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*Fecal Coliform Total Maximum Daily Load for the  
Upper North Buffalo Creek Watershed  
City of Greensboro, Guilford County*

***Final Report***

January 2004 (Approved April 2004)

*Cape Fear River Basin*

Prepared by:



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**SUMMARY SHEET**  
**Total Maximum Daily Load (TMDL)**  
**North Buffalo Creek at and above Summit Avenue**

**1. 303(D) List Information**

State: North Carolina

County: Guilford

River Basin: Cape Fear River Basin

Watershed: Upper North Buffalo Creek

303(d) Listed Waters:

Name of Stream	Description	Class	Index #	8 Digit CU	Miles
North Buffalo Creek	From source to above WWTP	C NSW	16-11-14-1a	03030002	8.7

NC DWQ Subbasin: 03-06-02

8 Digit Cataloging Unit: 03030002

Area of Impairment: 8.7 miles

WQS Violated: Fecal Coliform

Pollutant of Concern: Fecal Coliform

Sources of Impairment: Point and nonpoint sources within the watershed

**2. Public Notice Information**

Form of Public Notification: A TMDL stakeholder group was formed to provide guidance and comment throughout the TMDL development process. The stakeholder group was comprised of public and private sector resource professionals potentially affected by the TMDL and/or having a general interest in water quality protection. Five formal stakeholder meetings were held over the course of the TMDL development process. [Additional public notification efforts will include an advertisement in the local newspaper, etc.]

Did notification contain specific mention of TMDL proposal? \_\_\_\_\_

Were comments received from the public? \_\_\_\_\_

Was a responsiveness summary prepared? \_\_\_\_\_

### 3. TMDL Information

**Critical condition:** Highest predicted instream fecal coliform concentrations occur during wet weather periods preceded by a period of dry weather. The period of highest risk to public health is during dry weather periods in the summer when recreational use of the waters is greatest and human sources of bacterial contamination dominate watershed loads.

**Seasonality:** A continuous simulation model during the period August 1998 through August 2001 (period of record for stream flow gage data and precipitation data in the watershed) includes seasonal fluctuations in fecal coliform loading.

**Development tools:** WinHSPF version 2.0.6

### 4. TMDLs

**Loading allowed at critical conditions reflective of both wet and dry weather conditions:**

Wasteload Allocation (WLA): 2.73E+11 counts/day

Load Allocation (LA): 1.25E+12 counts/day

Margin of Safety (MOS): More stringent geometric mean target of 180 counts/100mL, as opposed to the 200 counts/100mL WQS; conservative modeling assumptions.

TMDL (WLA+LA+MOS): 1.52E+12 counts/day

TMDL Component (wet and dry weather conditions)	TMDL Allocation Category	Fecal Coliform Load Reductions
Wasteload Allocation (WLA)	MS4 (NCS000248) <sup>1</sup>	96%
Load Allocation (LA)	Nonpoint Sources <sup>2</sup>	93%
Wasteload Allocation (WLA)	Cone Mills WWTP (NC0000876) <sup>3</sup>	N/A

**Notes:**

- MS4 = Municipal Separate Storm Sewer System. This allocation category covers individual sources contributing fecal coliform loads which are transported to the receiving stream via the City of Greensboro's NPDES permitted stormwater conveyance system.
- This allocation category covers individual sources whose loads are delivered to the receiving stream via modes not associated with the MS4.
- The Cone Mills WWTP ceased discharging treated industrial/domestic wastewater into North Buffalo Creek during the latter portion of the TMDL simulation period, therefore a load reduction is not applicable.

**Loading allowed at critical conditions during dry weather conditions:**

Wasteload Allocation (WLA): 1.98E+10 counts/day

Load Allocation (LA): 1.10E+11 counts/day

Margin of Safety (MOS): More stringent geometric mean target of 180 counts/100mL, as opposed to the 200 counts/100mL WQS; conservative modeling assumptions.

TMDL (WLA+LA+MOS): 1.30E+11 counts/day

TMDL Component (dry weather conditions)	TMDL Allocation Category	Fecal Coliform Load Reductions
Wasteload Allocation (WLA)	MS4 (NCS000248) <sup>1</sup>	72%
Load Allocation (LA)	Nonpoint Sources <sup>2</sup>	70%
Wasteload Allocation (WLA)	Cone Mills WWTP (NC0000876) <sup>3</sup>	N/A

**Notes:**

- 1 MS4 = Municipal Separate Storm Sewer System. This allocation category covers individual sources contributing fecal coliform loads which are transported to the receiving stream via the City of Greensboro's NPDES permitted stormwater conveyance system.
- 2 This allocation category covers individual sources whose loads are delivered to the receiving stream via modes not associated with the MS4.
- 3 The Cone Mills WWTP ceased discharging treated industrial/domestic wastewater into North Buffalo Creek during the latter portion of the TMDL simulation period, therefore a load reduction is not applicable.

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## ACRONYMS AND ABBREVIATIONS

BIMS	NC Basinwide Information Management System
BMP	Best Management Practices
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DA	Drainage Area
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
DENR	NC Department of Environment and Natural Resources
DWM	Dynamic Watershed Management System – City of Greensboro
DWQ	NC Division of Water Quality
EPA	US Environmental Protection Agency
FC	Fecal Coliform
GIS	Geographic Information System
GPS	Global Positioning System
GSO	City of Greensboro
I&I	Infiltration and Inflow
IR	Infrared
LA	Load Allocation
LULC	Land use/land cover
MF	Membrane Filter
MGD	Million Gallons per Day
mL	Milliliter
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PTCOG	Piedmont Triad Council of Governments
WRF	Water Reclamation Facility
SMD	City of Greensboro Stormwater Management Division
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WinHSPF	Windows version of Hydrological Simulation Program - FORTRAN
WLA	Waste Load Allocation
WQS	Water Quality Standard
WWTP	Wastewater Treatment Plant

## EXECUTIVE SUMMARY

The City of Greensboro's Department of Water Resources, in partnership with the NC Division of Water Quality (DWQ) and local stakeholders, have developed a fecal coliform Total Maximum Daily Load (TMDL) for the upper North Buffalo Creek watershed. A TMDL is an estimate of the maximum amount of pollutant load, e.g. fecal coliform, which a waterbody can receive and still maintain water quality standards.

The TMDL is designed to provide an objective analysis of potential sources of bacteriological contamination within the watershed, as well as the predicted impact these sources have on water quality under a variety of weather and stream flow conditions. This information is intended to enhance the City's ongoing efforts to improve instream water quality and provide a foundation for future management initiatives.



*Children enjoying a cool stream on a warm day. This tributary to North Buffalo Creek runs through Fisher Park, and is frequently used for recreation, especially in the summer. The TMDL summarized herein is designed to support management efforts to reduce instream human pathogens such that recreational uses will be protected, and where necessary restored.*

### **Water Quality Improvement Goals**

Approximately 8.7 stream miles of the upper North Buffalo Creek mainstem have been listed as *impaired* in NC's 2002 303(d) List due to elevated fecal coliform concentrations (DWQ, 2003). The stream's impaired status is a reflection that water quality standards for fecal coliform are not being met. This in turn is an indication that recreational users of the water resource may be at an elevated risk of contracting water borne diseases from human pathogens. The overall management goal is to reduce instream fecal coliform concentrations to a level such that recreational users can safely enjoy clean streams throughout the watershed.

To achieve this goal the TMDL defines two water quality targets: one target for dry weather when recreational use is at its highest; and another target for all weather conditions reflective of both wet and dry periods. Defining two TMDL targets is advantageous for several reasons. First, the *dry weather target* provides a framework for local watershed managers to focus their limited resources towards reducing pollutant loadings during a period when user exposure to potential pathogens is likely at its highest. Thereby, managers can optimize the use of their resources while also pursuing a target recognized by the DWQ and the US Environmental Protection Agency (EPA). Second, the *all weather conditions target* supports a traditional TMDL framework for

achieving fecal coliform water quality standards under the most critical weather and stream flow conditions identified within the analysis period (August 1998 – August 2001). This target reflects a longer term goal for achieving standards when the number of potential contributing sources are at its highest. Thus, the TMDL summarized herein is actually two TMDLs reflecting different rainfall runoff conditions.

For both TMDLs the target instream fecal coliform concentration is a geometric mean concentration of < 200 cfu/100mL. Beginning on p. 47 is additional information about the water quality targets. North Buffalo Creek at Summit Avenue is the point within the watershed at which these targets will be applied.

### **The Watershed in Brief**

Upstream of Summit Avenue - the TMDL compliance point - the watershed has a drainage area of 21.8 mi<sup>2</sup>. This area subject to the TMDL includes a portion of Greensboro's downtown and is generally "built-out" from a development perspective. Residential land uses dominate and cover approximately 38% of the TMDL area, with roads (right-of-ways) covering approximately 15%. Forests cover approximately 20% of the TMDL area.

Based on an analysis of 2000 US Census data, approximately 59,000 people reside within the TMDL area, which translates into an average population density of 4.2 persons per acre. This compares to a city-wide population density of approximately 3.0 persons per acre. The average impervious coverage across the TMDL area is 26%, which is a level high enough to result in significant measurable impacts to water quality (Schueler, 1994).

### **Existing Water Quality Conditions**

Nine water quality monitoring stations, sampled by various organizations, are located within the TMDL area. Monitoring data indicate that fecal coliform concentrations in streams reaches throughout the watershed are high by most measures. Based on data collected at these monitoring stations the following generalizations can be made about the observed bacteriological conditions in the upper North Buffalo Creek watershed:

- With only a few exceptions, the geometric means of the various datasets are consistently above 200 cfu/100mL - suggesting bacteriological contamination of the creek is occurring under a variety of runoff and seasonal conditions (200 cfu/100mL is the threshold fecal coliform concentration referenced in NC's water quality standard).
- The geometric mean of the various ambient (dry weather) datasets are also consistently above 200 cfu/100mL – suggesting non-stormwater driven sources are important contributors.
- Fecal coliform concentrations tend to be higher in the summer than at other times of the year, which is consistent with other general findings reported in the literature

(CWP, 1999). This is significant as recreational use of the waters tends to be highest during the warm summer months.

- Fecal coliform concentrations during storm periods are consistently higher than during ambient conditions – suggesting nonpoint sources of bacteria are also important contributors.

### **Fecal Coliform Source Assessment**

A detailed assessment of potential sources of fecal coliform loads within the watershed was performed as part of the TMDL development process. With stakeholder input, an effort was made to explicitly identify as many source types as was practical. While this approach is more costly in terms of time and effort, in the long run a detailed assessment will better support future implementation decisions. The following is a list of sources included in the TMDL:

- **Cone Mills WWTP** – permitted to discharge 1.25 MGD of treated industrial/domestic wastewater (facility no longer directly discharging to North Buffalo Creek).
- **Exfiltrating sanitary sewers** – loads from this source were simulated as a constant fecal coliform concentration in groundwater based on limited studies conducted in Mecklenburg County for a TMDL approved by EPA in 2002.
- **Failing septic systems** - 56 addresses within the TMDL area were identified as possibly using on-site wastewater treatment. Based on the collective experience of the TMDL stakeholders an estimated failure rate of 15% was applied for calculating loads from this source.
- **Illicit discharges from the stormwater conveyance system** – 66 illicit discharges were simulated in the TMDL based on field mapping data.
- **Pets** – 13,700 dogs and 15,300 cats are estimated to reside within the TMDL area.
- **Sewer System Overflows (SSOs)** – 131 SSOs were accounted for in the TMDL based on data maintained by the City of Greensboro.
- **Waterfowl** – loads from waterfowl populations in Lake Hamilton, the Bog Garden, and Buffalo Lake were included in the TMDL.
- **Other sources** – source category designated to account for sources not explicitly identifiable/quantifiable within the watershed, e.g. urban wildlife populations. Loads from these sources were quantified using model calibration procedures, and were assumed to be delivered to the stream via stormwater runoff.

### **Water Quality Modeling Platform**

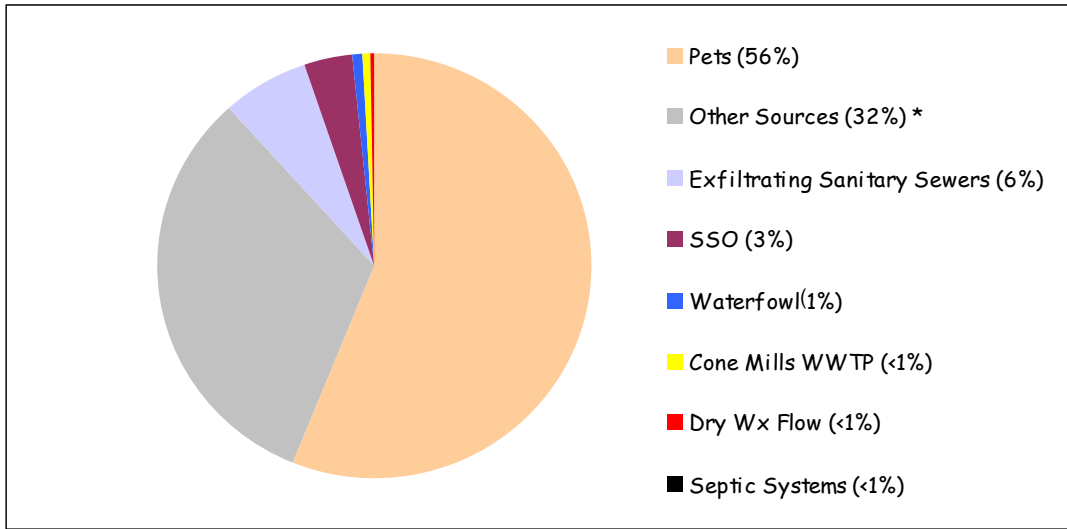
Water quality computer models are frequently used during TMDL development for establishing a relationship between instream water quality conditions and the contributing watershed. These models use mathematical equations to represent the important physical and chemical processes which affect the environment.

Hydrologic Simulation Program – Fortran (WinHSPF version 2.0.6) was chosen as the modeling platform for development of this TMDL. WinHSPF is a public domain watershed model maintained and distributed by the US EPA. WinHSPF is a continuous simulation, precipitation-driven model designed to calculate point and nonpoint source pollutant loadings, downstream transport, and instream pollutant decay. A model simulation period of 8/1/98 – 8/1/01 was chosen in order to take advantage of local precipitation and water quality data collected within the TMDL area for model calibration.

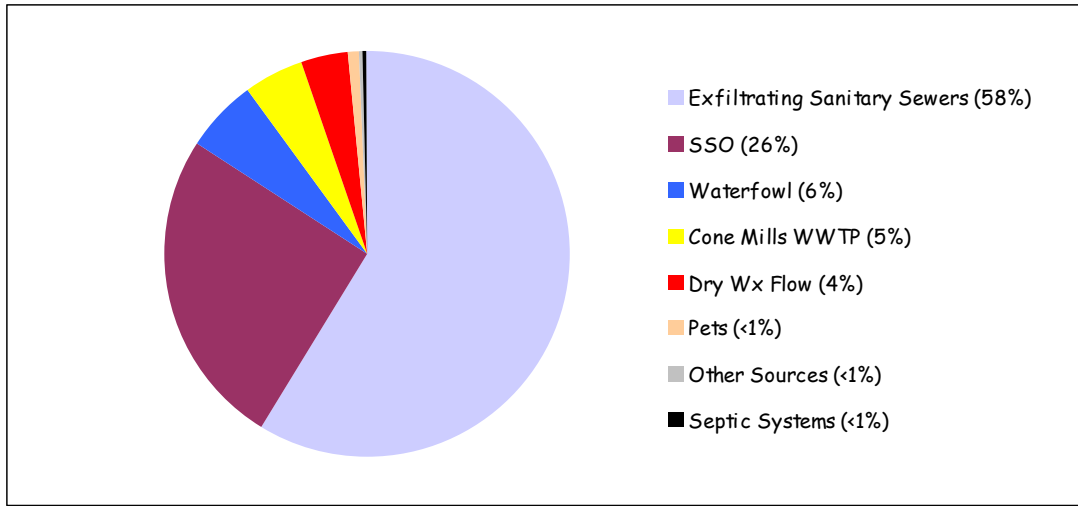
**Fecal Coliform Loads To Summit Avenue**

The calibrated WinHSPF model was used to assess the load contributions from the various sources delivered to the TMDL compliance point – Summit Avenue. The pie charts below illustrate the relative contributions under all weather conditions and dry weather conditions, respectively.

**Percentage of delivered load to Summit Avenue from each source category over the full simulation period (all weather conditions):**



\* When interpreting this pie chart it is important to keep in mind that *Other Sources* represent the load which could not reasonably be accounted for in the source assessment using the best available data. The *Other Sources* category could include, for instance, loads from unknown wildlife populations. However, contributions from *Other Sources* could also reflect an underestimation of the loads from one or more of the identified sources.

**Percentage of delivered load to Summit Avenue from each source category under dry weather conditions:**

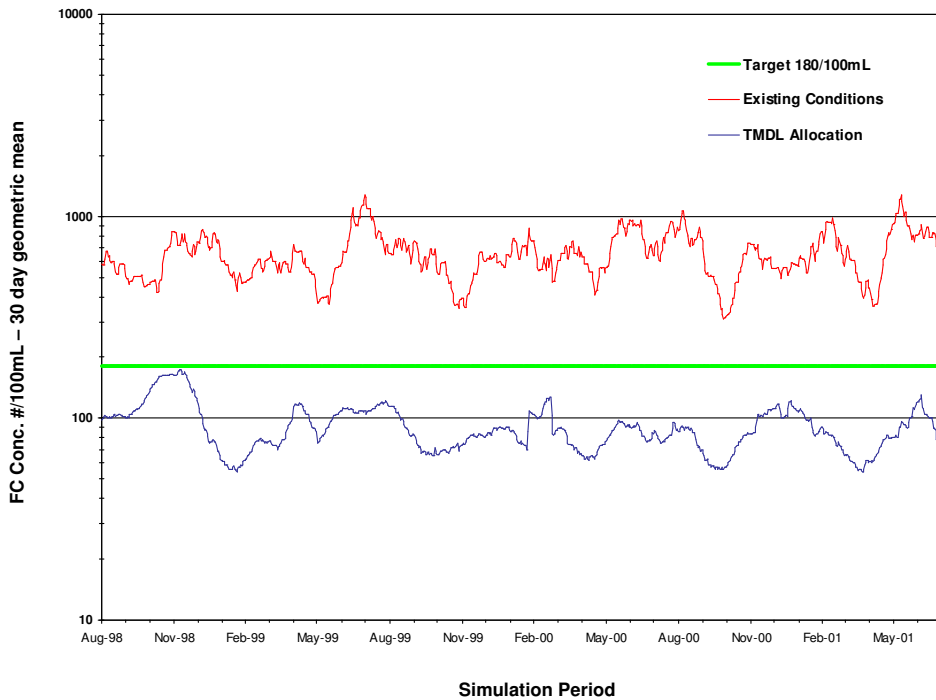
Note from the first pie chart that during the full simulation period (reflective of all weather conditions) stormwater related sources contribute the vast majority of the delivered load to Summit Avenue. During dry weather conditions, human sources of fecal coliform tend to comprise the majority of the delivered load.

**Total Maximum Daily Load**

A TMDL is the calculation of the maximum amount of pollutant loading that a receiving waterbody can assimilate while still achieving water quality targets. Per federal rules TMDLs must include a margin of safety which accounts for uncertainty in the analysis. As a means of meeting this requirement the water quality targets for both dry weather and all weather conditions were lowered from 200 cfu/100mL to 180 cfu/100mL.

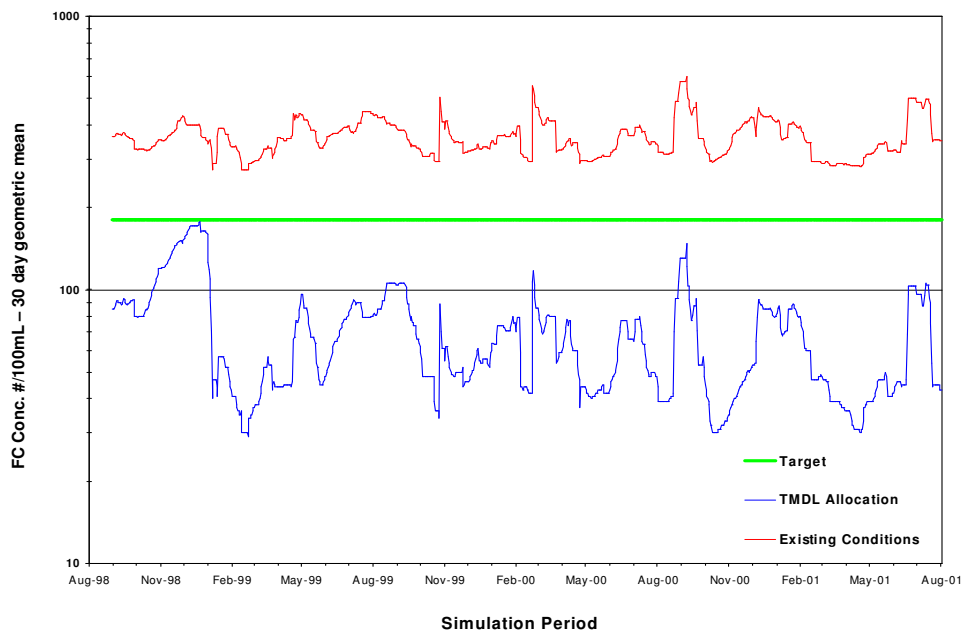
To calculate the TMDL, load reductions were taken from the calibrated model until all of the 30 day geometric means were below the target threshold of 180 cfu/100mL, which includes the explicit margin of safety. In addition, the model output was assessed to ensure that no more than 6 (20%) of the daily fecal coliform predictions were greater than 400 cfu/100mL, in accordance with the all conditions water quality target. The figure below illustrates the predicted rolling 30 day geometric mean fecal coliform concentration at Summit Avenue after load reductions were applied to the calibrated model.

**Predicted 30 day geometric mean fecal coliform concentration at Summit Avenue under all weather conditions. Geometric means for both existing conditions and under TMDL load reductions are shown:**



The following figure illustrates predicted geometric mean fecal coliform concentrations under dry weather conditions.

**Predicted “30 day” geometric mean fecal coliform concentration at Summit Avenue under dry weather conditions. Geometric means for both existing conditions and under dry weather TMDL load reductions are shown:**





The final stages of developing a TMDL involve making decisions about which sources should be reduced and by how much. In large measure these decisions are based on which sources are the major contributors, as well as which sources are controllable from a practical standpoint. To facilitate an adaptive management approach, as well as to logically partition the responsibility of implementation among management organizations, TMDLs typically group sources into allocation categories. These categories represent groups of sources which fall under common permitting or management frameworks.

The following two tables outline the allocation categories and the percent load reductions necessary to meet the TMDL requirements associated with the all weather conditions and dry weather conditions water quality targets. The distribution of individual sources among the categories are described in the footnotes, with additional detail presented in Part 4 of this report.

**Percent load reductions necessary to meet TMDL requirements associated with the all weather conditions water quality target.**

TMDL Allocation Category	TMDL % Reduction
MS4 <sup>1</sup>	96%
Nonpoint Sources <sup>2</sup>	93%
Cone Mills WWTP <sup>3</sup>	N/A

- 1 MS4 = Municipal Separate Storm Sewer System. This allocation category includes that portion of the load from pets, Other Sources, and the full load from illicit discharges, which are transported to the receiving stream via the NPDES permitted municipal stormwater conveyance system.
- 2 The nonpoint source TMDL allocation category includes that portion of the load from pets, Other Sources, and the full loads from exfiltrating sanitary sewers, SSOs, failing septic systems, and waterfowl which are transported to the receiving stream by means other than the MS4.
- 3 Since the Cone Mills WWTP is no longer discharging, a load reduction is not applicable for the purposes of this TMDL.

**Percent load reductions necessary to meet TMDL requirements associated with the dry weather conditions water quality target.**

TMDL Allocation Category	TMDL % Reduction
MS4	72%
Nonpoint Sources	70%
Cone Mills WWTP	N/A

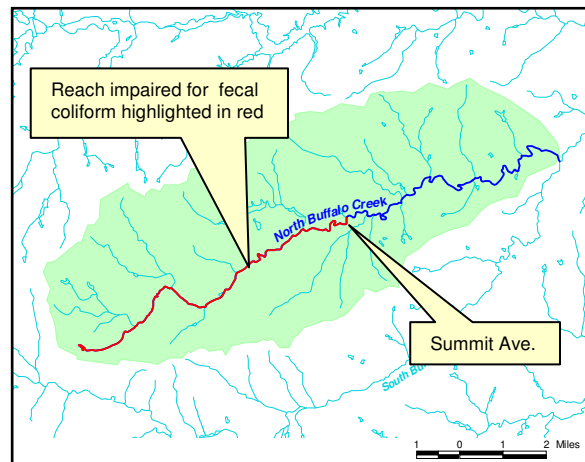
## 1.0 Introduction

### 1.1 BACKGROUND

The North Carolina Division of Water Quality (DWQ) has identified an 8.7 mile segment of North Buffalo Creek as impaired due to elevated fecal coliform concentrations (DWQ, 2003). The impaired segment extends from the stream's source to just above the North Buffalo wastewater treatment plant (WWTP) near Summit Avenue. Fecal coliform bacteria is a commonly used indicator test organism for detecting the possible presence of human pathogens in lakes, streams, and estuaries throughout NC.

DWQ has classified North Buffalo Creek as Class C waters (DWQ, 1985). In NC, waters with a primary classification of Class C are to be managed for the protection of secondary recreational uses such as swimming, wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental basis (DENR, 2003). The elevated levels of fecal coliform found in North Buffalo Creek during both wet and dry weather conditions suggest there may be an increased health risk to recreational and other users of the water resource from bodily contact with the stream.

Section 303(d) of the Clean Water Act (CWA) requires states to develop a list of waters not meeting water quality standards or which have impaired uses. This list, contained within Categories 4 through 7 of the Integrated Report, is submitted biennially to the US Environmental Protection Agency (EPA) for review. The 303(d) process requires that a Total Maximum Daily Load (TMDL) be developed for each of the waters appearing on Category 5 of the Integrated Report. The objective of a TMDL is to estimate the maximum amount of a pollutant (e.g. fecal coliform) that a waterbody can receive and still meet water quality standards, and to allocate that load among point and nonpoint sources (USEPA, 1991).



*North Buffalo Creek watershed. Approximately 8.7 miles of the upper North Buffalo Creek mainstream are listed in NC's 303(d) List due to elevated fecal coliform concentrations. Summit Avenue has been chosen as the TMDL compliance point.*

The City of Greensboro's Department of Water Resources has partnered with DWQ and interested local stakeholders to develop a TMDL for fecal coliform for the impaired segment of North Buffalo Creek. The TMDL is intended to serve as an important

management tool for guiding local implementation strategies designed to reduce loadings of potential human pathogens to the stream. Generally, the primary components of a TMDL, as identified by EPA (1991, 2000a) and the Federal Advisory Committee are as follows:

*Target Identification* or selection of pollutant(s) and endpoint(s) for consideration. An endpoint is an instream numeric target. The pollutant and endpoint are generally associated with measurable water quality related characteristics that indicate compliance with water quality standards. North Carolina indicates known problem pollutants on the 303(d) List.

*Source assessment.* Sources that contribute to the impairment should be identified and loads quantified, to the extent that that is possible.



North Buffalo Creek at Summit Avenue.

*Reduction target.* Estimation of the level of pollutant reduction needed to achieve the water quality goal. The level of pollution should be characterized for the waterbody, highlighting how current conditions deviate from the target endpoint. Generally, this component is identified through water quality modeling.

*Margin of safety.* The margin of safety addresses uncertainties associated with pollutant loads, modeling techniques, and data collection. Per EPA (2000a), the margin of safety may be expressed explicitly as unallocated assimilative capacity (portion of TMDL) or implicitly through conservative assumptions. The margin of safety should be included in the reduction target.

*Allocation of pollutant loads.* Allocating available pollutant load (TMDL), and hence pollutant control responsibility, to the sources of impairment. The wasteload allocation portion of the TMDL accounts for the loads associated with existing and future point sources. The load allocation portion of the TMDL accounts for the loads associated with existing and future nonpoint sources. Any future nonpoint source loading should remain within the TMDL that is calculated in this assessment; in other words, this TMDL does not leave allocation for future sources.

*Seasonal variation.* The TMDL should consider seasonal variation in the pollutant loads and endpoint. Variability can arise due to stream flows, temperatures, and exceptional events (e.g., droughts and hurricanes).

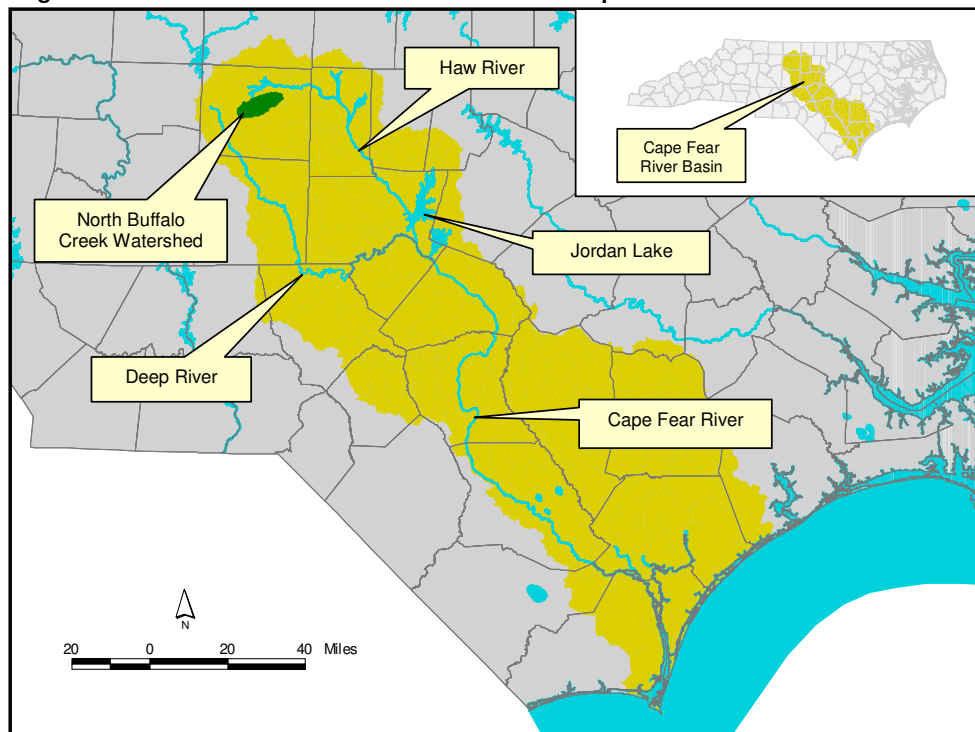
*Critical conditions.* Critical conditions occur when fecal coliform levels exceed the standard by the largest amount. If the modeled load reduction is able to meet the standard during critical conditions, then it should meet the standard at all, or nearly all, times.

The North Buffalo Creek TMDL establishes two instream water quality targets and defines a watershed “*compliance point*” along the mainstem at Summit Avenue. The targets are designed to be consistent with the State’s water quality standard for fecal coliform and provide general guidance for a future implementation plan. Section 303(d) of the CWA and the Water Quality Planning and Management regulation (USEPA, 2000a) require EPA to review all TMDLs for approval or disapproval. Once EPA approves the TMDL, then North Buffalo Creek may be moved to Category 4a of the 2002 Integrated Report. North Buffalo Creek will remain on Category 4a until compliance with water quality standards is achieved. Note that the entire length of North Buffalo Creek, from its source to the confluence with South Buffalo Creek, is also listed in the Integrated Report as being biologically impaired. This TMDL does not explicitly address this issue as the causal agents of the biological impairment have not yet been identified.

## 1.2 WATERSHED DESCRIPTION

The North Buffalo Creek watershed is located in the headwaters of the Cape Fear River Basin in Guilford County (Figure 1.2.1). North Buffalo Creek, just above its confluence with South Buffalo Creek, has a drainage area of approximately 44 mi<sup>2</sup>. Drainage from the North Buffalo Creek watershed generally flows in an easterly direction and ultimately feeds the Haw River above Jordan Lake.

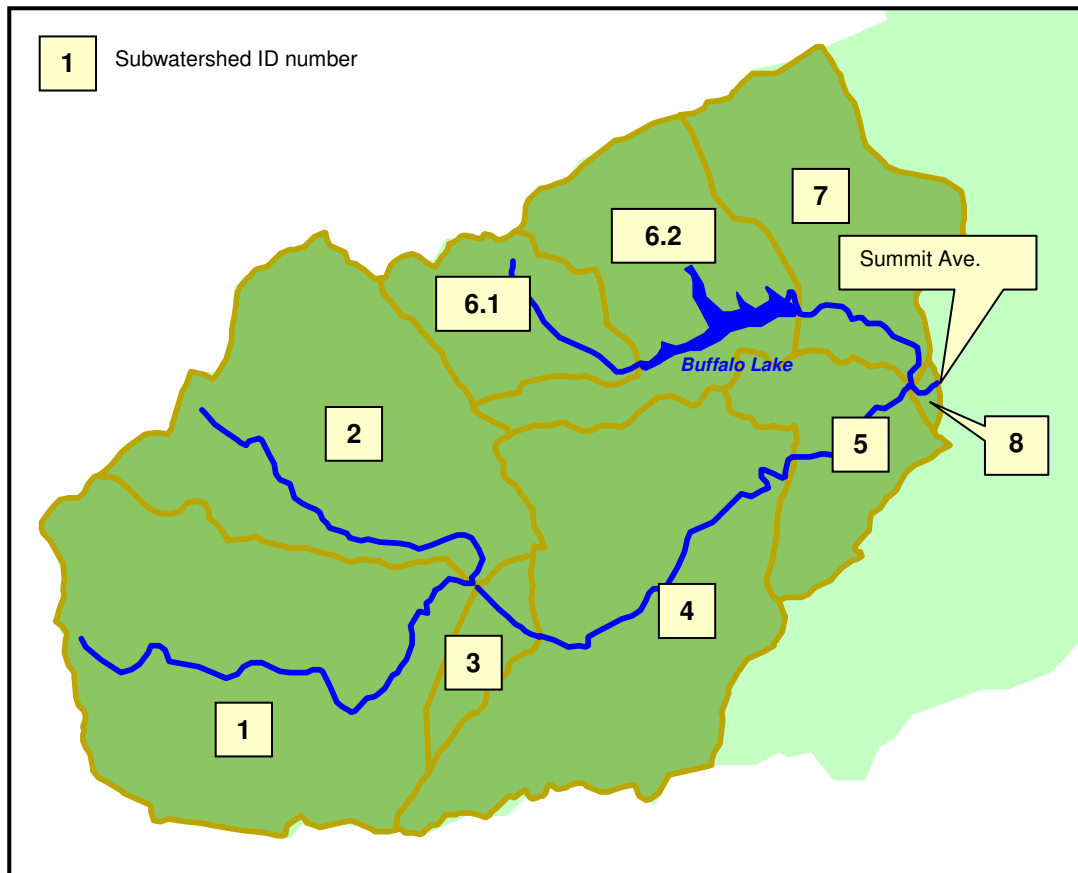
Figure 1.2.1 North Buffalo Creek watershed in the Cape Fear River Basin.



