Total Maximum Daily Load for Turbidity for Abbotts Creek, Ararat River, Hunting Creek, Second Creek, South Deep Creek, South Yadkin River, and Third Creek in North Carolina

[Assessment Units 12-119-(6)a, 12-72-(18), 12-72-(4.5)b, 12-108-16-(0.5)b, 12-108-21b, 12-84-2-(5.5), 12-108-(14.5), 12-108-(19.5)b, 12-108-20-4b]

Final Report
September 2011

Yadkin-Pee Dee River Basin

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TMDL Summary Sheet

303(d) List Information

State: North Carolina
Counties: Davidson, Davie, Forsyth, Iredell, Rowan, Surry, Wilkes, Yadkin
Basin: Yadkin- Pee Dee River Basin

Waterbody Name	Assessment Unit (AU):	Class	10 digit HU	Impairment	Miles
Abbotts Creek	12-119-(6)a	C	0304010302	Turbidity	6.4
Ararat River	12-72-(18)	WS-IV	0304010109	Turbidity	2
Ararat River	12-72-(4.5)b	C	0304010109	Turbidity	13.7
Hunting Creek	12-108-16-(0.5)b	WS-III	0304010202	Turbidity	31.1
Second Creek	12-108-21b	C	0304010205	Turbidity	3.4
South Deep Creek	12-84-2-(5.5)	WS-IV	0304010111	Turbidity	2.8
South Yadkin River	12-108-(14.5)	WS-IV	0304010206	Turbidity	9.5
South Yadkin River	12-108-(19.5)b	C	0304010301	Turbidity	5.3
Third Creek	12-108-20-4b	C	0304010203	Turbidity	22.1

Constituent of Concern: Turbidity
Reason for Listing: Standard Violations

Applicable Water Quality Standard:

The turbidity in the receiving water shall not exceed 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters and 10 NTU in stream, lakes or reservoirs designated as trout water; for lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level cannot be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) recommended by the Designated Nonpoint Source Agency. BMPs must be in full compliance with all specifications governing the proper design, installation, operation and maintenance of such BMPs.

TMDL Development

Analysis/Modeling:
Load duration curves are based on cumulative frequency distribution of flow conditions in the watershed. Allowable loads are average loads over the recurrence interval between the 90^{th} and 10^{th} percent flow exceeded (excludes extreme drought (>90^{th} percentile) and floods (<10^{th} percentile). Percent reductions are expressed as the average value between existing loads (typically calculated using an equation to fit a curve through actual water quality violations) and the allowable load at each percent flow exceeded.

Turbidity is a measure of cloudiness and is reported in Nephelometric Turbidity Units (NTU). Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, total suspended solid (TSS) was selected as the measure for this study.

Critical Conditions:
Critical conditions are accounted in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining at what flow (percent flow exceeded) the existing load violations occur.

Seasonal Variation:
Seasonal variation in hydrology, climatic conditions, and watershed activities are represented through the use of a continuous flow gage and the use of all readily available water quality data collected in the watershed.

TMDL Allocation Summary

Pollutants/Watershed	Existing Load	WLA	LA	MOS	TMDL
Total Suspended Sediment (tons/day)					
Abbotts Creek	21.30	0.064	9.236	10%	9.30
Ararat River	28.20	0.170	12.830	10%	13.00
Hunting Creek	23.40	0.000	11.200	10%	11.20
Second Creek	5.20	0.17	2.977	10%	3.10
South Deep Creek	16.40	0.003	8.497	10%	8.50
South Yadkin River	50.20	0.179	25.221	10%	25.40
Third Creek	13.30	0.489	6.411	10%	6.90

Notes:
WLA = Wasteload Allocation, LA = Load Allocation, MOS = Margin of Safety.

1. LA = TMDL – WLA – MOS.
2. TMDL represents the average allowable load between the 90^{th} and 10^{th} percent recurrence interval.

3. Explicit (10%) margin of safety is considered.

Public Notice Date: July 26, 2011
Submittal Date:
EPA Approval Date:

Table of Contents

1.0 Introduction 1

1.1 TMDL Definition 1

1.2 Water Quality Target: North Carolina Standards and Classifications 3

1.3 Watershed Description 3

1.4 Water Quality Monitoring 19

2.0 General Source Assessment 20

2.1 Nonpoint Sources of Turbidity 20

2.2 Point Sources of Turbidity 21

3.0 Abbotts Creek Impairment 22

3.1 Source Assessment 22

3.2 Technical Approach 22

3.2.1 Endpoint for Turbidity 23

3.2.2 Methodology 23

3.3 Flow Duration Curve 23

3.4 Load Duration Curve 24

3.5 TMDL 25

3.6 Margin of Safety (MOS) 26

3.7 Target Reduction 26

3.8 TMDL Allocation 27

3.8.1 Waste Load Allocation (WLA) 27

3.8.2 Load Allocation (LA) 28

3.8.3 Critical Conditions and Seasonal Variation 29

4.0 Ararat River Impairment 29

4.1 Source Assessment 29

4.2 Technical Approach 30

4.3 Flow Duration Curve 31

4.4 Load Duration Curve 31

4.5 TMDL 33

4.5.1 Margin of Safety (MOS) 33

4.6 Target Reduction 33

4.7 TMDL Allocation 34

4.7.1 Waste Load Allocation (WLA) 34

4.7.2 Load Allocation (LA) 35

4.7.3 Critical Condition and Seasonal Variation 36

5.0 Hunting Creek 36
5.1 Source Assessment 36
5.2 Technical Approach 37
5.3 Flow Duration Curve 37
5.4 Load Duration Curve 38
5.5 TMDL 40
5.5.1 Margin of Safety (MOS) 40
5.6 Target Reduction 40
5.7 TMDL Allocation 41
5.7.1 Waste Load Allocation (WLA) 41
5.7.2 Load Allocation (LA) 42
5.7.3 Critical Condition and Seasonal Variation 42
6.0 Second Creek 43
6.1 Source Assessment 43
6.2 Technical Approach 43
6.3 Flow Duration Curve 44
6.4 Load Duration Curve 45
6.5 TMDL 46
6.5.1 Margin of Safety (MOS) 47
6.6 Target Reduction 47
6.7 TMDL Allocation 48
6.7.1 Waste Load Allocation (WLA) 48
6.7.2 Load Allocation (LA) 50
6.7.3 Critical Condition and Seasonal Variation 50
7.0 South Deep Creek 50
7.1 Source Assessment 50
7.2 Technical Approach 51
7.3 Flow Duration Curve 52
7.4 Load Duration Curve 53
7.5 TMDL 54
7.5.1 Margin of Safety (MOS) 55
7.6 Target Reduction 55
7.7 TMDL Allocation 56
7.7.1 Waste Load Allocation (WLA) 56
7.7.2 Load Allocation (LA) 57

7.7.3 Critical Condition and Seasonal Variation ... 58
8.0 South Yadkin River ... 58
8.1 Source Assessment ... 58
8.2 Technical Approach ... 59
8.3 Flow Duration Curve ... 60
8.4 Load Duration Curve ... 61
8.5 TMDL ... 62
8.5.1 Margin of Safety (MOS) ... 63
8.6 Target Reduction ... 63
8.7 TMDL Allocation ... 64
8.7.1 Waste Load Allocation (WLA) ... 64
8.7.2 Load Allocation (LA) ... 65
8.7.3 Critical Condition and Seasonal Variation ... 66
9.0 Third Creek ... 66
9.1 Source Assessment ... 66
9.2 Technical Approach ... 67
9.3 Flow Duration Curve ... 68
9.4 Load Duration Curve ... 69
9.5 TMDL ... 70
9.5.1 Margin of Safety (MOS) ... 71
9.6 Target Reduction ... 71
9.7 TMDL Allocation ... 72
9.7.1 Waste Load Allocation (WLA) ... 72
9.7.2 Load Allocation (LA) ... 73
9.7.3 Critical Condition and Seasonal Variation ... 74
10.0 Summary and Future Implementation ... 74
10.1 TMDL Implementation ... 75
11.0 Public Participation ... 75
12.0 References ... 76
Appendix A: Land Cover Data in Square Miles and Percent Area for the Impaired Watersheds 77
Appendix B. Water Quality Data Used for TMDL Development ... 78
Appendix C. Load Reduction Estimations ... 86
Appendix D: Public Notification of TMDL for Yadkin River Basin Turbidity TMDLS ... 93
Appendix E: Public Comments ... 94

1.0 Introduction

1.1 TMDL Definition

This report presents the development of turbidity TMDLs for seven waterbodies (9 assessment units) in the Yadkin-Pee Dee River Basin (Figure 1.1) in North Carolina. As identified by the North Carolina Division of Water Quality (DWQ), the impaired segments of each waterbody are described in Table 1.1.

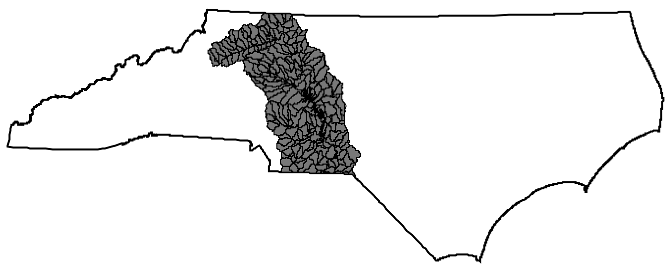


Figure 1.1 Location of the Yadkin River Basin within North Carolina

Table 1.1 Description of turbidity impaired assessment units

Waterbody Name	Description	Assessment Unit (AU):	Class	Miles
Abbotts Creek	From upstream side of culvert at U.S. Hwys. 29 & 70 to SR1243	12-119-(6)a	C	6.4
Ararat River	From a point 0.1 mile upstream of Surry County SR 2080 to Yadkin River	12-72-(18)	WS-IV	2
Ararat River	From Stoney Creek 12-72-12 to a point 0.1 mile upstream of Surry County SR 2080	12-72-(4.5)b	C	13.7
Hunting Creek	From Little Hunting Creek to a point 1.1 miles upstream of Davie County SR 1147	12-108-16-(0.5)b	WS-III	31.1
Second Creek	From Withrow Creek to Beaverdam Creek	12-108-21b	C	3.4
South Deep Creek	From a point 0.6 mile upstream of Yadkin County SR 1710 to Deep Creek	12-84-2-(5.5)	WS-IV	2.8
South Yadkin River	From a point 1.0 mile upstream of Davie County SR 1159 to N.C. Hwy. 801	12-108-(14.5)	WS-IV	9.5
South Yadkin River	From mouth of Fourth Creek to Yadkin River	12-108-(19.5)b	C	5.3
Third Creek	From SR 2359 to SR 1970	12-108-20-4b	C	22.1

Section 303(d) of the Clean Water Act (CWA) requires States to develop a list of waterbodies that do not meet water quality standards. The list, referred to as the 303(d) list, is submitted biennially to the U.S. Environment Protection Agency (USEPA) for review and approval. The

303(d) process requires that a Total Maximum Daily Load (TMDL) be developed for each of the waters appearing on the 303(d) list.

The objective of a TMDL is to allocate allowable pollutant loads to known sources so that actions may be taken to restore the water to its intended uses (USEPA, 1991). Generally, the primary components of a TMDL, as identified by USEPA (1991, 2000) and the Federal Advisory Committee (USEPA, 1998) are as follows:

Target identification or selection of pollutant(s) and end-point(s) for consideration. The pollutant and end-point are generally associated with measurable water quality related characteristics that indicate compliance with water quality standards.

Source assessment. All sources that contribute to the impairment should be identified and loads quantified, where sufficient data exist.

Assimilative Capacity. Estimation of level of pollutant reduction needed to achieve water quality goal. The level of pollution should be characterized for the water body, highlighting how current conditions deviate from the target end-point. Generally, this component is identified through water quality modeling.

Allocation of Pollutant Loads. Allocating pollutant control responsibility to the sources of impairment. The waste load allocation portion of the TMDL accounts for the loads associated with point sources, including NPDES stormwater. Similarly, the load allocation portion of the TMDL accounts for the loads associated with nonpoint sources.

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 or implicitly due to conservative assumptions.

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

Critical Conditions. Critical conditions indicate the combination of environmental factors that result in just meeting the water quality criterion and have an acceptably low frequency of occurrence.

Section 303(d) of the CWA requires EPA to review all TMDLs for approval. Once EPA approves a TMDL, the water body is moved off the 303(d) list. Waterbodies remain impaired until compliance with water quality standards is achieved.

1.2 Water Quality Target: North Carolina Standards and Classifications

The North Carolina fresh water quality standard for turbidity (15A NCAC 02B. 0211) states:

> *The turbidity in the receiving water shall not exceed 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters and 10 NTU in stream, lakes or reservoirs designated as trout water; for lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level cannot be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) recommended by the Designated Nonpoint Source Agency. BMPs must be in full compliance with all specifications governing the proper design, installation, operation and maintenance of such BMPs.*

1.3 Watershed Description

The impaired waterbodies are located in the Yadkin-Pee Dee River Basin. Watersheds of the impaired waterbodies were delineated using USGS -12 digit HUCs. Location maps for the impaired waterbodies are shown in the following Figures.

Land Cover

The land cover dataset used for this project was created by the NC Center for Geographic Information and Analysis (CGIA) for the upper portion of the Yadkin River Basin, including the entire High Rock Lake watershed. Data are derived from Landsat 5 imagery from 2006 and 2007. The methodology used to create this dataset was based on that used to create the 2001 National Land Cover Database (NLCD). Land cover distribution maps of the watersheds are shown in the following figures, and a comparison is shown in Figure 1.20. A detailed land cover distribution by square miles and percent area are shown for each impaired watershed in Appendix A.

Figure 1.21 shows the land cover distribution adjacent to streams. These data were derived by using GIS to select only land cover grid cells that were intersected by a 1:24000 stream segment.

