets (e.g., an Annual Volume Difference < 10% is described as "very good"). Three USGS gaging station flow records were used for this purpose. Hourly rainfall data were obtained from the regional NOAA weather station at the Lexington Bluegrass Airport. The hydrologic calibration was performed using observed streamflow values from 1997 to 2001. The resulting model was then validated against 2002 streamflow values.

Model performance can be evaluated using both graphical and statistical methods. Common graphical methods include: 1) time series plots, 2) scatter plots, and 3) cumulative frequency curves. All three methods were used in evaluating the model performance in this study. In general, all three methods showed fairly good performance. Plots of the observed and calibrated/validated hydrographs, as well as scatter diagrams for each year of the simulation period, are shown in Appendix B. The predicted hydrographs matched the observed hydrographs fairly closely. In addition, the best-fit line through the scatter plots yielded a line with a fairly high correlation coefficient for most years, as well as a slope fairly close to one. The latter observation confirms that the resulting calibration is fairly free of any model parameter bias as a function of the magnitude of the flows.

Observed flow hydrographs and simulated flow hydrographs were compared after each simulation and the essential parameters were tuned in subsequent trials. The best-tuned model was used for fecal coliform loading and reduction runs. Comparisons between the observed and predicted values for the USGS gaging stations are provided in Figures 4.6 through 4.11 of the Modeling Report. This includes a plot of the residual series (i.e., the simulated flow results minus the observed results), flow duration curves, and a visualization of the deviation of the annual volumes. The hydrologic model showed good calibration for the Royal Spring gage, as determined by a mean annual volumetric deviation less than 10% and a maximum observed deviation of 15% in 2004; a mean annual volume deviation of less than or equal to 10% was the target for the calibration effort. The model showed good calibration at the outlet of Cane Run, with a mean annual volumetric deviation of 10% and a maximum observed deviation of 15% in 2003. For both gages, the residual plots reveal the absence of model bias. The simulated and observed flow duration curves for each station also reveal fairly consistent results. The annual volume deviation plots illustrated the deviation of the predicted from the observed values for each station and also reveal the absence of any persistent model bias.

Additional statistical tests of model performance include: 1) error statistics, 2) correlation tests and 3) cumulative distribution tests. Example of statistics related to the hydrology calibration include:

- Nash and Sutcliffe (1970) have proposed a general statistic for model efficiency assessment called the Nash-Sutcliffe coefficient (NSE), which can range from negative infinity to 1.0. The closer the coefficient is to 1.0 the better the model performance. Moriasi (2007) in *Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations* found that Nash-Sutcliffe efficiencies greater than 0.5 are generally considered satisfactory.
- The Root Mean Square Error (RMSE also known as the Root Mean Square Deviation) and the Mean Absolute Error (MAE) are measures of the differences between the observed and the predicted model values (http://en.wikipedia.org/wiki/Root_mean_square_deviation, http://en.wikipedia.org/wiki/Mean_absolute_error). According to Moriasi (2007), "...RMSE and MAE values less than half the Standard Deviation (SD) of the measured data may be considered low..." where "low" means the model performance is acceptable.
- The Pearson Correlation Coefficient is also known as R. Moriasi (2007) states, "Pearson's correlation coefficient (R) and coefficient of determination (R^2) describe the degree of collinearity between simulated and measured data. The correlation coefficient, which ranges from -1.0 to 1.0, is an index of the degree of linear relationship between observed and simulated data. If R = 0, no linear relationship exists. If R = 1.0 or -1.0, a perfect positive or negative linear relationship exists." Ideally, the R value would approach 1.0.
- The Standard Deviation Ratio (RSR) is the ratio of the RMSE to the SD. Moriasi (2007) states the RSR is considered satisfactory if its value is less than 0.7.

Royal Spring Model Efficiency Statistics

Table 6.1 gives model efficiency statistics for the hydrology calibration at Royal Spring.

Table 6.1 Calibration Statistics for Royal Spring

Year	SD	MAE	RMSE	RSR	NSE	R
1998	98.2	22.95	45.55	0.46	0.78	0.90
1999	28.5	11.40	22.26	0.78	0.39	0.72
2000	21.8	9.37	17.06	0.78	0.39	0.75
2001	18.3	14.02	23.50	1.28	-0.65	0.65
2002	73.7	20.34	44.54	0.60	0.63	0.80

For Royal Springs, the NSE is above 0.5 for two years of the five years of the simulation. The low NSE performance for 1999-2000 may be attributable to the lower observed flows during these years (1999 was a 25-year drought). The underperformance for 2001 is thought to be due to the consistent overprediction of peak discharges during a year with relatively lower flows.

However, 2002 was the year when the water quality data were collected, and 2002 had fairly good model performance statistics, including an acceptable NSE.

As shown in Table 6.1, the MAE is less than half of the SD for four of the five years in the simulation. This was not the case for the RMSE, which was over half of the SD for four of the five years in the simulation (1998 showed an acceptable ratio). The RSR, which is considered satisfactory if its value is less than 0.7, showed acceptable values for two of the five years. Again, 1999-2000, influenced by drought, was outside the accepted range, as was 2001. Last the R values do not all approach 1.0, but overall indicate an acceptable model performance given the challenges inherent in modeling this system.

As stated, while not all model performance indicators were within the standard acceptable ranges, the predictive ability of the model is highly dependent upon the spatial variability of the measured rainfall (which had to be disaggregated hourly from a local rainfall gage using a more distant NOAA gage) and the complexities added by the karst hydrology (Cane Run is a losing stream for most of its length, and a variable amount of flow enters the subsurface as flow travels down the main channel; the amount of lost flow increases with the amount of initial flow, which again depends on rainfall). Given these factors, and considering the graphical model performance metrics in Figures 4.6 through 4.8, the hydrologic model exceeded expectations and was deemed to be adequate for modeling the karst system.

<u>Cane Run Model Efficiency Statistics</u>

Table 6.2 gives model efficiency statistics for the hydrology calibration at the outlet of Cane Run.

Table 6.2 Calibration Statistics for the Outlet of Cane Run (Estimated Using the USGS Gage on North Elkhorn)

Year	SD	MAE	RMSE	RSR	NSE	R
1998	67.0	17.14	44.92	0.67	0.55	0.75
1999	28.0	5.79	14.24	0.51	0.74	0.88
2000	43.2	6.86	21.12	0.49	0.76	0.88
2001	37.9	9.97	27.09	0.71	0.49	0.71
2002	67.5	17.60	37.00	0.55	0.70	0.86

The NSE is above 0.5 for four of the five years of the simulation. The MAE was less than half of the SD for all years in the simulation, but the RMSE was less than half for one year, with one other year only slightly exceeding the criterion, and three exceeding the criterion. The RSR was less than 0.7 for all years except 2001. With the exception of 1998, R values more closely approached 1.0 than the R values for Royal Spring, indicating better model performance. Again, given the challenges inherent in modeling this system, including the lack of hourly rainfall data and diversion of flow into the karst terrane along the Cane Run mainstem, this indicates acceptable model performance.

Water Quality Calibration Statistics

In calibrating the water quality parameters, an attempt was made to minimize the difference between the observed and predicted fecal coliform values such that the difference was within 0.5 logs. This parallels the procedure (EPA, 1986) for setting a level approximately equal to ½ of a 90% confidence band. Statistics were also computed using a full 90% confidence band, see Table 6.3. Due to the highly variable nature of fecal coliform predictions, these comparisons were only made on those results where the observed fecal coliform counts exceeded the instantaneous WQC of 400 colonies/100mL. As can be seen from the results, not all of the stations met the target values. The main calibration problems may be related to SSO and cross-connection problems which were difficult to explicitly simulate, or to the complex karst flow routing. However, deviations outside the limits typically occur when the predicted value is above the upper limit of the observed values, or in other words an overestimate which therefore provides an implicit MOS. In addition to comparing the predicted and observed results for a given day, a comparison was also made between the observed values and the geometric mean of five days of predicted values centered on the date of the observed data point. This analysis was conducted to account for any variability of model performance as influenced by variations due to timing effects associated with hydrologic errors. The log difference of 0.5 criterion of geometric mean values was satisfied for the vast majority of the time for all of the sites.

Table 6.3 Calibration Statistics for Fecal Coliform Observations for All Stations

Site	Upper 90% CL[1]	Full 90% CL[1]
C0	100%	100%
C1	67%	100%
C2	no data	no data
C3	100%	100%
C4	56%	78%
C5	75%	88%
C6	75%	100%
C7	50%	100%

[1]Shaded values below 90% CL

6.2.6 Analysis and Interpretation of Results

As discussed, the modeling effort produced a useful product, however with some measure of error. Of course, all hydrologic/water quality models are expected to some have some error, especially modeling involving the prediction of fecal coliform concentrations. Potential sources of errors in the current model include:

1) Potential errors in predicted flowrates due to an assumption of spatially uniform rainfall as derived from point rainfall data from the Lexington Bluegrass Airport.
2) Potential inaccuracies in the EPA BASIN database that was used to initialize the basic model parameters. Where possible, these errors were minimized through a visual inspection of the suggested model parameters (e.g., FTABLES) and through

subsequent model calibration.

3) Potential inaccuracies in census data, landcover, soil maps, etc.
4) Potential inaccuracies in the assignment of observed loads to point and nonpoint sources.
5) Potential inaccuracies associated with observed karst features in the watershed. For the purposes of modeling, all runoff and pollutant loads emanating from a particular catchment were assumed to have originated in that catchment (exclusive of SSO discharges).
6) Potential failure to adequately model the complex sewer system within the watershed including the numerous documented SSOs and potential cross-connections with storm sewers.

6.2.7 Validation

Ideally a water quality model would be validated using a different dataset than that used to calibrate it, to determine its predictive value for a different dataset than the one used to set its physical parameters. Water quality data collected by BAE during 2008 and 2009 (see Table 2.6 and Figure 2.3 of the TMDL document) were used to validate the water quality results. In this case, "observed" fecal coliform values were determined using the measured *E. coli* values and Equation (2). A comparison of the "observed" and model-predicted values are provided for site CR03 in the upper part of the basin and site CR12 in the lower part of the basin, see Figures 6.1 and 6.2. Confidence limits (upper and lower bounds) are also provided which are based on a 0.5 log deviation from the observed values. As can be seen from the results, the model is able to simulate the observed values fairly well (i.e., within 0.5 log), especially for the higher values, which is the more critical range for the TMDL development.

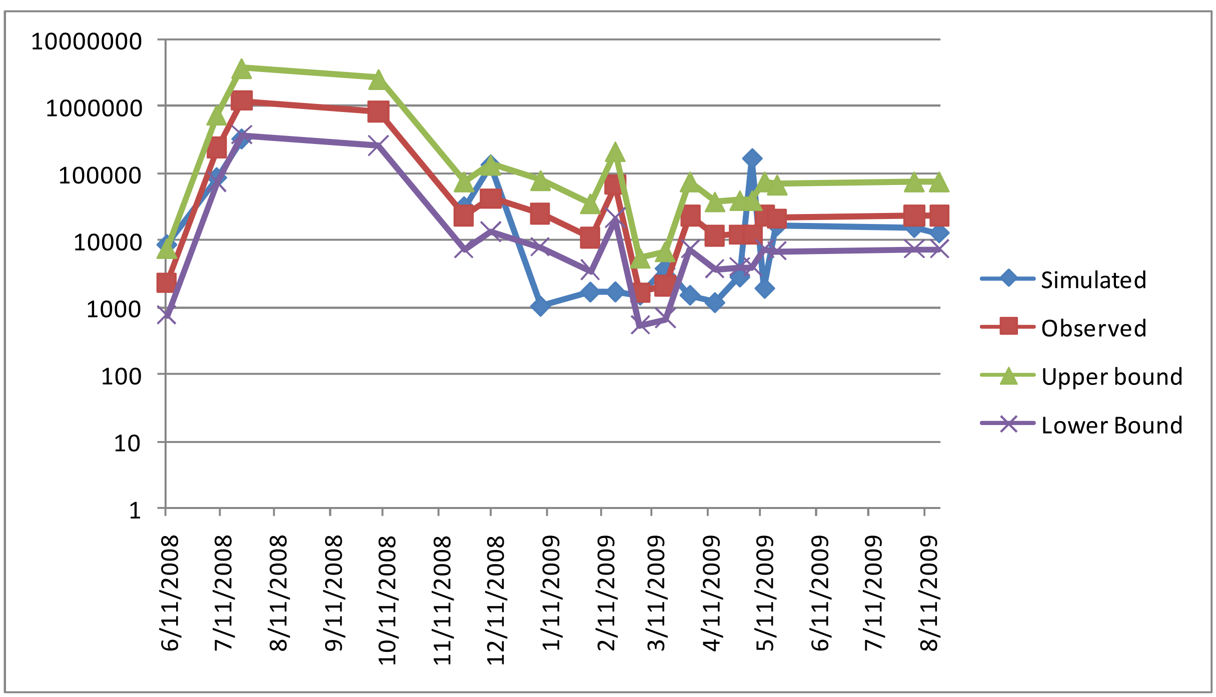

Figure 6.1 Comparison of "Observed" and Simulated Fecal Coliform Values for Site CR03

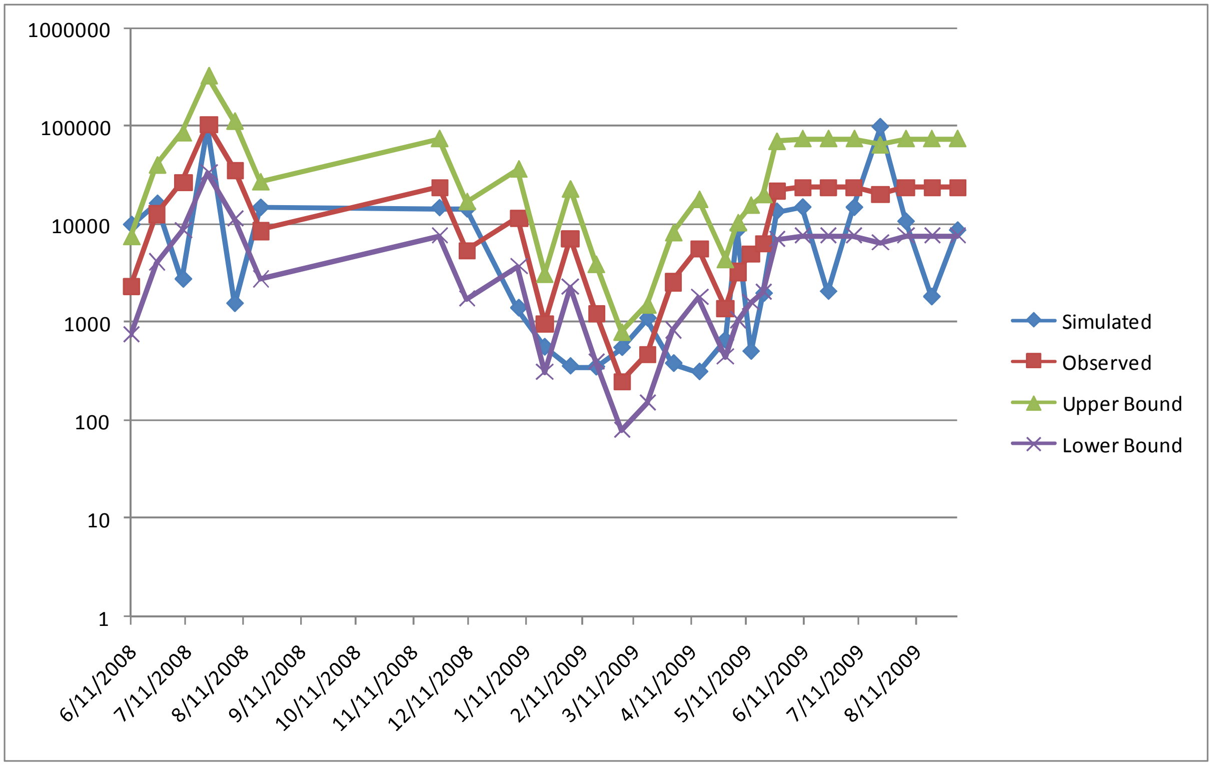

Figure 6.2 Comparison of "Observed" and Simulated Fecal Coliform Values for Site CR12

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APPENDIX A1: KWRRI SAMPLING RESULTS

Appendix A contains the results of the water quality sampling conducted during the summer of 2002 by the KWRRI. Ten rounds of samples were collected at 8 different sites along Cane Run from 6/11/2002 through 9/30/2002.

Table A1: 2002 Fecal Coliform Results: Cane Run Observations

Date	C0 (colonies/ 100ml)	C1 (colonies/ 100ml)	C2 (colonies/ 100ml)	C3 (colonies/ 100ml)	C4 (colonies/ 100ml)	C5 (colonies/ 100ml)	C6 (colonies/ 100ml)	C7 (colonies/ 100ml)
6/11/2002	9,215	2,289	DRY	334	832	387	1,497	4,697
6/14/2002	6,482	4,469	DRY	250	723	373	1,294	698
7/2/2002	7,058	DRY	DRY	391	3,972	840	4,176	1,930
7/9/2002	DRY	DRY	DRY	204	7,470	612	290	495
7/15/2002	DRY	DRY	DRY	1,055	34,605	704	5,385	552
7/22/2002	DRY	DRY	DRY	1,030	18,624	672	1,144	519
7/29/2002	DRY	DRY	DRY	5,239	441	425	572	2,116
9/9/2002	DRY	DRY	DRY	6,088	362	1,270	137	199
9/23/2002	7,361	DRY	DRY	986	414	221	789	201
9/30/2002	2,121	721	DRY	1,179	909	282	997	519

APPENDIX A2: UK COLLEGE OF AGRICULTURE SAMPLING RESULTS

Appendix A2 contains the results of the water quality sampling conducted during the years of 2008 and 2009 by the Biosystems and Agricultural Engineering Department of the University of Kentucky College of Agriculture. Samples were collected at 14 different sites along Cane Run from 6/11/2008 through 1/6/2010.

Table A2: *E. coli* Results: Cane Run Observations

Date	CR1 (colonies/ 100ml)	CR2 (colonies/ 100ml)	CR3 (colonies/ 100ml)	CR4 (colonies/ 100ml)	CR5 (colonies/ 100ml)	CR6 (colonies/ 100ml)	CR7 (colonies/ 100ml)
6/11/2008					374	1,035	1,129
6/25/2008	684			10,708	404		1,861
7/9/2008	18,202	14,910	110,120	7,893	1,786		6,631
7/23/2008	37,917	90,500	62,917	18,917	34,200	48,267	164,767
8/6/2008	26,540			8,973	10,730		28,093
8/20/2008	9,003			13,867	4,923		11,083
9/3/2008	13,267			6,630	4,093		18,180
9/17/2008	667			32,940	500		667
10/1/2008	250,460			30,983	23,153		10,147
10/8/2008	44,950	41,297	42,953	83,225	51,050	126,237	25,623
10/15/2008	26,943			56,853	29,990		3,410
10/22/2008	643			1,680	667		1,520
10/29/2008	1,006			16,960	667		1,000
11/12/2008	898			10,237	3,688		1,240
11/25/2008	2,369	32,567	1,746	706	1,401		1,248
12/10/2008	833	18,663	6,350	1,173	2,367	5,217	2,373
1/7/2009	1,170	5,580	1,860	4,090	1,007	2,367	667
1/21/2009	1,000			4,137	1,000		1,000
2/4/2009	1,828	741	5,912	13,360	202	1,188	1,008
2/18/2009	5,636	2,896	7,982	2,033	100	6,281	342
3/4/2009	134	134	83	2,363	100	100	83
3/18/2009	257	2,282	113	2,027	10		54
4/1/2009	1,676	3,171	4,260	7,020	129	4,639	539
4/15/2009	3,878	3,238	975	2,367	7	1,824	440
4/29/2009	468	4,542	687	5,550	72		173
5/6/2009	362	1,945	669	3,797	20		504
5/13/2009	485	2,184	1,275	969,020	295	429	1,015
5/20/2009	379		1,784	7,787	45		409
5/27/2009	731			8,867	151		663
6/10/2009	1,030			28,507	179		331
6/24/2009	2,780			5,930	191		513
7/8/2009	1,222			19,020	454		672
7/22/2009	2,135			36,273	630		2,364
8/5/2009	7,660	25,000	25,000	12,147	7,076	15,286	6,869
8/19/2009	2,048		4,449	6,743	947		460
9/2/2009	1,032			14,463	1,309		1,269
9/16/2009	1,132			2,367	244		1,034
9/30/2009	496	1,612	637	39,973	140	716	229
10/7/2009	4,643			39,507	218		230
10/14/2009	12,532	12,675	19,618	23,520	1,099	1017	10,109
10/21/2009	477		395	1,353	27		141
10/28/2009	1,597	4,644	2,096	48,430	415	4,438	2,616
11/11/2009	631			12,607	133		90
12/2/2009	9,825		781	17,017	294		191
12/16/2009	414	534	183	12,203	35	202	15

Date	CR1 (colonies/ 100ml)	CR2 (colonies/ 100ml)	CR3 (colonies/ 100ml)	CR4 (colonies/ 100ml)	CR5 (colonies/ 100ml)	CR6 (colonies/ 100ml)	CR7 (colonies/ 100ml)
1/6/2010	105			1000	12		

Date	CR8 (colonies/ 100ml)	CR9 (colonies/ 100ml)	CR10 (colonies/ 100ml)	CR11 (colonies/ 100ml)	CR12 (colonies/ 100ml)	CR13 (colonies/ 100ml)	CR14 (colonies/ 100ml)
6/11/2008	497	618	715		1,161		
6/25/2008	100	1,615			278	649	
7/9/2008	535	3,627			1,035	36,047	
7/23/2008	6,583	16,600			10,550	59,767	26,117
8/6/2008	5,640	7,013			10,890	170,103	
8/20/2008	2,730	2,023			2,367		
9/3/2008		13,153					
9/17/2008	500						
10/1/2008	20,850						
10/8/2008	26,597					42,380	44,140
10/15/2008	14,033						
10/22/2008	500						
10/29/2008	500						
11/12/2008	952						
11/25/2008	3,272	6,562			997	3,194	
12/10/2008	4,153	1,680	4,577	4,160	500	42,433	1,173
1/7/2009	500	500	667	1,007	500	27,110	2,200
1/21/2009	500	500			500	11,253	
2/4/2009	956	2,507	664	2,369	2,080	8,563	1,390
2/18/2009	67	50	50	83	83	7,133	974
3/4/2009	67	50	50	83	67	3,637	50
3/18/2009	101	12			8	6,663	105
4/1/2009	780	83	1,437	207	68	13,747	471
4/15/2009	140	38	798	101	164	5,200	352
4/29/2009	196	86			15	2,010	
5/6/2009	1,079	155			38	5,927	
5/13/2009	510	285			162	8,153	1,204
5/20/2009	168	95			31	10,207	
5/27/2009	518	207			980	29,107	
6/10/2009	64	823			31	7,427	
6/24/2009	203	572			48		
7/8/2009	406	702			1,068	12,490	
7/22/2009		1,372			797		
8/5/2009	5,907	17,574	10,708	15,286	14,601	29,340	1,981
8/19/2009	292	373			428	65,837	
9/2/2009	1,176	542			5,342	5,193	
9/16/2009	343	262					
9/30/2009	238	105		155	139	1,170	924
10/7/2009	364	97				55,583	
10/14/2009	7,290	917		1,599	1,184	30,290	8,626
10/21/2009	358	31		45	297	3,093	

Date	CR8 (colonies/ 100ml)	CR9 (colonies/ 100ml)	CR10 (colonies/ 100ml)	CR11 (colonies/ 100ml)	CR12 (colonies/ 100ml)	CR13 (colonies/ 100ml)	CR14 (colonies/ 100ml)
10/28/2009	3,015	82	3,717	3,080	5,097	40,527	4,851
11/11/2009	404	113			114	2,743	
12/2/2009	219	720				34,473	9,825
12/16/2009	17	7		153	5,982	1,680	90
1/6/2010	20	27				1,340	

APPENDIX B: HYDROLOGIC CALIBRATION/VALIDATION RESULTS

Appendix B contains the results of the hydrologic calibration/validation of the HSPF models used to simulate the hydrology of the Cane Run watershed under non-karst conditions. The results are presented through a series of hydrographs and scatter plots for the specific locations of Royal Spring and the Cane Run watershed lower outlet for the 10-year time period, from January 1, 1998, to December 30, 2007. Graphs B.1 through B.20 show the modeled flow, in cubic feet per second, at Royal Spring. Graphs B.21 through B.40 show the results for the watershed outlet. The hydrographs and scatter plots compare the observed vs. predicted values as measured at the USGS gaging station for Royal Spring and observed (synthesized based on nearby USGS gaging station) vs. predicted values for the watershed lower outlet.

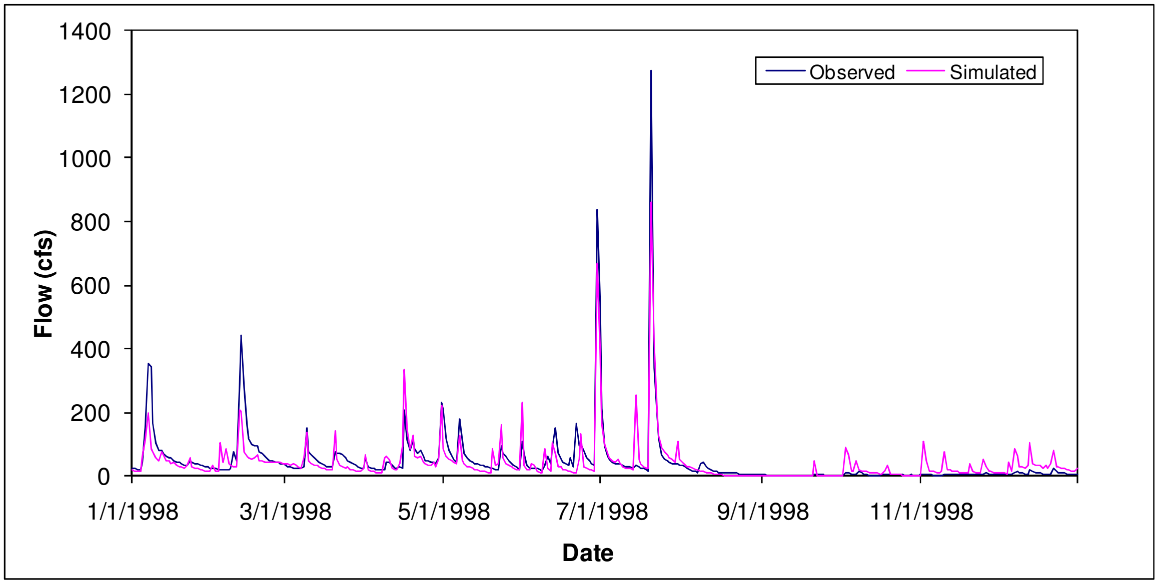

Figure B.1 Hydrology Calibration at Royal Spring for Cane Run (1998)

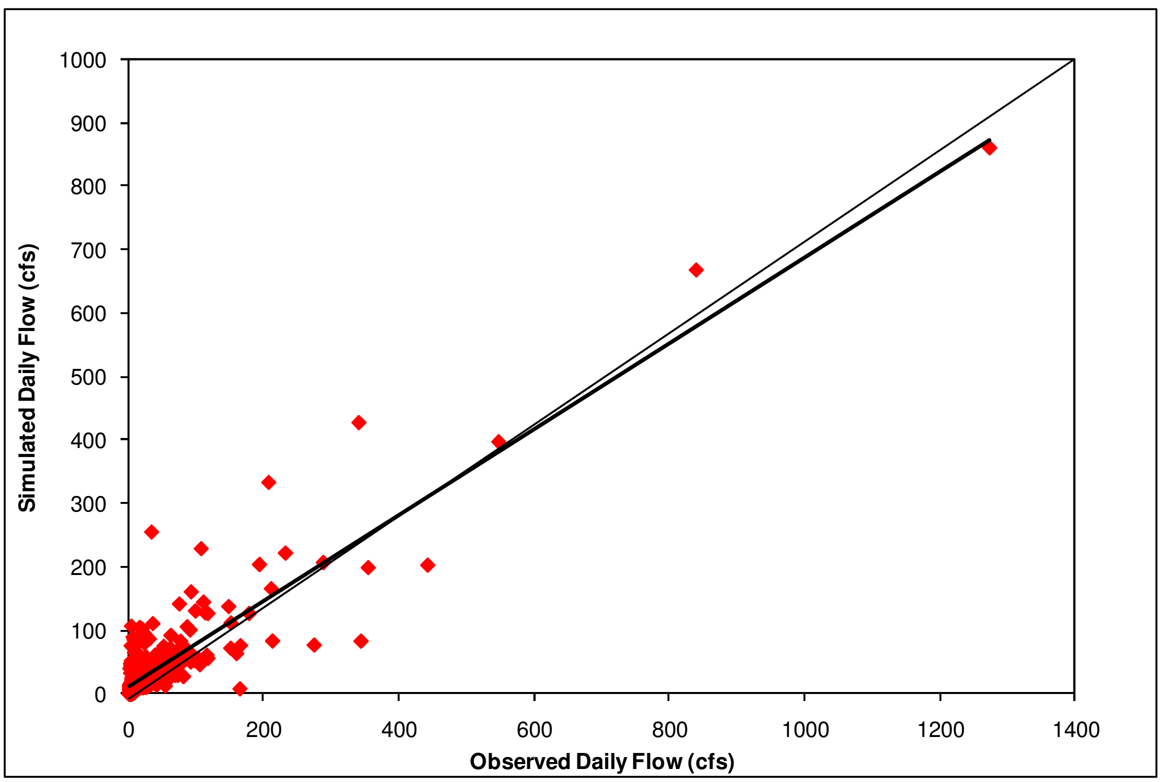

Figure B.2 Bias Plot for Cane Run at Royal Spring (1998)