### 1.3 SUBWATERSHEDS

This TMDL addresses fecal coliform impairment in the upper half of the North Buffalo Creek watershed as outlined in NC's 2002 303(d) List. For management and modeling purposes the upper watershed was delineated into nine subwatersheds (Figure 1.3.1). Delineation of these subwatersheds was based on hydrologic considerations, land use/land cover patterns, and the locations of stream flow and water quality monitoring stations for model calibration/confirmation. The upper watershed defined for this TMDL, which has a drainage area of 21.8 mi<sup>2</sup>, is wholly within the city limits of Greensboro. Table 1.3.1 summarizes total contributing and individual drainage areas for each subwatershed.

Figure 1.3.1 Upper North Buffalo Creek watershed and modeled subwatersheds.



**Table 1.3.1 Drainage area (DA) summary for the TMDL subwatersheds.**

Subwatershed	Subwatershed DA (sq. mi)	Total Contributing DA to the Subwatershed Outlet (sq. mi) <sup>1</sup>
1	5.1	5.1
2	4.0	4.0
3	0.5	9.6
4	4.7	14.3
5	1.4	15.7
6.1 <sup>2</sup>	1.3	1.3
6.2 <sup>2</sup>	2.5	3.8
7	2.3	6.1
8	0.05	21.8

- 1 Example: the cumulative drainage area to the outlet of subwatershed 3 equals the drainage areas of subwatersheds 1, 2, and 3 (5.1+4.0+0.5=9.6).
- 2 Subwatershed 6 drains to the largest open waterbody in the watershed – Buffalo Lake. The upper subwatershed (6.1) drains to the head of the lake and subwatershed 6.2 drains directly into the lake.

## 1.4 POPULATION ESTIMATES

Approximately 26% of Greensboro's total population (223,891 as per 2000 US census) lives in the upper North Buffalo Creek watershed. Population density in the upper watershed averages 4.2 persons/ac. Subwatersheds 3 and 4 have the densest populations as well as some of the oldest residential developments. Table 1.4.1 summarizes the 2000 population by subwatershed based on US census block data.

**Table 1.4.1 Summary of 2000 population in the upper North Buffalo Creek watershed.**

Subwatershed	2000 Population Estimate	2000 Density (persons/ac)
1	13,123	4.0
2	8,886	3.5
3	1,532	4.6
4	16,117	5.3
5	3,058	3.4
6.1	3,515	4.2
6.2	6,439	4.1
7	6,353	4.3
8	0	0.0
	<b>Total = 59,023</b>	<b>Average density = 4.2</b>

## 1.5 EXISTING LAND USE / LAND COVER

In 2002 the City of Greensboro completed a city-wide GIS land use/land cover (LULC) characterization project. A hybrid land use/land cover classification system comprised of 33 categories was devised to specifically support a variety of water resources management and planning initiatives. The LULC GIS database was built from 2000 orthophotography, parcel and zoning data, as well as numerous additional planimetric data sources. For modeling and reporting purposes the LULC categories were condensed into 9 broader categories. Table 1.5.1 summarizes the LULC categories used to support the TMDL.

**Table 1.5.1 Land use/land cover categories used for TMDL modeling.**

LULC Category	Description
Dwntwn	Downtown area - Includes a specific densely developed, multi-use area near the center of the city.
HERB	Managed herbaceous – Cemeteries, lawns (>1 ac), open parks, golf courses, and athletic fields.
ICO	Industrial/Commercial/Office – includes low, medium, and high density industrial, commercial, and office properties greater than 1 acre.
INST	Institutional – includes schools, university/colleges, churches, and government uses.
MF	Multi-family residential – includes apartments, condominiums, and townhomes.
RES	Single family residential – includes all single family detached homes. Also includes duplexes.
ROW	Right-of-way – includes all roadways and adjacent right-of-way on either side of the road.
WATER	Open waterbodies – includes lakes and ponds with a surface area greater than 1 acre.
WOODS	Wooded and natural areas – includes areas greater than 1 acre where tree cover predominates (>75%). Also includes 1 acre or greater areas with a mix of trees and grass/herbaceous vegetation/low-growing brush.

Table 1.5.2 and 1.5.3 summarizes the area and percent coverage of each LULC type, respectively. **On average the upper North Buffalo Creek watershed is dominated by single family residential land uses** as illustrated in the Figure 1.5.1. Roadways and industrial/commercial/office properties are the second and third most prominent developed land uses, respectively. On average, wooded areas cover slightly less than 20% of the upper watershed.

**Table 1.5.2 Summary of 2000 land use/land cover area. Values rounded to the nearest acre. Area in square miles presented in parenthesis.**

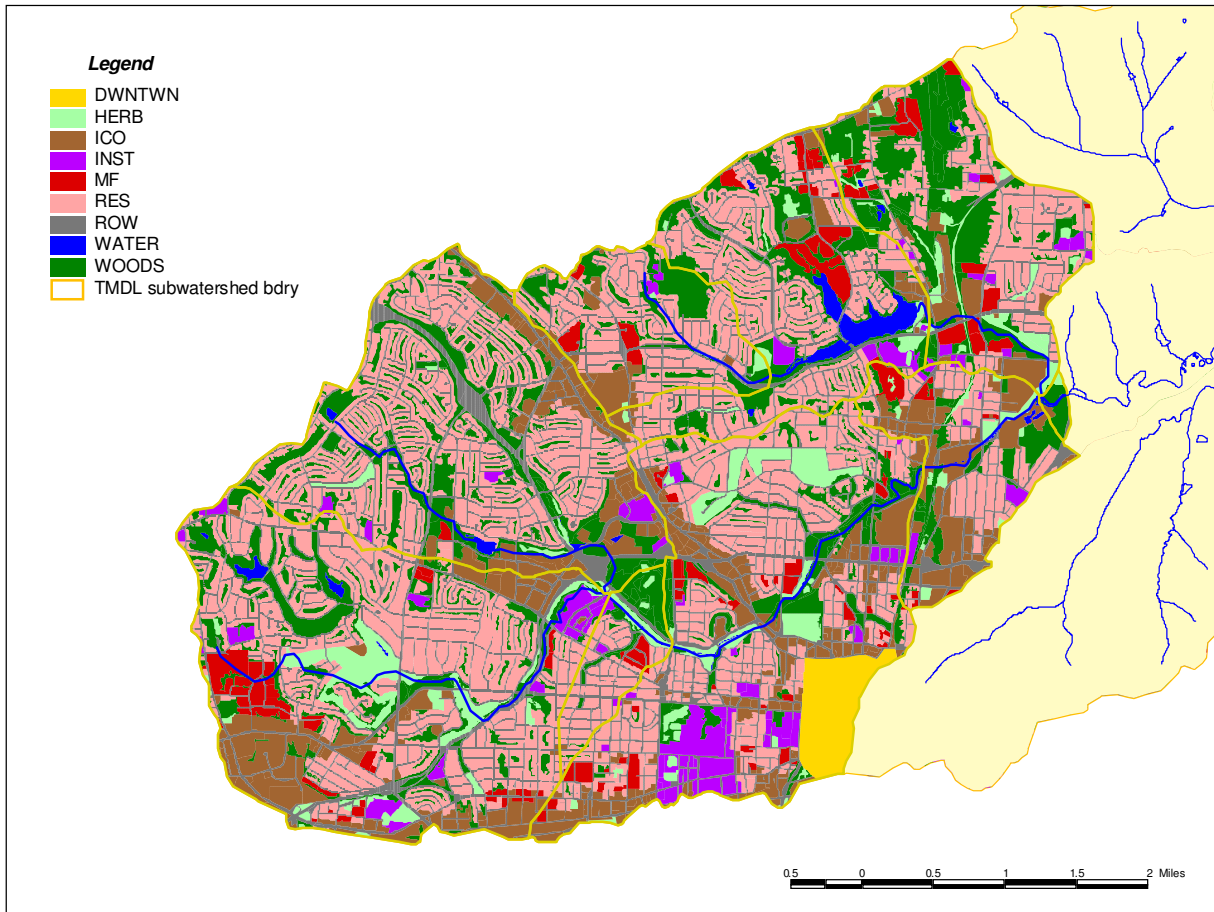
Subwater-shed	Dwntwn	HERB	ICO	INST	MF	RES	ROW	WATER	WOODS	Totals
1	0 (0)	228 (0.36)	452 (0.71)	104 (0.16)	155 (0.24)	1,288 (2.01)	497 (0.78)	19 (0.03)	521 (0.81)	<b>3,263</b> (5.10)
2	0 (0)	29 (0.05)	288 (0.45)	38 (0.06)	6 (0.01)	1,110 (1.73)	438 (0.68)	14 (0.02)	613 (0.96)	<b>2,536</b> (3.96)
3	0 (0)	23 (0.04)	1 (0.00)	7 (0.01)	16 (0.03)	146 (0.23)	57 (0.09)	2 (0.00)	80 (0.13)	<b>331</b> (0.52)
4	215 (0.34)	205 (0.32)	445 (0.70)	218 (0.34)	119 (0.19)	967 (1.51)	506 (0.79)	6 (0.01)	338 (0.53)	<b>3,019</b> (4.72)
5	0 (0)	40 (0.06)	287 (0.45)	25 (0.04)	37 (0.06)	223 (0.35)	139 (0.22)	7 (0.01)	134 (0.21)	<b>892</b> (1.39)
6.1	0 (0)	10 (0.02)	79 (0.12)	7 (0.01)	35 (0.05)	396 (0.62)	114 (0.18)	0 (0)	191 (0.30)	<b>832</b> (1.30)
6.2	0 (0)	40 (0.06)	67 (0.10)	42 (0.07)	104 (0.16)	684 (1.07)	209 (0.33)	95 (0.15)	342 (0.53)	<b>1,583</b> (2.47)
7	0 (0)	93 (0.15)	141 (0.22)	40 (0.06)	108 (0.17)	438 (0.68)	139 (0.22)	5 (0.01)	526 (0.82)	<b>1,490</b> (2.33)
8	0 (0)	3 (0.00)	3 (0.00)	0 (0)	0 (0)	0 (0)	3 (0.00)	2 (0.00)	26 (0.04)	<b>37</b> (0.06)
<b>Totals</b>	<b>215</b> (0.34)	<b>671</b> (1.05)	<b>1,764</b> (2.76)	<b>482</b> (0.75)	<b>578</b> (0.90)	<b>5,250</b> (8.20)	<b>2,102</b> (3.28)	<b>150</b> (0.23)	<b>2,771</b> (4.33)	<b>13,984</b> (21.85)

**Table 1.5.3 Percent coverage of each land use/land cover type.**

Subwater-shed	Dwntwn	HERB	ICO	INST	MF	RES	ROW	WATER	WOODS	Totals
1	0.0%	7.0%	13.9%	3.2%	4.7%	39.5%	15.2%	0.6%	16.0%	<b>100%</b>
2	0.0%	1.1%	11.4%	1.5%	0.2%	43.8%	17.3%	0.5%	24.2%	<b>100%</b>
3	0.0%	6.8%	0.3%	2.2%	4.9%	44.0%	17.1%	0.6%	24.1%	<b>100%</b>
4	7.1%	6.8%	14.7%	7.2%	3.9%	32.0%	16.8%	0.2%	11.2%	<b>100%</b>
5	0.0%	4.5%	32.2%	2.8%	4.1%	25.0%	15.6%	0.7%	15.1%	<b>100%</b>
6.1	0.0%	1.2%	9.5%	0.9%	4.2%	47.5%	13.7%	0.0%	23.0%	<b>100%</b>
6.2	0.0%	2.5%	4.2%	2.6%	6.6%	43.2%	13.2%	6.0%	21.6%	<b>100%</b>
7	0.0%	6.2%	9.5%	2.7%	7.2%	29.4%	9.4%	0.4%	35.3%	<b>100%</b>
8	0.0%	8.6%	8.3%	0.0%	0.0%	0.0%	8.6%	4.3%	70.3%	<b>100%</b>
<b>Totals</b>	<b>1.5%</b>	<b>4.8%</b>	<b>12.6%</b>	<b>3.4%</b>	<b>4.1%</b>	<b>37.5%</b>	<b>15.0%</b>	<b>1.1%</b>	<b>19.8%</b>	<b>100%</b>



Figure 1.5.1 Land use/land cover within the TMDL subwatersheds (2000).

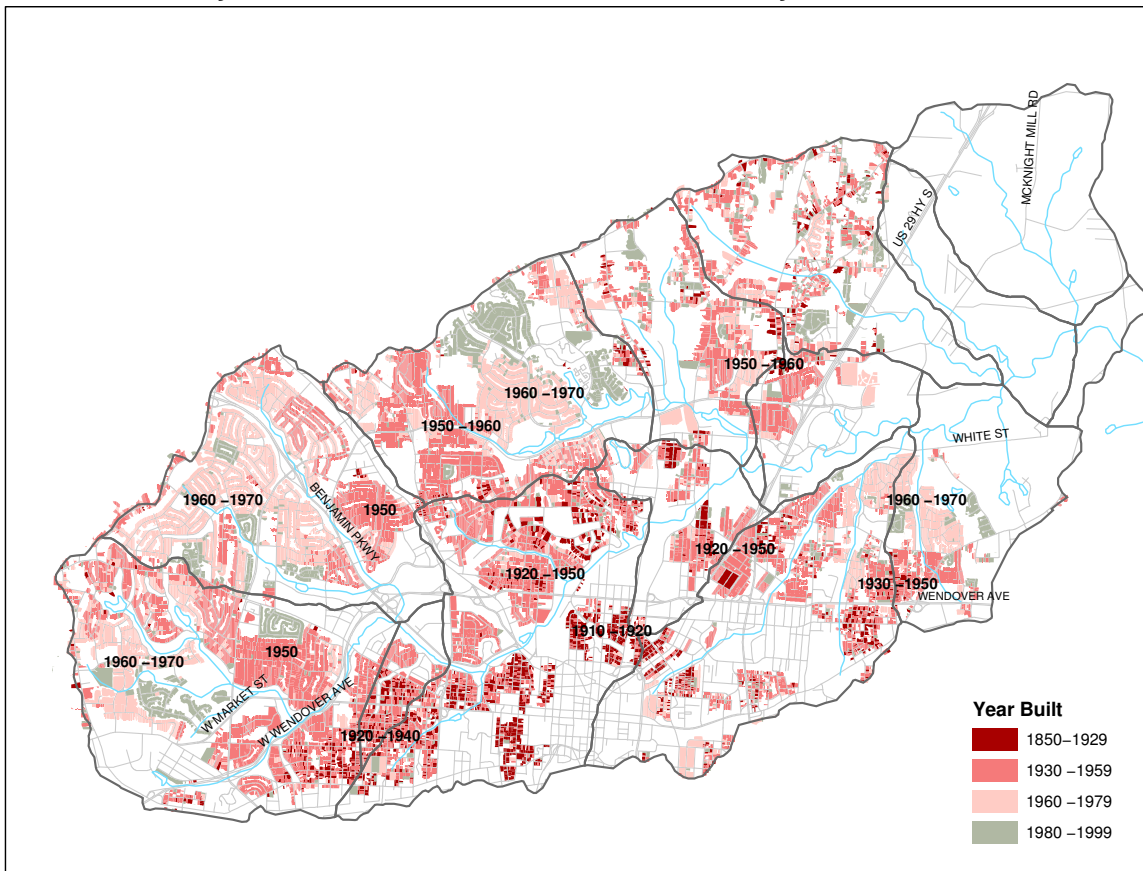


## 1.6 AGE OF RESIDENTIAL DEVELOPMENT

Given the predominance of residential land uses in the upper North Buffalo Creek watershed (average >41% combined single and multi-family), it is useful to examine the age of these developments as a prelude to the fecal coliform source assessment. The age of residential development, as determined using parcel records, can provide some insight into the possible age (and condition) of the stormwater and sanitary sewer infrastructure systems. Older drainage and sanitary sewer systems, particularly those constructed using clay pipe, as was common in NC pre-1970s, may be more subject to varying degrees of deterioration. In particular, deteriorating sanitary sewer lines can be a significant source of fecal coliform loading to a watershed.

It is important to note however that older residential subdivisions do not necessarily equate to areas of high fecal coliform loads, particularly where systems have been well maintained. However, these data do provide useful information for targeting follow-up investigations to the TMDL. Figure 1.6.1 illustrates the age of residential development in the upper watershed.

**Figure 1.6.1 Age of residential development in the upper North Buffalo Creek watershed. Only residential areas within the Greensboro city limits are shown.**



## 1.7 IMPERVIOUS SURFACES

Impervious surfaces, such as rooftops and parking lots, prevent rainfall from infiltrating into the ground. The result is an increase in runoff volumes, instream peak flows, and pollutant loads delivered to a receiving stream. Given the importance of impervious surfaces in the field of water resources management, the City of Greensboro has invested in the development of a comprehensive city-wide GIS database of impervious surfaces. This GIS database includes polygon representations of road surfaces, railroad beds, parking lots, driveways, rooftops (including residential out buildings), swimming pools, storage tanks, along with other impervious feature types.

Table 1.7.1 summarizes the results of a GIS analysis undertaken to estimate the average impervious surface coverage for each LULC type used in this TMDL. Table 1.7.2 outlines the percentage of impervious cover in each subwatershed.

**Table 1.7.1 Average impervious surface coverage for each LULC type.**

LULC	Average % Impervious Cover
DWNTWN	66%
HERB	0%
ICO	57%
INST	43%
MF	36%
RES	15%
ROW	63%
WATER	0%
WOODS	0%

**Table 1.7.2 Average impervious surface coverage in each subwatershed.**

Subwatershed	% Impervious Cover
1	26%
2	25%
3	20%
4	33%
5	35%
6.1	23%
6.2	21%
7	19%
8	10%
TMDL area average	26%

## 1.8 MONITORING STATIONS

Within the TMDL subwatersheds there are ten fecal coliform monitoring stations and two USGS stream flow and precipitation gaging stations. The City of Greensboro's Stormwater Management Division has four ambient (dry weather) stations at which fecal coliform samples are collected. Other physical/chemical water quality parameters are also monitored at these stations. The Aycock Street station also serves as a storm monitoring station for fecal coliform and other water quality parameters.

In 2001 the Piedmont Triad Council of Governments initiated a special study which included five sampling stations within the TMDL subwatersheds, in addition to stations in other watersheds within the Triad region of NC (PTCOG, 2003). A central objective of the study is to examine instream fecal coliform concentrations during dry weather conditions.

The USGS, with financial support from the Greensboro Department of Water Resources, operates two stream flow and precipitation gaging stations within the TMDL subwatersheds. The Westover Terrace station (02095181) on North Buffalo Creek began recording daily stream flow in June 1999. The Church Street station (02095271), also on North Buffalo Creek, began recording in August 1998. Table 1.8.1 and Figure 1.8.1 provide additional information on the monitoring stations located within the TMDL subwatersheds.

**Table 1.8.1 Monitoring stations within the TMDL subwatersheds.**

Map ID	Subwater-shed	Location	Stream	Agency <sup>1</sup>	Ambient <sup>2</sup>	Storm <sup>3</sup>	Flow <sup>4</sup>	PPT <sup>5</sup>
A	1	Market St.	N. Buffalo	PTCOG	✓			
B	1	Arboretum/ Lindley Park	N. Buffalo	SMD	✓			
C	Head of 3	Elam St.	N. Buffalo	PTCOG	✓			
D	Outlet of 3	Aycock/Westover Terrace	N. Buffalo	USGS			✓	✓
E	Outlet of 3	Aycock/Westover Terrace	N. Buffalo	SMD	✓	✓		
F	4	Garland Ave.	N. Buffalo	PTCOG	✓			
G	4	Cridland Ave.	N. Buffalo	PTCOG	✓			
H	Outlet of 4	Church St.	N. Buffalo	USGS			✓	✓
I	Outlet of 4	Church St.	N. Buffalo	SMD	✓			
J	Outlet of 4	Church St.	N. Buffalo	PTCOG	✓			
K	7	16 <sup>th</sup> St.	UT to N. Buffalo	SMD	✓			
L	Outlet of 8	Summit Ave.	N. Buffalo	Cone Mills WWTP	✓	✓		

1 PTCOG = Piedmont Triad Council of Governments; SMD = City of Greensboro Stormwater Management Division; USGS = US Geological Survey; Cone Mills WWTP = instream sampling station downstream of discharge.

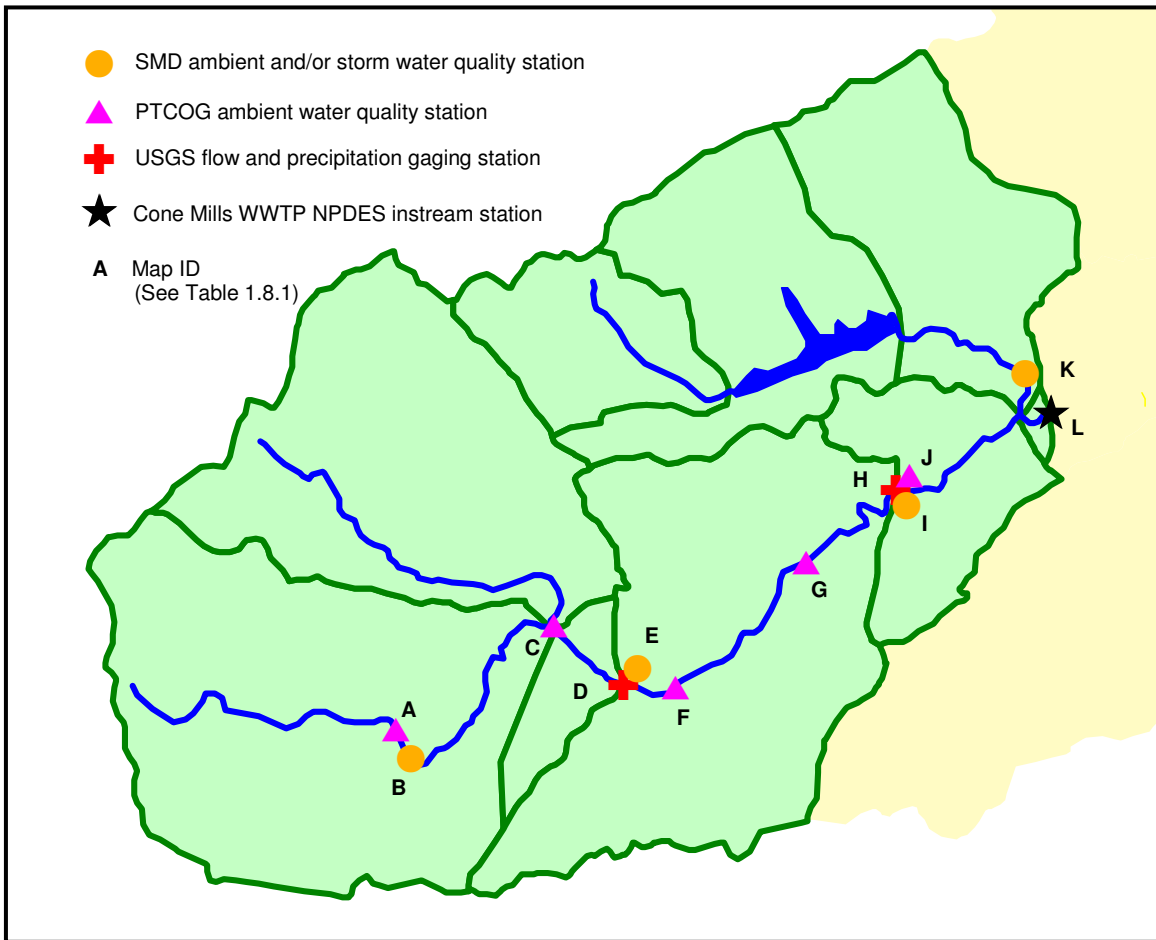
2 Ambient (dry weather) sampling refers to instream water quality data collected 72 or more hours after a rainfall event.

3 Storm sampling refers to instream water quality data collected within 72 hours of a rainfall event.

4 Flow = Stream flow

5 PPT = Precipitation (rainfall)

**Figure 1.8.1 Monitoring stations within the TMDL subwatersheds.**



**1.9 OBSERVED INSTREAM FECAL COLIFORM DATA**

The nine different sampling locations within the TMDL subwatersheds provides a reasonably good picture of bacteriological water quality – particularly during dry weather conditions when recreational use of the resource is highest. Generally speaking fecal coliform concentrations at all of the stations are elevated with geometric means of the observed datasets tending to be over the 200 cfu/100mL threshold referenced in NC’s bacteriological water quality standard for Class C waters.

Below is a summary of the instream fecal coliform data collected by the three agencies, SMD, PTCOG, and Cone Mills WWTP, which sample within the TMDL subwatersheds. Each agency has appropriate quality control procedures in place and uses a State certified laboratory to process the samples.

Greensboro’s Stormwater Management Division Fecal Coliform Data

SMD samples at 4 locations within the TMDL subwatersheds (see Figure 1.8.1). All stations are ambient monitoring locations with the exception of the Aycock Street station from which storm (runoff event) samples are also collected. Table 1.9.1 provides a summary of fecal coliform data collected at each of the SMD monitoring locations. Appendix 1 includes a listing of the complete dataset with sampling dates and individual results.

**Table 1.9.1 Summary of ambient (dry weather) fecal coliform data collected by Greensboro’s Stormwater Management Division.<sup>1</sup>**

Map ID <sup>2</sup>	Station	Geometric Mean Of Ambient Dataset	Geometric Mean Of Summer Ambient Dataset <sup>3</sup>	Geometric Mean Of Non-Summer Ambient Dataset <sup>3</sup>	Total Number of Samples
B	Arboretum	1,161	2,626	788	28
E	Aycock St.	433	1,124	211	14
I	Church St.	306	630	178	14
K	16 <sup>th</sup> St.	309	542	203	14

- 1 Ambient samples are collected 72 or more hours after the last measurable rainfall event. All stations were sampled during the period 7/22/99 – 9/18/01 with the exception of the Arboretum station which was sampled 7/9/96 – 4/14/99. Geometric means expressed in units of #/100mL.
- 2 See Figure 1.8.1 for a map of station locations.
- 3 Summer dataset is defined as those samples collected during the months of June through October. Non-summer is defined as November through May.

**Table 1.9.2 Summary of storm fecal coliform data collected by Greensboro’s Stormwater Management Division at the Aycock Street station.<sup>1</sup>**

Station	Geometric Mean Of Storm Dataset	Geometric Mean Of Summer Storm Dataset <sup>2</sup>	Geometric Mean Of Non-summer Storm Dataset <sup>2</sup>	Geometric Mean Of Ambient & Storm Dataset	Geometric Mean Of Summer Ambient & Storm Dataset	Geometric Mean Of Non-summer Ambient & Storm Dataset	Number of Samples
Aycock St.	4,586	11,303	2,921	1,090	2,427	652	9 storm 14 ambient

- 1 Storm samples are typically collected during or shortly after (within 24 hours) rainfall events. Geometric means expressed in units of #/100mL. Samples collected during the period 7/22/99 – 9/18/01.
- 2 Summer dataset is defined as those samples collected during the months of June through October. Non-summer is defined as November through May

Piedmont Triad Council of Governments Fecal Coliform Data

PTCOG sampled 5 stations along the North Buffalo Creek mainstem within the TMDL subwatersheds as part of a special study conducted in Greensboro and High Point, NC (PTCOG, 2003). All samples summarized herein were collected at ambient conditions during the period 6/11/01 – 10/30/01, with the exception of the Elam Street station which was sampled during 6/5/01 – 10/30/01. Table 1.9.3 summarizes the PTCOG instream fecal coliform data. Appendix 1 includes a listing of the complete dataset with sampling dates and individual results.

**Table 1.9.3 Summary of ambient (dry weather) fecal coliform data collected by the Piedmont Triad Council of Governments.**<sup>1</sup>

Map ID <sup>2</sup>	Station	Geometric Mean Of Ambient Dataset	Geometric Mean Of Ambient Summer Dataset <sup>3</sup>	Geometric Mean Of Ambient Non-summer Dataset <sup>3</sup>	Total Number of Samples
A	Market St.	683	822	454	16
C	Elam St.	409	518	172	14
F	Garland Ave.	852	1,006	462	14
G	Cridland Ave.	470	610	197	13
J	Church St.	309	348	206	13

<sup>1</sup> Ambient samples are collected 72 or more hours after the last measurable rainfall event. Geometric means expressed in units of #/100mL.

<sup>2</sup> See Figure 1.8.1 for a map of station locations.

<sup>3</sup> Summer dataset is defined as those samples collected during the months of June through October. Non-summer is defined as November through May

### Cone Mills WWTP Instream Fecal Coliform Data

As a condition of the Cone Mill NPDES wastewater discharge permit (NC0000876) the facility is required to conduct instream sampling for fecal coliform and other water quality parameters at Summit Avenue.<sup>†</sup> Table 1.9.4 summarizes 300 fecal coliform samples collected during the period 8/3/1998 – 11/24/2000 as reported in the facility's discharge monitoring reports (DMRs). Appendix 1 includes a listing of the complete dataset with sampling dates and individual results.

**Table 1.9.4 Summary of instream fecal coliform data collected at Summit Avenue by Cone Mills WWTP.**<sup>1</sup>

Map ID <sup>2</sup>	Station	Geometric Mean Of Complete Dataset	Geometric Mean Of Ambient Samples <sup>3</sup>	Geometric Mean Of Storm Samples <sup>3</sup>	Geometric Mean Of Summer Dataset <sup>4</sup>	Geometric Mean Of Non-summer Dataset <sup>4</sup>	Total Number Of Samples
L	Summit Ave.	429	206	680	619	300	300

<sup>1</sup> Geometric means expressed in units of #/100mL.

<sup>2</sup> See Figure 1.8.1 for a map of station locations.

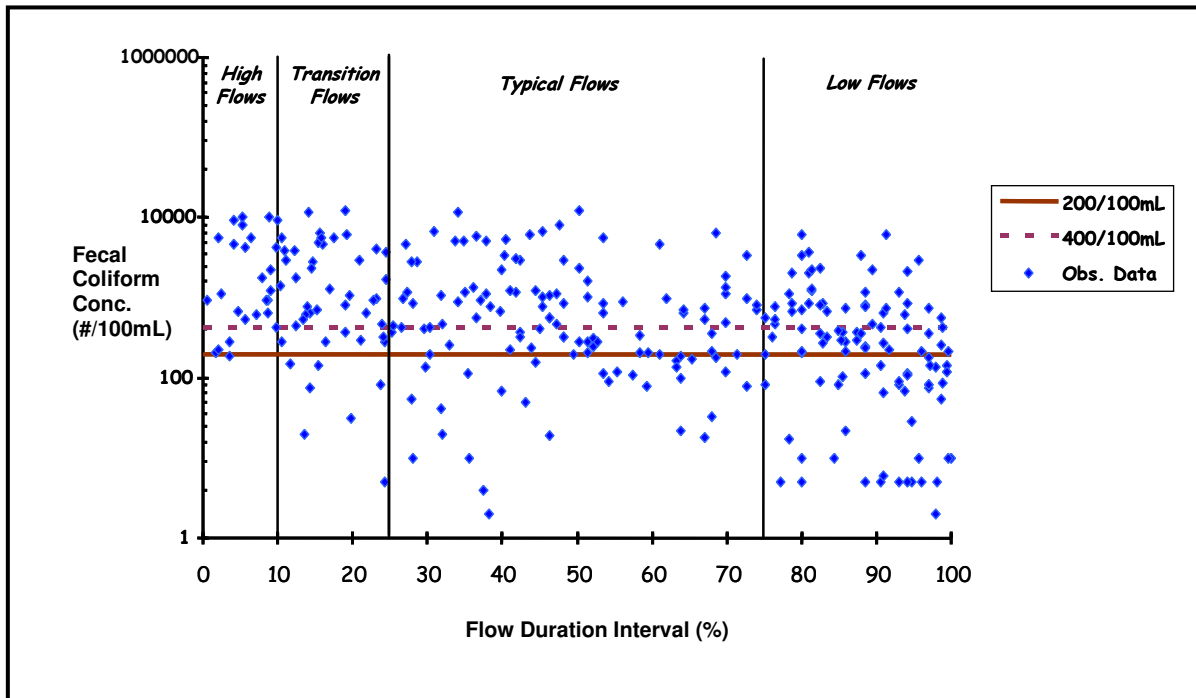
<sup>3</sup> Cone Mills was not required by permit to parse their sampling into ambient and storm sampling periods. However, for the purposes of this TMDL the complete dataset was segregated into samples collected during dry weather periods (ambient) and samples collected during or soon after a rainfall event. Precipitation data collected at the USGS gaging stations at Westover Terrace and Church Street were used to identify dates in which the cumulative daily rainfall total was 0.1" or more. Instream samples collected within 72 hours of these rain event days were classified as storm samples. All others were considered ambient samples.