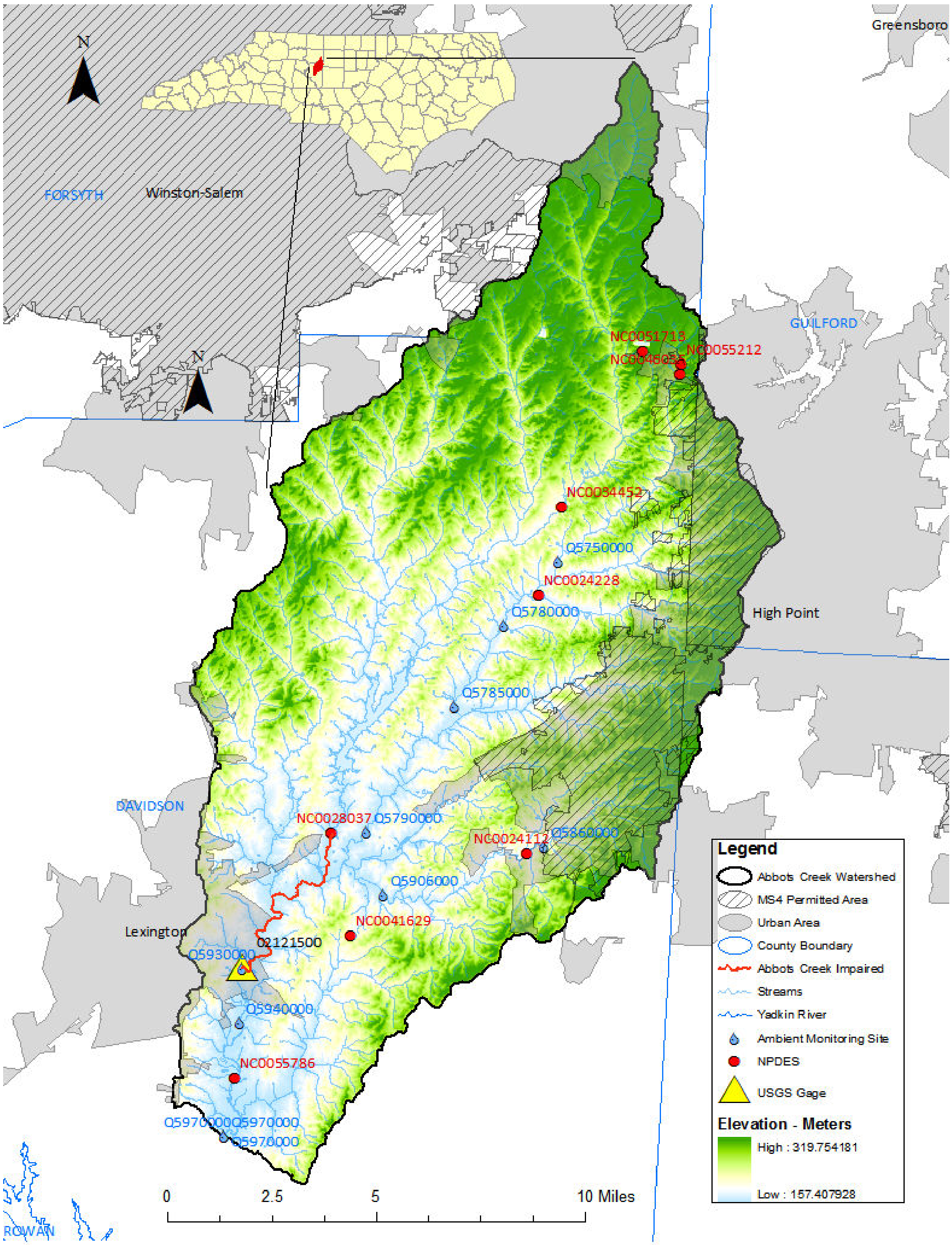


Figure 1.2 Abbotts Creek Watershed

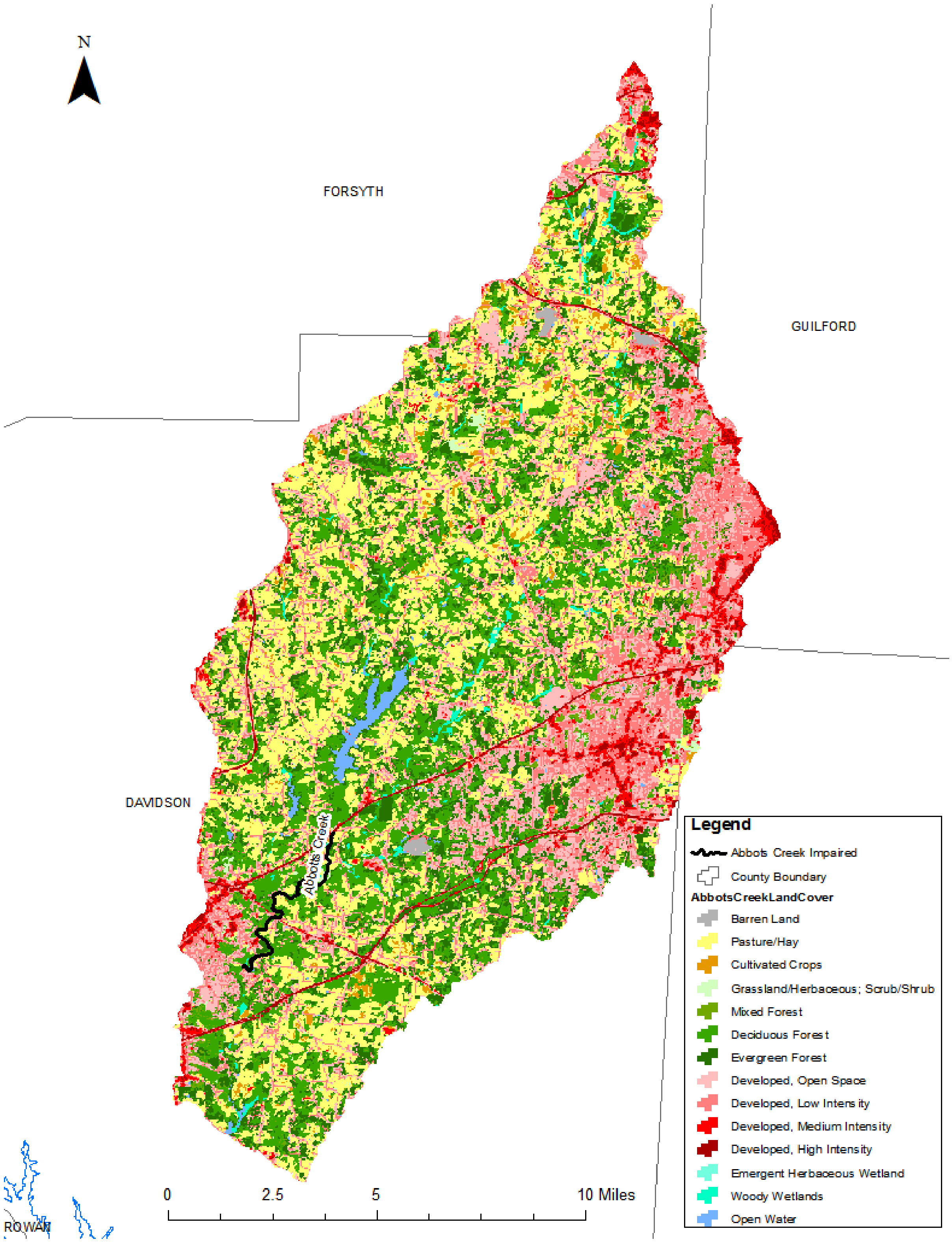


Figure 1.3 Land cover distribution in the Abbotts Creek watershed

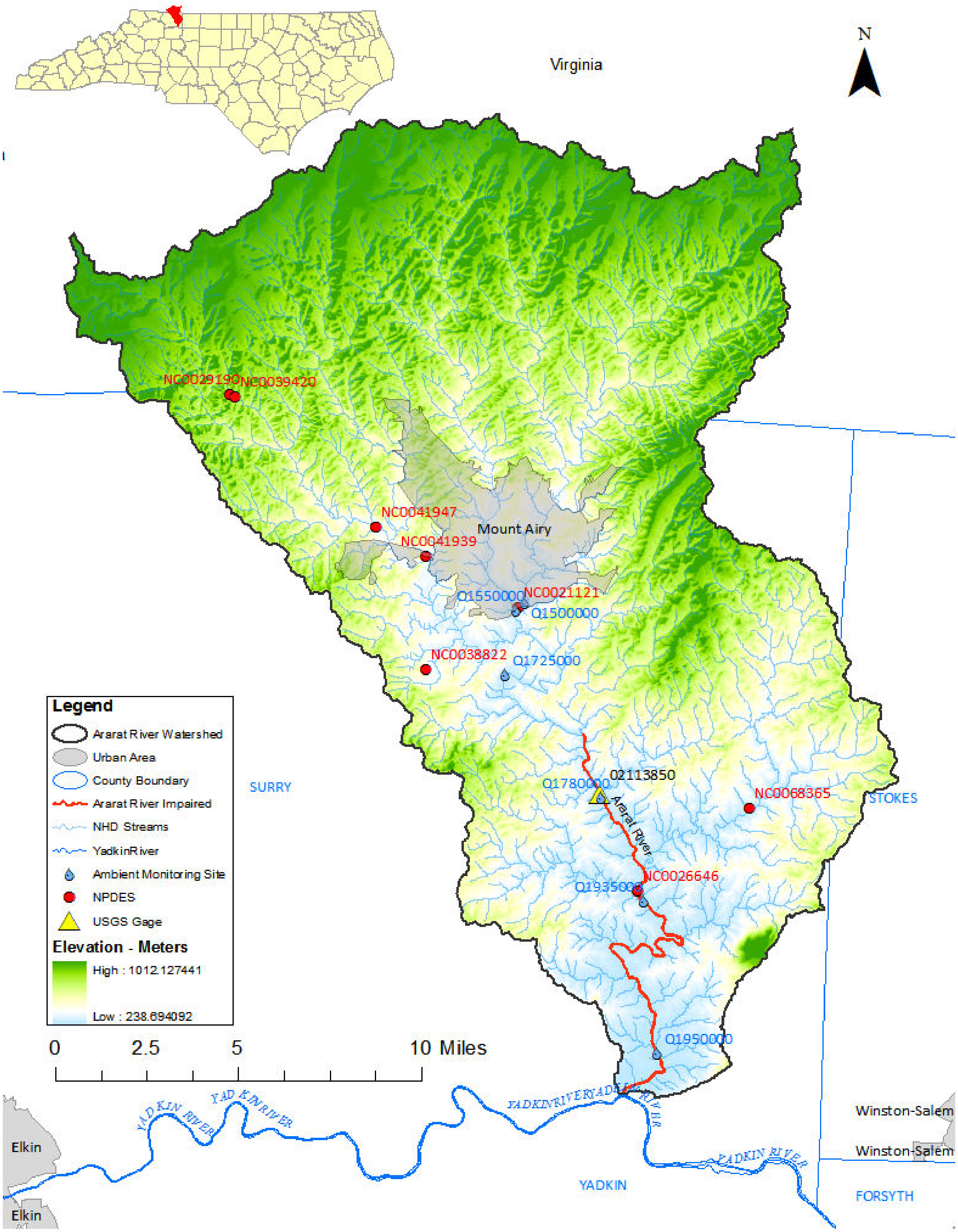


Figure 1.4 Ararat River watershed

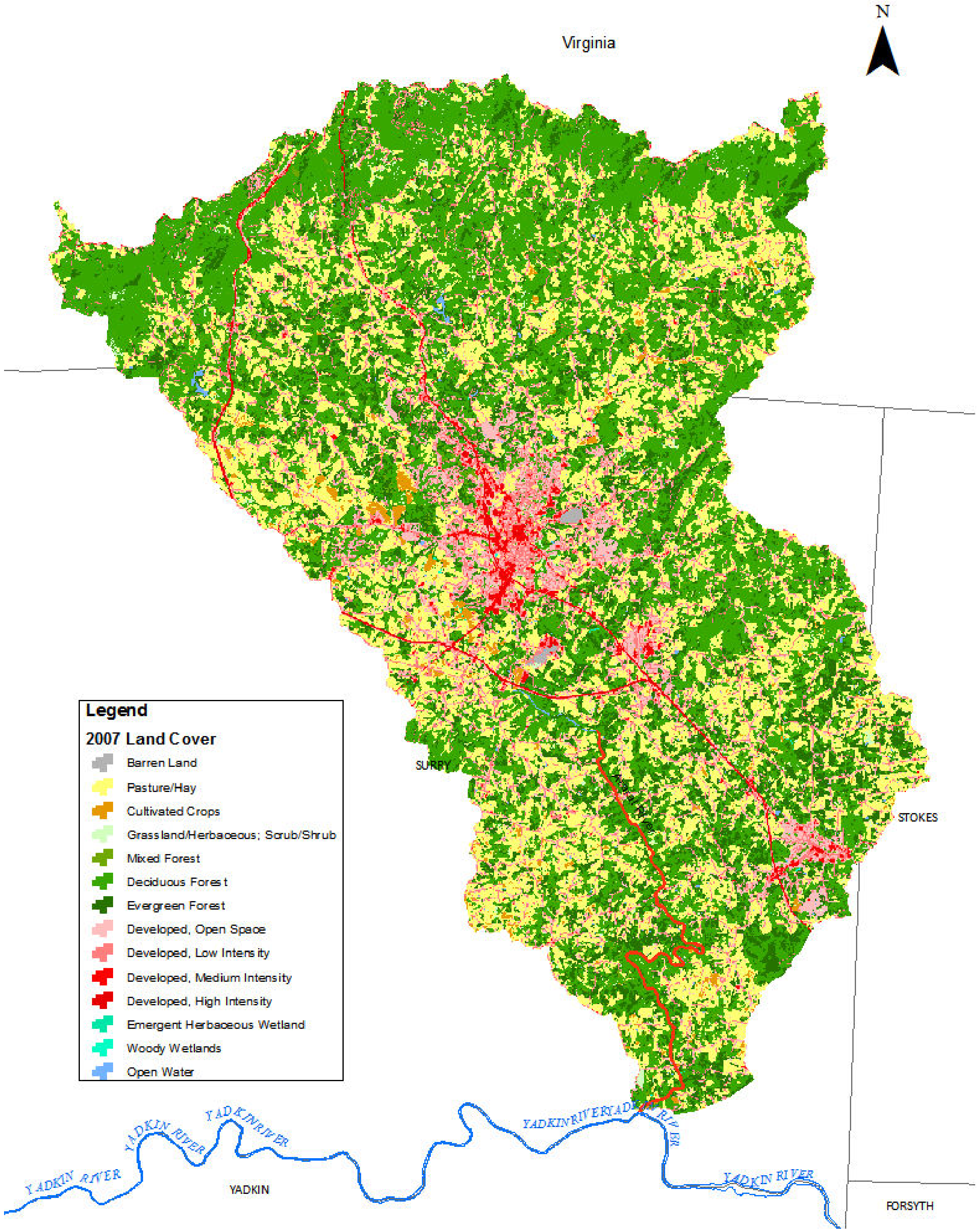


Figure 1.5 Land cover distribution in the Ararat River watershed

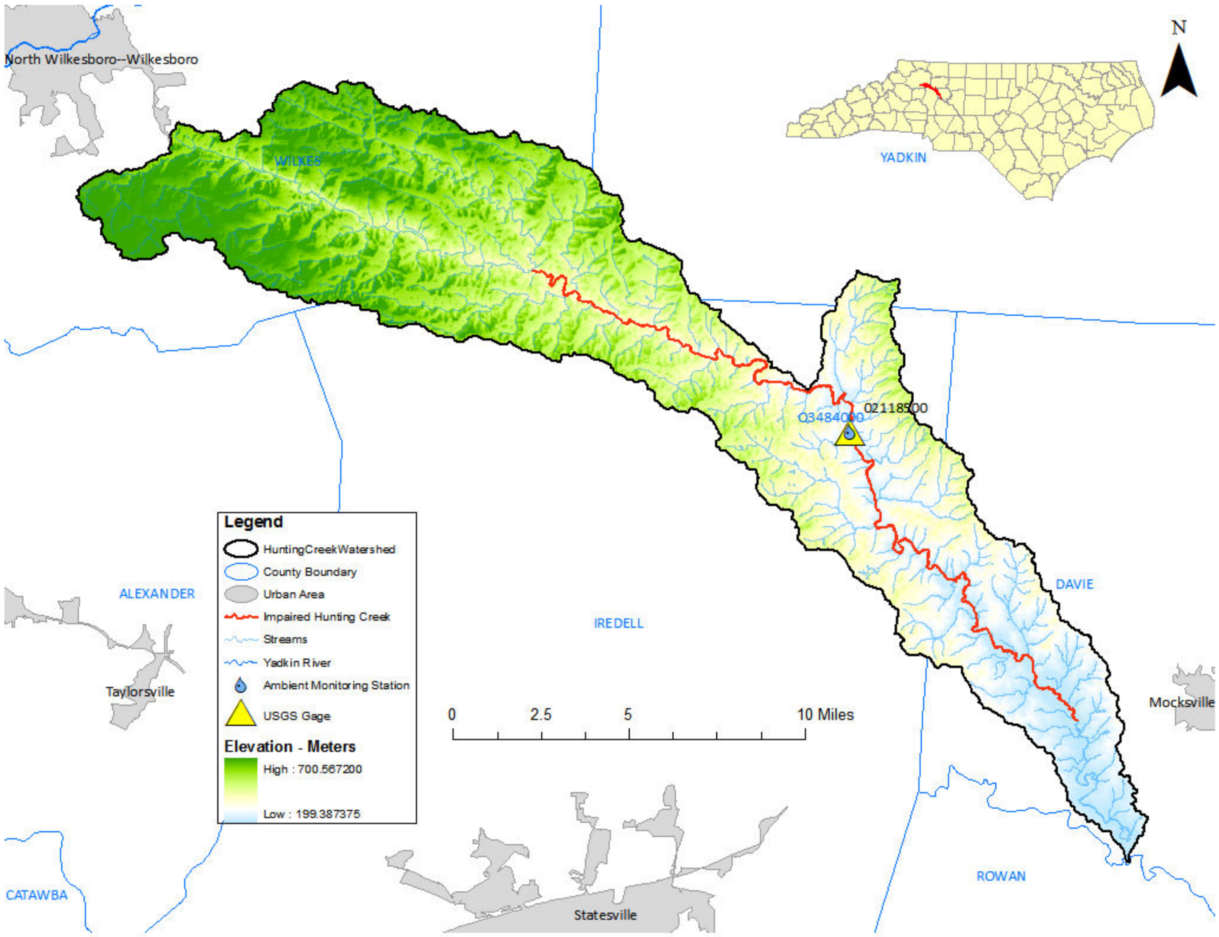


Figure 1.6 Hunting Creek watershed

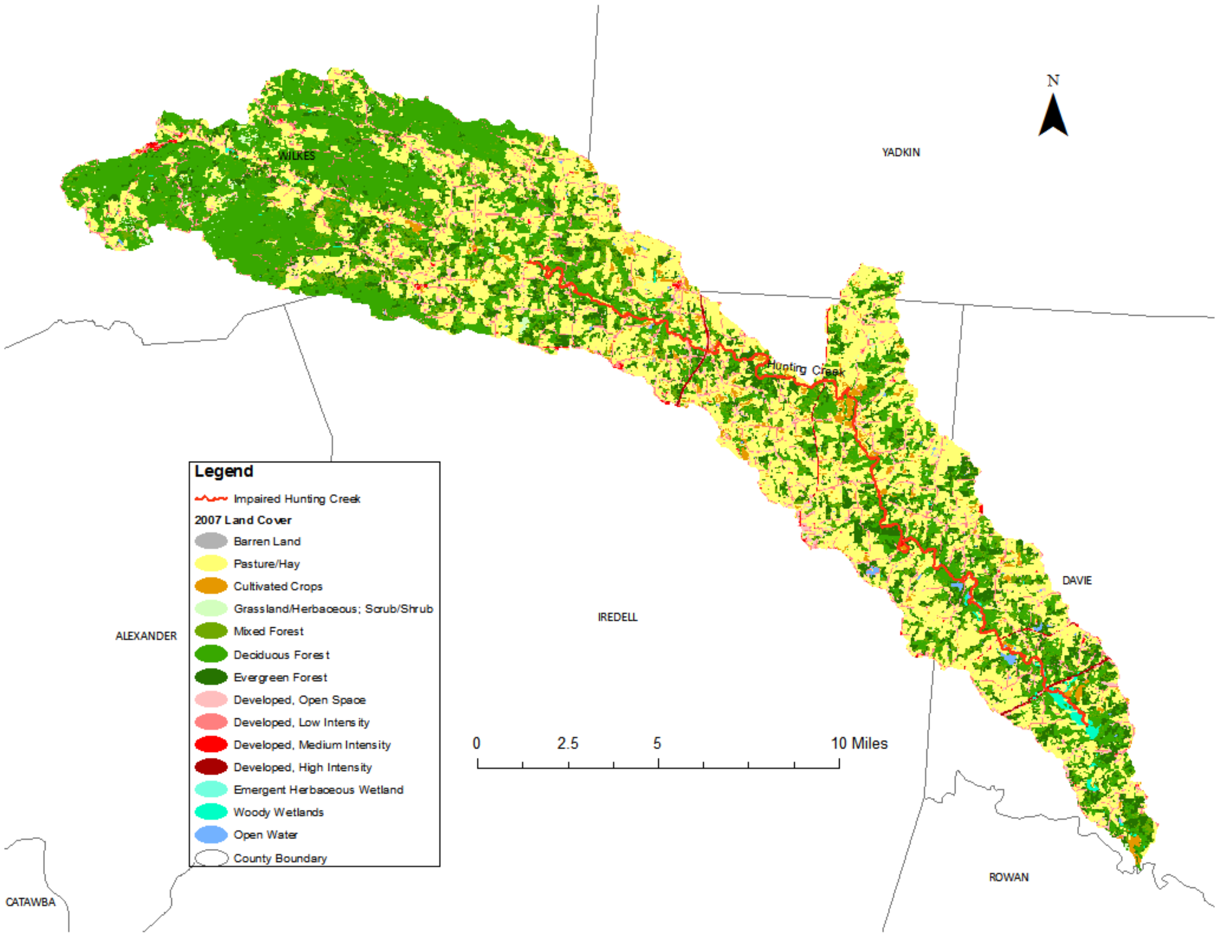


Figure 1.7 Land cover distribution in the Hunting Creek watershed

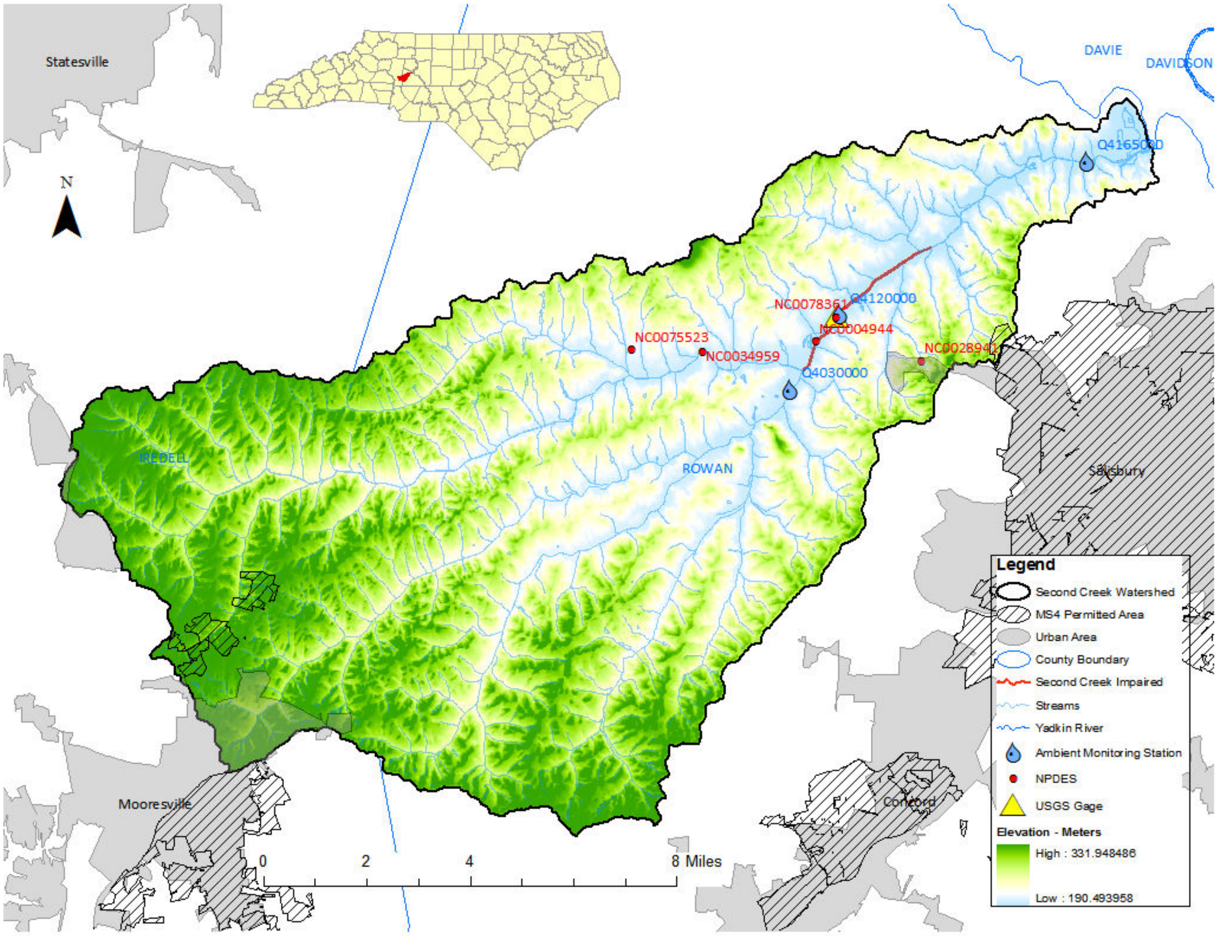


Figure 1.8 Second Creek watershed

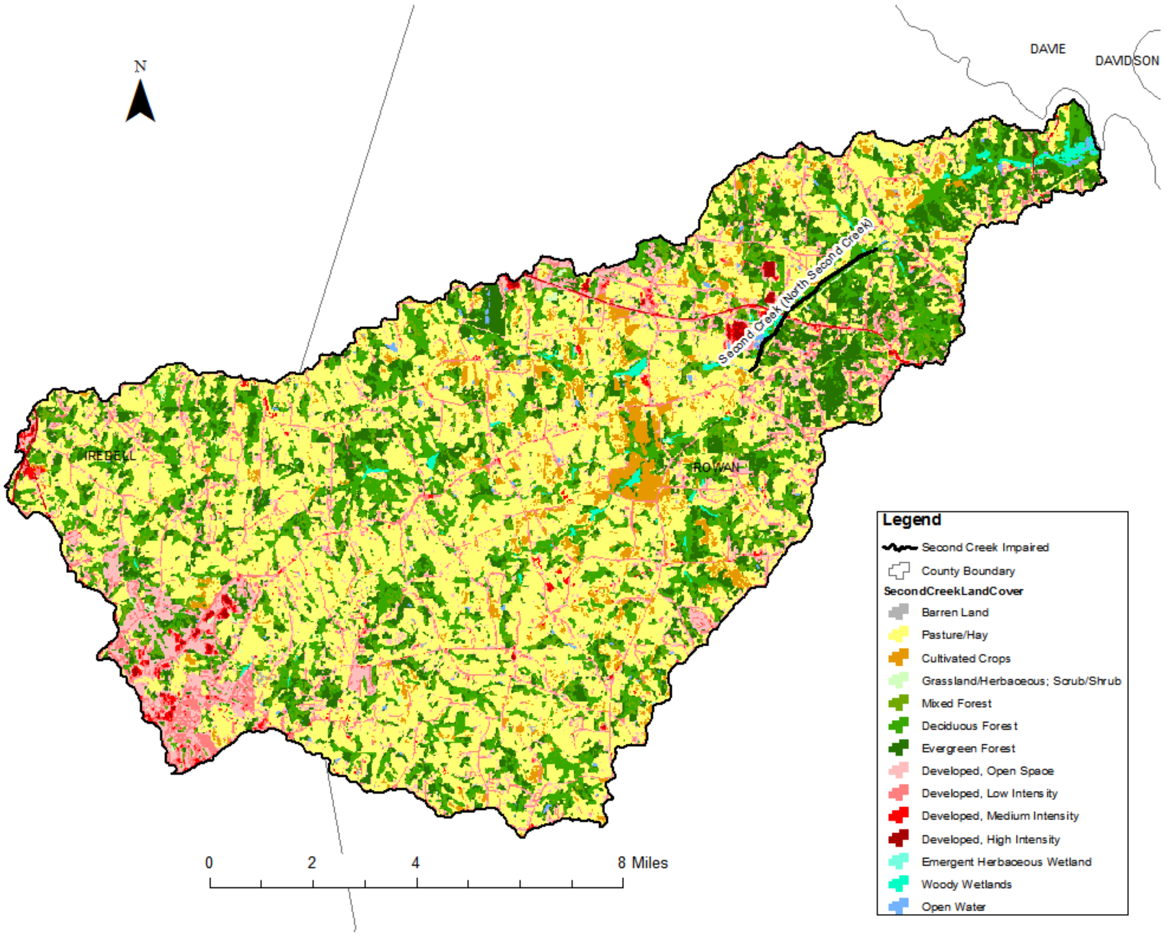


Figure 1.9 Land cover distribution in the Second Creek watershed

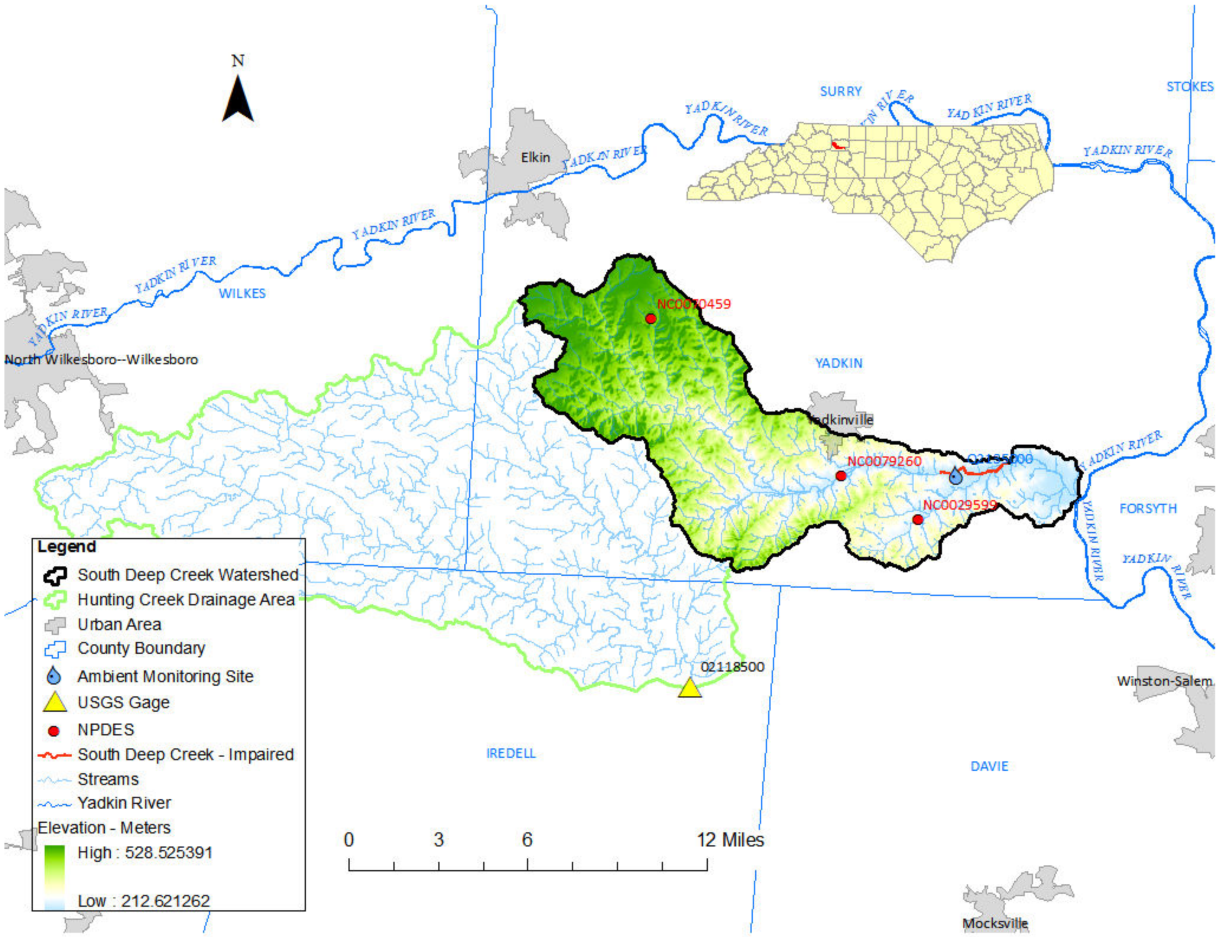


Figure 1.10 South Deep Creek watershed

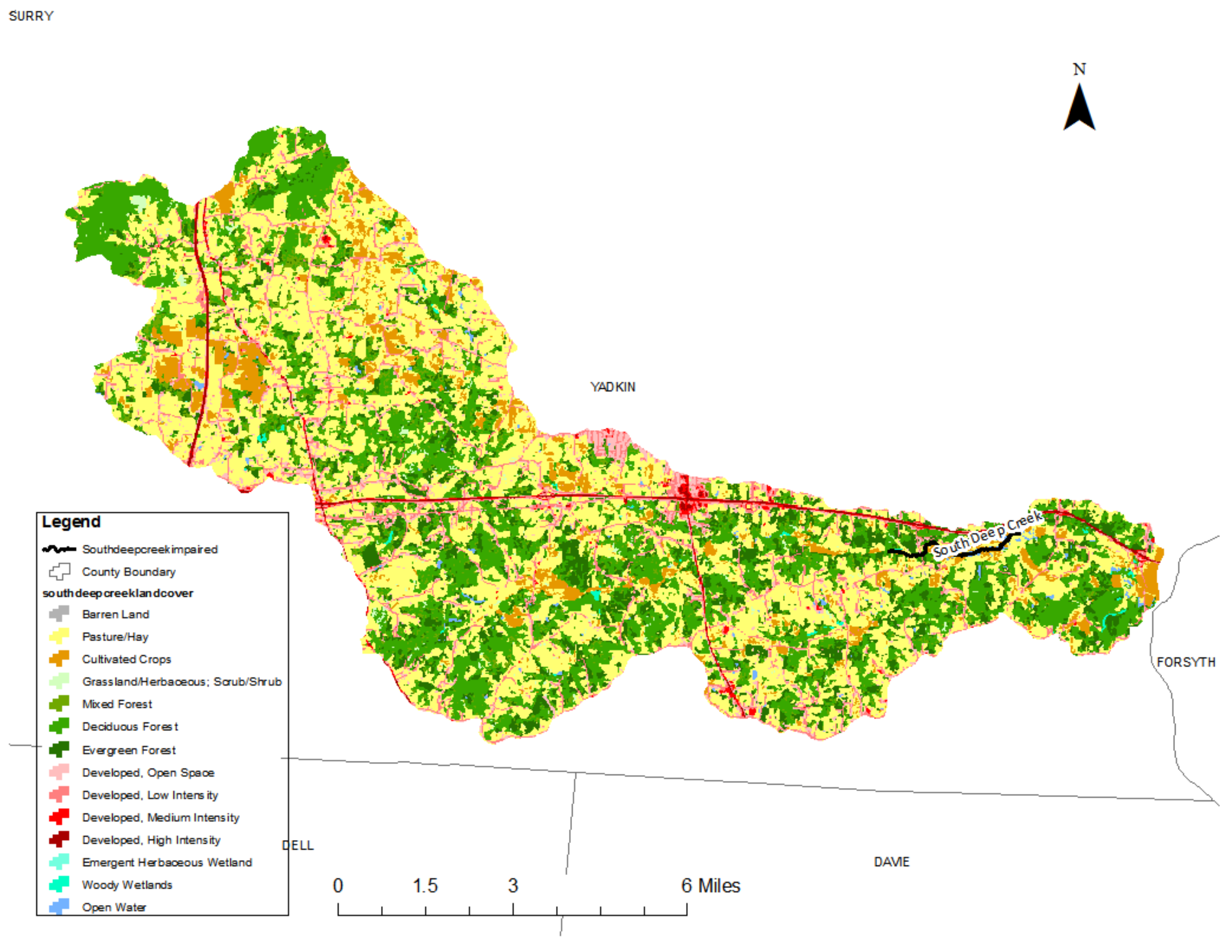


Figure 1.11 Land cover distribution in the South Deep Creek watershed

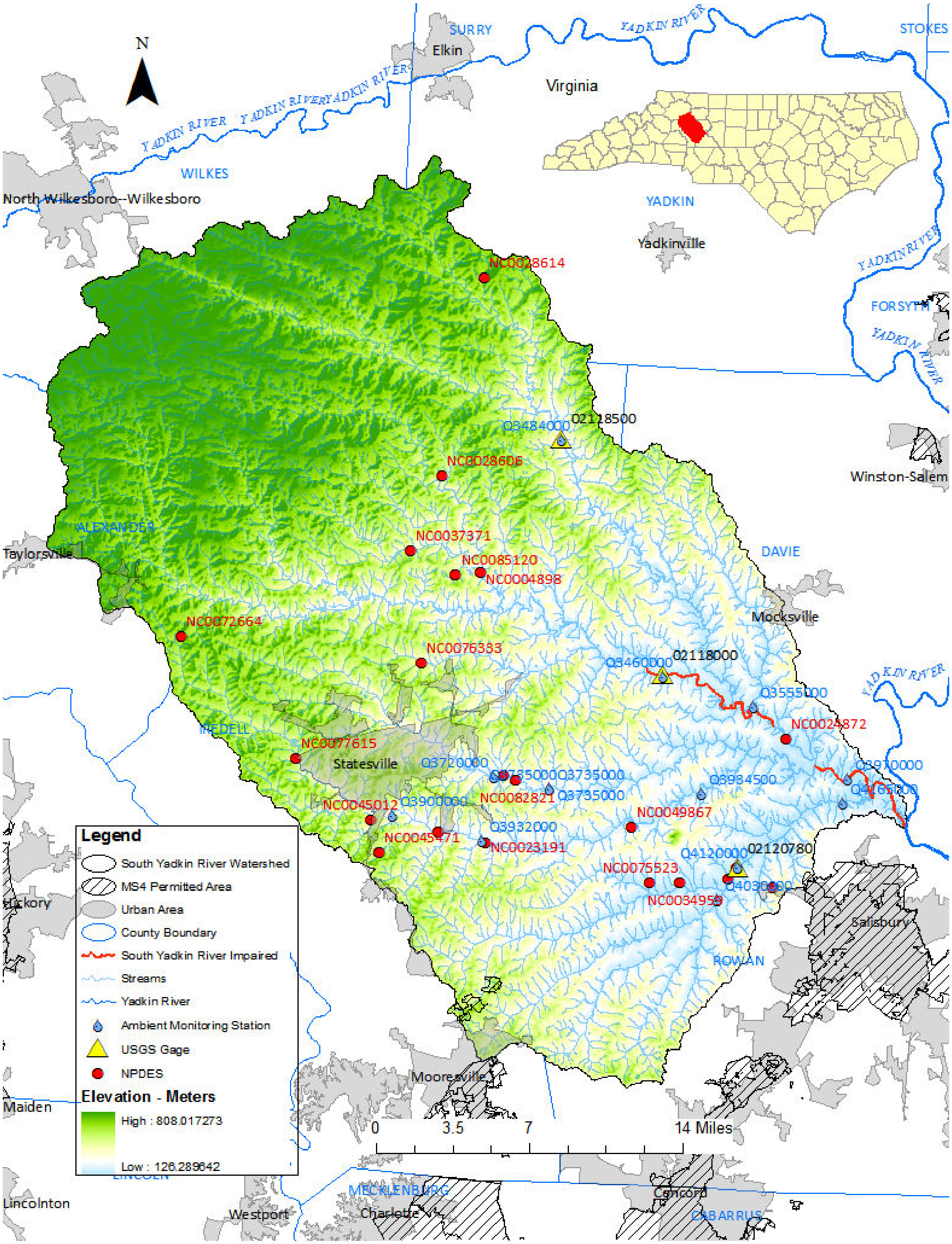


Figure 1.12 South Yadkin River watershed

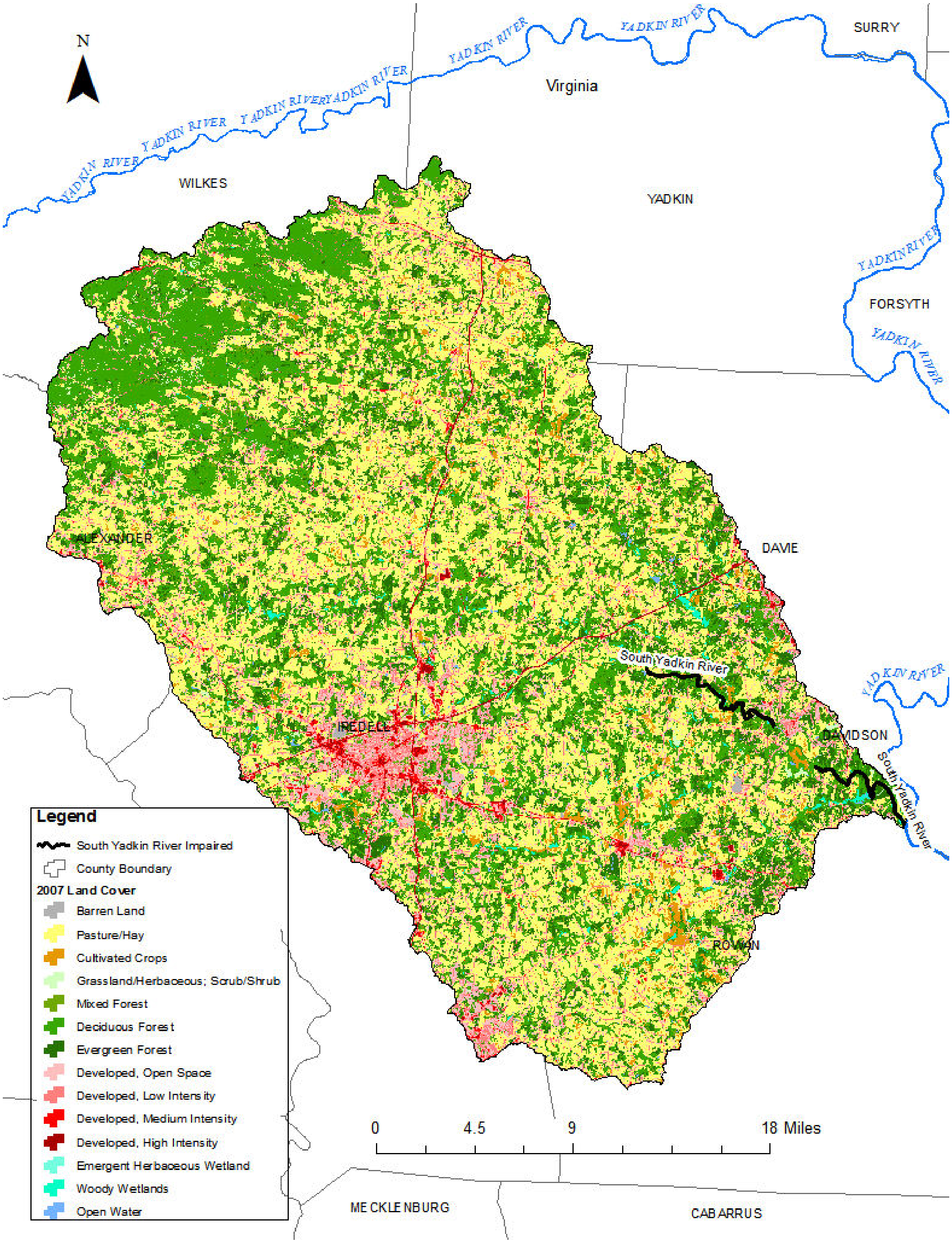


Figure 1.13 Land cover distribution in the South Yadkin River watershed

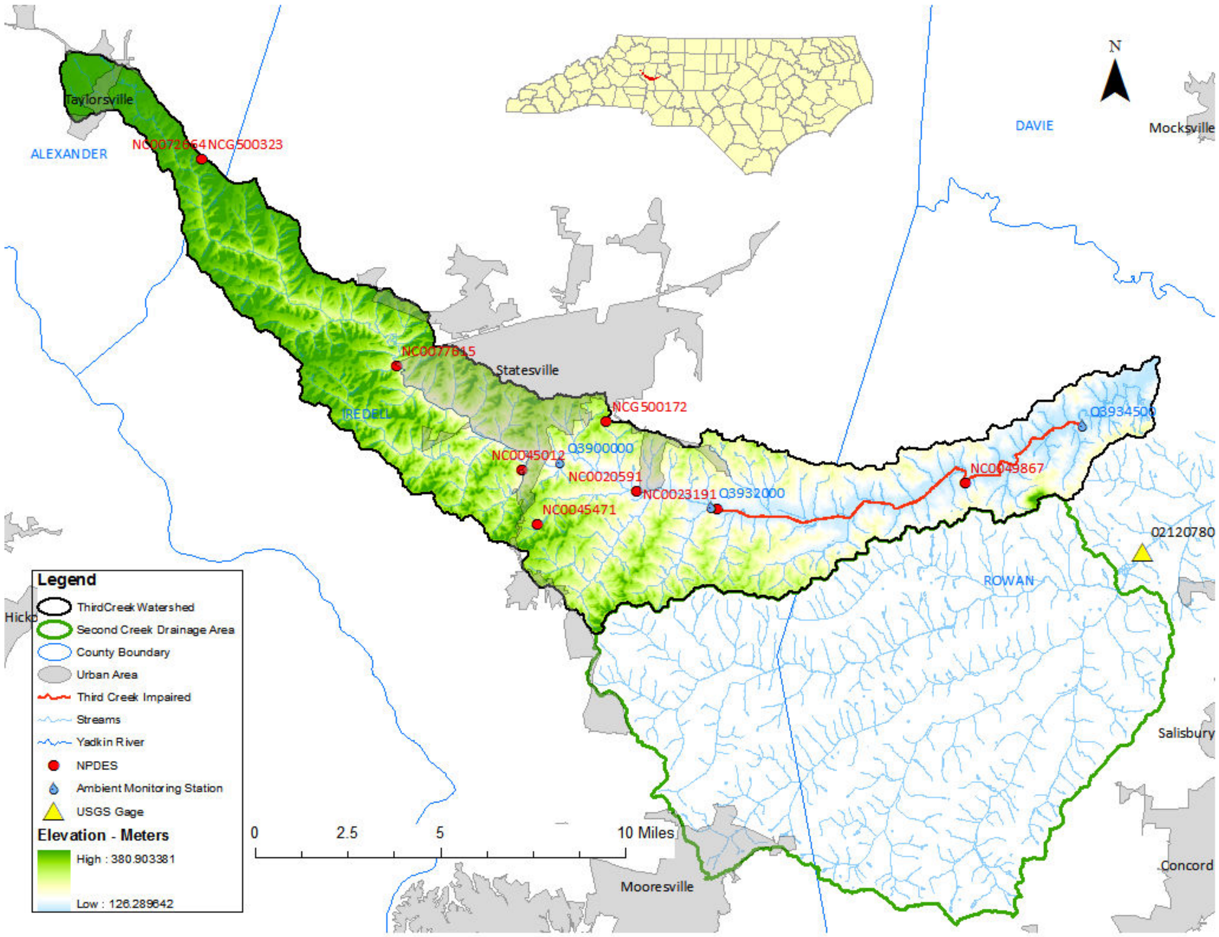


Figure 1.14 Third Creek watershed

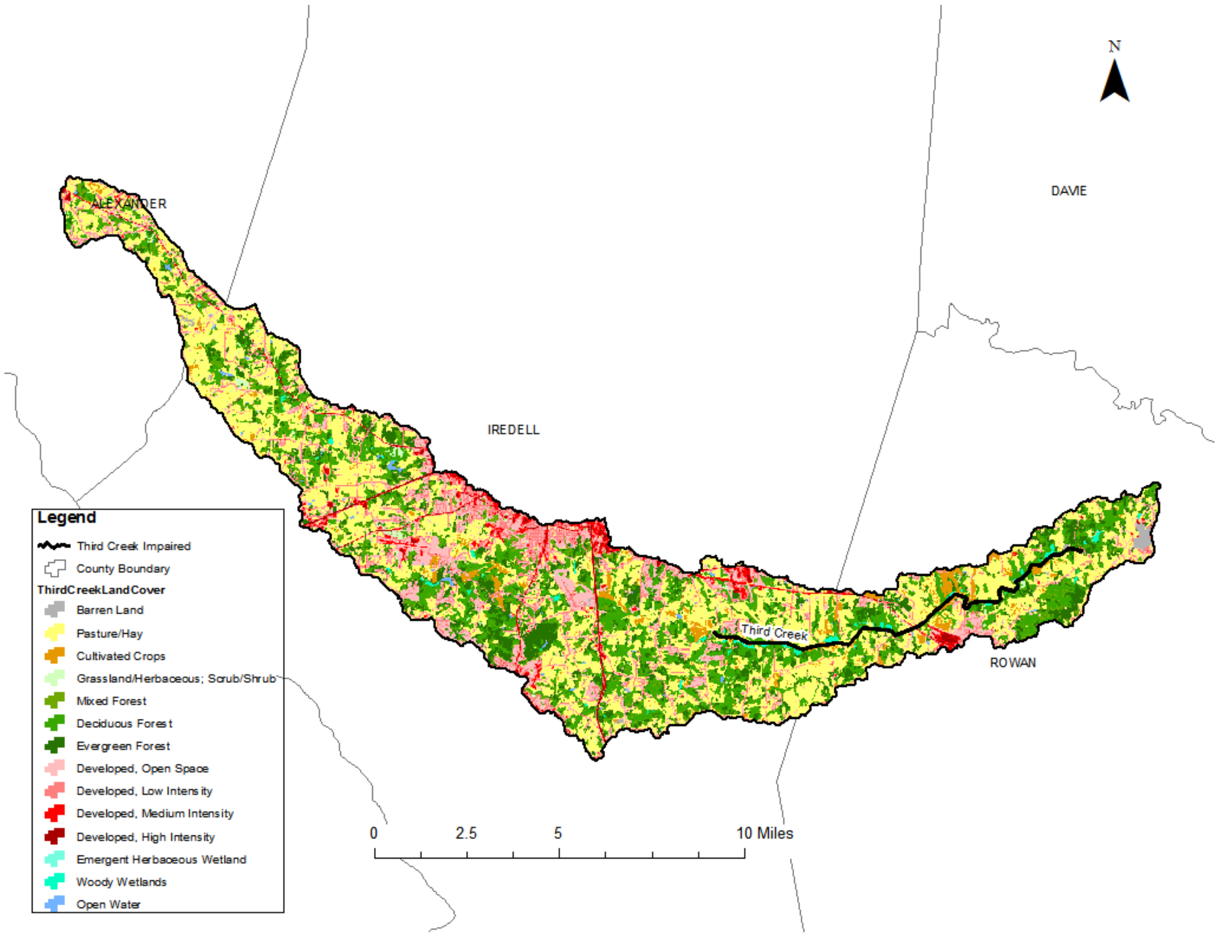


Figure 1.15 Land cover distribution in the Third Creek watershed

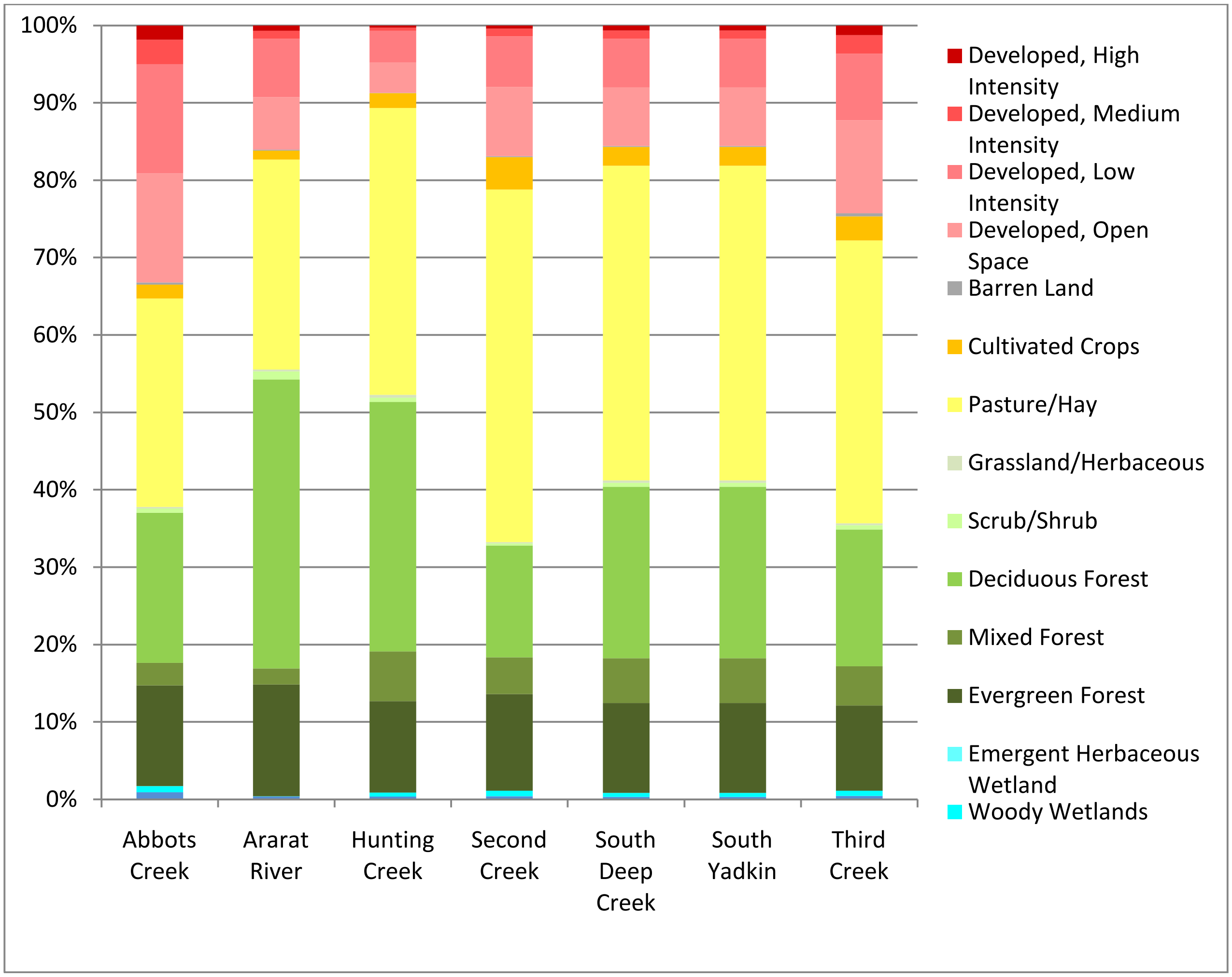


Figure 1.16 Land cover distribution in the impaired watersheds

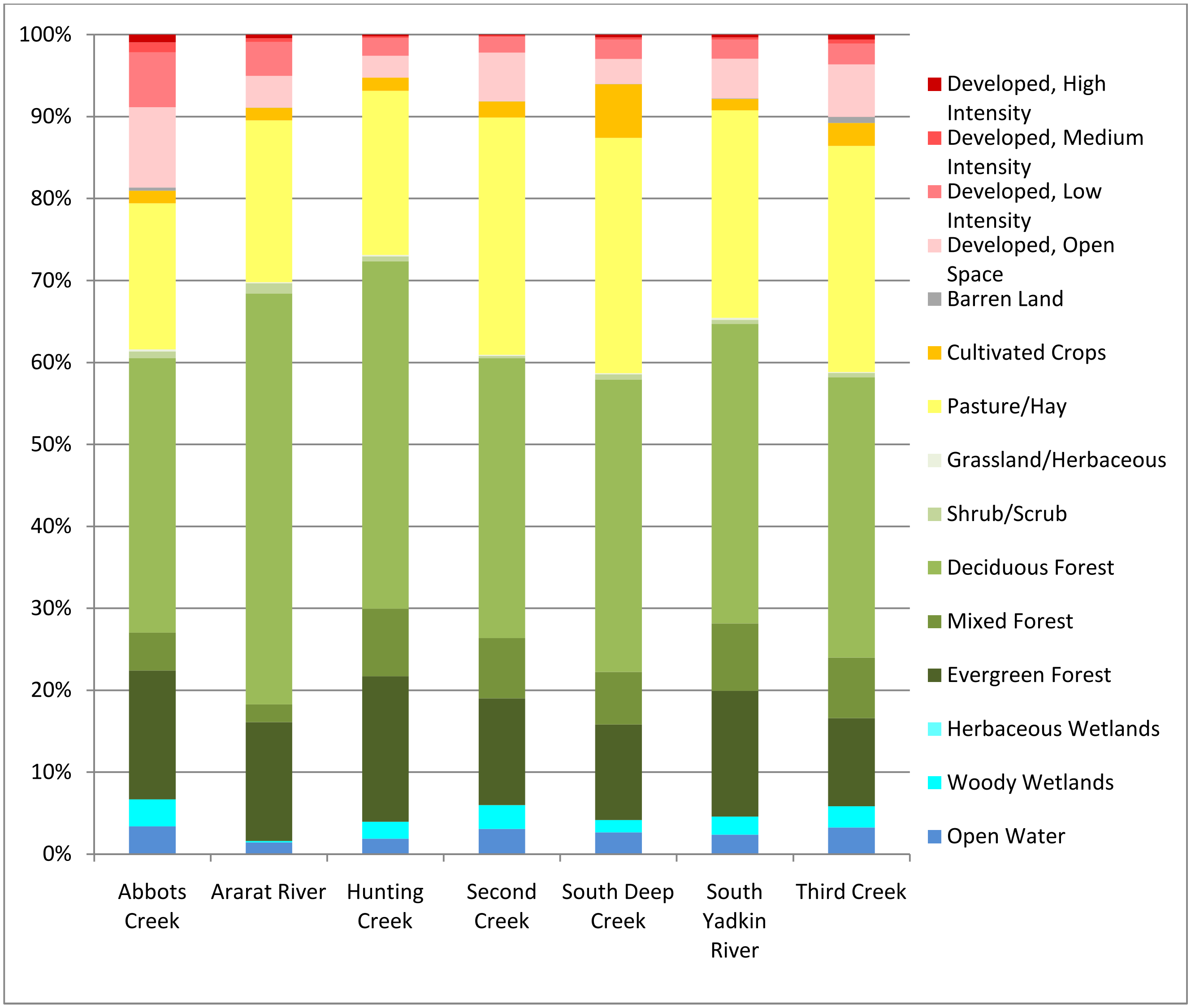


Figure 1.17 Land cover adjacent to streams in the impaired watersheds

1.4 Water Quality Monitoring

Turbidity and total suspended solids (TSS) data collected monthly at DWQ Ambient Monitoring Stations and one Yadkin Pee Dee River Basin Association were used for the TMDLs. The data period used for the TMDLs was from 2000 through 2009. The data used for the 2010 303(d) list assessment are summarized in Table 1.2. Detailed data used in this study is included in Appendix B.

Table 1.2 Summary of 2010 turbidity assessment (data from 2004-2008)

Waterbody	Assessment Unit	Station	Number of Samples	Number Exceeding Standard	Exceeding Percentage
Abbotts Creek	12-119-(6)a	Q5930000	77	8	10.4
Ararat River	12-72-(18)	Q1950000	36	5	13.9
Ararat River	12-72-(4.5)b	Q1780000	71	8	11.3
Hunting Creek	12-108-16-(0.5)b	Q3484000	59	6	10.2
Second Creek	12-108-21b	Q4120000	58	7	12.1
South Deep Creek	12-84-2-(5.5)	Q2135000	60	7	11.7
South Yadkin River	12-108-(14.5)	Q3460000	77	9	11.7
South Yadkin River	12-108-(19.5)b	Q3970000	60	7	11.7
Third Creek	12-108-20-4b	Q3934500	58	8	13.8

2.0 General Source Assessment

Turbidity is a measure of the cloudiness of water. In a waterbody, the cloudiness can be increased due to silt and clay from watershed and stream erosion, organic detritus from streams and wastewater, and phytoplankton growth. In this study, turbidity is measured in Nephelometric Turbidity Units (NTU), which is significantly correlated with total suspended solid (TSS) in this watershed. The relationship between turbidity and TSS is discussed below.

2.1 Nonpoint Sources of Turbidity

Potential sources of turbidity from nonpoint sources are forests, agricultural lands, land disturbance, urban runoff, and stream channel erosion. Surface runoff is the main carrier of sediments from forests and agricultural land. Normally, runoff flowing through undisturbed forest carries insignificant amounts of sediments. Runoff flowing through agricultural land can carry a substantial amount of sediments, depending on erodibility of soils, types of agricultural practices, crop type and density, rainfall intensity, and existence and type of agricultural BMPs.

Urbanization also increases the amount of sediment transported to receiving waters. Impervious urban landscapes like roads, bridges, parking lots, and buildings prevent rainwater from percolating into the ground. In impervious areas, rainwater remains above the land surface, gathers sediments and solid materials, and runs off in large amounts.

2.2 Point Sources of Turbidity

Point sources are distinguished from nonpoint sources in that they discharge directly into streams at discrete points. Point sources of turbidity consist primarily of industries, wastewater treatment plants, and Municipal Separate Storm Sewer Systems (MS4). Municipal storm sewer systems can quickly channel urban runoff from roads and other impervious surfaces. When it leaves the system and empties into a stream, large volumes of quickly flowing runoff erode stream banks, damage streamside vegetation, and widen stream channels. The amount of sediment depends on erodibility of soils, types of surfaces, vegetation, rainfall intensity, and existence and type of BMPs. DWQ implements the Clean Water Act National Pollutant Discharge Elimination System (NPDES) permit program to control water pollution due to point sources. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters.

<u>NPDES-Regulated Municipal and Industrial Wastewater Treatment Facilities</u>

Discharges from wastewater treatment facilities may contribute sediment to receiving waters as total suspended solids (TSS) and/or turbidity. Municipal and industrial treatment plants are assigned enforceable TSS limits to protect water quality. Notices of violation and civil penalties are examples of enforcement tools DWQ uses in order to bring non-compliant facilities into compliance.

<u>NPDES Stormwater Permits</u>

Most stormwater permittees are subject to TSS benchmarks. Relatively few permittees are required by the stormwater permits to monitor or address turbidity per se. Generally, permitted facilities are required to develop a stormwater pollution prevention plan, and conduct qualitative and/or quantative monitoring at stormwater outfalls. Monitoring parameters and monitoring frequency are selected for each site, or each industry group, based on DWQ's assessment of the stormwater runoff pollution risks posed by the particular industrial activities under consideration.

<u>Municipal Separate Storm Sewer System (MS4)</u>

EPA requires NPDES permitted stormwater to be placed in the waste load allocation (WLA) of a TMDL (Wayland, 2002). In 1990, EPA promulgated rules establishing Phase I of the NPDES stormwater program. The Phase I program for Municipal Separate Storm Sewer System (MS4) requires operators of medium and large MS4s, which generally serve populations of 100,000 or greater, to implement a stormwater management program as a means to control polluted discharges from these MS4s. Phase II of the program expanded permit requirements to construction disturbing an acre or more and smaller communities (< 100,000 population) and public entities that own or operate an MS4.

3.0 Abbotts Creek Impairment

3.1 Source Assessment

Nonpoint Sources

Potential sources of turbidity from nonpoint sources are described in section 2.1

Point Sources

NPDES wastewater and stormwater permittees upstream of an ambient monitoring site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL. Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below.

NPDES Wastewater Permits:

There are three facilities that discharge wastewater continuously to Abbotts Creek and tributaries under the NPDES program (Table 3.1). In general, facilities are permitted to discharge a monthly average TSS concentration up to 30 mg/L. Locations of dischargers are shown in Figure 1.2.

Table 3.1 NPDES Wastewater Dischargers in the Abbotts Creek Watershed

Permit Number	Facility Name	Permit Flow (gpd)	Total Suspended Solids Monthly Average Limit
NC0028037	Lexington WTP #1 & 2	467,000	30 mg/L
NC0034452	Willow Creek WWTP	80,000	30 mg/L