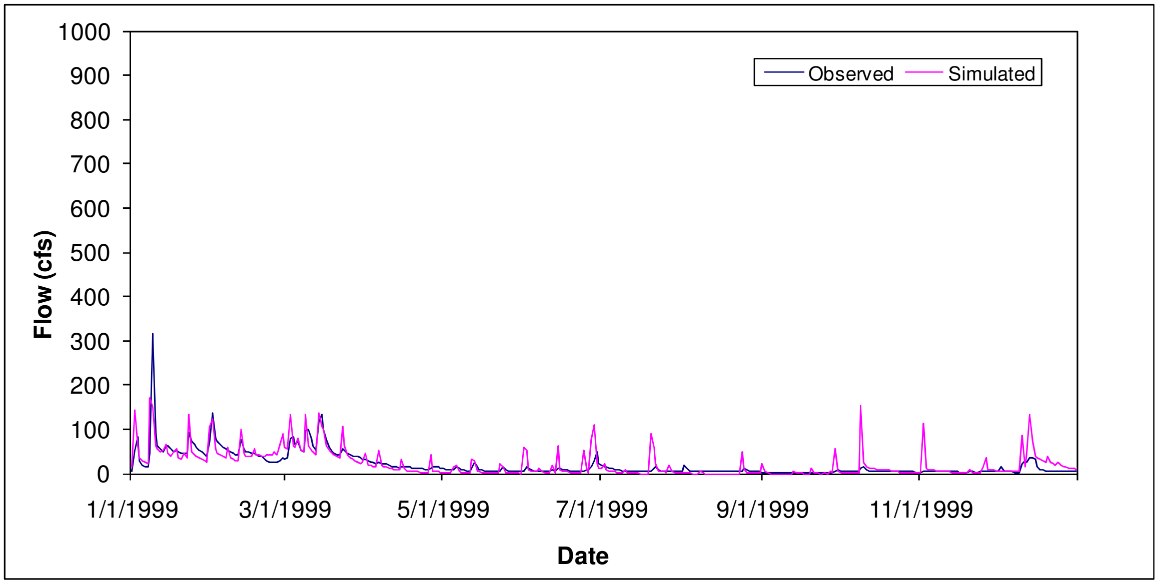

Figure B.3 Hydrology Calibration for Cane Run at Royal Spring (1999)

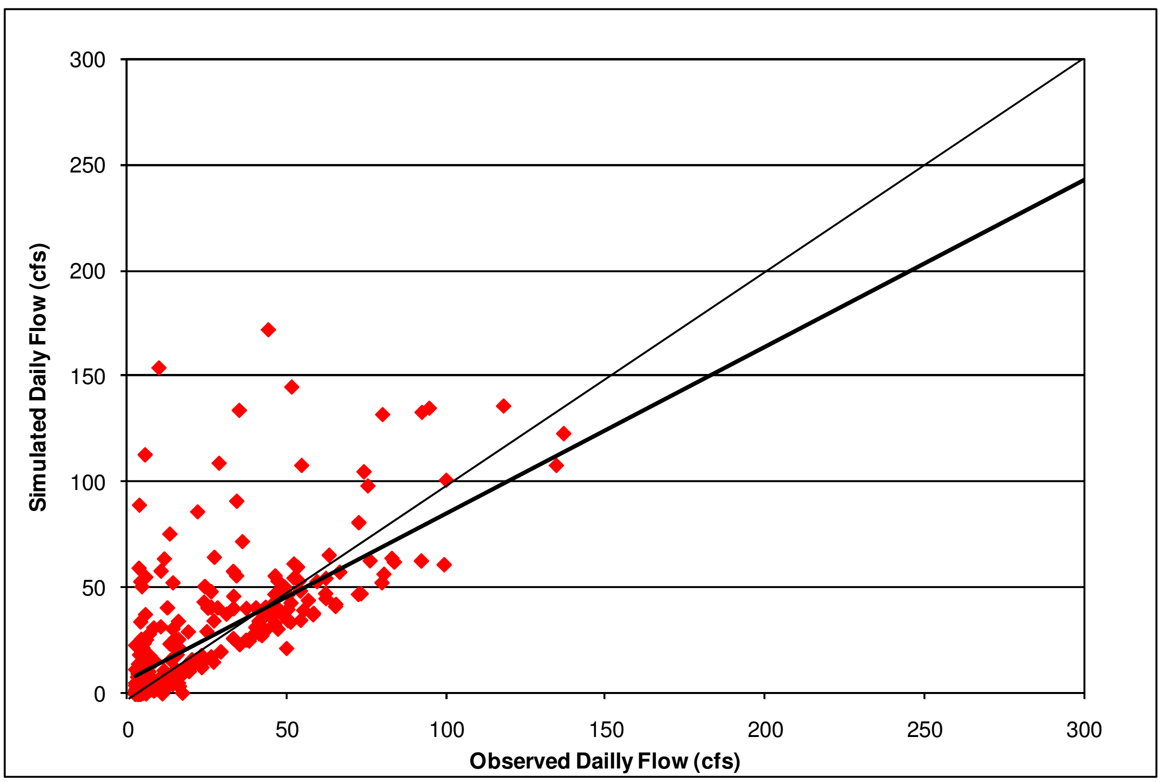

Figure B.4 Bias Plot for Cane Run at Royal Spring (1999)

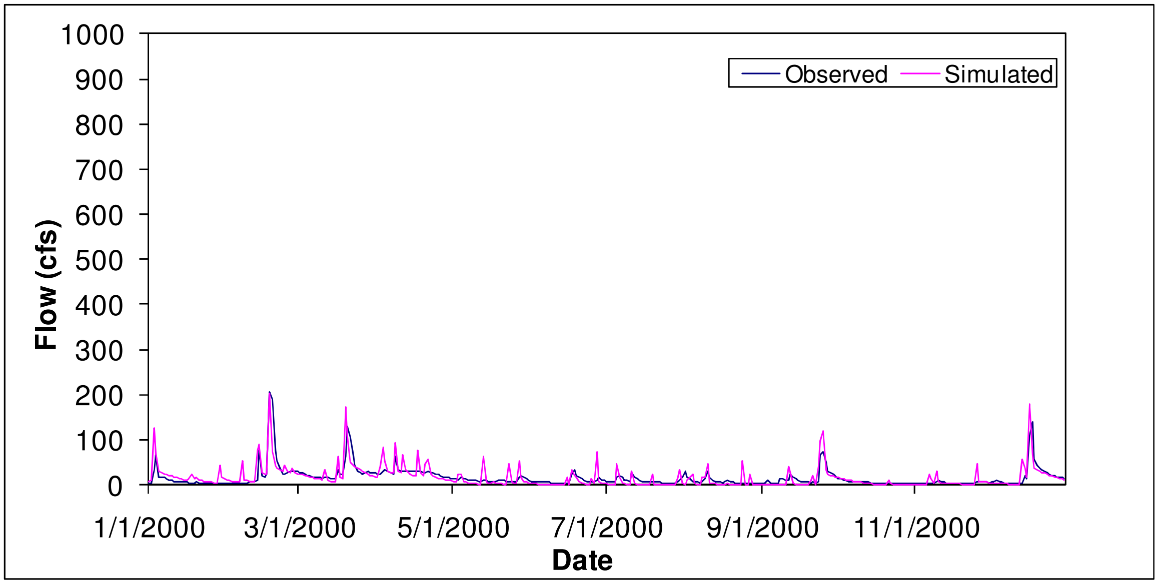

Figure B.5 Hydrology Calibration for Cane Run at Royal Spring (2000)

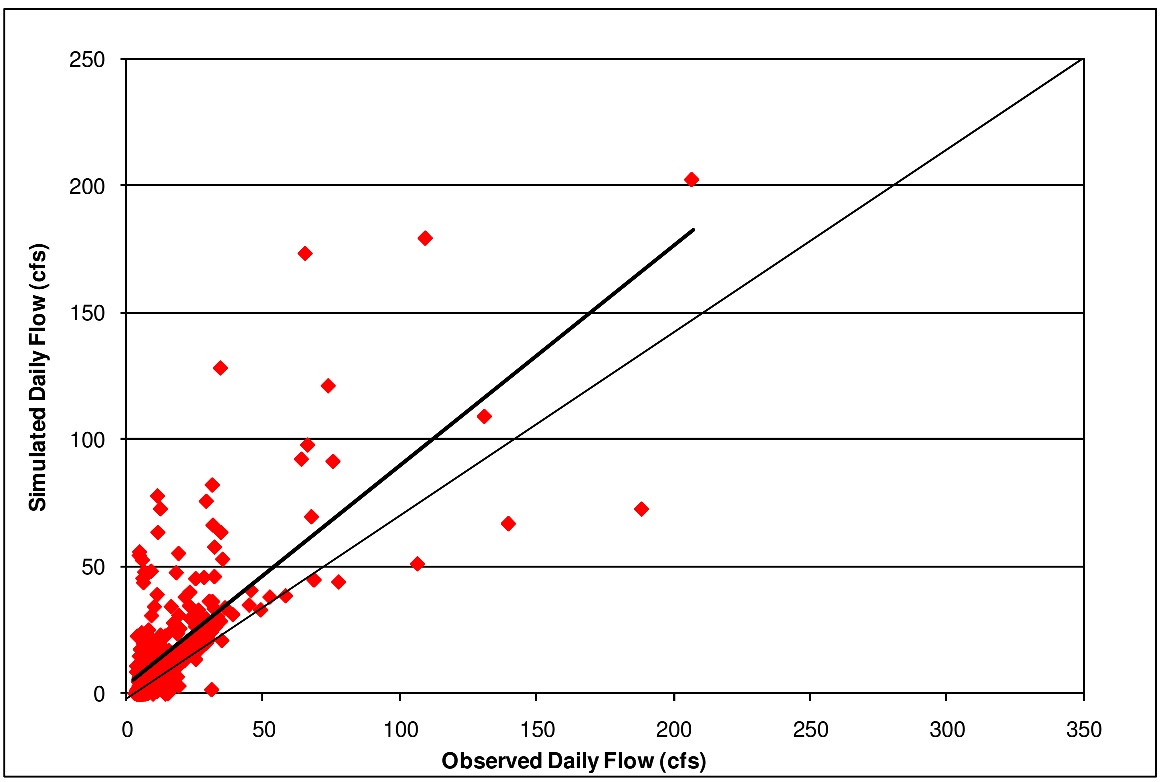

Figure B.6 Bias Plot for Cane Run at Royal Spring (2000)

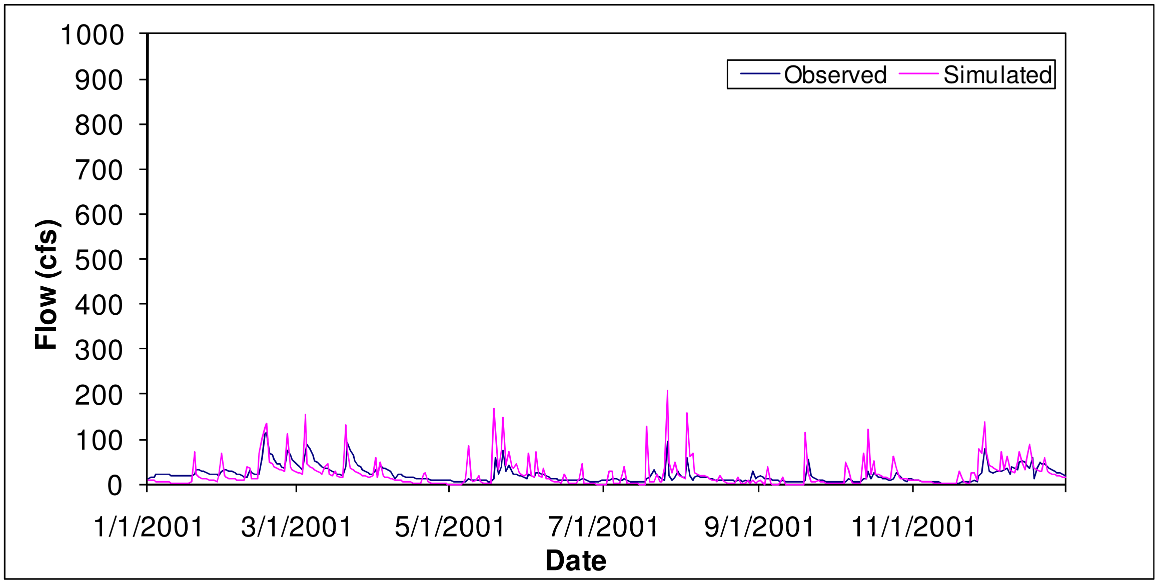

Figure B.7 Hydrology Calibration at for Cane Run Royal Spring (2001)

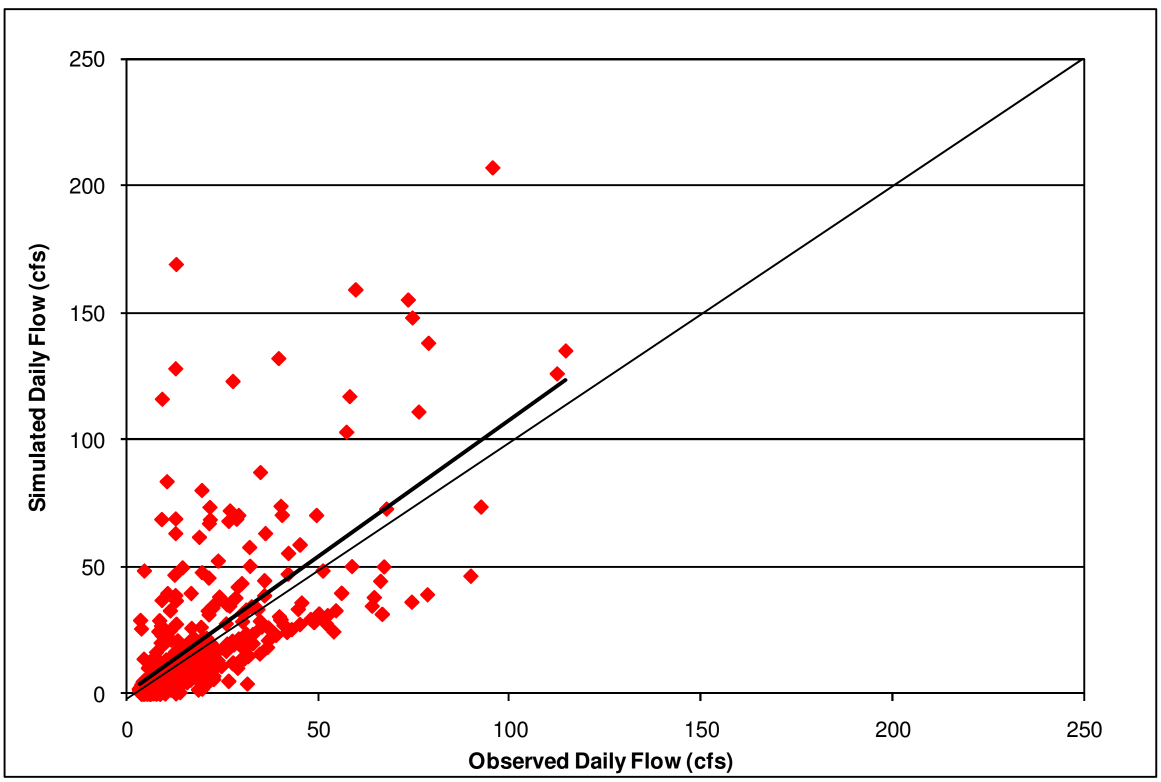

Figure B.8 Bias Plot for Cane Run at Royal Spring (2001)

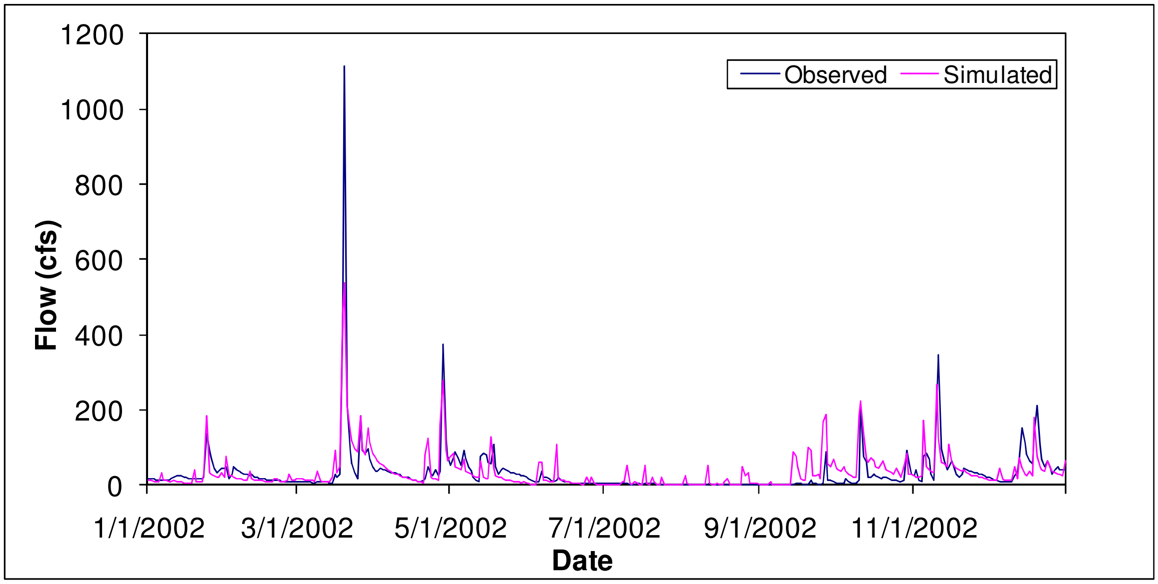

Figure B.9 Hydrology Calibration for Cane Run at Royal Spring (2002)

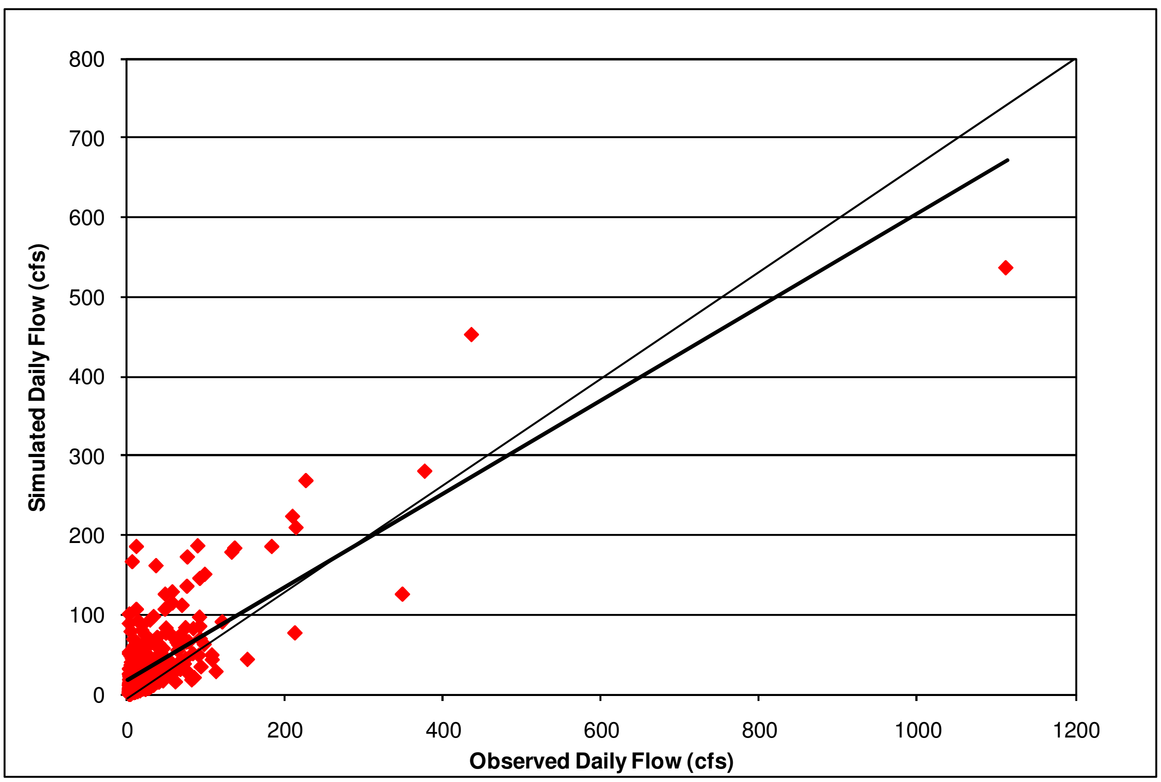

Figure B.10 Bias Plot for Cane Run at Royal Spring (2002)

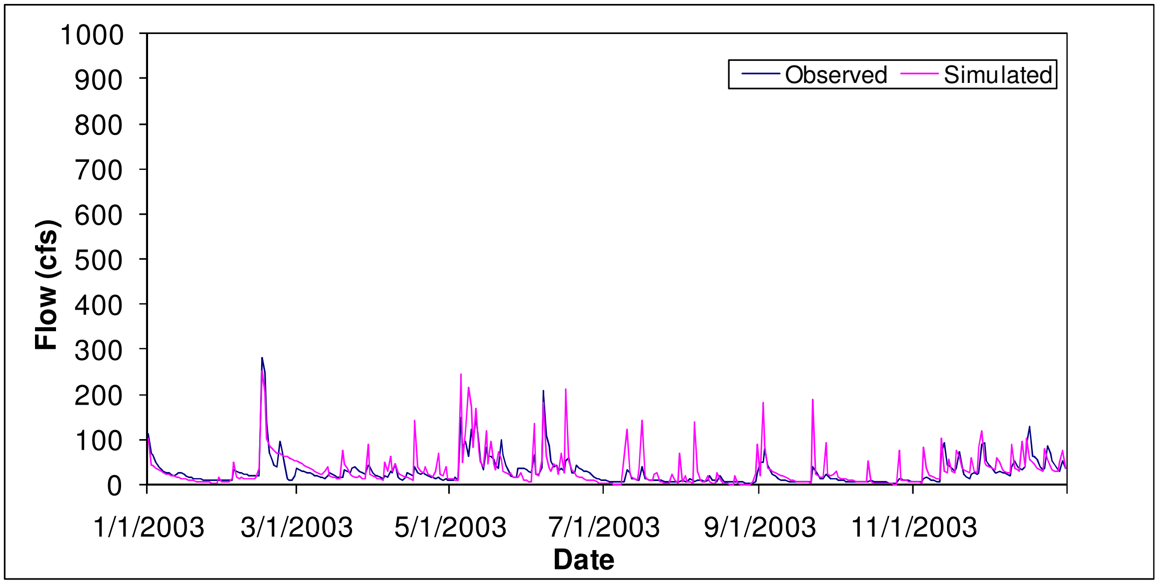

Figure B.11 Hydrology Calibration at Royal Spring for Cane Run (2003)

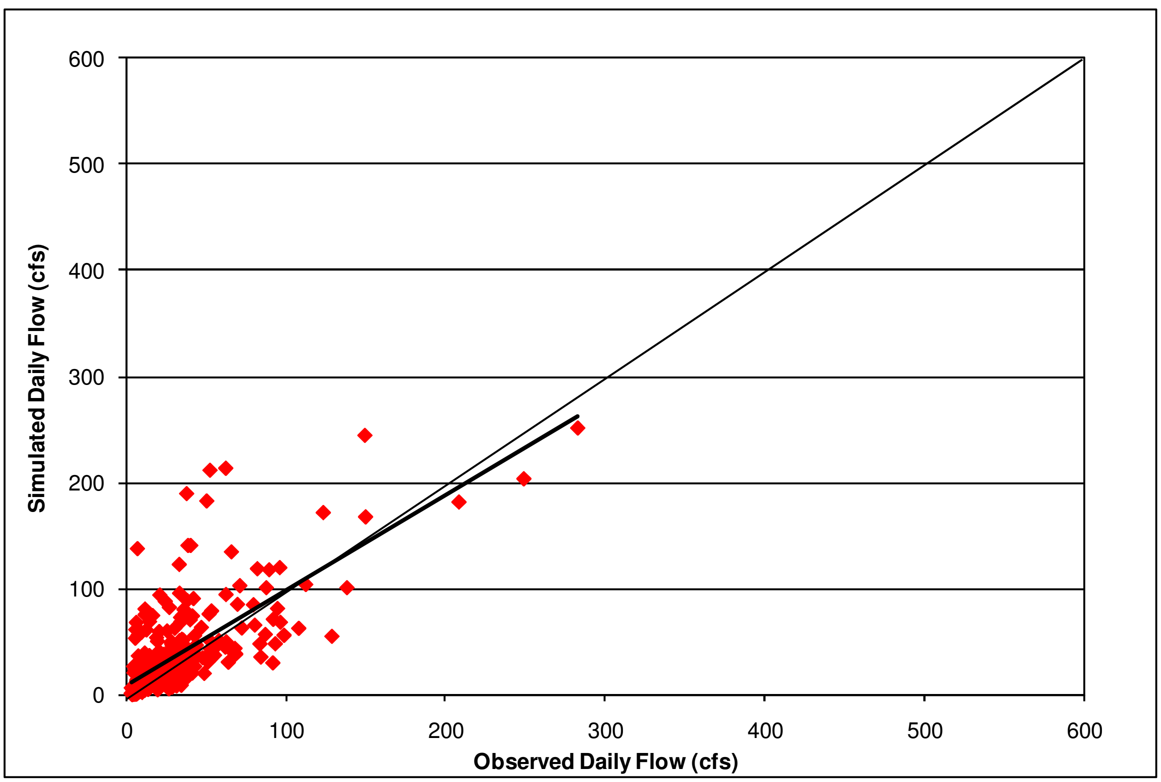

Figure B.12 Bias Plot for Cane Run at Royal Spring (2003)

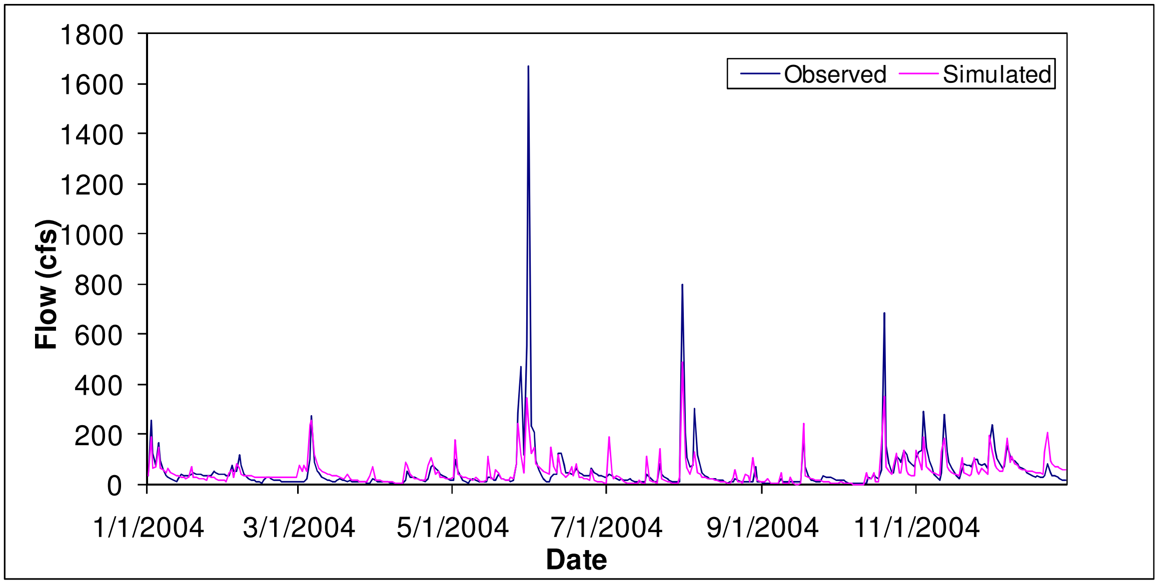

Figure B.13 Hydrology Calibration for Cane Run at Royal Spring (2004)

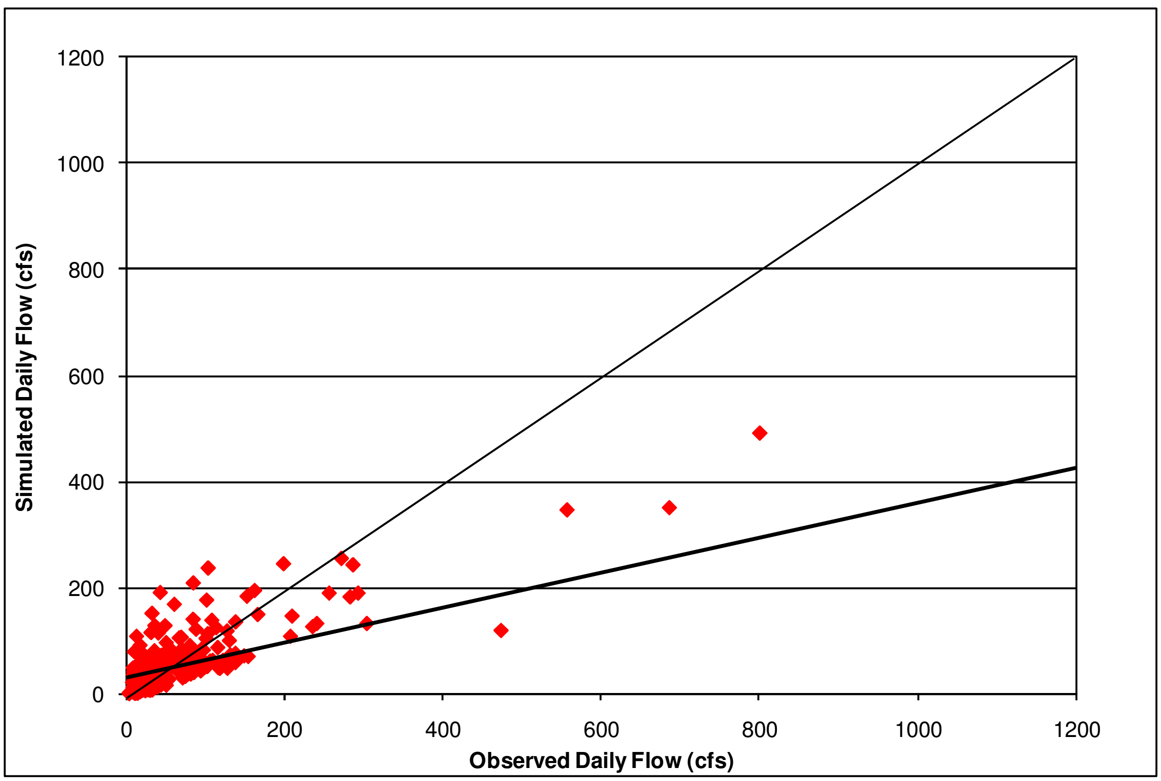

Figure B.14 Bias Plot for Cane Run at Royal Spring (2004)