<sup>4</sup> Summer dataset is defined as those samples collected during the months of June through October. Non-summer is defined as November through May.

<sup>†</sup> During the TMDL simulation period (August 1998 – August 2001) Cone Mills was permitted to discharge 1.25 MGD of treated industrial/domestic wastewater into North Buffalo Creek approximately 0.2 miles upstream of Summit Avenue. During the summer of 2001 Cone Mills began diverting its discharge to the City of Greensboro's North Buffalo Creek WWTP for treatment and ultimate discharge below Summit Ave.

Figure 1.9.1 illustrates the observed fecal coliform concentrations at Summit Avenue over four stream flow regimes.<sup>†</sup> The x-axis is analogous to the percent chance of exceedance for a given flow. For example, data points in line with the 50% flow duration interval represent fecal coliform concentrations collected during predicted median flow.

**Figure 1.9.1 Observed fecal coliform concentrations at Summit Avenue distributed by predicted stream flow.<sup>1</sup>**



<sup>1</sup> High flows: 559 (modeled peak) – 70 cfs; Transition flows: 69 – 22 cfs; Typical flows: 21 - 10 cfs; Low flows: 9 – 3.4 (modeled low) cfs

The following is a summary of findings derived from Figure 1.9.1. The data summary is not a direct comparison to the NC fecal coliform standard. Rather, it is intended to be a general characterization of bacteriological water quality over a snap shot in time. The 200/100mL and 400/100mL values presented in the first six bullets are referenced against grab sample results and not geometric means.

- 72% of all the samples are above 200/100mL
- 55% of all the samples are above 400/100mL
- 62% of samples collected during low flow conditions exceed 200/100mL
- 72% of samples collected during typical flow conditions exceed 200/100mL
- 85% of samples collected during transition flow conditions exceed 200/100mL
- 96% of samples collected during high flow conditions exceed 200/100mL
- Geometric mean of samples collected during high flows = 1,465/100mL
- Geometric mean of samples collected during transition flows = 942/100mL
- Geometric mean of samples collected during typical flows = 479/100mL
- Geometric mean of samples collected during low flows = 209/100mL

<sup>†</sup> There is no stream flow gaging station at Summit Avenue. Hence, predicted flows from the model were used in this analysis.



- Over all flow regimes, except *high*, the range of observed concentrations (highest and lowest values) is relatively consistent.

Exceedances of the 200/100mL threshold value occur over the full range of flows, but generally occur at higher percentages as flows increase. Given that elevated fecal coliform concentrations occur over the full spectrum of flow conditions, both stormwater and non-stormwater driven sources need to be considered in the TMDL.

#### General Findings Applicable To Each Sampling Station

Based on a review of the data presented in Tables 1.9.1 through 1.9.4 the following generalizations can be made about the observed bacteriological conditions in the upper North Buffalo Creek watershed. Note that these generalizations are not intended to be a formal evaluation of secondary recreational use support.

- With only a few exceptions, the geometric means of the various datasets are consistently above 200 cfu/100mL - suggesting bacteriological contamination of the creek is occurring under a variety of runoff and seasonal conditions.
- The geometric mean of the various ambient (dry weather) datasets are also consistently above 200 cfu/100mL – suggesting non-stormwater driven sources are important contributors.
- Fecal coliform concentrations tend to be higher in the summer than at other times of the year which is consistent with other general findings reported in the literature (CWP, 1999). This is significant as recreational use of the waters tends to be highest during the warm summer months.
- Fecal coliform concentrations during storm periods are consistently higher than during ambient conditions – suggesting nonpoint sources of bacteria are also important contributors.

## 2.0 Source Assessment

One of the key elements of a TMDL analysis is the identification of sources of fecal coliform throughout a watershed, and the estimate of the amount of pollutant loading contributed by each source. Potential sources of fecal coliform are numerous, widely distributed spatially, and often occur in combination. In addition, different sources translate into varying degrees of risk to recreational users of the water resource. However, it is generally recognized that human sources of fecal coliform pose the greatest health risks (CWP, 1999).

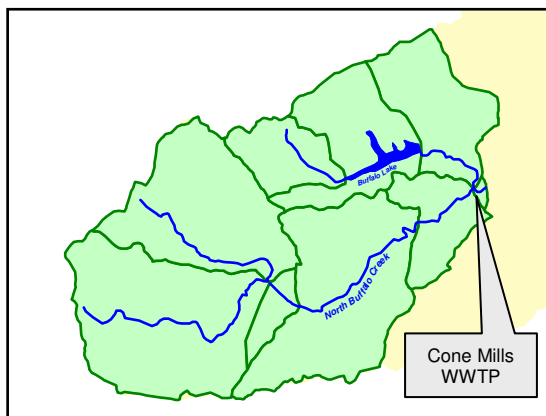
Sources of fecal coliform loads can be assigned to two broad classes: point source loads and nonpoint source loads. Point sources of fecal coliform are characterized as those which enter a water body from discrete, often identifiable locations such as pipes. Nonpoint sources of fecal coliform are diffuse sources often not entering a water body at discrete, fixed locations. Nonpoint source loads tend to be variable in time and space, making them particularly challenging to quantify.

Working with the project stakeholders eight fecal coliform source types were identified as being potentially significant contributors in the upper North Buffalo Creek watershed. This list includes: Cone Mills WWTP (NC0000876); illicit discharges from the City of Greensboro's NPDES Phase I permitted stormwater conveyance system; pets (specifically dogs and cats); exfiltrating sanitary sewer lines; sewer system overflows (SSOs); failing septic systems; waterfowl (specifically ducks and geese); and other sources, presently unidentifiable, with delivery mechanisms assumed to be associated with rainfall runoff events.

### 2.1 POINT SOURCE ASSESSMENT

#### 2.1.1 Cone Mills WWTP

Cone Mills Corporation had a major industrial discharge approximately 0.2 stream miles above Summit Avenue during the TMDL model simulation period. The facility was permitted to discharge 1.25 MGD of treated effluent with a monthly geometric mean fecal coliform limit of 200 cfu/100mL. Cone Mills is a textile manufacture for the apparel and home furnishings market. The facility is still in operation, however it no longer directly discharges to the stream. Rather, its pretreated wastewater is now sent to the City of Greensboro's North Buffalo Creek

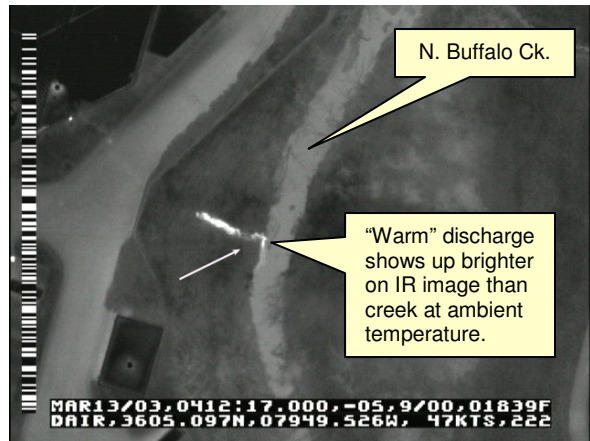


*The Cone Mills facility is the only NPDES permitted WWTP with a limit for fecal coliform within the TMDL watersheds.*

WWTP for final treatment and disposal. The North Buffalo Creek WWTP discharges downstream of the reach impaired for fecal coliform and is therefore not included in this TMDL. Daily effluent flow and daily fecal coliform monitoring data submitted to DWQ by Cone Mills were used to estimate loads from this facility (Kebede, 2003).

**2.1.2 Illicit Discharges From Greensboro’s Stormwater Conveyance System**

Greensboro’s Stormwater Management Division (SMD) is the lead local government agency responsible for managing the city’s stormwater conveyance infrastructure. Greensboro is permitted under EPA’s Phase I stormwater program. In 2002 SMD completed a state-of-the-art GIS mapping project of its stormwater conveyance system. This project involved locating stormwater inlets, manholes, pipes, and culverts using a combination of GPS and traditional survey technologies. These data were incorporated into a GIS framework. Natural streams, man-made open channels, and lake/ponds were also included in the GIS database to provide complete hydrologic conductivity within a watershed. Table 2.1.2.1 summarizes the number of stormwater inlets and length of drainage pipe (12” or greater) within the TMDL subwatersheds as identified through the stormwater infrastructure mapping project.



*Nighttime aerial infrared thermographic image of a possible inappropriate discharge into North Buffalo Creek from an institutional facility in subwatershed 1. Data from the infrared flyover became available too late for use in the TMDL source assessment. However, these data will be used to support implementation strategies.*

**Table 2.1.2.1 Summary of selected stormwater infrastructure features within the TMDL subwatersheds.**

Subwatershed	Number Of Stormwater Inlets (e.g. curb inlet, yard inlet, etc.)	Total Length Of 12” Or Greater Diameter Pipe (miles)
1	2,070	40.1
2	1,781	35.2
3	210	3.0
4	2,693	47.7
5	647	11.9
6.1	457	10.2
6.2	1,012	21.3
7	557	12.7
8	13	0.4
<b>Total</b>	<b>9,440</b>	<b>182.5</b>

In addition to the locational mapping, various attributes which describe the conveyance system were also collected such as inlet type, pipe size, and pipe invert elevation. Attribution of the conveyance system also included an inventory of any illegal tie-ins to the system. An illegal tie-in is defined as any unauthorized private piped connection to the public stormwater conveyance system. The mapping project was not designed to assess whether or not discharges from illegal tie-ins are comprised solely of stormwater. These determinations are being made through follow-up investigations over time.

However, the mapping database does include a number of useful attributes which were used to identify the possible presence of illicit discharges to the stormwater system. These attributes included whether or not an unusual **odor**, such as from raw sewage, was emanating from the system; whether or not flows in the system were unnaturally **colored or cloudy**; as well as specific **comments** recorded in the database by the mapping field crews which would suggest the presence of an illicit discharge in the system. Using these attributes an analysis of the stormwater infrastructure database was conducted to identify the number of structures and pipes possibly containing non-stormwater flows (illicit discharges). The outfalls from which these non-stormwater flows ultimately discharge were identified using the system connectivity built within the GIS database. Table 2.1.2.2 summarizes the results of this analysis. Figure 2.1.2.1 illustrates the locations of stormwater structures and pipes suspected of containing non-stormwater flows.

**Table 2.1.2.2 Summary of the number of stormwater structures, pipes, and outfalls possibly containing non-stormwater flows.**

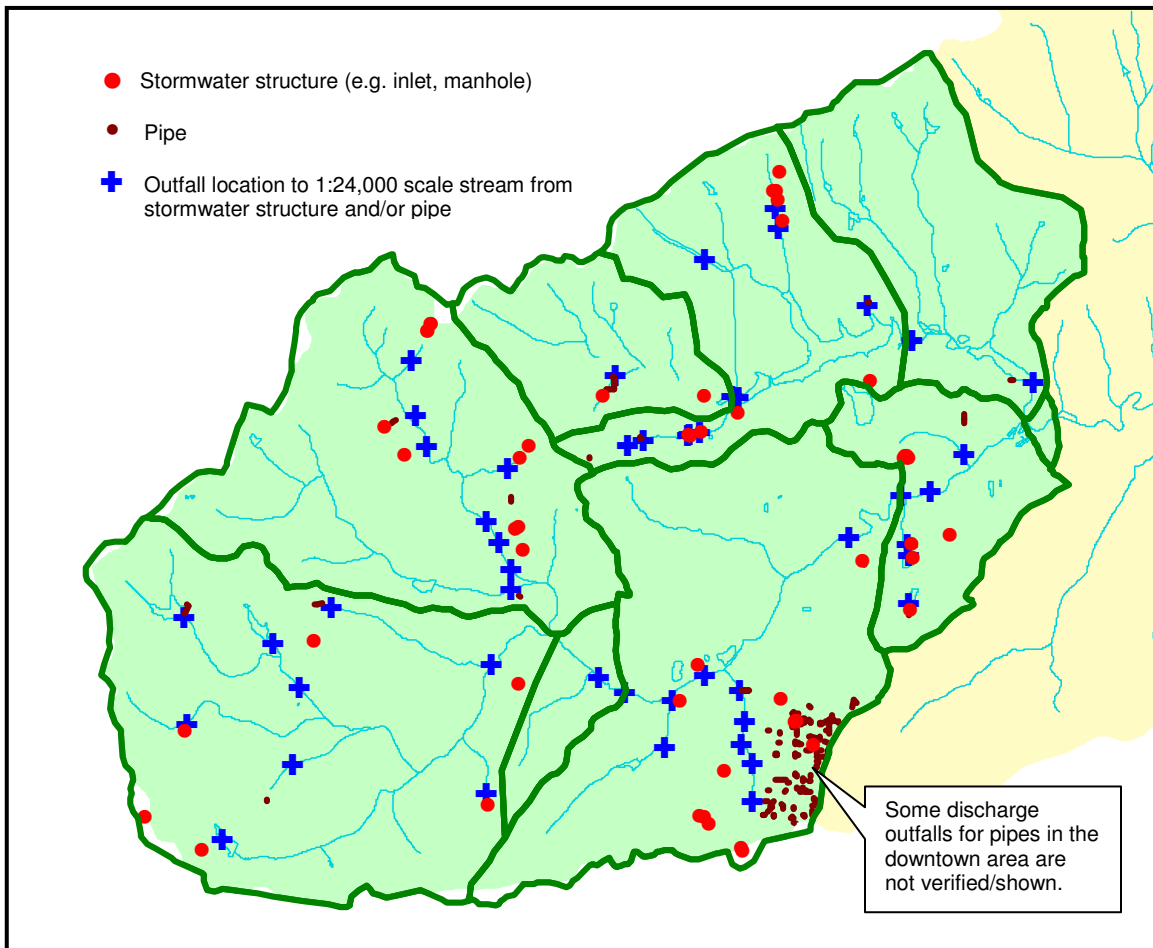
Subwatershed	Number of Structures (e.g. inlets, manholes)	Number of Pipes	Number of Outfalls to 1:24K Scale Streams <sup>1</sup>
1	6	10	9
2	11	12	8
3	0	0	2 <sup>2</sup>
4	14	5	27 <sup>3</sup>
5	8	8	6
6.1	2	7	1
6.2	9	8	11
7	1	1	2
8	0	0	0
<b>Total</b>	<b>51</b>	<b>51</b>	<b>66</b>

1 This column represents the number of discreet locations the possible discharge enters a 1:24,000 scale stream. For example, in subwatershed 1 based on the connectivity of the stormwater conveyance system, the 6 structures and 10 pipes suspected of possibly containing non-stormwater flows ultimately discharge to a stream at 9 unique locations.

2 The stormwater infrastructure database indicated possible evidence that an illicit discharge had occurred at 2 instream locations. The database did not yield any evidence that the discharge was associated with a specific stormwater structure or pipe.

3 Based on the connectivity of the stormwater conveyance system, 14 structures and 5 pipes were identified as possibly containing non-stormwater flows discharging at 9 unique locations. However, this number of non-stormwater discharges is suspected of being an underestimate due to uncertainties associated with the mapping database. Approximately 215 acres of Greensboro's downtown area is within subwatershed 4. The downtown area contains some of the City's older stormwater infrastructure – much of which was inaccessible during the mapping project. Due in part to buried manholes, 183 stormwater pipes in the downtown area could not be inspected and their network connectivity verified. For the purposes of this TMDL, it was assumed that 10% of these older, inaccessible pipes may contain illicit tie-ins (i.e.  $183 * 10\% = 18$  pipes). It was also assumed that each of these pipes discharge to a discreet location. Therefore in subwatershed 4 a total of 27 (18+9) outfalls possibly containing non-stormwater flows were used to estimate fecal coliform loads from illicit discharges.

**Figure 2.1.2.1 Stormwater structures and pipes, along with corresponding stream outfalls, suspected of containing non-stormwater flows.**



Flow and fecal coliform concentration measurements are not available at stream outfalls suspected of containing non-stormwater flows for use in calculating loads. To estimate loads from each outfall for the TMDL, data from various dry weather flow investigations were obtained from the Mecklenburg County Department of Environmental Protection (Kroening, 2002). These data are described in the fecal coliform TMDL for Irwin, McAlpine, Little Sugar, and Sugar Creek Watersheds approved in February 2002 (MCDEP/DWQ, 2002), and presented in Appendix 4.

A median dry weather flow rate of 0.00675 cfs from each outfall was calculated from the Mecklenburg County studies based on an analysis of outfalls in the county possessing dry weather flow. A geometric mean fecal coliform concentration in the dry weather flow of 676 cfu/100mL was also calculated from the Mecklenburg County data. These “typical” flow and fecal coliform concentration values were applied to each outfall suspected of containing non-stormwater flows in the upper North Buffalo Creek watershed in order to calculate fecal coliform loads for each subwatershed. These loads are assumed to be constant. Table 2.1.2.3 summarizes the loading estimates from illicit discharges (non-stormwater flows) used in this TMDL.

**Table 2.1.2.3 Fecal coliform loading estimates from illicit discharges (non-stormwater flows) from the stormwater conveyance system.**

Subwatershed	Number of Outfalls to 1:24K Scale Streams	Total Flow (cfs) <sup>1</sup>	Total Load (#/day) <sup>2</sup>
1	9	0.06075	1.01E+09
2	8	0.05400	8.94E+08
3	2	0.01350	2.23E+08
4	27	0.18225	3.02E+09
5	6	0.04050	6.70E+08
6.1	1	0.00675	1.12E+08
6.2	11	0.07425	1.23E+09
7	2	0.01350	2.23E+08
8	0	0.00000	0.00E+00

<sup>1</sup> Total flow = Number of outfalls \* 0.00675 cfs

<sup>2</sup> Total load (#/d) = Total flow (cfs) \* 676/100mL \* conversion factor (24470000)

## 2.2 NONPOINT SOURCE ASSESSMENT

### 2.2.1 Pets

Given the predominance of residential land uses in the upper North Buffalo Creek watershed, pets, specifically dogs and cats, are believed to be potential significant contributing sources of fecal coliform loads in the watershed. The City of Greensboro does not have a pet licensing program, so dog and cat populations were estimated based on national average pet ownership statistics published by the American Veterinary Medical Association (AVMA 1997). The City of Wilmington, NC conducted a comparison of pet population estimates made using AVMA statistics versus local county health department records of registered pet owners. Wilmington found that AVMA statistics yielded reasonably similar results for watershed source assessment purposes (Wilmington, 2002). According to AVMA statistics:



*Greensboro's city parks, such as Latham Park shown above along North Buffalo Creek, are popular places for walking dogs.*

**# of dogs** in a given area = 0.534 \* total number of households in the area

**# of cats** in a given area = 0.598 \* total number of households in the area

2000 US Census block data, which includes household counts, were used to estimate the number of households in each subwatershed which was then used in turn to estimate the dog and cat population (Table 2.2.1.1).

**Table 2.2.1.1 Estimated dog and cat population in the upper North Buffalo Creek watershed based on AVMA statistics.**

Subwatershed	No. of Dogs	No. of Cats	No. of Households
1	3,047	3,412	5,706
2	2,063	2,310	3,863
3	356	398	667
4	3,742	4,190	7,007
5	710	795	1,330
6.1	816	914	1,528
6.2	1,495	1,674	2,800
7	1,475	1,652	2,762
8	0	0	0
Totals	<b>13,704</b>	<b>15,345</b>	<b>25,663</b>

Based on published animal feces production rates approximately 4,400 lb/day of feces is generated from the dog population and 2,300 lb/day of feces is produced from the cat population within the TMDL subwatersheds (CWP, 1999). Using input from the local stakeholders group it was assumed for the purposes of this TMDL that 100% of the dog waste generated is deposited outside, on residential land, and subject to rainfall runoff processes. Fifty percent (50%) of cat waste was assumed to be deposited outside, on residential land, and subject to runoff. Based on these data and assumptions, daily fecal coliform accumulation rates were calculated as outlined in Table 2.2.1.2.

**Table 2.2.1.2 Fecal coliform accumulation rates from pet waste.**

Subwatershed	Accumulation Rate On Residential Land <sup>1</sup> (count/acre/day) (ACQOP)	Total Residential Acreage
1	$9.28 \times 10^9$	1,443
2	$8.12 \times 10^9$	1,116
3	$9.65 \times 10^9$	162
4	$1.51 \times 10^{10}$	1,086
5	$1.20 \times 10^{10}$	260
6.1	$8.33 \times 10^9$	431
6.2	$8.33 \times 10^9$	788
7	$1.19 \times 10^{10}$	546
8	0	0

<sup>1</sup> Calculations based on a fecal coliform loading rate from dogs of  $4.09\text{E}+09$  cfu/dog/day (Roessler, 2002) and a rate from cats of  $5.37\text{E}+08$  cfu/cat/day (calculated from data provided in CWP, 1999).

## 2.2.2 Sanitary Sewer Line Exfiltration

The City of Greensboro operates over 1,382 miles of sanitary sewer lines ranging in size from 6 to 72 inches in diameter. The sanitary sewer collection system transports wastewater to either the North Buffalo Water Reclamation Facility (WRF) or the T.Z. Osborne WRF on South Buffalo Creek. Both plants have advanced tertiary limits for oxygen consuming wastes as permitted under NPDES.

The infiltration and inflow (I&I) of groundwater and/or rainwater into the sanitary sewer collection system is an important management issue for municipalities. Excessive I&I can result in sewer system overflows and reduced treatment capacity at the WWTP. The City of Greensboro has an on-going inspection and maintenance program which includes the rehabilitation of aging sewer lines. Over \$1.7 million is spent annually on the rehabilitation program with a particular focus on reducing I&I related problems. The rehabilitation program also addresses exfiltration problems, i.e. when sewage is leaking out of the collection system. Hydraulically this situation can occur when a sewer line is above the water table or stream water surface, or is under pressure as is the case with force mains. Unfortunately, exfiltration problems are much more difficult to detect because often there is little visual evidence that a problem is occurring.



The majority of Greensboro's sanitary collection system (~97%) are lines which generally follow the terrain to take advantage of gravity flow. Hence, by design collection arteries are often located in close proximity to streams and tributaries to transport wastewater downhill to the treatment plant. This situation presents an opportunity for untreated sewage to reach a stream through abnormalities in the line, such as through cracks at a joint.

In the North Buffalo Creek watershed data on exfiltrating sanitary sewer lines are very limited, as is generally the case throughout NC. The best professional judgment of the local TMDL stakeholders is that exfiltrating sanitary lines could be a potential significant source of fecal coliform loads. However, actual load contributions from this source are not well understood. A special study being conducted by the City of Greensboro on dry weather sources of fecal coliform within the TMDL subwatersheds was initiated in the Spring of 2003. One of the goals of this study is to gather additional information on this potential source to support implementation strategies.

Most NC municipalities have very little data for quantifying the degree of exfiltration which is occurring from their sanitary sewer collection system. However, in 2000 Mecklenburg County published the results of a limited study designed to investigate fecal coliform concentrations in groundwater in the vicinity of underground sanitary sewer lines. The study is summarized in the Fecal Coliform TMDL for the Irwin, McAlpine, Little Sugar, and Sugar Creek Watersheds (MCDEP/DWQ, 2002), and the data presented in Appendix 5. Briefly, Mecklenburg County found that 3 out of 4 down gradient wells, positioned near sewer lines located above the water table, had an average groundwater fecal coliform concentration of 58 cfu/100mL. Measured concentrations



ranged from < 10 cfu/100mL to 1,700 cfu/100mL. None of the samples collected from the 4 up gradient wells had measurable fecal coliform concentrations. None of the samples collected from wells positioned near sewer lines located below the water table had measurable fecal coliform concentrations.

For this TMDL exfiltrating sanitary sewer lines were simulated in the model as a constant fecal coliform concentration in groundwater. Per the Mecklenburg County study, groundwater concentrations for most of the subwatersheds were assumed to be 58 cfu/100mL. In subwatershed 4 which includes 215 acres of downtown area and some turn of the century (1900s) residential development (see Figure 1.6.1), and in subwatershed 7 which also has elevated instream fecal concentrations during dry weather, groundwater concentrations were assumed to be 700 cfu/100mL. An assumed groundwater concentration of 700 cfu/100mL is based primarily on model calibrations during dry weather periods when loadings from most other sources are reduced. It is important to note however that although the 700 cfu/100mL fecal coliform concentration assumed for groundwater in selected subwatersheds is well within the range observed within Mecklenburg County, there is no local data to substantiate this assumption. In general, fecal coliform loads from exfiltrating sanitary sewer lines represent a significant source of uncertainty in the TMDL. Exfiltrating sewer lines and other dry weather sources of fecal coliform loads will be investigated in more detail as part of a special study initiated in the spring of 2003 with funding from the Cape Fear River Assembly.

### 2.2.3 Sewer System Overflows

Sewer system overflows can generally be characterized as unpermitted discharges from the sanitary sewer collection system. To varying degrees SSOs occur in virtually every municipal collection system. Often SSOs are caused by excessive volumes of rain water entering the collection system which exceeds the systems capacity to transport all the flow to the WWTP. SSOs can also be caused by blockages in the lines from grease, debris, tree roots, and other obstructions.

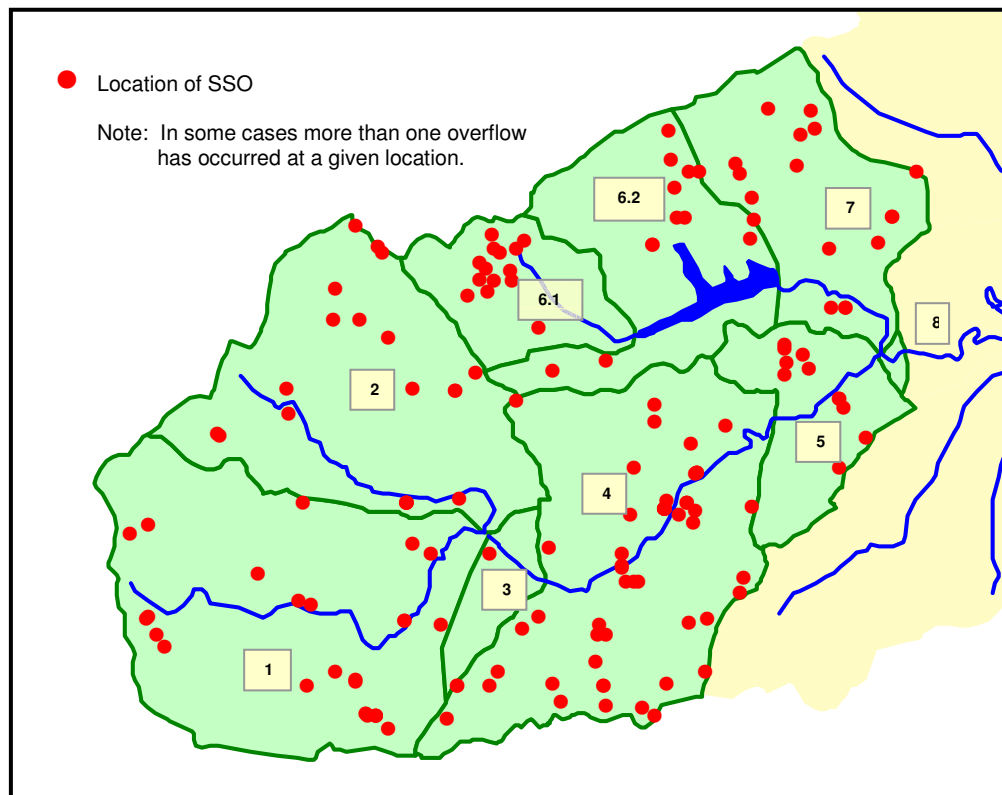


*Sewer system overflow draining into North Buffalo Creek within subwatershed 4. The City of Greensboro maintains a database of SSOs as part of a program to minimize the occurrence of uncontrolled discharges from the sanitary sewer collection system.*

The City of Greensboro's Department of Water Resources maintains a database of spills and overflows from the sanitary sewer collection system. The database includes among other attributes the location, date and time the discharge started and stopped, estimated discharge volume, whether or not the discharge reached a surface water body, and an explanation of the possible cause of the discharge. Table 2.2.3.1 and Figure 2.2.3.1 summarize the SSOs which occurred within the TMDL subwatersheds during the model simulation period. Appendix 6 includes data for each individual SSO.

**Table 2.2.3.1 Summary of SSOs within the TMDL subwatersheds during the model simulation period August 1998 through August 2001.**

Subwatershed	No. of SSOs	Total Volume Spilled (gal)
1	25	5,575
2	18	3,875
3	1	200
4	42	72,115
5	7	2,780
6.1	14	1,615
6.2	13	6,950
7	11	7,325
8	0	0
<b>Total</b>	<b>131</b>	<b>100,435</b>

**Figure 2.2.3.1 Distribution of SSOs within the TMDL subwatersheds during the period August 1998 through August 2001.**

Loads from SSOs were estimated based on an assumed fecal coliform concentration in untreated sewage of  $6.4 \times 10^6$  cfu/100mL (CWP, 1999), and flow rates calculated from the spill start and stop times and estimated spill volume reported in the SSO database. Within the model framework, fecal coliform loads from SSOs are simulated as direct discharges to a stream reach. Start and stop times for each individual SSO are maintained within the model.

### 2.2.4 Failing Septic Systems

On-site wastewater treatment systems are a very common means of treating and depositing of wastewater in areas of NC not served by a centralized sanitary sewer system. Since all of the area within the TMDL subwatersheds is within the Greensboro city limits, septic systems were not believed to be in common use. However, even in urban areas it is possible for these systems to be in existence and thus were considered as part of the TMDL analysis.

No direct accounting of the number of septic systems in use within the TMDL subwatersheds is available. Therefore, in order to quantify loads from improperly functioning (failing) septic systems, the total number of systems in use had to be estimated. This was accomplished through an analysis of water and sewer billing records maintained by the Greensboro Department of Water Resources. Based on a comparison of these records, it was assumed that city customers with developed properties receiving a water bill but not a sewer bill, were disposing wastewater via an on-site system. There are no NPDES permitted privately owned package plants within the TMDL subwatersheds.

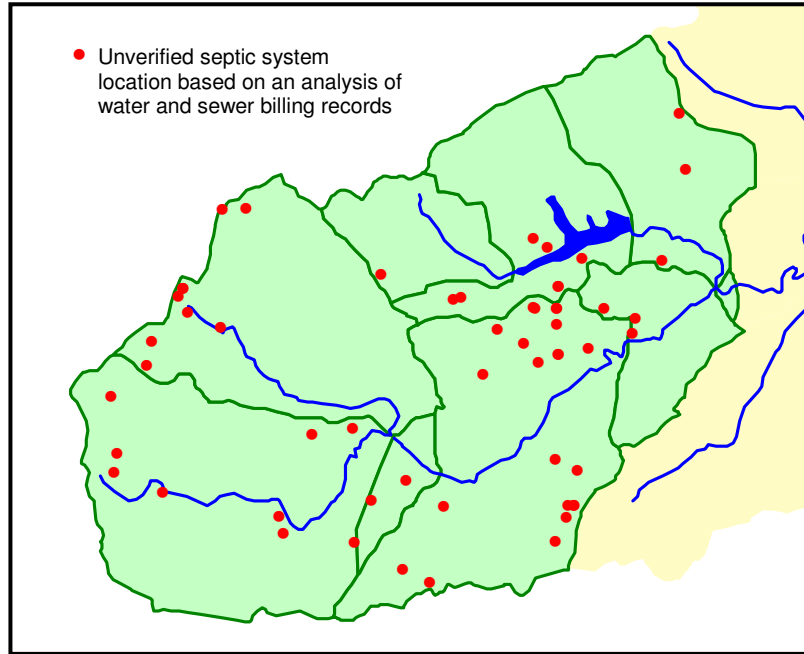
Based on the collective experience of the TMDL stakeholders an estimated failure rate of 10% – 20% was believed to be appropriate. This range was corroborated by the opinion of an experienced septic system inspector with the Guilford County Health Department (Edwards, 2002). Table 2.2.4.1 and Figure 2.2.4.1 summarize the septic system source assessment.

**Table 2.2.4.1 Septic systems within the TMDL subwatersheds.**

Subwatershed	Estimated Total Number of Septic Systems	Estimated Number of Failing Septic Systems <sup>1</sup>
1	9	1
2	9	1
3	2	0
4	22	4
5	3	0
6.1	1	0
6.2	7	1
7	3	0
8	0	0
<b>Total</b>	<b>56</b>	<b>7</b>

<sup>1</sup> The number of failing septic systems was estimated by assuming a 15% failure rate from the total number of systems and rounding to the nearest integer. In the case of subwatershed 4 the number of failing systems was rounded up to the nearest integer, as this subwatershed had a disproportionately high number of systems.

**Figure 2.2.4.1 Distribution of septic systems within the TMDL subwatersheds.**



Fecal coliform loads from failing septic systems were calculated by assuming 2.3 individuals are served by each septic system which is based on the average number of persons in a Greensboro household according to the 2000 US Census. A per capita flow rate of 70 gallons per person per day, and a fecal coliform concentration of 10,000 cfu/100mL was assumed for the loading calculations (Horsely and Whitten, 1996). Table 2.2.4.2 summarizes the estimated fecal coliform load from failing septic systems within the TMDL subwatersheds.

**Table 2.2.4.2 Estimated fecal coliform load from failing septic systems located within the upper North Buffalo Creek watershed.**

Subwatershed	No. of Failing systems	Flow (cfs)	FC Concentration in Effluent (#/100mL)	FC Load (#/day)
1	1	0.00025	10,000	6.09E+07
2	1	0.00025	10,000	6.09E+07
3	0	0.00000	10,000	0.00E+00
4	4	0.00100	10,000	2.44E+08
5	0	0.00000	10,000	0.00E+00
6.1	0	0.00000	10,000	0.00E+00
6.2	1	0.00025	10,000	6.09E+07
7	0	0.00000	10,000	0.00E+00
8	0	0.00000	10,000	0.00E+00
<b>Totals</b>	<b>7</b>	<b>0.00174</b>		<b>4.27E+08</b>

## 2.2.5 Waterfowl

Within the City of Greensboro there are over 580 ponds and lakes.<sup>†</sup> Due in part to the large number of open waterbodies in the area, the City of Greensboro supports a sizable waterfowl population, particularly Canada geese and mallard ducks.