NC0051713	Lakeview Mobile Home Park	15,000	30 mg/L

MS4 and Individual Stormwater Permits:

Duracell holds an individual stormwater permit (NCS000310) and discharges into Abbotts Creek. The North Carolina Department of Transportation holds a statewide MS4 stormwater permit (NCS000250).

3.2 Technical Approach

Because the magnitude of turbidity in a water body is associated with flow, a load duration approach is adopted for this study. This approach is used to estimate pollutant loads under different flow conditions (high flow, transition flow, typical flow, and low flow) to identify source types, specify assimilative capacity of a stream, and to estimate magnitude of load reduction required to meet the water quality standard. The methodology used to develop a load duration curve is based on Cleland (2002).

3.2.1 Endpoint for Turbidity

As discussed in Section 2.1, turbidity is a measure of cloudiness and is reported in Nephelometric Turbidity Units (NTU). Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, total suspended solid (TSS) was selected as the measure for this study.

In order to determine the relationship between TSS and turbidity in Abbotts Creek, a regression equation between the two parameters was developed using the observed data collected from February 2000 through December 2009 at ambient station Q5930000 on Abbotts Creek. The relationship is shown in Equation 3.1. The coefficient of determination (R-Square) between the two parameters was 0.88, indicating a strong linear relationship between the two parameters. The R^2 value is the percentage of the total variation in turbidity that is explained or accounted for by the fitted regression (TSS).

$$y = 0.8499x - 0.6076 \quad R^2 = 0.8782 \qquad (3.1)$$

Where Y = TSS in mg/l and X = turbidity in NTU.

The corresponding TSS value at the turbidity standard of 50 NTU is 42 mg/L.

3.2.2 Methodology

The load duration curve method is intended to be a simple method to calculate pollutant reductions. This method was chosen for Abbotts Creek because of the availability of long-term data. It is also an efficient method to calculate a percent load reduction from nonpoint sources. The methodology used to develop the load duration curve was based on Cleland (2002). The required load reduction was determined based on water quality monitoring and stream flow data from January 2000 through December 2009.

3.3 Flow Duration Curve

Development of a flow duration curve is the first step of the load duration approach. A flow duration curve employs a cumulative frequency distribution of measured daily stream flow over the period of record. The curve relates flow values measured at the monitoring station for the percent of time the flow values were equaled or exceeded. Flows are ranked from lowest, which are exceeded nearly 100 percent of the time, to highest, which are exceeded less than 1 percent of the time. Reliability of the flow duration curve depends on the period of record available at monitoring stations. Accuracy of the curve increases when longer periods of record are used. The flow duration curve, shown in Figure 3.1, was used to determine the seasonality and flow regimes during which the exceedances of the pollutants occurred.

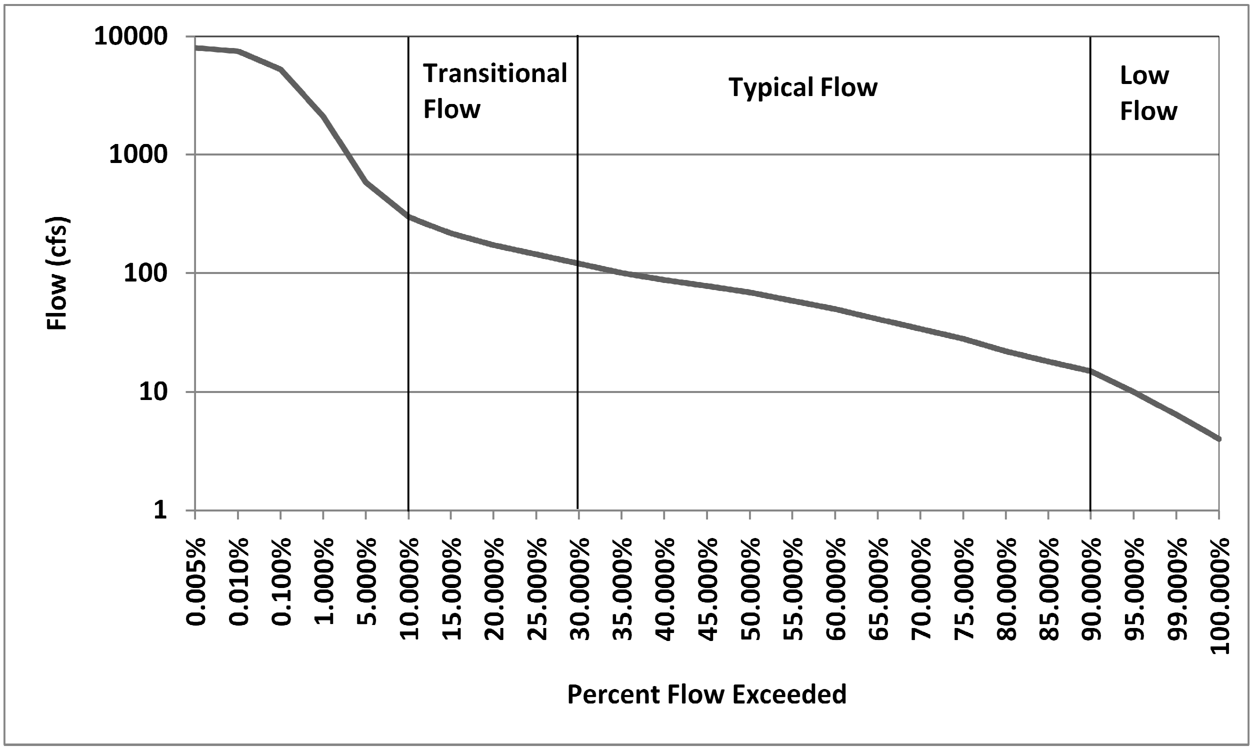


Figure 3.1 Flow Duration Curve for Abbotts Creek at DWQ Station Q5930000

Daily flow data were used from USGS Abbotts Creek gauging station 02121500, co-located with the DWQ water quality monitoring station.

3.4 Load Duration Curve

A load duration curve is developed by multiplying the flow values along the flow duration curve by the pollutant concentrations and the appropriate conversion factors. As shown in Figure 3.2, allowable and existing loads are plotted against the flow recurrence interval. The allowable load is based on the water quality numerical standard, margin of safety, and flow duration curve. The target line is represented by the line drawn through the allowable load data points and hence, it determines the assimilative capacity of a stream or river under different flow conditions. Any values above the line are exceeded loads and the values below the line are acceptable loads. Therefore, a load duration curve can help define the flow regime during which exceedances occur. Exceedances that occur during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and non-point sources may cause exceedances during normal flows.

Existing TSS loads to Abbotts Creek were determined by multiplying the observed TSS concentration by the flow observed on the date of observation and converting the result to daily loading values. The assimilative capacities of the waterbodies were determined by multiplying the TSS concentration that is equivalent to a turbidity value of 50 NTU by the full range of measured flow values.

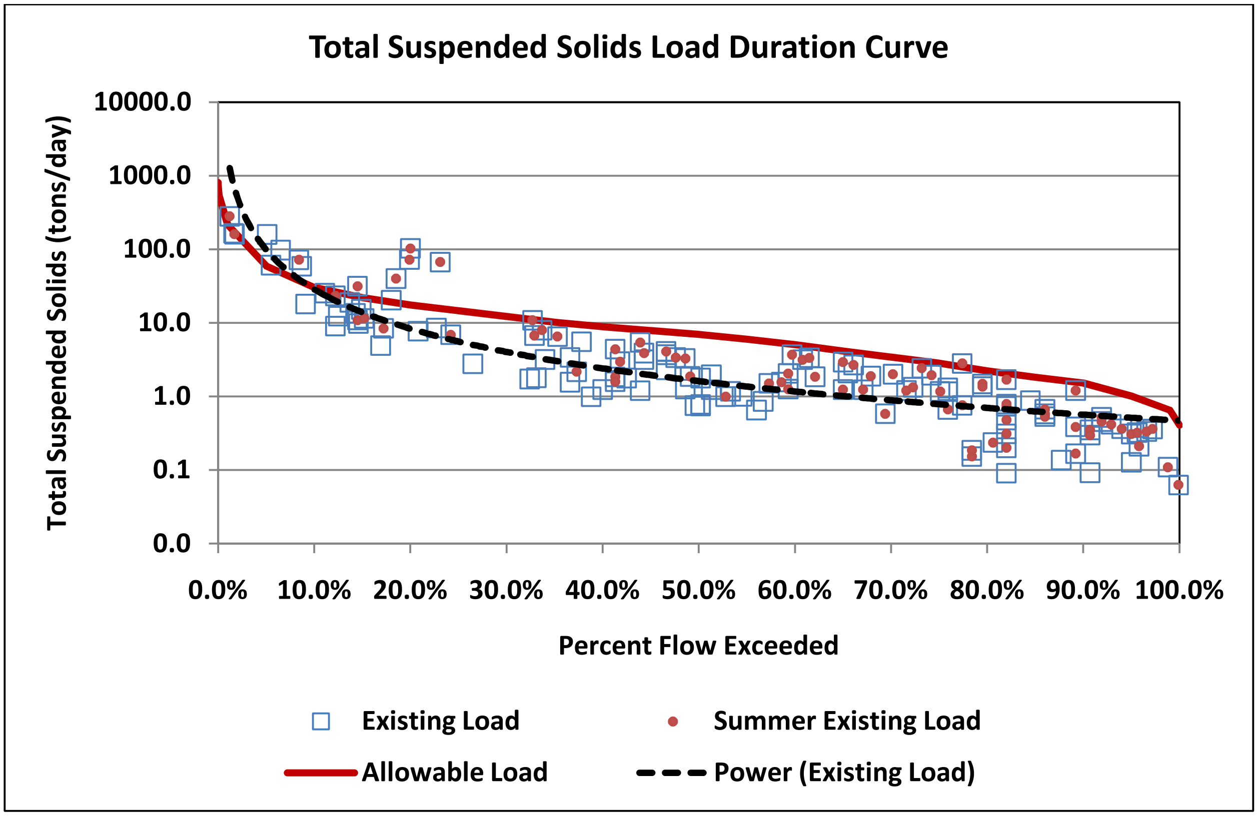


Figure 3.2 Load Duration Curve for Abbotts Creek at DWQ station Q5930000

The assimilative capacity was exceeded primarily during high-flows (< 10% of flow exceedance) and transitional-flows (10% –30% flow exceedance) in Abbotts Creek. There was no exceedance during typical-flows (30% - 90% flow exceedance) and low-flows (>90% flow exceedance). High loads during high and transitional flows suggest that the sources of turbidity could be storm runoff and/or bank erosion. During the high flow periods, runoff would carry a substantial amount of sediments and solid materials from impermeable as well as permeable land surfaces. Bank erosion may be another result of high and transitional flows. Bank erosion occurs when high volume and velocity runoff exceeds the resistance of the lateral (side) soil material.

TSS load under typical flows stayed under the turbidity standard of 50 NTU (42 mg/L TSS) in Abbotts Creek. The power curve fitted to the average TSS loads under different flow conditions in figure 3.2 clearly shows that the TSS loads did not exceed the allowable load except during high flow periods (<10% flow exceeded). The loads during highest flow periods are considered unmanageable and hence are excluded in the TMDL estimation in this study.

3.5 TMDL

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source wasteload allocations (WLAs), nonpoint source load allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 3.2.

$$TMDL = \sum WLAs + \sum LAs + MOS \qquad (3.2)$$

The purpose of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For TSS (measure for turbidity), TMDLs are expressed as tons per day. TMDLs represent the maximum one-day load the river can assimilate and maintain the water quality criterion. Load duration curve approach was utilized to estimate the TMDL for turbidity. The systematic procedures adopted to estimate TMDLs are described below.

3.6 Margin of Safety (MOS)

Conceptually, the MOS is included in the TMDL estimation to account for the uncertainty in the simulated relationship between the pollutants and the water quality standard. In this study, the MOS was explicitly included in the TMDL analysis by setting the TMDL target at 10 percent lower than the water quality target for turbidity.

3.7 Target Reduction

To determine the amount of turbidity reduction necessary to comply with the water quality standard, exceedances of the standard (estimated as 42 mg TSS/L) were identified within the 10^{th} to 90^{th} percentile flow recurrence range. Typically the remaining flow recurrence range is not included in the TMDL calculation to allow cases of extreme drought or flood to be excluded.

A power curve equation for the data points violating the water quality criterion was estimated. The equation is presented in Equation 3.2.