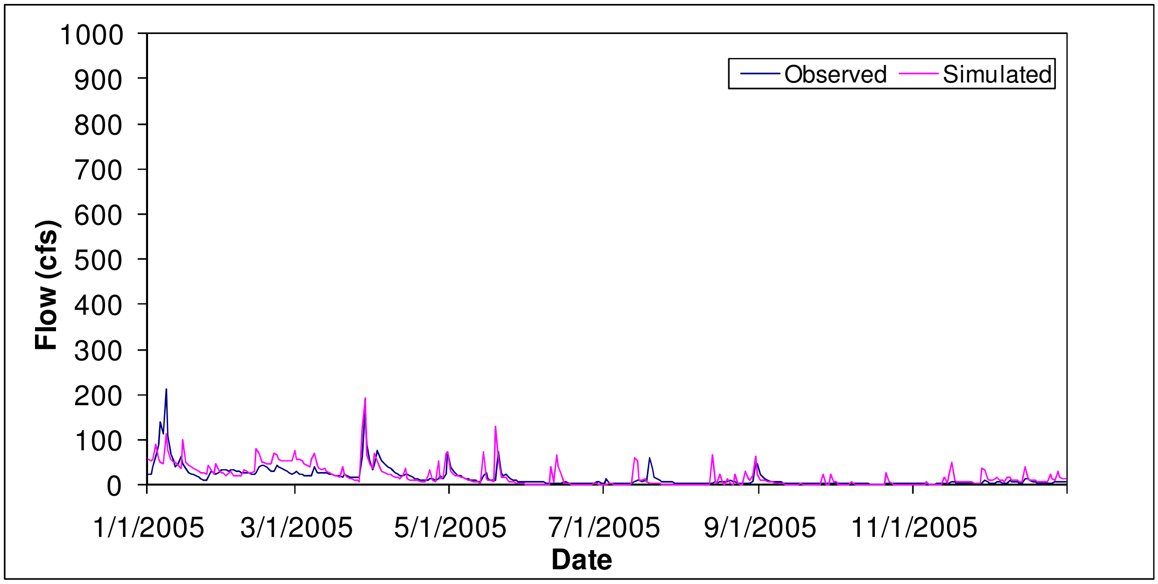

Figure B.15 Hydrology Calibration for Cane Run at Royal Spring (2005)

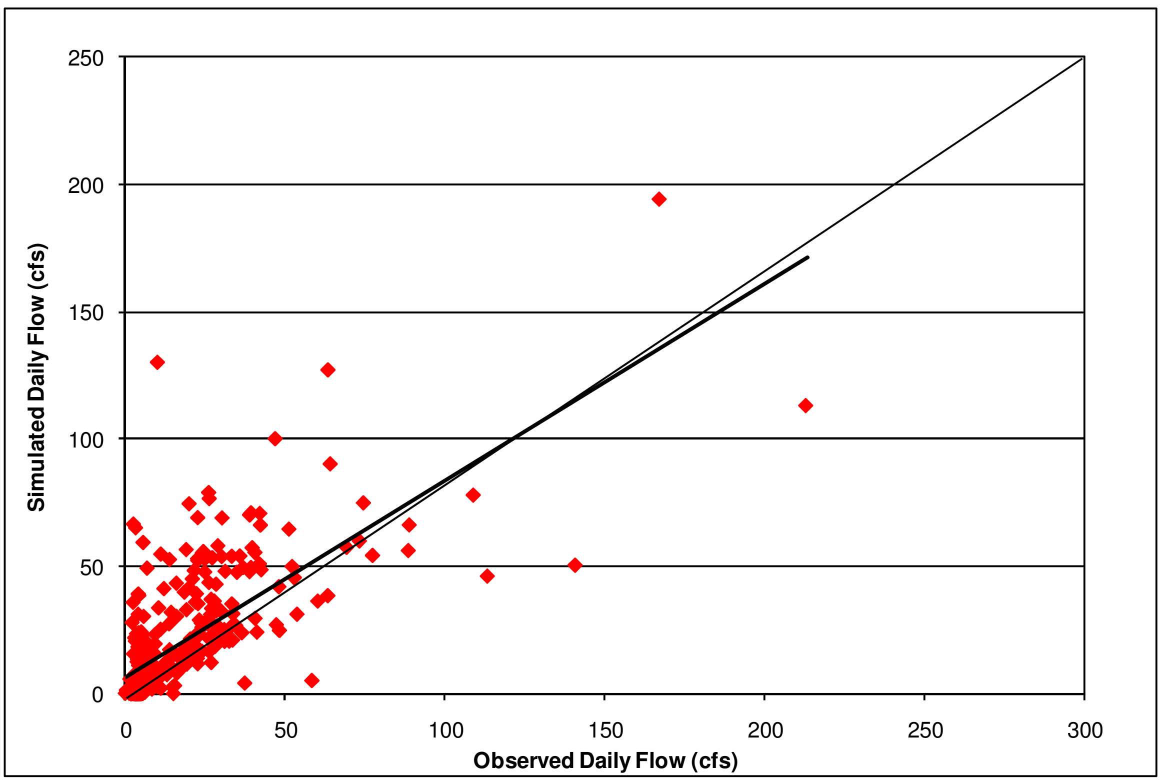

Figure B.16 Bias Plot for Cane Run at Royal Spring (2005)

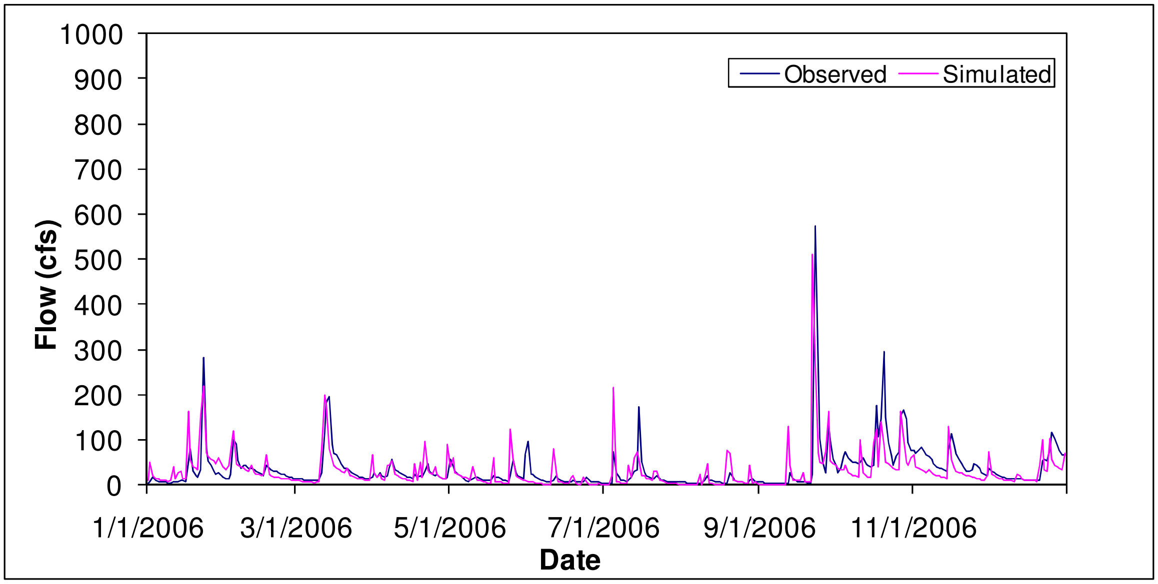

Figure B.17 Hydrology Calibration at for Cane Run Royal Spring (2006)

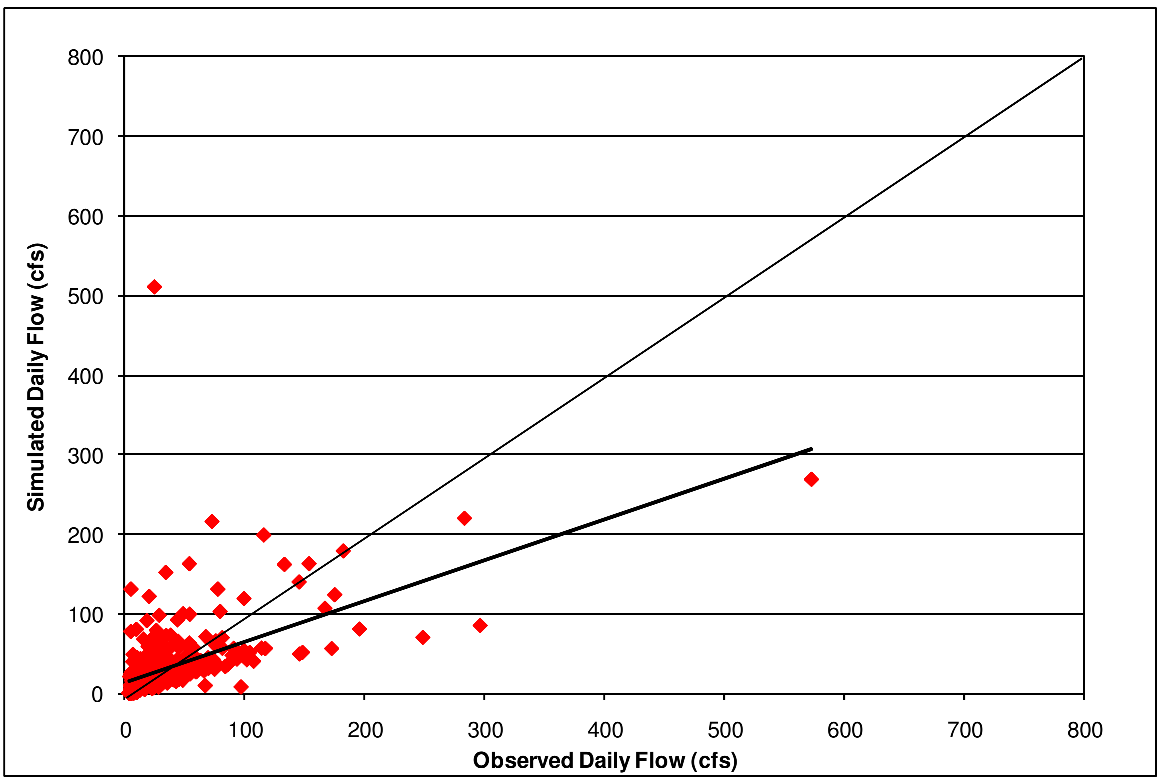

Figure B.18 Bias Plot for Cane Run at Royal Spring (2006)

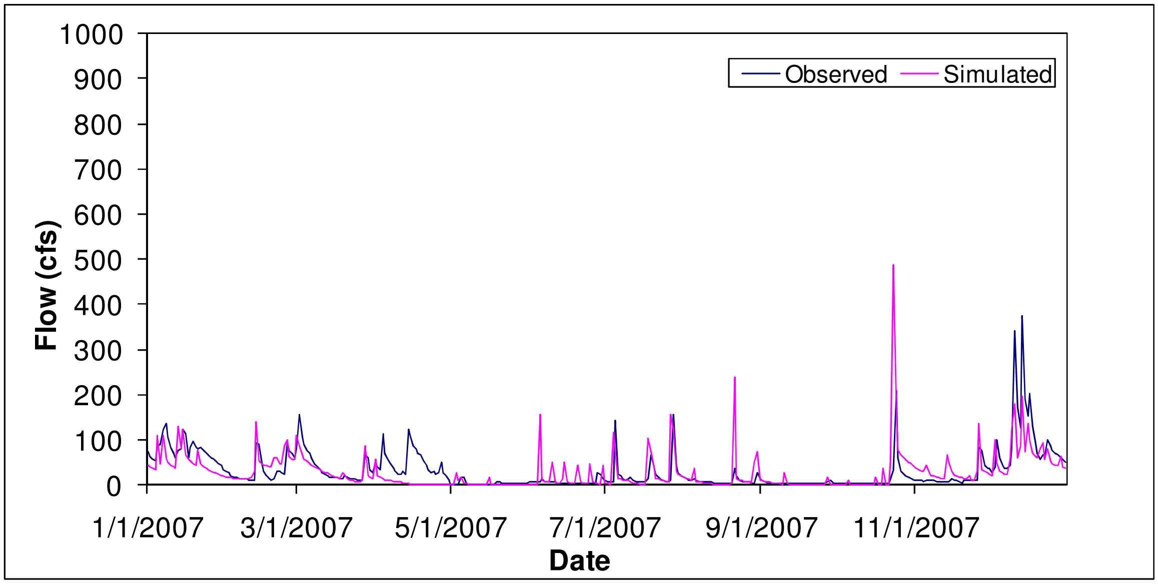

Figure B.19 Hydrology Calibration for Cane Run at Royal Spring (2007)

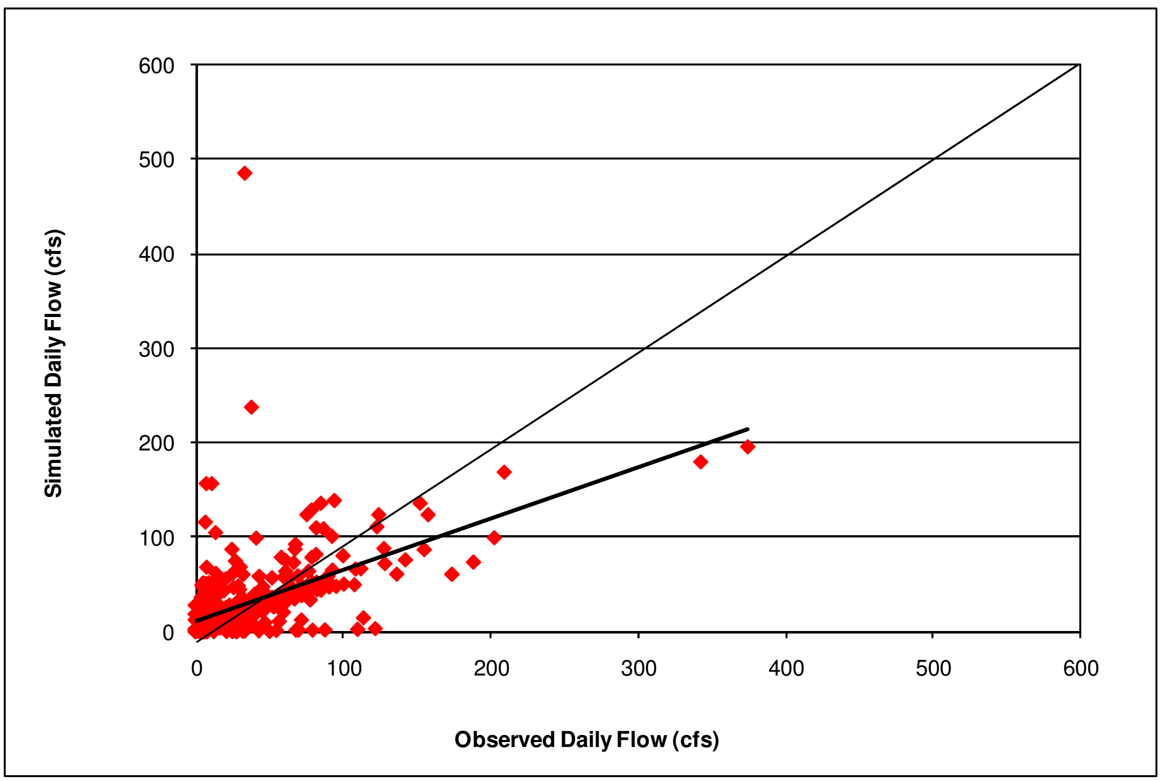

Figure B.20 Bias Plot for Cane Run at Royal Spring (2007)

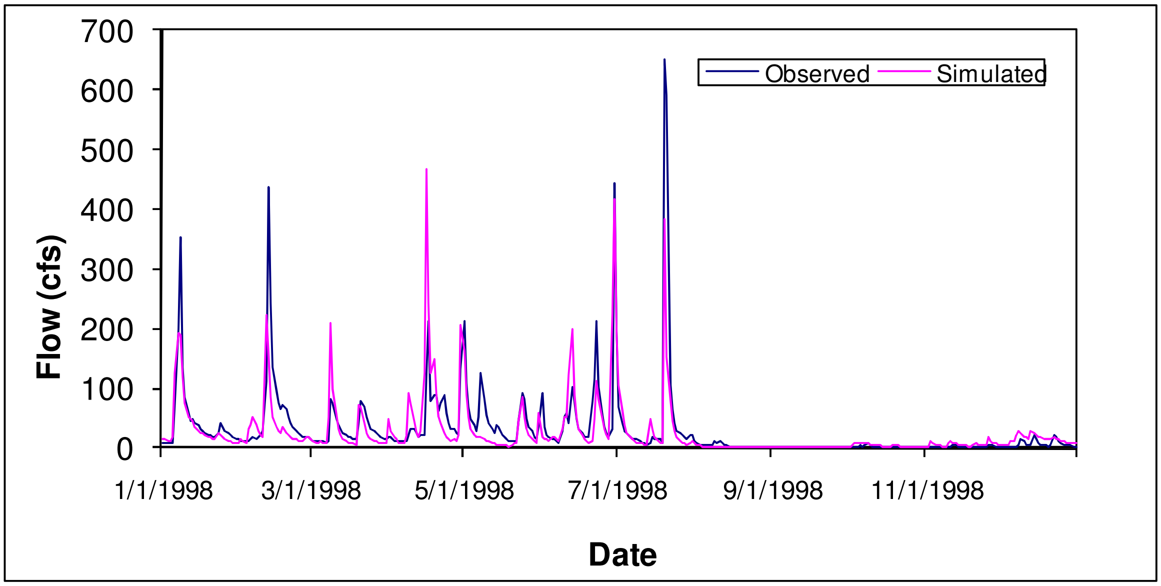

Figure B.23 Hydrology Calibration at Outlet of Cane Run Watershed (1998)

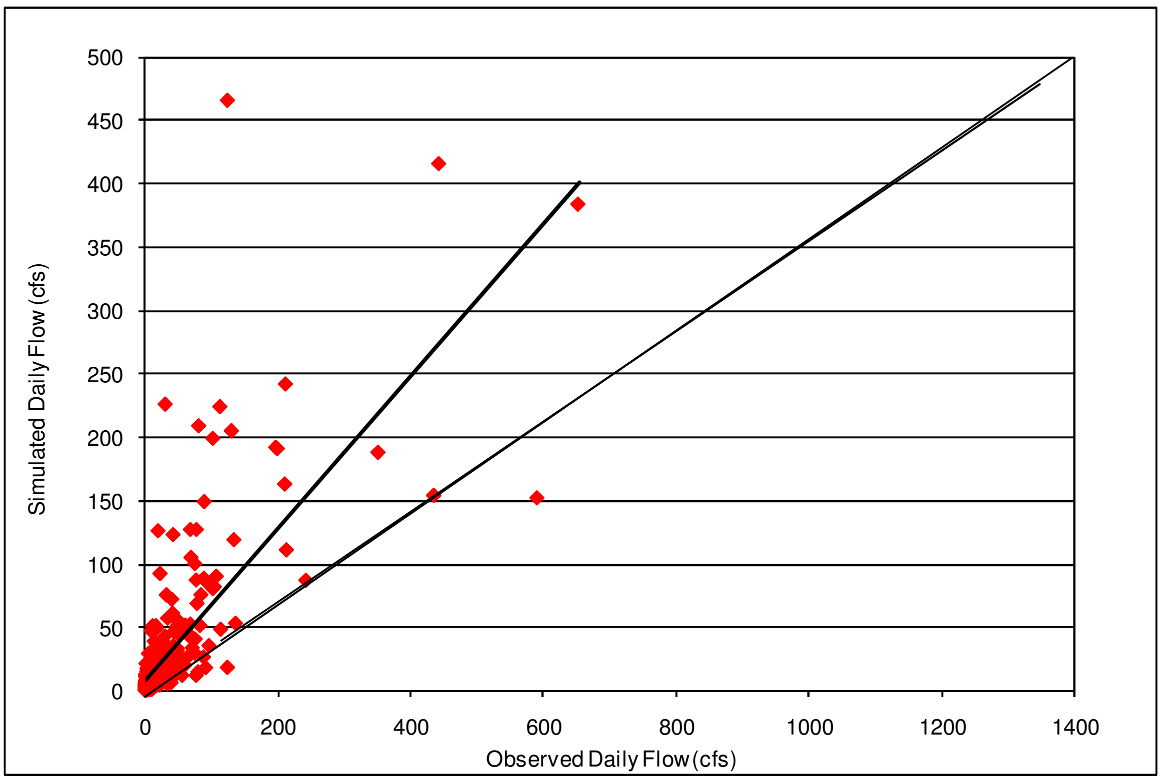

Figure B.24 Bias Plot for Cane Run at Outlet of Watershed (1998)

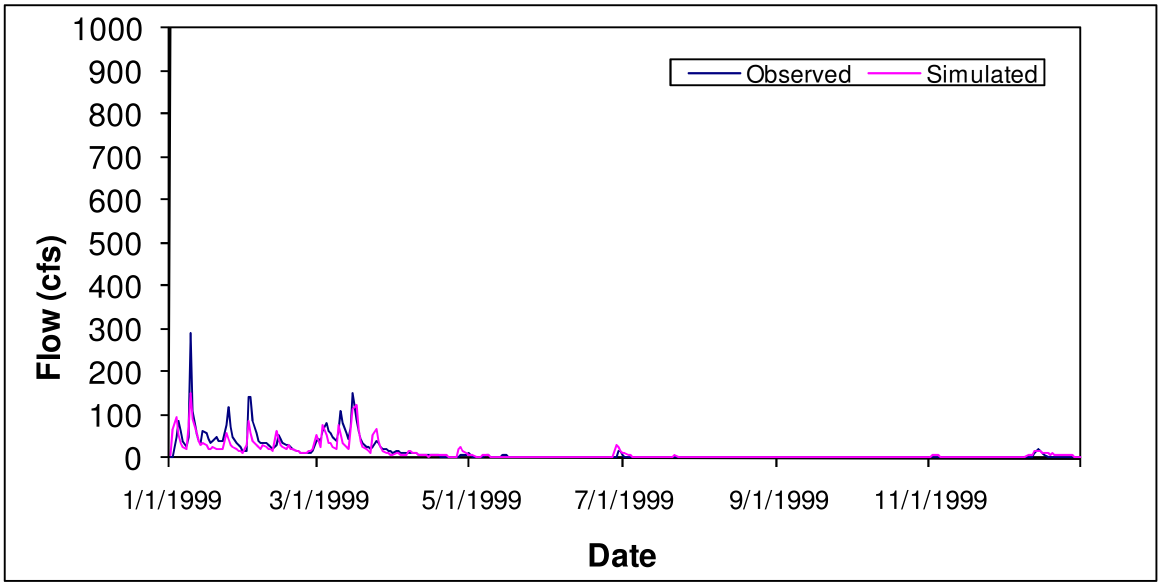

Figure B.23 Hydrology Calibration at Outlet of Cane Run Watershed (1999)

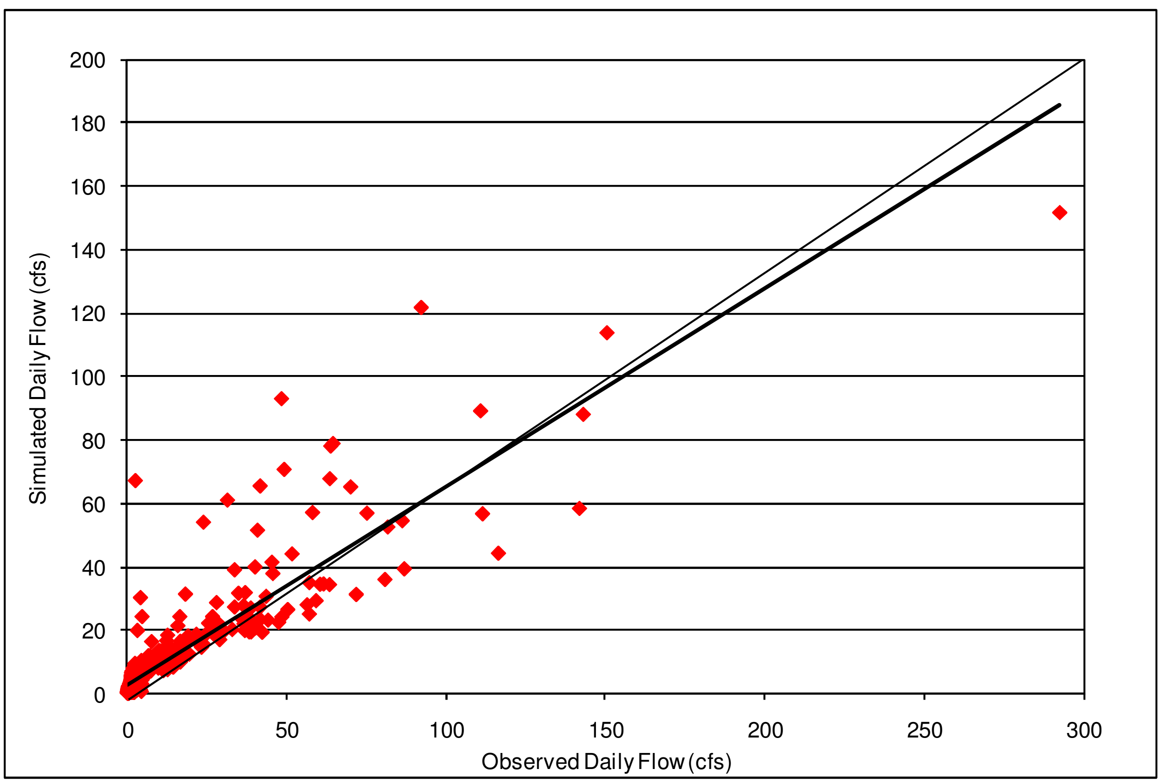

Figure B.24 Bias Plot for Cane Run at Outlet of Watershed (1999)

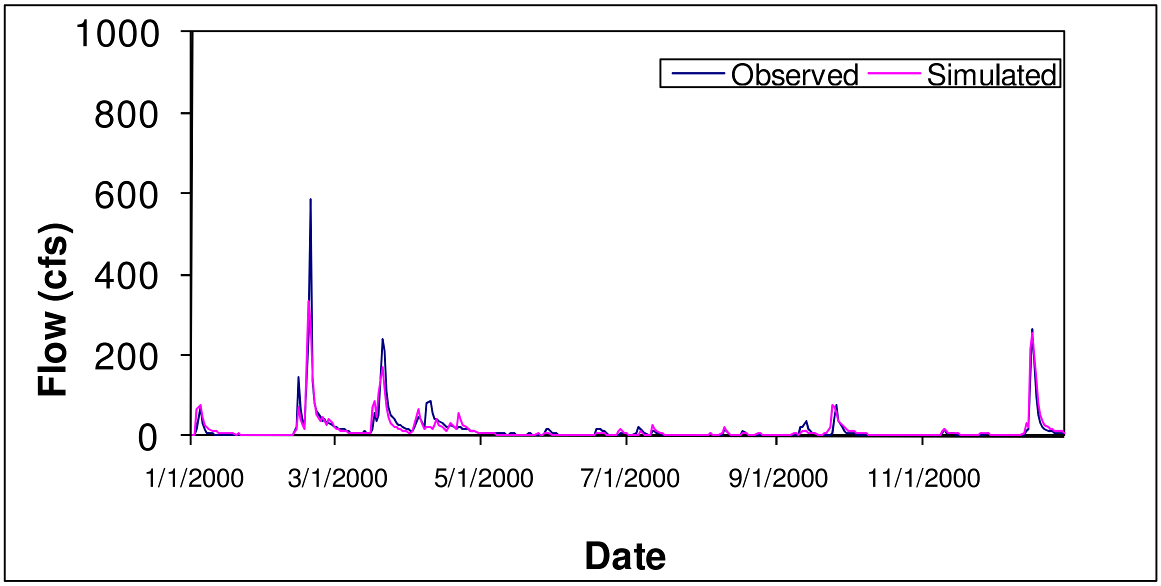

Figure B.25 Hydrology Calibration at Outlet of Cane Run Watershed (2000)

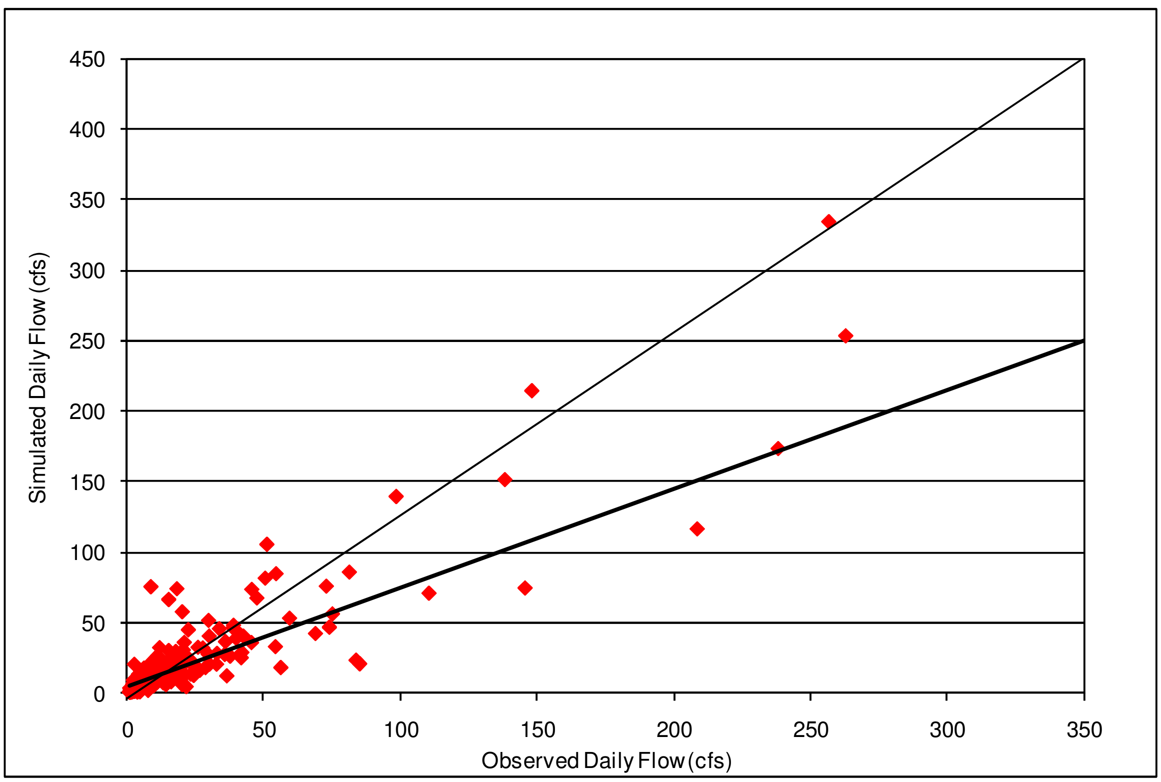

Figure B.26 Bias Plot for Cane Run at Outlet of Watershed (2000)