According to data published by the National Audubon Society, over 10,400 sightings of Canada geese and 6,300 sightings of mallards have been recorded in the Greensboro area during the annual Christmas Bird Counts for the period 1991-2001 (Audubon, 2003). The 2001 one-day Greensboro Audubon count included 1,341 Canada geese. Many NC geese populations are no longer migratory due to the year round availability of food. Geese are primarily terrestrial feeders, often seen harvesting grass and seeds along maintained lawn areas surrounding ponds, lakes, and golf courses. In recent decades, non-migratory geese populations have been a growing problem in these maintained areas because of the quantity of feces deposited by the birds.



*Canada geese feeding near the banks of North Buffalo Creek near Church St.*

In an effort to compile site specific data on geese and mallard populations within the TMDL subwatersheds, several locations mostly associated with lakes and ponds, were investigated for evidence of significant waterfowl populations. Table 2.2.5.1 outlines the locations investigated.

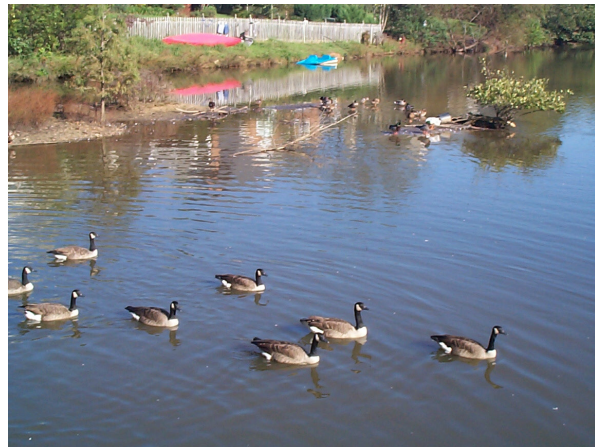
**Table 2.2.5.1 Locations investigated for evidence of waterfowl populations in the upper North Buffalo Creek watershed. Survey conducted on 10/23/02.**

Subwatershed	Location	Comment
1	Lake Hamilton	Evidence of significant waterfowl populations.
1	Lake Euphemia	Access very limited due to surrounding private property.
1	Starmount CCGC	No evidence of significant waterfowl populations.
1	Starmount Park, Lindley Park, Arboretum	No evidence of significant waterfowl populations.
2	Bog Garden	Large year round waterfowl population according to a volunteer park naturalist. Ducks and geese fed daily by park visitors.
2	Bicentennial Garden	No evidence of significant waterfowl populations.

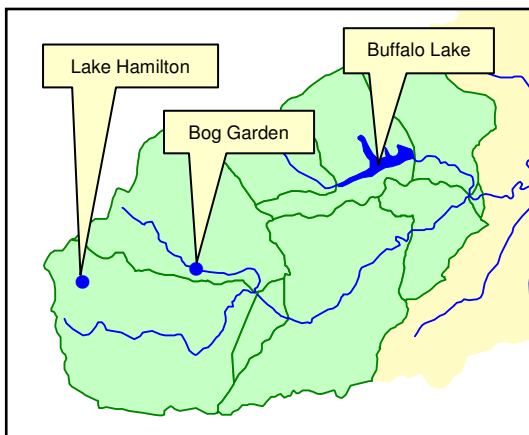
<sup>†</sup> Data based on an inventory of open waterbodies conducted during the stormwater infrastructure mapping project. Ponds include both natural and engineered wet detention ponds designed as water quality BMPs.

4	Lake Daniel	No evidence of significant waterfowl populations.
4	Greensboro CCGC	No evidence of significant waterfowl populations.
4	UNC-G golf course practice holes	No evidence of significant waterfowl populations.
6.2	Buffalo Lake	Evidence of significant waterfowl populations.
6.2	Private pond at Irving Park Village	Evidence present of problematic waterfowl populations but few birds observed.
7	Pond near Mizell Rd.	No evidence of significant waterfowl populations.
7	Pond at Craft Rec. Center near Leo Dr.	No evidence of significant waterfowl populations.

Of the sites described in Table 2.2.5.1 Lake Hamilton, the Bog Garden, and Buffalo Lake were identified as the locations most likely to support year round populations of waterfowl. It is important to note that waterfowl populations are constantly changing over space and time, however these three locations appear most likely to support sizable populations for inclusion in the TMDL. Figure 2.2.5.1 illustrates the locations of these three waterfowl sites.



**Figure 2.2.5.1 Lakes and ponds in the upper North Buffalo Creek watershed identified as likely supporting significant year-round waterfowl populations.**



*The Bog Garden Park pond, shown in the above two pictures, supports a relatively large year-round waterfowl population for its size. Many of the ducks and geese have become "tame" from routine feedings from park visitors.*

To calculate fecal coliform loads for the TMDL, waterfowl populations from the three locations were estimated by averaging survey data collected on 10/23/02 (and 11/8/02 for Buffalo Lake) with 10 years of National Audubon Society Christmas Bird Count data (1991-2001). Based on data from the National Audubon Society available from their website, the average annual Audubon one-day count for geese in the Greensboro area is 949 and for mallards is 578 (Audubon, 2003).

For the purposes of estimating how many waterfowl might be residing at the three locations of interest for this TMDL, it was assumed that the average Audubon populations are evenly distributed across open waterbodies within Greensboro (including the water supply reservoirs which border the city's northern edge). Based on the city-wide stormwater infrastructure GIS mapping project discussed in Section 2.1.2, there are approximately 3,320 acres of open waterbodies (lakes, ponds, and reservoirs) in the Greensboro area. These data were used to calculate areal weighted average waterfowl populations for the three waterbodies of interest in the TMDL as described in Table 2.2.5.2.

**Table 2.2.5.2 Estimated waterfowl populations for three locations identified within the TMDL subwatersheds as likely supporting year-round populations.**

Subwatershed	Location	10/23/02 Survey <sup>1</sup>	11/8/02 Survey <sup>1</sup>	Audubon Areal Weighted Average <sup>2</sup>	Average Populations Assumed for TMDL <sup>3</sup>
1	Lake Hamilton	Geese: 0 Ducks: 22	n/a	Geese: 5 Ducks: 3	<b>Geese: 2.5 Ducks: 12</b>
2	Bog Garden	Geese: 10 Ducks: 42	n/a	Geese: 4 Ducks: 2	<b>Geese: 14 Ducks: 22</b>
6.2	Buffalo Lake	Geese: 20 Ducks: 4	Geese: 0 Ducks: 57	Geese: 26 Ducks: 15	<b>Geese: 15 Ducks: 25</b>

<sup>1</sup> Observed waterfowl population in and adjacent to the waterbody based on a count conducted over roughly a one hour time period.

<sup>2</sup> Areal weighted averages were calculated by assuming that the average annual Audubon bird count populations are evenly distributed over Greensboro's 3,320 acres of open waterbodies. The resulting bird/acre ratio was multiplied by the area of the three waterbodies of interest within the TMDL subwatersheds to estimate geese and duck populations.

<sup>3</sup> This column represents the populations used for calculating fecal coliform loads from waterfowl for the TMDL. These numbers represent an arithmetic average of the survey data and Audubon data.

Tables 2.2.5.3 through 2.2.5.5 summarize fecal coliform loading rates from waterfowl populations at Lake Hamilton, the Bog Garden, and Buffalo Lake.

**Table 2.2.5.3 Estimated fecal coliform loads from waterfowl populations at Lake Hamilton.**

Waterfowl	Population	Daily FC Loading Rate (#/bird/day) <sup>1</sup>	% of Load Deposited Directly in Waterbody <sup>2</sup>	FC Load Deposited Directly in Water (#/day) <sup>3</sup>	FC Load Deposited on Land (#/day)
Geese	2.5	$4.90 \times 10^{10}$	5%	$3.06 \times 10^8$	$1.16 \times 10^{11}$
Ducks (mallards)	12	$2.43 \times 10^9$	80%	$1.17 \times 10^9$	$5.83 \times 10^9$

1 Source: Roessler, 2002.

2 Percentages based on best professional judgment estimates of the percentage of time each species spends in the water.

3 Estimates of the load deposited directly in the water factors in a 95% removal efficiency for the waterbody.

**Table 2.2.5.4 Estimated fecal coliform loads from waterfowl populations at the Bog Garden.**

Waterfowl	Population	Daily FC Loading Rate (#/bird/day) <sup>1</sup>	% of Load Deposited Directly in Waterbody	FC Load Deposited Directly in Water (#/day) <sup>1</sup>	FC Load Deposited on Land (#/day)
Geese	14	$4.90 \times 10^{10}$	5%	$3.43 \times 10^9$	$6.52 \times 10^{11}$
Ducks (mallards)	22	$2.43 \times 10^9$	80%	$4.28 \times 10^9$	$1.07 \times 10^{10}$

1 Estimates of the load deposited directly in the water factors in a 90% removal efficiency for the waterbody.

**Table 2.2.5.5 Estimated fecal coliform loads from waterfowl populations at Buffalo Lake.**

Waterfowl	Population	Daily FC Loading Rate (#/bird/day)	% of Load Deposited Directly in Waterbody	FC Load Deposited Directly in Water (#/day) <sup>1</sup>	FC Load Deposited on Land (#/day)
Geese	15	$4.90 \times 10^{10}$	5%	$1.84 \times 10^9$	$6.98 \times 10^{11}$
Ducks (mallards)	25	$2.43 \times 10^9$	80%	$2.43 \times 10^9$	$1.22 \times 10^{10}$

1 Estimates of the load deposited directly in the water factors in a 95% removal efficiency for the waterbody.



### **2.2.6 Other Sources**

During the development of this TMDL a significant amount of effort has been directed towards explicitly accounting for likely sources of fecal coliform loads in the upper North Buffalo Creek watershed. Explicitly identifying sources is an important step towards the ultimate implementation of successful load reduction strategies.

However, it should be recognized that it is not possible to explicitly account for every source of fecal coliform loading in the watershed - as the potential number of individual source types is huge and site specific data much too scarce. Therefore, these other sources, which are surely in the watershed but are not individually identifiable, have been lumped into a category known as *Other (unidentified) sources*. For the purposes of this TMDL loads from unidentified sources are assumed to be land deposited and nonpoint source in nature. The load delivery mechanism to the stream is simulated in the model by rainfall runoff-type processes.

## **3.0 Modeling Approach**

Water quality computer models are frequently used during TMDL development for establishing a relationship between instream water quality conditions and the contributing watershed. These models use mathematical equations to represent the important physical and chemical processes which are believed to affect the environment. By necessity models are simplified versions of reality, as the environment is much too complex to fully simulate with mathematics. However, models have proven over time to be very useful tools for gaining a better understanding of the cause-effect relationship between pollutant loadings and the water quality issues we are concerned about.

The TMDL modeling process typically proceeds in two distinct phases. The objective of the first phase is to simulate existing water quality conditions. Once the model is deemed to be adequately simulating existing conditions (referred to as a calibrated model), then the second modeling phase can begin. In the second phase, the objective is to evaluate various pollutant load reduction strategies in order to achieve a water quality goal – which is typically the achievement of state numeric water quality standards.

### **3.1 MODEL SELECTION**

EPA's Hydrologic Simulation Program – Fortran (WinHSPF version 2.0.6) was chosen as the modeling platform for development of this TMDL. WinHSPF is a public domain watershed model maintained and distributed by the US EPA. WinHSPF is a continuous simulation, precipitation-drive model designed to calculate point and nonpoint source pollutant loadings, downstream transport, and instream pollutant decay.

In the world of water quality models, WinHSPF is generally considered a relatively complex, highly parameterized model. These same characteristics also make WinHSPF a relatively flexible model for addressing a variety of pollutant and water quality issues. While this TMDL solely addresses fecal coliform, the Greensboro Stormwater Management Division desired a flexible modeling platform for addressing other water quality issues in the North Buffalo Creek watershed as the need arises, hence the selection of WinHSPF.

### **3.2 MODEL SETUP**

EPA's BASINS 3.0 GIS interface was used to set up the initial WinHSPF user input file. Given the relatively large amount of detailed local data available, most of the GIS layers packaged with BASINS 3.0 were not used as part of the model setup. Below is a description of the basic model setup.

### 3.2.1 Subwatersheds and Stream Reaches

The upper North Buffalo Creek watershed was delineated into nine subwatersheds, corresponding to the various water quality & stream flow monitoring stations, and to selected hydrologic features such as Lake Buffalo (refer to Sections 1.3 and 1.8 for additional details). One stream reach is simulated within each subwatershed. Most of the information needed for estimating stream reach length, slope, and cross sectional dimension was adopted from the GIS stormwater conveyance system mapping project described in Section 2.1.2. As part of this project 169 surveyed cross sections were conducted on the mainstem and tributaries within the TMDL subwatersheds. The cross section database was reviewed and stream dimension data deemed representative of the reach as a whole was incorporated into the model. Stage-discharge relationships were estimated using Mannings equation.

### 3.2.2 Meteorological Data

Most of the meteorological data used by the model, except precipitation, was collected at the Piedmont Triad International Airport (PTIA), and obtained from the National Climatic Data Center in Asheville, NC. PTIA is located approximately 3.4 miles west of the headwaters of the North Buffalo Creek watershed. Precipitation data (15 minute interval) collected at the USGS Church Street rain gage (02095271) were used to supplement the PTIA meteorological data for the model. The Church Street rain gage is centrally located within the upper North Buffalo Creek watershed and has the longest period of record (beginning in August 1998) of the two rain gages in the watershed. Precipitation data from the USGS rain gage at Westover Terrace (02095181) was used to fill gaps in the Church Street precipitation record when that gage was down due to maintenance or malfunction. The Westover Terrace gage is located approximately 2.1 miles southwest of the Church Street gage.

Having local precipitation data collected within the watershed is a big advantage during model calibration of stream flow. In the piedmont of NC, summertime thunderstorms can result in significantly different precipitation amounts over relatively short distances. For example, on 6/19/00 the following daily rainfall totals were recorded at the three gages:

PTIA gage: 0.32 in  
Westover Terrace gage: 2.69 in  
Church Street gage: 3.22 in



*USGS stream flow and precipitation gaging station on North Buffalo Creek at Church Street. This and other gaging stations in the area are operated with support from Greensboro's Department of Water Resources.*

### **3.2.3 Model Simulation Period**

A continuous model simulation period from August 1, 1998 to August 1, 2001 was used for the TMDL analysis. The TMDL simulation period start time corresponds to the earliest available daily stream flow and precipitation data from the USGS gage at Church St. This time window also corresponds to the period when the majority of instream fecal coliform data within the TMDL subwatersheds were collected.

### **3.2.4 Land Use/Land Cover and Impervious Surfaces**

Sections 1.5 and 1.7 describe in detail the land use/land cover data and impervious surface estimates used to set up the model. In summary, these data sets were based primarily on 2000 orthophotography and numerous updated GIS planimetric data layers. On balance, the TMDL subwatersheds are dominated by residential land uses (>41%) and have an average percent impervious surface coverage of approximately 26%. The vast majority of the residential development was constructed between 1920-1970, with some turn-of-the-century residential areas mostly concentrated adjacent to the downtown area.

The total area of open waterbodies in most of the subwatersheds comprised <1% of the total subwatershed area. Hence, these small ponds were not explicitly simulated in the model, and were treated as another 100% pervious land cover type. However, in subwatershed 6.2 Buffalo Lake comprises 6% of the subwatershed area and was explicitly simulated in the model as a lake.

### **3.2.5 Water Withdrawals**

Buffalo Lake in subwatershed 6.2 is an industrial water supply reservoir for the Cone Mills textile manufacturing facility. Based on an analysis of water withdrawal registration records obtained from the NC Division of Water Resources for the calendar year 1999, the monthly average withdrawal rate from Buffalo Lake averages 115% of the monthly average wastewater discharge rate (DWR, 2002). For model simulation purposes, it was assumed that the daily average withdrawal rate was also 115% of the daily discharge rate. Appendix 3 outlines daily discharge rates for the Cone Mills WWTP.

## **3.3 FECAL COLIFORM SOURCE REPRESENTATION**

The fecal coliform source assessment described in Part 2 details the eight source categories and load quantification methods used for the TMDL. This section outlines how these data were incorporated within the WinHSPF modeling framework.

Both point and nonpoint sources are represented in the model using various methods. Several nonpoint source categories are not associated with land loading processes and

thus are represented in the model as direct inputs into the stream. These sources include SSOs, failing septic tanks, and a portion of the waterfowl load contribution. Land loading nonpoint sources are represented as indirect contributions to the stream through build-up and wash-off processes. These sources include pets, a portion of the waterfowl load contribution, and the *Other Sources* category.

### **3.3.1 Cone Mills WWTP NPDES Discharge**

Cone Mills is the sole NPDES permitted wastewater discharger within the TMDL subwatersheds which contributes fecal coliform loads. The discharge is represented as a point source with direct input to the mainstem in subwatershed 8. Daily measurements of flow and fecal coliform concentration as reported in the facilities NPDES Discharge Monitoring Reports were used to calculate daily variable loads. For those days (e.g. weekends) for which no fecal coliform concentration data were reported, a concentration equal to the average of the two most recent samples preceding, and the two most recent samples following, the missing data day were assumed. For example, if no fecal coliform data were reported for a Saturday and Sunday then those missing values were filled by calculating the average fecal coliform concentration from samples collected on Thursday, Friday, Monday, and Tuesday. Section 2.1.1 provides additional details on the Cone Mills WWTP, and Appendix 3 includes the complete effluent flow and fecal coliform dataset used to simulate the discharge.

### **3.3.2 Illicit Discharges From Stormwater Conveyance System**

Section 2.1.2 provides additional information on the 102 stormwater conveyance structures (e.g. manholes and pipes) suspected of having an elevated chance of transporting an illicit discharge. Flow passing through these structures ultimately drain to 66 stream outfalls. Since the locations of these outfalls are known, the number in each subwatershed is also known. Since WinHSPF simulates one stream reach per subwatershed, the loads from each outfall within a given subwatershed were added together and combined into a single direct discharge to the reach.

### **3.3.3 Pets**

Given the relatively high percentage of residential land uses in the upper North Buffalo Creek watershed pets, specifically dogs and cats, are suspected to be a potential significant contributor of fecal coliform loads. Section 2.2.1 describes the process used for estimating pet populations in the TMDL subwatersheds. Based on an estimate of dog and cat populations within each subwatershed, a daily fecal coliform accumulation rate was calculated (Table 2.2.1.2). This accumulation rate was applied to all single and multifamily residential lands, but not to any other land cover classes. The accumulation rate on residential lands was not changed during the water quality calibration process.

### **3.3.4 Exfiltrating Sanitary Sewer Lines**

In the model exfiltrating sanitary sewer lines are assumed to be leaking sewage into the ground and delivering pollutant loads to the stream via groundwater inflow. WinHSPF allows a constant fecal coliform concentration in groundwater to be assigned to each subwatershed. Loads from exfiltrating sewer lines vary over time based on the volume of groundwater entering a stream reach. Section 2.2.2 provides additional details on this source and groundwater concentrations of fecal coliform used in the model.

### **3.3.5 Sanitary Sewer Overflows**

For this TMDL SSOs were classified as time variable (hourly) nonpoint sources which directly discharge into the stream. For modeling purposes, all SSOs which occurred within a given subwatershed were grouped into a single time variable discharge for that subwatershed. No SSOs occurred within subwatershed 8 during the model simulation period. The discharge was assumed to start and stop according to the event start and stop times within the City's SSO database. The total discharge duration time was rounded up to the nearest whole hour. For the few records in which a start or stop time was not indicated a 3 hour discharge duration was assumed. Section 2.2.3 provides additional details and loading information from this source. Appendix 6 includes the complete SSO dataset used in the model.

### **3.3.6 Failing Septic Systems**

Fecal coliform loads from failing septic systems were simulated in the model as a continuous direct discharge into a stream reach. Loads did not vary over time but were allowed to vary spatially depending on the estimated number of failing systems within a given subwatersheds. Similar to SSOs and illicit discharges, multiple discharges from failing septic systems within a given subwatershed were combined into a single discharge for that subwatershed. Section 2.2.4 provides additional details and loading information from this source.

### **3.3.7 Waterfowl**

Unlike the sources described above, loads from ducks and geese were partitioned into both loads directly discharged into a stream reach, and into land applied loads subject to build-up and wash-off processes. This approach was taken because geese spend the majority of the day on land feeding (and defecating), whereas ducks tend to spend most of their time in the water. Based on a field survey of favorable waterfowl habitat described in Section 2.2.5, only subwatersheds 1, 2, and 6.2 received direct instream fecal coliform loads from waterfowl in the model.

Buffalo Lake is impounded by an earthen dam covered in grass which is routinely mowed and is prime geese habitat. The dam forms the divide between subwatersheds 6.2 and 7. Based on field observations the majority of the dam area covered in grass appears to drain into subwatershed 7 as opposed to the lake. Thus, the land applied fecal coliform load from waterfowl associated with Buffalo Lake was input into subwatershed 7.

### **3.3.8 Other Sources**

As discussed in section 2.2.6 it is not possible to explicitly identify all sources of fecal coliform in the watershed. However, it is recognized that other potential sources do likely exist. Sources which were not individually identifiable were lumped into a category labeled unidentified sources. For the purposes of this TMDL, loads from unidentified sources are assumed to be land deposited and nonpoint source in nature. The load delivery mechanism to the stream was simulated in the model by build-up and wash-off type processes. An accumulation rate from these sources was assigned to each land cover type, except for residential types - MF & RES, and WATER. Since by definition it is not possible to estimate the population of unidentified sources, the accumulation rate was used as a water quality calibration parameter.

## **3.4 MODEL CALIBRATION AND CONFIRMATION**

Model calibration is the process of tuning or adjusting the various model parameters in order to obtain an optimal agreement between the model calculations and the observed monitoring data. Calibration of a dynamic watershed model such as WinHSPF involves tuning both hydrologic and water quality components. Since WinHSPF is driven by precipitation and the subsequent treatment of the water budget, the process of calibration begins with adjusting the model's hydrologic parameters to achieve a best fit between predicted and observed stream flows. After the model's hydrologic calibration has been deemed satisfactory then the water quality calibration process begins.

Once calibrated, the model was confirmed by comparing predictions against a new set of observed data not used during calibration. During the confirmation period the physical forcing parameters, such as the meteorological data, are changed to reflect the new conditions but the model's hydrologic and water quality parameters remain fixed at the values set during the calibration process. A model that agrees with the observed data during the confirmation period can be used with greater confidence to make management decisions. Table 3.4.1 outlines the calibration and confirmation periods specified during model development.

**Table 3.4.1 Model calibration and confirmation periods.**

Model Development Phase	Period	Comment
Calibration	August 1, 1998 – August 1, 2000	Calibration start date corresponds to the earliest available USGS flow gaging data within the TMDL subwatersheds (Church St. gage – 02095271).
Confirmation	August 2, 2000 – August 1, 2001	One year confirmation period.

### 3.4.1 Hydrologic Calibration

In the hydrologic calibration simulated stream flows were compared to the observed stream flow at two USGS continuous recording stations on the North Buffalo Creek mainstem within the TMDL subwatersheds (see Figure 1.8.1 for a map of the station locations). Hydrologic parameters, including infiltration, upper and lower zone storage, groundwater storage and recession, interflow, and evapotranspiration, were adjusted within EPA recommended ranges (USEPA, 2000). Table 3.4.1.1 summarizes the hydrologic calibration statistics for reach 4 at Church Street - the downstream most USGS gaging station within the TMDL subwatersheds. Figure 3.4.1.1 and 3.4.1.2 illustrate predicted and observed flows at Church St.



**Table 3.4.1.1 Hydrologic calibration statistics for reach 4 at the Church Street USGS gage.**

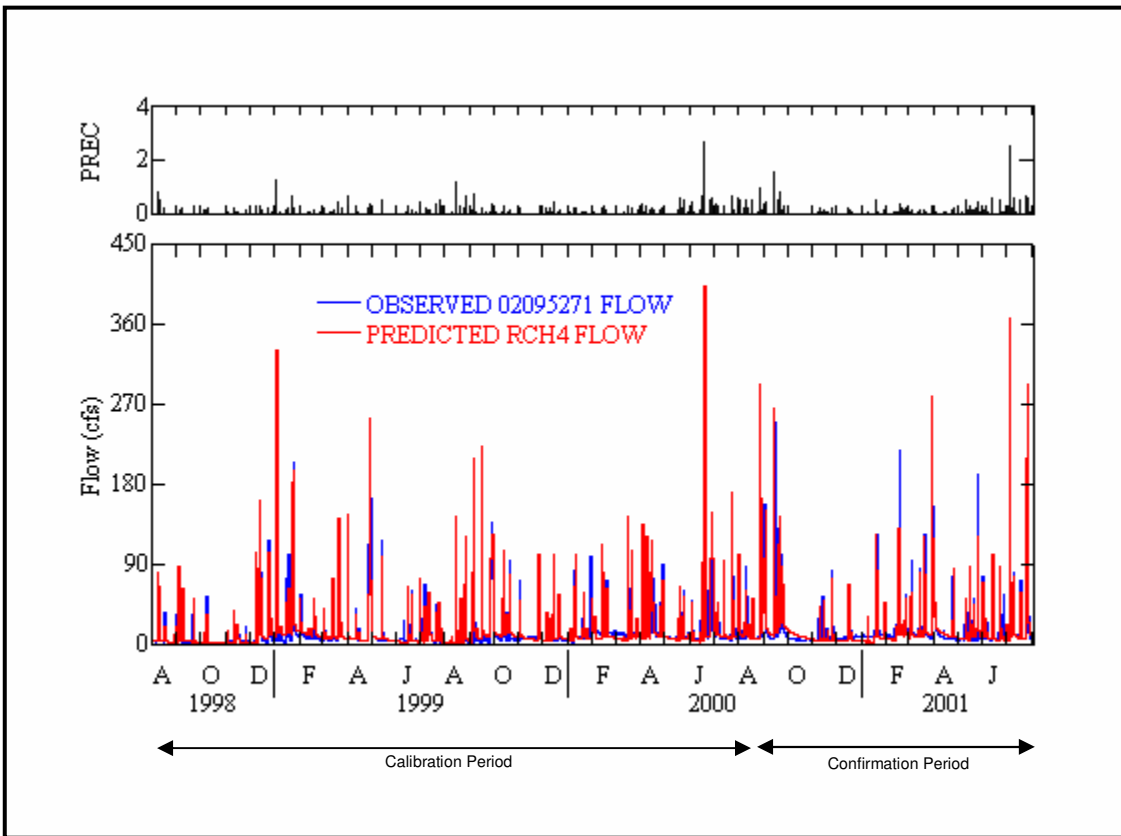
Calibration period: 8/1/98 – 8/1/00		Contributing area to subwatershed 4 outlet (mi <sup>2</sup> ): 14.3	
<b>Predicted Flow Volumes <sup>1</sup></b>		<b>Observed Flow Volumes <sup>1</sup></b>	
Total predicted instream flow:	35.6	Total observed instream flow:	32.9
Total of highest 10% flows:	19.5	Total of highest 10% flows:	17.3
Total of lowest 50% flows:	4.2	Total of lowest 50% flows:	4.2
Total of lowest 25% flows:	1.5	Total of lowest 25% flows:	1.3
Predicted Summer Flow Volume ( months 7-9):	9.4	Observed Summer Flow Volume ( months 7-9):	8.8
Predicted Fall Flow Volume (months 10-12):	6.3	Observed Fall Flow Volume (months 10-12):	5.7
Predicted Winter Flow Volume (months 1-3):	9.9	Observed Winter Flow Volume (months 1-3):	9.1
Predicted Spring Flow Volume (months 4-6):	10.0	Observed Spring Flow Volume (months 4-6):	9.3
<b>Prediction Error (predicted – observed)</b>		<b>Recommended Criteria <sup>2</sup></b>	
Error in total volume:	7.7%		10%
Error in 50% lowest flows:	0.7%		10%
Error in 10% highest flows:	11.4%		15%
Seasonal volume error - Summer:	7.2%		30%
Seasonal volume error - Fall:	8.9%		30%
Seasonal volume error - Winter:	7.8%		30%
Seasonal volume error - Spring:	7.3%		30%
Standard error <sup>3</sup> :	0.19		
R <sup>2</sup> <sup>3</sup> :	0.815		
Observed mean <sup>3</sup> :	0.95		
Number of observations:	732		

1 Flow volumes in inches normalized by watershed area.

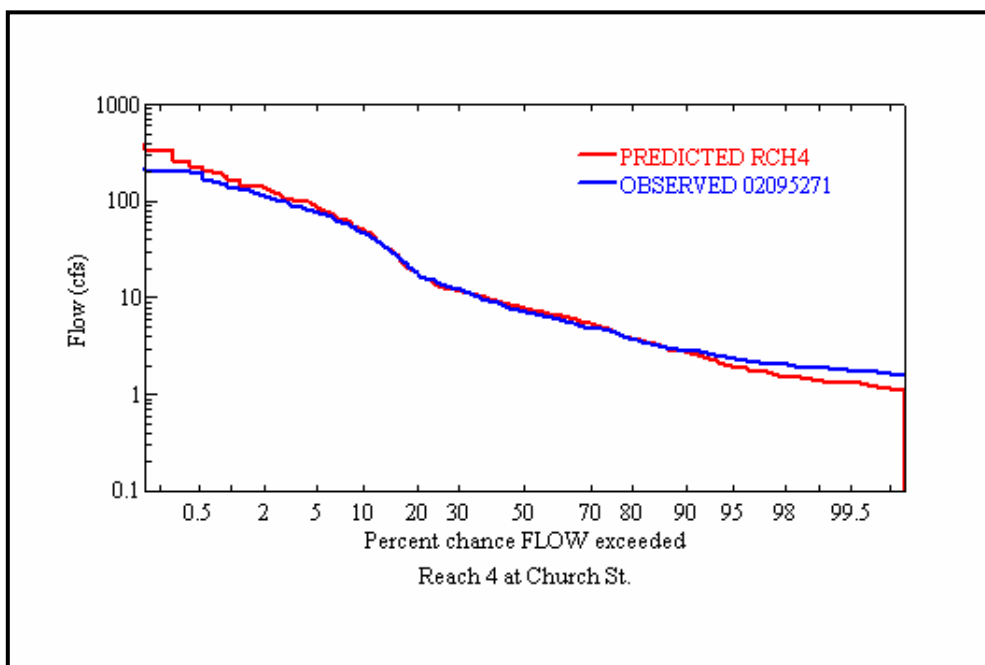
2 Adopted from the USGS HSPEXP – Expert System for Calibration of HSPF (USGS, 1994).

3 Statistics using log base 10.

**Figure 3.4.1.1 Observed versus predicted flows at Church Street (Reach 4).**  
(Units: Precipitation in inches and flow in cfs)



**Figure 3.4.1.2 Frequency distribution of observed and predicted stream flows at Church Street during the calibration period (8/1/98 – 8/1/00).**

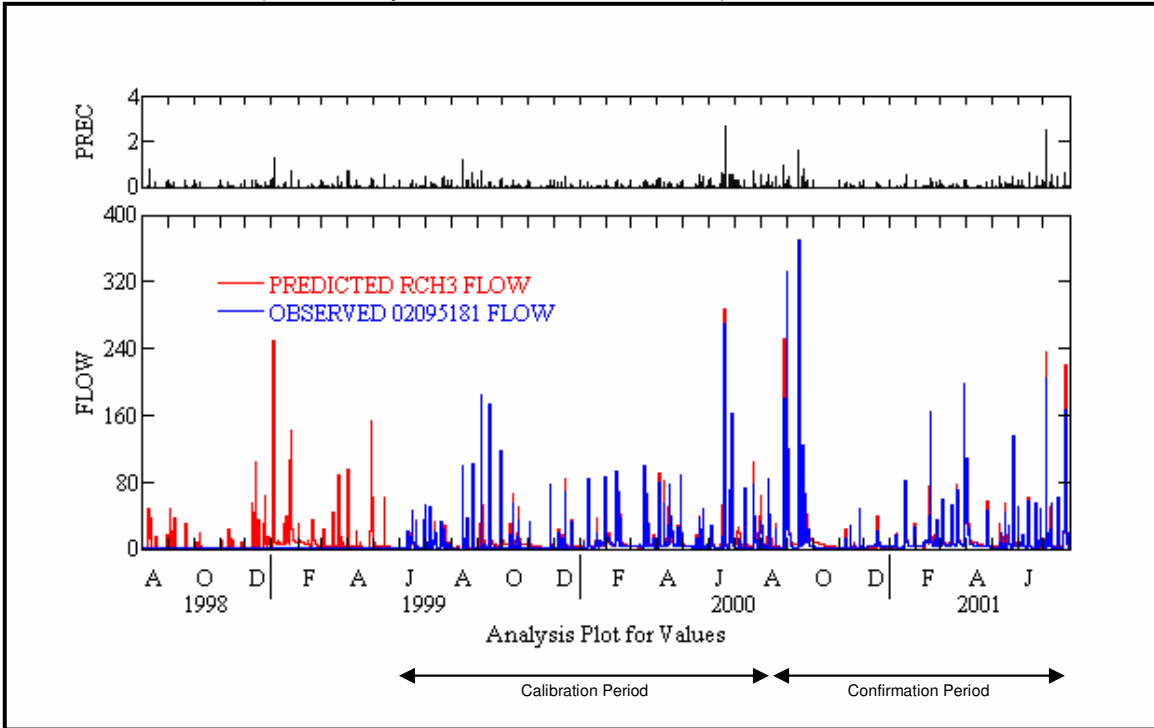


Figures 3.4.1.3 and 3.4.1.4 illustrate observed and predicted flows at Westover Terrace – the upstream most USGS gaging station.