$y = 2.1577x^{-1.803}$ $R^2 = 0.6434$
Where, Y = TSS (tons/day) and X = Percent Flow Exceeded.

To present the TMDLs as a single value, the existing load was calculated from the power curve equation as the average of the load violations occurring between 10 and 90 percent flow exceedances. The allowable loadings for each exceedance were calculated from the TMDL target value, which includes the 10 percent MOS. The target curve based on the allowable load and the power curve based on the exceedances are shown in Figure 3.3.

The necessary percent reduction was calculated by taking the difference between the average of the power curve load estimates and the average of the allowable load estimates. At each recurrence interval between 10 and 90 (again using recurrence intervals in multiples of 5), the equation of the power curve was used to estimate the existing load. The allowable load was then calculated in a similar fashion by substituting the allowable load curve. The estimated values are given in Appendix C.

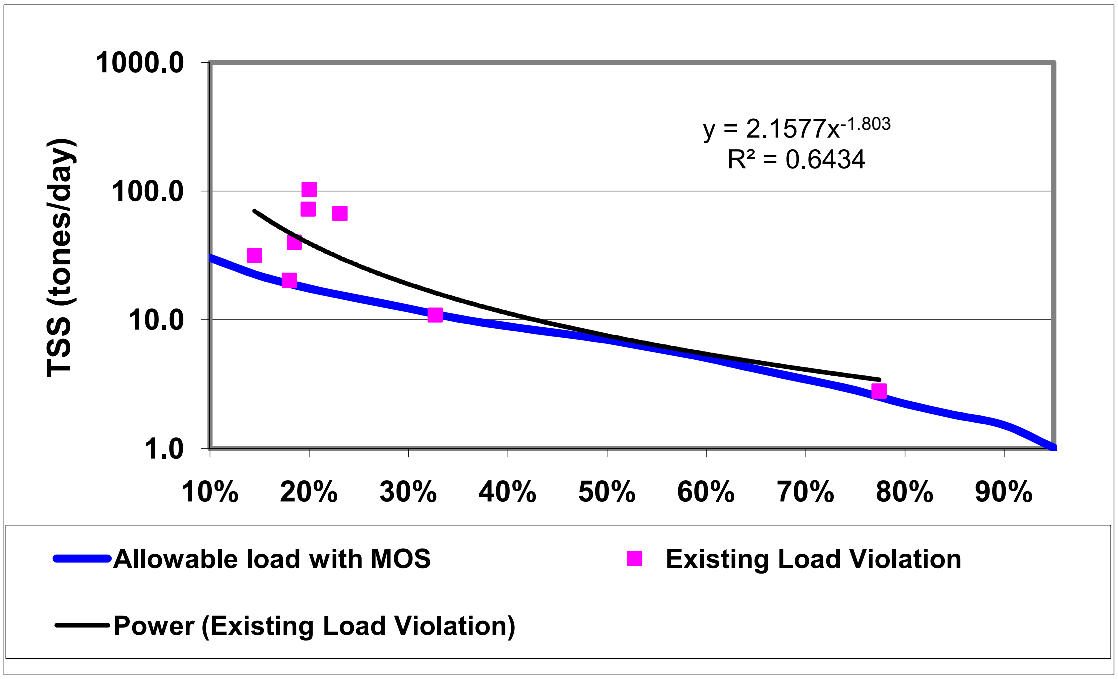


Figure 3.3 Load duration curve allowable TSS load and existing total TSS load in Abbotts Creek

3.8 TMDL Allocation

3.8.1 Waste Load Allocation (WLA)

Three wastewater treatment plants (WWTP) plus Duracell and the NC Department of Transportation hold NPDES permits in the Abbotts Creek Watershed. The wastewater load contributions are shown in Table 3.2

Table 3.2 Existing NPDES WW Load Contributions

Facility Name	Permit Number	Flow (gpd)	Permit Limit (monthly max in mg/L)	Load (tons/day)	% of Average Ambient Station Load
Lexington WTP #1 & 2	NC0028037	467,000	30	0.0530	0.25
Willow Creek WWTP	NC0034452	80,000	30	0.0091	0.04
Lakeview Mobile Home Park	NC0051713	15,000	30	0.0017	0.01

In order to estimate contributions from the WWTPs, it was assumed that all TSS discharged reaches the ambient station with no settling. Based on facility permit limits of flow and the monthly average permit limits for TSS, the combined WWTP load contributes less than 1% of the average load at DWQ station Q5930000 based on data from years 2000 through 2009. The limit of 30 mg/l is less than the equivalent concentration necessary to meet the turbidity standard (50 NTU ≈ 42 mg/l). In addition, as discussed previously, violations of the turbidity standard did not occur during low flows when continuous dischargers' contributions would be greatest. These WWTPs do not represent a significant load to Abbotts Creek; therefore it was concluded that the WWTPs are adequately regulated under existing permits and the waste load allocations in this TMDL were calculated at the existing permit limits. In addition, when individual industrial stormwater permittees are in compliance with their permits, they are assumed to be adequately regulated; therefore, no reduction in TSS loading is required.

NCDOT was considered a significant contributor, and was assigned a percent reduction identical to the nonpoint source reduction. The NCDOT is currently in compliance with their NPDES stormwater permit, and will continue to implement measures required by the permit (NCS000250). Because of the nature of drainage from roads and other impervious areas, data are not available (n/a) to calculate a WLA for the stormwater permittees as a load.

The wasteload allocation and required reductions for NPDES permittees in the Abbotts Creek watershed are shown in Table 3.3.

Table 3.3 NPDES waste load allocations and required reductions

NPDES Permittee	Permitted Load (tons/day)	WLA (tons/day)	Percent Reduction Required
Lexington WTP #1 & 2	0.0530	0.0530	0%
Willow Creek WWTP	0.0091	0.0091	0%
Lakeview Mobile Home Park	0.0017	0.0017	0%
Duracell - Stormwater	N/A	N/A	0%
NCDOT - Stormwater	N/A	N/A	57%

3.8.2 Load Allocation (LA)

All TSS loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as the LA. The estimated TMDL and allocation of TSS from point and nonpoint sources are presented in Table 3.4. The estimated percent reductions needed from NPDES stormwater and nonpoint sources is 57%, as shown in Table 3.5.

Table 3.4 Estimated TMDL and load allocation for TSS (tons/day) for Abbotts Creek

Pollutant	Water Body	Existing Load	WLA	LA	Explicit MOS	TMDL
TSS	Abbotts Creek	21.30	0.064	9.236	10%	9.30

Note: The Margin of safety is included in the TMDL by lowering TSS value calculated at the 50 NTU standard by 10%

Table 3.5 Estimated reduction by source for TSS (tons/day) for Abbotts Creek

	NPDES Wastewater WLA	NPDES Stormwater WLA	LA
Existing Load (tons/day)	0.064	N/A	21.24
Allocation (tons/day)	0.064	N/A	9.236
Percent Reduction	0%	57%	57%

3.8.3 Critical Conditions and Seasonal Variation

Critical conditions are considered in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining the flows (percent flow exceeded) where the existing loads exceed the target.

Seasonal variation is considered in the development of the TMDLs, because the allocation applies to all seasons. In the load duration curves, the mark inside a square box indicates pollutant load during the summer period.

According to the load duration curve (Figure 3.2), the greatest frequency of exceedances of turbidity occurred during high-flow periods. The result shows that wet weather is the critical period for turbidity in Abbotts Creek.

4.0 Ararat River Impairment

4.1 Source Assessment

Nonpoint Sources

Potential sources of turbidity from nonpoint sources are described in section 2.1

Point Sources

NPDES wastewater and stormwater permittees upstream of an ambient monitoring site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL. Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below.

NPDES Wastewater Permits

There are two facilities that discharge wastewater continuously to the Ararat River and tributaries under the NPDES program (Table 4.1). In general, facilities are permitted to discharge a monthly average TSS concentration up to 30 mg/L. Locations of dischargers are shown in Figure 1.4.

Table 4.1 NPDES Wastewater Dischargers in the Ararat River Watershed

Permit Number	Facility Name	Permit Flow (gpd)	Total Suspended Solids Monthly Average Limit
NC0026646	Pilot Mountain WWTP	1,500,000	30 mg/L
NC0068365	Pilot Mountain WTP	No Flow Limit	30 mg/L

MS4 and Individual Stormwater Permits

The NCDOT (NCS000250) is the only MS4 stormwater permitted entity in the Ararat River watershed.

4.2 Technical Approach

Endpoint for Turbidity

Turbidity is a measure of cloudiness and is reported in NTU. Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, TSS was selected as the measure for this study.

In order to determine the relationship between TSS and turbidity in the Ararat River, a regression equation between the two parameters was developed using the observed data collected from February 2000 through December 2009 at ambient station, Q1780000, on the Ararat River. The relationship is shown in Equation 4.1. The coefficient of determination (R-Square) between the two parameters was 0.92, showing a strong relationship between the two parameters. The R^2 value is the percentage of the total variation in turbidity that is explained or accounted for by the fitted regression (TSS).

$$y = 0.0128x^2 - 0.3967x + 11.084 \quad R^2 = 0.9251 \qquad (4.1)$$

Where, Y = TSS in mg/l and X = turbidity in NTU.

The corresponding TSS value at the turbidity standard of 50 NTU is 23 mg/L.

Methodology

The load duration curve method is intended to be a simple method to calculate pollutant reductions. This method was chosen for the Ararat River because of the availability of long-term data. It is also an efficient method to calculate a percent load reduction from nonpoint sources. The methodology used to develop the load duration curve was based on Cleland (2002). The required load reduction was determined based on water quality monitoring and stream flow data from January 2000 through December 2009.

4.3 Flow Duration Curve

Development of a flow duration curve is the first step of the load duration approach. A flow duration curve employs a cumulative frequency distribution of measured daily stream flow over the period of record. The curve relates flow values measured at the monitoring station for the percent of time the flow values were equaled or exceeded. Flows are ranked from lowest, which are exceeded nearly 100 percent of the time, to highest, which are exceeded less than 1 percent of the time. Reliability of the flow duration curve depends on the period of record available at monitoring stations. Accuracy of the curve increases when longer periods of record are used. The flow duration curve, shown in Figure 4.1, was used to determine the seasonality and flow regimes during which the exceedances of the pollutants occurred.

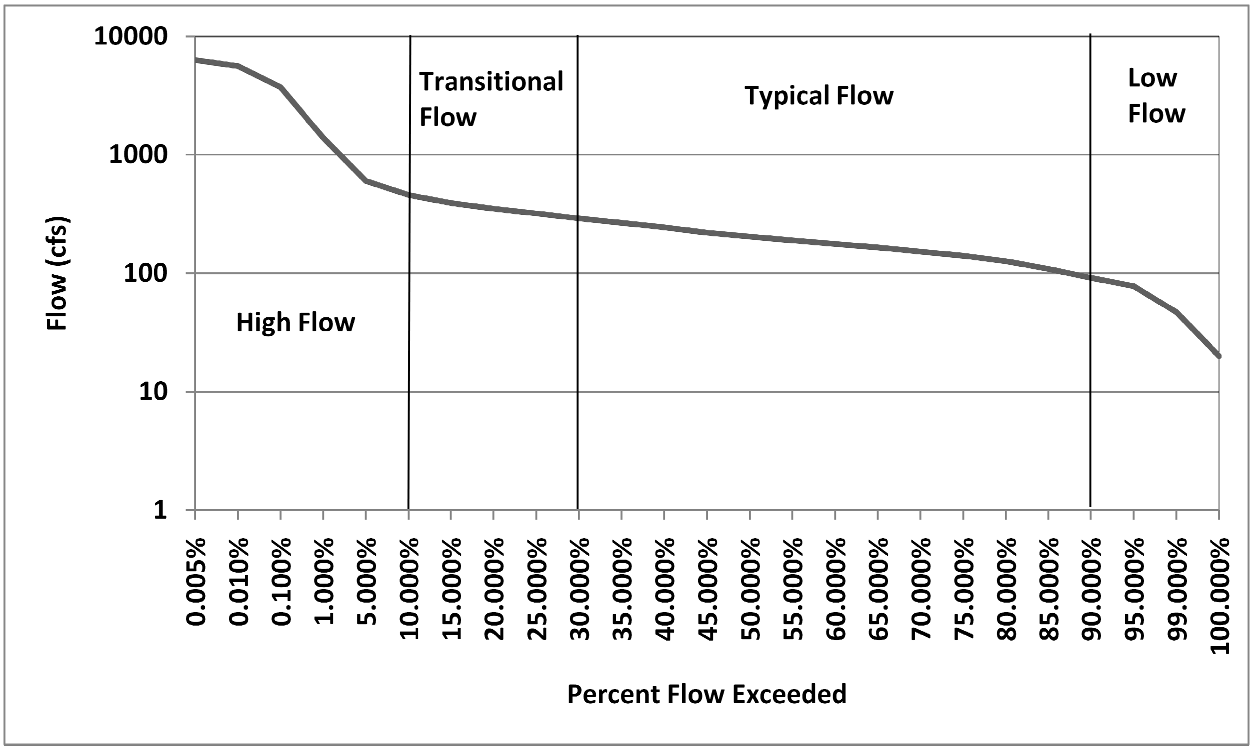


Figure 4.1 Flow Duration Curve for the Ararat River at DWQ Station Q1780000

Daily flow data were used from USGS Ararat River gauging station 02113850, co-located with the DWQ water quality monitoring station.

4.4 Load Duration Curve

A load duration curve is developed by multiplying the flow values along the flow duration curve by the pollutant concentrations and the appropriate conversion factors. As shown in Figure 4.2, allowable and existing loads are plotted against the flow recurrence interval. The allowable load is based on the water quality numerical standard, margin of safety, and flow duration curve. The target line is represented by the line drawn through the allowable load data points and hence, it determines the assimilative capacity of a stream or river under different flow conditions. Any values above the line are exceeded loads and the values below the line are acceptable loads. Therefore, a load duration curve can help define the flow regime during which exceedances occur. Exceedances that occur during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and non-point sources may cause exceedances during normal flows.

Existing TSS loads to the Ararat River were determined by multiplying the observed TSS concentration by the flow observed on the date of observation and converting the result to daily loading values. The assimilative capacities of the waterbodies were determined by multiplying the TSS concentration that is equivalent to a turbidity value of 50 NTU by the full range of measured flow values.

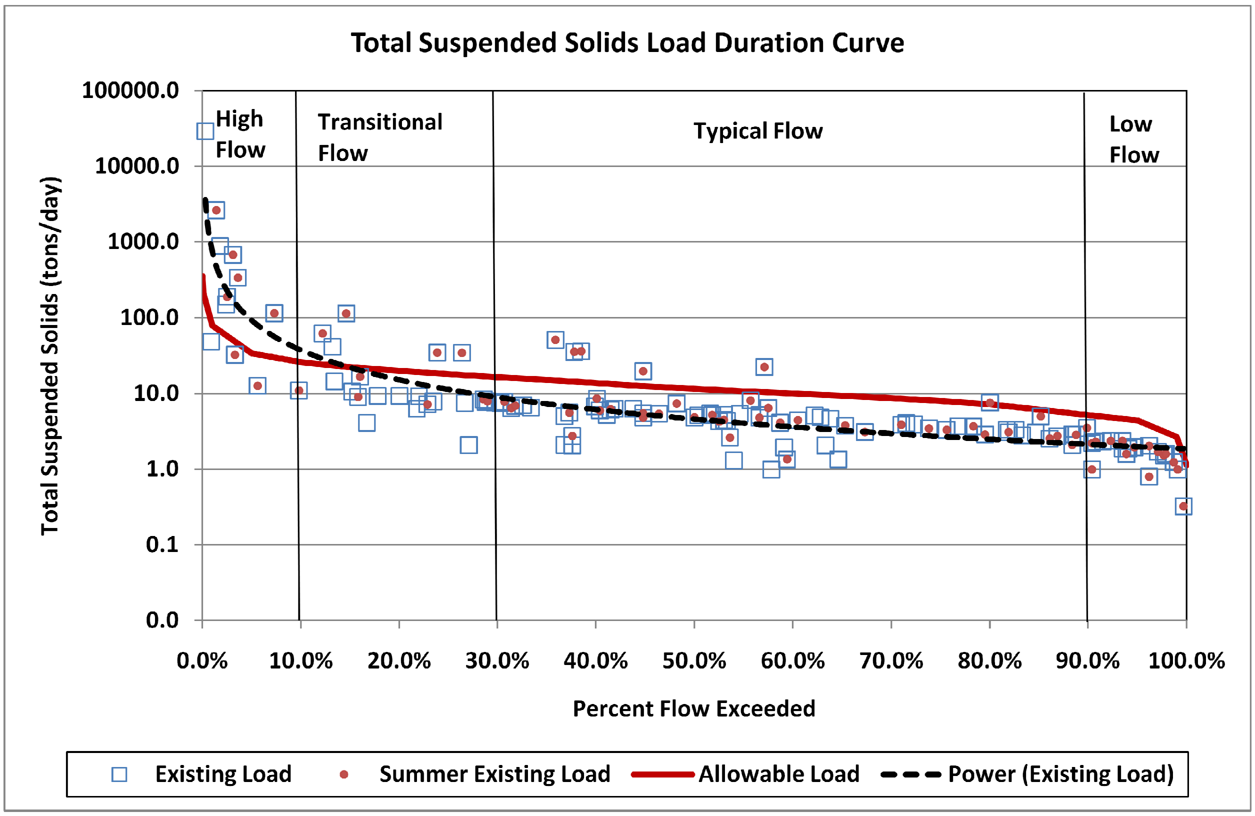


Figure 4.2 Load Duration Curve for the Ararat River at DWQ station Q1780000

For the Ararat River, the standard violations occurred mostly during typical to high flow conditions. Few exceedances during low-flow conditions suggest that point sources in the watershed may not be a significant source of TSS in this watershed. The higher loads during high and transitional flows suggest that the sources of turbidity could be from storm runoff and/or bank erosion. In addition most of the exceedances occurred during summer when thunderstorms would increase runoff. Stormwater runoff would carry a substantial amount of sediments and solid materials from impermeable as well as permeable land surfaces. Bank erosion may be another result of high and transitional flows. Bank erosion occurs when high volume and velocity runoff exceeds the resistance of the lateral (side) soil material. The loads during high flow period are considered unmanageable and hence are excluded from the TMDL estimation in this study.

4.5 TMDL

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source wasteload allocations (WLAs), nonpoint source load allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 4.2.

$$TMDL = \sum WLAs + \sum LAs + MOS \qquad (4.2)$$

The purpose of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For TSS (measure for turbidity), TMDLs are expressed as tons per day. TMDLs represent the maximum one-day load the river can assimilate and maintain the water quality criterion. Load duration curve approach was utilized to estimate the TMDL for TSS. The systematic procedures adopted to estimate TMDLs are described below.

4.5.1 Margin of Safety (MOS)

Conceptually, the MOS is included in the TMDL estimation to account for the uncertainty in the simulated relationship between the pollutants and the water quality standard. In this study, the MOS was explicitly included in the TMDL analysis by setting the TMDL target at 10 percent lower than the water quality target for turbidity.

4.6 Target Reduction

To determine the amount of turbidity reduction necessary to comply with the water quality standard, exceedances of the estimated standard (23 mg TSS/L) were identified within the 10^{th} to 90^{th} percentile flow recurrence range. Typically the remaining flow recurrence range is not included in the TMDL calculation to allow cases of extreme drought or flood to be excluded.

An exponential curve equation for the data points violating the water quality criterion was estimated. The equation is presented in Equation 4.3.

$$y = 95.357e^{-2.93x} \quad R^2 = 0.7667 \qquad (4.3)$$

Where, Y = TSS (tons/day) and X = Percent Flow Exceeded.

To present the TMDLs as a single value, the existing load was calculated from the exponential curve equation as the average of the load violations occurring between 10% and 90% flow exceedances. The average load was calculated by using percent flow exceedances in multiples of 5 percent. The allowable loadings for each exceedance were calculated from the TMDL target value, which includes the 10 percent MOS. The target curve based on the allowable load and the exponential curve based on the exceedances are shown in Figure 4.3.

The necessary percent reduction was calculated by taking the difference between the average of the exponential curve load estimates and the average of the allowable load estimates. For example, at each recurrence interval between 10 and 90 (again using recurrence intervals in multiples of 5), the equation of the exponential curve was used to estimate the existing load. The allowable load was then calculated in a similar fashion by substituting the allowable load curve. The estimated values are given in Appendix C.

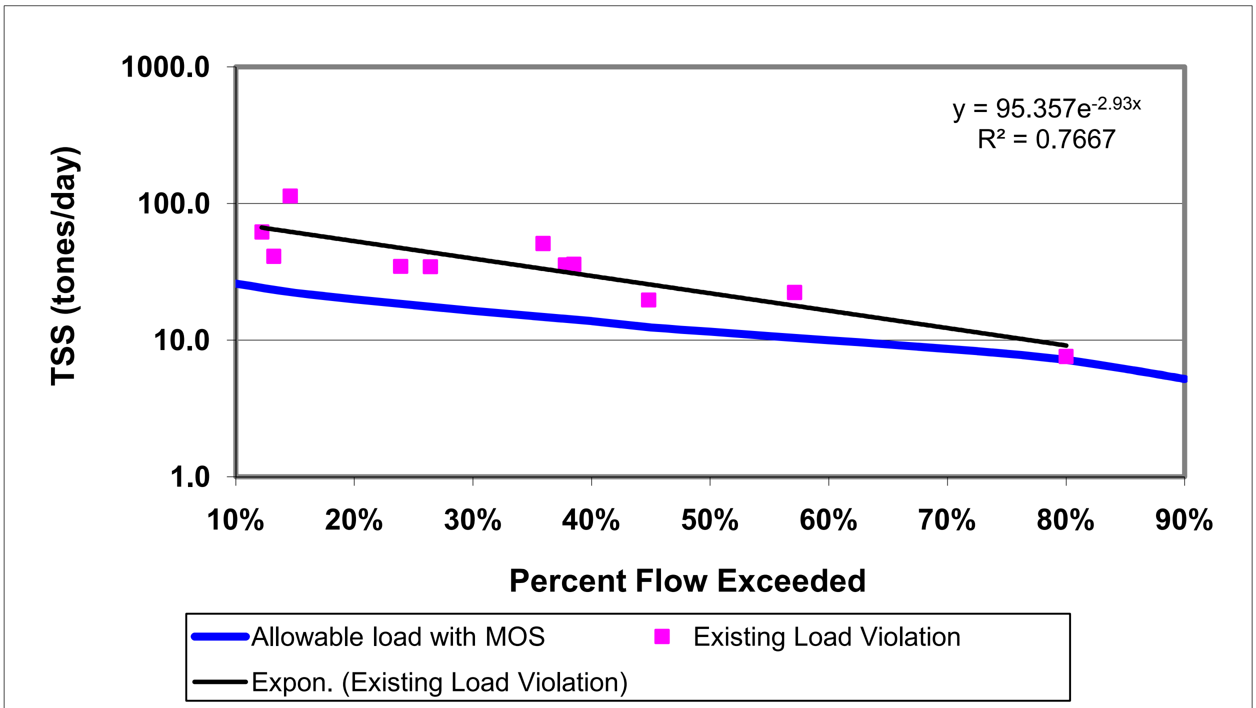


Figure 4.3 Load duration curve allowable TSS load and existing total TSS load violation in the Ararat River

4.7 TMDL Allocation

4.7.1 Waste Load Allocation (WLA)

Two wastewater treatment plants (WWTP) plus the NC Department of Transportation hold NPDES permits in the Ararat River Watershed. The wastewater load contributions are shown in Table 4.2

Table 4.2 Existing NPDES WW Load Contributions

Facility Name	Permit Number	Flow (gpd)	Permit Limit (monthly max in mg/L)	Load (tons/day)	% of Average Ambient Station Load
Pilot Mountain WWTP	NC0026646	1,500,000	30.00	0.17	0.60
Pilot Mountain WTP	NC0068365	No Flow Limit	30.00	N/A	N/A

The Pilot Mountain WTP does not have a flow limit, therefore a load will not be calculated for this facility. In order to estimate contributions from the WWTPs, it was assumed that all TSS discharged reaches the ambient station with no settling. Based on facility permit limits of flow and the monthly average permit limits for TSS, the combined WWTP load contributes less than 1% of the average load at DWQ station Q1780000 based on data from years 2000 through 2009. It appears that these WWTPs do not present a significant load to the Ararat River. Therefore it was assumed that the WWTPs are adequately regulated under existing permits and the waste load allocations in this TMDL were calculated at the existing permit limits.

The NCDOT was considered a significant contributor, and was assigned a percent reduction identical to the nonpoint source reduction. The NCDOT is currently in compliance with their NPDES stormwater permit, and will continue to implement measures required by the permit (NCS000250). Because of the nature of drainage from roads and highways, data are not available (n/a) to calculate a WLA for the NCDOT as a load.

The waste load allocation and required reductions for NPDES permittees in the Ararat River watershed are shown in Table 4.3.

Table 4.3 NPDES waste load allocations and required reductions

NPDES Permittee	Permitted Load (tons/day)	WLA (tons/day)	Percent Reduction Required
Pilot Mountain WWTP	0.17	0.17	0%
Pilot Mountain WTP	N/A	N/A	N/A
NCDOT - Stormwater	N/A	N/A	54%

4.7.2 Load Allocation (LA)

All TSS loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as the LA. The estimated TMDL and allocation of TSS to point and nonpoint sources are presented in Table 4.4. The estimated percent reduction needed from NPDES stormwater and nonpoint sources is 54%, as shown in Table 4.5.

Table 4.4 Estimated TMDL and load allocation for TSS (tons/day) for the Ararat River

Pollutant	Water Body	Existing Load (tons/day)	WLA	LA	MOS	TMDL
TSS	Ararat River	28.20	0.170	12.830	Explicit 10%	13.00

Note: The Margin of safety is included in the TMDL by lowering TSS value calculated at the 50 NTU standard by 10%

Table 4.5 Estimated reduction by source for TSS (tons/day) for the Ararat River

	NPDES Wastewater WLA	NPDES Stormwater WLA	LA
Existing Load (tons/day)	0.170	N/A	28.03
Allocation (tons/day)	0.170	N/A	12.83
Percent Reduction	0%	54%	54%

4.7.3 Critical Condition and Seasonal Variation

Critical conditions are considered in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining the flows (percent flow exceeded) where the existing loads exceed the target.

Seasonal variation is considered in the development of the TMDLs, because allocation applies to all seasons. In the load duration curves, the mark inside a square box indicates pollutant load during the summer period.

The greatest frequency of exceedances of turbidity occurred during normal to high flow periods. The result shows that wet weather under the high-flow period is the critical period for turbidity in the Ararat River.

5.0 Hunting Creek

5.1 Source Assessment

<u>Nonpoint Sources</u>

Potential sources of turbidity from nonpoint sources are described in section 2.1

<u>Point Sources</u>

NPDES wastewater and stormwater permittees upstream of an ambient monitoring site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL. Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below.

NPDES Wastewater Permits:

There are no NPDES wastewater dischargers in the Hunting Creek Watershed.

MS4 and Individual Stormwater Permits:

The NCDOT (NCS000250) is the only MS4 stormwater permitted entity in the Hunting Creek Watershed.

5.2 Technical Approach

Endpoint for Turbidity

Turbidity is a measure of cloudiness and is reported in NTU. Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, TSS was selected as the measure for this study.

In order to determine the relationship between TSS and turbidity in Hunting Creek, a regression equation between the two parameters was developed using the observed data collected from February 2000 through December 2009 at ambient station, Q3484000, on Hunting Creek. The relationship is shown in Equation 5.1. The coefficient of determination (R-Square) between the two parameters was 0.91, showing a strong relationship between the two parameters. The R^2 value is the percentage of the total variation in turbidity that is explained or accounted for by the fitted regression (TSS).

$$y = 0.7125x + 1.5044 \quad R^2 = 0.9055 \qquad (5.1)$$

Where Y = TSS in mg/l and X = turbidity in NTU.

The corresponding TSS value at the turbidity standard of 50 NTU is 37 mg/L.

Methodology

The load duration curve method is intended to be a simple method to calculate pollutant reductions. This method was chosen for Hunting Creek because of the availability of long- term data. It is also an efficient method to calculate a percent load reduction from nonpoint sources. The methodology used to develop the load duration curve was based on Cleland (2002).The required load reduction was determined based on water quality monitoring and stream flow data from January 2000 through December 2009.

5.3 Flow Duration Curve

Development of a flow duration curve is the first step of the load duration approach. A flow duration curve employs a cumulative frequency distribution of measured daily stream flow over the period of record. The curve relates flow values measured at the monitoring station for the percent of time the flow values were equaled or exceeded. Flows are ranked from lowest, which are exceeded nearly 100 percent of the time, to highest, which are exceeded less than 1 percent of the time. Reliability of the flow duration curve depends on the period of record available at monitoring stations. Accuracy of the curve increases when longer periods of record are used. The flow duration curve, shown in Figure 5.1, was used to determine the seasonality and flow regimes during which the exceedances of the pollutants occurred.