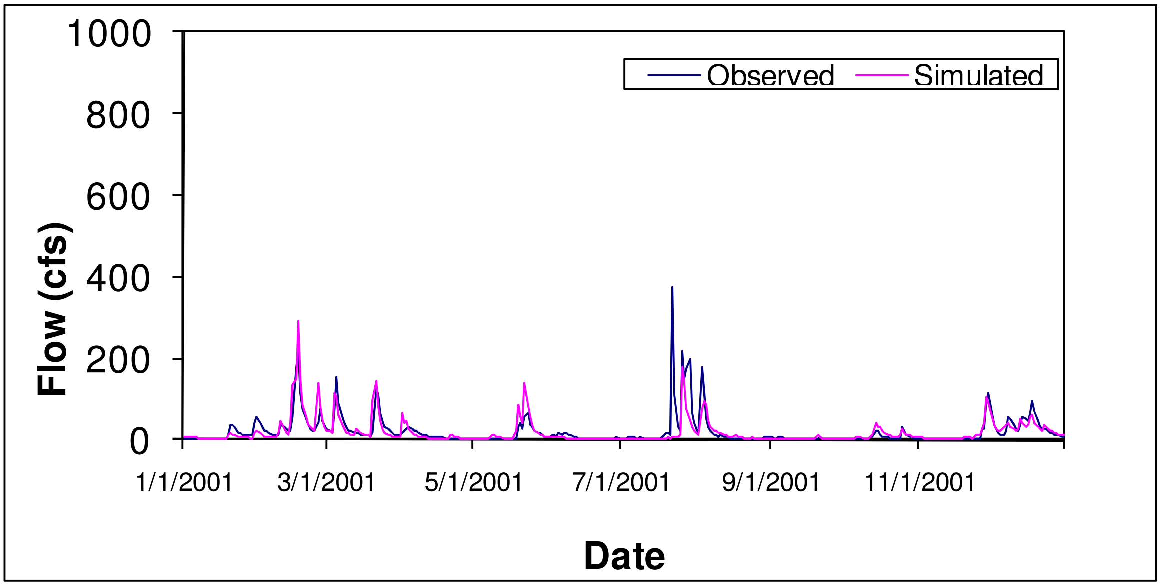

Figure B.27 Hydrology Calibration at Outlet of Cane Run Watershed (2001)

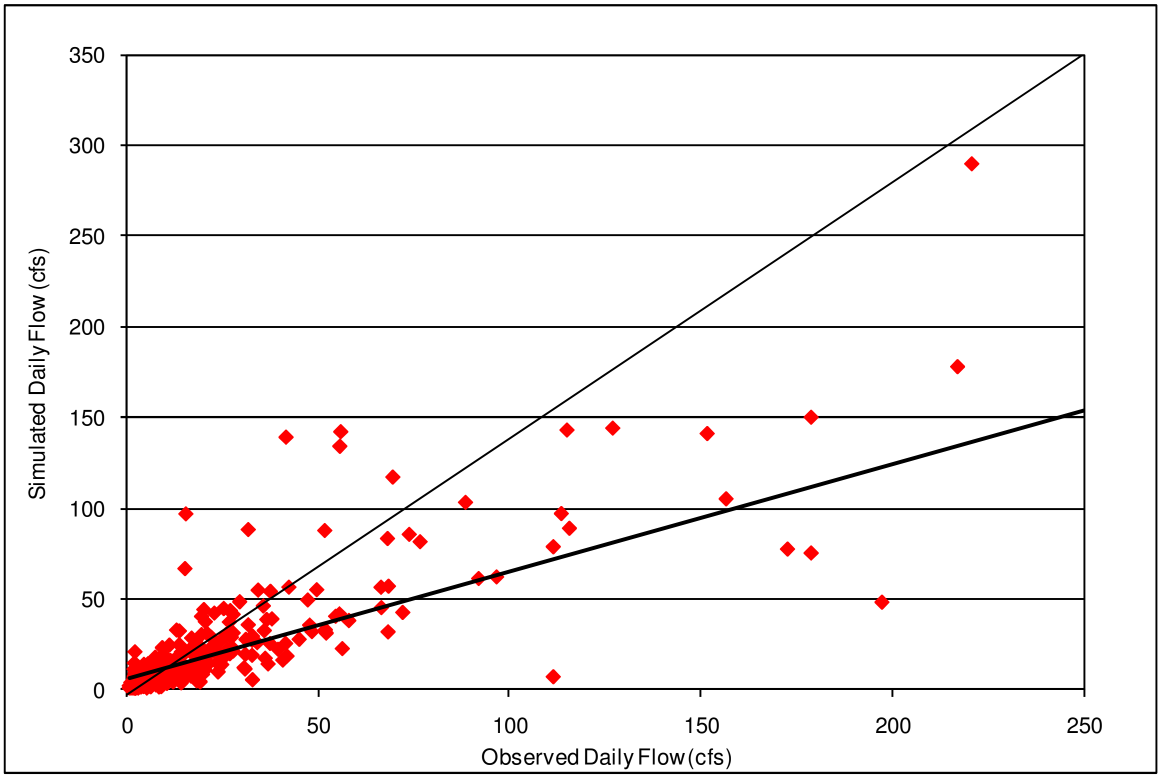

Figure B.28 Bias Plot for Cane Run at Outlet of Watershed (2001)

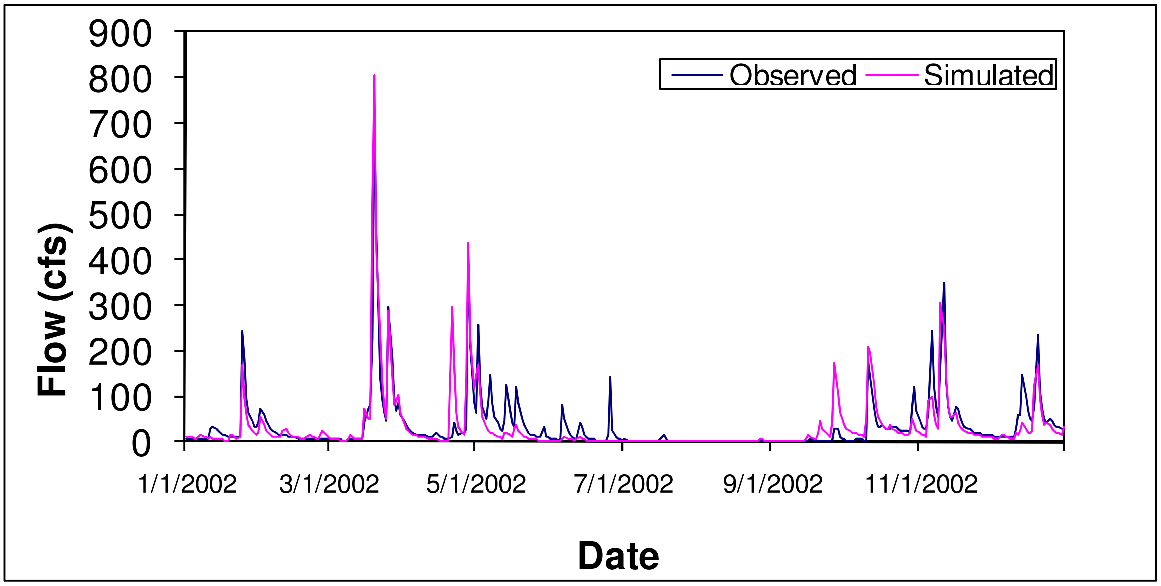

Figure B.29 Hydrology Calibration at Outlet of Cane Run Watershed (2002)

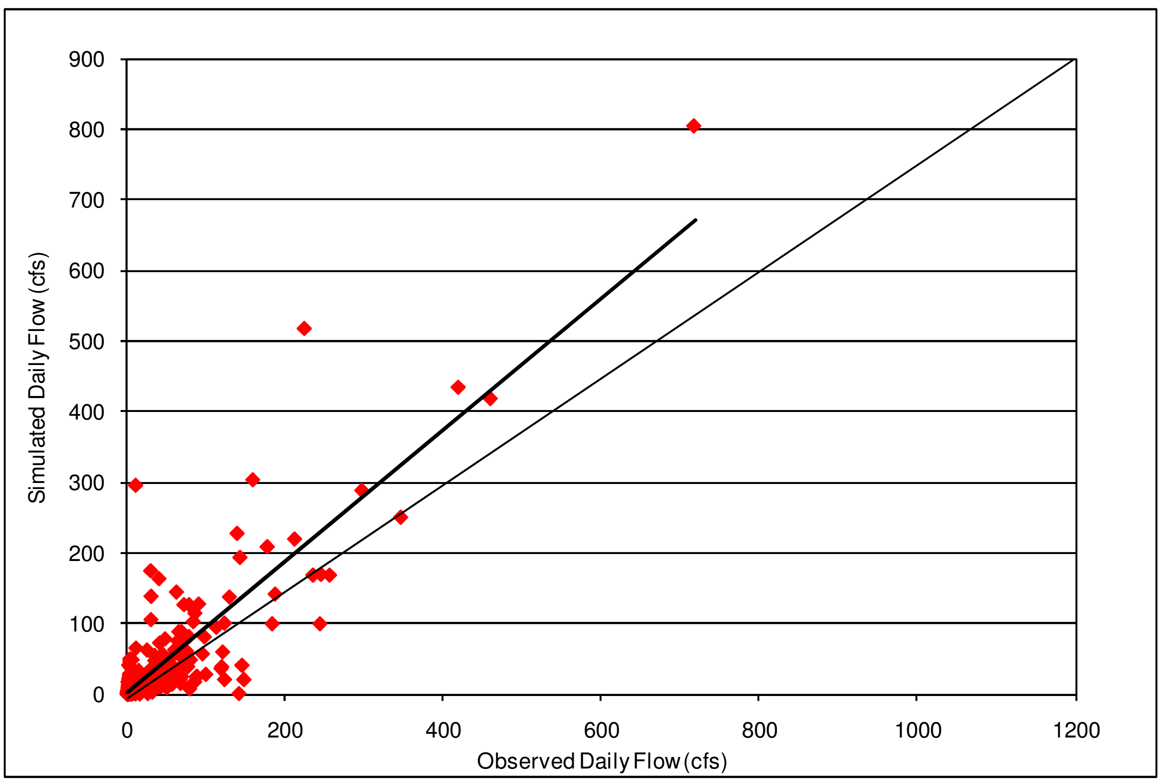

Figure B.30 Bias Plot for Cane Run at Outlet of Watershed (2002)

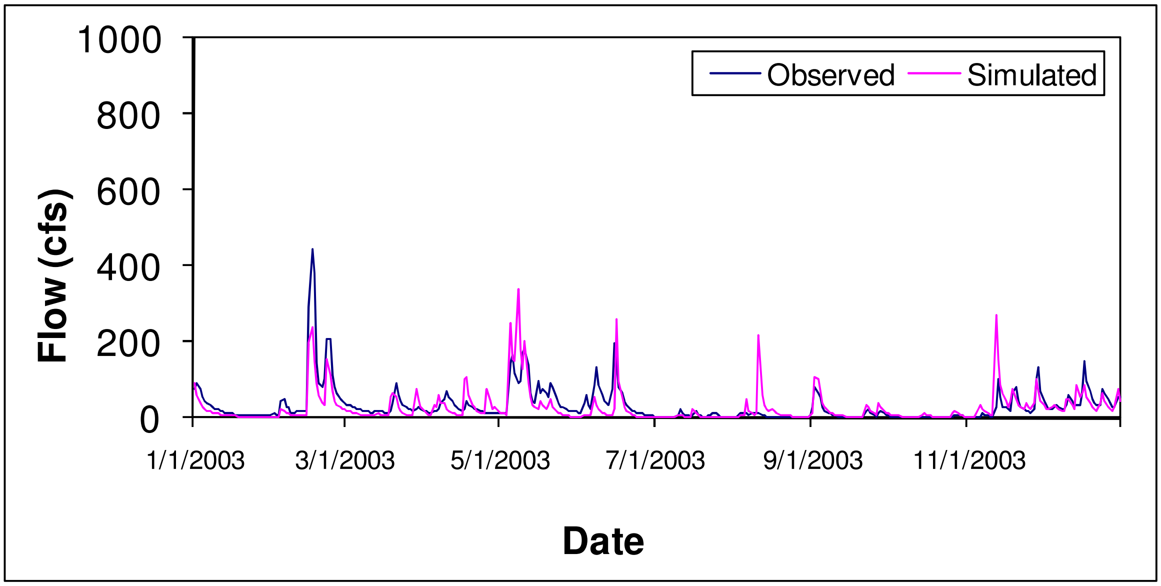

Figure B.31 Hydrology Calibration at Outlet of Cane Run Watershed (2003)

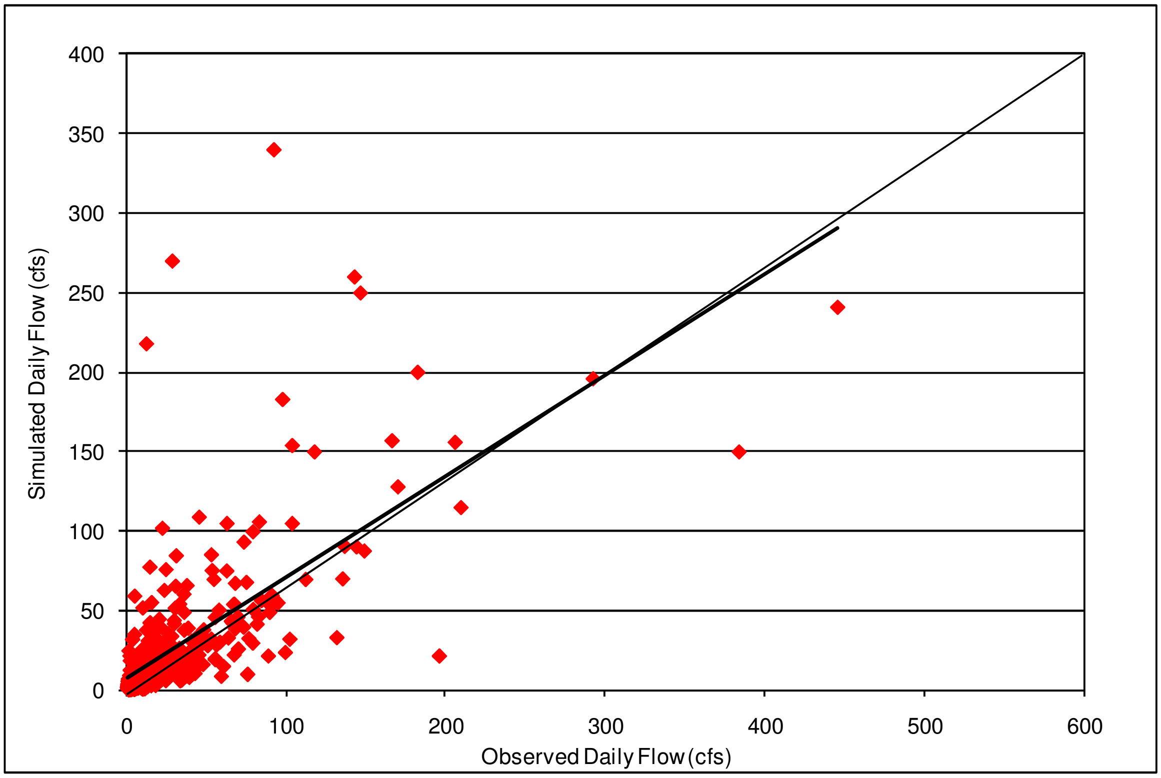

Figure B.32 Bias Plot for Cane Run at Outlet of Watershed (2003)

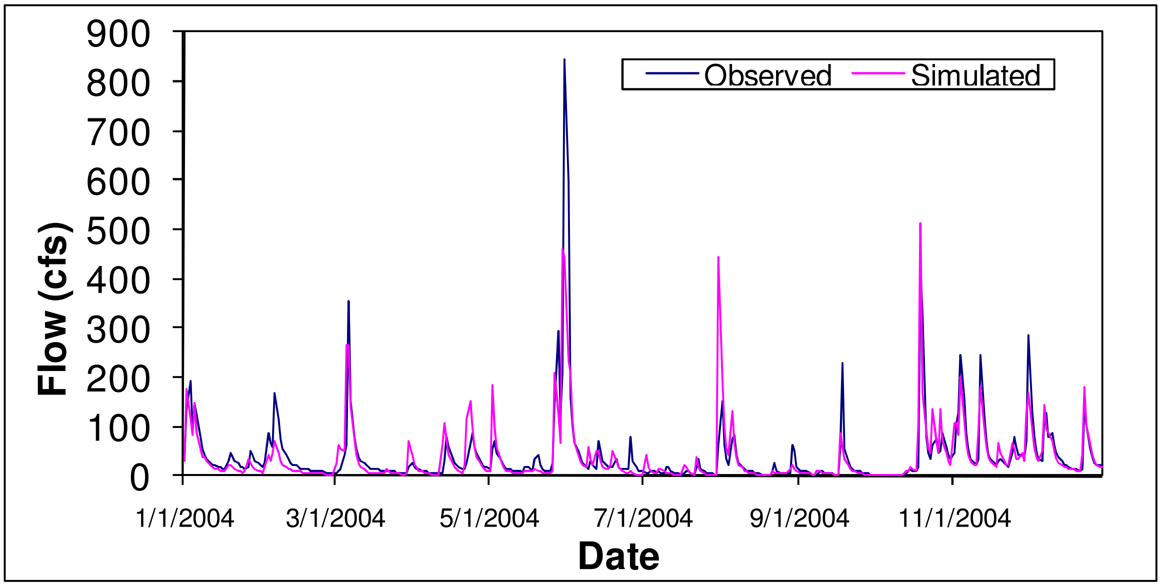

Figure B.33 Hydrology Calibration at Outlet of Cane Run Watershed (2004)

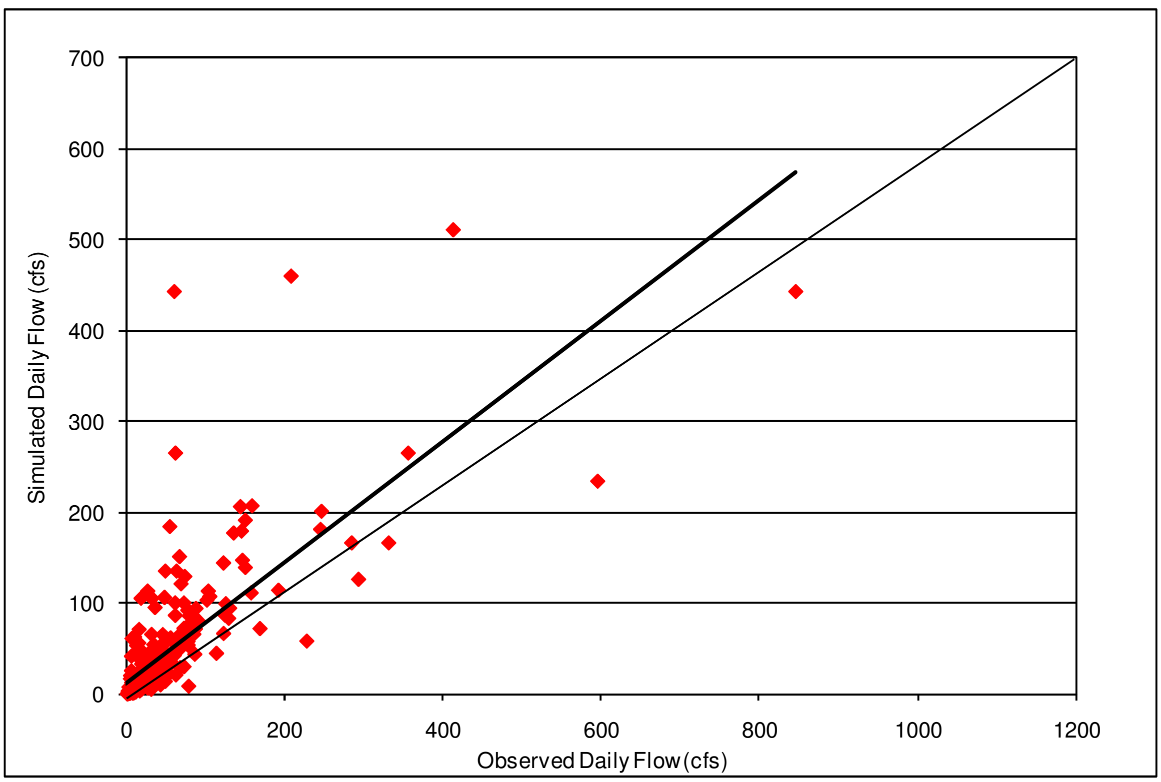

Figure B.34 Bias Plot for Cane Run at Outlet of Watershed (2004)

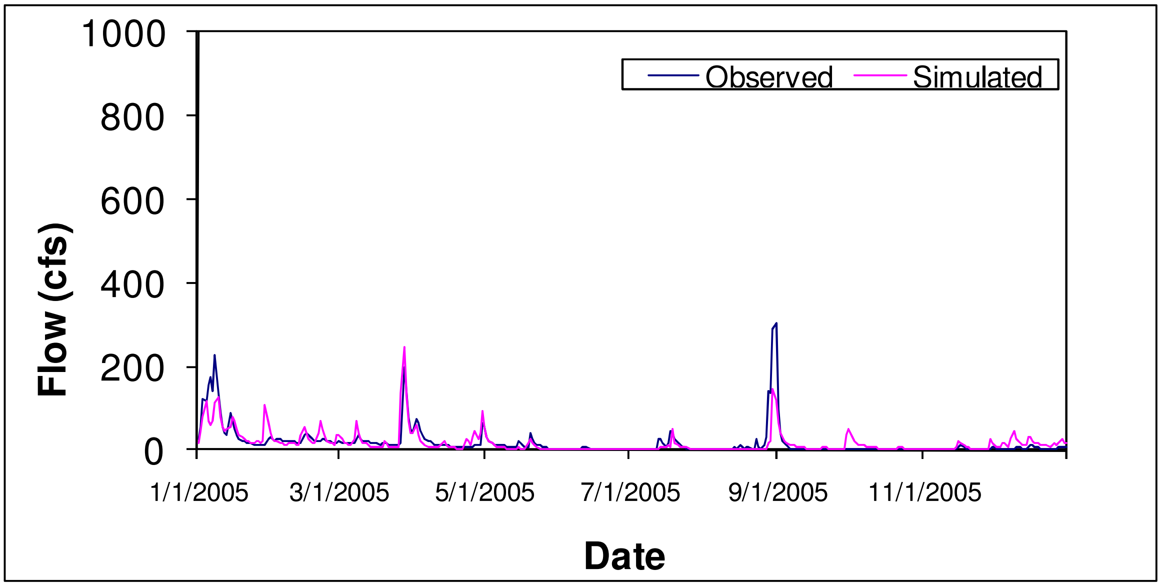

Figure B.35 Hydrology Calibration at Outlet of Cane Run Watershed (2005)

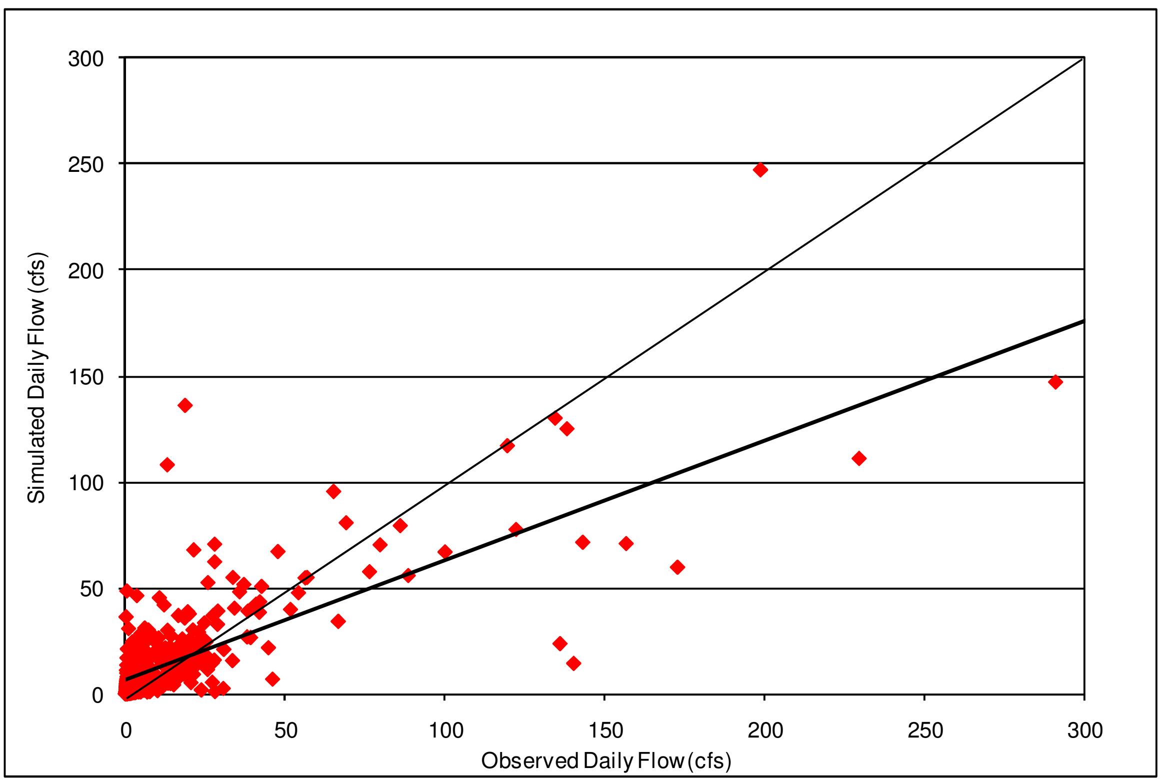

Figure B.36 Bias Plot for Cane Run at Outlet of Watershed (2005)

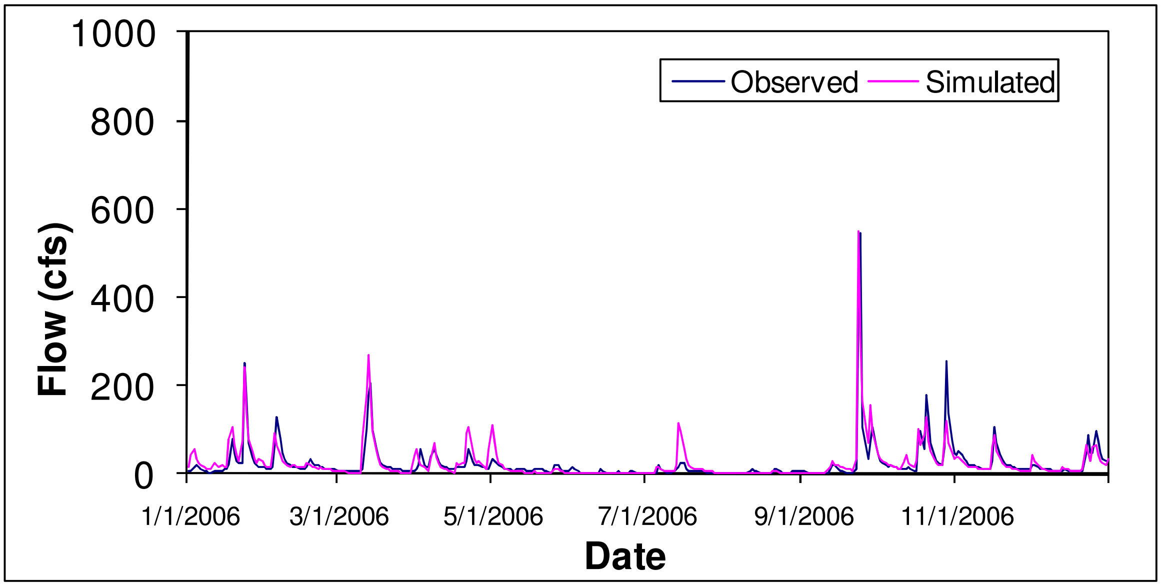

Figure B.37 Hydrology Calibration at Outlet of Cane Run Watershed (2006)

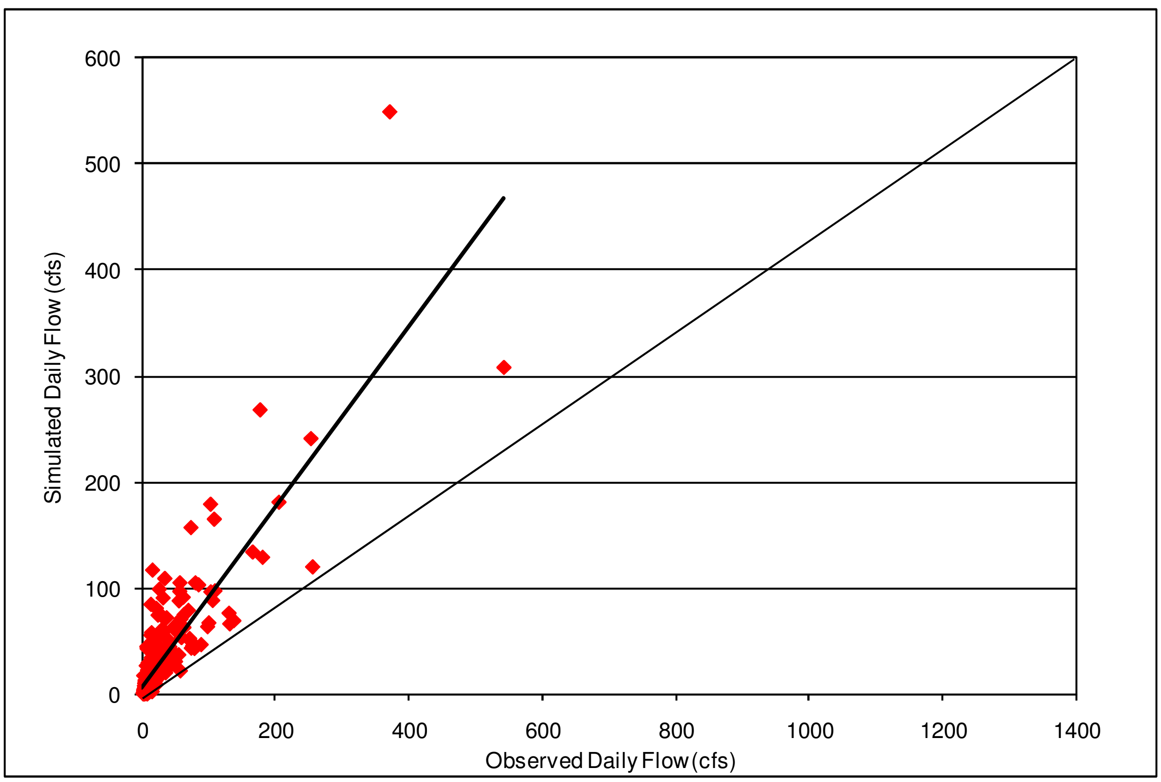

Figure B.38 Bias Plot for Cane Run at Outlet of Watershed (2006)