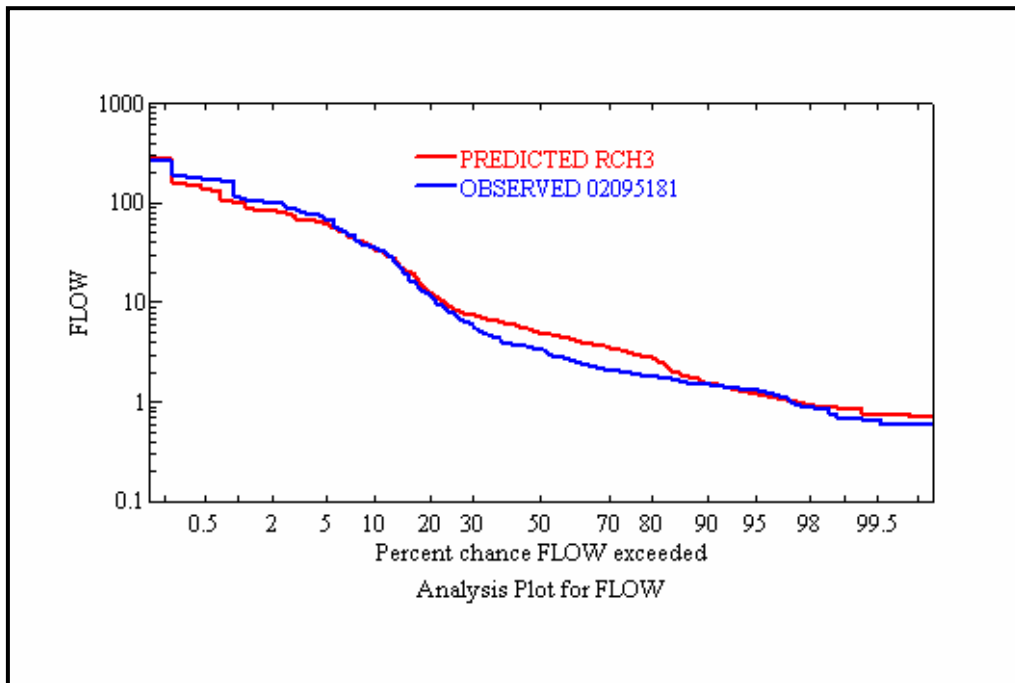
**Figure 3.4.1.3 Observed versus predicted flows at Westover Terrace (Reach 3).**

**Note: Westover Terrace gage began operation in June 1999.**

(Units: Precipitation in inches and flow in cfs)



**Figure 3.4.1.4 Frequency distribution of observed and predicted flows at Westover Terrace (Reach 3) during the calibration period.**



### 3.4.2 Water Quality Calibration

After the hydrologic calibration was completed the model was calibrated for water quality (fecal coliform) by adjusting model parameters within appropriate limits until an acceptable agreement between simulation output and instream observed data was achieved. The key model variables adjusted include:

- Rate of accumulation of fecal coliform on land (ACQOP)
- Maximum storage of fecal coliform (SQOLIM)
- Rate of surface runoff which will remove 90% of stored fecal coliform (WSQOP)
- Concentration of fecal coliform in interflow outflow (IOQC)
- Concentration of fecal coliform in groundwater outflow (AOQC)

Fecal coliform is one of the more challenging water quality parameters to accurately model. Observed instream fecal coliform concentrations, particularly in stormwater runoff, are notoriously variable. This is due in part to the fact that most concentrations represent a grab sample (discrete point in time) rather than a true flow composite sample.<sup>†</sup> In addition, there is often a significant amount of measurement variability when samples are counted. It is not unusual to find a one or more fold difference in reported fecal coliform concentrations between split samples. The transient nature of many of the sources, such as illicit discharges, also adds to the modeling challenge.

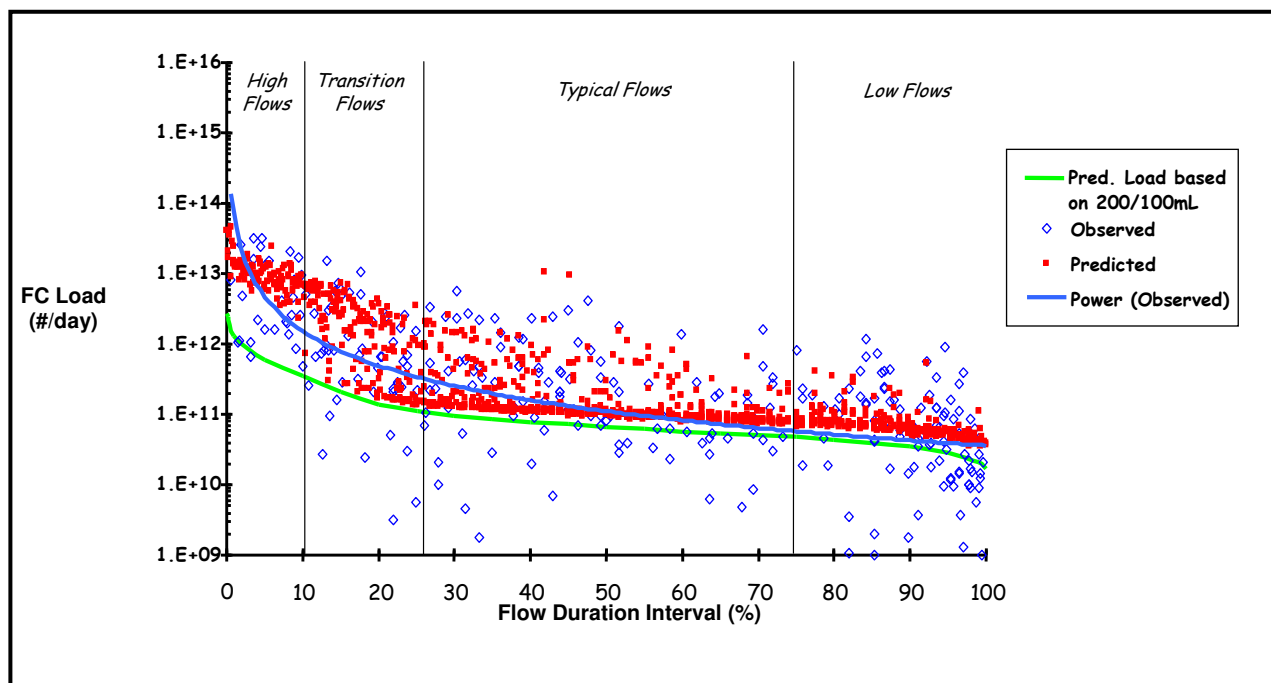
For these reasons and others, the water quality calibration strategy was to achieve agreement with general patterns in the observed data, rather than to attempt to fit the model output to individual instream observations. As subject to the available data, calibration proceeded in an upstream to downstream fashion. Additional emphasis was placed on the water quality calibration during dry weather (ambient) conditions, as this is generally the period of highest risk of exposure to pathogens by recreational users, and thus the period when most of the observed data has been collected (refer to Section 1.9 for a summary of the observed data).

Since TMDLs are designed to identify maximum loads a stream can assimilate and still meet water quality targets, it is helpful to compare predicted and observed loads. Daily fecal coliform loads (#/day) are calculated by taking the product of concentration (#/100mL), flow (cfs), and a conversion factor (24465755). Figure 3.4.2.1 illustrates predicted and observed daily fecal coliform loads at Summit Avenue during the calibration period. Since there is not a flow gage at Summit Avenue, modeled flows combined with observed fecal coliform concentrations measured by the Cone Mills WWTP were used to calculate observed fecal coliform loads. Note from the figure that a trend line reflecting the least squares fit through the observed data points suggest that the observed loads tend to be over the predicted allowable load (based on 200 cfu/100mL) throughout the various flow regimes. The departure from the allowable load tends to be greatest during high and transition flows and least during low flows.

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<sup>†</sup> Holding time restrictions often make composite sampling for fecal coliform impractical.

Figure 3.4.2.1 Observed and predicted fecal coliform loads at Summit Avenue during the calibration period (August 1998 – August 2000).



Note from Figure 3.4.2.1 that the predicted loads generally follow the trend of the observed loads over the spectrum of flows - indicating that the model can be used within reasonable bounds for supporting management decisions. Note though that the model does not predict well the lowest daily loads ( $<4.0 \times 10^{11}$ ). This is due in part to the fact that several of the modeled sources (such as illicit discharges, failing septic systems, and a portion of the waterfowl load) are represented as continuous, non-varying loads into a stream reach. This has the effect in the model of “establishing” a minimum load level during non-stormwater runoff periods. In reality, however, dry weather loads are not constant over time. For example, illicit discharges are often very transient in nature and vary tremendously in magnitude over time. The sporadic “low” observed loads over the various flow conditions could be a reflection of the transient nature of the actual loads throughout the watershed. Representing selected sources as continuous, non-varying loads is a conservative modeling assumption which is part of the implicit margin of safety built into the TMDL (refer to Part 4 for additional discussion on the margin of safety).

It is important to note that during the source assessment phase of the TMDL, the best available data were used to estimate loads from the various known sources. During model calibration these loads were not altered for the purposes of fitting the observed data.<sup>†</sup>

<sup>†</sup> The one identified source which is an exception to this statement is exfiltrating sanitary sewer lines. Loads from this source in subwatersheds 4 and 7 were varied from initial estimates when it became apparent that predicted instream FC concentrations were being underestimated. The lack of local data on

Table 3.4.2.1 is a comparison of geometric means between predicted and observed fecal coliform concentrations over four stream flow regimes during the calibration period.

**Table 3.4.2.1 Predicted geometric means over four flow regimes.<sup>1</sup>**

<b>Predicted Geometric Mean FC Concentration (#/100mL)</b>	<b>Observed Geometric Mean FC Concentration (#/100mL)</b>
High flows : 3,172	High flows : 1,790
Transition flows : 1,887	Transition flows : 736
Typical flows : 443	Typical flows : 423
Low flows : 390	Low flows : 209

<sup>1</sup> High flows: 559 (modeled peak) – 70 cfs; Transition flows: 69 – 22 cfs; Typical flows: 21 - 10 cfs;  
Low flows: 9 – 3.4 (modeled low) cfs

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exfiltrating sewer lines is a significant source of uncertainty in the model. Targeted field studies associated with this source are being planned to support implementation strategies.

## 4.0 Total Maximum Daily Load

A TMDL is the calculation of the maximum amount of pollutant loading that a receiving waterbody can assimilate while still achieving water quality standards. TMDLs include an allocation of that amount among point and nonpoint sources. In total a TMDL is comprised of the sum of wasteload allocations (WLA) for point sources, load allocations (LA) for nonpoint sources, and a margin of safety (MOS). This definition can be expressed as:

$$\text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

where:  $\sum$  WLA is the sum of the allowable loads from point sources and;  
 $\sum$  LA is the sum of the allowable loads from nonpoint sources and;  
MOS is the Margin of Safety

The margin of safety is intended to be an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The MOS in a TMDL can be provided implicitly through conservative analytical/modeling assumptions, or explicitly by reserving a portion of the assimilative capacity, or a combination of both methods (USEPA, 2000a).

Traditionally, geographically diffuse stormwater driven sources of fecal coliform have been classified as nonpoint sources of pollution. Compared to WWTP discharges, which in many respects have been the comparative basis for the definition of a point source, sources such as pets have generally been considered nonpoint sources.

In November 2002 EPA headquarters published guidance which clarifies the regulatory requirements for establishing wasteload allocations for stormwater discharges (USEPA, 2002). In summary, this guidance states that sources which are transported to a stream via a NPDES regulated stormwater system must be considered point sources, and thus be addressed in the wasteload allocation component of a TMDL. Since Greensboro is an NPDES Phase I community, pollutant loads from pets for instance, which are discharged to a stream reach via the stormwater conveyance system, must be considered as point sources. Pollutant loads from pets not discharged through the stormwater conveyance system can be considered nonpoint sources, and thus addressed by the load allocation component of a TMDL.

Since some runoff delivered sources, such as pets, are mobile and therefore impractical to determine the load delivered through the stormwater conveyance system using field data, a generic yet defensible method was needed to partition the WLA and the LA. In an effort to meet the EPA guidance, and after considering several alternatives, the stakeholders group decided to use the average impervious surface coverage within the TMDL subwatersheds, which is 26%, as the method for partitioning loads from runoff

driven sources between the WLA and LA categories. Since most of the impervious surfaces within the TMDL subwatersheds are connected to the NPDES permitted stormwater conveyance system, the consensus opinion of the stakeholders was that this method is reasonable and defensible. Table 4.0.1 summarizes the load percentage allocated to the WLA and LA categories for each source.

**Table 4.0.1 Partition of loads between the WLA and LA categories for each source.**

Source	WLA category	LA category
Pets	26%	74%
Other Sources	26%	74%
Sanitary Sewers	0%	100%
SSOs	0%	100%
Septic Systems	0%	100%
Waterfowl	0%	100%
Cone Mills WWTP	100%	0%
Illicit Discharges	100%	0%

#### **4.1 INSTREAM WATER QUALITY TARGET**

The underlying basis of a TMDL calculation is achieving a defined water quality target which represents a desired future condition of the waterbody. The desired condition for North Buffalo Creek is to have a stream which can be safely used for secondary recreation (as defined by DENR for Class C waters), specifically with respect to risks posed by human pathogens. In other words, users of the resource should expect a relatively low risk of contracting water borne diseases from bodily contact with the stream.

In most cases this target is expressed in a TMDL as an interpretation of the water quality standard for the pollutant of interest. NC's fecal coliform standard for Class C waters, which applies to North Buffalo Creek, is as follows (DENR, 2003):

*Fecal coliforms shall not exceed a geometric mean of 200/100ml (MF count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100ml in more than 20 percent of the samples examined during such period; violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution; all coliform concentrations are to be analyzed using the membrane filter technique unless high turbidity or other adverse conditions necessitate the tube dilution method; in case of controversy over results, the MPN 5-tube dilution technique shall be used as the reference method.*



NC's fecal coliform standard includes both numeric and narrative components. The numeric component defines threshold concentrations which should not be exceeded during a 30 day period. The narrative component suggests that these thresholds may not be achievable during rainfall events due to uncontrollable nonpoint sources. The application of NC's fecal coliform standard within a TMDL framework is subject to a variety of interpretations in large measure because of this narrative component.

For this TMDL two water quality targets are defined:

- ✓ one target for dry weather conditions;
- ✓ and another for all weather conditions, i.e. reflective of both wet and dry weather periods.

From a management and implementation perspective, having two targets makes sense for several reasons. First, the period of highest recreational use in North Buffalo Creek is during warm dry weather conditions. Naturally, this period should be a focus for implementation with the aid of a TMDL analysis. Second, dry weather sources of fecal coliform are often associated with human sources, such as illicit discharges and exfiltrating sanitary sewers. Human sources of fecal coliform tend to represent a higher disease risk than other sources (CWP, 1999). In addition, dry weather sources tend to be more technically feasible to control (although not necessarily less expensive to control). Thus, from an implementation perspective, achieving the dry weather target should be pursued first.

The dry weather water quality target is a logical management stepping stone towards the second objective of controlling stormwater driven sources. A second target, reflective of both wet and dry weather conditions, has been defined as the ultimate goal to pursue. This target may be very difficult to achieve within an urban environment due to the multitude and diversity of nonpoint sources - as the narrative portion of the standard suggests. However, the type of active ongoing stormwater management necessary to make progress towards meeting this target has widespread advantages for restoring and protecting the water resource.

#### **4.1.1 Dry Weather TMDL Target**

The dry weather TMDL target is defined as a geometric mean not to exceed 200/100mL based on samples collected at least 72 hours after the last measurable rainfall event over the course of any 30 day period. In addition, no more than 20% of these samples over the 30 day period are to exceed 400/100mL. Note that a minimum sample number is not specified as this can not always be guaranteed in the event of an unusually rainy period. For the TMDL calculation model predictions for days following a 72 hour dry period will be used.

#### **4.1.2 All Weather Conditions TMDL Target**

The all conditions TMDL target is defined as a geometric mean not to exceed 200/100mL based on 5 or more samples collected over the course of any 30 day period. No more than 20% of these samples over the 30 day period are to exceed 400/100mL. For the TMDL calculation all 30 daily model predictions are used. For compliance monitoring purposes, the 5 or more samples within a 30 day period should not intentionally be disproportionately reflective of wet or dry conditions.

#### **4.1.3 TMDL Watershed Compliance Point**

The TMDL compliance point is the location along North Buffalo Creek at which the TMDL calculation will be made. The compliance point also represents the location where long-term monitoring will be conducted to gauge progress towards achieving the two water quality targets defined above.

North Buffalo Creek at Summit Avenue has been designated as the TMDL compliance point. Summit Avenue represents the safest, readily accessible, public access point at the downstream end of the impaired reach as designated in NC's 2002 Integrated 305(b) and 303(d) List.

### **4.2 MARGIN OF SAFETY AND MODEL UNCERTAINTY**

According to federal rules a margin of safety must be included in all TMDLs to provide a measure of assurance that the impaired waterbody will meet water quality targets once load reductions are realized. The MOS is intended to offset model uncertainty about the relationship between pollutant loads and receiving water quality. There is uncertainty associated with all modeling endeavors since computer models do not perfectly simulate the complexities of natural systems. Factors such as field and laboratory measurement error, lack of source assessment information - particularly associated with estimating time variable loads from unmonitored sources, model error, and gaps in our scientific knowledge, all contribute to model uncertainty. Unfortunately, most mechanistic models, including WinHSPF, do not include formal statistical procedures for estimating model uncertainty. Hence, the choice of a MOS is somewhat arbitrary, but made in good faith using best professional judgment.

In TMDLs the MOS can be *implicit* through the use of conservative modeling assumptions and analytical techniques; or *explicit* by reserving a portion of the loading capacity; or a combination of both methods. For this TMDL both an explicit and implicit MOS was incorporated. An explicit MOS is achieved through the use of water quality targets based on **180 counts/100mL** instead of 200/100mL. In addition, an implicit MOS is included through the use of conservative modeling techniques, such as assuming that selected sources contribute loads on a continuous basis, when in reality they probably do

not (see Section 4.1.3 for additional discussion). Therefore, model results should be carefully interpreted in light of the model limitations and prediction uncertainty.

### 4.3 SEASONAL VARIATION

Federal rules require consideration of season variation in watershed conditions and pollutant loads during development of the TMDL. Through the use of a dynamic continuous simulation model over a 3 year period (August 1998 – August 2001) seasonal variations have been incorporated into the TMDL calculation.

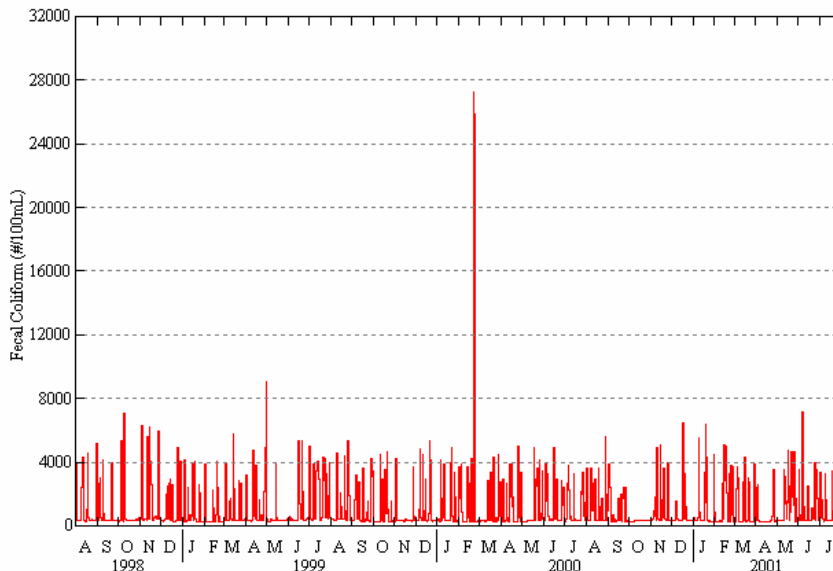
### 4.4 PREDICTED EXISTING WATER QUALITY CONDITIONS

Using the calibrated model continuous daily average water quality conditions can be analyzed. The model predictions are used to develop insights into the relative contributions of the various sources under different weather conditions. In addition, existing loads can be estimated and the deviation from the allowable load can be quantified. With this information at hand, management decisions can be made as to how the allowable load should be allocated to meet the two water quality targets.

#### 4.4.1 Predicted Existing Water Quality Under All Weather Conditions

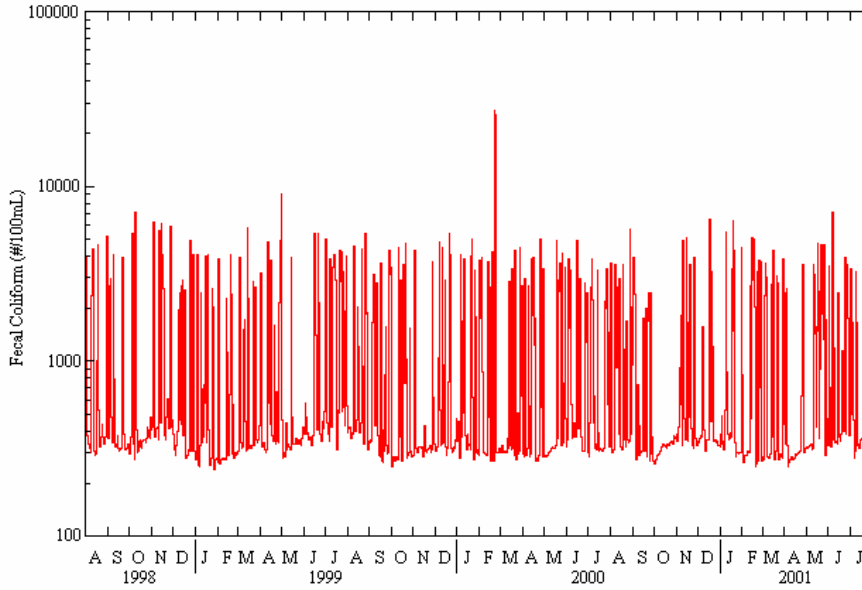
Figures 4.4.1.1 and 4.4.1.2 illustrate predicted existing fecal coliform concentrations in North Buffalo Creek at Summit Avenue displayed using arithmetic and log scales, respectively. Figure 4.4.1.3 illustrates the rolling 30-day geometric mean of predicted fecal coliform concentrations at Summit Avenue under existing conditions. Note from Figure 4.4.1.3 that the predicted 30-day geometric mean is consistently above 200/100mL throughout the simulation period.

**Figure 4.4.1.1 Predicted fecal coliform concentrations at Summit Avenue under existing conditions (arithmetic scale).**



*Note that the spike in predicted fecal coliform concentration which occurred in February 2000 was associated with an SSO.*

**Figure 4.4.1.2 Predicted fecal coliform concentrations at Summit Avenue under existing conditions (log base 10 scale).**



**Figure 4.4.1.3 Predicted rolling 30-day geometric mean fecal coliform concentration at Summit Avenue under existing conditions.**

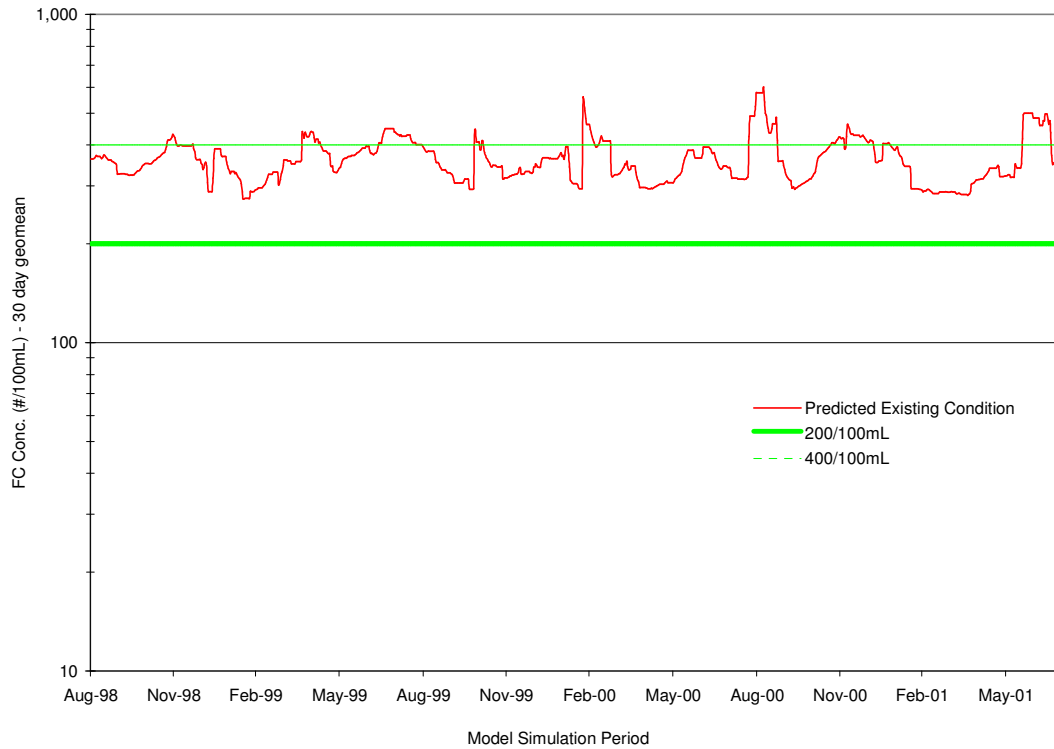


**4.4.2 Predicted Existing Water Quality Under Dry Weather Conditions**

The objective of the dry weather assessment was to evaluate instream conditions during a period when the effects of fecal coliform loads from surface runoff are minimized. To assess instream water quality under dry weather conditions a list of dates was compiled which represent days in which 72 or more hours had elapsed without any measurable rainfall (refer to Appendix 2 for the list of dry weather days). Precipitation data collected at the USGS Church Street rain gage, centrally located within the TMDL subwatersheds, was used as the source for rainfall measurements. In this report these dates are referred to as *dry weather days*. This definition approximates the actual criteria used by many NC local governments for identifying when conditions are appropriate for dry weather instream sampling.

Within the model simulation period predicted daily fecal coliform concentrations for dry weather days were compiled. A rolling geometric mean of all predicted dry weather day fecal coliform concentrations within a 30 consecutive day period was calculated (Figure 4.4.1.4). Note from Figure 4.4.1.4 that the 30 day geometric means are significantly lower when the effect of stormwater driven loads are minimized. However, geometric means are still consistently above the 200/100mL water quality target.

**Figure 4.4.1.4 Predicted rolling 30-day geometric mean fecal coliform concentration at Summit Avenue under existing dry weather conditions.**

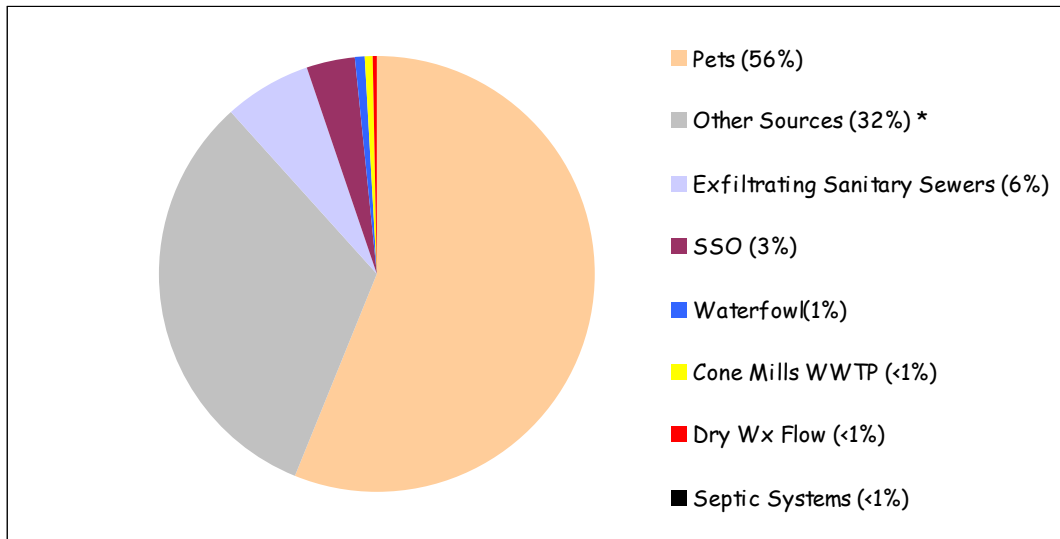


## 4.5 TMDL AND ALLOCATION FOR ALL WEATHER CONDITIONS

The data presented in Section 4.4 above, shows that geometric mean fecal coliform concentrations are consistently higher when rainfall runoff is factored into the analysis, as compared to dry weather only conditions. Stormwater driven nonpoint sources are widely recognized in most fecal coliform TMDLs as being significant contributors of watershed bacterial loads. The findings from this analysis appear to be consistent with a situation where stormwater-driven nonpoint sources are one of the major causes of water quality impairment.

Using the calibrated model an analysis was conducted to estimate the relative percentage of delivered load to Summit Avenue from each of the source categories over the full simulation period. The delivered load is that portion of the total load generated in the watershed and transported downstream to Summit Avenue. Hence, the delivered load reflects the various bacterial die-off processes simulated in the model. Figure 4.5.1 illustrates the relative load contributions from each source.

**Figure 4.5.1 Percentage of delivered load to Summit Avenue from each source category over the full simulation period.**



\* When interpreting this pie chart it is important to keep in mind that *Other Sources* represent the load which could not reasonably be accounted for in the source assessment using the best available data. The *Other Sources* category could include for instance loads from unknown wildlife populations. However, contributions from *Other Sources* could also reflect an underestimation of the loads from one or more of the identified sources.

Note that pets (dogs and cats) are estimated to account for the largest percentage of delivered load over the full simulation period - which includes both wet and dry weather conditions. *Other Sources* are estimated to account for approximately one third of the delivered load. It is important to keep in mind that *Other Sources* represent a category which might include unknown wildlife populations or other unidentified source types. However, it is also reasonable to assume that loads from *Other Sources* could potentially include contributions which were underestimated from one or more of the identified

source types. In other words, it is possible that the load from pets, for instance, could be greater than what is reflected in Figure 4.5.1.

From Figure 4.5.1 it is clear that stormwater-driven sources have to be a focus during allocation. However from Figure 4.4.1.4, which illustrates that geometric mean concentrations are also elevated during dry weather conditions, it is evident that reducing stormwater-driven loads alone will not result in achieving the water quality target. **Hence, a balanced allocation incorporating both stormwater and non-stormwater driven sources is needed to meet the all conditions water quality target.**

To calculate the TMDL, load reductions were taken from the calibrated model until all of the 30 day geometric means were below the target threshold of 180/100mL (which includes the explicit margin of safety). In addition, the model output was assessed to ensure that no more than 6 (20%) of the daily fecal coliform predictions were greater than 400/100mL, in accordance with the all conditions water quality target. Figure 4.5.2 illustrates the predicted rolling 30 day geometric mean fecal coliform concentration at Summit Avenue after load reductions were applied to the calibrated model. Table 4.5.1 summarizes predicted gross loads from each source before and after modeled reductions are employed.

**Figure 4.5.2 Predicted geometric mean fecal coliform concentration at Summit Avenue before and after load reductions were applied to the calibrated model.**



**Table 4.5.1 Predicted loads from each source during the all weather conditions water quality target critical period (11/9/98 – 12/8/98).**

Source Category	Source	FC Load Under Existing Conditions (#/30 days)	FC Load After Reduction (#/30 days)
WLA & LA	Pets	1.42E+13	4.23E+11
WLA & LA	Other Sources	8.48E+12	2.53E+11
LA	Sanitary Sewers	1.01E+12	1.61E+11
LA	SSOs	1.50E+10	7.70E+09
LA	Septic Systems <sup>1</sup>	9.57E+09	5.55E+08
LA	Waterfowl <sup>2</sup>	5.78E+11	No reduction
WLA	Cone Mills WWTP <sup>3</sup>	3.90E+11	No longer discharging
WLA	Illicit Discharges	2.42E+11	9.67E+10

- 1 Failing septic systems are estimated to be a minor contributor of fecal coliform loads to the watershed and technically a large reduction is not needed to achieve the target. However, since failing septic systems are a controllable source, and since human sources of fecal coliforms are generally recognized as representing a greater disease risk, a large reduction was applied.
- 2 Due to the practical difficulties of controlling waterfowl populations, no reduction from this source was applied.
- 3 Cone Mills WWTP no longer discharges directly to North Buffalo Creek as of the summer of 2001.

For the TMDL calculation the **critical 30 day period** was identified as 11/9/98 – 12/8/98. This period corresponds to the 30 day period with the highest geometric mean fecal coliform concentration after load reductions were taken. It is interesting to note from Figure 4.5.2 that the critical period is not the same as the period of highest geometric mean concentrations under existing conditions.

This is due in part to the fact that the summer and fall of 1998 was an exceptionally dry period. In the three months (August, September, and October 1998) leading up to the critical period, the cumulative rainfall total was 6.07 inches as measured at the Church Street rain gage. This compares to the long term (68 year) average rainfall total of 10.93 inches for those same three months as measured at the airport (PTIA). Hence, for the three months leading up to the critical period rainfall was approximately 4.9 inches below normal.

Rainfall during the critical period totaled 2.01 inches. This compares to a long term average rainfall for the month of November of 2.82 inches. The notable dry spell preceding the critical period allowed land-based fecal coliform loads to buildup across the watershed. Although rainfall during the critical period was somewhat below average also, there was sufficient rain to transport these loads into the stream. To compound the problem, low stream flows during the critical period minimized the beneficial effects of dilution, so direct loads to the stream from waterfowl, exfiltrating sanitary sewers, etc, also contributed significantly to the elevated bacterial concentrations.



The same load reductions applied during wetter conditions, e.g. July 1999, have a larger affect on reducing geometric mean fecal coliform concentrations, as shown in Figure 4.5.2. During July 1999, for example, rainfall totaled 7.12 inches as compared to a long term average for the month of July of 4.5 inches. The significant amount of runoff which occurred during July 1999 contributed to one of the highest predicted geometric mean fecal coliform concentrations within the simulation period. However, mean stream flow for July 1999 was approximately double the mean flow during the TMDL critical period (5.6 cfs vs. 2.8 cfs, respectively as measured at the Church St USGS gage). The additional instream dilution available during July 1999, as compared to that in November 1998, is part of the reason why load reductions have a larger predicted effect during wetter conditions.