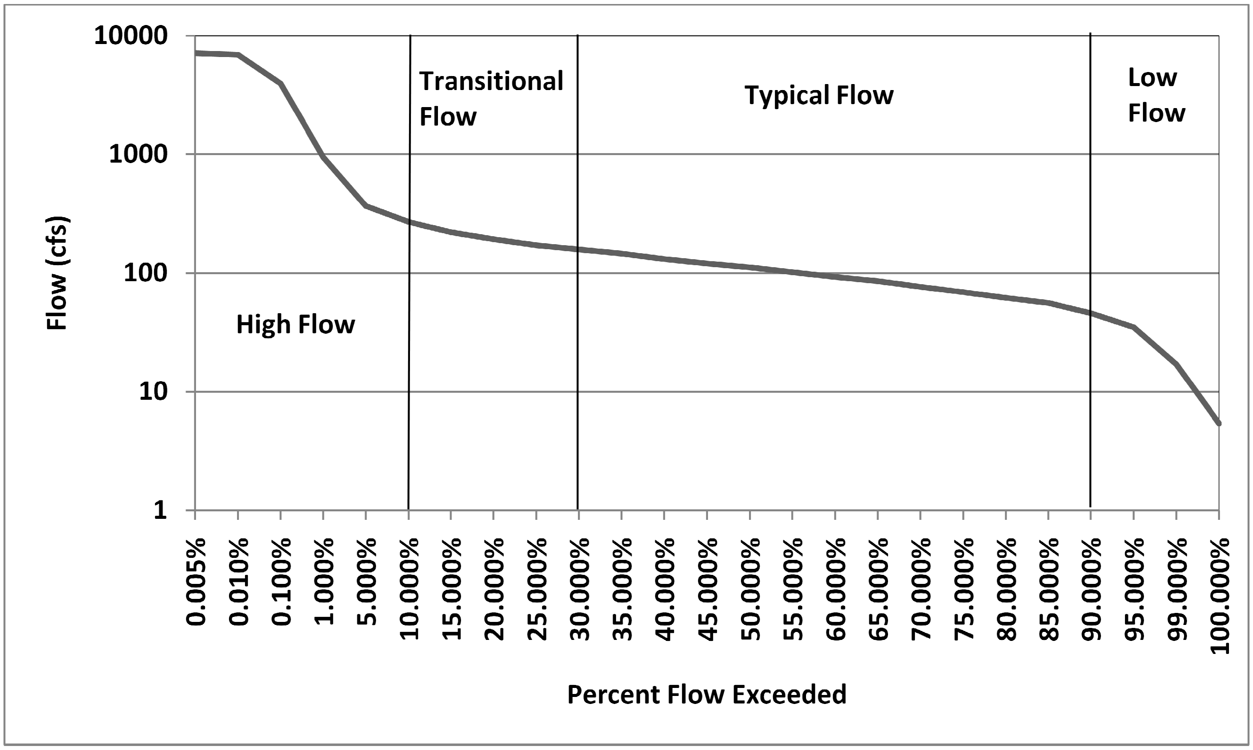


Figure 5.1 Flow Duration Curve for Hunting Creek at DWQ Station Q3484000

Daily flow data were used from USGS Hunting Creek gauging station 02118500, co-located with the DWQ water quality monitoring station.

5.4 Load Duration Curve

A load duration curve is developed by multiplying the flow values along the flow duration curve by the pollutant concentrations and the appropriate conversion factors. As shown in Figure 5.2, allowable and existing loads are plotted against the flow recurrence interval. The allowable load is based on the water quality numerical standard, margin of safety, and flow duration curve. The target line is represented by the line drawn through the allowable load data points and hence, it determines the assimilative capacity of a stream or river under different flow conditions. Any values above the line are exceeded loads and the values below the line are acceptable loads. Therefore, a load duration curve can help define the flow regime during which exceedances occur. Exceedances that occur during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and non-point sources may cause exceedances during normal flows.

Existing TSS loads to Hunting Creek were determined by multiplying the observed TSS concentration by the flow observed on the date of observation and converting the result to daily loading values. The assimilative capacities of the waterbodies were determined by multiplying the TSS concentration that is equivalent to a turbidity value of 50 NTU by the full range of measured flow values.

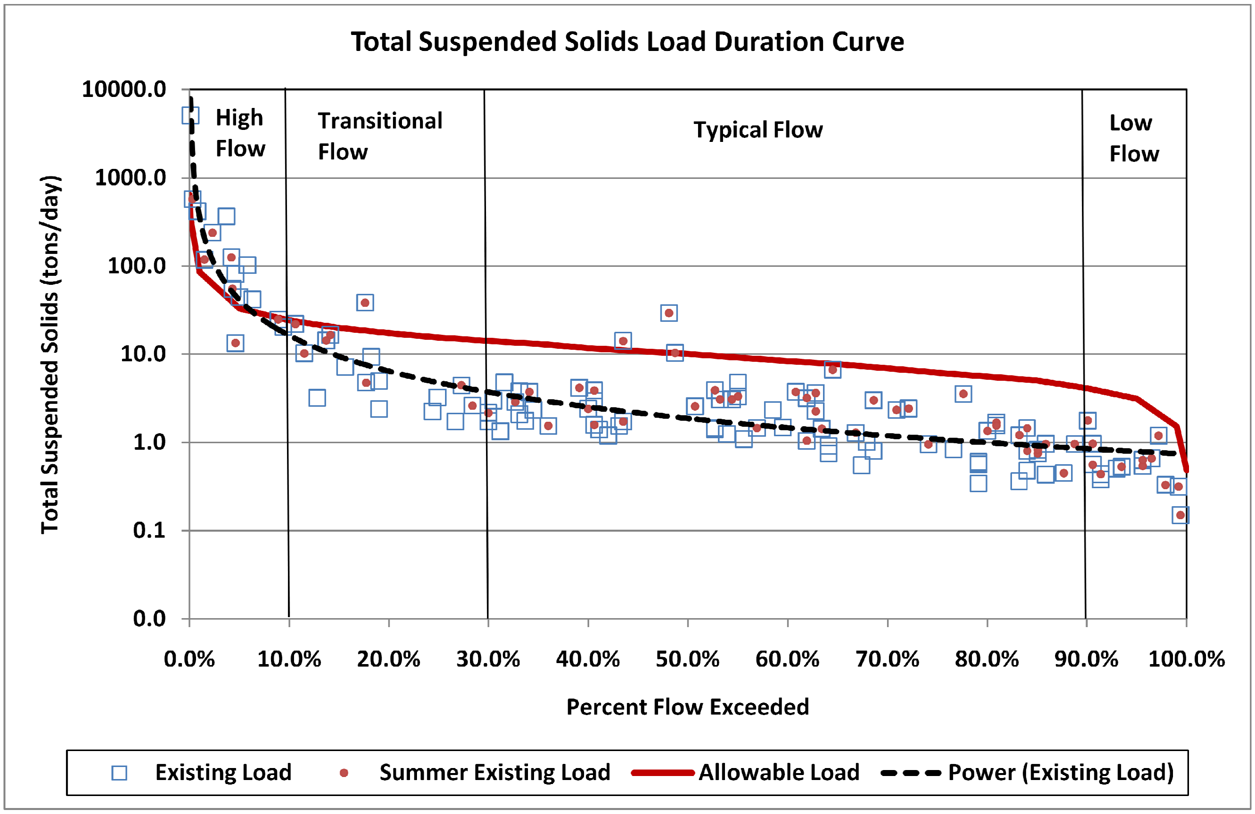


Figure 5.2 Load Duration Curve for Hunting Creek at DWQ station Q3484000

For Hunting Creek, the standard violations occurred during typical to high flow conditions. The higher loads during high and transitional flows suggest that the sources of turbidity could be from storm runoff and/or bank erosion. Stormwater runoff would carry a substantial amount of sediments and solid materials from impermeable as well as permeable land surfaces. Bank erosion may be another result of high and transitional flows. Bank erosion occurs when high volume and velocity runoff exceeds the resistance of the lateral (side) soil material. The loads during high flow period are considered unmanageable and hence are excluded from the TMDL estimation in this study.

5.5 TMDL

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source wasteload allocations (WLAs), nonpoint source load allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 5.2.

$$TMDL = \sum WLAs + \sum LAs + MOS \qquad (5.2)$$

The purpose of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For TSS (measure for turbidity), TMDLs are expressed as tons per day. TMDLs represent the maximum one-day load the river can assimilate and maintain the water quality criterion. Load duration curve approach was utilized to estimate the TMDL for TSS. The systematic procedures adopted to estimate TMDLs are described below.

5.5.1 Margin of Safety (MOS)

Conceptually, the MOS is included in the TMDL estimation to account for the uncertainty in the simulated relationship between the pollutants and the water quality standard. In this study, the MOS was explicitly included in the TMDL analysis by setting the TMDL target at 10 percent lower than the water quality target for turbidity.

5.6 Target Reduction

To determine the amount of turbidity reduction necessary to comply with the water quality standard, exceedances of the estimated standard (37 mg TSS/L) were identified within the 10^{th} to 95^{th} percentile flow recurrence range. Typically the remaining flow recurrence range is not included in the TMDL calculation to allow cases of extreme drought or flood to be excluded.

A power curve equation for the data points violating the water quality criterion was estimated. The equation is presented in Equation 5.3.

$$y = 13.001x^{-0.598} \quad R^2 = 0.4097 \qquad (5.3)$$

Where, Y = TSS (tons/day) and X = Percent Flow Exceeded.

To present the TMDLs as a single value, the existing load was calculated from the power curve equation as the average of the load violations occurring between 10% and 90% flow exceedances. The average load was calculated by using percent flow exceedances in multiples of 5 percent. The allowable loadings for each exceedance were calculated from the TMDL target value, which includes the 10 percent MOS. The target curve based on the allowable load and the power curve based on the exceedances are shown in Figure 5.3.

The necessary percent reduction was calculated by taking the difference between the average of the power curve load estimates and the average of the allowable load estimates. For example, at each recurrence interval between 10 and 90 (again using recurrence intervals in multiples of 5), the equation of the exponential curve was used to estimate the existing load. The allowable load was then calculated in a similar fashion by substituting the allowable load curve. The estimated values are given in Appendix C.

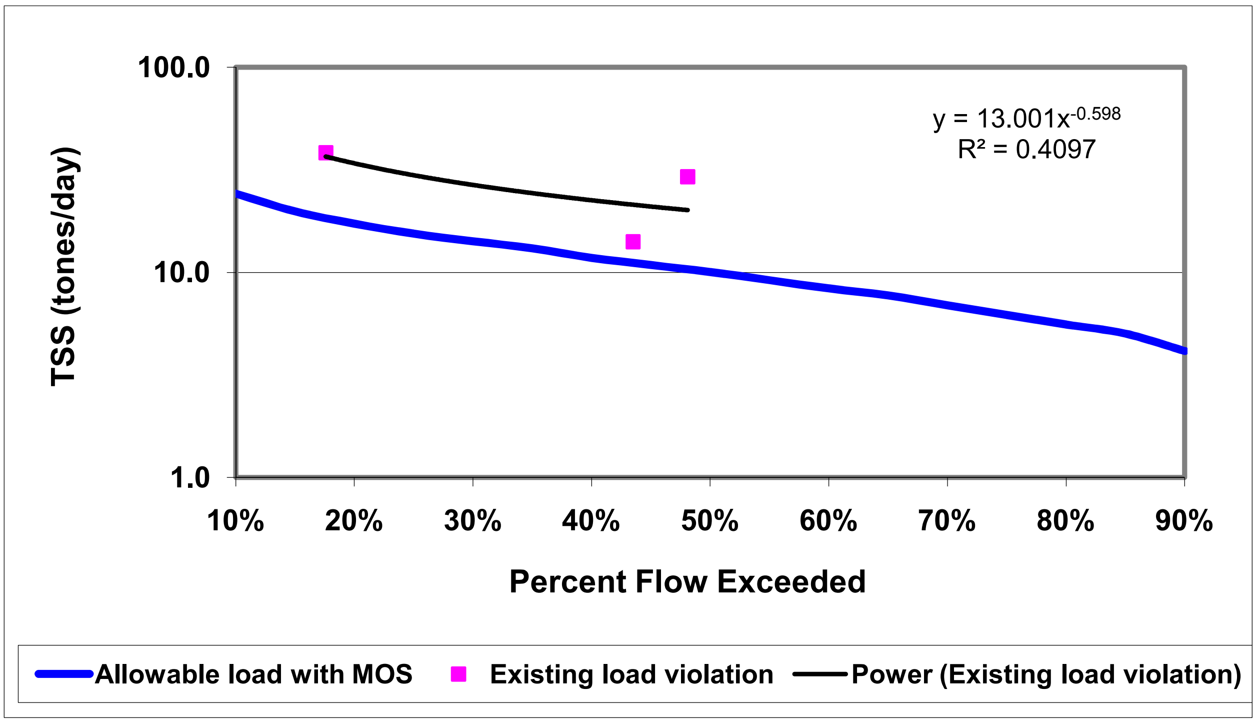


Figure 5.3 Load duration curve allowable TSS load and existing total TSS load violation in Hunting Creek

5.7 TMDL Allocation

5.7.1 Waste Load Allocation (WLA)

The NCDOT is the only NPDES permitted entity in the Hunting Creek Watershed. The NCDOT was considered a significant contributor, and was assigned a percent reduction identical to the nonpoint source reduction. The NCDOT is currently in compliance with their NPDES stormwater permit, and will continue to implement measures required by the permit (NCS000250). Because of the nature of drainage from roads and highways, data are not available (n/a) to calculate a WLA for the NCDOT as a load.

The reduction required for the NCDOT in the Hunting Creek watershed is shown in Table 5.1.

Table 5.1 NPDES waste load allocations and required reductions

NPDES Permittee	Permitted Load (tons/day)	WLA (tons/day)	Percent Reduction Required
NCDOT - Stormwater	N/A	N/A	52%

5.7.2 Load Allocation (LA)

All TSS loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as the LA. The estimated TMDL and allocation of TSS to point and nonpoint sources are presented in Table 5.2. The estimated percent reduction needed from NPDES stormwater and nonpoint sources is 52%, as shown in Table 5.3.

Table 5.2 Estimated TMDL and load allocation for TSS (tons/day) for Hunting Creek

Pollutant	Water Body	Existing Load (tons/day)	WLA	LA	MOS	TMDL
TSS	Hunting Creek	23.40	0.000	11.200	Explicit 10%	11.20

Note: The Margin of safety is included in the TMDL by lowering TSS value calculated at the 50 NTU standard by 10%

Table 5.3 Estimated reduction by source for TSS (tons/day) for Hunting Creek

	NPDES Wastewater WLA	NPDES Stormwater WLA	LA
Existing Load (tons/day)	N/A	N/A	23.40
Allocation (tons/day)	N/A	N/A	11.2
Percent Reduction	N/A	52%	52%

5.7.3 Critical Condition and Seasonal Variation

Critical conditions are considered in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining the flows (percent flow exceeded) where the existing loads exceed the target.

Seasonal variation is considered in the development of the TMDLs, because allocation applies to all seasons. In the load duration curves, the mark inside a square box indicates pollutant load during the summer period.

The exceedances of turbidity occurred during normal to high flow periods. The result shows that wet weather under high-flow period is the critical period for turbidity in Hunting Creek.

6.0 Second Creek

Nonpoint Sources

Potential sources of turbidity from nonpoint sources are described in section 2.1

Point Sources

NPDES wastewater and stormwater permittees upstream of an ambient monitoring site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL. Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below.

6.1 Source Assessment

NPDES Wastewater Permits

There are five facilities that discharge wastewater continuously to Second Creek and tributaries under the NPDES program (Table 6.1). In general, facilities are permitted to discharge a monthly average TSS concentration up to 30 mg/L. Locations of dischargers are shown in Figure 1.8.

Table 6.1 NPDES Wastewater Dischargers in the Second Creek Watershed

Permit Number	Facility Name	Permit Flow (gpd)	Total Suspended Solids Monthly Average Limit
NC0004944	Performance Fibers Operations, Inc.	2,305,000	120 lbs/day
NC0028941	Pine Valley Subdivision WWTP	25,000	30 mg/L
NC0034959	West Rowan High School	10,000	30 mg/L
NC0075523	RDH Tire & Retread	No flow limit	32 lbs/day
NC0078361	Second Creek WWTP	30,000	30 mg/L

MS4 and Individual Stormwater Permits

The NCDOT (NCS000250) is the only MS4 stormwater permitted entity in the Second Creek Watershed.

6.2 Technical Approach

Endpoint for Turbidity

Turbidity is a measure of cloudiness and is reported in NTU. Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, TSS was selected as the measure for this study.

In order to determine the relationship between TSS and turbidity in Second Creek, a regression equation between the two parameters was developed using the observed data collected from February 2000 through December 2009 at ambient station, Q4120000, on Second Creek. The relationship is shown in Equation 7.1. The coefficient of determination (R-Square) between the two parameters was 0.98, showing a strong relationship between the two parameters. The R^2 value is the percentage of the total variation in turbidity that is explained or accounted for by the fitted regression (TSS).

$y = 0.8078x - 2.9658 \quad R^2 = 0.9795$ (6.1)
Where Y = TSS in mg/l and X = turbidity in NTU.

The corresponding TSS value at the turbidity standard of 50 NTU is 37 mg/L.

Methodology

The load duration curve method is intended to be a simple method to calculate pollutant reductions. This method was chosen for Second Creek because of the availability of long-term data. It is also an efficient method to calculate a percent load reduction from nonpoint sources. The methodology used to develop the load duration curve was based on Cleland (2002). The required load reduction was determined based on water quality monitoring and stream flow data from January 2000 through December 2009.

6.3 Flow Duration Curve

Development of a flow duration curve is the first step of the load duration approach. A flow duration curve employs a cumulative frequency distribution of measured daily stream flow over the period of record. The curve relates flow values measured at the monitoring station for the percent of time the flow values were equaled or exceeded. Flows are ranked from lowest, which are exceeded nearly 100 percent of the time, to highest, which are exceeded less than 1 percent of the time. Reliability of the flow duration curve depends on the period of record available at monitoring stations. Accuracy of the curve increases when longer periods of record are used. The flow duration curve, shown in Figure 6.1, was used to determine the seasonality and flow regimes during which the exceedances of the pollutants occurred.

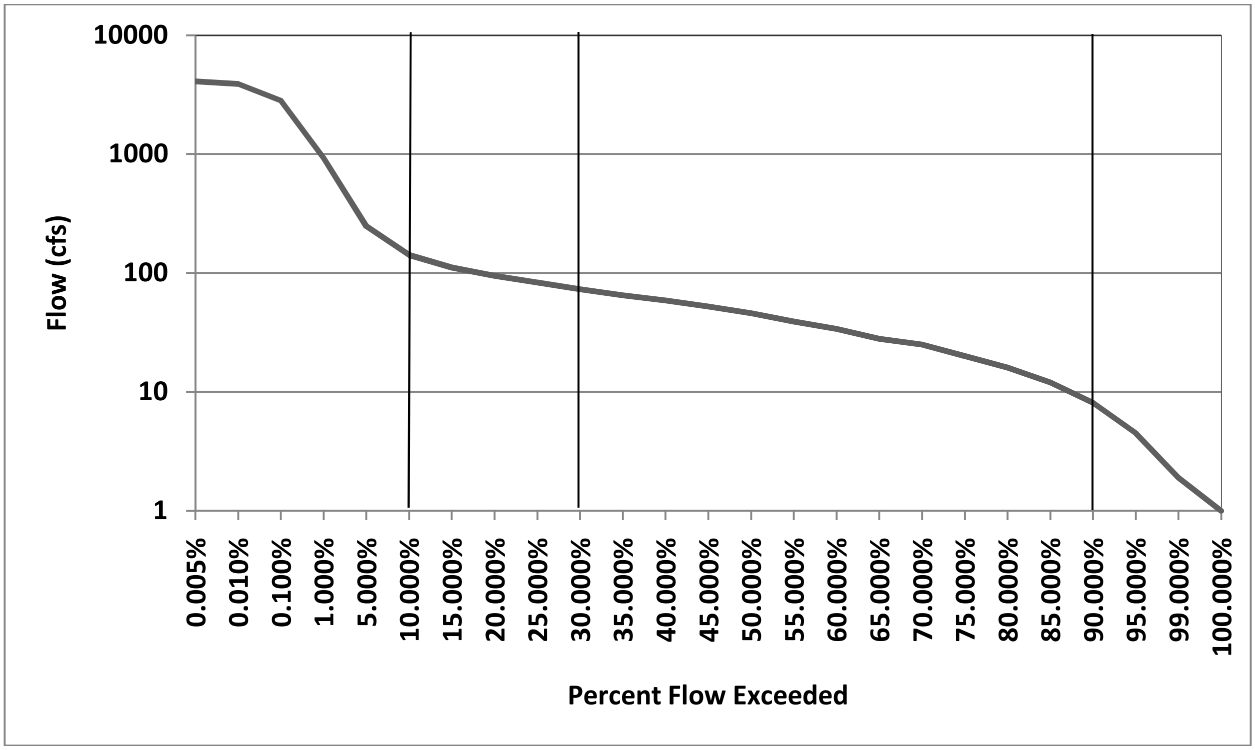


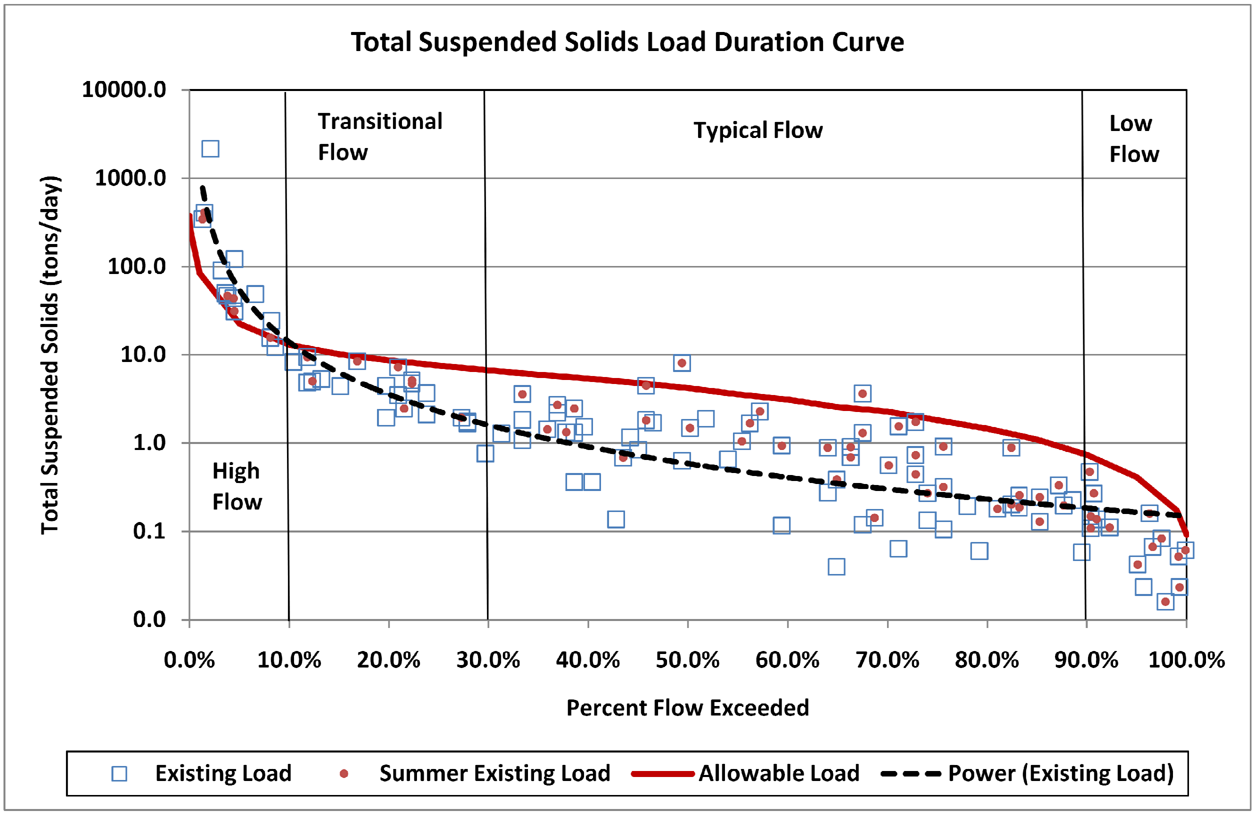
Figure 6.1 Flow Duration Curve for Second Creek at DWQ Station Q4120000

Daily flow data were used from USGS Second Creek gauging station 02120780, co-located with the DWQ water quality monitoring station.

6.4 Load Duration Curve

A load duration curve is developed by multiplying the flow values along the flow duration curve by the pollutant concentrations and the appropriate conversion factors. As shown in Figure 6.2, allowable and existing loads are plotted against the flow recurrence interval. The allowable load is based on the water quality numerical standard, margin of safety, and flow duration curve. The target line is represented by the line drawn through the allowable load data points and hence, it determines the assimilative capacity of a stream or river under different flow conditions. Any values above the line are exceeded loads and the values below the line are acceptable loads. Therefore, a load duration curve can help define the flow regime during which exceedances occur. Exceedances that occur during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and non-point sources may cause exceedances during normal flows.

Existing TSS loads to Second Creek were determined by multiplying the observed TSS concentration by the flow observed on the date of observation and converting the result to daily loading values. The assimilative capacities of the waterbodies were determined by multiplying the TSS concentration that is equivalent to a turbidity value of 50 NTU by the full range of measured flow values.



6.2 Load Duration Curve for Second Creek at DWQ station Q4120000

For Second Creek, the standard violations occurred mostly during typical to high flow conditions. Few exceedances during low-flow conditions suggest that point sources in the watershed may not be a significant source of TSS in this watershed. The higher loads during high and transitional flows suggest that the sources of turbidity could be from storm runoff and/or bank erosion. In addition most of the exceedances occurred during summer when thunderstorms would increase runoff. Stormwater runoff would carry a substantial amount of sediments and solid materials from impermeable as well as permeable land surfaces. Bank erosion may be another result of high and transitional flows. Bank erosion occurs when high volume and velocity runoff exceeds the resistance of the lateral (side) soil material. The loads during high flow period are considered unmanageable and hence are excluded in the TMDL estimation in this study.

6.5 TMDL

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source wasteload allocations (WLAs), nonpoint source load allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 6.2.

$$TMDL = \sum WLAs + \sum LAs + MOS \qquad (6.2)$$

The purpose of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For TSS (measure for turbidity), TMDLs are expressed as tons per day. TMDLs represent the maximum one-day load the river can assimilate and maintain the water quality criterion. Load duration curve approach was utilized to estimate the TMDL for TSS. The systematic procedures adopted to estimate TMDLs are described below.

6.5.1 Margin of Safety (MOS)

Conceptually, the MOS is included in the TMDL estimation to account for the uncertainty in the simulated relationship between the pollutants and the water quality standard. In this study, the MOS was explicitly included in the TMDL analysis by setting the TMDL target at 10 percent lower than the water quality target for turbidity.

6.6 Target Reduction

To determine the amount of turbidity reduction necessary to comply with the water quality standard, exceedances of the estimated standard (estimated as 37 mg TSS/L) were identified within the 10^{th} to 90^{th} percentile flow recurrence range. Typically the remaining flow recurrence range is not included in the TMDL calculation to allow cases of extreme drought or flood to be excluded.

A power curve equation for the data points violating the water quality criterion was estimated. The equation is presented in Equation 6.3.

$$y = 1.2969x^{-2.598} \quad R^2 = 1 \qquad (6.3)$$

Where, Y = TSS (tons/day) and X = Percent Flow Exceeded.

Typically, to present the TMDLs as a single value, the existing load is calculated from the power curve equation as the average of the load violations occurring when the flow exceeded at a frequency greater than 10 percent and less than 90 percent. However, only two data points exceeded the allowable load in the TMLD calculation which occurred in the 50 to 70 percent flow exceedance. Therefore only the 50-70 percent flow exceedance range was used in the TMDL calculation and reduction needed. Additionally, the average load was calculated by using percent flow exceedances in multiples of 5 percent. The allowable loadings for each exceedance were calculated from the TMDL target value, which includes the 10 percent MOS. The target curve based on the allowable load and the power curve based on the exceedances are shown in Figure 6.3.

The necessary percent reduction was calculated by taking the difference between the average of the power curve load estimates and the average of the allowable load estimates. For example, at each recurrence interval between 50 to 70 (again using recurrence intervals in multiples of 5), the equation of the exponential curve was used to estimate the existing load. The allowable load was then calculated in a similar fashion by substituting the allowable load curve. The estimated values are given in Appendix C.

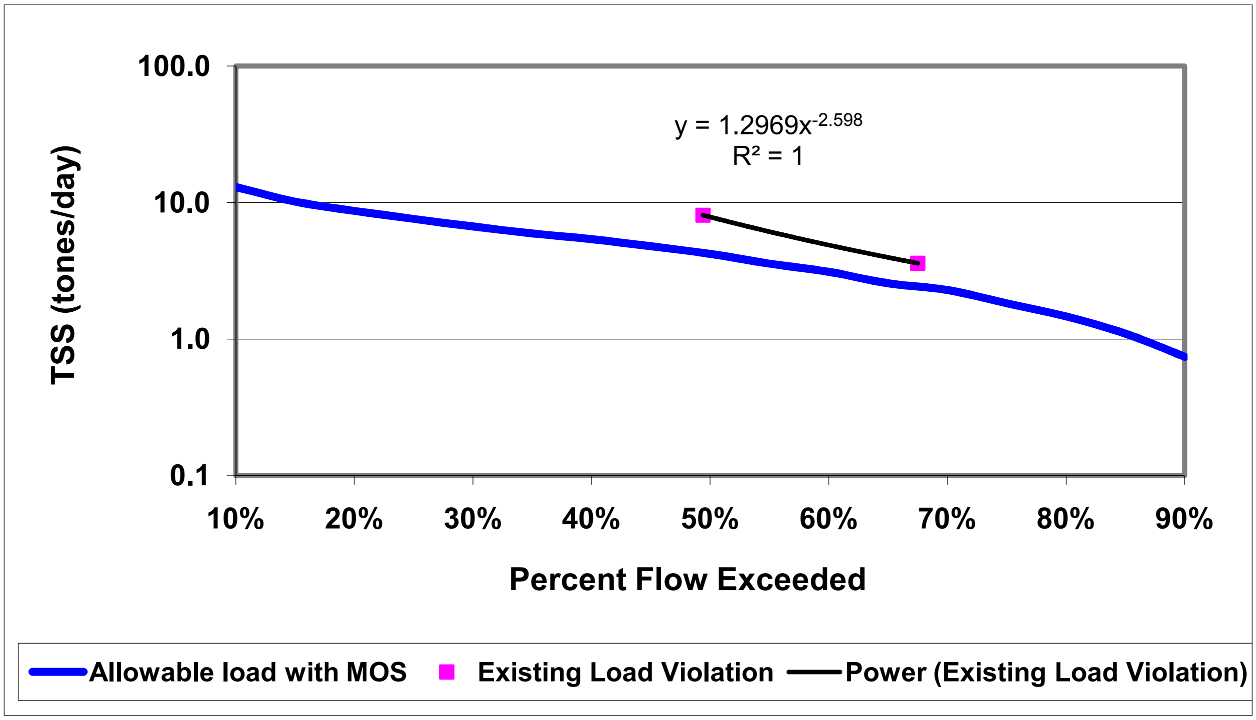


Figure 6.3 Load duration curve allowable TSS load and existing total TSS load violation in Second Creek

6.7 TMDL Allocation

6.7.1 Waste Load Allocation (WLA)

Five wastewater treatment plants (WWTP) plus the NC Department of Transportation hold NPDES permits in the Second Creek Watershed. The wastewater load contributions are shown in Table 6.2.