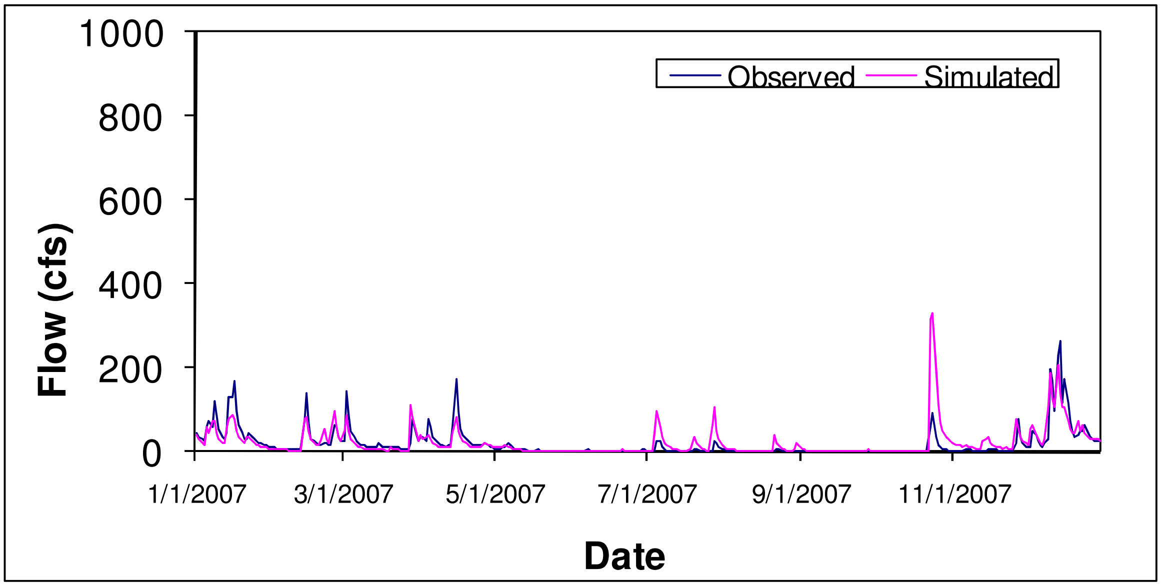

Figure B.39 Hydrology Calibration at Outlet of Cane Run Watershed (2007)

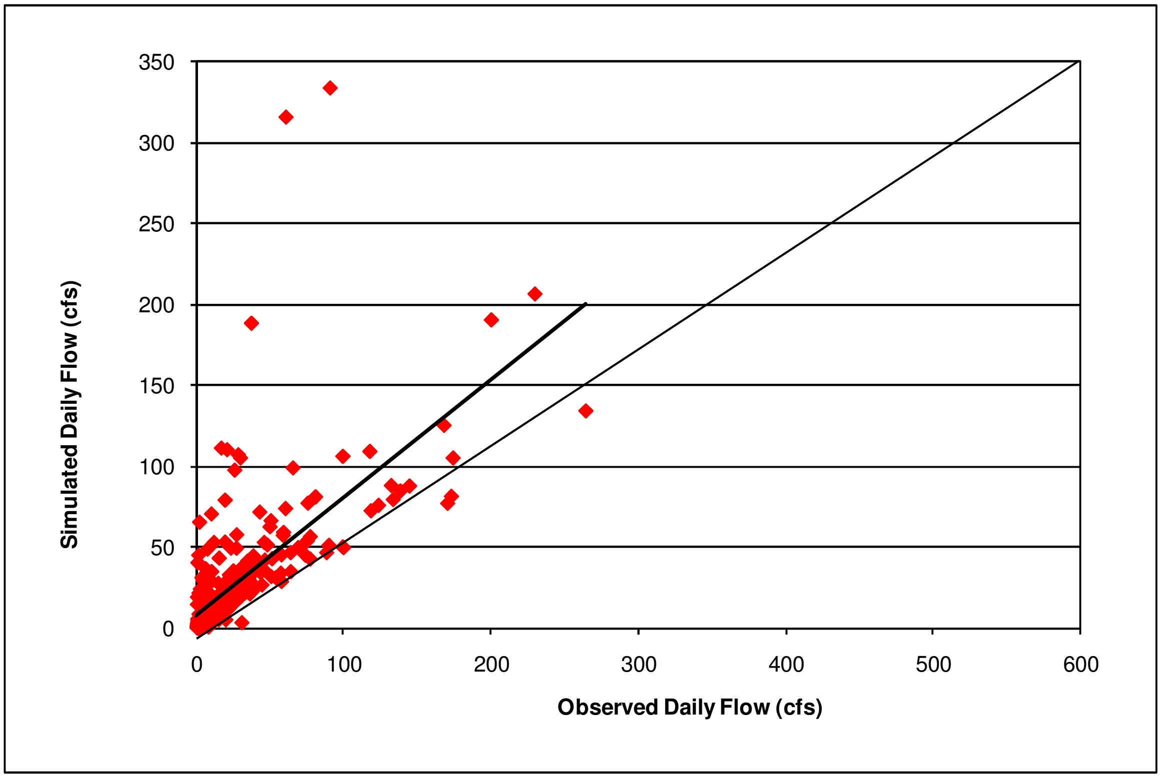

Figure B.40 Bias Plot for Cane Run at Outlet of Watershed (2007)

APPENDIX C: WATER QUALITY CALIBATION

Appendix C contains the results of the water quality calibration. The predicted results are compared to the observed results for each of the sample dates and locations presented in Appendix A1. Due to the high variability of fecal coliform, model performance associated with the replication of individual daily fecal loads were evaluated using a log differential range of 0.5. An attempt was made to calibrate the model so that the daily difference between an observed and predicted fecal load was within a value of 0.5 of the differences of the logarithms of the actual values. This parallels EPA's (1986) approach for setting a 90% confidence limit. The results of these comparisons are shown in Appendix C. The results suggest that the predicted values tend to fall within these bounds for the majority of days and the majority of stations. In general, when there is a deviation outside the limits, the predicted value is above the upper limit, thus providing for a more conservative analysis. In addition to comparing the predicted and observed results for a given day, a comparison was also made between the observed values and the geometric mean of five days of predicted values centered on the date of the observed data point. The analysis was done to account for any variability of model performance as influenced by variations due to timing affects associated with hydrologic errors. The plots illustrate the log difference of 0.5 was satisfied the vast majority of the time for all of the sites. Gaps within the plots occur when no data could be collected due to dry streambeds.

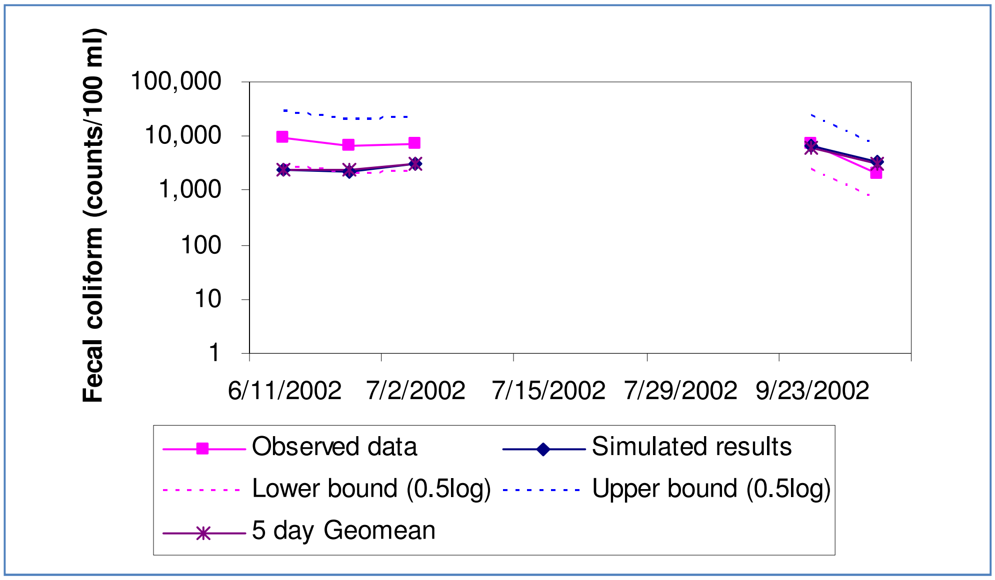

Figure C 1. Simulated and Observed Results (C0 Site)

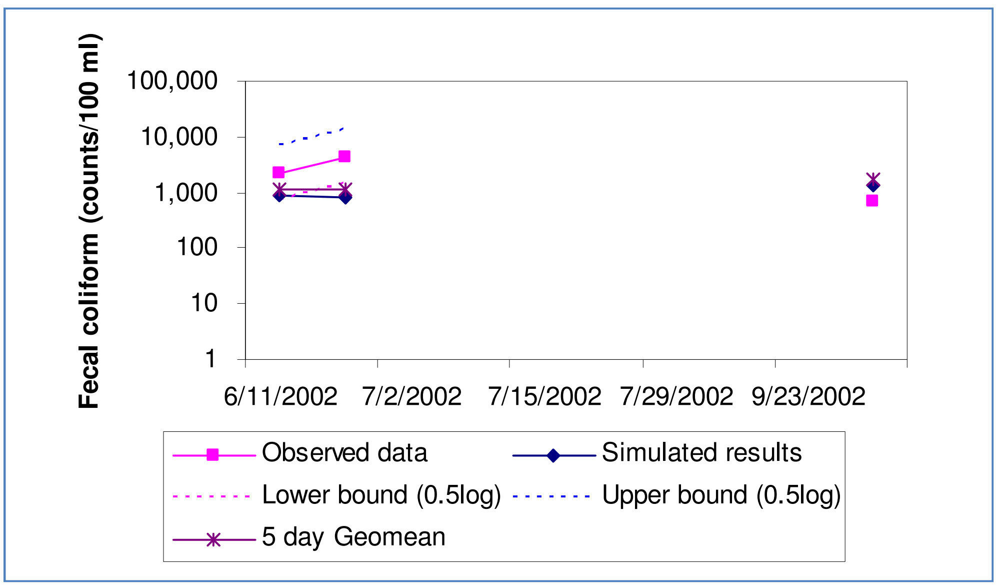

Figure C 2. Simulated and Observed Results (C1 Site)

(Site C2 Site was Dry for all Sample Dates)

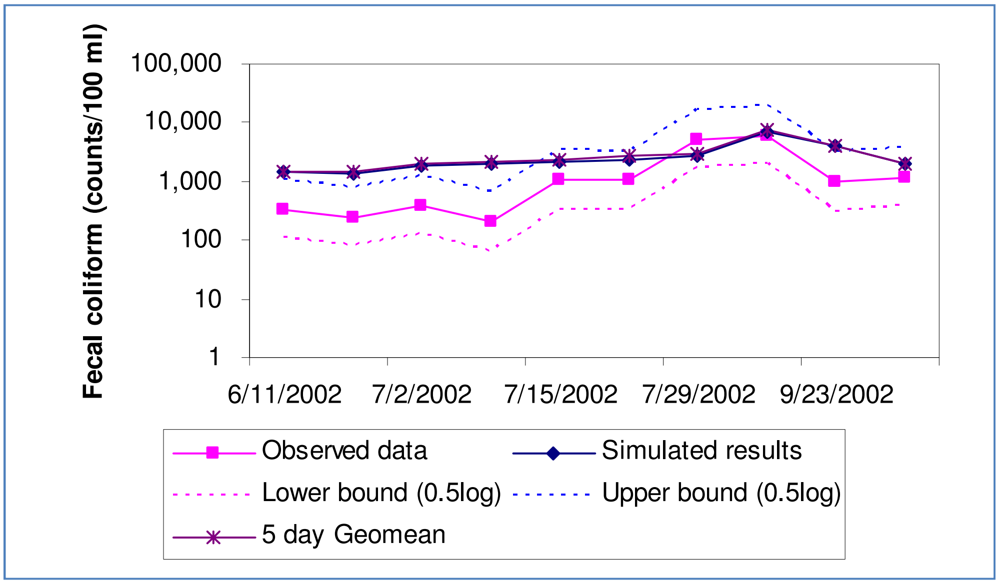

Figure C 3. Simulated and Observed Results (C3 Site)

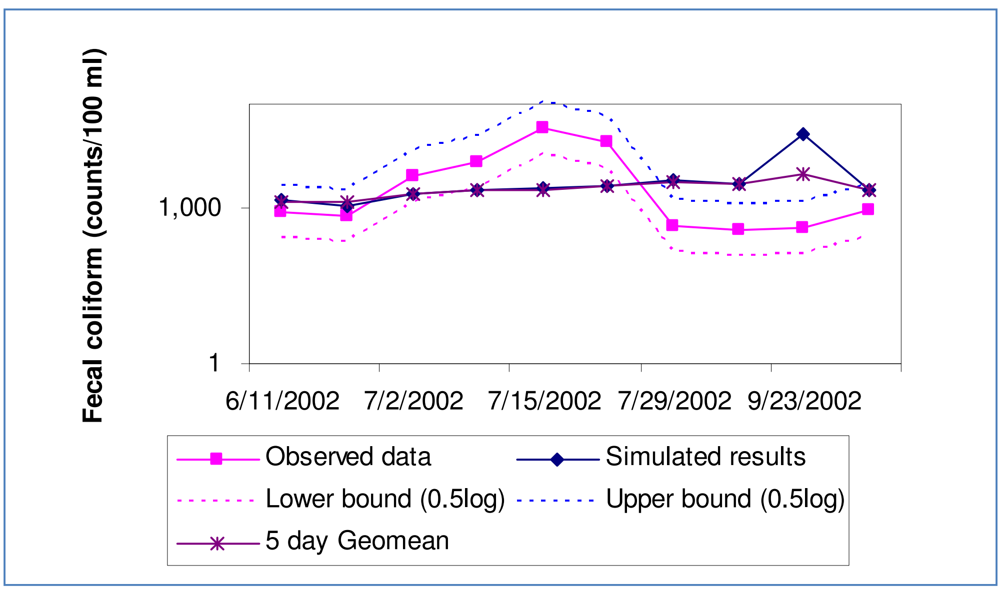

Figure C 4. Simulated and Observed Results (C4 Site)

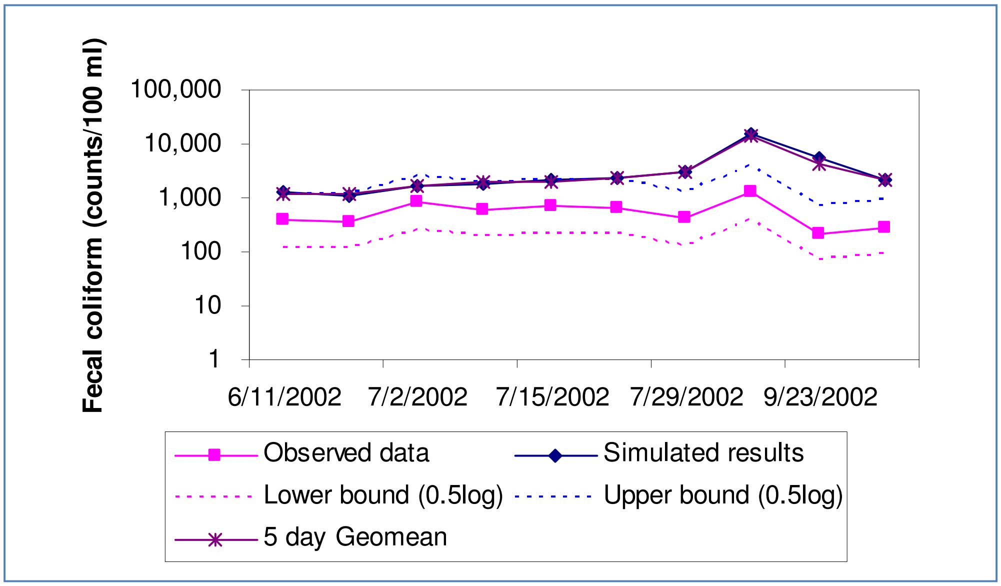

Figure C 5. Simulated and Observed Results (C5 Site)

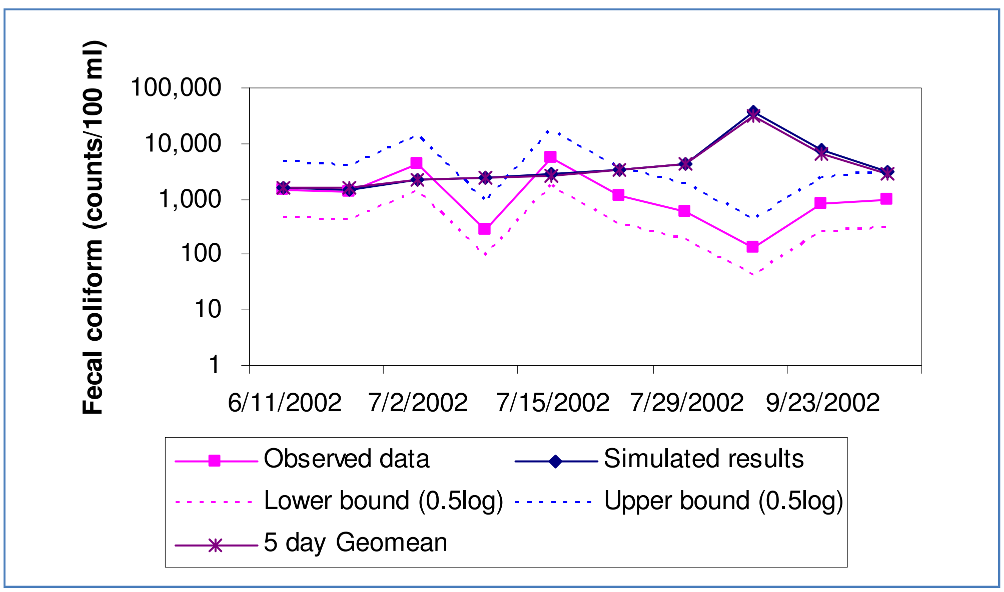

Figure C 6. Simulated and Observed Results (C6 Site)

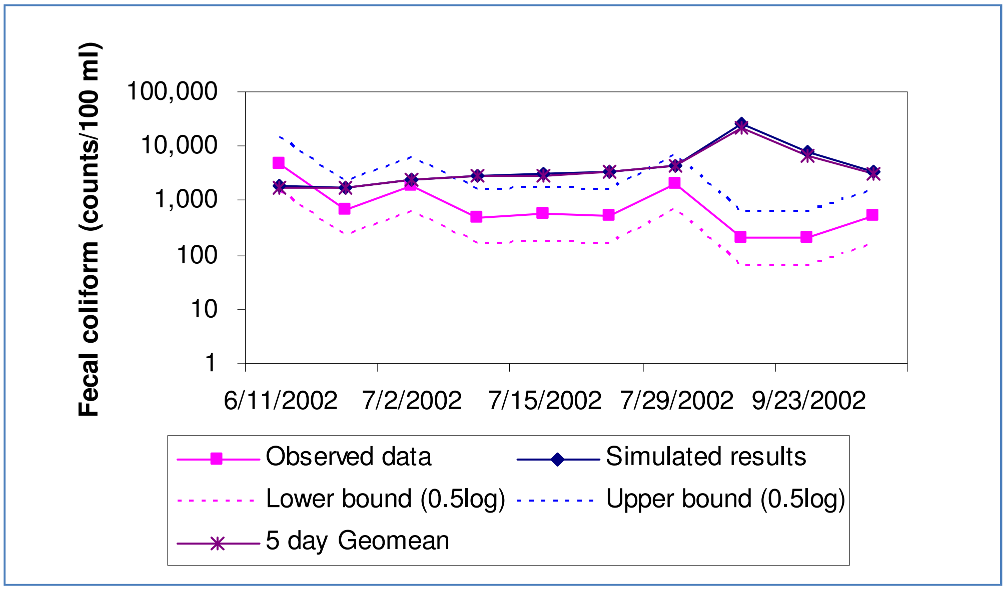

Figure C 7. Simulated and Observed Results (C7 Site)

APPENDIX D: PRE- AND POST REDUCTION FECAL COLIFORM GEOMETRIC MEAN SERIES

Appendix D shows the fecal coliform geometric means series before and after load reductions were effected for water quality sampling sites in the Cane Run watershed. The pre-reduction geometric means clearly exceed the WQC of 200 colonies/100ml. The geometric means meet the WQC after the reduction scenario was applied.

The fecal coliform concentrations shown are the predicted result of one possible allocation scenario; these concentrations are not equivalent to the TMDL allocation for any given source. Source allocations must be given in terms of daily loading. Further, the concentrations shown are mostly lower than the WQCs, therefore no source can legally be held to these concentrations or to any other concentrations lower than the WQC (with the possible exception of a voluntary pollutant trading scenario, which has not been enacted).

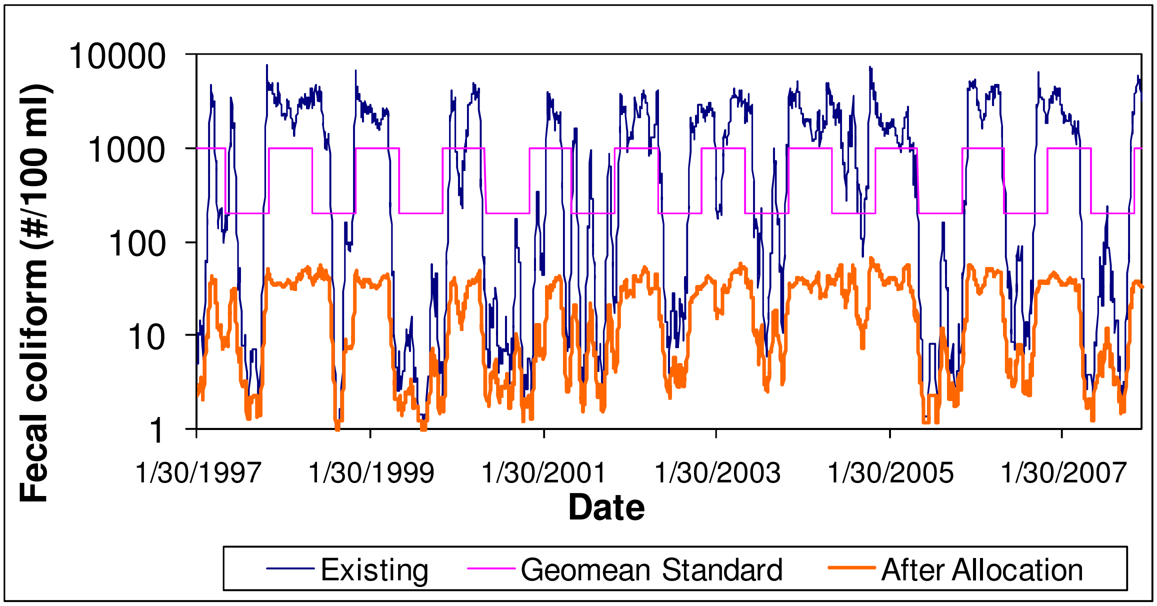

Figure D.1 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C0)

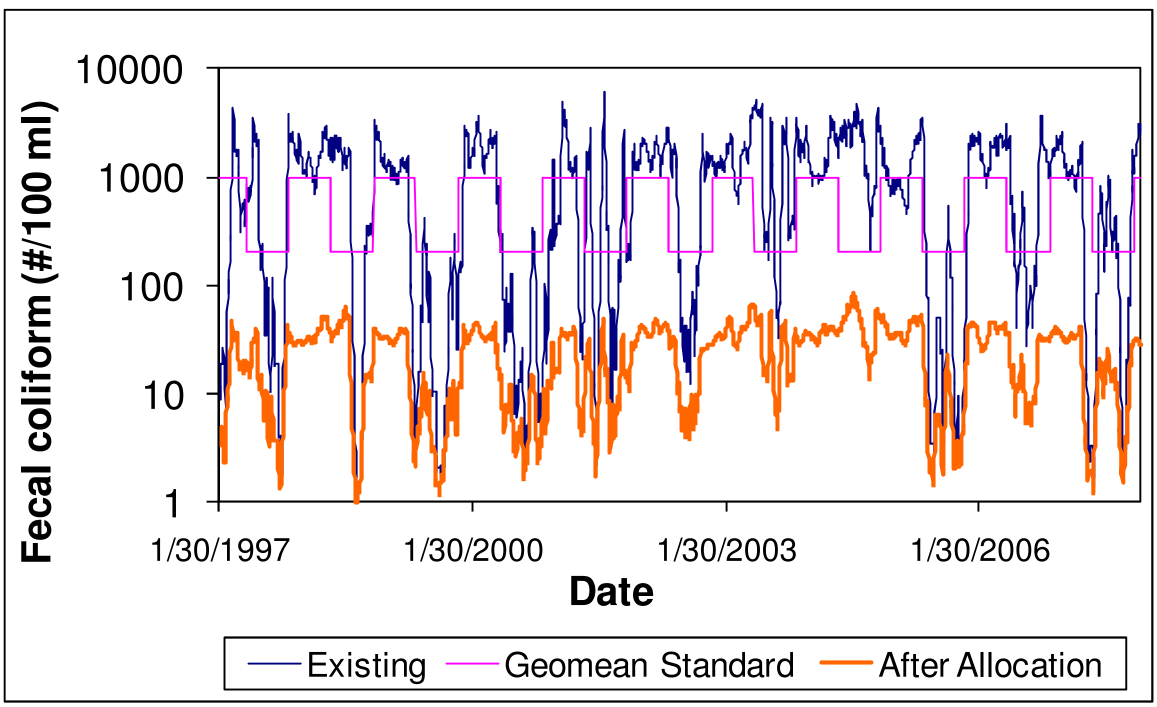

Figure D.2 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C1)

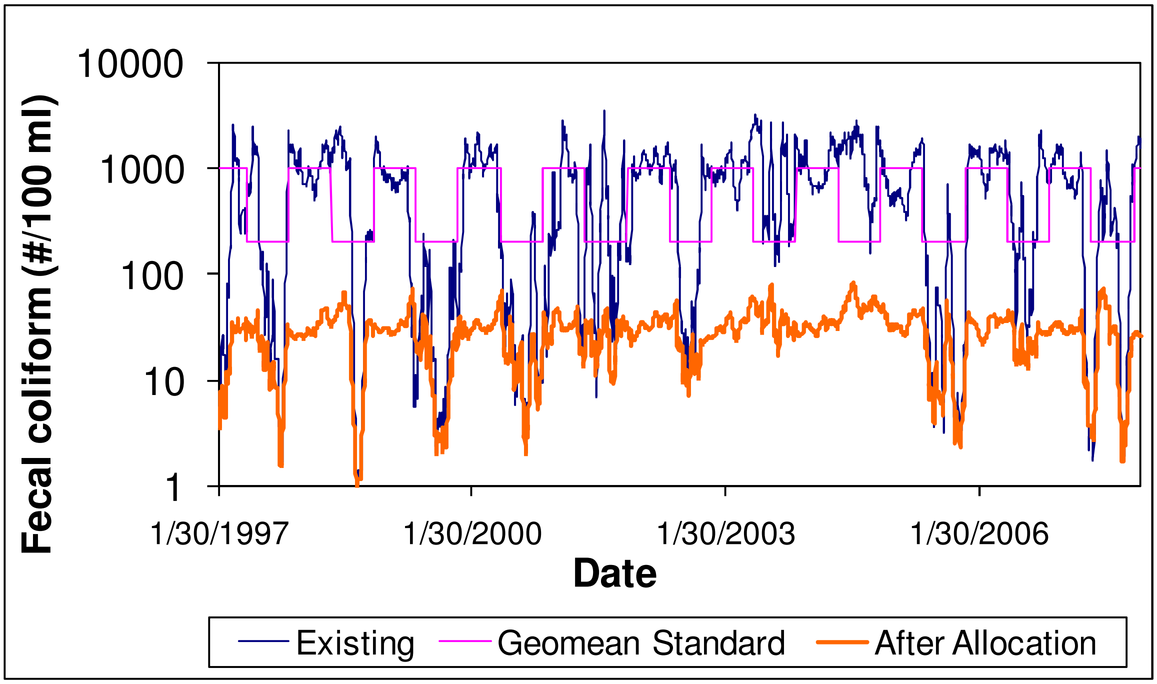

Figure D.3 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C2)