**Table 4.5.2 specifies the percent reductions needed from the major allocation categories to meet the TMDL requirements associated with the all weather conditions water quality target.** Individual sources (i.e. pets, waterfowl, etc.) have been grouped into categories to facilitate the distribution of responsibility for implementation. For example, the MS4 allocation category represents that portion of the fecal coliform load which is to be addressed through implementation strategies managed as part of the City of Greensboro's NPDES stormwater permit. Implementation of load reduction measures associated with the Nonpoint Source (NPS) allocation category will be addressed through other local government programs. For the sake of completeness, the Cone Mills WWTP is presented as an individual allocation category, since implementation is specifically associated with a NPDES wastewater discharge permit. However, since this facility was no longer discharging by the end of the TMDL simulation period, a TMDL load reduction is not applicable (N/A).

**Table 4.5.2 Percent load reductions necessary to meet TMDL requirements associated with the all weather conditions water quality target.**

TMDL Allocation Category	TMDL % Reduction
MS4 <sup>1</sup>	96%
Nonpoint Sources <sup>2</sup>	93%
Cone Mills WWTP <sup>3</sup>	N/A

- 1 MS4 = Municipal Separate Storm Sewer System. This allocation category includes that portion of the load from pets, Other Sources, and the full load from illicit discharges, which are transported to the receiving stream via the NPDES permitted municipal stormwater conveyance system.
- 2 The nonpoint source TMDL allocation category includes that portion of the load from pets, Other Sources, and the full loads from exfiltrating sanitary sewers, SSOs, failing septic systems, and waterfowl which are transported to the receiving stream by means other than the MS4.
- 3 Since the Cone Mills WWTP is no longer discharging, a load reduction is not applicable for the purposes of this TMDL.

Table 4.5.3 outlines the sum of the WLAs and LAs for the all weather conditions TMDL. To calculate the sum of the WLAs and LAs, loads for each source (after reductions were taken as presented in Tables 4.5.1 and 4.5.2) were partitioned between the two TMDL components as summarized in Table 4.0.1.

**Table 4.5.3 TMDL components to meet the all weather conditions water quality target.**

$\sum$ WLA (#/30 days)	$\sum$ LA (#/30 days)	MOS	TMDL (#/30 days)
2.73E+11	1.25E+12	Explicit <sup>1</sup> and Implicit	1.52E+12

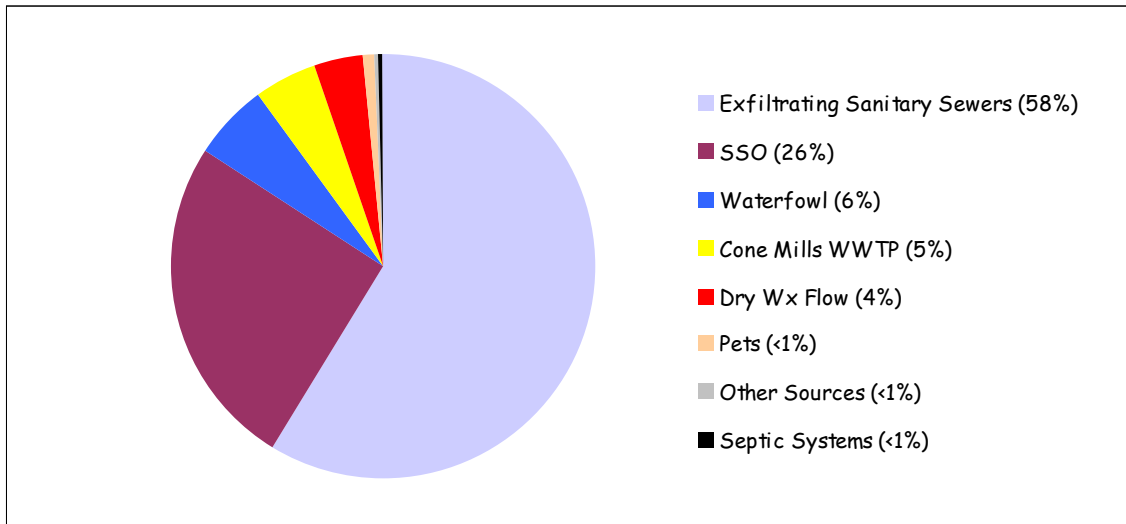
1 Explicit Margin of Safety (MOS) is equivalent to 10% of the 30 day geometric mean fecal coliform water quality standard.

#### 4.6 TMDL AND ALLOCATION FOR DRY WEATHER CONDITIONS

Managing fecal coliform loads is a complex and difficult task, especially in urban watersheds containing a wide variety of potential sources. From a management perspective in an urban watershed, focusing resources on the control of dry weather loads should be the first step. Dry weather fecal coliform loads are often associated with human sources which are generally recognized as representing a greater risk of disease. In addition, the recreational use of North Buffalo Creek is generally higher during dry weather periods. These combination of factors warrant development of a dry weather TMDL to serve as a guide for targeting implementation strategies.

Using the calibrated model, an analysis was conducted to estimate the relative percentage of delivered load to Summit Avenue from each of the source categories during dry weather conditions (72 or more hours after a measurable rainfall event). Figure 4.6.1 illustrates the relative delivered load contributions to Summit Avenue from each source.

**Figure 4.6.1 Percentage of delivered load to Summit Avenue from each source category during dry weather conditions occurring over the full model simulation period.**

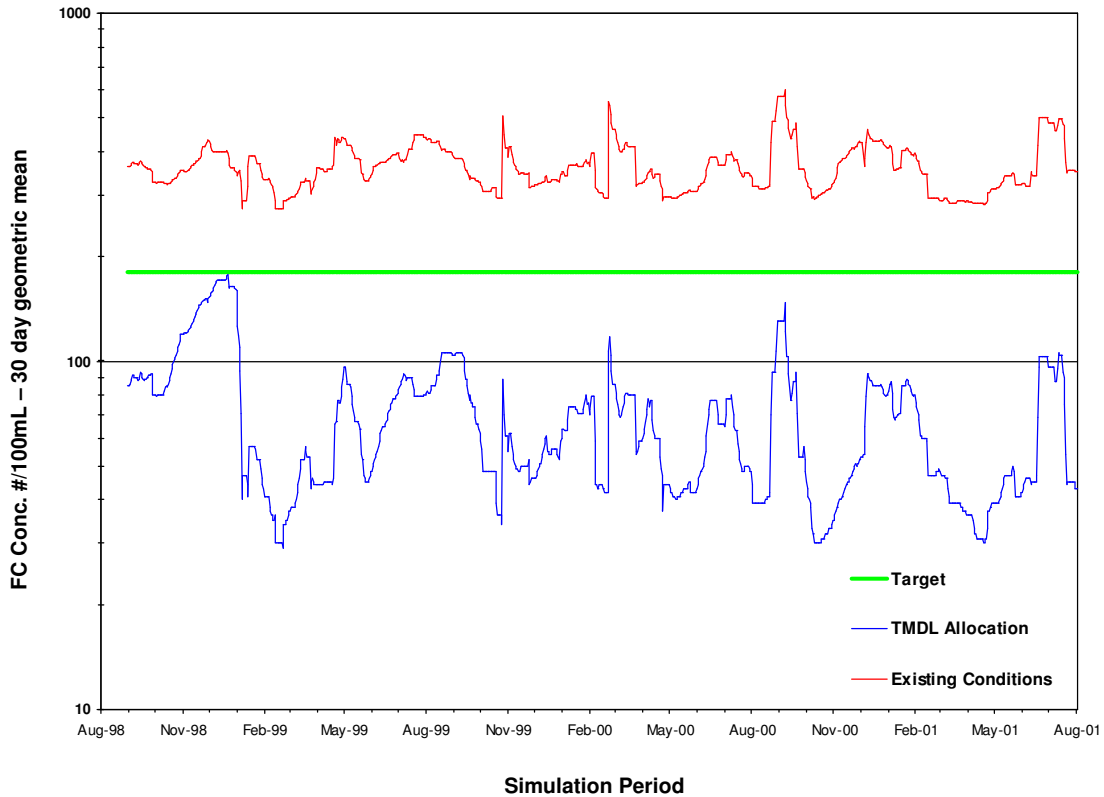


Note from Figure 4.6.1 that over three quarters of the total delivered dry weather load to Summit Avenue is from human sources (exfiltrating sanitary sewers and SSOs). The

residual precipitation induced load from sources such as pets and Other Sources is negligible, which verifies that 72 hours or more hours after a rainfall event is adequate for defining dry weather conditions.

From Figure 4.6.1 it is clear that reducing the loads from exfiltrating sanitary sewers and SSOs have to be a focus in order to meet the dry weather water quality target. To calculate the dry weather TMDL, load reductions were taken from the calibrated model until the geometric mean of fecal coliform concentrations for dry weather days during any 30 day period were below the target threshold of 180/100mL. In addition, the model output was assessed to ensure that no more than 20% of the daily dry weather fecal coliform concentrations were greater than 400/100mL, in accordance with the dry weather water quality target. Figure 4.6.2 illustrates the predicted rolling geometric mean of dry weather fecal coliform concentrations over any 30 day period at Summit Avenue.

**Figure 4.6.2 Predicted dry weather geometric mean fecal coliform concentration at Summit Avenue before and after load reductions were applied to the calibrated model.**



Note from Figure 4.6.2 above that the critical period, i.e. the 30 day period preceding the highest predicted geometric mean concentration, is very similar to the critical period reflective of all weather conditions. For the dry weather TMDL the critical period was identified as 11/9/98 – 12/8/98. Recall from the discussion in Section 4.5, the summer and fall of 1998 was an especially dry period with very low stream flows to provide dilution of pollutant loads. Table 4.6.1 summarizes predicted gross loads from each source before and after modeled reductions are employed during dry weather conditions.

**Table 4.6.1 Predicted loads from each source during the dry weather conditions water quality target critical period (11/9/98 – 12/8/98).**

Source Category	Source	Dry Weather FC Load Under Existing Conditions (#/30 days)	Dry Weather FC Load After Reduction (#/30 days)
WLA & LA	Pets	3.76E+09	No reduction <sup>1</sup>
WLA & LA	Other Sources	1.13E+09	No reduction <sup>1</sup>
LA	Sanitary Sewers	2.63E+11	9.81E+09
LA	SSOs	No SSOs occurred during the critical period	
LA	Septic Systems	5.07E+09	2.40E+08 <sup>2</sup>
LA	Waterfowl	9.67E+10	No reduction
WLA	Cone Mills WWTP	6.57E+10	No longer discharging <sup>3</sup>
WLA	Illicit Discharges	6.82E+10	1.85E+10

- 1 No reductions in precipitation driven sources, such as pets and Other Sources, is warranted during dry weather conditions as these sources are negligible contributors.
- 2 Failing septic systems are estimated to be a minor contributor of fecal coliform loads to the watershed and technically a large reduction is not needed to achieve the target. However, since failing septic systems are a controllable source, and since human sources of fecal coliforms are generally recognized as representing a greater disease risk, a large reduction was applied.
- 3 Cone Mills WWTP no longer discharges directly to North Buffalo Creek as of the summer of 2001.

Table 4.6.2 specifies the percent reductions needed from the major allocation categories to meet the TMDL requirements associated with the dry weather conditions water quality target. During dry weather conditions, illicit discharges to the stormwater conveyance system are the only individual source type which contributes significant fecal coliform loads via the MS4.

**Table 4.6.2 Percent load reductions necessary to meet TMDL requirements associated with the dry weather conditions water quality target.**

TMDL Allocation Category	TMDL % Reduction
MS4 <sup>1</sup>	72%
Nonpoint Sources <sup>2</sup>	70%
Cone Mills WWTP <sup>3</sup>	N/A

- 1 MS4 = Municipal Separate Storm Sewer System. This allocation category includes that portion of the load from pets, Other Sources, and the full load from illicit discharges, which are transported to the receiving stream via the NPDES permitted municipal stormwater conveyance system. During dry weather conditions, illicit discharges are the only individual source type which contributes significant fecal coliform loads from the MS4.
- 2 The nonpoint source TMDL allocation category includes that portion of the load from pets, Other Sources, and the full loads from exfiltrating sanitary sewers, SSOs, failing septic systems, and waterfowl which are transported to the receiving stream by means other than the MS4.
- 3 Since the Cone Mills WWTP is no longer discharging, a load reduction is not applicable for the purposes of this TMDL.

Table 4.6.3 outlines the sum of the WLAs and LAs for the dry weather conditions TMDL. To calculate the sum of the WLAs and LAs, the loads for each source after reductions were taken (as presented in Table 4.6.1), and partitioned between the two categories as summarized in Table 4.0.1.

**Table 4.6.3 TMDL components to meet the dry weather conditions water quality target.**

$\Sigma$ WLA (#/30 days)	$\Sigma$ LA (#/30 days)	MOS	TMDL (#/30 days)
1.98E+10	1.10E+11	Explicit <sup>1</sup> and Implicit	1.30E+11

1 Explicit Margin of Safety (MOS) is equivalent to 10% of the 30 day geometric mean fecal coliform water quality standard.

## 5.0 Summary and Future Considerations

Observed instream monitoring data in North Buffalo Creek and its tributaries indicate that fecal coliform concentrations are above acceptable levels during both dry and wet weather conditions. The sources of fecal coliform in this urban watershed are many and diverse. In order to make effective, measurable progress at reducing loads, it will be important to target implementation efforts in a systematic fashion. A key to success will be to divide implementation strategies into two categories: one which focuses on addressing dry weather sources, and another which focuses on stormwater driven sources. To support the development of these strategies, this document includes a TMDL for dry weather conditions and another TMDL reflective of all weather (both wet and dry) conditions.

The dry weather source assessment and TMDL suggests that human sources of fecal coliform, such as exfiltrating sanitary sewer lines and SSOs, are primary contributors. Achieving measurable reductions in instream fecal coliform concentrations during dry weather depends in large measure on controlling these sources. Mapping the major components of the sanitary sewer collection system is an important component of the implementation strategy. The control of other sources, such as illicit discharges to the stormwater conveyance system, may also be a key to a successful implementation strategy.



*Aging sanitary sewer lines, especially those constructed with short sections (2') of clay pipe as shown above, have the potential to be significant sources of bacterial contamination due to leaks at the joints. Mapping the major components of the sanitary sewer collection system will be an important foundation to future implementation strategies.*

One of the primary benefits of a TMDL comes from compiling and analyzing data about sources in the watershed. Although exfiltrating sanitary sewers are estimated to be an significant source within the watershed, an important consideration to keep in mind is that very little local data exists to quantify loads from this source. In this TMDL studies from another NC local government and best professional judgment were relied upon to estimate loads from exfiltrating sewers. Therefore, successful implementation must first be preceded by local studies to further our understanding of this source.

During stormwater runoff conditions, dogs and cats are estimated to be significant sources. Reducing fecal coliform loads from pets is especially difficult because the most effective strategies involve changing the behavior of pet owners. Pet waste ordinances requiring owners to clean up after their pets are often not very effective as a primary

management strategy. Few local governments have the resources to enforce such an ordinance. Rather, a community culture must be developed where citizens expect and demand that pet owners clean up after their animals. This will require a targeted long-term public education campaign.

## **ADDITIONAL MONITORING**

In the spring of 2003 Greensboro's Department of Water Resources initiated a follow up study of dry weather fecal coliform sources in the watershed. This study is supported by aerial infrared imagery taken in March 2003 to aid in the detection of illicit discharges from the stormwater conveyance system and other sources. A primary goal of this study is to target specific catchments within the TMDL area and identify actions to be taken as part of a comprehensive implementation strategy.

Greensboro is one of a number of municipalities providing support for a Microbial Source Tracking (MST) study managed by the NC Division of Water Quality. North Buffalo Creek is one of several streams statewide being investigated using MST technologies. While considerable effort went into the source assessment for this TMDL, the MST study may provide additional insight as to the importance of sources such as wildlife, for which very little is known.



*Wildlife, such as the raccoon who left this track, were grouped and accounted for in this TMDL with other unknown sources for which no field data was available. The MST study currently underway may provide some insight as to the importance of wildlife as a source of fecal coliform contamination in North Buffalo Creek.*

Public education initiatives aimed at encouraging citizens to use tight fitting trash can lids, and other proper solid waste disposal practices, can be effective at discouraging nuisance urban wildlife. However, a balanced wildlife population is an important component of a healthy ecosystem. Future implementation strategies targeted towards wildlife populations will need to be carefully considered.

## **WATERSHED-BASED PLANNING**

Greensboro's Department of Water Resources is currently engaged in a multi-year effort to develop stormwater masterplans for each of the major watersheds within its jurisdictions. The objective of each plan is to identify the major water quantity and quality issues within the watershed and outline structural and nonstructural BMPs to correct/minimize the identified problems. The South Buffalo Creek watershed masterplan was completed in 2002, and the draft Horsepen Creek watershed masterplan was completed in the spring of 2003. The City's Horsepen Creek planning process



included significant support for, and coordination with DWQ's Watershed Assessment and Restoration Project (WARP), to add value to both water quality improvement initiatives. Such multi-agency cooperative efforts are essential for solving complex urban water quality challenges. The City of Greensboro will continue its tradition of supporting the Division of Water Quality and other organizations dedicated to improving water quality and restoring impaired uses.

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## Appendix 1 Instream Fecal Coliform Monitoring Data

<b>Piedmont Triad Council of Governments Sampling Data</b> <b>All Stations in North Buffalo Creek</b>  <b>Fecal coliform concentrations - #/100mL (<i>Hours since previous rainfall</i>)</b> <b>Source: PTCOG, 2003</b>					
Date	Market St. (Subwatershed 1)	Elam St. (Head of subwatershed 3)	Garland Ave. (subwatershed 4)	Cridland Ave. (subwatershed 4)	Church St. (outlet of subwatershed 4)
6/5/2001		515 (72)			
6/11/2001	1,081 (96)	1,182 (96)	800 (96)	786 (96)	891 (96)
6/18/2001	540 (48)	740 (48)	600 (48)	6,000 (48)	365 (48)
6/20/2001	2,400 (96)		840 (96)		
7/23/2001	890 (96)	520 (96)	1,140 (96)	211 (96)	1,100 (96)
8/6/2001	493 (72)	510 (72)	1,040 (72)	460 (72)	280 (72)
8/8/2001	1,000 (120)	300 (120)	1,140 (120)	370 (120)	150 (120)
8/17/2001	880 (72)	595 (72)	2,300 (72)	620 (72)	460 (72)
8/23/2001	820 (72)	1,060 (72)	1,220 (72)	840 (72)	500 (72)
9/10/2001	1,230 (120)	550 (120)	585 (120)	483 (120)	200 (120)
9/17/2001	853 (144)	300 (144)	780 (144)	430 (144)	181 (144)
9/18/2001	250 (168)	194 (168)	1,530 (168)	390 (168)	210 (168)
10/2/2001	507 (72)	131 (72)	540 (72)	373 (72)	200 (72)
10/4/2001	690 (72)	445 (72)	730 (72)	195 (72)	220 (72)
10/17/2001	790 (48)				
10/30/2001	200 (72)	88 (72)	250 (72)	105 (72)	200 (72)
11/1/2001	350 (48)				
12/5/2001	600 (48)				
12/20/2001	330 (48)				
5/8/2002		947 (72)	800 (72)		
7/18/2002		800 (48)	800 (48)		
10/22/2002	3,300 (72)	2,200 (72)	3,400 (72)	3,400 (72)	3,700 (24)
10/24/2002	760 (96)	460 (96)	3,900 (96)	700 (96)	720 (72)
10/30/2002	2,500 (96)	5,000 (96)	3,600 (96)	5,656 (96)	5,500 (96)
11/7/2002	1,267 (48)	860 (48)	2,467 (48)	4,900 (48)	460 (48)
11/13/2002	960 (24)	2,300 (24)	2,600 (24)	3,550 (24)	3,867 (24)
11/18/2002	600 (36)	2,350 (36)	2,600 (36)	2,350 (36)	2,950 (36)
11/19/2002	580 (48)	600 (48)	2,150 (48)	1,530 (48)	2,300 (na)
12/16/2002		968 (48)	968 (48)		

PTCOG Sampling Data - continued					
Date	Market St. (Subwatershed 1)	Elam St. (Head of subwatershed 3)	Garland Ave. (subwatershed 4)	Cridland Ave. (subwatershed 4)	Church St. (outlet of subwatershed 4)
12/18/2002			1,180 ( <i>na</i> )		
12/19/2002					400 ( <i>na</i> )
1/30/2003			1,060 ( <i>na</i> )		
2/24/2003		440 ( <i>24</i> )			
Shading indicates data collected outside the model simulation period. These data are presented for information purposes, but were not used for model calibration.					

Greensboro Stormwater Management Division Sampling Data All Stations Except 16 <sup>th</sup> St. in North Buffalo Creek				
Fecal coliform concentrations - #/100mL Source: Greensboro Stormwater Management Division				
Date	Arboretum (subwatershed 1)	Aycock St. (outlet of subwatershed 3)	Church St. (outlet of subwatershed 4)	16th St. (subwatershed 7)
7/9/1996	4,200			
8/13/1996	8,900			
9/10/1996	4,500			
10/9/1996	2,200			
11/12/1996	520			
12/10/1996	560			
1/13/1997	210			
2/11/1997	140			
3/11/1997	220			
4/8/1997	460			
5/13/1997	1,200			
6/10/1997	790			
7/8/1997	10,000			
8/12/1997	1,400			
9/9/1997	1,900			
10/14/1997	750			
11/14/1997	240			
12/10/1997	19,000			
1/13/1998	2,000			
2/10/1998	260			
3/10/1998	500			
4/14/1998	5,800			
5/12/1998	1,200			
6/9/1998	1,400			
7/14/1998	1,200			
10/12/1998	3,700			
1/13/1999	270			
4/14/1999	770			
7/22/1999		17,000	9,100	4,500
8/25/1999		29,000		
9/20/1999		760	1,200	1,000
11/10/1999		450	790	580
12/10/1999		6,400		
2/17/2000		74	2	98

<b>Greensboro Sampling Data - continued</b>				
<b>Date</b>	<b>Arboretum</b> (subwatershed 1)	<b>Aycock St.</b> (outlet of subwatershed 3)	<b>Church St.</b> (outlet of subwatershed 4)	<b>16th St.</b> (subwatershed 7)
2/18/2000		2,600		
3/15/2000		400	480	54
4/13/2000		5,700		
5/10/2000		760	810	570
7/11/2000		4,800		
7/12/2000			6,000	2,300
8/18/2000		8,300		
9/12/2000		970	580	2,100
11/9/2000		8,400		
11/13/2000		380	1,100	590
1/16/2001		37	72	40
1/30/2001		150		
3/27/2001		72	58	150
4/24/2001		5,200		
5/1/2001		390	360	460
7/17/2001		4,200	330	580
7/25/2001		6,000		
9/18/2001		8	5	2
	Shading indicates data collected outside the model simulation period. These data are presented for information purposes, but were not used for model calibration.			



**Cone Mills WWTP – Instream fecal coliform sampling data from North Buffalo Creek at Summit Avenue.**

Date	Summit Ave. Fecal coliform (#/100mL)	Date	Summit Ave. Fecal coliform (#/100mL)	Date	Summit Ave. Fecal coliform (#/100mL)
8/3/1998	870	9/25/1998	10	11/17/1998	740
8/4/1998	10	9/28/1998	5	11/18/1998	840
8/5/1998	5	9/29/1998	5	11/19/1998	2,100
8/6/1998	5	9/30/1998	213	11/20/1998	3,000
8/7/1998	17	10/1/1998	64	11/23/1998	120
8/10/1998	653	10/2/1998	82	11/24/1998	570
8/11/1998	1,210	10/5/1998	415	11/25/1998	90
8/12/1998	1,900	10/6/1998	370	11/27/1998	423
8/13/1998	720	10/7/1998	290	11/30/1998	10
8/14/1998	328	10/8/1998	4,700	12/1/1998	53
8/17/1998	290	10/9/1998	870	12/2/1998	145
8/18/1998	570	10/12/1998	460	12/3/1998	82
8/19/1998	210	10/13/1998	623	12/4/1998	212
8/20/1998	2,000	10/14/1998	407	12/7/1998	76
8/21/1998	270	10/15/1998	113	12/8/1998	537
8/24/1998	810	10/16/1998	5	12/9/1998	4,900
8/25/1998	280	10/19/1998	10	12/10/1998	1,280
8/26/1998	750	10/20/1998	5	12/11/1998	1,170
8/27/1998	790	10/21/1998	5	12/14/1998	1,090
8/28/1998	270	10/22/1998	5	12/15/1998	930
9/1/1998	252	10/23/1998	109	12/16/1998	447
9/2/1998	650	10/26/1998	260	12/17/1998	195
9/3/1998	613	10/27/1998	5	12/18/1998	165
9/4/1998	143	10/28/1998	2	12/21/1998	119
9/8/1998	430	10/29/1998	28	12/22/1998	1,000
9/9/1998	77	10/30/1998	363	12/23/1998	3,000
9/10/1998	770	11/2/1998	214	12/29/1998	667
9/11/1998	2,000	11/3/1998	2,750	12/30/1998	1,010
9/14/1998	860	11/4/1998	114	12/31/1998	5,600
9/15/1998	810	11/5/1998	135	1/4/1999	970
9/16/1998	1,210	11/6/1998	84	1/5/1999	400
9/17/1998	350	11/9/1998	10	1/6/1999	1,070
9/18/1998	2,300	11/10/1998	141	1/7/1999	5,000
9/21/1998	152	11/11/1998	2,800	1/8/1999	950
9/22/1998	860	11/12/1998	3,400	1/11/1999	790
9/23/1998	3,700	11/13/1998	730	1/12/1999	5,100
9/24/1998	330	11/16/1998	4,600	1/13/1999	2,200

Date	Summit Ave. Fecal coliform (#/100mL)
1/14/1999	1,200
1/15/1999	1,800
1/18/1999	4,200
1/19/1999	420
1/20/1999	20
1/21/1999	1,180
1/22/1999	1,100
1/25/1999	640
1/26/1999	370
1/27/1999	660
1/28/1999	377
1/29/1999	1,000
2/1/1999	5,500
2/2/1999	1,300
2/3/1999	280
2/4/1999	10
2/5/1999	42
2/8/1999	114
2/9/1999	10
2/10/1999	4
2/11/1999	2
2/12/1999	5
2/15/1999	240
2/16/1999	19
2/17/1999	54
2/18/1999	3,800
2/22/1999	3,000
3/3/1999	76
3/10/1999	2,900
3/17/1999	110
3/24/1999	820
4/1/1999	5,630
4/7/1999	97
4/14/1999	175
4/21/1999	198
4/28/1999	9,200
5/5/1999	475
5/12/1999	333
5/19/1999	980

Date	Summit Ave. Fecal coliform (#/100mL)
5/26/1999	6,300
6/1/1999	213
6/2/1999	690
6/3/1999	3,300
6/7/1999	373
6/9/1999	362
6/11/1999	6,000
6/14/1999	6,100
6/16/1999	2,200
6/17/1999	5,900
6/21/1999	780
6/23/1999	470
6/25/1999	720
6/28/1999	1,160
6/29/1999	2,200
6/30/1999	665
7/6/1999	293
7/7/1999	620
7/8/1999	2,300
7/12/1999	1,440
7/13/1999	6,030
7/14/1999	1,340
7/19/1999	2,200
7/20/1999	6,500
7/21/1999	4,000
7/27/1999	740
7/28/1999	135
7/29/1999	6,600
8/3/1999	89
8/4/1999	6
8/5/1999	235
8/9/1999	645
8/10/1999	22
8/12/1999	83
8/17/1999	220
8/18/1999	69
8/19/1999	176
8/24/1999	430
8/25/1999	1,250

Date	Summit Ave. Fecal coliform (#/100mL)
8/26/1999	185
8/31/1999	81
9/1/1999	105
9/3/1999	145
9/8/1999	114
9/9/1999	330
9/13/1999	348
9/14/1999	213
9/16/1999	10,000
9/20/1999	555
9/21/1999	378
9/22/1999	1,180
9/28/1999	7,900
9/29/1999	286
9/30/1999	280
10/8/1999	50
10/14/1999	470
10/22/1999	255
10/27/1999	570
11/3/1999	1,220
11/10/1999	22
11/17/1999	33
11/23/1999	83
12/1/1999	195
12/8/1999	1,100
12/15/1999	1,140
12/21/1999	278
12/29/1999	3,400
1/4/2000	81
1/12/2000	88
1/19/2000	455
1/28/2000	18
2/2/2000	198
2/10/2000	135
2/16/2000	323
2/24/2000	278
3/2/2000	640
3/9/2000	78
3/16/2000	1,120

Date	Summit Ave. Fecal coliform (#/100mL)
3/23/2000	330
3/29/2000	285
4/6/2000	205
4/12/2000	120
4/20/2000	67
4/27/2000	155
5/3/2000	320
5/10/2000	170
5/17/2000	5,700
5/24/2000	495
6/1/2000	535
6/2/2000	860
6/6/2000	3,100
6/7/2000	800
6/8/2000	1,100
6/13/2000	395
6/14/2000	575
6/15/2000	5,600
6/20/2000	1,660
6/21/2000	5,350
6/22/2000	1,020
6/27/2000	685
6/28/2000	210
6/29/2000	9,200
7/5/2000	3,950
7/6/2000	5,500
7/7/2000	11,800
7/11/2000	12,000
7/12/2000	8,200
7/13/2000	10,000
7/17/2000	1,630
7/18/2000	310
7/19/2000	250
7/20/2000	280
7/25/2000	2,900
7/26/2000	700
7/27/2000	3,400
8/1/2000	4,650
8/2/2000	11,600

Date	Summit Ave. Fecal coliform (#/100mL)
8/3/2000	5,030
8/9/2000	780
8/10/2000	1,780
8/11/2000	12,400
8/14/2000	920
8/15/2000	210
8/16/2000	210
8/22/2000	198
8/23/2000	188
8/24/2000	710
8/29/2000	2,800
8/30/2000	3,700
8/31/2000	2,300
9/6/2000	860
9/7/2000	460
9/8/2000	880
9/12/2000	6,000
9/13/2000	400
9/14/2000	940
9/19/2000	4,200
9/20/2000	1,060
9/21/2000	230
9/25/2000	952
9/26/2000	20
9/27/2000	31
10/5/2000	430
10/13/2000	230
10/18/2000	6,600
10/25/2000	880
11/1/2000	545
11/9/2000	535
11/15/2000	4,600
11/24/2000	1,320

## Appendix 2 Dry Weather Dates

### Dry weather dates used for calculations associated with the dry weather TMDL

8/3/1998	9/26/1998	11/21/1998	2/8/1999	5/11/1999	7/5/1999	10/25/1999	1/2/2000
8/4/1998	9/27/1998	11/22/1998	2/9/1999	5/12/1999	7/6/1999	10/26/1999	1/3/2000
8/5/1998	9/28/1998	11/23/1998	2/10/1999	5/13/1999	7/17/1999	10/27/1999	1/7/2000
8/6/1998	9/29/1998	11/24/1998	2/11/1999	5/17/1999	7/18/1999	10/28/1999	1/8/2000
8/13/1998	10/3/1998	11/29/1998	2/16/1999	5/18/1999	7/19/1999	11/1/1999	1/16/2000
8/14/1998	10/11/1998	11/30/1998	2/22/1999	5/19/1999	8/1/1999	11/5/1999	1/17/2000
8/15/1998	10/12/1998	12/1/1998	2/23/1999	5/20/1999	8/2/1999	11/6/1999	1/18/2000
8/20/1998	10/13/1998	12/2/1998	2/24/1999	5/21/1999	8/3/1999	11/7/1999	2/6/2000
8/21/1998	10/14/1998	12/3/1998	2/25/1999	5/22/1999	8/4/1999	11/8/1999	2/7/2000
8/22/1998	10/15/1998	12/4/1998	3/13/1999	5/23/1999	8/5/1999	11/9/1999	2/8/2000
8/23/1998	10/16/1998	12/5/1998	3/19/1999	5/24/1999	8/6/1999	11/10/1999	2/9/2000
8/24/1998	10/17/1998	12/6/1998	3/20/1999	5/25/1999	8/7/1999	11/11/1999	2/10/2000
8/25/1998	10/18/1998	12/7/1998	3/28/1999	5/29/1999	8/12/1999	11/12/1999	2/11/2000
8/26/1998	10/19/1998	12/22/1998	3/29/1999	5/30/1999	8/13/1999	11/13/1999	2/22/2000
8/27/1998	10/20/1998	1/1/1999	3/30/1999	5/31/1999	8/17/1999	11/14/1999	2/23/2000
8/28/1998	10/21/1998	1/6/1999	3/31/1999	6/1/1999	8/18/1999	11/15/1999	2/24/2000
8/29/1998	10/22/1998	1/7/1999	4/4/1999	6/2/1999	8/19/1999	11/19/1999	2/25/2000
9/2/1998	10/23/1998	1/12/1999	4/8/1999	6/3/1999	8/23/1999	11/20/1999	2/26/2000
9/7/1998	10/24/1998	1/13/1999	4/19/1999	6/4/1999	8/30/1999	12/3/1999	3/1/2000
9/11/1998	10/25/1998	1/14/1999	4/20/1999	6/5/1999	8/31/1999	12/4/1999	3/2/2000
9/12/1998	10/26/1998	1/21/1999	4/21/1999	6/6/1999	9/1/1999	12/9/1999	3/3/2000
9/13/1998	10/27/1998	1/22/1999	4/22/1999	6/7/1999	9/2/1999	12/17/1999	3/4/2000
9/14/1998	10/28/1998	1/27/1999	4/23/1999	6/8/1999	9/3/1999	12/18/1999	3/5/2000
9/15/1998	10/29/1998	1/28/1999	4/24/1999	6/9/1999	9/13/1999	12/26/1999	3/6/2000
9/16/1998	11/6/1998	1/29/1999	4/25/1999	6/10/1999	9/14/1999	12/27/1999	3/7/2000
9/17/1998	11/7/1998	1/30/1999	5/3/1999	6/11/1999	9/19/1999	12/28/1999	3/8/2000
9/18/1998	11/8/1998	1/31/1999	5/4/1999	6/12/1999	9/20/1999	12/29/1999	3/9/2000
9/19/1998	11/9/1998	2/5/1999	5/8/1999	6/19/1999	9/25/1999	12/30/1999	3/10/2000
9/20/1998	11/19/1998	2/6/1999	5/9/1999	6/29/1999	9/26/1999	12/31/1999	3/14/2000
9/25/1998	11/20/1998	2/7/1999	5/10/1999	7/4/1999	10/3/1999	1/1/2000	3/15/2000