Table 6.2 Existing NPDES WW Load Contributions

Facility Name	Permit Number	Flow (gpd)	Permit Limit (monthly max)	Load (tons/day)	% of Average Ambient Station Load
Performance Fibers Operations, Inc.	NC0004944	2,305,000	120 lbs/day	0.05	1.05
Pine Valley Subdivision WWTP	NC0028941	25,000	30 mg/L	0.00	0.05
West Rowan High School	NC0034959	10,000	30 mg/L	0.00	0.02
RDH Tire & Retread	NC0075523	No flow limit	32 lbs/day	0.01	0.28
Second Creek WWTP	NC0078361	30,000	30 mg/L	0.003	0.07

In order to estimate contributions from the WWTPs, it was assumed that all TSS discharged reaches the ambient station with no settling. Based on facility permit limits of flow and the monthly average permit limits for TSS, the combined WWTP load contributes 1.6% of the average load at DWQ station Q4120000 based on data from years 2000 through 2009. It appears that these WWTPs do not present a significant load to Second Creek. Therefore it was concluded that the WWTPs are adequately regulated under existing permits and the waste load allocations in this TMDL were calculated at the existing permit limits.

The NCDOT was considered a significant contributor, and was assigned a percent reduction identical to the nonpoint source reduction. The NCDOT is currently in compliance with their NPDES stormwater permit, and will continue to implement measures required by the permit (NCS000250). Because of the nature of drainage from roads and highways, data are not available (n/a) to calculate a WLA for the NCDOT as a load.

The waste load allocation and required reductions for NPDES permittees in Second Creek watershed are shown in Table 6.3.

Table 6.3 NPDES waste load allocations and required reductions

NPDES Permittee	Permitted Load (tons/day)	WLA (tons/day)	Percent Reduction Required
Performance Fibers Operations, Inc.	0.05	0.05	0%
Pine Valley Subdivision WWTP	0.00	0.00	0%
West Rowan High School	0.00	0.00	0%
RDH Tire & Retread	0.01	0.01	0%
Second Creek WWTP	0.01	0.01	0%
NCDOT - Stormwater	N/A	N/A	41%

6.7.2 Load Allocation (LA)

All TSS loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as the LA. The estimated TMDL and allocation of TSS to point and nonpoint sources are presented in Table 6.4. The estimated percent reduction needed from NPDES stormwater and nonpoint sources is 41%, as shown in Table 6.5.

Table 6.4 Estimated TMDL and load allocation for TSS (tons/day) for Second Creek

6.5 Pollutant	Water Body	Existing Load (tons/day)	WLA	LA	MOS	TMDL
TSS	Second Creek	5.20	0.17	2.977	Explicit 10%	3.10

Note: The Margin of safety is included in the TMDL by lowering TSS value calculated at the 50 NTU standard by 10%

Table 6.5 Estimated reduction by source for TSS (tons/day) for Second Creek

	NPDES Wastewater WLA	NPDES Stormwater WLA	LA
Existing Load (tons/day)	0.170	N/A	5.03
Allocation (tons/day)	0.170	N/A	2.977
Percent Reduction	0%	41%	41%

6.7.3 Critical Condition and Seasonal Variation

Critical conditions are considered in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining the flows (percent flow exceeded) where the existing loads exceed the target.

Seasonal variation is considered in the development of the TMDLs, because allocation applies to all seasons. In the load duration curves, the mark inside a square box indicates pollutant load during the summer period.
The exceedances of turbidity occurred during normal to high flow periods. The result shows that wet weather under high-flow period is the critical period for turbidity in Second Creek.

7.0 South Deep Creek

7.1 Source Assessment

Nonpoint Sources

Potential sources of turbidity from nonpoint sources are described in section 2.1

Point Sources

NPDES wastewater and stormwater permittees upstream of an ambient monitoring site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL. Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below.

NPDES Wastewater Permits

There are three facilities that discharge wastewater continuously to South Deep Creek and tributaries under the NPDES program (Table 7.1). In general, facilities are permitted to discharge a monthly average TSS concentration up to 30 mg/L. Locations of dischargers are shown in Figure 1.10.

Table 7.1 NPDES Wastewater Dischargers in the South Deep Creek Watershed

Permit Number	Facility Name	Permit Flow (gpd)	Total Suspended Solids Monthly Average Limit
NC0029599	Courtney Elementary School WWTP	5,000	30 mg/L
NC0070459	Starmount High School WWTP	26,000	30 mg/L
NC0079260	Yadkinville WTP	No Permit Limit	30 mg/L

MS4 and Individual Stormwater Permits

The NCDOT (NCS000250) is the only MS4 stormwater permitted entity in the South Deep Creek Watershed.

7.2 Technical Approach

Endpoint for Turbidity

Turbidity is a measure of cloudiness and is reported in NTU. Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, TSS was selected as the measure for this study.

The ambient monitoring station on South Deep Creek (Q2135000) does not monitor TSS. In order to determine the relationship between TSS and turbidity in South Deep Creek, a regression equation between TSS and NTU is used from the other combined ambient stations used for the waterbodies in this TMDL. These stations include Q5930000, Q3484000, Q2600000, Q2720000, Q4120000, and Q3934500 using observed data from February 2000 through December 2009. The combined relationship is shown in Equation 7.1. The coefficient of determination (R-Square) between the two parameters was 0.92, showing a strong relationship between the two parameters. The R^2 value is the percentage of the total variation in turbidity that is explained or accounted for by the fitted regression (TSS).

$$y = -0.0002x^2 + 1.1917x - 4.665 \quad R^2 = 0.9249 \qquad (7.1)$$

Where Y = TSS in mg/l and X = turbidity in NTU.

The corresponding TSS value at the turbidity standard of 50 NTU is 54 mg/L.

Methodology

The load duration curve method is intended to be a simple method to calculate pollutant reductions. This method was chosen for the South Deep Creek because of the availability of long- term data. It is also an efficient method to calculate a percent load reduction from nonpoint sources. The methodology used to develop the load duration curve was based on Cleland (2002).The required load reduction was determined based on water quality monitoring and stream flow data from January 2000 through April 2010.

7.3 Flow Duration Curve

Development of a flow duration curve is the first step of the load duration approach. A flow duration curve employs a cumulative frequency distribution of measured daily stream flow over the period of record. The curve relates flow values measured at the monitoring station for the percent of time the flow values were equaled or exceeded. Flows are ranked from lowest, which are exceeded nearly 100 percent of the time, to highest, which are exceeded less than 1 percent of the time. Reliability of the flow duration curve depends on the period of record available at monitoring stations. Accuracy of the curve increases when longer periods of record are used. The flow duration curve, shown in Figure 7.1, was used to determine the seasonality and flow regimes during which the exceedances of the pollutants occurred.

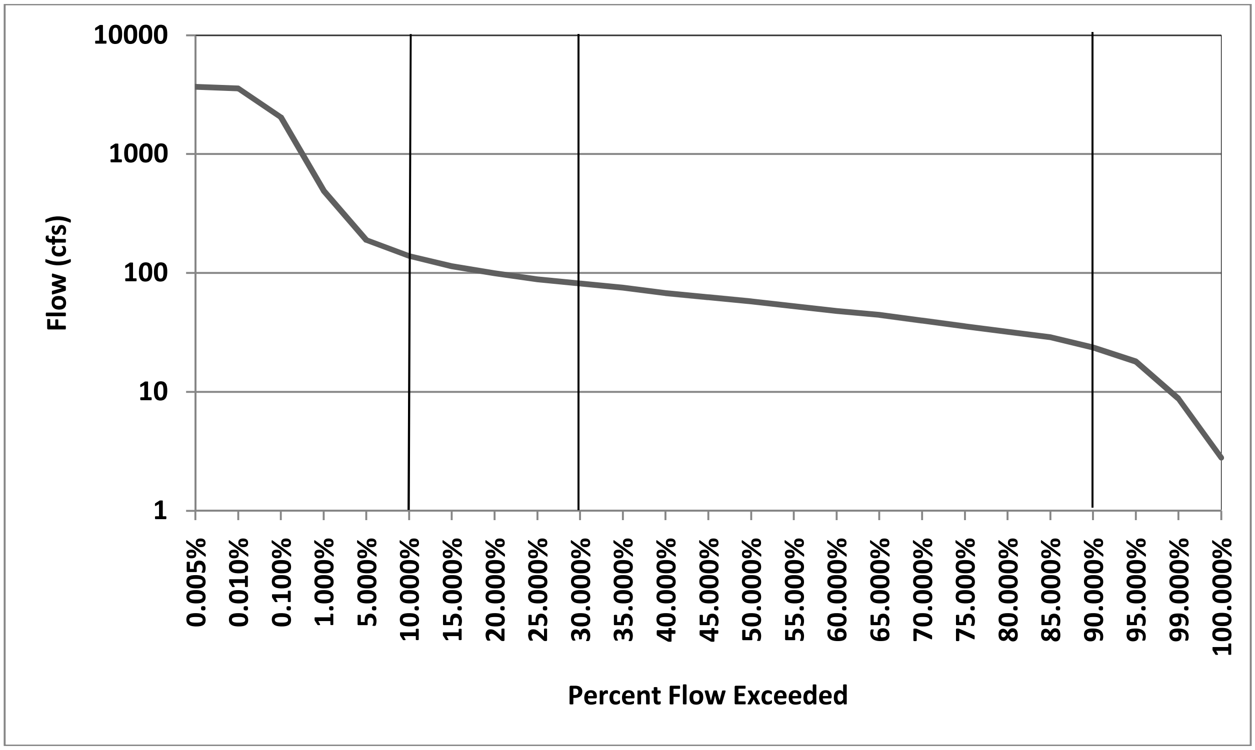


Figure 7.1 Flow Duration Curve for South Deep Creek at DWQ Station Q21350000

The South Deep Creek watershed does not have a USGS flow gage. Daily flow data were used from USGS gage on Hunting Creek (02118500), which is located adjacent to the south of South Deep Creek. The South Deep Watershed area is 80 square miles while the Hunting Creek water area is 155 square miles. A drainage area ratio between the two watersheds was used to estimate the flow on South Deep Creek.

7.4 Load Duration Curve

A load duration curve is developed by multiplying the flow values along the flow duration curve by the pollutant concentrations and the appropriate conversion factors. As shown in Figure 7.2, allowable and existing loads are plotted against the flow recurrence interval. The allowable load is based on the water quality numerical standard, margin of safety, and flow duration curve. The target line is represented by the line drawn through the allowable load data points and hence, it determines the assimilative capacity of a stream or river under different flow conditions. Any values above the line are exceeded loads and the values below the line are acceptable loads. Therefore, a load duration curve can help define the flow regime during which exceedances occur. Exceedances that occur during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and non-point sources may cause exceedances during normal flows.

Existing TSS loads to South Deep Creek were determined by multiplying the observed TSS concentration by the flow observed on the date of observation and converting the result to daily loading values. The assimilative capacities of the waterbodies were determined by multiplying the TSS concentration that is equivalent to a turbidity value of 50 NTU by the full range of measured flow values.

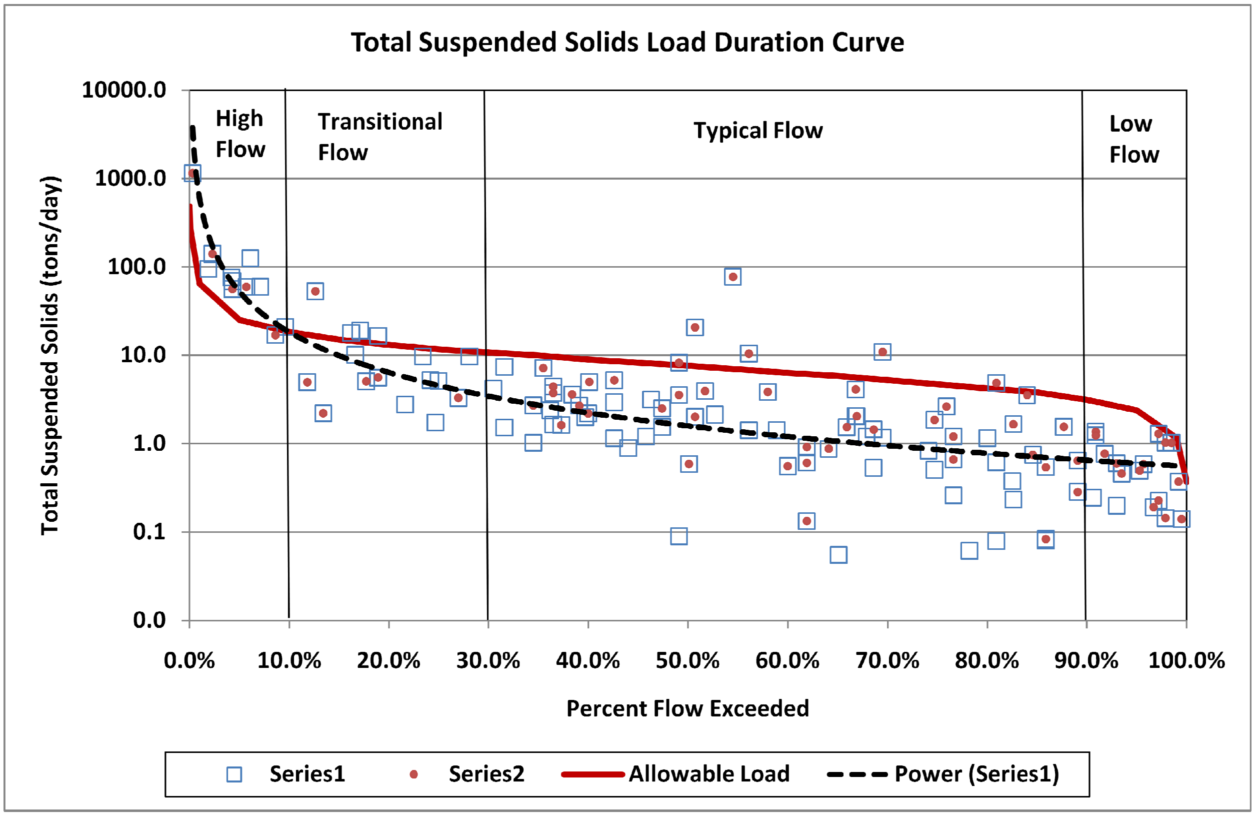


Figure 7.2 Load Duration Curve for South Deep Creek at DWQ station Q2135000

For South Deep Creek, the standard violations occurred during typical to high flow conditions. Few exceedances during low-flow conditions suggest that point sources in the watershed may not be a significant source of TSS in this watershed. The higher loads during high and transitional flows suggest that the sources of turbidity could be from storm runoff and/or bank erosion. Stormwater runoff would carry a substantial amount of sediments and solid materials from impermeable as well as permeable land surfaces. Bank erosion may be another result of high and transitional flows. Bank erosion occurs when high volume and velocity runoff exceeds the resistance of the lateral (side) soil material. The loads during high flow period are considered unmanageable and hence are excluded in the TMDL estimation in this study.

7.5 TMDL

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source wasteload allocations (WLAs), nonpoint source load allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 8.2.

$$TMDL = \sum WLAs + \sum LAs + MOS \qquad (8.2)$$

The purpose of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For TSS (measure for turbidity), TMDLs are expressed as tons per day. TMDLs represent the maximum one-day load the river can assimilate and maintain the water quality criterion. Load duration curve approach was utilized to estimate the TMDL for TSS. The systematic procedures adopted to estimate TMDLs are described below.

7.5.1 Margin of Safety (MOS)

Conceptually, the MOS is included in the TMDL estimation to account for the uncertainty in the simulated relationship between the pollutants and the water quality standard. In this study, the MOS was explicitly included in the TMDL analysis by setting the TMDL target at 10 percent lower than the water quality target for turbidity.

7.6 Target Reduction

To determine the amount of turbidity reduction necessary to comply with the water quality standard, exceedances of the estimated standard (estimated as 54 mg TSS/L) were identified within the 10^{th} to 90^{th} percentile flow recurrence range. Typically the remaining flow recurrence range is not included in the TMDL calculation to allow cases of extreme drought or flood to be excluded.

An exponential curve equation for the data points violating the water quality criterion was estimated. The equation is presented in Equation 7.3.

$$y = 34.556e^{-1.645x} \quad R^2 = 0.2386 \qquad (7.3)$$

Where, Y = TSS (tons/day) and X = Percent Flow Exceeded.

To present the TMDLs as a single value, the existing load was calculated from the exponential curve equation as the average of the load violations occurring between 10% and 90% flow exceedances. The average load was calculated by using percent flow exceedances in multiples of 5 percent. The allowable loadings for each exceedance were calculated from the TMDL target value, which includes the 10 percent MOS. The target curve based on the allowable load and the exponential curve based on the exceedances are shown in Figure 7.3.

The necessary percent reduction was calculated by taking the difference between the average of the exponential curve load estimates and the average of the allowable load estimates. For example, at each recurrence interval between 10 and 90 (again using recurrence intervals in multiples of 5), the equation of the exponential curve was used to estimate the existing load. The allowable load was then calculated in a similar fashion by substituting the allowable load curve. The estimated values are given in Appendix C.

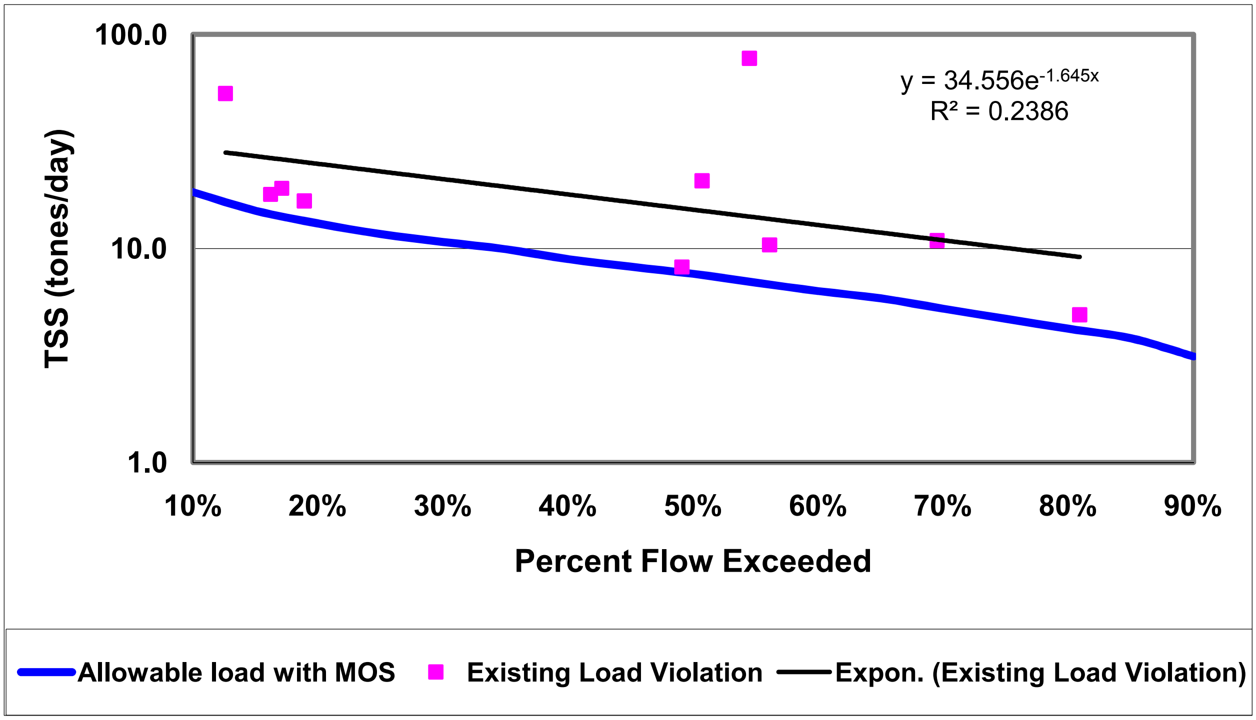


Figure 7.3 Load duration curve allowable TSS load and existing total TSS load violation in South Deep Creek

The power line representing the exceeding TSS loads in Figure 7.3 has a lower R-Square value due to presence of an observation that is numerically distant from the rest of the loads.

7.7 TMDL Allocation

7.7.1 Waste Load Allocation (WLA)

Three wastewater treatment plants (WWTP) plus the NC Department of Transportation hold NPDES permits in the South Deep Creek Watershed. The wastewater load contributions are shown in Table 7.2

Table 7.2 Existing NPDES WW Load Contributions

Facility Name	Permit Number	Flow (gpd)	Permit Limit (monthly max in mg/L)	Load (tons/day)	% of Average Ambient Station Load
Courtney Elementary School WWTP	NC0029599	5,000	30	0.0006	0.003
Starmount High School WWTP	NC0070459	26,000	30	0.0030	0.018
Yadkinville WTP	NC0079260	No Permit Limit	30	N/A	N/A

The Yadkinville WTP does not have a flow limit, therefore a load will not be calculated for this facility. In order to estimate contributions from the WWTPs, it was assumed that all TSS discharged reaches the ambient station with no settling. Based on facility permit limits of flow and the monthly average permit limits for TSS, the combined WWTP load contributes less than 1% of the average load at DWQ station Q2135000 based on data from years 2000 through 2009. It appears that these WWTPs do not present a significant load to South Deep Creek. Therefore it was concluded that the WWTPs are adequately regulated under existing permits and the waste load allocations in this TMDL were calculated at the existing permit limits.

The NCDOT was considered a significant contributor, and was assigned a percent reduction identical to the nonpoint source reduction. The NCDOT is currently in compliance with their NPDES stormwater permit, and will continue to implement measures required by the permit (NCS000250). Because of the nature of drainage from roads and highways, data are not available (n/a) to calculate a WLA for the NCDOT as a load.

The waste load allocation and required reductions for NPDES permittees in the South Deep Creek watershed are shown in Table 7.3.

Table 7.3 NPDES waste load allocations and required reductions

NPDES Permittee	Permitted Load (tons/day)	WLA (tons/day)	Percent Reduction Required
Courtney Elementary School WWTP	0.0006	0.0006	0%
Starmount High School WWTP	0.0030	0.0030	0%
Yadkinville WTP	N/A	N/A	N/A
NCDOT - Stormwater	N/A	N/A	48%

7.7.2 Load Allocation (LA)

All TSS loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as the LA. The estimated TMDL and allocation of TSS to point and nonpoint sources are presented in Table 7.4. The estimated percent reduction needed from NPDES stormwater and nonpoint sources is 48%, as shown in Table 7.5.

Table 7.4 Estimated TMDL and load allocation for TSS (tons/day) for South Deep Creek

Pollutant	Water Body	Existing Load (tons/day)	WLA	LA	MOS	TMDL
TSS	South Deep Creek	16.40	0.003	8.497	Explicit 10%	8.50

Table 7.5 Estimated reduction by source for TSS (tons/day) for South Deep Creek

	NPDES Wastewater WLA	NPDES Stormwater WLA	LA
Existing Load (tons/day)	0.003	N/A	16.40
Allocation (tons/day)	0.003	N/A	8.497
Percent Reduction	0%	48%	48%

7.7.3 Critical Condition and Seasonal Variation

Critical conditions are considered in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining the flows (percent flow exceeded) where the existing loads exceed the target.

Seasonal variation is considered in the development of the TMDLs, because allocation applies to all seasons. In the load duration curves, the mark inside a square box indicates pollutant load during the summer period.

The exceedances of turbidity occurred during normal to high flow periods. The result shows that wet weather under high-flow period is the critical period for turbidity in South Deep Creek.

8.0 South Yadkin River

8.1 Source Assessment

Nonpoint Sources

Potential sources of turbidity from nonpoint sources are described in section 2.1

Point Sources

NPDES wastewater and stormwater permittees upstream of an ambient monitoring site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL.

Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below.

NPDES Wastewater Permits

There are six facilities that discharge wastewater continuously to the South Yadkin River and tributaries under the NPDES program (Table 8.1). In general, facilities are permitted to discharge a monthly average TSS concentration up to 30 mg/L. Locations of dischargers are shown in Figure 1.12.

Table 8.1 NPDES Wastewater Dischargers in the South Yadkin River Watershed

Permit Number	Facility Name	Permit Flow (gpd)	Total Suspended Solids Monthly Average Limit
NC0004898	Turnersburg Plant	10,000	30 mg/L
NC0024872	Cooleemee WWTP	1,500,000	30 mg/L
NC0028606	I-77 Rest Area Iredell County	18,000	30 mg/L
NC0037371	North Iredell High School	12,500	30 mg/L
NC0076333	Statesville Auto Auction WWTP	25,000	30 mg/L
NC0085120	Iredell Distribution Center WWTP	16,000	30 mg/L

MS4 and Individual Stormwater Permits

The NCDOT (NCS000250) is the only MS4 stormwater permitted entity in the South Yadkin River Watershed.

8.2 Technical Approach

Endpoint for Turbidity

Turbidity is a measure of cloudiness and is reported in NTU. Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, TSS was selected as the measure for this study.

In order to determine the relationship between TSS and turbidity in the South Yadkin River, a regression equation between the two parameters was developed using the observed data collected from January 2000 through December 2009 at ambient station Q3460000 on the South Yadkin River. The relationship is shown in Equation 8.1. The coefficient of determination (R-Square) between the two parameters was 0.88, showing a strong relationship between the two parameters. The R^2 value is the percentage of the total variation in turbidity that is explained or accounted for by the fitted regression (TSS).

$y = 1.104x - 1.8288 \quad R^2 = 0.88$ (8.1)
Where Y = TSS in mg/l and X = turbidity in NTU.

The corresponding TSS value at the turbidity standard of 50 NTU is 53 mg/L.

Methodology

The load duration curve method is intended to be a simple method to calculate pollutant reductions. This method was chosen for the South Yadkin River because of the availability of long- term data. It is also an efficient method to calculate a percent load reduction from nonpoint sources. The methodology used to develop the load duration curve was based on Cleland (2002).The required load reduction was determined based on water quality monitoring and stream flow data from January 2000 through December 2009.

8.3 Flow Duration Curve

Development of a flow duration curve is the first step of the load duration approach. A flow duration curve employs a cumulative frequency distribution of measured daily stream flow over the period of record. The curve relates flow values measured at the monitoring station for the percent of time the flow values were equaled or exceeded. Flows are ranked from lowest, which are exceeded nearly 100 percent of the time, to highest, which are exceeded less than 1 percent of the time. Reliability of the flow duration curve depends on the period of record available at monitoring stations. Accuracy of the curve increases when longer periods of record are used. The flow duration curve, shown in Figure 8.1, was used to determine the seasonality and flow regimes during which the exceedances of the pollutants occurred.

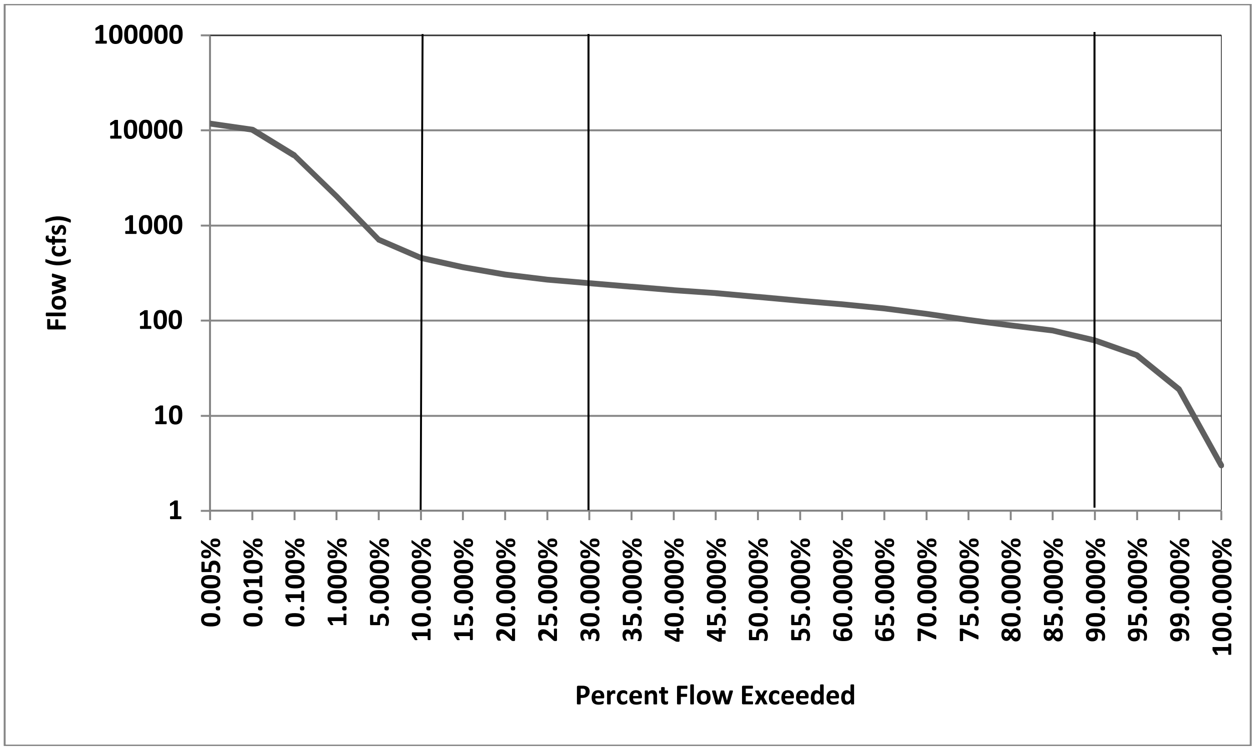


Figure 8.1 Flow Duration Curve for the South Yadkin River at DWQ Station Q3460000

Daily flow data were used from USGS South Yadkin River gauging station 02118000, co-located with the DWQ water quality monitoring station.

8.4 Load Duration Curve

A load duration curve is developed by multiplying the flow values along the flow duration curve by the pollutant concentrations and the appropriate conversion factors. As shown in Figure 8.2, allowable and existing loads are plotted against the flow recurrence interval. The allowable load is based on the water quality numerical standard, margin of safety, and flow duration curve. The target line is represented by the line drawn through the allowable load data points and hence, it determines the assimilative capacity of a stream or river under different flow conditions. Any values above the line are exceeded loads and the values below the line are acceptable loads. Therefore, a load duration curve can help define the flow regime during which exceedances occur. Exceedances that occur during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and non-point sources may cause exceedances during normal flows.