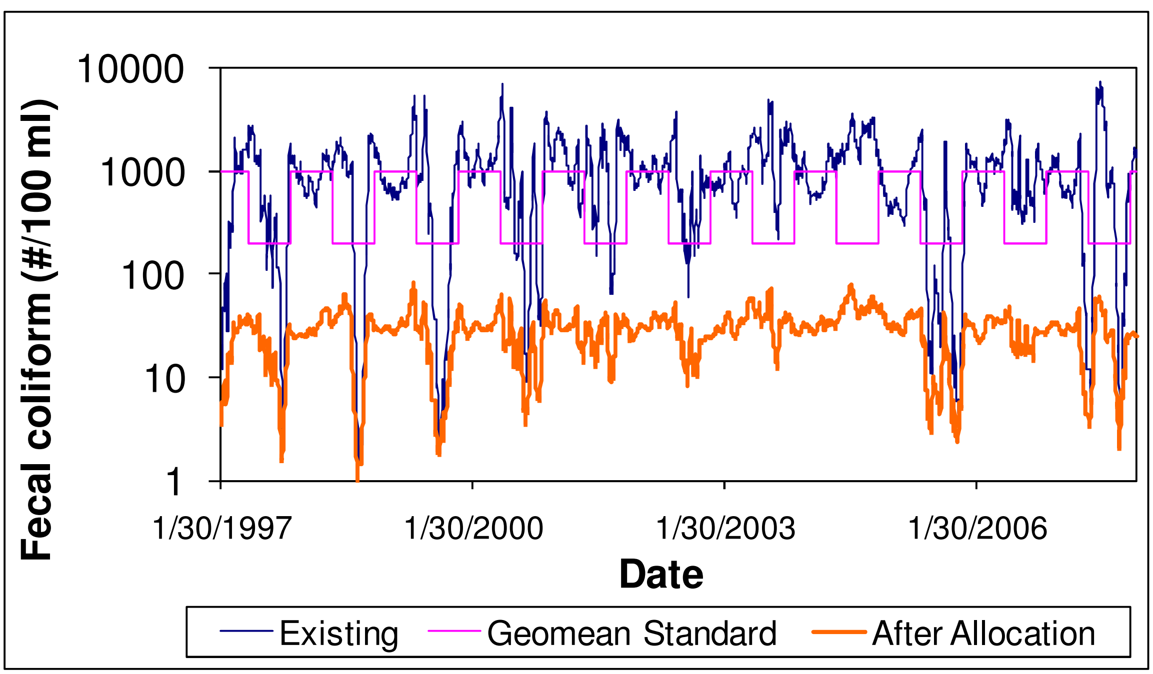

Figure D.4 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C3)

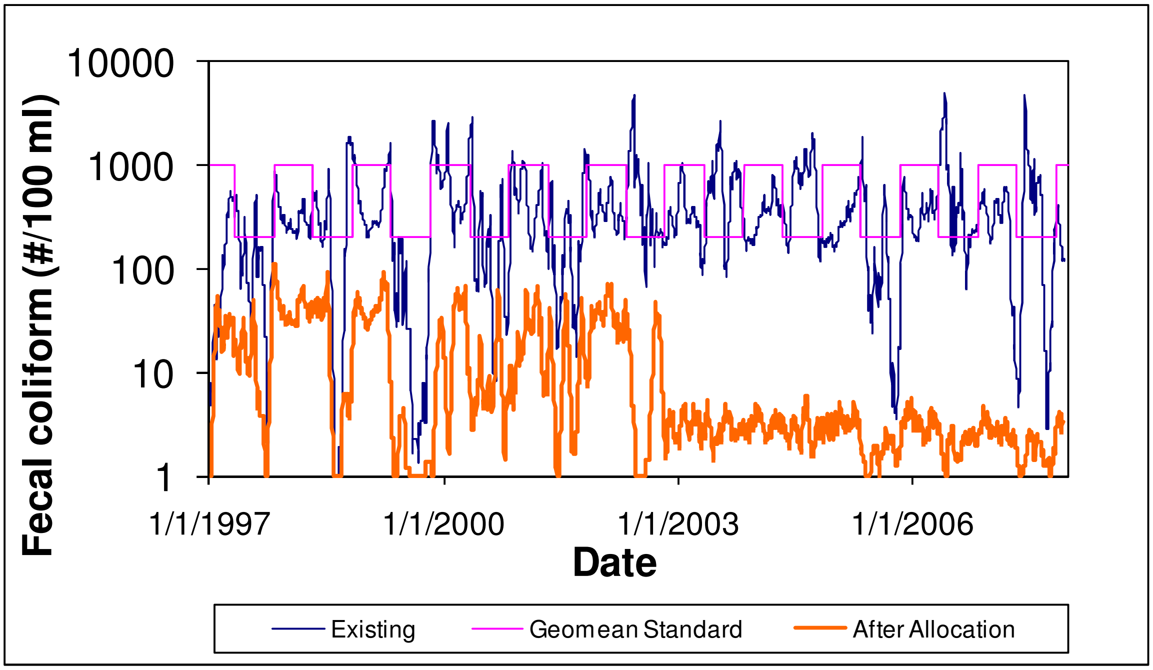

Figure D.5 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C4)

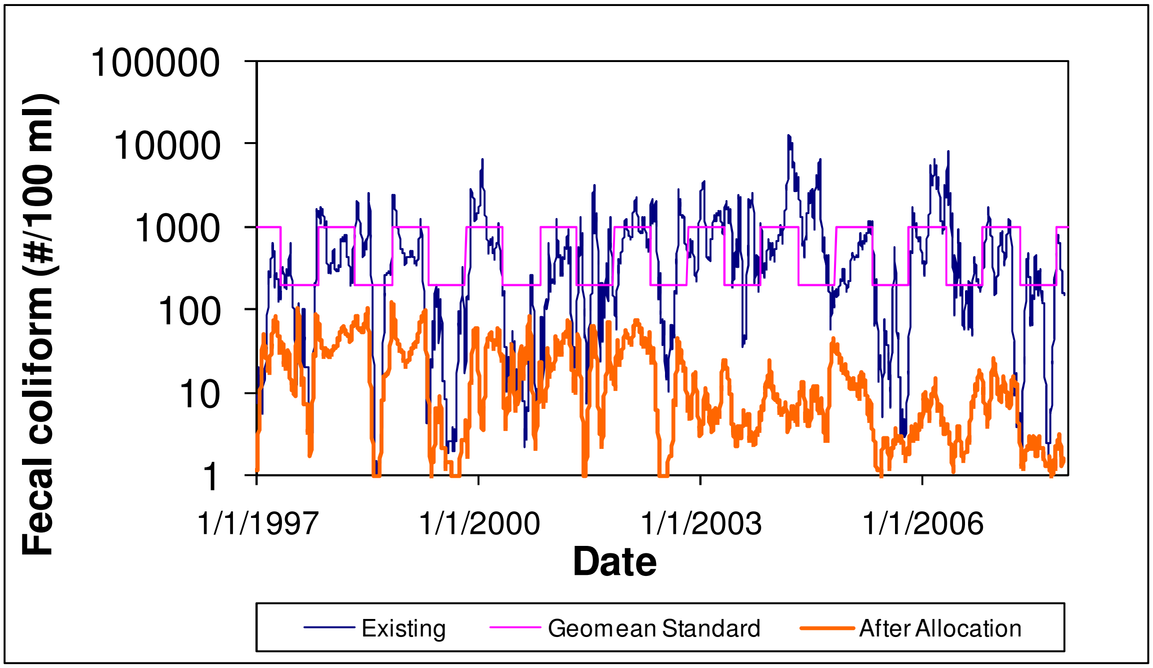

Figure D.6 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C5)

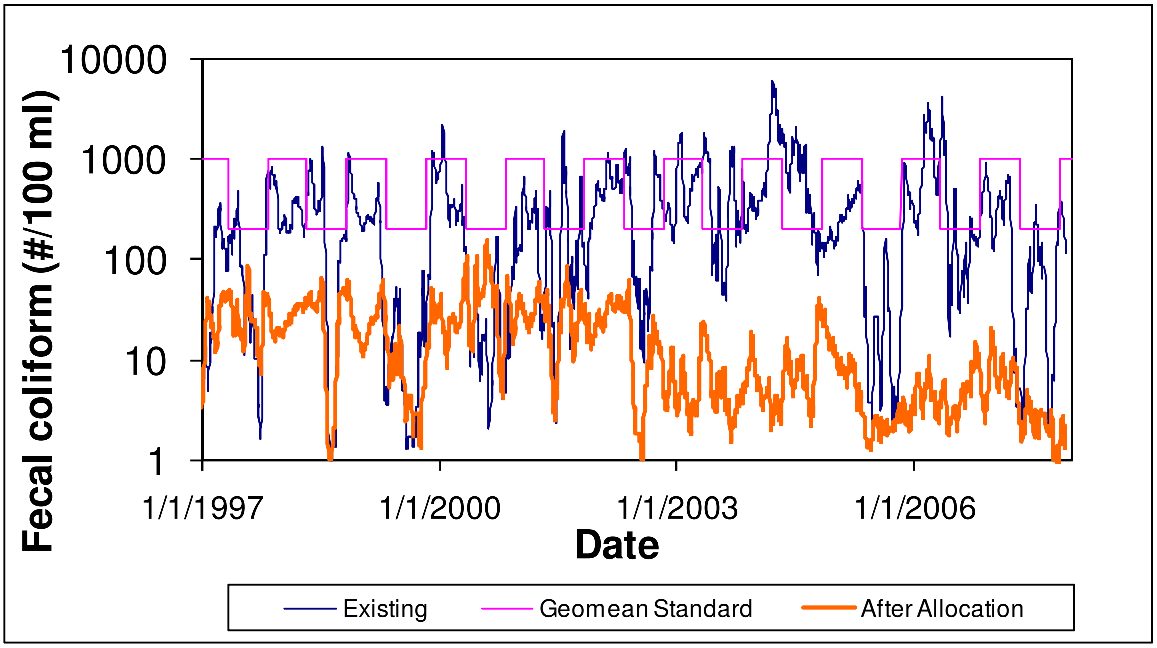

Figure D.7 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C7)

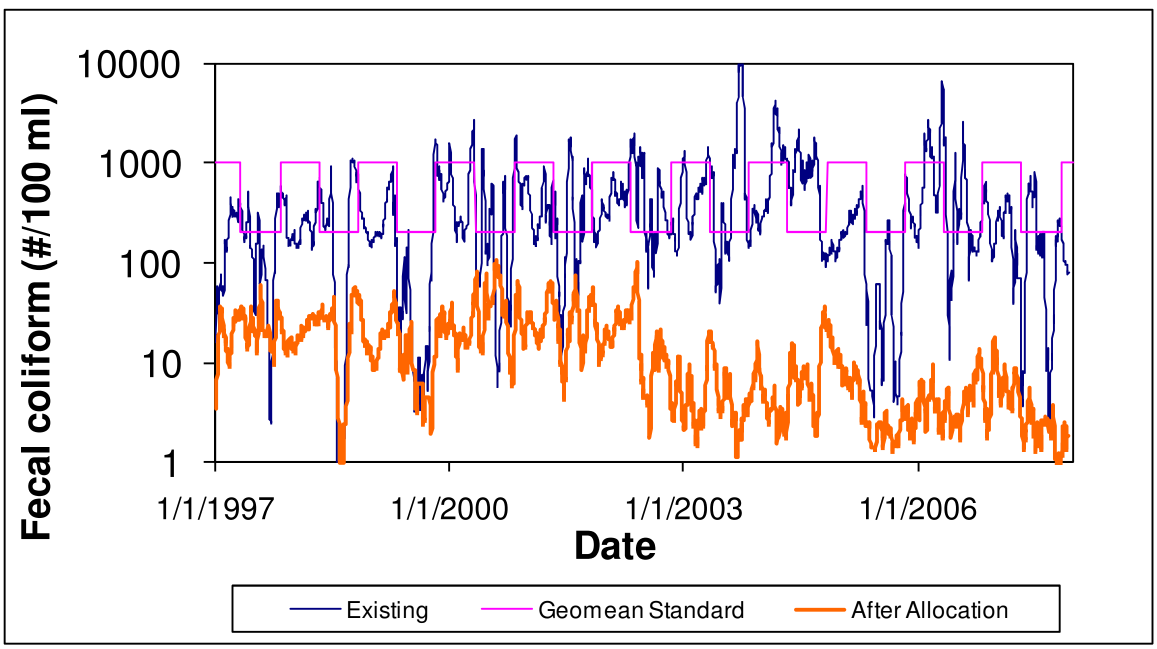

Figure D.8 30-day Geometric Mean for Fecal Coliform Bacteria Before and After TMDL Reductions (Site C6)

APPENDIX E: POST-REDUCTION FECAL SERIES

In addition to analyzing the pre-reduction and post-reduction geometric means series, the post-reduction daily fecal coliform series were also examined for the water quality sampling sites of Cane Run in order to insure compliance with the secondary WQC (i.e. 80% of the samples within a 30-day period less than 400 colonies/100 ml).

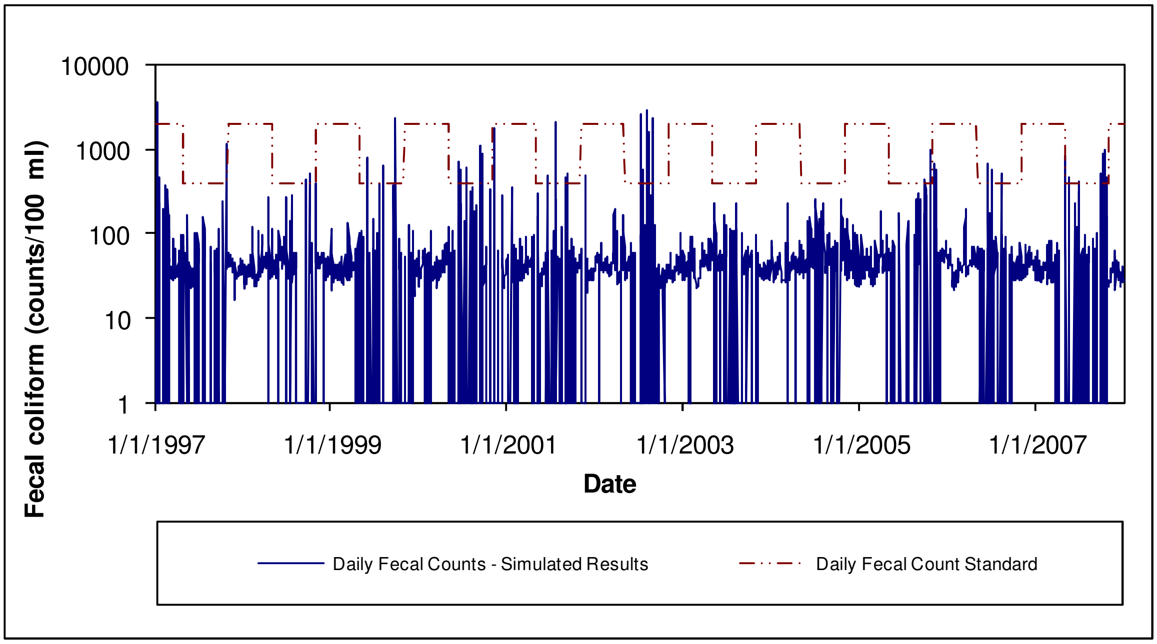

Figure E.1 Simulated Fecal Coliform at Site C0 After TMDL Reductions

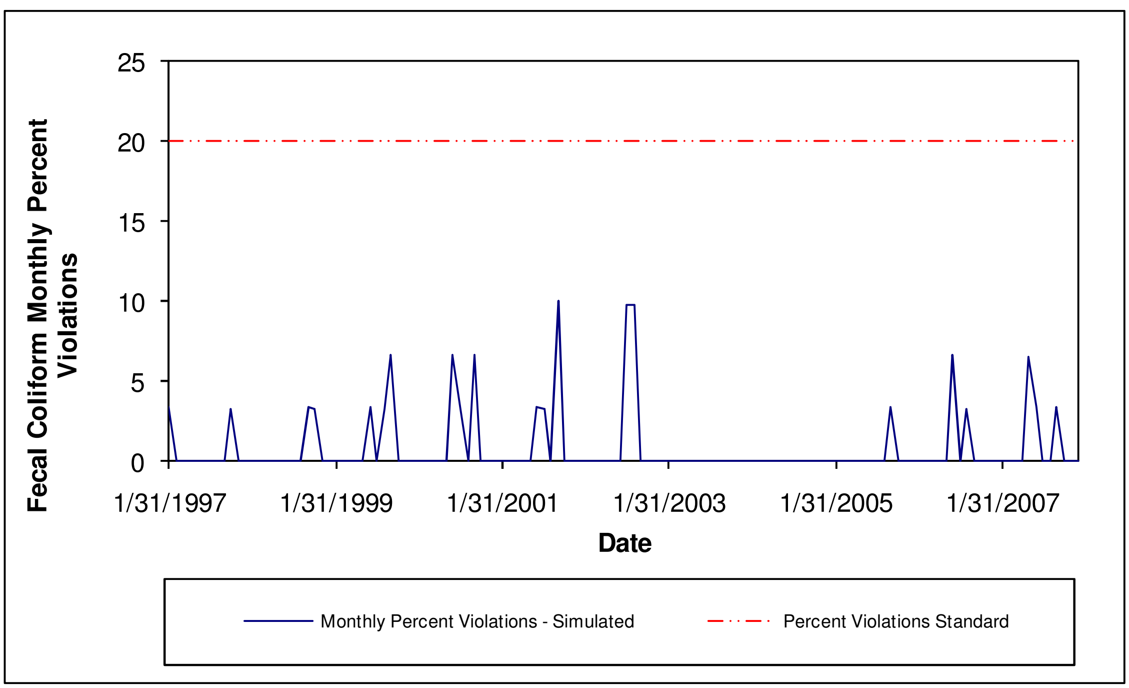

Figure E.2 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C0 After TMDL Reductions

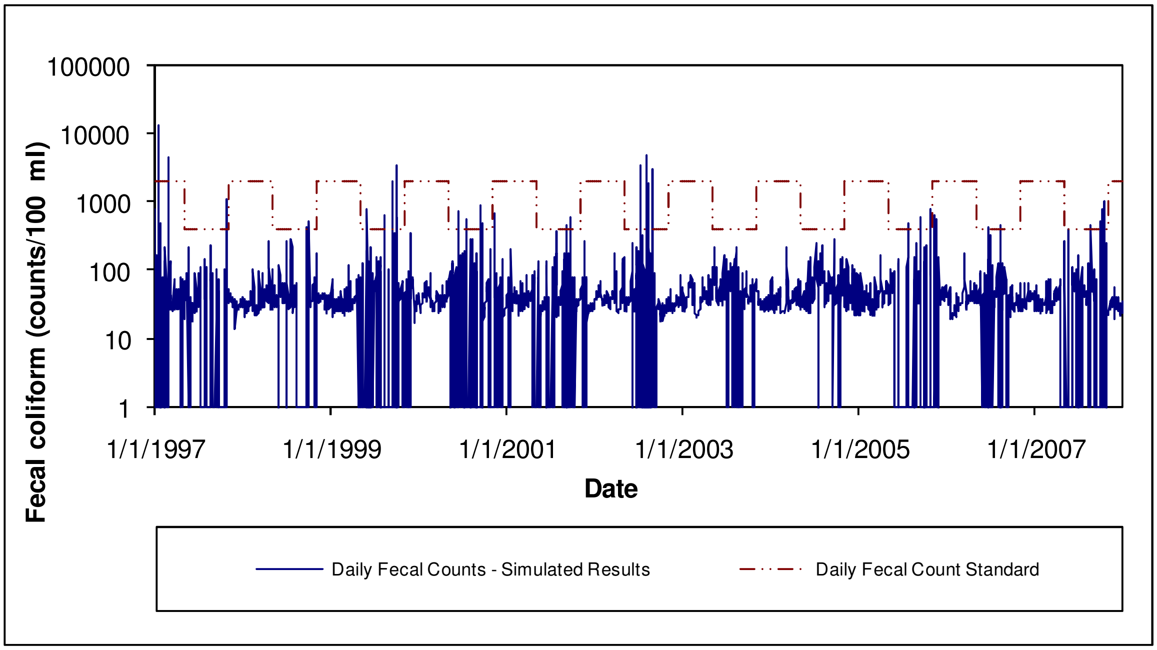

Figure E.3 Simulated Fecal Coliform at Site C1 After TMDL Reductions

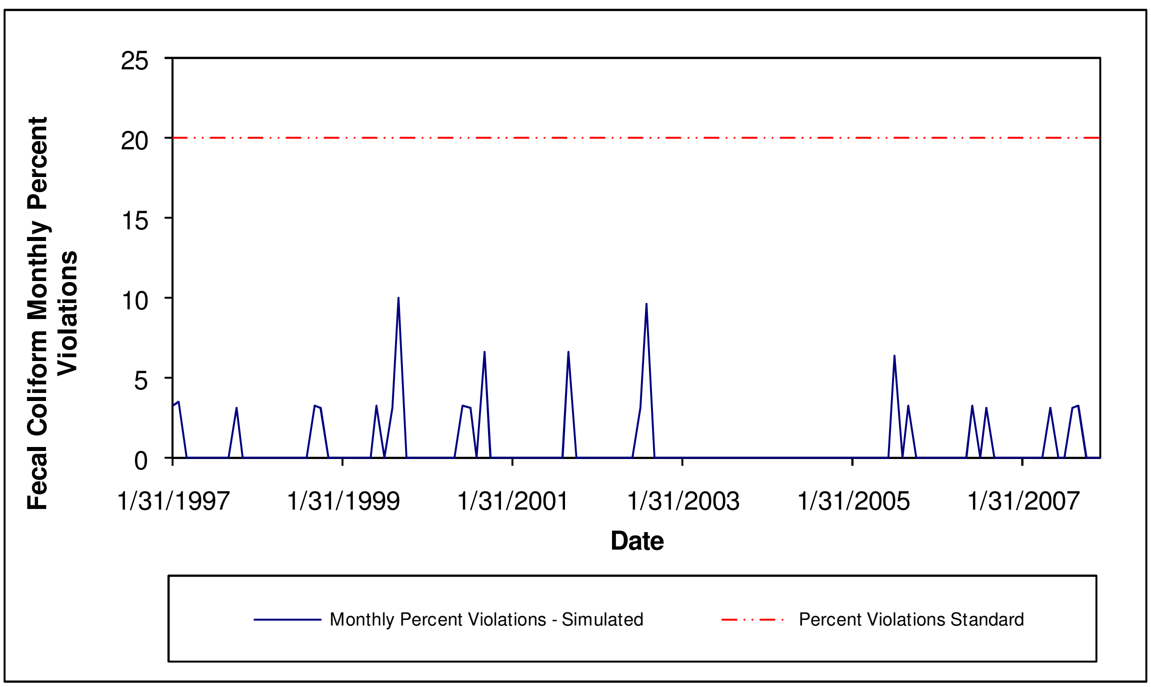

Figure E.4 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C1 After TMDL Reductions

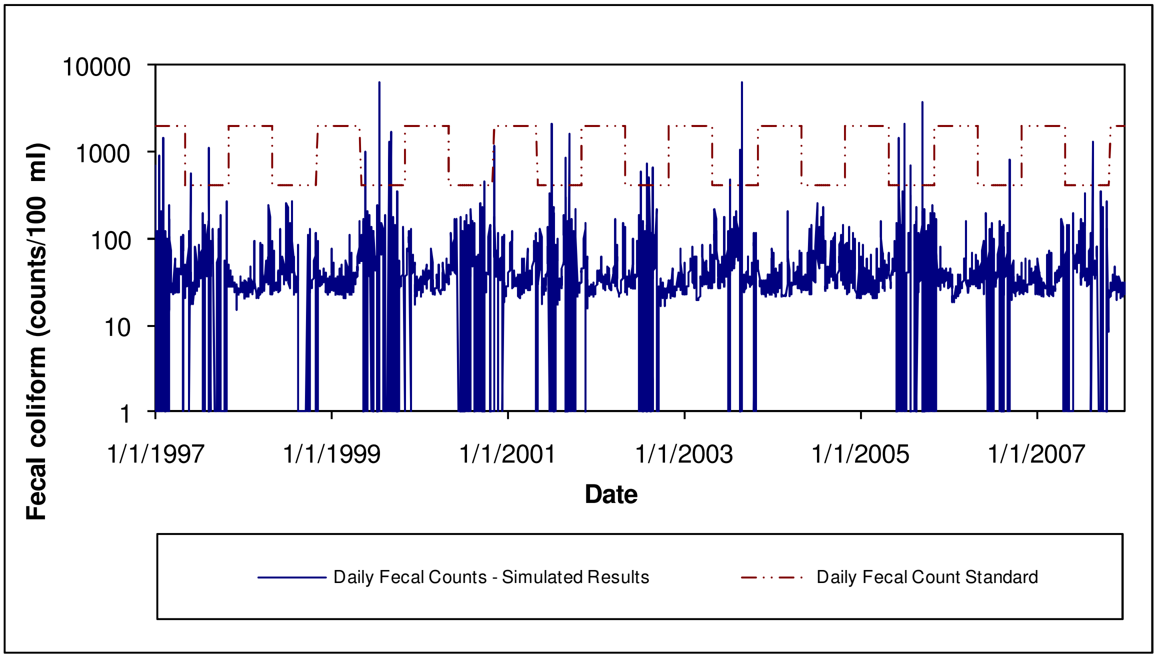

Figure E.5 Simulated Fecal Coliform at Site C2 After TMDL Reductions

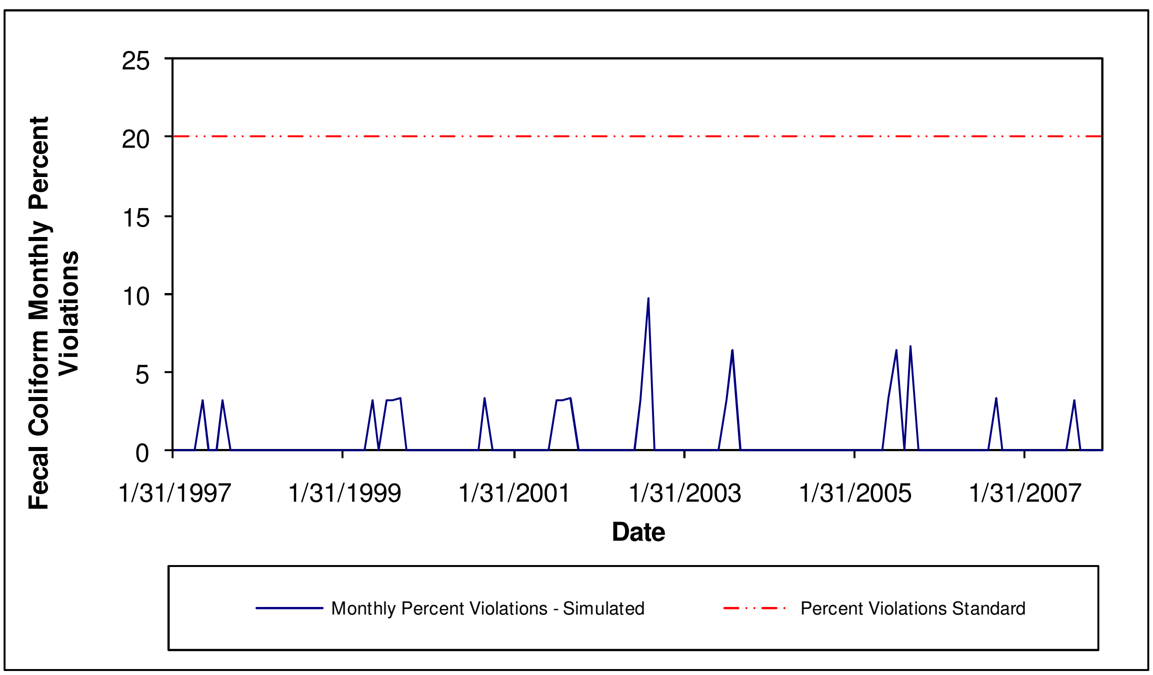

Figure E.6 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C2 After TMDL Reductions

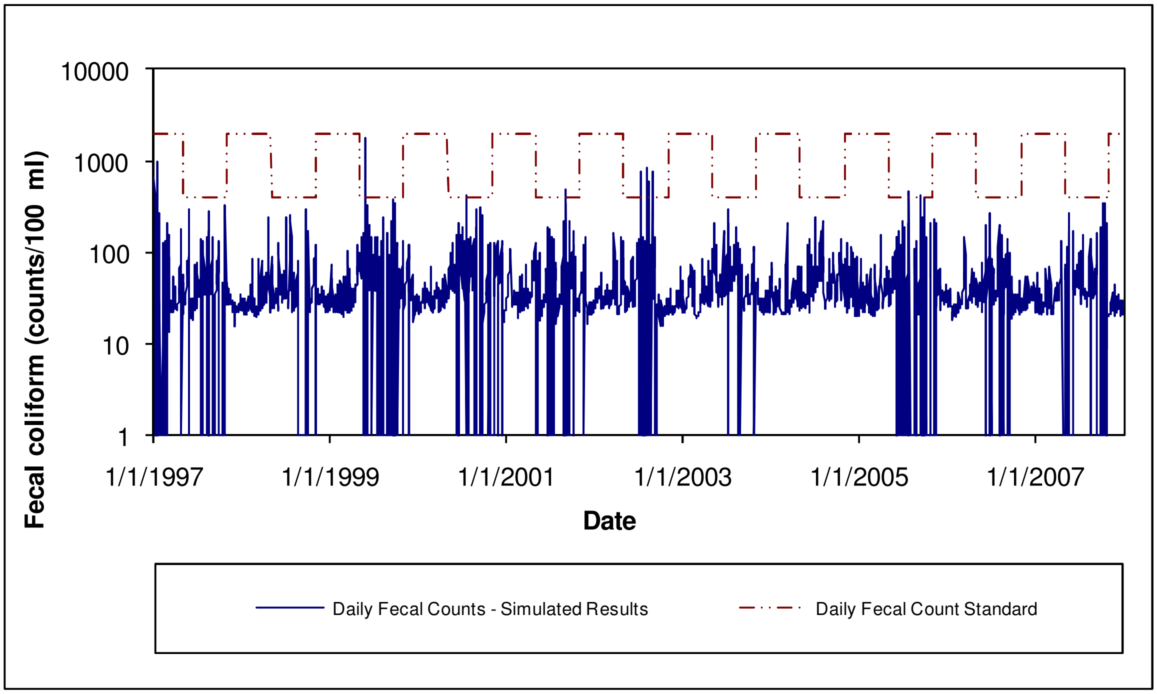

Figure E.7 Simulated Fecal Coliform at Site C3 After TMDL Reductions

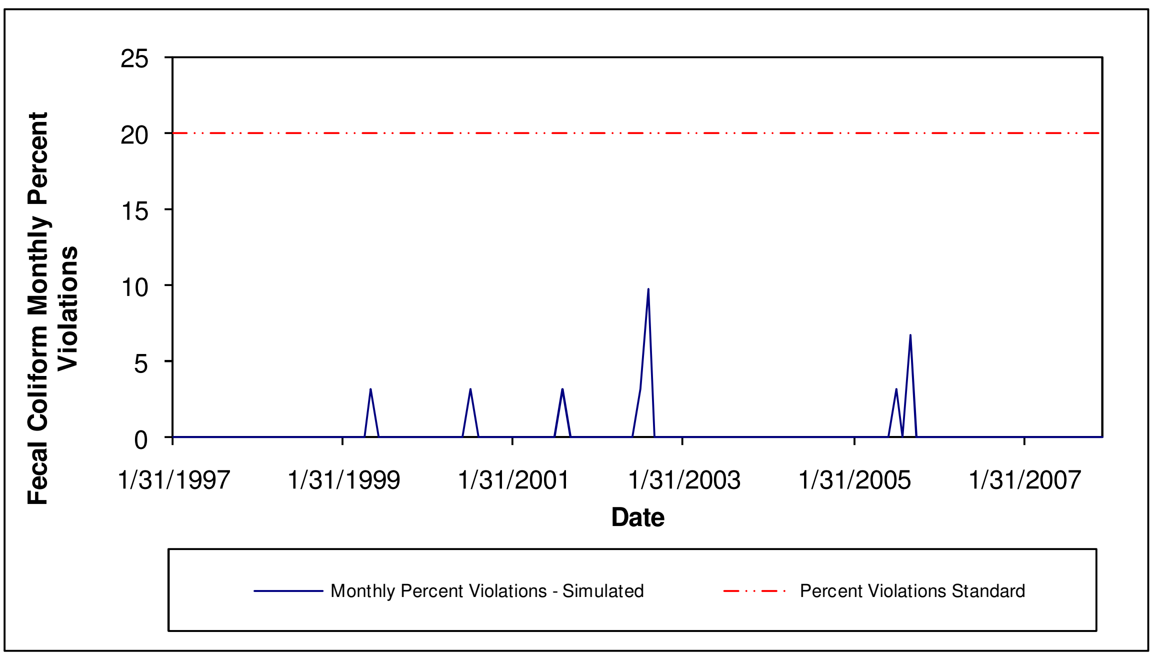

Figure E.8 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C3 After TMDL Reductions