**Dry weather dates - continued**

3/24/2000	6/12/2000	9/30/2000	10/30/2000	12/23/2000	2/7/2001	5/1/2001
4/7/2000	6/13/2000	10/1/2000	10/31/2000	12/24/2000	2/8/2001	5/2/2001
4/11/2000	6/23/2000	10/2/2000	11/1/2000	12/25/2000	2/9/2001	5/3/2001
4/12/2000	6/24/2000	10/3/2000	11/2/2000	12/26/2000	2/28/2001	5/4/2001
4/20/2000	7/2/2000	10/4/2000	11/3/2000	12/27/2000	3/1/2001	5/5/2001
4/21/2000	7/3/2000	10/5/2000	11/4/2000	12/28/2000	3/2/2001	5/9/2001
4/22/2000	7/10/2000	10/6/2000	11/5/2000	12/29/2000	3/8/2001	6/10/2001
4/23/2000	7/16/2000	10/7/2000	11/6/2000	12/30/2000	3/9/2001	6/11/2001
4/24/2000	7/17/2000	10/8/2000	11/12/2000	12/31/2000	3/10/2001	6/12/2001
5/1/2000	7/18/2000	10/9/2000	11/13/2000	1/1/2001	3/11/2001	6/17/2001
5/2/2000	7/19/2000	10/10/2000	11/22/2000	1/2/2001	3/19/2001	6/18/2001
5/3/2000	7/20/2000	10/11/2000	11/23/2000	1/3/2001	3/24/2001	6/19/2001
5/4/2000	7/21/2000	10/12/2000	11/24/2000	1/4/2001	3/25/2001	6/20/2001
5/5/2000	7/22/2000	10/13/2000	11/30/2000	1/5/2001	3/26/2001	6/30/2001
5/6/2000	7/29/2000	10/14/2000	12/1/2000	1/6/2001	3/27/2001	7/7/2001
5/7/2000	7/30/2000	10/15/2000	12/2/2000	1/7/2001	3/28/2001	7/12/2001
5/8/2000	8/16/2000	10/16/2000	12/3/2000	1/15/2001	4/6/2001	7/16/2001
5/9/2000	8/17/2000	10/17/2000	12/4/2000	1/16/2001	4/7/2001	7/17/2001
5/10/2000	8/21/2000	10/18/2000	12/5/2000	1/23/2001	4/8/2001	7/21/2001
5/11/2000	8/22/2000	10/19/2000	12/6/2000	1/24/2001	4/9/2001	7/22/2001
5/12/2000	8/23/2000	10/20/2000	12/7/2000	1/25/2001	4/10/2001	7/23/2001
5/13/2000	9/7/2000	10/21/2000	12/8/2000	1/26/2001	4/11/2001	
5/14/2000	9/8/2000	10/22/2000	12/9/2000	1/27/2001	4/12/2001	
5/15/2000	9/9/2000	10/23/2000	12/10/2000	1/28/2001	4/20/2001	
5/16/2000	9/10/2000	10/24/2000	12/11/2000	1/29/2001	4/21/2001	
6/1/2000	9/11/2000	10/25/2000	12/12/2000	2/2/2001	4/22/2001	
6/2/2000	9/12/2000	10/26/2000	12/13/2000	2/3/2001	4/23/2001	
6/9/2000	9/13/2000	10/27/2000	12/14/2000	2/4/2001	4/28/2001	
6/10/2000	9/28/2000	10/28/2000	12/15/2000	2/5/2001	4/29/2001	
6/11/2000	9/29/2000	10/29/2000	12/22/2000	2/6/2001	4/30/2001	

### Appendix 3 Cone Mills WWTP Effluent Data

**Cone Mills WWTP effluent data. Flow and fecal coliform concentrations (August 1998 – June 2001) (Kebede, 2003).**

Date	Flow (mgd)	FC (#/100mL)
8/1/1998	0.76	1
8/2/1998	0.70	1
8/3/1998	0.75	1
8/4/1998	1.09	1
8/5/1998	1.58	1
8/6/1998	1.33	1
8/7/1998	1.46	9
8/8/1998	1.45	3
8/9/1998	1.27	3
8/10/1998	1.16	1
8/11/1998	1.27	1
8/12/1998	1.63	4
8/13/1998	1.62	1
8/14/1998	1.58	8
8/15/1998	1.11	7
8/16/1998	0.82	6
8/17/1998	1.00	1
8/18/1998	1.08	16
8/19/1998	1.09	1
8/20/1998	1.12	4
8/21/1998	1.00	85
8/22/1998	0.85	27
8/23/1998	0.04	27
8/24/1998	0.76	13
8/25/1998	1.17	8
8/26/1998	1.05	1
8/27/1998	0.84	1
8/28/1998	0.84	27
8/29/1998	0.84	29
8/30/1998	0.54	29
8/31/1998	0.97	78
9/1/1998	0.97	7
9/2/1998	0.90	1
9/3/1998	0.97	1
9/4/1998	0.88	1
9/5/1998	0.80	1
9/6/1998	0.73	1

Date	Flow (mgd)	FC (#/100mL)
9/7/1998	0.73	1
9/8/1998	0.89	1
9/9/1998	1.18	1
9/10/1998	1.17	1
9/11/1998	1.14	88
9/12/1998	1.19	37
9/13/1998	1.08	37
9/14/1998	1.13	11
9/15/1998	1.22	48
9/16/1998	1.29	62
9/17/1998	1.33	113
9/18/1998	1.38	98
9/19/1998	1.01	54
9/20/1998	1.01	54
9/21/1998	1.25	4
9/22/1998	1.95	1
9/23/1998	1.20	15
9/24/1998	1.20	1
9/25/1998	1.20	1
9/26/1998	1.20	1
9/27/1998	1.20	1
9/28/1998	0.97	1
9/29/1998	0.97	1
9/30/1998	1.17	1
10/1/1998	0.97	12
10/2/1998	0.91	1
10/3/1998	0.70	24
10/4/1998	0.55	24
10/5/1998	0.91	9
10/6/1998	0.89	76
10/7/1998	1.46	9
10/8/1998	1.45	23
10/9/1998	1.27	22
10/10/1998	1.16	1
10/11/1998	1.27	4
10/12/1998	1.13	4
10/13/1998	0.71	4

Date	Flow (mgd)	FC (#/100mL)
10/14/1998	0.73	2
10/15/1998	0.77	2
10/16/1998	0.98	2
10/17/1998	1.06	2
10/18/1998	0.77	2
10/19/1998	0.83	1
10/20/1998	0.97	2
10/21/1998	1.13	1
10/22/1998	1.12	1
10/23/1998	1.10	7
10/24/1998	0.98	3
10/25/1998	0.62	3
10/26/1998	0.71	2
10/27/1998	0.82	1
10/28/1998	0.87	20
10/29/1998	1.47	17
10/30/1998	1.25	58
10/31/1998	0.89	61
11/1/1998	0.54	61
11/2/1998	0.54	12
11/3/1998	0.58	156
11/4/1998	0.67	8
11/5/1998	0.69	1
11/6/1998	0.70	1
11/7/1998	0.46	1
11/8/1998	0.33	1
11/9/1998	0.36	1
11/10/1998	0.69	1
11/11/1998	0.90	10
11/12/1998	0.95	100
11/13/1998	1.02	197
11/14/1998	0.98	152
11/15/1998	0.41	152
11/16/1998	0.84	2
11/17/1998	0.94	311
11/18/1998	1.00	124
11/19/1998	1.12	183

Date	Flow (mgd)	FC (#/100mL)
11/20/1998	1.11	101
11/21/1998	0.89	430
11/22/1998	0.44	429
11/23/1998	0.57	1198
11/24/1998	0.94	233
11/25/1998	0.94	96
11/26/1998	0.26	90
11/27/1998	0.33	5
11/28/1998	0.94	40
11/29/1998	0.38	40
11/30/1998	0.70	27
12/1/1998	1.01	87
12/2/1998	1.49	24
12/3/1998	1.49	1
12/4/1998	1.49	125
12/5/1998	1.49	180
12/6/1998	1.49	180
12/7/1998	1.49	359
12/8/1998	1.49	235
12/9/1998	1.33	329
12/10/1998	1.33	214
12/11/1998	1.25	325
12/12/1998	1.12	177
12/13/1998	0.78	176
12/14/1998	0.56	83
12/15/1998	0.88	83
12/16/1998	0.78	54
12/17/1998	0.79	25
12/18/1998	0.67	43
12/19/1998	0.87	78
12/20/1998	0.87	78
12/21/1998	0.60	117
12/22/1998	0.60	125
12/23/1998	0.67	150
12/24/1998	0.72	153
12/25/1998	0.64	153
12/26/1998	0.58	153
12/27/1998	0.65	153
12/28/1998	0.67	153
12/29/1998	0.61	236
12/30/1998	0.62	102
12/31/1998	0.61	116
1/1/1999	0.67	81
1/2/1999	0.76	81
1/3/1999	0.74	81
1/4/1999	0.77	81
1/5/1999	0.96	65

Date	Flow (mgd)	FC (#/100mL)
1/6/1999	1.67	42
1/7/1999	1.55	62
1/8/1999	1.61	260
1/9/1999	1.28	278
1/10/1999	1.06	719
1/11/1999	1.06	1139
1/12/1999	1.75	1199
1/13/1999	1.44	4303
1/14/1999	1.82	24
1/15/1999	1.76	2
1/16/1999	1.39	30
1/17/1999	1.25	30
1/18/1999	1.34	2
1/19/1999	1.15	93
1/20/1999	1.34	10
1/21/1999	1.18	66
1/22/1999	0.85	222
1/23/1999	0.78	163
1/24/1999	0.95	162
1/25/1999	0.80	172
1/26/1999	0.79	190
1/27/1999	0.81	274
1/28/1999	1.23	384
1/29/1999	1.10	218
1/30/1999	0.72	151
1/31/1999	0.57	151
2/1/1999	0.55	2
2/2/1999	0.54	2
2/3/1999	0.50	2
2/4/1999	0.45	2
2/5/1999	0.40	1
2/6/1999	0.38	1
2/7/1999	0.45	1
2/8/1999	0.94	2
2/9/1999	1.11	1
2/10/1999	1.15	1
2/11/1999	1.30	1
2/12/1999	1.46	1
2/13/1999	1.00	2
2/14/1999	0.85	2
2/15/1999	0.92	2
2/16/1999	1.05	2
2/17/1999	1.14	2
2/18/1999	1.26	2
2/19/1999	1.41	9
2/20/1999	1.41	4
2/21/1999	1.19	4

Date	Flow (mgd)	FC (#/100mL)
2/22/1999	1.12	2
2/23/1999	1.27	2
2/24/1999	1.36	1
2/25/1999	1.43	21
2/26/1999	1.38	121
2/27/1999	1.14	55
2/28/1999	0.83	55
3/1/1999	0.92	35
3/2/1999	0.62	42
3/3/1999	0.75	49
3/4/1999	0.72	22
3/5/1999	0.60	42
3/6/1999	0.46	19
3/7/1999	0.62	19
3/8/1999	0.36	7
3/9/1999	0.73	4
3/10/1999	1.07	2
3/11/1999	1.14	1
3/12/1999	1.15	1
3/13/1999	0.91	1
3/14/1999	0.70	1
3/15/1999	0.72	1
3/16/1999	0.82	1
3/17/1999	0.94	1
3/18/1999	1.00	4
3/19/1999	1.07	19
3/20/1999	0.83	152
3/21/1999	0.61	152
3/22/1999	0.69	204
3/23/1999	0.82	379
3/24/1999	0.94	471
3/25/1999	0.97	280
3/26/1999	1.00	380
3/27/1999	0.93	439
3/28/1999	0.79	441
3/29/1999	0.79	280
3/30/1999	1.03	819
3/31/1999	1.24	1140
4/1/1999	1.41	363
4/2/1999	1.40	627
4/3/1999	1.28	317
4/4/1999	1.01	316
4/5/1999	0.78	381
4/6/1999	0.95	206
4/7/1999	0.74	62
4/8/1999	1.24	20
4/9/1999	1.34	105

Date	Flow (mgd)	FC (#/100mL)
4/10/1999	1.09	123
4/11/1999	0.83	124
4/12/1999	0.79	105
4/13/1999	0.92	264
4/14/1999	0.99	127
4/15/1999	1.09	69
4/16/1999	1.09	281
4/17/1999	0.88	170
4/18/1999	0.74	170
4/19/1999	0.80	206
4/20/1999	1.01	122
4/21/1999	1.16	85
4/22/1999	1.31	92
4/23/1999	1.48	108
4/24/1999	1.31	163
4/25/1999	1.04	163
4/26/1999	1.04	254
4/27/1999	1.28	197
4/28/1999	1.32	234
4/29/1999	1.54	131
4/30/1999	1.41	106
5/1/1999	1.25	118
5/2/1999	1.21	118
5/3/1999	1.22	115
5/4/1999	1.32	119
5/5/1999	1.32	5
5/6/1999	1.34	26
5/7/1999	1.33	128
5/8/1999	1.29	134
5/9/1999	1.01	134
5/10/1999	1.04	197
5/11/1999	1.59	186
5/12/1999	1.55	197
5/13/1999	1.50	140
5/14/1999	1.44	287
5/15/1999	1.37	246
5/16/1999	1.23	247
5/17/1999	1.32	252
5/18/1999	1.47	305
5/19/1999	1.24	225
5/20/1999	1.32	328
5/21/1999	1.33	195
5/22/1999	1.30	157
5/23/1999	0.98	157
5/24/1999	0.84	69
5/25/1999	1.12	38
5/26/1999	1.39	239

Date	Flow (mgd)	FC (#/100mL)
5/27/1999	1.40	88
5/28/1999	1.08	136
5/29/1999	0.70	392
5/30/1999	0.69	390
5/31/1999	0.70	392
6/1/1999	1.09	136
6/2/1999	1.27	1200
6/3/1999	1.48	647
6/4/1999	1.66	260
6/5/1999	1.35	232
6/6/1999	1.23	234
6/7/1999	1.14	18
6/8/1999	1.29	8
6/9/1999	1.36	14
6/10/1999	1.78	46
6/11/1999	1.87	136
6/12/1999	1.75	82
6/13/1999	1.10	82
6/14/1999	1.00	80
6/15/1999	1.19	66
6/16/1999	1.25	591
6/17/1999	1.88	143
6/18/1999	1.30	781
6/19/1999	1.42	277
6/20/1999	1.32	276
6/21/1999	1.24	85
6/22/1999	1.32	97
6/23/1999	1.38	331
6/24/1999	1.30	331
6/25/1999	0.99	226
6/26/1999	0.70	486
6/27/1999	0.62	485
6/28/1999	0.59	305
6/29/1999	0.60	1081
6/30/1999	0.59	1332
7/1/1999	1.47	2
7/2/1999	1.30	669
7/3/1999	0.79	169
7/4/1999	0.84	169
7/5/1999	0.91	169
7/6/1999	1.22	2
7/7/1999	1.08	2
7/8/1999	0.96	2
7/9/1999	1.07	14
7/10/1999	1.12	58
7/11/1999	1.09	58
7/12/1999	1.25	82

Date	Flow (mgd)	FC (#/100mL)
7/13/1999	1.65	135
7/14/1999	1.82	1179
7/15/1999	1.57	135
7/16/1999	1.68	2
7/17/1999	1.39	975
7/18/1999	1.15	977
7/19/1999	1.24	468
7/20/1999	1.48	3296
7/21/1999	1.78	1010
7/22/1999	1.38	2
7/23/1999	1.41	2
7/24/1999	1.41	13
7/25/1999	1.12	13
7/26/1999	0.17	13
7/27/1999	0.27	2
7/28/1999	0.40	46
7/29/1999	1.00	2
7/30/1999	0.88	27
7/31/1999	0.65	21
8/1/1999	0.46	21
8/2/1999	0.43	39
8/3/1999	0.43	15
8/4/1999	0.67	7
8/5/1999	1.23	16
8/6/1999	1.16	82
8/7/1999	1.20	37
8/8/1999	1.12	37
8/9/1999	0.86	50
8/10/1999	1.10	1
8/11/1999	0.95	8
8/12/1999	0.86	17
8/13/1999	0.84	212
8/14/1999	1.04	86
8/15/1999	0.61	86
8/16/1999	0.74	86
8/17/1999	0.93	25
8/18/1999	1.15	88
8/19/1999	0.58	25
8/20/1999	1.12	4
8/21/1999	1.01	42
8/22/1999	0.94	26
8/23/1999	1.13	26
8/24/1999	1.14	27
8/25/1999	1.14	31
8/26/1999	1.14	4
8/27/1999	1.10	27
8/28/1999	1.00	49



Date	Flow (mgd)	FC (#/100mL)
8/29/1999	0.96	20
8/30/1999	0.97	20
8/31/1999	1.00	20
9/1/1999	1.00	1
9/2/1999	1.01	3
9/3/1999	1.00	1
9/4/1999	1.00	8
9/5/1999	0.98	8
9/6/1999	1.04	8
9/7/1999	1.01	13
9/8/1999	1.01	16
9/9/1999	0.99	55
9/10/1999	0.97	28
9/11/1999	1.01	23
9/12/1999	1.01	23
9/13/1999	1.00	4
9/14/1999	1.03	3
9/15/1999	1.48	4
9/16/1999	1.95	39
9/17/1999	1.25	58
9/18/1999	1.11	43
9/19/1999	0.97	43
9/20/1999	0.95	22
9/21/1999	0.92	54
9/22/1999	0.85	72
9/23/1999	0.99	38
9/24/1999	0.79	32
9/25/1999	0.73	62
9/26/1999	0.52	62
9/27/1999	0.65	38
9/28/1999	0.74	141
9/29/1999	0.90	8
9/30/1999	0.91	55
10/1/1999	1.93	7
10/2/1999	1.95	17
10/3/1999	0.58	17
10/4/1999	0.46	3
10/5/1999	1.00	2
10/6/1999	1.02	2
10/7/1999	1.02	3
10/8/1999	1.02	9
10/9/1999	1.02	6
10/10/1999	0.98	6
10/11/1999	0.97	7
10/12/1999	1.11	4
10/13/1999	10.10	28
10/14/1999	1.06	17

Date	Flow (mgd)	FC (#/100mL)
10/15/1999	1.06	25
10/16/1999	0.80	26
10/17/1999	0.69	25
10/18/1999	0.83	5
10/19/1999	0.75	55
10/20/1999	0.98	86
10/21/1999	1.01	24
10/22/1999	0.94	8
10/23/1999	0.89	115
10/24/1999	0.72	115
10/25/1999	0.83	285
10/26/1999	0.52	142
10/27/1999	0.63	196
10/28/1999	0.87	19
10/29/1999	0.87	27
10/30/1999	0.79	21
10/31/1999	0.82	22
11/1/1999	0.63	18
11/2/1999	0.66	22
11/3/1999	0.85	391
11/4/1999	0.54	119
11/5/1999	0.75	12
11/6/1999	0.73	81
11/7/1999	0.51	81
11/8/1999	0.42	12
11/9/1999	0.67	182
11/10/1999	0.63	106
11/11/1999	0.35	87
11/12/1999	0.77	6
11/13/1999	1.26	27
11/14/1999	0.97	27
11/15/1999	0.84	13
11/16/1999	1.02	2
11/17/1999	1.01	10
11/18/1999	1.03	4
11/19/1999	1.01	51
11/20/1999	0.99	139
11/21/1999	0.81	139
11/22/1999	0.20	200
11/23/1999	0.35	301
11/24/1999	0.81	38
11/25/1999	0.67	114
11/26/1999	0.44	112
11/27/1999	0.39	39
11/28/1999	0.39	39
11/29/1999	0.41	4
11/30/1999	0.99	2

Date	Flow (mgd)	FC (#/100mL)
12/1/1999	1.06	2
12/2/1999	1.00	58
12/3/1999	1.15	65
12/4/1999	1.05	123
12/5/1999	0.86	123
12/6/1999	0.91	270
12/7/1999	1.07	100
12/8/1999	1.11	188
12/9/1999	0.96	234
12/10/1999	0.88	96
12/11/1999	0.94	125
12/12/1999	0.93	125
12/13/1999	0.77	130
12/14/1999	0.67	40
12/15/1999	0.81	84
12/16/1999	1.18	67
12/17/1999	0.57	5
12/18/1999	0.77	174
12/19/1999	0.60	174
12/20/1999	0.60	355
12/21/1999	0.66	268
12/22/1999	0.68	337
12/23/1999	0.52	155
12/24/1999	0.72	155
12/25/1999	0.65	155
12/26/1999	0.41	155
12/27/1999	0.36	155
12/28/1999	0.29	12
12/29/1999	0.55	3
12/30/1999	0.45	5
12/31/1999	0.44	5
1/1/2000	0.44	5
1/2/2000	0.54	5
1/3/2000	0.94	10
1/4/2000	1.08	1
1/5/2000	1.03	1
1/6/2000	0.32	1
1/7/2000	0.49	54
1/8/2000	0.67	75
1/9/2000	0.98	75
1/10/2000	1.09	165
1/11/2000	0.99	80
1/12/2000	0.95	80
1/13/2000	0.59	117
1/14/2000	0.50	299
1/15/2000	0.49	252
1/16/2000	0.51	252

Date	Flow (mgd)	FC (#/100mL)
1/17/2000	0.50	360
1/18/2000	0.38	232
1/19/2000	0.40	620
1/20/2000	0.68	243
1/21/2000	0.78	165
1/22/2000	0.99	138
1/23/2000	0.97	138
1/24/2000	0.90	5
1/25/2000	0.60	73
1/26/2000	0.56	35
1/27/2000	0.54	86
1/28/2000	0.55	56
1/29/2000	0.07	159
1/30/2000	0.70	184
1/31/2000	0.80	184
2/1/2000	0.99	257
2/2/2000	0.97	238
2/3/2000	0.99	346
2/4/2000	1.00	311
2/5/2000	0.92	270
2/6/2000	0.84	270
2/7/2000	0.84	208
2/8/2000	1.02	216
2/9/2000	1.06	231
2/10/2000	1.06	95
2/11/2000	1.09	100
2/12/2000	1.13	72
2/13/2000	1.09	72
2/14/2000	1.11	83
2/15/2000	1.22	9
2/16/2000	1.27	24
2/17/2000	1.32	194
2/18/2000	1.37	105
2/19/2000	1.39	80
2/20/2000	1.07	81
2/21/2000	1.08	19
2/22/2000	0.93	4
2/23/2000	1.15	101
2/24/2000	1.23	262
2/25/2000	1.21	246
2/26/2000	0.91	245
2/27/2000	0.85	245
2/28/2000	0.85	365
2/29/2000	0.94	110
3/1/2000	0.94	130
3/2/2000	0.92	310
3/3/2000	0.89	92

Date	Flow (mgd)	FC (#/100mL)
3/4/2000	0.94	119
3/5/2000	0.91	119
3/6/2000	0.90	54
3/7/2000	0.91	21
3/8/2000	1.21	32
3/9/2000	1.19	31
3/10/2000	1.07	46
3/11/2000	1.06	51
3/12/2000	0.99	51
3/13/2000	0.99	74
3/14/2000	1.03	53
3/15/2000	1.05	39
3/16/2000	1.32	59
3/17/2000	1.18	88
3/18/2000	1.04	80
3/19/2000	1.04	80
3/20/2000	0.92	98
3/21/2000	0.86	75
3/22/2000	1.12	37
3/23/2000	1.01	16
3/24/2000	1.05	1
3/25/2000	0.99	5
3/26/2000	0.80	5
3/27/2000	0.77	1
3/28/2000	0.96	1
3/29/2000	1.20	5
3/30/2000	1.15	28
3/31/2000	1.20	68
4/1/2000	1.24	66
4/2/2000	1.12	66
4/3/2000	1.26	117
4/4/2000	1.18	51
4/5/2000	1.10	35
4/6/2000	0.93	66
4/7/2000	0.67	50
4/8/2000	0.72	54
4/9/2000	0.65	54
4/10/2000	0.73	67
4/11/2000	0.93	32
4/12/2000	0.97	98
4/13/2000	1.12	72
4/14/2000	1.00	99
4/15/2000	1.08	46
4/16/2000	0.96	46
4/17/2000	1.07	46
4/18/2000	0.99	10
4/19/2000	1.00	2

Date	Flow (mgd)	FC (#/100mL)
4/20/2000	1.17	66
4/21/2000	1.41	20
4/22/2000	1.30	20
4/23/2000	0.78	20
4/24/2000	1.01	1
4/25/2000	1.01	11
4/26/2000	0.65	13
4/27/2000	0.87	3
4/28/2000	0.91	4
4/29/2000	0.77	3
4/30/2000	0.69	3
5/1/2000	0.97	1
5/2/2000	0.91	3
5/3/2000	0.96	6
5/4/2000	1.07	31
5/5/2000	1.04	8
5/6/2000	0.99	11
5/7/2000	0.87	11
5/8/2000	0.96	4
5/9/2000	0.74	1
5/10/2000	0.78	3
5/11/2000	0.88	2
5/12/2000	0.91	1
5/13/2000	0.89	1
5/14/2000	0.79	1
5/15/2000	0.82	1
5/16/2000	0.80	1
5/17/2000	0.87	29
5/18/2000	0.95	2
5/19/2000	1.06	3
5/20/2000	1.06	14
5/21/2000	0.95	13
5/22/2000	0.92	27
5/23/2000	0.93	22
5/24/2000	0.79	9
5/25/2000	0.59	6
5/26/2000	0.84	59
5/27/2000	0.84	17
5/28/2000	0.84	17
5/29/2000	0.84	17
5/30/2000	0.85	2
5/31/2000	0.85	2
6/1/2000	0.85	27
6/2/2000	0.84	121
6/3/2000	0.84	53
6/4/2000	0.84	53
6/5/2000	0.85	18

Date	Flow (mgd)	FC (#/100mL)
6/6/2000	0.84	47
6/7/2000	0.84	27
6/8/2000	0.72	89
6/9/2000	0.70	108
6/10/2000	0.07	69
6/11/2000	0.70	69
6/12/2000	0.96	50
6/13/2000	0.95	31
6/14/2000	0.95	121
6/15/2000	0.96	33
6/16/2000	0.91	89
6/17/2000	0.81	148
6/18/2000	0.81	148
6/19/2000	0.81	188
6/20/2000	0.96	280
6/21/2000	1.28	229
6/22/2000	0.96	89
6/23/2000	1.01	116
6/24/2000	0.91	99
6/25/2000	0.91	99
6/26/2000	0.91	131
6/27/2000	1.30	58
6/28/2000	0.91	64
6/29/2000	0.81	241
6/30/2000	0.81	247
7/1/2000	0.81	217
7/2/2000	0.81	217
7/3/2000	0.81	164
7/4/2000	0.81	136
7/5/2000	0.91	58
7/6/2000	1.01	75
7/7/2000	1.01	129
7/8/2000	1.12	197
7/9/2000	1.12	197
7/10/2000	1.12	360
7/11/2000	0.81	224
7/12/2000	0.81	193
7/13/2000	0.81	106
7/14/2000	0.81	142
7/15/2000	0.81	63
7/16/2000	0.81	63
7/17/2000	0.81	1
7/18/2000	1.01	2
7/19/2000	1.34	16
7/20/2000	1.12	1
7/21/2000	1.01	14
7/22/2000	1.01	97

Date	Flow (mgd)	FC (#/100mL)
7/23/2000	1.01	97
7/24/2000	1.01	127
7/25/2000	1.01	248
7/26/2000	1.01	137
7/27/2000	1.34	184
7/28/2000	1.34	268
7/29/2000	1.34	187
7/30/2000	1.01	187
7/31/2000	0.81	51
8/1/2000	1.01	247
8/2/2000	1.01	212
8/3/2000	1.01	170
8/4/2000	1.01	229
8/5/2000	1.01	122
8/6/2000	0.91	122
8/7/2000	0.30	51
8/8/2000	1.01	37
8/9/2000	0.82	48
8/10/2000	1.11	268
8/11/2000	1.16	135
8/12/2000	1.14	102
8/13/2000	1.10	102
8/14/2000	1.55	2
8/15/2000	1.43	2
8/16/2000	0.89	13
8/17/2000	1.24	7
8/18/2000	1.28	20
8/19/2000	0.98	33
8/20/2000	0.51	33
8/21/2000	0.87	59
8/22/2000	0.96	44
8/23/2000	1.01	25
8/24/2000	0.91	212
8/25/2000	1.01	217
8/26/2000	1.01	211
8/27/2000	1.01	211
8/28/2000	1.01	124
8/29/2000	1.06	291
8/30/2000	1.06	87
8/31/2000	1.06	189
9/1/2000	1.06	189
9/2/2000	1.06	218
9/3/2000	1.06	218
9/4/2000	1.06	218
9/5/2000	1.06	68
9/6/2000	0.95	427
9/7/2000	0.88	1

Date	Flow (mgd)	FC (#/100mL)
9/8/2000	1.17	1
9/9/2000	1.09	57
9/10/2000	1.04	57
9/11/2000	0.93	102
9/12/2000	0.70	123
9/13/2000	0.73	101
9/14/2000	1.02	158
9/15/2000	1.32	529
9/16/2000	1.10	427
9/17/2000	0.77	425
9/18/2000	0.96	621
9/19/2000	1.29	394
9/20/2000	1.06	210
9/21/2000	1.06	286
9/22/2000	1.06	900
9/23/2000	1.06	358
9/24/2000	1.06	358
9/25/2000	1.02	244
9/26/2000	1.02	2
9/27/2000	1.02	1
9/28/2000	1.01	77
9/29/2000	0.48	138
9/30/2000	1.20	76
10/1/2000	1.36	76
10/2/2000	0.69	56
10/3/2000	0.57	33
10/4/2000	0.54	32
10/5/2000	0.76	60
10/6/2000	1.83	164
10/7/2000	1.31	140
10/8/2000	0.54	141
10/9/2000	0.76	113
10/10/2000	1.01	225
10/11/2000	1.06	242
10/12/2000	1.08	225
10/13/2000	1.08	354
10/14/2000	0.71	208
10/15/2000	0.60	208
10/16/2000	0.60	118
10/17/2000	1.18	138
10/18/2000	1.27	332
10/19/2000	1.17	225
10/20/2000	1.18	200
10/21/2000	0.92	218
10/22/2000	0.70	218
10/23/2000	0.54	174
10/24/2000	0.37	272

Date	Flow (mgd)	FC (#/100mL)
10/25/2000	0.84	227
10/26/2000	1.25	238
10/27/2000	1.14	217
10/28/2000	0.51	230
10/29/2000	0.46	230
10/30/2000	0.51	140
10/31/2000	0.63	325
11/1/2000	0.89	108
11/2/2000	1.18	179
11/3/2000	0.88	181
11/4/2000	0.88	4674
11/5/2000	0.88	4674
11/6/2000	0.53	310
11/7/2000	0.59	18054
11/8/2000	0.59	42
11/9/2000	1.20	70
11/10/2000	1.10	104
11/11/2000	0.96	104
11/12/2000	0.72	104
11/13/2000	0.52	89
11/14/2000	0.61	213
11/15/2000	0.72	104
11/16/2000	1.04	170
11/17/2000	1.44	258
11/18/2000	1.13	193
11/19/2000	0.63	193
11/20/2000	0.57	105
11/21/2000	0.58	237
11/22/2000	0.91	105
11/23/2000	1.55	167
11/24/2000	1.39	108
11/25/2000	1.37	180
11/26/2000	0.60	180
11/27/2000	0.99	219
11/28/2000	1.22	213
11/29/2000	1.24	105
11/30/2000	1.30	219
12/1/2000	1.23	195
12/2/2000	0.77	216
12/3/2000	0.42	216
12/4/2000	0.21	239
12/5/2000	0.52	214
12/6/2000	0.85	160
12/7/2000	0.84	243
12/8/2000	1.02	173
12/9/2000	0.97	150
12/10/2000	0.83	150

Date	Flow (mgd)	FC (#/100mL)
12/11/2000	1.12	75
12/12/2000	1.12	108
12/13/2000	1.03	235
12/14/2000	1.10	304
12/15/2000	1.16	400
12/16/2000	1.22	322
12/17/2000	0.99	322
12/18/2000	0.94	272
12/19/2000	1.10	307
12/20/2000	1.06	160
12/21/2000	1.13	308
12/22/2000	0.88	244
12/23/2000	0.26	193
12/24/2000	0.58	192
12/25/2000	0.75	192
12/26/2000	0.94	192
12/27/2000	0.91	192
12/28/2000	0.91	115
12/29/2000	0.88	102
12/30/2000	0.94	122
12/31/2000	1.11	122
1/1/2001	0.54	122
1/2/2001	0.68	74
1/3/2001	1.25	198
1/4/2001	1.30	268
1/5/2001	1.44	110
1/6/2001	1.25	186
1/7/2001	1.10	186
1/8/2001	1.06	177
1/9/2001	0.83	189
1/10/2001	0.77	222
1/11/2001	0.86	238
1/12/2001	0.98	138
1/13/2001	0.90	182
1/14/2001	0.47	182
1/15/2001	0.33	182
1/16/2001	0.83	168
1/17/2001	0.79	354
1/18/2001	1.10	355
1/19/2001	1.20	279
1/20/2001	1.03	292
1/21/2001	0.78	292
1/22/2001	0.75	263
1/23/2001	0.95	272
1/24/2001	1.03	205
1/25/2001	0.91	123
1/26/2001	0.97	123