Existing TSS loads to the South Yadkin River were determined by multiplying the observed TSS concentration by the flow observed on the date of observation and converting the result to daily loading values. The assimilative capacities of the waterbodies were determined by multiplying the TSS concentration that is equivalent to a turbidity value of 50 NTU by the full range of measured flow values.

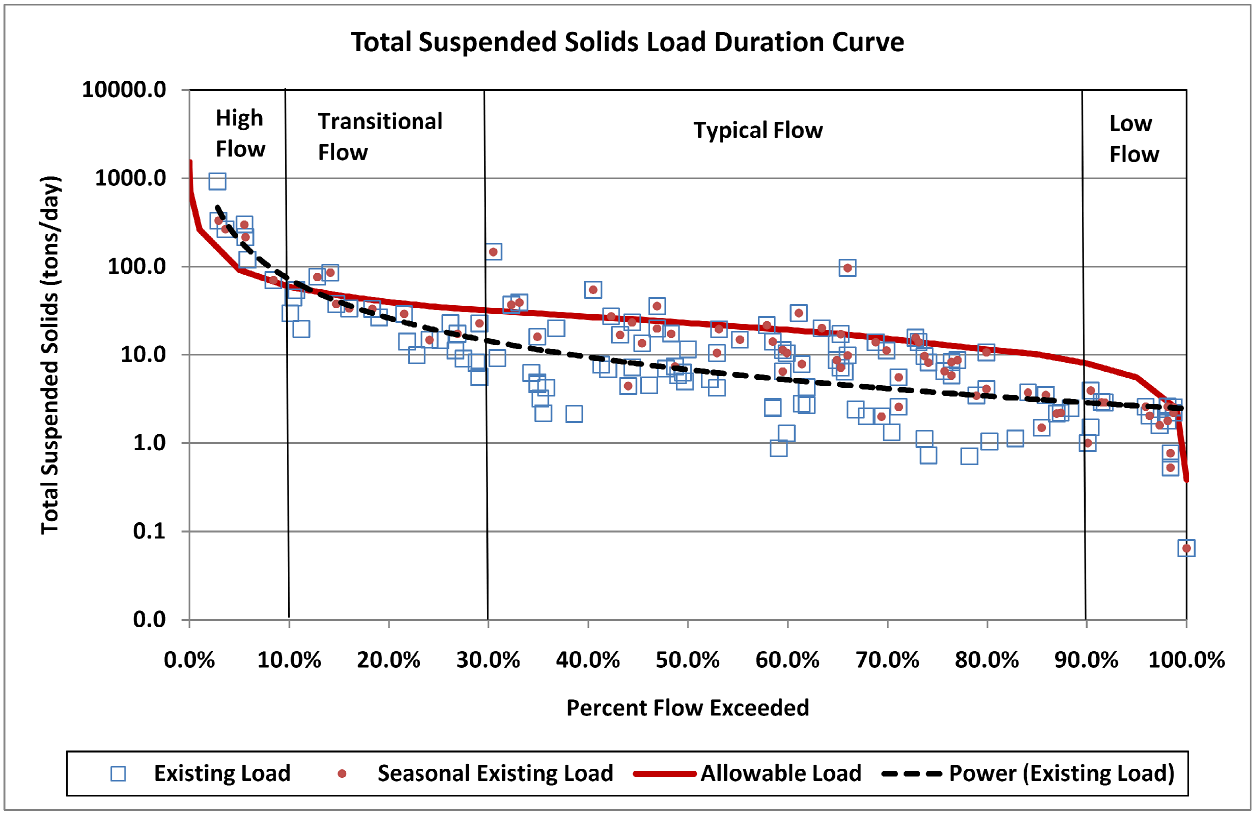


Figure 8.2 Load Duration Curve for the South Yadkin River at DWQ station Q3460000

For the South Yadkin River, the standard violations occurred during typical to high flow conditions. Few exceedances during low-flow conditions suggest that point sources in the watershed may not be a significant source of TSS in this watershed. The higher loads during high and transitional flows suggest that the sources of turbidity could be from storm runoff and/or bank erosion. In addition most of the exceedances occurred during summer when thunderstorms would increase runoff. Stormwater runoff would carry a substantial amount of sediments and solid materials from impermeable as well as permeable land surfaces. Bank erosion may be another result of high and transitional flows. Bank erosion occurs when high volume and velocity runoff exceeds the resistance of the lateral (side) soil material. The loads during high flow period are considered unmanageable and hence are excluded in the TMDL estimation in this study.

8.5 TMDL

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source wasteload allocations (WLAs), nonpoint source load allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 8.2.

$$TMDL = \sum WLAs + \sum LAs + MOS \quad (8.2)$$

The purpose of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For TSS (measure for turbidity), TMDLs are expressed as tons per day. TMDLs represent the maximum one-day load the river can assimilate and maintain the water quality criterion. Load duration curve approach was utilized to estimate the TMDL for TSS. The systematic procedures adopted to estimate TMDLs are described below.

8.5.1 Margin of Safety (MOS)

Conceptually, the MOS is included in the TMDL estimation to account for the uncertainty in the simulated relationship between the pollutants and the water quality standard. In this study, the MOS was explicitly included in the TMDL analysis by setting the TMDL target at 10 percent lower than the water quality target for turbidity.

8.6 Target Reduction

To determine the amount of turbidity reduction necessary to comply with the water quality standard, exceedances of the standard (estimated as 53 mg TSS/L) were identified within the 10^{th} to 90^{th} percentile flow recurrence range. Typically the remaining flow recurrence range is not included in the TMDL calculation to allow cases of extreme drought or flood to be excluded.

A power curve equation for the data points violating the water quality criterion was estimated. The equation is presented in Equation 8.3.

$$y = 31.051x^{-0.5} \quad R^2 = 0.2229 \quad (8.3)$$

Where, Y = TSS (tons/day) and X = Percent Flow Exceeded.

To present the TMDLs as a single value, the existing load was calculated from the power curve equation as the average of the load violations occurring between 10% and 90% flow exceedances. The average load was calculated by using percent flow exceedances in multiples of 5 percent. The allowable loadings for each exceedance were calculated from the TMDL target value, which includes the 10 percent MOS. The target curve based on the allowable load and the power curve based on the exceedances are shown in Figure 8.3.

The necessary percent reduction was calculated by taking the difference between the average of the power curve load estimates and the average of the allowable load estimates. For example, at each recurrence interval between 10 and 90 (again using recurrence intervals in multiples of 5), the equation of the power curve was used to estimate the existing load. The allowable load was then calculated in a similar fashion by substituting the allowable load curve. The estimated values are given in Appendix C.

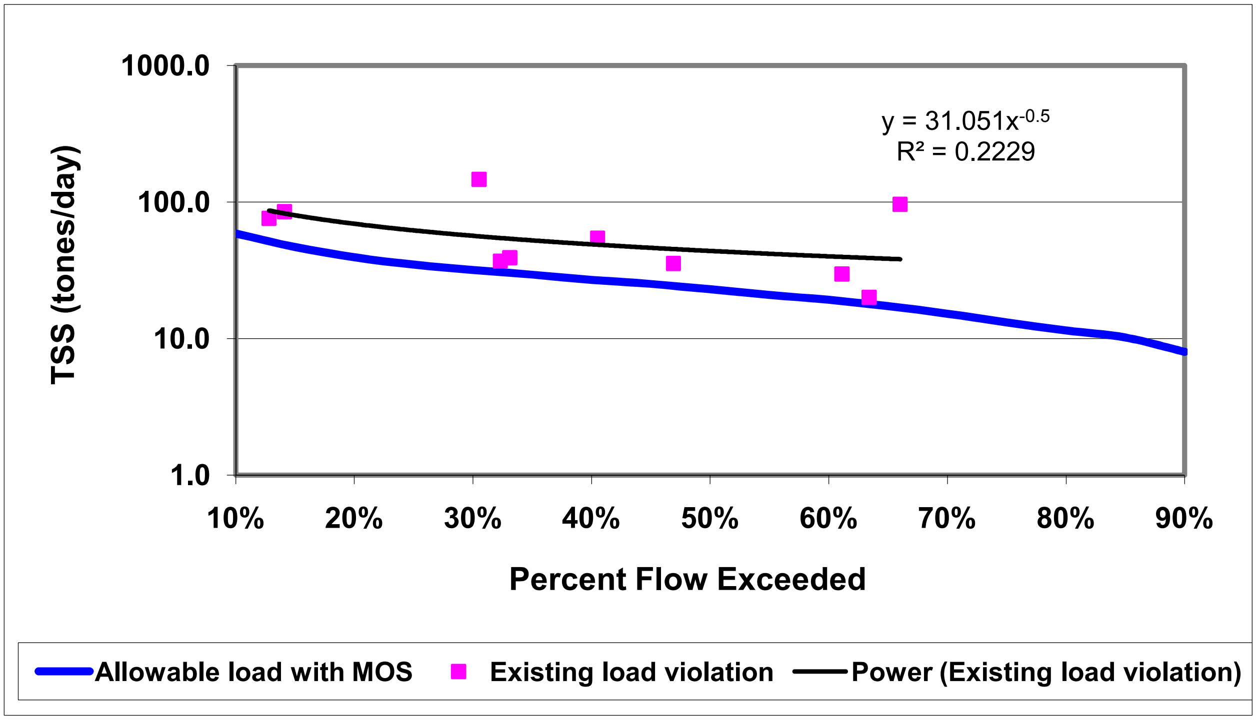


Figure 8.3 Load duration curve allowable TSS load and existing total TSS load violation in the South Yadkin River

The power line representing the exceeding TSS loads in Figure 8.3 has a lower R-Square value due to presence of an observation that is numerically distant from the rest of the loads.

8.7 TMDL Allocation

8.7.1 Waste Load Allocation (WLA)

Six wastewater treatment plants (WWTP) plus the NC Department of Transportation hold NPDES permits in the South Yadkin River Watershed. The wastewater load contributions are shown in Table 8.2.

Table 8.2 Existing NPDES WW Load Contributions

Facility Name	Permit Number	Flow (gpd)	Permit Limit (monthly max in mg/L)	Load (tons/day)	% of Average Ambient Station Load
Turnersburg Plant	NC0004898	10,000	30	0.0011	0.002
Cooleemee WWTP	NC0024872	1,500,000	30	0.1703	0.339
I-77 Rest Area Iredell County	NC0028606	18,000	30	0.0020	0.004
North Iredell High School	NC0037371	12,500	30	0.0014	0.003
Statesville Auto Auction WWTP	NC0076333	25,000	30	0.0028	0.006

Facility Name	Permit Number	Flow (gpd)	Permit Limit (monthly max in mg/L)	Load (tons/day)	% of Average Ambient Station Load
Iredell Distribution Center WWTP	NC0085120	16,000	30	0.0018	0.004

In order to estimate contributions from the WWTPs, it was assumed that all TSS discharged reaches the ambient station with no settling. Based on facility permit limits of flow and the monthly average permit limits for TSS, the combined WWTP load contributes less than 1% of the average load at DWQ station Q3460000 based on data from years 2000 through 2009. It appears that these WWTPs do not present a significant load to the South Yadkin River. Therefore it was concluded that the WWTPs are adequately regulated under existing permits and the waste load allocations in this TMDL were calculated at the existing permit limits.

The NCDOT was considered a significant contributor, and was assigned a percent reduction identical to the nonpoint source reduction. The NCDOT is currently in compliance with their NPDES stormwater permit, and will continue to implement measures required by the permit (NCS000250). Because of the nature of drainage from roads and highways, data are not available (n/a) to calculate a WLA for the NCDOT as a load.

The waste load allocation and required reductions for NPDES permittees in the South Yadkin River watershed are shown in Table 8.3.

Table 8.3 NPDES waste load allocations and required reductions

NPDES Permittee	Permitted Load (tons/day)	WLA (tons/day)	Percent Reduction Required
Turnersburg Plant	0.0011	0.0011	0%
Cooleemee WWTP	0.1703	0.1703	0%
I-77 Rest Area Iredell County	0.0020	0.0020	0%
North Iredell High School	0.0014	0.0014	0%
Statesville Auto Auction WWTP	0.0028	0.0028	0%
Iredell Distribution Center WWTP	0.0018	0.0018	0%
NCDOT - Stormwater	N/A	N/A	50%

8.7.2 Load Allocation (LA)

All TSS loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as the LA. The estimated TMDL and allocation of TSS from point and nonpoint sources are presented in Table 8.4. The estimated percent reduction needed from NPDES stormwater and nonpoint sources is 50%, as shown in Table 8.5.

Table 8.4 Estimated TMDL and load allocation for TSS (tons/day) for the South Yadkin River

Pollutant	Water Body	Existing Load (tons/day)	WLA	LA	MOS	TMDL
TSS	South Yadkin River	50.20	0.179	25.221	Explicit 10%	25.40

Table 8.5 Estimated reduction by source for TSS (tons/day) for the South Yadkin River

	NPDES Wastewater WLA	NPDES Stormwater WLA	LA
Existing Load (tons/day)	0.179	N/A	50.02
Allocation (tons/day)	0.179	N/A	25.221
Percent Reduction	0%	50%	50%

8.7.3 Critical Condition and Seasonal Variation

Critical conditions are considered in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining the flows (percent flow exceeded) where the existing loads exceed the target.

Seasonal variation is considered in the development of the TMDLs, because allocation applies to all seasons. In the load duration curves, the mark inside a square box indicates pollutant load during the summer period.

The exceedances of turbidity occurred during normal to high flow periods. The result shows that wet weather under high-flow period is the critical period for turbidity in the South Yadkin River.

9.0 Third Creek

9.1 Source Assessment

Nonpoint Sources

Potential sources of turbidity from nonpoint sources are described in section 2.1

Point Sources

NPDES wastewater and stormwater permittees upstream of an ambient monitoring site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL. Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below.

NPDES Wastewater Permits

There are four facilities that discharge wastewater continuously to Third Creek and tributaries under the NPDES program (Table 9.1). In general, facilities are permitted to discharge a monthly average TSS concentration up to 30 mg/L. Locations of dischargers are shown in Figure 1.14.

Table 9.1 NPDES Wastewater Dischargers in the Third Creek Watershed

Permit Number	Facility Name	Permit Flow (gpd)	Total Suspended Solids Monthly Average Limit
NC0020591	Third Creek WWTP	4,000,000	30 mg/L
NC0023191	Seven Cedars Mobile Home Park WWTP	10,000	30 mg/L
NC0045471	Barium Springs Home WWTP	30,000	30 mg/L
NC0049867	Cleveland WWTP	270,000	30 mg/L

MS4 and Individual Stormwater Permits

The NCDOT (NCS000250) is the only MS4 stormwater permitted entity in the Third Creek Watershed.

9.2 Technical Approach

Endpoint for Turbidity

Turbidity is a measure of cloudiness and is reported in NTU. Therefore, turbidity is not measured in terms of concentrations and cannot be directly converted into loadings required for developing a load duration curve. For this reason, TSS was selected as the measure for this study.

In order to determine the relationship between TSS and turbidity in Third Creek, a regression equation between the two parameters was developed using the observed data collected from January 2000 through December 2009 at ambient station, Q3934500, on Third Creek. The relationship is shown in Equation 9.1. The coefficient of determination (R-Square) between the two parameters was 0.97, showing a strong relationship between the two parameters. The R^2 value is the percentage of the total variation in turbidity that is explained or accounted for by the fitted regression (TSS).

$$y = 1.2711x - 2.0421 \quad R^2 = 0.9783 \qquad (9.1)$$

Where Y = TSS in mg/l and X = turbidity in NTU.

The corresponding TSS value at the turbidity standard of 50 NTU is 62 mg/L.

Methodology

The load duration curve method is intended to be a simple method to calculate pollutant reductions. This method was chosen for Third Creek because of the availability of long- term data. It is also an efficient method to calculate a percent load reduction from nonpoint sources. The methodology used to develop the load duration curve was based on Cleland (2002).The required load reduction was determined based on water quality monitoring and stream flow data from January 2000 through December 2009.

9.3 Flow Duration Curve

Development of a flow duration curve is the first step of the load duration approach. A flow duration curve employs a cumulative frequency distribution of measured daily stream flow over the period of record. The curve relates flow values measured at the monitoring station for the percent of time the flow values were equaled or exceeded. Flows are ranked from lowest, which are exceeded nearly 100 percent of the time, to highest, which are exceeded less than 1 percent of the time. Reliability of the flow duration curve depends on the period of record available at monitoring stations. Accuracy of the curve increases when longer periods of record are used. The flow duration curve, shown in Figure 9.1, was used to determine the seasonality and flow regimes during which the exceedances of the pollutants occurred.

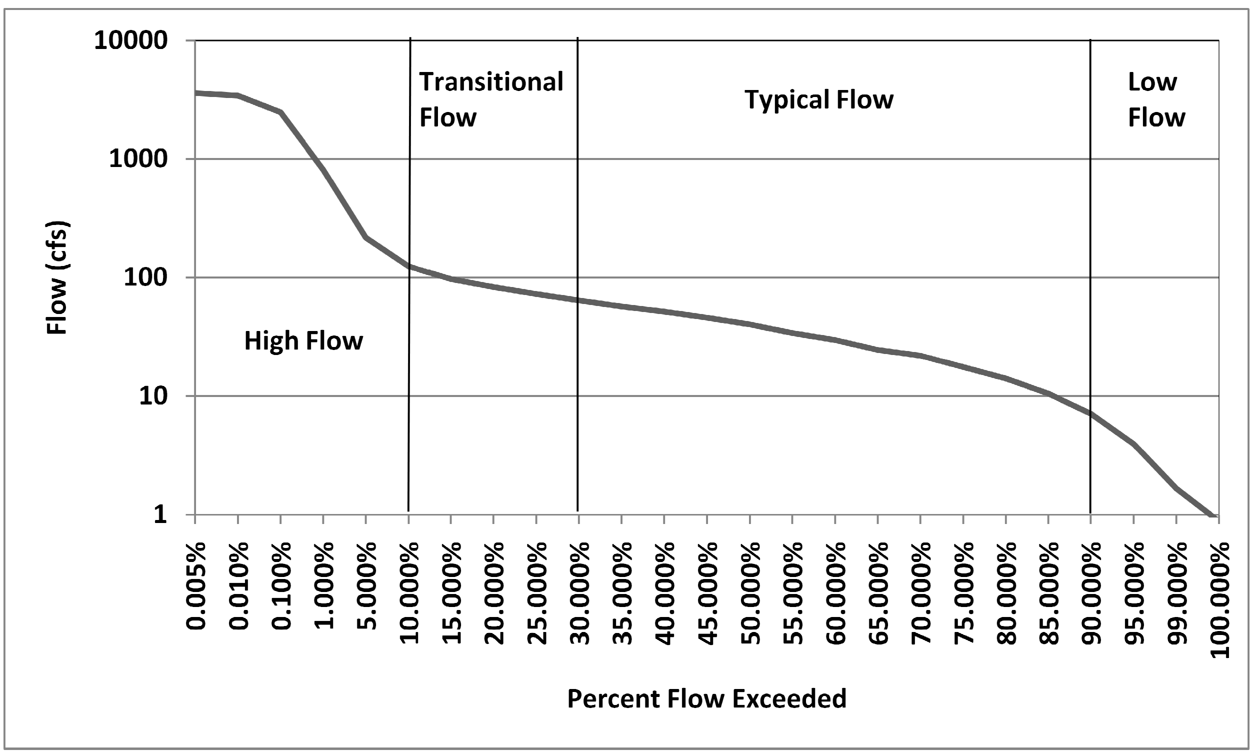


Figure 9.1 Flow Duration Curve for the Third Creek at DWQ Station Q3934500

The Third Creek watershed does not have a USGS flow gage. Daily flow data were used from USGS gage on Second Creek (02120780), which is located adjacent to the south of Third Creek.

The Third Creek Watershed area is 100 square miles while the Second Creek water area is 114 square miles. A drainage area ratio between the two watersheds was used to estimate the flow on Third Creek.

9.4 Load Duration Curve

A load duration curve is developed by multiplying the flow values along the flow duration curve by the pollutant concentrations and the appropriate conversion factors. As shown in Figure 9.2, allowable and existing loads are plotted against the flow recurrence interval. The allowable load is based on the water quality numerical standard, margin of safety, and flow duration curve. The target line is represented by the line drawn through the allowable load data points and hence, it determines the assimilative capacity of a stream or river under different flow conditions. Any values above the line are exceeded loads and the values below the line are acceptable loads. Therefore, a load duration curve can help define the flow regime during which exceedances occur. Exceedances that occur during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and non-point sources may cause exceedances during normal flows.

Existing TSS loads to the Third Creek were determined by multiplying the observed TSS concentration by the flow observed on the date of observation and converting the result to daily loading values. The assimilative capacities of the waterbodies were determined by multiplying the TSS concentration that is equivalent to a turbidity value of 50 NTU by the full range of measured flow values.

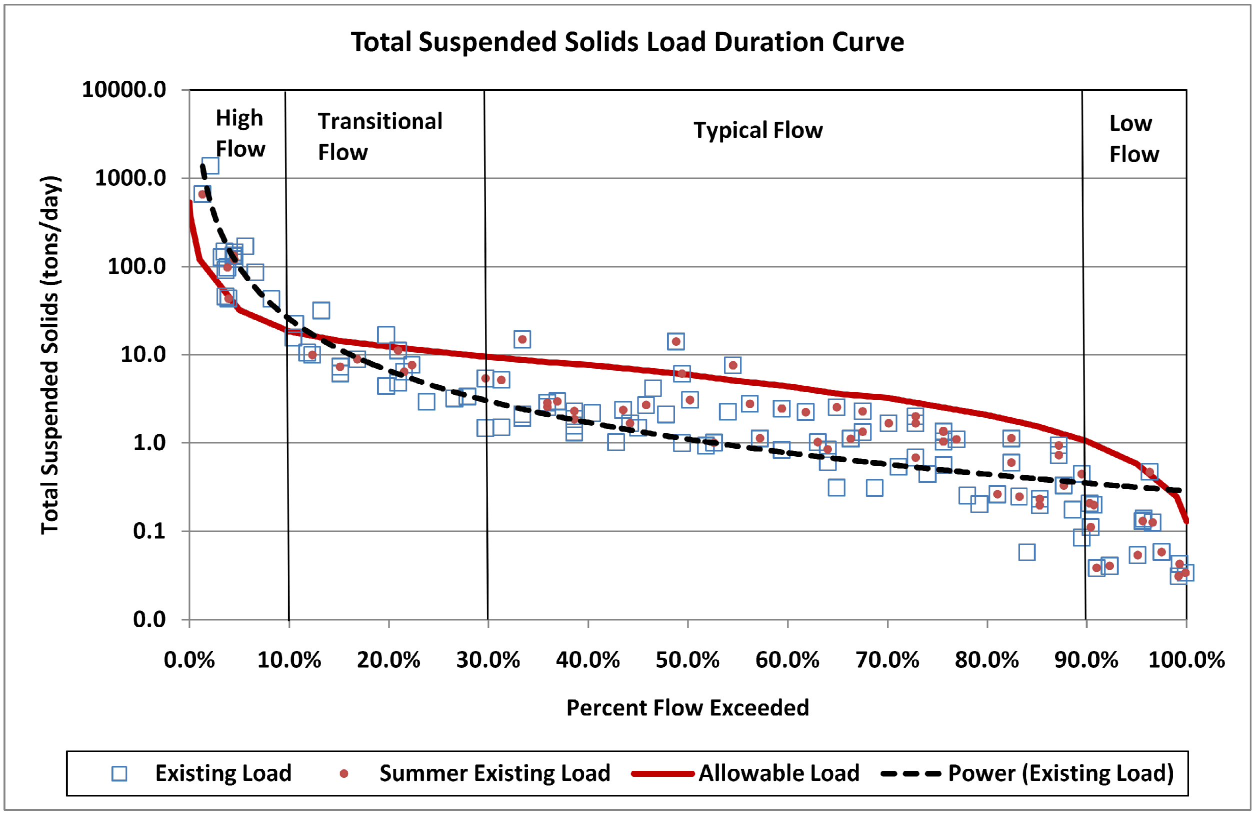


Figure 9.2 Load Duration Curve for the Third Creek at DWQ station Q3934500

For Third Creek, the standard violations occurred during typical to high flow conditions. Few exceedances during low-flow conditions suggest that point sources in the watershed may not be a significant source of TSS in this watershed. The higher loads during high and transitional flows suggest that the sources of turbidity could be from storm runoff and/or bank erosion. Stormwater runoff would carry a substantial amount of sediments and solid materials from impermeable as well as permeable land surfaces. Bank erosion may be another result of high and transitional flows. Bank erosion occurs when high volume and velocity runoff exceeds the resistance of the lateral (side) soil material. The loads during high flow period are considered unmanageable and hence are excluded in the TMDL estimation in this study.

9.5 TMDL

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source wasteload allocations (WLAs), nonpoint source load allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 9.2.

$$TMDL = \sum WLAs + \sum LAs + MOS \qquad (9.2)$$

The purpose of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For TSS (measure for turbidity), TMDLs are expressed as tons per day. TMDLs represent the maximum one-day load the river can assimilate and maintain the water quality criterion. Load duration curve approach was utilized to estimate the TMDL for TSS. The systematic procedures adopted to estimate TMDLs are described below.

9.5.1 Margin of Safety (MOS)

Conceptually, the MOS is included in the TMDL estimation to account for the uncertainty in the simulated relationship between the pollutants and the water quality standard. In this study, the MOS was explicitly included in the TMDL analysis by setting the TMDL target at 10 percent lower than the water quality target for turbidity.

9.6 Target Reduction

To determine the amount of turbidity reduction necessary to comply with the water quality standard, exceedances of the estimated standard (62 mg TSS/L) were identified within the 10^{th} to 90^{th} percentile flow recurrence range. Typically the remaining flow recurrence range is not included in the TMDL calculation to allow cases of extreme drought or flood to be excluded.

A power curve equation for the data points violating the water quality criterion was estimated. The equation is presented in Equation 9.3.

$$y = 6.17x^{-0.753} \quad R^2 = 0.794 \qquad (9.3)$$

Where, Y = TSS (tons/day) and X = Percent Flow Exceeded.

To present the TMDLs as a single value, the existing load was calculated from the power curve equation as the average of the load violations occurring between 10% and 90% flow exceedances. The average load was calculated by using percent flow exceedances in multiples of 5 percent. The allowable loadings for each exceedance were calculated from the TMDL target value, which includes the 10 percent MOS. The target curve based on the allowable load and the power curve based on the exceedances are shown in Figure 9.3.

The necessary percent reduction was calculated by taking the difference between the average of the power curve load estimates and the average of the allowable load estimates. For example, at each recurrence interval between 10 and 90 (again using recurrence intervals in multiples of 5), the equation of the power curve was used to estimate the existing load. The allowable load was then calculated in a similar fashion by substituting the allowable load curve. The estimated values are given in Appendix C.

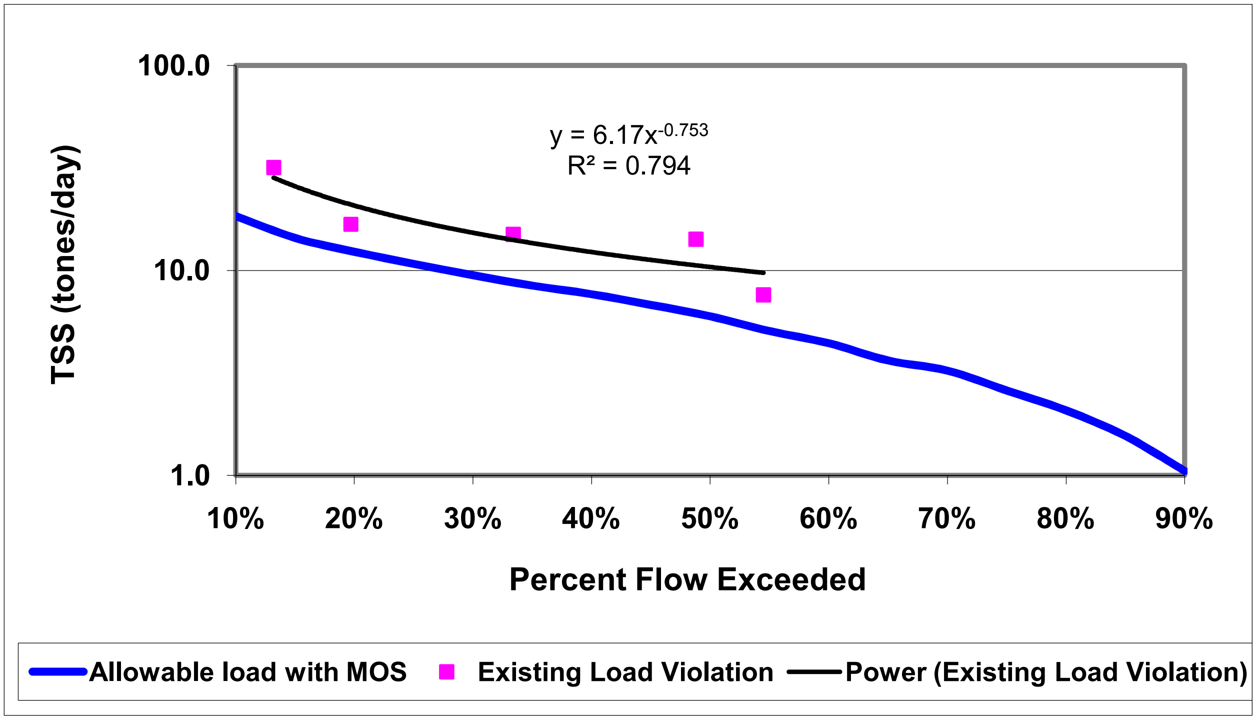


Figure 9.3 Load duration curve allowable TSS load and existing total TSS load violation in Third Creek

9.7 TMDL Allocation

9.7.1 Waste Load Allocation (WLA)

Four wastewater treatment plants (WWTP) plus the NC Department of Transportation hold NPDES permits in the Third Creek Watershed. The wastewater load contributions are shown in Table 9.2

Table 9.2 Existing NPDES WW Load Contributions

Facility Name	Permit Number	Flow (gpd)	Permit Limit (monthly max in mg/L)	Load (tons/day)	% of Average Ambient Station Load
Third Creek WWTP	NC0020591	4,000,000	30	0.4542	3.415
Seven Cedars Mobile Home Park WWTP	NC0023191	10,000	30	0.0011	0.009
Barium Springs Home WWTP	NC0045471	30,000	30	0.0034	0.026
Cleveland WWTP	NC0049867	270,000	30	0.0307	0.231

In order to estimate contributions from the WWTPs, it was assumed that all TSS discharged reaches the ambient station with no settling. Based on facility permit limits of flow and the monthly average permit limits for TSS, the combined WWTP load contributes approximately 3.7% of the average load at DWQ station Q3934500 based on data from years 2000 through

2009. It appears that these WWTPs do not present a significant load to the Third Creek. Therefore it was concluded that the WWTPs are adequately regulated under existing permits and the waste load allocations in this TMDL were calculated at the existing permit limits.