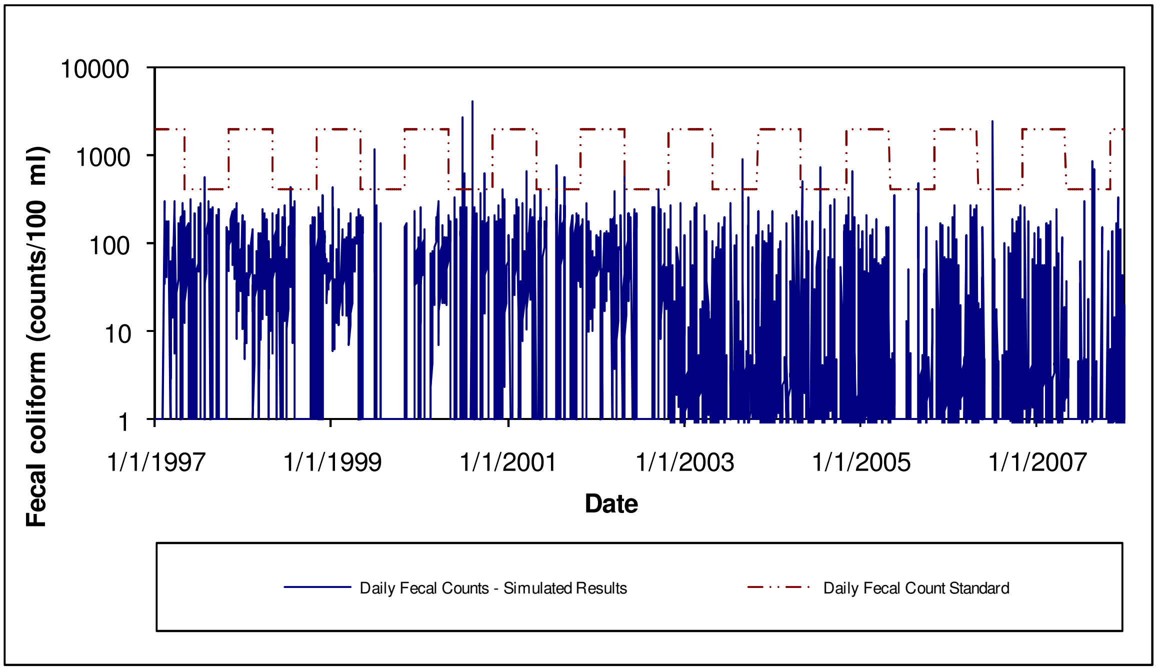

Figure E.9 Simulated Fecal Coliform at Site C4 After TMDL Reductions

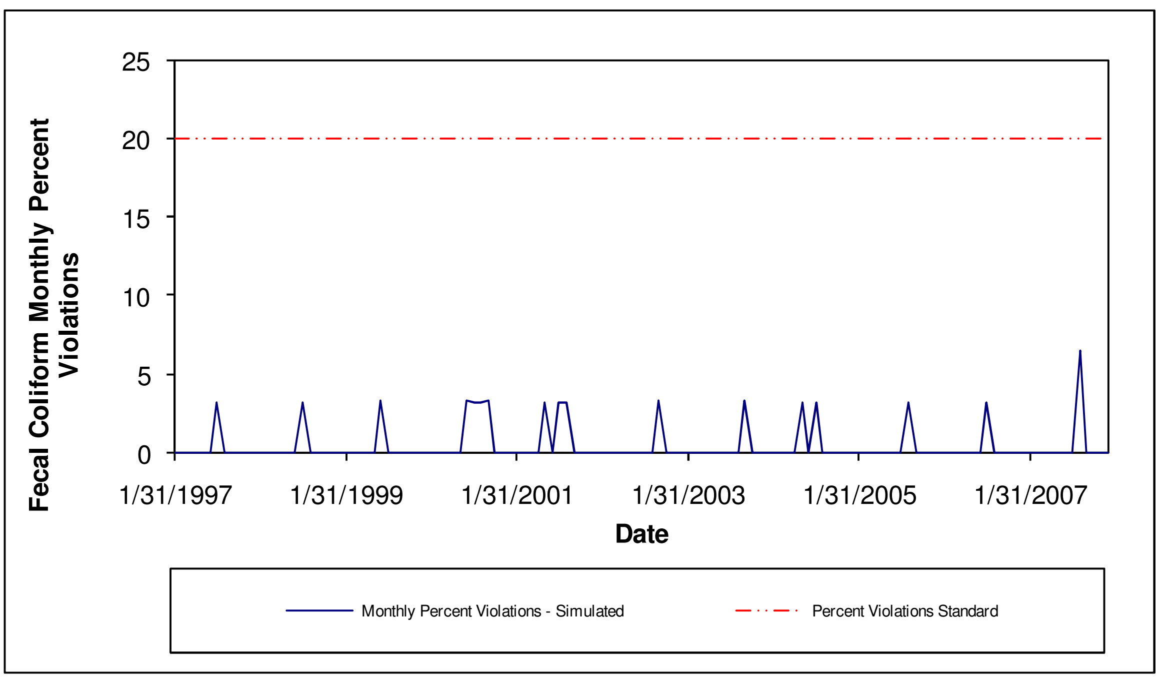

Figure E.10 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C4 After TMDL Reductions

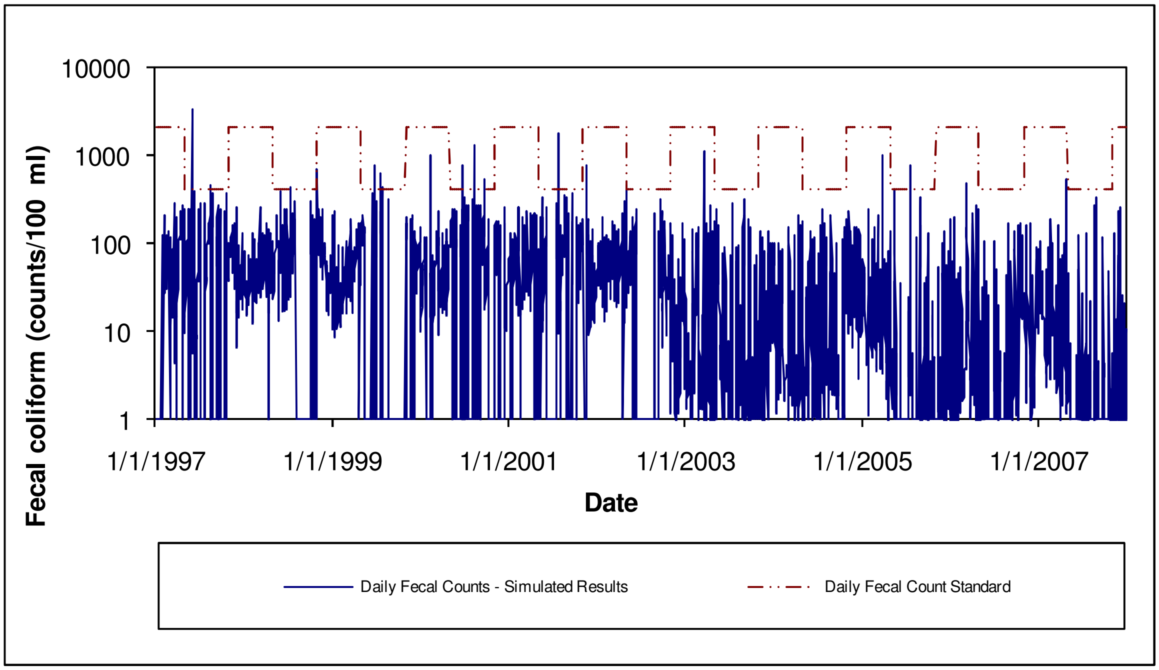

Figure E.11 Simulated Fecal Coliform at Site C5 After TMDL Reductions

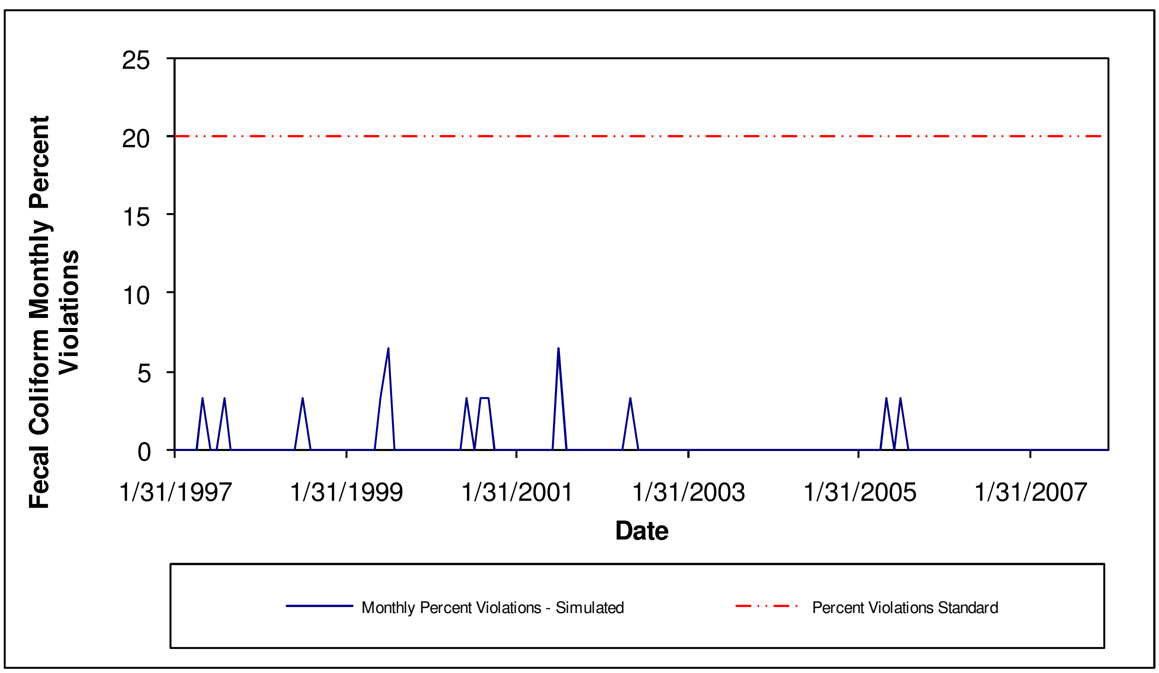

Figure E.12 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C5 After TMDL Reductions

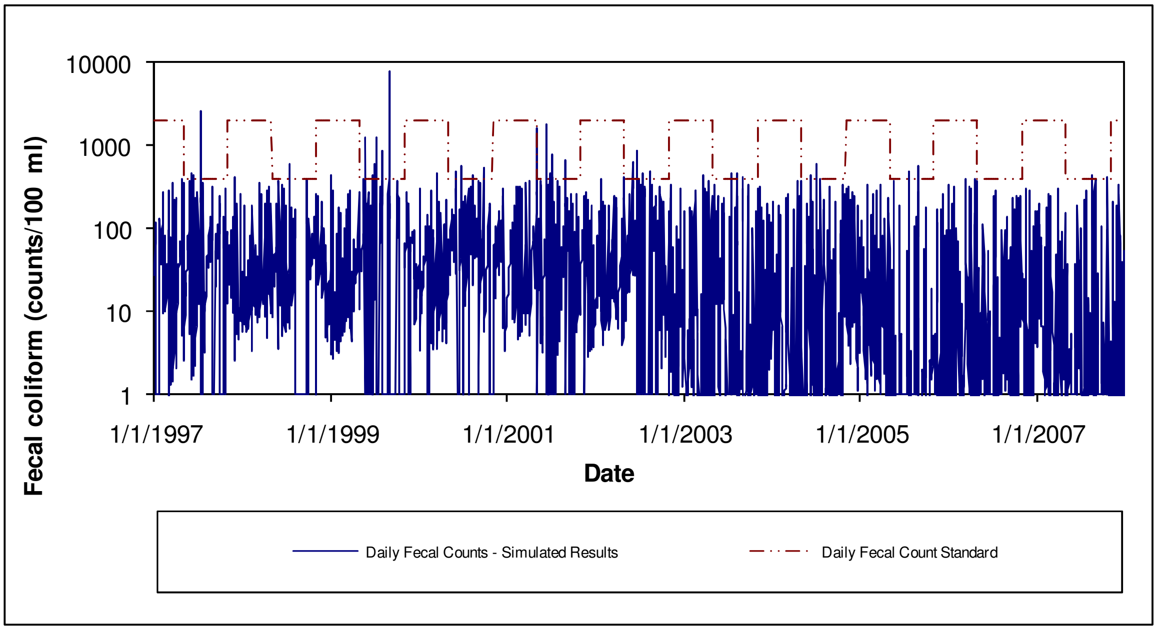

Figure E.13 Simulated Fecal Coliform at Site C6 After TMDL Reductions

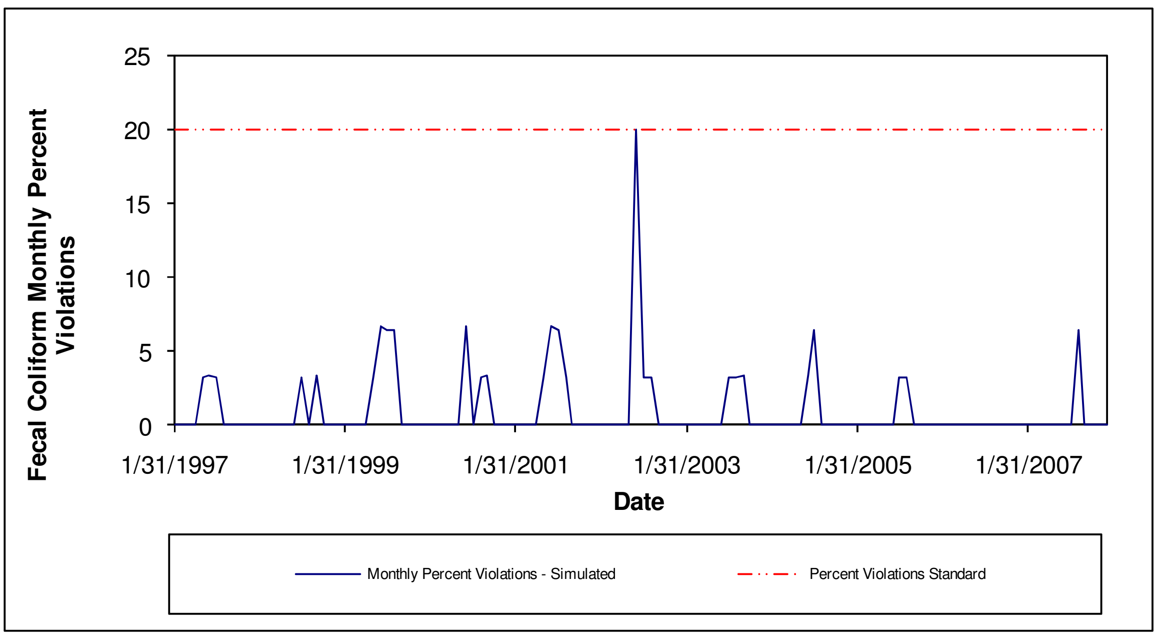

Figure E.14 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C6 After TMDL Reductions

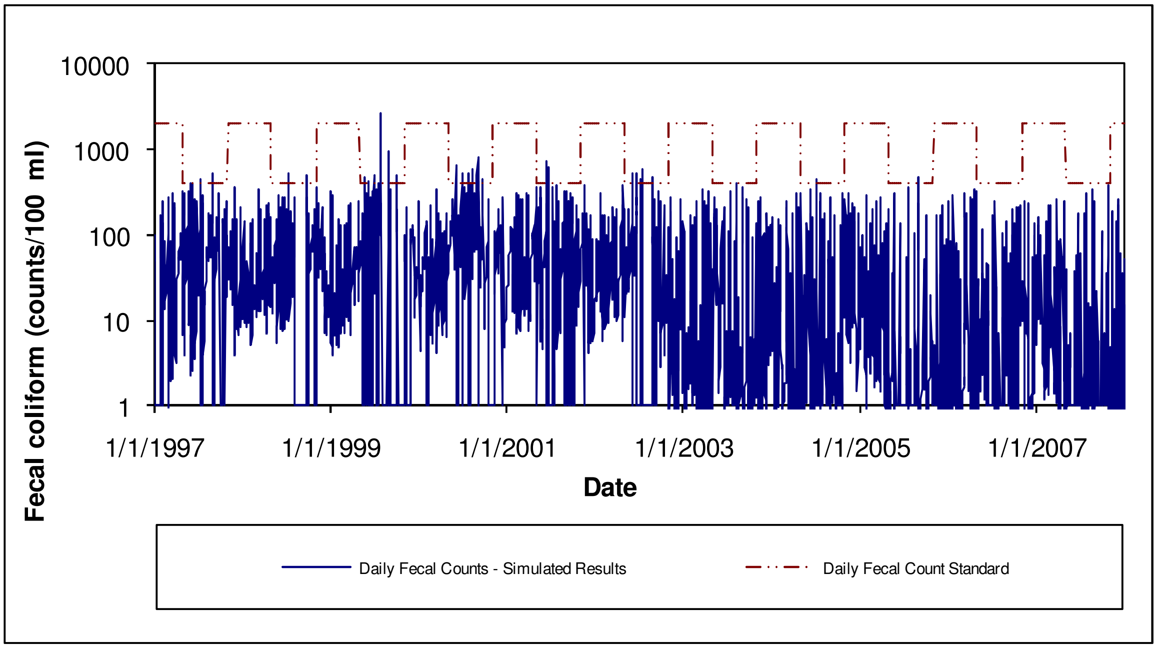

Figure E.15 Simulated Fecal Coliform at Site C7 After TMDL Reductions

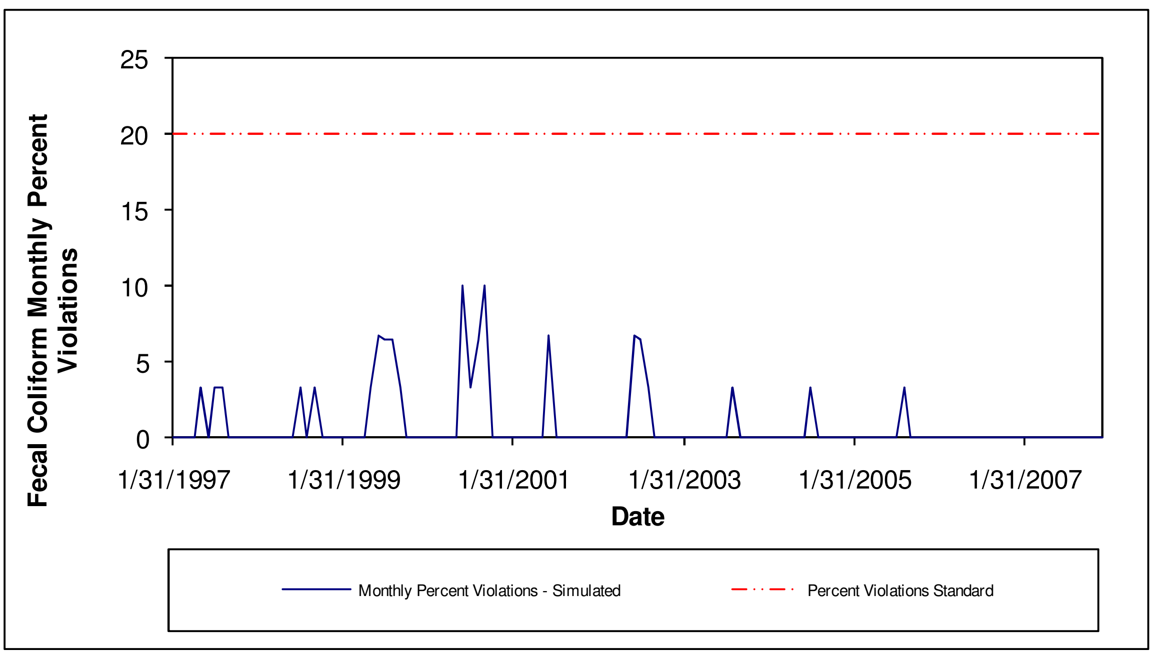

Figure E.16 Percent of Simulated Fecal Coliform Values > 400 colonies/100ml per Month at Site C7 After TMDL Reductions

APPENDIX F: KENTUCKY RIVER WATERSHED WATCH DATA

Below are tables showing KRWW's sampling station locations and fecal coliform data collected in the Cane Run watershed: Also, a map showing KRWW's sampling stations is included as Figure F.1 (KRWW, 2011b). While the first map shows all stations, only the two stations in the lower part of the watershed (i.e., stations 744 and 1221) have associated pathogen data, the others are included for reference only.

Table F.1 Kentucky River Watershed Watch Sampling Station Locations

Site ID	Historic ID	Location	County	Latitude	Longitude
744	K05	0.2 miles upstream of 460 bridge	Scott	38.20944	-84.61074
1221	K556	Intersection of Coleman Lane and Hwy 25	Scott	38.1666	-84.5532
1299	K635	Berea Road bridge crossing	Fayette	38.137381	-84.51739
1308	K644	Intersection of Hollow Creek off Russell Cave at the park	Fayette	38.07799	-84.48034

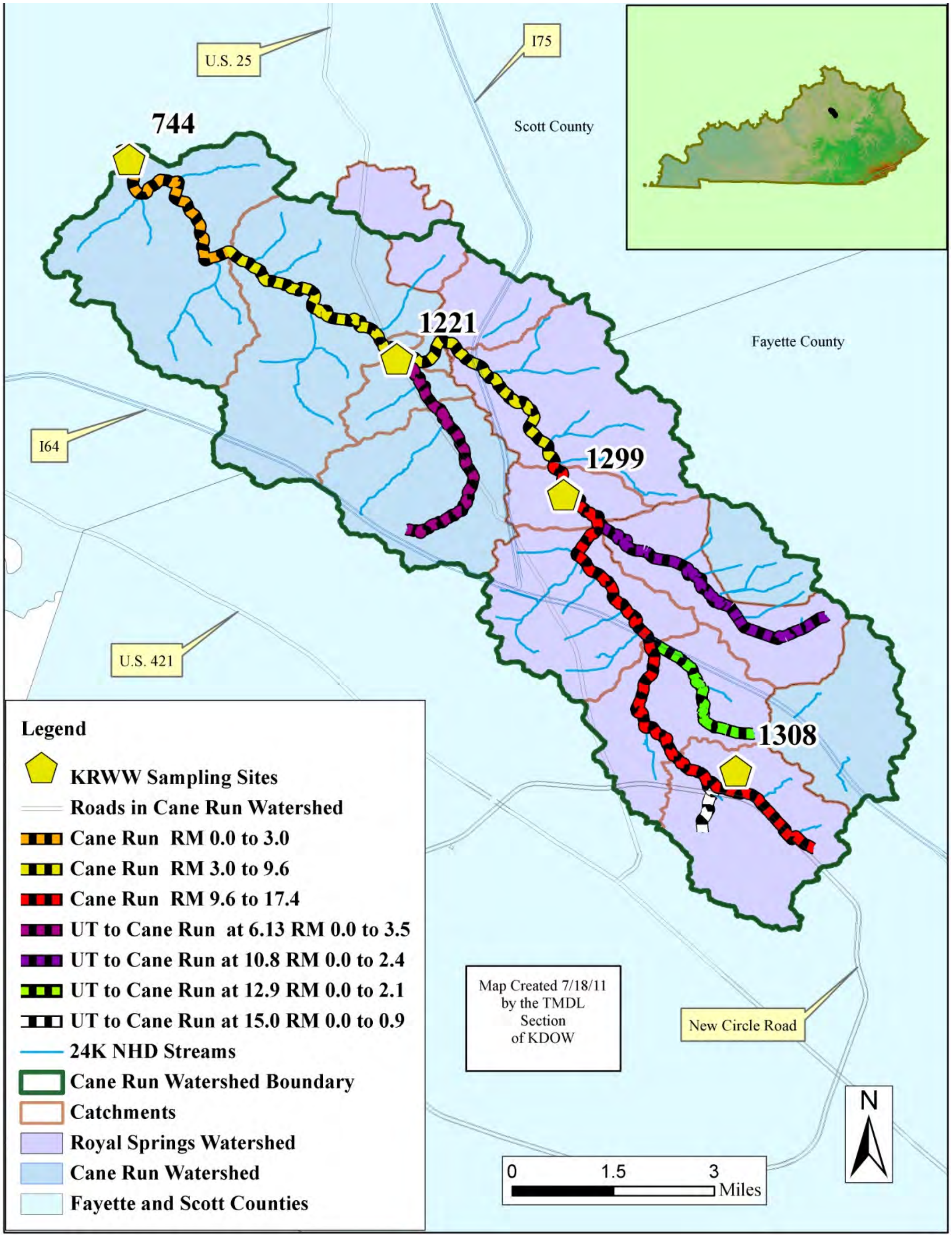

Figure F.1 Map 1 of Kentucky River Watershed Watch Sampling Stations

KRWW (http://www.uky.edu/OtherOrgs/KRWW/DataAnalysisRep.htm) collects *E. coli* and fecal coliform data, as did KWRRI. However, KRWW also collects other parameters; see the 2003 Annual Summary Report for further explanation (http://www.uky.edu/OtherOrgs/KRWW/AnnualReport03.htm). These parameters include:

1) AC/TC Ratio: This is the ratio of atypical coliform to typical coliform bacteria. While there are no WQC for typical or atypical coliform, this ratio can be used to gain an understanding of the age of the fecal bacteria; the higher the ratio, the older the sample;
2) Flow: Based on visual observations, the flow rate in the streams was assessed using the following ordinal scale:
   0 – Dry
   1 – Ponded
   2 – Low
   3 – Normal
   4 – Bank Full
   5 – Flood;
3) Total Coliform: Total coliform is used as an indicator for fecal contamination of drinking water, but not surface water;
4) Fecal Coliform/Fecal Streptococci Ratio: This was formerly used to determine whether fecal bacteria were human or non-human in origin, however this test is no longer recommended, and;
5) *E. coli*/Fecal Coliform Ratio: This ratio, when it exceeds 1.0, can indicate when bacteria have been stressed; an example is bacteria that have undergone treatment by a SWS.