Date	Flow (mgd)	FC (#/100mL)
1/27/2001	0.95	123
1/28/2001	0.89	123
1/29/2001	0.91	123
1/30/2001	0.96	123
1/31/2001	1.14	123
2/1/2001	1.55	5
2/2/2001	1.44	11
2/3/2001	1.02	29
2/4/2001	0.86	29
2/5/2001	0.85	51
2/6/2001	0.87	48
2/7/2001	0.88	26
2/8/2001	0.89	69
2/9/2001	0.93	106
2/10/2001	0.67	56
2/11/2001	0.54	56
2/12/2001	0.61	27
2/13/2001	0.71	22
2/14/2001	0.77	35
2/15/2001	0.87	18
2/16/2001	1.30	42
2/17/2001	1.34	29
2/18/2001	1.12	29
2/19/2001	0.95	54
2/20/2001	1.10	2
2/21/2001	1.16	4
2/22/2001	1.21	4
2/23/2001	1.16	3
2/24/2001	1.18	3
2/25/2001	1.13	3
2/26/2001	0.86	2
2/27/2001	1.23	2
2/28/2001	0.56	10
3/1/2001	1.06	8
3/2/2001	1.13	292
3/3/2001	1.49	121
3/4/2001	0.87	121
3/5/2001	0.47	70
3/6/2001	0.95	114
3/7/2001	0.47	175
3/8/2001	1.13	70
3/9/2001	1.14	70
3/10/2001	1.07	169
3/11/2001	0.72	168
3/12/2001	0.68	168
3/13/2001	1.14	169
3/14/2001	1.09	169

Date	Flow (mgd)	FC (#/100mL)
3/15/2001	1.16	168
3/16/2001	1.10	268
3/17/2001	0.89	233
3/18/2001	0.54	233
3/19/2001	0.70	266
3/20/2001	1.46	330
3/21/2001	1.19	268
3/22/2001	1.08	200
3/23/2001	0.99	230
3/24/2001	0.61	204
3/25/2001	0.45	204
3/26/2001	0.98	210
3/27/2001	1.09	175
3/28/2001	1.12	70
3/29/2001	1.30	70
3/30/2001	1.15	241
3/31/2001	0.98	238
4/1/2001	0.90	238
4/2/2001	0.90	270
4/3/2001	1.73	370
4/4/2001	1.60	110
4/5/2001	1.48	80
4/6/2001	1.00	89
4/7/2001	0.71	78
4/8/2001	0.47	78
4/9/2001	0.90	96
4/10/2001	1.01	48
4/11/2001	1.16	50
4/12/2001	1.26	24
4/13/2001	1.26	35
4/14/2001	0.91	35
4/15/2001	0.66	35
4/16/2001	1.08	27
4/17/2001	1.03	40
4/18/2001	0.98	44
4/19/2001	0.94	37

Date	Flow (mgd)	FC (#/100mL)
4/20/2001	1.04	25
4/21/2001	0.93	35
4/22/2001	0.76	35
4/23/2001	0.89	48
4/24/2001	0.84	30
4/25/2001	1.21	34
4/26/2001	1.03	10
4/27/2001	1.30	14
4/28/2001	0.89	8
4/29/2001	0.81	8
4/30/2001	0.73	4
5/1/2001	0.80	13
5/2/2001	0.86	3
5/3/2001	0.92	16
5/4/2001	0.93	19
5/5/2001	0.90	12
5/6/2001	0.66	12
5/7/2001	0.63	8
5/8/2001	0.99	5
5/9/2001	1.19	28
5/10/2001	1.10	228
5/11/2001	0.98	21
5/12/2001	0.87	69
5/13/2001	0.44	70
5/14/2001	0.51	70
5/15/2001	1.14	3
5/16/2001	1.23	13
5/17/2001	1.12	26
5/18/2001	1.08	16
5/19/2001	0.87	9
5/20/2001	0.51	8
5/21/2001	0.75	13
5/22/2001	1.01	2
5/23/2001	0.99	21
5/24/2001	0.97	6
5/25/2001	1.16	65

Date	Flow (mgd)	FC (#/100mL)
5/26/2001	0.97	56
5/27/2001	0.63	56
5/28/2001	0.72	56
5/29/2001	0.85	66
5/30/2001	0.80	86
5/31/2001	1.07	90
6/1/2001	1.09	41
6/2/2001	0.45	38
6/3/2001	0.50	38
6/4/2001	0.78	7
6/5/2001	0.88	13
6/6/2001	1.01	16
6/7/2001	0.94	22
6/8/2001	0.78	33
6/9/2001	0.59	24
6/10/2001	0.50	25
6/11/2001	0.76	12
6/12/2001	0.95	31
6/13/2001	0.98	24
6/14/2001	0.96	31
6/15/2001	0.92	57
6/16/2001	0.85	39
6/17/2001	0.53	39
6/18/2001	0.68	30
6/19/2001	0.83	38
6/20/2001	0.83	22
6/21/2001	0.85	25
6/22/2001	0.96	35
6/23/2001	0.79	33
6/24/2001	0.54	33
6/25/2001	0.48	28
6/26/2001	0.71	45
6/27/2001	0.78	91
6/28/2001	0.76	103
6/29/2001	0.73	76
6/30/2001	0.70	76

## Appendix 4 Mecklenburg County Dry Weather Flow Study Data

Data from Mecklenburg County dry weather flow study (Kroening, 2002). Flow and fecal coliform concentrations from outfalls found to possess dry weather flow. These data were used to support calculations associated with dry weather flow/illicit discharges from stormwater outfalls in the North Buffalo Creek TMDL subwatersheds.

Outfall	Flow (cfs)	Fecal coliform (#/100mL)
1	0.02000	6,000
2	0.13000	100
3	0.02000	100
4	0.00200	15,000
5	0.01800	100
6	0.00020	2,700
7	0.00100	600
8	0.01400	4,600
9	0.00800	100
10	0.01100	100
11	0.00550	6,000
12	0.04170	100
13	0.00900	200
14	0.00070	6,000
15	0.00010	8,000
16	0.00050	6,000
17	0.03500	6,600
18	0.00800	100
19	0.00060	100
20	0.00020	1,200
21	0.00350	100
22	0.00520	100

## Appendix 5 Mecklenburg County Ground Water Study Data

**Data from Mecklenburg County ground water study (Kroening, 2002).** Fecal coliform concentrations in ground water sampled from wells up and down gradient from sanitary sewer lines. These data were used to support calculations associated with exfiltrating sanitary sewer lines in the North Buffalo Creek TMDL subwatersheds.

Site	Date	MW-2 (Upgradient) Fecal coliform (#/100 ml)	MW-1 (Downgradient) Fecal coliform (#/100 ml)
Beatties Ford Road	11/13/2000	<200	<200
Beatties Ford Road	11/20/2000	<10	<200
Beatties Ford Road	11/28/2000	<10	<10
Beatties Ford Road	12/5/2000	<10	<10
Latta Park	11/16/2000	-	<200
Latta Park	11/20/2000	-	<10
Latta Park	11/28/2000	-	<10
Latta Park	12/5/2000	-	<10
Latta Park	12/13/2000	-	<10
Latta Park	12/20/2000	-	<10
Latta Park	12/27/2000	-	<10
Latta Park	7/11/2001	-	<10
Masonic	11/16/2000	<200	<200
Masonic	11/20/2000	<200	<200
Masonic	11/28/2000	<10	1,700
Masonic	12/5/2000	<10	80
Masonic	12/14/2000	<10	<10
Masonic	12/20/2000	<10	<10
Masonic	12/27/2000	<10	<10
Masonic	7/11/2001	<10	<10
McDonald	11/13/2000	<200	330
McDonald	11/20/2000	<10	<200
McDonald	11/28/2000	<20	30
McDonald	12/5/2000	<10	<10
McDonald	12/13/2000	<10	<10
McDonald	12/20/2000	<10	20
McDonald	12/27/2000	<10	<10
McDonald	7/11/2001	<10	<10
Meadowbrook	11/13/2000	2000	<200
Meadowbrook	11/20/2000	30	<200
Meadowbrook	11/28/2000	<10	<10
Meadowbrook	12/6/2000	<10	<10

Site	Date	MW-2 (Upgradient) Fecal coliform (#/100 ml)	MW-1 (Downgradient) Fecal coliform (#/100 ml)
Meadowbrook	12/20/2000	<10	<10
Meadowbrook	12/27/2000	<10	<10
Mint Museum	11/13/2000	<200	<200
Mint Museum	11/20/2000	<200	<200
Mint Museum	11/28/2000	<10	<10
Mint Museum	12/6/2000	<10	<10
Sharon View	11/16/2000	<200	<200
Sharon View	11/20/2000	<10	<10
Sharon View	11/28/2000	<10	<10
Sharon View	12/5/2000	<10	<10
Sharon View	12/21/2000	<10	<10
Sharon View	12/27/2000	<10	<10
Southwest Blvd.	11/13/2000	<200	<200
Southwest Blvd.	11/20/2000	<200	<200
Southwest Blvd.	11/28/2000	<10	<10
Southwest Blvd.	12/5/2000	<10	<10
Thermal Road	11/16/2000	<200	<200
Thermal Road	11/21/2000	<200	<200
Thermal Road	11/29/2000	<10	140
Thermal Road	12/5/2000	<10	30
Thermal Road	12/21/2000	<10	<10
Thermal Road	12/27/2000	<10	<10
Thermal Road	7/11/2001	40	100



## Appendix 6 Sewer System Overflows

SSOs in subwatershed 1 during the model simulation period. Source: City of Greensboro Department of Water Resources.

Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
1998/10/29	15:00 (start)	0.00186	1.21E+10
1998/10/29	16:00 (stop)		
1998/12/05	09:00	0.00062	4.04E+09
1998/12/05	12:00		
1998/12/20	14:00	0.00037	2.42E+09
1998/12/20	17:00		
1998/12/28	10:00	0.00186	1.21E+10
1998/12/28	11:00		
1999/01/29	15:00	0.00093	6.06E+09
1999/01/29	17:00		
1999/03/10	07:00	0.00743	4.85E+10
1999/03/10	08:00		
1999/03/17	10:00	0.00031	2.02E+09
1999/03/17	13:00		
1999/06/26	09:00	0.00124	8.08E+09
1999/06/26	12:00		
1999/11/14	12:00	0.00031	2.02E+09
1999/11/15	12:00		
1999/11/26	12:00	0.00464	3.03E+10
1999/11/26	16:00		

SSOs in subwatershed 1 - continued			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
1999/12/04	16:00	0.00093	6.06E+09
1999/12/04	18:00		
1999/12/29	15:00	0.00371	2.42E+10
1999/12/29	17:00		
1999/12/31	16:00	0.00149	9.69E+09
1999/12/31	21:00		
2000/01/07	08:00	0.00743	4.85E+10
2000/01/07	09:00		
2000/01/11	09:00	0.00186	1.21E+10
2000/01/11	11:00		
2000/03/11	13:00	0.01485	9.69E+10
2000/03/11	18:00		
2000/03/13	12:00	0.00093	6.06E+09
2000/03/13	13:00		
2000/03/23	12:00	0.00046	3.03E+09
2000/03/23	14:00		
2000/03/24	09:00	0.00046	3.03E+09
2000/03/24	13:00		
2000/09/19	16:00	0.00371	2.42E+10
2000/09/19	17:00		
2000/09/27	19:00	0.00464	3.03E+10
2000/09/27	23:00		
2000/10/11	11:00	0.00012	8.08E+08
2000/10/11	14:00		
2001/01/06	18:00	0.00111	7.27E+09
2001/01/06	23:00		

SSOs in subwatershed 1 - continued			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
2001/04/10	10:00	0.00012	8.08E+08
2001/04/10	13:00		
2001/04/22	17:00	0.01300	8.48E+10
2001/04/22	19:00		

**SSOs in subwatershed 2 during the model simulation period. Source: City of Greensboro Department of Water Resources.**

Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
3/1/1999	20:00 (start)	0.00173	1.13E+10
3/1/1999	24:00 (stop)		
6/18/1999	12:00	0.00086	5.59E+09
6/18/1999	14:00		
9/8/1999	12:00	0.00743	4.85E+10
9/8/1999	13:00		
9/19/1999	8:00	0.00301	1.96E+10
9/19/1999	11:00		
10/7/1999	13:00	0.00053	3.46E+09
10/7/1999	15:00		
10/13/1999	17:00	0.00134	8.72E+09
10/13/1999	18:00		
5/19/2000	13:00	0.00093	6.06E+09
5/19/2000	14:00		
6/20/2000	8:00	0.00474	3.09E+10
6/20/2000	9:00		
7/2/2000	16:00	0.00906	5.91E+10
7/2/2000	19:00		
7/4/2000	19:00	0.00127	8.26E+09
7/4/2000	21:00		
7/7/2000	18:00	0.01921	1.25E+11
7/7/2000	19:00		
7/7/2000	18:00	0.00113	7.34E+09
7/7/2000	20:00		
8/19/2000	11:00	0.00025	1.65E+09
8/19/2000	13:00		

SSOs in subwatershed 2 - continued			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
12/6/2000	8:00	0.01160	7.57E+10
12/6/2000	10:00		
12/7/2000	14:00	0.04285	2.80E+11
12/7/2000	15:00		
1/1/2001	17:00	0.00142	9.28E+09
1/1/2001	21:00		
1/16/2001	13:00	0.00028	1.82E+09
1/16/2001	15:00		
1/16/2001	8:00	0.05570	3.63E+11
1/16/2001	9:00		

**SSOs in subwatershed 3 during the model simulation period. Source: City of Greensboro Department of Water Resources.**

<b>Date</b>	<b>Start/Stop hour used in model</b>	<b>Flow (cfs)</b>	<b>Fecal coliform load (#/hr)</b>
2/21/2000	17:00 (start)	0.00356	6.52E+12
2/21/2000	20:00 (stop)		

**SSOs in subwatershed 4 during the model simulation period. Source: City of Greensboro Department of Water Resources.**

Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
9/14/1998	9:00 (start)	0.00074	4.85E+09
9/14/1998	11:00 (stop)		
12/13/1998	13:00	0.02153	1.40E+11
12/13/1998	17:00		
12/24/1998	11:00	0.14417	9.41E+11
12/24/1998	14:00		
1/2/1999	10:00	0.00147	9.56E+09
1/2/1999	12:00		
1/7/1999	8:00	0.00088	5.77E+09
1/7/1999	10:00		
1/7/1999	8:00	0.00177	1.15E+10
1/7/1999	11:00		
1/21/1999	11:00	0.00056	3.63E+09
1/21/1999	13:00		
2/24/1999	14:00	0.00014	8.94E+08
2/25/1999	11:00		
4/13/1999	11:00	0.00117	7.65E+09
4/13/1999	15:00		
4/13/1999	12:00	0.00619	4.04E+10
4/13/1999	15:00		
4/21/1999	10:00	0.00099	6.46E+09
4/21/1999	11:00		
4/23/1999	9:00	0.00768	5.01E+10
4/23/1999	10:00		
4/30/1999	7:00	0.24866	1.62E+12
4/30/1999	15:00		

SSOs in subwatershed 4 – continued			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
7/1/1999	12:00	0.01238	8.08E+10
7/1/1999	15:00		
9/1/1999	12:00	0.00025	1.62E+09
9/1/1999	13:00		
9/29/1999	14:00	0.01114	7.27E+10
9/29/1999	15:00		
10/1/1999	14:00	0.00023	1.50E+09
10/1/1999	16:00		
1/8/2000	9:00	0.00099	6.43E+09
1/8/2000	11:00		
1/14/2000	10:00	0.00107	6.99E+09
1/14/2000	12:00		
1/19/2000	12:00	0.00092	5.97E+09
1/19/2000	14:00		
1/26/2000	8:00	0.00098	6.38E+09
1/26/2000	10:00		
3/9/2000	13:00	0.00111	7.27E+09
3/9/2000	15:00		
5/22/2000	14:00	0.00025	1.62E+09
5/22/2000	15:00		
6/11/2000	17:00	0.00166	1.08E+10
6/11/2000	19:00		
6/28/2000	22:00	0.00174	1.14E+10
6/29/2000	1:00		
6/29/2000	10:00	0.00594	3.88E+10
6/29/2000	12:00		



SSOs in subwatershed 4 – continued			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
8/22/2000	16:00	0.03229	2.11E+11
8/22/2000	19:00		
9/7/2000	8:00	0.01447	9.44E+10
9/7/2000	10:00		
9/15/2000	12:00	0.00248	1.62E+10
9/15/2000	15:00		
9/27/2000	17:00	0.00265	1.73E+10
9/27/2000	18:00		
10/27/2000	8:00	0.00039	2.55E+09
10/27/2000	13:00		
11/10/2000	11:00	0.00446	2.91E+10
11/10/2000	12:00		
12/8/2000	15:00	0.00315	2.06E+10
12/8/2000	16:00		
1/31/2001	11:00	0.01485	9.69E+10
1/31/2001	12:00		
3/8/2001	10:00	0.00037	2.42E+09
3/8/2001	11:00		
6/20/2001	12:00	0.00248	1.62E+10
6/20/2001	15:00		
6/27/2001	10:00	0.00186	1.21E+10
6/27/2001	11:00		
7/4/2001	11:00	0.01238	8.08E+10
7/4/2001	13:00		
7/30/2001	13:00	0.00019	1.21E+09
7/30/2001	14:00		

**SSOs in subwatershed 5 during the model simulation period. Source: City of Greensboro Department of Water Resources.**

Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
2/22/1999	15:00 (start)	0.00637	4.15E+10
2/22/1999	17:00 (stop)		
4/20/1999	11:00	0.01547	1.01E+11
4/20/1999	13:00		
6/1/2000	12:00	0.00036	2.34E+09
6/1/2000	13:00		
7/27/2000	13:00	0.00477	3.11E+10
7/27/2000	14:00		
7/28/2000	13:00	0.02958	1.93E+11
7/28/2000	15:00		
7/28/2000	11:00	0.00175	1.14E+10
7/28/2000	16:00		
6/8/2001	9:00	0.02228	1.45E+11
6/8/2001	10:00		

**SSOs in subwatersheds 6.1 & 6.2 during the model simulation period. Source: City of Greensboro Department of Water Resources.**

Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
1/30/1999	14:00 (start)	0.00159	1.04E+10
1/30/1999	17:00 (stop)		
2/11/1999	16:00	0.00696	4.54E+10
2/11/1999	18:00		
3/4/1999	9:00	0.01375	8.97E+10
3/4/1999	11:00		
3/19/1999	8:00	0.00679	4.43E+10
3/19/1999	10:00		
4/1/1999	20:00	0.00201	1.31E+10
4/1/1999	22:00		
4/14/1999	13:00	0.01342	8.76E+10
4/14/1999	15:00		
10/15/1999	10:00	0.00093	6.06E+09
10/15/1999	11:00		
10/29/1999	9:00	0.03713	2.42E+11
10/29/1999	11:00		
11/2/1999	10:00	0.00637	4.15E+10
11/2/1999	12:00		
12/23/1999	10:00	0.00371	2.42E+10
12/23/1999	11:00		
1/11/2000	21:00	0.00061	3.96E+09
1/12/2000	4:00		
2/7/2000	13:00	0.00124	8.08E+09
2/7/2000	15:00		

SSOs in subwatersheds 6.1 & 6.2 - continued			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
2/21/2000	15:00	0.00365	2.38E+10
2/21/2000	18:00		
3/15/2000	11:00	0.00248	1.62E+10
3/15/2000	13:00		
4/25/2000	16:00	0.00191	1.25E+10
4/25/2000	19:00		
5/4/2000	14:00	0.00149	9.69E+09
5/4/2000	17:00		
5/23/2000	8:00	0.00371	2.42E+10
5/23/2000	10:00		
6/10/2000	23:00	0.00321	2.10E+10
6/11/2000	1:00		
8/7/2000	12:00	0.00052	3.38E+09
8/7/2000	14:00		
9/3/2000	22:00	0.00259	1.69E+10
9/3/2000	24:00		
11/30/2000	8:00	0.00535	3.49E+10
11/30/2000	11:00		
2/7/2001	9:00	0.04165	2.72E+11
2/7/2001	11:00		
2/22/2001	7:00	0.01663	1.08E+11
2/22/2001	9:00		
3/27/2001	10:00	0.01013	6.61E+10
3/27/2001	12:00		
4/4/2001	14:00	0.00011	7.13E+08
4/5/2001	10:00		

SSOs in subwatersheds 6.1 & 6.2 - continued			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
5/7/2001	19:00	0.00413	2.69E+10
5/7/2001	21:00		
7/20/2001	12:00	0.00016	1.04E+09
7/20/2001	15:00		

**SSOs in Subwatershed 7 during the model simulation period. Source: City of Greensboro Department of Water Resources.**

SSOs in Subwatershed 7			
Date	Start/Stop hour used in model	Flow (cfs)	Fecal coliform load (#/hr)
5/7/1999	14:00 (start)	0.00262	1.71E+10
5/7/1999	16:00 (stop)		
5/15/1999	10:00	0.00036	2.38E+09
5/15/1999	16:00		
10/26/1999	10:00	0.01505	9.82E+10
10/26/1999	14:00		
3/24/2000	12:00	0.00518	3.38E+10
3/24/2000	13:00		
9/10/2000	17:00	0.00190	1.24E+10
9/10/2000	21:00		
12/21/2000	11:00	0.00836	5.45E+10
12/21/2000	12:00		
2/26/2001	11:00	0.00316	2.06E+10
2/26/2001	17:00		
6/5/2001	14:00	0.11140	7.27E+11
6/5/2001	15:00		
6/18/2001	19:00	0.00285	1.86E+10
6/19/2001	11:00		
6/23/2001	14:00	0.08569	5.59E+11
6/23/2001	15:00		
7/20/2001	13:00	0.00637	4.15E+10
7/20/2001	14:00		

Note: no SSOs occurred in subwatershed 8 during the model simulation period.

## Appendix 7 Calibrated Water Quality Model Parameters

Subwatershed	Land use/land cover	ACQOP <sup>1</sup>	SQOLIM <sup>2</sup>	IOQC/AOQC <sup>3</sup>
1	Roads (ROW)	1.37E+09	2.47E+09	16400
1	Woods	1.37E+09	2.47E+09	16400
1	Institutional	1.60E+10	2.88E+10	16400
1	Residential	9.28E+09	1.67E+10	16400
1	Industrial/Commercial	1.60E+10	2.88E+10	16400
1	Herbaceous	1.37E+09	2.47E+09	16400
2	Roads (ROW)	1.37E+09	2.47E+09	16400
2	Woods	1.37E+09	2.47E+09	16400
2	Institutional	1.60E+10	2.88E+10	16400
2	Residential	8.12E+09	1.46E+10	16400
2	Industrial/Commercial	1.60E+10	2.88E+10	16400
2	Herbaceous	1.37E+09	2.47E+09	16400
3	Roads (ROW)	1.37E+09	2.47E+09	82100
3	Woods	1.37E+09	2.47E+09	82100
3	Institutional	1.60E+10	2.88E+10	82100
3	Herbaceous	1.37E+09	2.47E+09	82100
3	Residential	9.65E+09	1.74E+10	82100
4	Roads (ROW)	1.37E+09	2.47E+09	200000
4	Woods	1.37E+09	2.47E+09	200000
4	Institutional	1.60E+10	2.88E+10	200000
4	Residential	1.51E+10	2.72E+10	200000
4	Industrial/Commercial	1.60E+10	2.88E+10	200000
4	Herbaceous	1.37E+09	2.47E+09	200000
4	Downtown	1.60E+10	2.88E+10	200000
5	Roads (ROW)	1.37E+09	2.47E+09	16400
5	Woods	1.37E+09	2.47E+09	16400
5	Institutional	1.60E+10	2.88E+10	16400
5	Industrial/Commercial	1.60E+10	2.88E+10	16400
5	Herbaceous	1.37E+09	2.47E+09	16400
5	Residential	1.20E+10	2.16E+10	16400
6.1	Roads (ROW)	1.37E+09	2.47E+09	16400
6.1	Woods	1.37E+09	2.47E+09	16400
6.1	Institutional	1.60E+10	2.88E+10	16400
6.1	Residential	8.33E+09	1.50E+10	16400
6.1	Industrial/Commercial	1.60E+10	2.88E+10	16400
6.1	MF	8.33E+09	1.50E+10	16400
6.1	Herbaceous	1.37E+09	2.47E+09	16400
6.1	Residential	8.33E+09	1.50E+10	16400

Subwatershed	Land use/land cover	ACQOP <sup>1</sup>	SQOLIM <sup>2</sup>	IOQC/AOQC <sup>3</sup>
6.2	Roads (ROW)	1.37E+09	2.47E+09	16400
6.2	Woods	1.37E+09	2.47E+09	16400
6.2	Institutional	1.60E+10	2.88E+10	16400
6.2	Residential	8.33E+09	1.50E+10	16400
6.2	Industrial/Commercial	1.60E+10	2.88E+10	16400
6.2	Herbaceous	1.37E+09	2.47E+09	16400
7	Roads (ROW)	1.37E+09	2.47E+09	200000
7	Woods	1.37E+09	2.47E+09	200000
7	Institutional	1.60E+10	2.88E+10	200000
7	Residential	1.19E+10	2.14E+10	200000
7	Industrial/Commercial	1.60E+10	2.88E+10	200000
7	Herbaceous	1.37E+09	2.47E+09	200000
8	Roads (ROW)	1.37E+09	2.47E+09	16400
8	Woods	1.37E+09	2.47E+09	16400
8	Industrial/Commercial	1.60E+10	2.88E+10	16400
8	Herbaceous	1.37E+09	2.47E+09	16400

- 1 ACQOP is the rate of accumulation of fecal coliform (#/ac-day). Rate given used for both the pervious and impervious portions of the land cover. See Part 2 – Source Assessment for additional details.
- 2 SQOLIM is the maximum storage of fecal coliform (#/ac). Rate given used for both the pervious and impervious portions of the land cover.
- 3 IOQC and AOQC is the concentration of fecal coliform in interflow outflow and groundwater outflow, respectively (#/ft<sup>3</sup>). See Part 2 – Source Assessment for additional details.



## Appendix 8 Calibrated Model Hydraulic Parameters

Subwatershed	LZSN <sup>1</sup>	INFILT <sup>2</sup>	AGWRC <sup>3</sup>	DEEPFR <sup>4</sup>	INTFW <sup>5</sup>	IRC <sup>6</sup>	LZETP <sup>7</sup>
1	10	0.06	0.99	0.1	1	0.3	0.1-0.5
2	10	0.06	0.99	0.1	1	0.3	0.1-0.5
3	10	0.06	0.99	0.1	1	0.3	0.2-0.5
4	7	0.25	0.98	0.1	1	0.3	0.1-0.7
5	6	0.16	0.98	0.1	0.75	0.5	0.1-0.7
6.1	10	0.16	0.98	0.1	1	0.3	0.3
6.2	6	0.16	0.98	0.1	0.75	0.5	0.1-0.7
7	6	0.16	0.98	0.1	0.75	0.5	0.1-0.7
8	6	0.16	0.98	0.1	0.75	0.5	0.1-0.7

- 1 Lower zone nominal storage (inches)
- 2 Soil infiltration rate (in/hr)
- 3 Groundwater recession rate (/day)
- 4 Fraction of infiltrating water which is lost to deep aquifers (no units)
- 5 Interflow inflow (no units)
- 6 Interflow recession coefficient (no units)
- 7 Lower zone evapotranspiration (no units)

## **Appendix 9 Greensboro's Municipal NPDES Stormwater Permit**

The City of Greensboro is authorized to discharge stormwater from its Municipal Separate Storm Sewer System (MS4) under EPA's NPDES Phase I stormwater permit program. The NC Division of Water Quality is the delegated permitting authority for the NPDES program. Greensboro's NPDES permit (NCS000248) became effective on December 30, 1994 with the first five year term expiring on June 30, 1999. The second NPDES permit term began on July 1, 1999 and is set to expire on June 30, 2004. The City's NPDES stormwater permit, and associated Stormwater Quality Management Program (SWQMP), is designed to control the discharge of pollutants from the MS4 to the maximum extent practicable. To meet this objective and comply with NPDES stormwater regulations, the City has developed four major program areas as follows:

- ✓ Commercial and Residential Program
- ✓ Illicit Discharge and Improper Disposal Detection and Elimination Program
- ✓ Industrial and Related Facilities Program, and;
- ✓ Construction Site Runoff Program

### **Commercial and Residential Program**

The focus of the Commercial and Residential Program is to develop structural and source control measures to reduce pollutants from runoff from commercial and residential areas that are discharged from the MS4. The program also includes development of pollutant load reduction estimates resulting from these activities and a proposed schedule for implementing such controls. The program is divided into six main components as follows:

- ◆ BMP maintenance and inspections
- ◆ New development and regional master planning
- ◆ Street maintenance and operations
- ◆ Flood control structures and retrofitting
- ◆ Municipal waste management
- ◆ Pesticide, fertilizer, and herbicide management

### **Illicit Discharge and Improper Disposal Detection and Elimination Program**

The focus of this program is to detect and remove illicit discharges into the stormwater conveyance system. The City has developed its illicit discharge detection and elimination program into seven categories as follows:

- ◆ Establishment of legal authority
- ◆ Field screening program
- ◆ Follow-up investigation program
- ◆ Spill response program
- ◆ Public reporting program
- ◆ Used oil and household hazardous waste program
- ◆ Sanitary waste management program

### **Industrial and Related Facilities Program**

The focus of this program is to monitor and control pollutants in stormwater discharges from municipal landfills, hazardous waste treatment, disposal, and recovery facilities, industrial facilities that are subject to section 313 of title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA), and industrial facilities that are contributing a substantial pollutant loading to the MS4. The industrial and related facilities program is divided into two main components as follows:

- ◆ Inspections, control, and training
- ◆ Monitoring

### **Construction Site Runoff Program**

The focus of this program is to implement and maintain structural and non-structural BMPs to reduce pollutants in stormwater runoff from construction sites to the MS4. The construction site runoff program is divided into four main components as follows:

- ◆ Site planning
- ◆ BMP requirements
- ◆ Site inspections and enforcement
- ◆ Site operator education

Implementation of Greensboro's NPDES Phase I permit is supported by a Stormwater Utility funding mechanism which ensures a dedicated source of revenue for the aforementioned programs and activities. More information about the City's Stormwater Management Program can be found at the following web address:

<http://www.ci.greensboro.nc.us/stormwater/>

**Appendix 10 Public Notification of North Buffalo Creek Fecal Coliform TMDL**

Now Available Upon Request

**Fecal Coliform  
Total Maximum Daily Load  
North Buffalo Creek  
Public Review Draft – January 2004**

Is now available upon request from the North Carolina Division of Water Quality. This TMDL study was prepared as a requirement of the Federal Water Pollution Control Act, Section 303(d). The study identifies the sources of the pollutants, determines allowable loads to surface waters, and suggests pollutant allocations.

**TO OBTAIN A FREE COPY OF THE TMDL REPORTS:**

Please contact Ms. Robin Markham (919) 733-5083, extension 558 or write to:

A dugna Kebede  
Water Quality Planning Branch  
NC Division of Water Quality  
1617 Mail Service Center  
Raleigh, NC 27699-1617

The draft TMDL is also located on the following website: <http://h2o.enr.state.nc.us/tmdl>. Interested parties are invited to comment on the draft TMDL study by February 13, 2004. Comments concerning the report should be directed to the Division of Water Quality at the above address.

**Public Meeting Notice**

A public meeting to discuss the TMDL will be held on  
**January 29 at 9 AM** at the following address:  
CITY OF GREENSBORO WATER RESOURCES DEPARTMENT  
201 North Green Street (2<sup>nd</sup> floor), NC 27402  
Phone: 336-373-2707

News & Record

Published by  
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Affidavit of Publication

1/9/2004

Before the undersigned, a Notary Public of said County and State, duly commissioned, qualified and authorized by law to administer oaths, personally appeared the Publisher's Representative who being first duly sworn, deposed and says:

1. That he/she is the Publisher's Representative of the Greensboro News & Record, Inc. a corporation, engaged in the publication of newspapers known as "News & Record", published, issued and entered as second class mail in the City of Greensboro in said County and State.
2. That he/she is authorized to make this affidavit and sworn statement; that the notice or other legal advertisement, a copy of which is attached hereto, was published in the News & Record on the dates listed below.
3. That the said newspaper (or newspapers) in which such notice, paper, document, or legal advertisement was published was, at the time of each and every such publication, a newspaper meeting all of the requirements and qualifications of Section 1-597 of the General Statutes of North Carolina and was a qualified newspaper within the meaning of Section 1-597 of the General Statutes of North Carolina.

Publisher's Representative Donna Satterfield

Sworn to and subscribed before me, this 12<sup>th</sup> day of January, 2004.

Valerie McNeil  
 Notary Public

VALERIE McNEIL  
 NOTARY PUBLIC  
 GUILFORD COUNTY, NC  
 Commission Expires 8-23-2005

My commission expires: August 23, 2005

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Public Notice  
 State of North Carolina  
 Division of Water Quality  
 and  
 City of Greensboro,  
 Department of Water Resources  
 Stormwater Management  
 Division

Availability of the Fecal Coliform  
 Total Maximum Daily Load  
 (TMDL) for North Buffalo Creek

Copies of the TMDL may be ob-  
 tained by calling Robin  
 Markham at (919) 733-5083  
 ext. 558 or on the Internet at  
<http://h2o.enr.state.nc.us/im>  
 dl or  
[www.greensboro-nc.gov/storm-](http://www.greensboro-nc.gov/storm-)  
[water/nbundi.pdf](http://water/nbundi.pdf).

A public meeting to discuss the  
 TMDL will be held on Thursday,  
 January 29th, 2004 at 9:00am  
 in the City of Greensboro Wa-  
 ter Resources Department  
 Conference Room located at  
 201 North Greene St. (2nd  
 floor), Greensboro, NC.

Written comments regarding this  
 TMDL will be accepted until  
 February 13, 2004.  
 Please mail comments to  
 NCDWQ Planning Branch, attn:  
 Aduigna Kebede, 1617 Mail  
 Service Center, Raleigh NC  
 27689.