Table F.2 Kentucky River Watershed Watch Pathogen Data

Station Name	Historic Name	Sample Date	Analyte(1)	Results	Units
744	K005	7/27/2002	AC/TC Ratio	5.98	colonies/100 ml
744	K005	7/28/2006	AC/TC Ratio	25.455	
744	K005	7/19/2007	AC/TC Ratio	20	
744	K005	7/27/2007	AC/TC Ratio	4.25	
744	K005	7/27/2007	AC/TC Ratio	0.235	
744	K005	7/27/2002	Atypical Coliform	27,500	colonies/100 ml
744	K005	7/28/2006	Atypical Coliform	28,000	colonies/100 ml
744	K005	7/12/2007	Atypical Coliform	13,000	colonies/100 ml

Station Name	Historic Name	Sample Date	Analyte(1)	Results	Units
744	K005	7/19/2007	Atypical Coliform	15,000	colonies/100 ml
744	K005	7/27/2007	Atypical Coliform	5,100	colonies/100 ml
744	K005	7/27/2007	Atypical Coliform	1,200	colonies/100 ml
744	K005	6/29/2007	*E. coli*	1,040	colonies/100 ml
744	K005	6/29/2007	*E. coli*	1,040	colonies/100 ml
744	K005	6/29/2007	*E. coli*	1,040	colonies/100 ml
744	K005	7/5/2007	*E. coli*	8,160	colonies/100 ml
744	K005	7/12/2007	*E. coli*	373	colonies/100 ml
744	K005	7/19/2007	*E. coli*	428	colonies/100 ml
744	K005	7/27/2007	*E. coli*	417	colonies/100 ml
744	K005	7/12/2008	*E. coli*	613	colonies/100 ml
744	K005	8/1/2008	*E. coli*	2,360	colonies/100 ml
744	K005	7/10/2009	*E. coli*	1,120	colonies/100 ml
744	K005	7/31/2009	*E. coli*	7,700	colonies/100 ml
744	K005	8/2/2003	*E. coli*	201	colonies/100 ml
744	K005	7/7/2006	*E. coli*	448	colonies/100 ml
744	K005	7/28/2006	*E. coli*	857	colonies/100 ml
744	K005	7/27/2007	*E. coli*	417	colonies/100 ml
744	K005	8/2/2003	*E. coli/Fecal Ratio*	2.010	colonies/100 ml
744	K005	7/31/2000	Fecal Coliform	1,400	colonies/100 ml
744	K005	8/9/2000	Fecal Coliform	270	colonies/100 ml
744	K005	8/16/2000	Fecal Coliform	60	colonies/100 ml
744	K005	8/21/2000	Fecal Coliform	500	colonies/100 ml
744	K005	8/28/2000	Fecal Coliform	450	colonies/100 ml
744	K005	7/19/1999	Fecal Coliform	2,700	colonies/100 ml
744	K005	7/10/2000	Fecal Coliform	140	colonies/100 ml

Station Name	Historic Name	Sample Date	Analyte(1)	Results	Units
744	K005	7/17/2001	Fecal Coliform	100	colonies/100 ml
744	K005	7/15/2002	Fecal Coliform	18,000	colonies/100 ml
744	K005	7/27/2002	Fecal Coliform	280	colonies/100 ml
744	K005	8/2/2003	Fecal Coliform	100	colonies/100 ml
744	K005	7/31/2000	Fecal Strep	900	colonies/100 ml
744	K005	8/9/2000	Fecal Strep	1,200	colonies/100 ml
744	K005	8/16/2000	Fecal Strep	250	colonies/100 ml
744	K005	8/21/2000	Fecal Strep	2,500	colonies/100 ml
744	K005	8/28/2000	Fecal Strep	500	colonies/100 ml
744	K005	7/19/1999	Fecal Strep	4,200	colonies/100 ml
744	K005	7/10/2000	Fecal Strep	500	colonies/100 ml
744	K005	7/19/1999	Fecal/Strep Ratio	6.400	
744	K005	7/10/2000	Fecal/Strep Ratio	0.280	
744	K005	7/31/2000	Fecal/Strep Ratio	1.556	
744	K005	8/9/2000	Fecal/Strep Ratio	0.225	
744	K005	8/16/2000	Fecal/Strep Ratio	0.240	
744	K005	8/21/2000	Fecal/Strep Ratio	0.200	
744	K005	8/28/2000	Fecal/Strep Ratio	0.900	
744	K005	7/7/2006	Flow Conditions	2	
744	K005	7/28/2006	Flow Conditions	3	
744	K005	9/15/2006	Flow Conditions	3	
744	K005	5/21/2007	Flow Conditions	3	

Station Name	Historic Name	Sample Date	Analyte(1)	Results	Units
744	K005	6/29/2007	Flow Conditions	2	
744	K005	7/5/2007	Flow Conditions	5	
744	K005	7/27/2007	Flow Conditions	3	
744	K005	9/14/2007	Flow Conditions	2	
744	K005	9/11/2008	Flow Conditions	1	
744	K005	7/5/2007	Total Coliform	1,000	colonies/100 ml
744	K005	7/19/2007	Total Coliform	750	colonies/100 ml
744	K005	7/27/2007	Total Coliform	1,200	colonies/100 ml
744	K005	7/27/2002	Total Coliform	4,600	colonies/100 ml
744	K005	7/28/2006	Total Coliform	1,100	colonies/100 ml
744	K005	7/27/2007	Total Coliform	5,100	colonies/100 ml
1221	K556	7/27/2007	AC/TC Ratio	3.125	
1221	K556	7/27/2007	AC/TC Ratio	0.320	
1221	K556	6/29/2007	Atypical Coliform	6,000	colonies/100 ml
1221	K556	7/6/2007	Atypical Coliform	6,000	colonies/100 ml
1221	K556	7/12/2007	Atypical Coliform	11,000	colonies/100 ml
1221	K556	7/27/2007	Atypical Coliform	10,000	colonies/100 ml
1221	K556	7/27/2007	Atypical Coliform	3,200	colonies/100 ml

Station Name	Historic Name	Sample Date	Analyte[1]	Results	Units
1221	K556	6/29/2007	*E. coli*	6,130	colonies/100 ml
1221	K556	6/29/2007	*E. coli*	6,130	colonies/100 ml
1221	K556	6/29/2007	*E. coli*	6,130	colonies/100 ml
1221	K556	7/6/2007	*E. coli*	8,660	colonies/100 ml
1221	K556	7/12/2007	*E. coli*	1,110	colonies/100 ml
1221	K556	7/19/2007	*E. coli*	2,420	colonies/100 ml
1221	K556	7/27/2007	*E. coli*	1,420	colonies/100 ml
1221	K556	7/12/2008	*E. coli*	171	colonies/100 ml
1221	K556	7/10/2009	*E. coli*	131	colonies/100 ml
1221	K556	7/27/2007	*E. coli*	1,420	colonies/100 ml
1221	K556	5/21/2007	Flow Conditions	3	
1221	K556	6/29/2007	Flow Conditions	2	
1221	K556	7/6/2007	Flow Conditions	5	
1221	K556	7/27/2007	Flow Conditions	3	
1221	K556	9/15/2007	Flow Conditions	2	
1221	K556	9/11/2008	Flow Conditions	1	
1221	K556	7/19/2007	Total Coliform	14,000	colonies/100 ml
1221	K556	7/27/2007	Total Coliform	3,200	colonies/100 ml
1221	K556	7/27/2007	Total Coliform	10,000	colonies/100 ml

APPENDIX G: LFUCG SEWER SYSTEM IMPROVEMENTS

Table G.1 shows the locations of SSOs originating in manholes associated with the sanitary sewer collection system for the Town Branch SWS. These areas were identified by the draft Cane Run Watershed-Based Plan (WBP, BAE, 2011). This table includes Lexington's efforts to address the problem areas as of July, 2011 (Personal Communication, Susan Plueger, 2011b).

Table G.1 SSOs identified by the Cane Run Watershed Based Plan, Draft 2011

SSO Location	SSO Category	LFUCG Status
Seventh and Jackson	Manhole	Sewers were replaced in 2004
Shelby St.	Manhole	Sewers were replaced in 2004
Edgelawn Ave.	Manhole	Sewers upstream were replaced in 2006
Pierson Dr.	Manhole	
Cane Run/Russell Cave Rd.	Manhole	
Pennebaker Dr.	Manhole	Infiltration and Inflow program performed work in 2009
Stanton Way (1950)	Manhole	Pump Station is in the process of being replaced
Newton Pike	Manhole	
Deepwood Dr.	Manhole	
Louden Ave. (115)	Manhole	
772 N. Broadway	Cross Connection	

Lexington has also begun a storm water and flooding abatement project in the Green Acres/Hollow Creek subdivision in northern Lexington. This project, which received $2.6 million in grant funding in 2007, was implemented in two phases. The first phase included stakeholder input, education and outreach. The second phase, which is still ongoing, includes floodproofing of residences, sanitary sewer redirection, installation of a riparian buffer and rehabilitation of storm sewers (BAE, 2011). See Figure G.1 for a map showing the location of the subdivision.

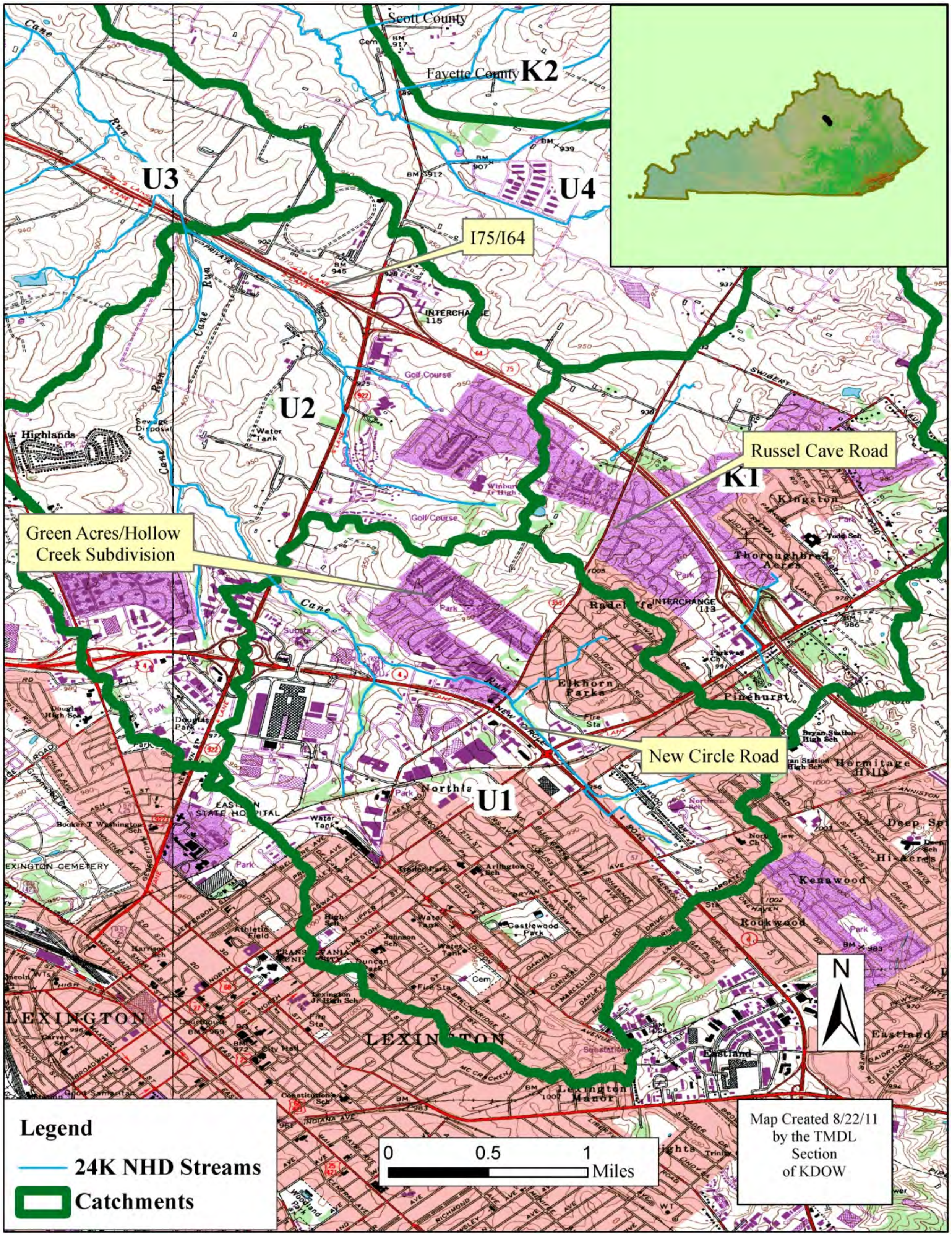

Figure F.1 Location of the Green Acres/Hollow Creek Subdivision

Tables G.2 and G.3 show Storm Water Quality Projects Incentive Grant recipients that are in or may affect the Cane Run watershed, see Section 5.2.1 for further details of the program (Personal Communication, Susan Plueger, 2011a).

Table G.2 LFUCG Incentive Grant Program, FY2011, Neighborhood Grants

Lexington-Fayette Urban County Government Stormwater Quality Projects Incentive Grant Program Class A (Neighborhood) Projects – FY2011 Projects Approved as of March 1, 2011
4. The Living Arts and Science Center, Inc. Target Watersheds: Town Branch and Cane Run Grant Amount $6,886.00 Develop and present educational workshops for the residents of the Martin Luther King Neighborhood. Implement a Rain Barrel/Rain Garden program for the neighborhood to improve water quality in the Town Branch and Cane Run Watersheds.

Table G.3 LFUCG Incentive Grant Program, FY2011, Education Grants

Lexington-Fayette Urban County Government Stormwater Quality Projects Incentive Grant Program Class B (Education) Projects – FY2011
1. WLEX Communications, LLC Target Watersheds: All of Fayette County Grant Amount: $115,869.06 Project to be part of a 10-month campaign “Water Quality is Everyone’s Responsibility.” Includes writing, production, and airing of 30-second vignettes on water quality and stormwater issues distributed throughout LEX18 programming with an emphasis on news. Vignettes will also run on the Fuel View two times per hour at 13 Fayette County Shell gas stations. The LEX18.com website will be updated with a water quality splash-page to include “how-to” information, water quality protection tips, links, and the vignettes. This project will be further enforced by other activities outside of the grant project, including quarterly or monthly water quality segments by local reporters on LEX18 News @ 12:30 p.m.

Lexington-Fayette Urban County Government
Stormwater Quality Projects Incentive Grant Program
Class B (Education) Projects – FY2011

2. University of Kentucky Research Foundation
Target Watersheds: All of Fayette County
Grant Amount: $113,375.00

Target audience includes professionals in the stormwater field, community and neighborhood groups, and educators and students. Plan includes direct involvement of 15 teachers from 4 Fayette County schools and 450 students. This project will utilize the existing Mill Creek stream restoration project as an outdoor classroom. Three Structural grant project applicants have also agreed to partner with this educational program, including Community Montessori School, Coca-Cola, and Clays Mill Elementary. Project elements include:

- Education of teachers and students on stormwater pollution, stream and wetland ecology.
- Develop and implement multiple units of study on stormwater quality and quantity and watershed-based issues.
- Disseminate these units to educators.
- Assist other schools in promoting water stewardship.
- Develop websites and wikis to encourage students to share knowledge.
- Create educational signs along streams/trails.
- Conduct culminating community event.

APPENDIX H: DMR REPORTS FOR SANITARY WASTEWATER SYSTEM FACILITIES

Tables H.1 through H.3 provide DMR data for the SWS facilities in the Cane Run watershed from 1997 through early 2011. KDOW is in the process of switching active permit holders from reporting in terms of fecal coliform to reporting in terms of *E. coli*; since these facilities were switched in the 2008-2009 timeframe, both parameters are reported in the tables below. The "B" data qualifier stands for "Below Method Detection Limit," and the "T" data qualifier stands for "TNTC," or "Too Numerous To Count." The "<" data qualifier stands for "less than," and the ">" data qualifier stands for "greater than."

Table H.1 Maple Grove MPH DMRs, 1997-2011

Maple Grove MPH DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
E. coli						
DMR OVERDUE (STATE)	6/30/2009					colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2009		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2009		2		2	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2009		2		2	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2009		B			colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2009		4		4	colonies/100ml
NUMERIC VIOLATION	12/31/2009		2,420		2,420	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2010		5		5	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2010		B			colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2010		B			colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2010		B			colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2010		1		1	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2010		B			colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2010		1		1	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2010		B			colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2010		3		3	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2010		6		6	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2010		30		30	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2010		7		7	colonies/100ml
DMR OVERDUE (STATE)	1/31/2011					colonies/100ml
Fecal Coliform						
MEASUREMENT ONLY, NO VIOLATION	1/31/1997	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/1997		182		3330	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/1997		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1997		130		130	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1997	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1997	<	10	<	10	colonies/100ml

Maple Grove MPH DMRs						
Description	Date		Average		Maximum	Units
MEASUREMENT ONLY, NO VIOLATION	7/31/1997		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1997		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1997		70		70	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1997		130		130	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1997		30		30	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1997		30		30	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/1998	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/1998		1,660		1,660	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/1998	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1998		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1998		60		120	colonies/100ml
NUMERIC VIOLATION	6/30/1998		3,468	>	5,700	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1998		120		120	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1998		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1998		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1998		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1998	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1998	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/1999	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	3/31/1999		297		4.42	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1999		90		90	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1999		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1999		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2000		120		120	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/29/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2000	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	6/30/2000		465.4		21,660	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2000	<	10	<	10	colonies/100ml

Maple Grove MPH DMRs						
Description	Date		Average		Maximum	Units
MEASUREMENT ONLY, NO VIOLATION	9/30/2000	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	10/31/2000		5,270		5,270	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2000	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	12/31/2000		5,840		5,840	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2001		130		130	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2001		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2001	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	4/30/2001		168.8		2850	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2001		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2001	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	11/30/2001		3,850		3,850	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2002		5.7		5.7	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2002	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	5/31/2002		3,990		3,990	colonies/100ml
NUMERIC VIOLATION	6/30/2002		1,330		1,330	colonies/100ml
NUMERIC VIOLATION	7/31/2002	>	5.7	>	5.7	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2002	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	10/31/2002		9120		9120	colonies/100ml
NUMERIC VIOLATION	11/30/2002		880		880	colonies/100ml
NUMERIC VIOLATION	12/31/2002	>	1,000	>	1,000	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2003	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/2003		16,000		16,000	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2003	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2003		10		10	colonies/100ml
NUMERIC VIOLATION	5/31/2003		1,880		1,880	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2003	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2003	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2003		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2003		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2003	<	10	<	10	colonies/100ml

Maple Grove MPH DMRs						
Description	Date		Average		Maximum	Units
MEASUREMENT ONLY, NO VIOLATION	11/30/2003	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2003	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/29/2004		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2004		70		70	colonies/100ml
NUMERIC VIOLATION	4/30/2004		7,410		7,410	colonies/100ml
NUMERIC VIOLATION	5/31/2004		520		520	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2005	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/2005		1,010		1,010	colonies/100ml
NUMERIC VIOLATION	3/31/2005		4,700		4,700	colonies/100ml
NUMERIC VIOLATION	4/30/2005		300		300	colonies/100ml
NUMERIC VIOLATION	5/31/2005	>	5,700	>	5,700	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2005		40		40	colonies/100ml
NUMERIC VIOLATION	7/31/2005		440		440	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2005		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2005		90		90	colonies/100ml
NUMERIC VIOLATION	10/31/2005		930		930	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2005		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2006	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/2006		220		220	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2006	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	5/31/2006		530		530	colonies/100ml
NUMERIC VIOLATION	6/30/2006		2,060		2,060	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2006		170		170	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2006	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	10/31/2006		8,400		8,400	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2006	<	10	<	10	colonies/100ml

Maple Grove MPH DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	1/31/2007	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/2007		740		740	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2007		10		10	colonies/100ml
NUMERIC VIOLATION	4/30/2007		9,600		9,600	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2007		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2007		60		60	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2007		170		170	colonies/100ml
NUMERIC VIOLATION	11/30/2007		330		330	colonies/100ml
NUMERIC VIOLATION	12/31/2007		2,500		2,500	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2008	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/29/2008		190		190	colonies/100ml
NUMERIC VIOLATION	3/31/2008		610		610	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2008	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2008	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2008	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2008		60		60	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2008		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2008		30		30	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2008		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2008		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2008		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2009		Plant Shutdown, Ice Storm			colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2009		120		120	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2009		70		70	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2009		10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2009		10	<	10	colonies/100ml

Table H.2 Ponderosa MHP DMRs, 1997-2011

Ponderosa MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
E. coli						
MEASUREMENT ONLY, NO VIOLATION	6/30/2008		70		70	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2008		36		36	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2008		30		30	colonies/100ml

Ponderosa MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
NUMERIC VIOLATION	9/30/2008		226		226	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2008		2		2	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2008		2		2	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2008	<	2	<	2	colonies/100ml
NUMERIC VIOLATION	1/31/2009		1,230		1,230	colonies/100ml
NUMERIC VIOLATION	2/28/2009		4800		4,800	colonies/100ml
NUMERIC VIOLATION	3/31/2009		330		330	colonies/100ml
NUMERIC VIOLATION	4/30/2009		266		266	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2009		90		90	colonies/100ml
NUMERIC VIOLATION	6/30/2009		140		140	colonies/100ml
NUMERIC VIOLATION	7/31/2009		1,553		1,553	colonies/100ml
NUMERIC VIOLATION	8/31/2009		2,420		2,420	colonies/100ml
NUMERIC VIOLATION	9/30/2009		2,420		2,420	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2009		1		1	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2009		B		B	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2009		13		13	colonies/100ml
NUMERIC VIOLATION	1/31/2010		326		326	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2010		7		7	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2010		B		B	colonies/100ml
NUMERIC VIOLATION	4/30/2010		2,420		2,420	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2010		31		31	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2010		B		B	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2010		B		B	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2010		6		6	colonies/100ml
DMR OVERDUE (STATE)	9/30/2010					colonies/100ml
DMR OVERDUE (STATE)	10/31/2010					colonies/100ml
DMR OVERDUE (STATE)	11/30/2010					colonies/100ml
DMR OVERDUE (STATE)	12/31/2010					colonies/100ml
DMR OVERDUE (STATE)	1/31/2011					colonies/100ml
Fecal Coliform						
MEASUREMENT ONLY, NO VIOLATION	1/31/1997	<	4	<	4	colonies/100ml
NUMERIC VIOLATION	2/28/1997		T		T	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1997		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1997		8		8	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1997					colonies/100ml

Ponderosa MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	9/30/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/1998	<	4	<	4	colonies/100ml
NUMERIC VIOLATION	2/28/1998		1,060		1,060	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/1998	<	4	<	4	colonies/100ml
NUMERIC VIOLATION	4/30/1998		4,820		4,820	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1998		4		4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1998		0		0	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1998		13		13	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/1999		0		0	colonies/100ml
NUMERIC VIOLATION	2/28/1999		78		600	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1999	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	11/30/1999		390		390	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1999		10		10	colonies/100ml
NUMERIC VIOLATION	1/31/2000		172.3		2,970	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/29/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2000	<	10	<	10	colonies/100ml

Ponderosa MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	11/30/2000		50		50	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2001	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	6/30/2001		3,280		3,280	colonies/100ml
NUMERIC VIOLATION	7/31/2001		2,850		2,850	colonies/100ml
NUMERIC VIOLATION	8/31/2001		1,430		1,430	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2001	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2003		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2003		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2003		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2003	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2003		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2003	<	10	<	10	colonies/100ml
DMR OVERDUE (STATE)	7/31/2003					colonies/100ml
DMR OVERDUE (STATE)	8/31/2003					colonies/100ml
DMR OVERDUE (STATE)	9/30/2003					colonies/100ml
DMR OVERDUE (STATE)	10/31/2003					colonies/100ml
DMR OVERDUE (STATE)	11/30/2003					colonies/100ml
DMR OVERDUE (STATE)	12/31/2003					colonies/100ml

Ponderosa MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
DMR OVERDUE (STATE)	1/31/2004					colonies/100ml
DMR OVERDUE (STATE)	2/29/2004					colonies/100ml
DMR OVERDUE (STATE)	3/31/2004					colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2004	<	10	<	10	colonies/100ml
DMR OVERDUE (STATE)	12/31/2004					colonies/100ml
DMR OVERDUE (STATE)	1/31/2005					colonies/100ml
DMR OVERDUE (STATE)	2/28/2005					colonies/100ml
DMR OVERDUE (STATE)	3/31/2005					colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2005		10		10	colonies/100ml
NUMERIC VIOLATION	5/31/2005	>	5,700	>	5,700	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2005					colonies/100ml
NUMERIC VIOLATION	7/31/2005		1,200		1,200	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2006	<	10	<	10	colonies/100ml
DMR OVERDUE (STATE)	4/30/2006					colonies/100ml
DMR OVERDUE (STATE)	5/31/2006					colonies/100ml
DMR OVERDUE (STATE)	6/30/2006					colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2007	<	10	<	10	colonies/100ml

Ponderosa MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	3/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2008	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/29/2008		3,600		3,600	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2008	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2008	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2008		104		104	colonies/100ml

Table H.3 Spindletop MHP DMRs, 1997-2000

Spindletop MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
E. coli						
MEASUREMENT ONLY, NO VIOLATION	6/30/2008		4.38		46	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2008		2	<	2	colonies/100ml
NUMERIC VIOLATION	8/31/2008		9.36		960	colonies/100ml
NUMERIC VIOLATION	9/30/2008		49.6		6,000	colonies/100ml
NUMERIC VIOLATION	10/31/2008		23.3		344	colonies/100ml
NUMERIC VIOLATION	11/30/2008		103		3,600	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2008		52.6		240	colonies/100ml
NUMERIC VIOLATION	1/31/2009		129		1,930	colonies/100ml
NUMERIC VIOLATION	2/28/2009		72		280	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2009		10	<	10	colonies/100ml
NUMERIC VIOLATION	4/30/2009		43		770	colonies/100ml
NUMERIC VIOLATION	5/31/2009		392		2,840	colonies/100ml
NUMERIC VIOLATION	6/30/2009		1,600		3,380	colonies/100ml
NUMERIC VIOLATION	7/31/2009		1,230		2,420	colonies/100ml
NUMERIC VIOLATION	8/31/2009		750		1,733	colonies/100ml
NUMERIC VIOLATION	9/30/2009		345		2,420	colonies/100ml
NUMERIC VIOLATION	10/31/2009		516		2,420	colonies/100ml

Spindletop MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
NUMERIC VIOLATION	11/30/2009		2,420		2,420	colonies/100ml
NUMERIC VIOLATION	12/31/2009		121		2,420	colonies/100ml
NUMERIC VIOLATION	1/31/2010		243		2,420	colonies/100ml
NUMERIC VIOLATION	2/28/2010		17		2,420	colonies/100ml
NUMERIC VIOLATION	3/31/2010		1,872		2,420	colonies/100ml
NUMERIC VIOLATION	4/30/2010		1,993		2,420	colonies/100ml
NUMERIC VIOLATION	5/31/2010		329		2,420	colonies/100ml
NUMERIC VIOLATION	6/30/2010		23		2,420	colonies/100ml
NUMERIC VIOLATION	7/31/2010		47		2,420	colonies/100ml
NUMERIC VIOLATION	8/31/2010		26		1,553	colonies/100ml
DMR OVERDUE (STATE)	9/30/2010					colonies/100ml
DMR OVERDUE (STATE)	10/31/2010					colonies/100ml
DMR OVERDUE (STATE)	11/30/2010					colonies/100ml
DMR OVERDUE (STATE)	12/31/2010					colonies/100ml
DMR OVERDUE (STATE)	1/31/2011					colonies/100ml
Fecal Coliform						
MEASUREMENT ONLY, NO VIOLATION	1/31/1997		180		180	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/1997		4		4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1997		4		4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1997		93		93	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1997		8		8	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1997	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1998		20		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1998	<	4		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1998	<	4	<	4	colonies/100ml

Spindletop MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	10/31/1998	<	4	<	4	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1998		0		0	colonies/100ml
NUMERIC VIOLATION	12/31/1998		733		733	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/1999		0		0	colonies/100ml
NUMERIC VIOLATION	2/28/1999		81		660	colonies/100ml
NUMERIC VIOLATION	3/31/1999		181		3,280	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/1999	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/29/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2000	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	7/31/2000		500		500	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2000		24.98		390	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2000		20		80	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2000	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2001	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/2001		61.7		510	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2001		20.9		190	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2001		34.6		240	colonies/100ml
NUMERIC VIOLATION	5/31/2001		56.7		910	colonies/100ml
NUMERIC VIOLATION	6/30/2001		170.6		20,680	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2001		19.68		50	colonies/100ml
NUMERIC VIOLATION	8/31/2001		30.63		880	colonies/100ml
NUMERIC VIOLATION	9/30/2001		60.73		850	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2001	<	10	<	10	colonies/100ml

Spindletop MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	11/30/2001	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	12/31/2001		25.4		420	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2002		11.9		20	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2002		21.9		190	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2002	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	5/31/2002		77.98		6,270	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2002	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	8/31/2002		39.7		2,500	colonies/100ml
NUMERIC VIOLATION	9/30/2002		114.3		1,710	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2002	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2002	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	12/31/2002		248.8		2,160	colonies/100ml
NUMERIC VIOLATION	1/31/2003		34		1,500	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2003		30		270	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2003		24		80	colonies/100ml
NUMERIC VIOLATION	4/30/2003		185.5		1,480	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2003	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2003	<	10	<	10	colonies/100ml
DMR OVERDUE (STATE)	7/31/2003					colonies/100ml
DMR OVERDUE (STATE)	8/31/2003					colonies/100ml
DMR OVERDUE (STATE)	9/30/2003					colonies/100ml
DMR OVERDUE (STATE)	10/31/2003					colonies/100ml
DMR OVERDUE (STATE)	11/30/2003					colonies/100ml
DMR OVERDUE (STATE)	12/31/2003					colonies/100ml
DMR OVERDUE (STATE)	1/31/2004					colonies/100ml
DMR OVERDUE (STATE)	2/29/2004					colonies/100ml
DMR OVERDUE (STATE)	3/31/2004					colonies/100ml
NUMERIC VIOLATION	4/30/2004		34.5		1,410	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	6/30/2004		12.5		30	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	7/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2004	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2004	<	10	<	10	colonies/100ml

Spindletop MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	12/31/2004	<	10	<	10	colonies/100ml
DMR OVERDUE (STATE)	1/31/2005					colonies/100ml
DMR OVERDUE (STATE)	2/28/2005					colonies/100ml
DMR OVERDUE (STATE)	3/31/2005					colonies/100ml
NUMERIC VIOLATION	4/30/2005		410.9	>	5,700	colonies/100ml
NUMERIC VIOLATION	5/31/2005		51.1		3,420	colonies/100ml
NUMERIC VIOLATION	6/30/2005		1,535		5,700	colonies/100ml
NUMERIC VIOLATION	7/31/2005		440.9	>	5,700	colonies/100ml
NUMERIC VIOLATION	8/31/2005		164		5,130	colonies/100ml
NUMERIC VIOLATION	9/30/2005		53.1		7,980	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2005	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2006	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/28/2006		27.5		570	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2006	<	10	<	10	colonies/100ml
DMR OVERDUE (STATE)	4/30/2006					colonies/100ml
DMR OVERDUE (STATE)	5/31/2006					colonies/100ml
DMR OVERDUE (STATE)	6/30/2006					colonies/100ml
NUMERIC VIOLATION	7/31/2006		29.1		720	colonies/100ml
NUMERIC VIOLATION	8/31/2006		45.5		2,140	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2006		13.8		50	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2006	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	1/31/2007		15.6		60	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	2/28/2007		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2007		10	<	10	colonies/100ml
NUMERIC VIOLATION	5/31/2007		36.7		1,810	colonies/100ml
NUMERIC VIOLATION	6/30/2007		86		8,400	colonies/100ml
NUMERIC VIOLATION	7/31/2007		34.8		1,460	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	8/31/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	9/30/2007	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	10/31/2007		13.2		30	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	11/30/2007		10		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	12/31/2007		10	<	10	colonies/100ml

Spindletop MHP DMRs						
Description	**Date**		**Average**		**Maximum**	**Units**
MEASUREMENT ONLY, NO VIOLATION	1/31/2008	<	10	<	10	colonies/100ml
NUMERIC VIOLATION	2/29/2008		33.9		1,320	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	3/31/2008	<	10	<	10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	4/30/2008		2.99		10	colonies/100ml
MEASUREMENT ONLY, NO VIOLATION	5/31/2008		3.59		15	colonies/100ml