The NCDOT was considered a significant contributor, and was assigned a percent reduction identical to the nonpoint source reduction. The NCDOT is currently in compliance with their NPDES stormwater permit, and will continue to implement measures required by the permit (NCS000250). Because of the nature of drainage from roads and highways, data are not available (n/a) to calculate a WLA for the NCDOT as a load.

The waste load allocation and required reductions for NPDES permittees in the Third Creek watershed are shown in Table 9.3.

Table 9.3 NPDES waste load allocations and required reductions

NPDES Permittee	Permitted Load (tons/day)	WLA (tons/day)	Percent Reduction Required
Third Creek WWTP	0.4542	0.4542	0%
Seven Cedars Mobile Home Park WWTP	0.0011	0.0011	0%
Barium Springs Home WWTP	0.0034	0.0034	0%
Cleveland WWTP	0.0307	0.0307	0%
NCDOT - Stormwater	N/A	N/A	50%

9.7.2 Load Allocation (LA)

All TSS loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as the LA. The estimated TMDL and allocation of TSS to point and nonpoint sources are presented in Table 9.4. The estimated percent reduction needed from NPDES stormwater and nonpoint sources is 50%, as shown in Table 9.5.

Table 9.4 Estimated TMDL and load allocation for TSS (tons/day) for Third Creek

Pollutant	Water Body	Existing Load (tons/day)	WLA	LA	MOS	TMDL
TSS	Third Creek	13.30	0.489	6.411	Explicit 10%	6.90

Note: The Margin of safety is included in the TMDL by lowering TSS value calculated at the 50 NTU standard by 10%

Table 9.5 Estimated reduction by source for TSS (tons/day) for Third Creek

	NPDES Wastewater WLA	NPDES Stormwater WLA	LA
Existing Load (tons/day)	0.489	N/A	12.81
Allocation (tons/day)	0.489	N/A	6.41
Percent Reduction	0%	50%	50%

9.7.3 Critical Condition and Seasonal Variation

Critical conditions are considered in the load duration curve analysis by using an extended period of stream flow and water quality data, and by examining the flows (percent flow exceeded) where the existing loads exceed the target.

Seasonal variation is considered in the development of the TMDLs, because allocation applies to all seasons. In the load duration curves, the mark inside a square box indicates pollutant load during the summer period.

The exceedances of turbidity occurred during normal to high flow periods. The result shows that wet weather under high-flow period is the critical period for turbidity in Third Creek.

10.0 Summary and Future Implementation

This report presents the development of the Total Maximum Daily Loads (TMDL) for nine waterbodies in the Yadkin Pee-Dee River Basin.

Available water quality data were reviewed to determine the critical periods and the sources that lead to exceedances of the standard. The necessary percent reduction to meet the TMDL requirement was then calculated by taking a difference between the average of the curve load estimates and the average of the allowable load estimates. The summary of the results is as follows:

- Abbots Creek: A 57% reduction in nonpoint source and NPDES stormwater contributions of TSS is required in order to meet the water quality standard.

- Ararat River: A 54% reduction in nonpoint source and NPDES stormwater contributions of TSS is required in order to meet the water quality standard.

- Hunting Creek: A 52% reduction in nonpoint source and NPDES stormwater contributions of TSS is required in order to meet the water quality standard in.

- Second Creek: A 41% reduction in nonpoint source and NPDES stormwater contributions of TSS is required in order to meet the water quality standard.

- South Deep Creek: A 48% reduction in nonpoint source and NPDES stormwater contributions of TSS is required in order to meet the water quality standard.

- South Yadkin River: A 50% reduction in nonpoint source and NPDES stormwater contributions of TSS is required in order to meet the water quality standard. This reduction may be achieved in part through the reductions required for Hunting Creek, Third Creek and Second Creek.

- Third Creek: A 50% reduction in nonpoint source and NPDES stormwater contributions of TSS is required in order to meet the water quality standard.

10.1 TMDL Implementation

This TMDL does not include an implementation plan. This section is intended to provide some initial assistance for implementing this TMDL.

Reduction of turbidity in these watersheds will result from reduced overland and stormwater runoff, and improved land management. Landowners, stakeholder groups, local governments, and agencies are encouraged to utilize all available funding sources for water quality improvement projects within the watershed. The following programs provide technical and financial resources for reducing non-point source pollution:

- The North Carolina Soil and Water Conservation Service
- The Natural Resources Conservation Service
- Clean Water Act Section 319 Nonpoint source pollution control grant
- North Carolina Clean Water Management Trust Fund
- 205(j) Water Quality Management Planning Grant

11.0 Public Participation

This TMDL was public noticed through the DWQ Modeling and TMDL unit website, through the Modeling and TMDL unit listserv, through the DWQ events calendar, and through the Water Resources Research Institute (WRRI) listserv of North Carolina State University. The announcement is provided in Appendix D. The TMDL was also available from DWQ's website at http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls during the comment period. The public comment period lasted from July 26 – August 25, 2011. NCDWQ received comments from seven entities. A summary of their comments and DWQ's response is provided in Appendix E.

12.0 References

Cleland, B.R. 2002. TMDL Development from the "Bottom Up" – Part II: Using load duration curves to connect the pieces. Proceedings from the WEF National TMDL Science and Policy 2002 Conference.

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U.S. Environmental Protection Agency (USEPA) 1998. Draft Final TMDL Federal Advisory Committee Report. U.S. Environmental Protection Agency, Federal Advisory Committee (FACA). Draft final TMDL Federal Advisory Committee Report. 4/28/98.

U.S. Environmental Protection Agency (USEPA) 2000. Revisions to the Water Quality Planning and Management Regulation and Revisions to the National Pollutant Discharge Elimination System Program in Support of Revisions to the Water Quality Planning and management Regulation; Final Rule. Fed. Reg. 65:43586-43670 (July 13, 2000).

Wayland, R. November 22, 2002. Memorandum from Rober Wayland of the U. S. Environmental Protection Agency to Water Division Directors. Subject: Establishing TMDL Waste Load Allocation for stormwater sources and NPDES permit requirements based on those allocations.

Appendix A: Land Cover Data in Square Miles and Percent Area for the Impaired Watersheds

Description	Third Creek		Abbots Creek		Ararat River		Hunting Creek		Second Creek		South Yadkin		S. Deep Creek	
Barren Land	0.4	0%	0.5	0%	0.4	0%	0.0	0%	0.2	0%	1.1	0%	1.1	0%
Cultivated Crops	3.1	3%	3.6	2%	3.6	1%	2.9	2%	5.9	4%	21.8	2%	21.8	2%
Deciduous Forest	17.8	18%	38.4	19%	117.0	37%	48.7	32%	20.4	14%	200.5	22%	200.5	22%
Developed, High Intensity	1.3	1%	3.7	2%	2.2	1%	0.4	0%	0.6	0%	6.1	1%	6.1	1%
Developed, Low Intensity	8.7	9%	28.0	14%	23.6	8%	6.2	4%	9.3	7%	56.9	6%	56.9	6%
Developed, Medium Intensity	2.4	2%	6.3	3%	3.3	1%	0.6	0%	1.4	1%	9.7	1%	9.7	1%
Developed, Open Space	12.1	12%	28.0	14%	21.2	7%	5.9	4%	12.7	9%	68.6	8%	68.6	8%
Emergent Herbaceous Wetland	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Evergreen Forest	11.1	11%	25.8	13%	45.3	14%	17.8	12%	17.6	12%	105.5	12%	105.5	12%
Grassland/Herbaceous	0.3	0%	0.4	0%	0.7	0%	0.5	0%	0.2	0%	2.8	0%	2.8	0%
Mixed Forest	5.1	5%	5.8	3%	6.6	2%	9.7	6%	6.7	5%	52.4	6%	52.4	6%
Open Water	0.4	0%	1.8	1%	1.1	0%	0.5	0%	0.6	0%	3.0	0%	3.0	0%
Pasture/Hay	36.8	37%	53.3	27%	85.1	27%	55.9	37%	64.4	46%	368.8	41%	368.8	41%
Scrub/Shrub	0.6	1%	1.1	1%	3.3	1%	0.8	1%	0.4	0%	4.7	1%	4.7	1%
Woody Wetlands	0.7	1%	1.6	1%	0.1	0%	0.8	1%	1.0	1%	4.4	0%	4.4	0%
Total SQMI	**101**		**198**		**313**		**151**		**141**		**906**		**906**	

Appendix B. Water Quality Data Used for TMDL Development

Abbotts Creek DWQ Station Q5930000 and USGS station 02121500									
Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)	Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)
2/28/2000	94	22.00	14	5.56	7/27/2005	23	24.00	32	1.48
3/6/2000	67	11.00	8.5	1.98	8/8/2005	30	30.00	29	2.42
4/27/2000	86	8.00	16	1.85	8/23/2005	29	25.00	24	1.95
5/15/2000	42	11.00	12	1.24	9/22/2005	18	12.00	11	0.58
6/19/2000	32	14.00	9.7	1.21	10/18/2005	27	9.20	13	0.67
7/18/2000	14	12.14	15	0.46	10/27/2005	22	4.00	4.8	0.24
8/21/2000	14	13.84	17	0.52	11/16/2005	27	16.00	7.5	1.16
9/11/2000	16	9.00	9	0.39	11/28/2005	111	5.80	7.6	1.73
10/19/2000	16	3.90	5.3	0.17	12/13/2005	138	7.50	19	2.78
11/27/2000	41	18.94	23	2.09	1/3/2006	586	101.00	110	159.21
12/13/2000	17	3.00	3.2	0.14	1/17/2006	219	26.00	22	15.32
4/24/2001	56	10.00	8	1.51	2/2/2006	89	5.20	12	1.24
5/16/2001	21	5.51	7.2	0.31	2/16/2006	97	6.00	12	1.57
6/11/2001	16	28.00	26	1.21	3/1/2006	81	5.50	7.4	1.20
7/23/2001	11	10.44	13	0.31	3/16/2006	69	4.20	7.4	0.78
8/13/2001	25	41.89	50	2.82	3/29/2006	69	4.00	6.4	0.74
9/12/2001	9.8	8.00	9.5	0.21	4/11/2006	64	5.80	9.4	1.00
10/16/2001	21	3.56	4.9	0.20	4/24/2006	86	19.00	18	4.40
11/14/2001	11	4.32	5.8	0.13	5/18/2006	49	24.00	20	3.16
12/13/2001	27	18.00	37	1.31	5/31/2006	21	13.00	14	0.73
1/16/2002	19	17.24	21	0.88	6/14/2006	226	52.00	65	31.61
2/12/2002	72	6.53	8.4	1.27	6/26/2006	81	24.89	30	5.42
4/30/2002	15	8.74	11	0.35	7/11/2006	51	27.00	21	3.70
5/30/2002	12	11.29	14	0.36	7/26/2006	106	28.00	25	7.98
6/25/2002	6.8	6.00	10	0.11	8/7/2006	40	25.00	28	2.69
7/18/2002	8.2	16.39	20	0.36	8/24/2006	21	14.00	17	0.79
8/14/2002	5	4.66	6.2	0.06	9/11/2006	37	19.00	22	1.89
9/23/2002	21	30.00	32	1.69	10/16/2006	24	2.37	3.5	0.15
10/17/2002	1430	41.89	50	161.13	11/7/2006	61	6.11	7.9	1.00
11/20/2002	235	29.99	36	18.96	12/18/2006	58	4.20	18	0.66
12/18/2002	189	40.00	24	20.34	1/22/2007	453	80.13	95	97.65
1/22/2003	76	18.09	22	3.70	2/7/2007	97	12.99	16	3.39
2/20/2003	223	16.39	20	9.83	3/20/2007	159	20.00	25	8.55
3/24/2003	278	34.00	80	25.43	4/19/2007	260	33.39	40	23.35
4/8/2003	1910	54.64	65	280.71	5/16/2007	47	14.69	18	1.86
5/29/2003	217	19.79	24	11.55	6/12/2007	175	154.00	210	72.50
6/26/2003	76	20.00	18	4.09	7/9/2007	18	13.84	17	0.67
7/17/2003	80	18.09	22	3.89	8/23/2007	28	15.54	19	1.17
8/14/2003	186	80.13	95	40.09	9/19/2007	10	12.00	24	0.32
9/15/2003	74	17.00	16	3.38	10/16/2007	15	7.38	9.4	0.30
10/15/2003	110	36.79	44	10.89	10/29/2007	38	12.14	15	1.24
11/1/2003	76	11.29	14	2.31	12/10/2007	15	2.28	3.4	0.09
12/8/2003	70	4.00	7.7	0.75	1/24/2008	67	6.87	8.8	1.24
1/7/2004	84	7.89	10	1.78	2/11/2008	69	9.59	12	1.78
2/3/2004	346	63.13	75	58.76	3/17/2008	228	22.00	22	13.49
3/4/2004	256	18.00	26	12.40	4/10/2008	196	16.00	18	8.44
4/6/2004	86	6.87	8.8	1.59	5/15/2008	53	11.00	11	1.57
5/20/2004	52	14.69	18	2.05	6/10/2008	21	8.50	10	0.48
6/28/2004	174	220.00	170	102.97	7/9/2008	23	22.00	29	1.36
7/28/2004	353	75.88	90	72.06	8/7/2008	8.9	14.00	18	0.34
8/24/2004	25	11.29	14	0.76	9/9/2008	18	11.00	15	0.53
9/16/2004	52	9.00	7.2	1.26	10/13/2008	24	2.88	4.1	0.19
10/7/2004	85	12.99	16	2.97	11/12/2008	21	1.60	2.6	0.09
11/8/2004	57	5.60	7.3	0.86	12/4/2008	63	6.96	8.9	1.18
12/7/2004	92	4.00	6.9	0.99	1/8/2009	1530	40.00	75	164.63
1/11/2005	80	14.69	18	3.16	2/3/2009	108	6.20	17	1.80
2/21/2005	105	11.29	14	3.19	3/5/2009	335	20.00	26	18.02
3/10/2005	169	17.00	21	7.73	4/15/2009	226	18.00	17	10.94
3/30/2005	540	42.00	50	61.01	5/14/2009	101	24.00	20	6.52
4/12/2005	149	17.24	21	6.91	6/25/2009	34	22.00	22	2.01
4/21/2005	95	8.50	12	2.17	7/22/2009	31	16.00	16	1.33
5/16/2005	71	9.80	8.6	1.87	8/24/2009	42	26.00	34	2.94
5/23/2005	72	17.00	32	3.29	9/16/2009	13	12.00	15	0.42
6/14/2005	109	23.00	22	6.74	10/13/2009	35	6.20	7.8	0.58
6/28/2005	156	160.00	210	67.14	11/16/2009	260	13.00	35	9.09
7/13/2005	48	26.00	27	3.36	12/7/2009	199	9.20	25	4.92

Ararat River DWQ Station Q1780000 and USGS station 02113850									
Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)	Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)
01/05/2000	173	11.00	8.2	5.12	07/06/2005	264	72.00	150	51.13
02/03/2000	183	2.00	10	0.98	07/14/2005	399	106.00	120	113.77
03/07/2000	180	4.00	4	1.94	07/26/2005	244	13.00	13	8.53
04/04/2000	427	54.00	28	62.03	08/11/2005	211	13.00	8.9	7.38
05/10/2000	184	13.00	6.5	6.43	08/25/2005	160	7.20	8.6	3.10
06/07/2000	185	45.00	45	22.39	09/22/2005	128	22.00	33	7.58
07/19/2000	74	4.00	3.4	0.80	10/17/2005	194	5.00	6.2	2.61
08/14/2000	84	7.00	10	1.58	10/25/2005	179	2.80	2.9	1.35
09/13/2000	96	11.00	7.9	2.84	11/15/2005	171	10.52	1.5	4.84
10/11/2000	87	10.11	2.7	2.37	11/29/2005	1070	308.00	140	886.52
11/14/2000	111	10.21	2.4	3.05	12/14/2005	245	10.21	2.4	6.73
12/27/2000	97	11.00	5.8	2.87	01/04/2006	341	6.80	9.1	6.24
01/10/2001	89	9.70	4	2.32	01/12/2006	414	37.00	55	41.21
02/13/2001	119	10.38	1.9	3.32	01/31/2006	260	7.20	5.8	5.04
04/23/2001	132	10.34	2	3.67	02/13/2006	227	10.24	2.3	6.25
05/07/2001	91	9.39	5.1	2.30	02/27/2006	191	10.52	1.5	5.40
06/13/2001	93	14.00	10	3.50	03/30/2006	170	4.50	3.6	2.06
08/16/2001	129	8.27	11	2.87	04/27/2006	328	39.38	65	34.74
09/10/2001	92	4.00	3.7	0.99	05/30/2006	140	8.77	7.8	3.30
10/10/2001	74	10.21	2.4	2.03	06/15/2006	109	17.00	15	4.98
11/13/2001	83	8.40	10	1.87	07/17/2006	256	8.09	13	5.57
12/06/2001	85	8.17	12	1.87	08/10/2006	199	9.70	27	5.19
01/14/2002	116	8.98	6.8	2.80	09/13/2006	520	82.00	71	114.70
02/20/2002	151	9.95	3.2	4.04	10/12/2006	186	9.53	4.6	4.77
03/07/2002	167	3.00	3.5	1.35	11/16/2006	2970	3664.90	550	29279.98
04/11/2002	205	8.75	7.9	4.82	12/05/2006	255	3.00	3	2.06
05/14/2002	251	53.33	75	36.01	01/18/2007	371	9.32	5.4	9.30
06/12/2002	69	9.12	6.2	1.69	02/19/2007	293	9.53	4.6	7.51
07/09/2002	53	8.67	8.3	1.24	03/07/2007	412	13.00	14	14.41
08/01/2002	63	8.98	6.8	1.52	04/26/2007	288	10.04	2.9	7.78
09/09/2002	30	4.00	6	0.32	05/09/2007	238	9.59	4.4	6.14
10/01/2002	121	9.47	4.8	3.08	06/19/2007	165	8.50	6.7	3.77
11/14/2002	355	9.70	27	9.27	07/16/2007	145	8.87	7.3	3.46
12/09/2002	193	2.50	4	1.30	08/08/2007	104	9.07	6.4	2.54
02/04/2003	240	8.01	15	5.17	09/10/2007	80	9.02	6.6	1.94
03/12/2003	290	9.56	4.5	7.46	10/10/2007	102	9.98	3.1	2.74
04/24/2003	466	8.73	8	10.94	10/31/2007	222	9.14	6.1	5.46
05/19/2003	387	8.65	8.4	9.01	11/27/2007	169	10.14	2.6	4.61
06/04/2003	739	170.00	140	337.94	01/10/2008	186	10.34	2	5.17
07/09/2003	583	8.04	14	12.61	02/19/2008	196	9.88	3.4	5.21
08/12/2003	798	15.08	39	32.37	03/06/2008	204	9.37	5.2	5.14
09/04/2003	1210	810.00	260	2636.47	04/14/2008	216	9.29	5.5	5.40
10/13/2003	298	9.85	3.5	7.90	05/12/2008	300	10.34	29	8.35
11/19/2003	1510	11.93	33	48.47	06/19/2008	92	8.93	7	2.21
12/02/2003	381	4.00	5.5	4.10	07/16/2008	97	8.01	15	2.09
01/08/2004	340	10.07	2.8	9.21	08/18/2008	46	8.01	15	0.99
02/19/2004	331	8.83	7.5	7.86	09/24/2008	61	9.67	4.1	1.59
03/22/2004	260	3.00	3	2.10	10/22/2008	85	10.27	2.2	2.35
04/21/2004	284	8.43	9.8	6.44	11/18/2008	122	10.11	2.7	3.32
05/12/2004	222	8.04	14	4.80	12/18/2008	195	8.27	20	4.34
06/10/2004	222	33.00	35	19.71	01/27/2009	149	9.76	3.8	3.91
07/26/2004	196	8.49	9.4	4.47	02/04/2009	137	10.04	2.9	3.70
08/23/2004	181	8.46	9.6	4.12	03/30/2009	275	8.8	5.3	6.51
09/29/2004	925	76.00	40	189.11	04/28/2009	177	9.28935	5.5	4.42
10/12/2004	283	9.02	6.6	6.87	05/07/2009	805	313.565	170	679.01
11/03/2004	236	9.91	3.3	6.29	06/29/2009	243	9.14042	6.1	5.97
12/16/2004	309	2.50	4.2	2.08	07/13/2009	197	8.039	14	4.26
01/06/2005	279	9.34	5.3	7.01	08/31/2009	152	9.4475	4.9	3.86
02/23/2005	311	8.93	7	7.47	09/09/2009	188	16	23	8.09
03/08/2005	394	10.00	3.2	10.60	10/01/2009	152	9.4205	5	3.85
03/29/2005	931	60.00	65	150.26	11/05/2009	200	10.1391	2.6	5.45
04/07/2005	386	16.00	10	16.61	12/08/2009	299	9.61486	4.3	7.73
04/27/2005	334	8.00	5.7	7.19					
05/10/2005	255	4.00	3.4	2.74					
06/02/2005	313	41.00	8.2	34.52					
06/15/2005	254	52.00	35	35.53					

Hunting Creek DWQ Station Q3484000 and USGS station 02118500									
Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)	Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)
1/4/2000	97	9.00	6.3	2.35	1/9/2006	152	5.14	5.1	2.10
2/14/2000	345	110.00	130	102.09	2/1/2006	156	3.20	4	1.34
3/14/2000	95	5.78	6	1.48	3/2/2006	131	8.42	9.7	2.97
4/19/2000	264	31.00	23	22.01	4/5/2006	111	8.63	10	2.58
5/16/2000	89	6.00	8.5	1.44	5/4/2006	93	15.00	5.4	3.75
6/15/2000	63	8.00	7.9	1.36	6/8/2006	62	10.05	12	1.68
7/17/2000	56	5.00	9	0.75	7/5/2006	66	20.03	26	3.56
8/6/2000	45	8.00	9	0.97	8/2/2006	55	6.50	6.7	0.96
9/5/2000	115	33.57	45	10.38	9/7/2006	76	11.48	14	2.35
10/16/2000	52	3.21	2.4	0.45	10/11/2006	58	5.14	5.1	0.80
11/16/2000	58	3.07	2.2	0.48	11/6/2006	82	2.50	1.6	0.55
12/6/2000	64	3.29	2.5	0.57	12/5/2006	102	4.00	3.5	1.10
1/8/2001	64	3.50	2.8	0.60	1/8/2007	1130	136.88	190	416.07
2/5/2001	64	2.00	2.5	0.34	2/7/2007	128	3.50	3.3	1.21
4/19/2001	100	5.42	5.5	1.46	3/8/2007	198	9.34	11	4.98
5/10/2001	71	5.00	4.3	0.95	4/3/2007	144	4.00	3.5	1.55
6/11/2001	56	5.49	5.6	0.83	5/2/2007	131	4.50	3.8	1.59
7/9/2001	87	28.58	38	6.69	6/6/2007	90	9.34	11	2.26
8/14/2001	125	42.00	50	14.12	7/5/2007	62	9.34	11	1.56
9/10/2001	39	5.07	5	0.53	8/8/2007	45	4.64	4.4	0.56
10/3/2001	33	6.14	6.5	0.54	9/6/2007	24	5.14	5.1	0.33
11/8/2001	40	4.71	4.5	0.51	10/2/2007	43	3.78	3.2	0.44
12/4/2001	43	3.29	2.5	0.38	11/1/2007	81	4.64	4.4	1.01
1/10/2002	67	4.64	4.4	0.84	12/4/2007	59	2.29	1.1	0.36
2/13/2002	107	5.07	5	1.46	1/3/2008	126	4.57	4.3	1.55
3/12/2002	88	3.86	3.3	0.91	2/5/2008	369	45.00	85	44.67
4/8/2002	91	4.28	3.9	1.05	3/5/2008	155	11.48	14	4.79
5/14/2002	116	94.00	160	29.33	4/1/2008	125	5.14	5.1	1.73
6/10/2002	33	7.13	7.9	0.63	5/5/2008	91	13.00	17	3.18
7/8/2002	16	7.35	8.2	0.32	6/2/2008	58	9.34	11	1.46
8/27/2002	14	4.00	6.9	0.15	7/1/2008	46	14.33	18	1.77
9/18/2002	27	16.47	21	1.20	8/5/2008	30	8.20	14	0.66
10/16/2002	227	27.15	36	16.58	9/2/2008	50	7.13	7.9	0.96
11/13/2002	385	78.00	75	80.78	10/2/2008	74	12.19	15	2.43
12/18/2002	152	9.34	11	3.82	11/3/2008	55	2.93	2	0.43
1/29/2003	105	4.43	4.1	1.25	12/1/2008	107	4.92	4.8	1.42
2/20/2003	173	7.00	9	3.26	1/6/2009	103	17.18	22	4.76
3/20/2003	6600	286.50	400	5086.60	2/2/2009	80	3.71	3.1	0.80
4/7/2003	400	51.38	70	55.28	3/3/2009	279	27.15	36	20.38
5/7/2003	386	12.90	16	13.40	4/1/2009	153	6.99	7.7	2.88
6/9/2003	2450	87.00	120	573.40	5/4/2009	103	12.00	10	3.32
7/1/2003	403	115.50	160	125.21	6/2/2009	233	22.88	30	14.34
8/13/2003	288	32.00	29	24.79	7/6/2009	132	6.78	7.4	2.41
9/10/2003	205	8.63	10	4.76	8/3/2009	104	11.00	12	3.08
10/6/2003	159	5.07	5	2.17	9/2/2009	106	10.77	13	3.07
11/3/2003	159	4.07	3.6	1.74	10/1/2009	83	5.78	6	1.29
12/1/2003	167	3.86	3.3	1.73	11/2/2009	332	47.00	45	41.97
1/7/2004	148	5.85	6.1	2.33	12/1/2009	150	4.35	4	1.76
2/3/2004	438	310.00	120	365.25					
3/1/2004	198	4.50	4.2	2.40					
4/13/2004	561	158.25	220	238.82					
5/3/2004	165	10.00	10	4.44					
6/2/2004	107	13.62	17	3.92					
7/8/2004	90	15.04	19	3.64					
8/4/2004	80	14.00	19	3.01					
9/9/2004	748	58.50	80	117.72					
10/6/2004	149	9.34	11	3.74					
11/1/2004	130	4.00	3.2	1.40					
12/2/2004	219	12.19	15	7.18					
1/4/2005	175	4.78	4.6	2.25					
2/14/2005	158	7.00	4.9	2.98					
3/3/2005	239	5.00	4.9	3.21					
4/4/2005	253	15.04	19	10.24					
5/4/2005	162	6.00	4.5	2.61					
6/6/2005	135	11.48	14	4.17					
7/6/2005	206	69.19	95	38.34					
8/3/2005	131	11.00	10	3.88					
10/4/2005	59	7.63	8.6	1.21					
11/2/2005	88	3.20	3.1	0.76					
12/5/2005	202	17.18	22	9.33					

Second Creek DWQ Station Q4120000 and USGS station 02120780									
Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)	Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)
02/15/2000	165	55.00	65	24.41	01/09/2006	93	14.00	18	3.50
03/13/2000	47	5.00	9.4	0.63	02/02/2006	78	8.34	14	1.75
04/17/2000	93	29.00	22	7.25	03/06/2006	71	6.73	12	1.28
05/15/2000	28	12.00	9.4	0.90	04/06/2006	61	15.00	13	2.46
06/07/2000	20	17.00	14	0.91	05/08/2006	68	19.65	28	3.59
07/24/2000	27	50.00	50	3.63	06/08/2006	29	4.95	9.8	0.39
08/15/2000	8	22.00	12	0.47	07/06/2006	47	64.00	70	8.09
09/12/2000	7.6	6.73	12	0.14	08/09/2006	22	29.35	40	1.74
10/05/2000	7.9	7.00	5.8	0.15	09/07/2006	20	5.92	11	0.32
11/06/2000	13	0.02	3.7	0.00	10/11/2006	16	4.20	6.7	0.18
12/11/2000	17	1.32	5.3	0.06	11/06/2006	29	0.51	4.3	0.04
01/17/2001	18	4.00	5.8	0.19	12/05/2006	53	5.92	11	0.84
02/12/2001	30	3.42	7.9	0.28	01/09/2007	318	58.00	90	49.61
05/23/2001	22	29.35	40	1.74	02/07/2007	68	5.92	11	1.08
06/25/2001	10	12.38	19	0.33	03/08/2007	140	22.08	31	8.31
07/25/2001	7.7	13.00	13	0.27	04/03/2007	63	16.00	8.7	2.71
08/13/2001	12	7.54	13	0.24	05/02/2007	55	4.63	9.4	0.68
09/13/2001	4.5	3.50	8	0.04	06/06/2007	25	8.34	14	0.56
10/09/2001	6.9	6.00	3.5	0.11	07/09/2007	15	22.00	24	0.89
11/28/2001	9.2	9.15	15	0.23	08/09/2007	2.7	2.20	6.4	0.02
12/27/2001	20	1.96	6.1	0.11	09/06/2007	1.8	10.77	17	0.05
01/23/2002	533	1500.00	1800	2150.66	10/02/2007	1.2	19.00	15	0.06
02/27/2002	24	0.99	4.9	0.06	11/01/2007	4.1	2.12	6.3	0.02
03/20/2002	51	12.38	19	1.70	12/04/2007	8.6	2.50	3.1	0.06
04/24/2002	15	5.00	7.7	0.20	01/08/2008	21	2.37	6.6	0.13
05/23/2002	9.7	7.54	13	0.20	02/05/2008	41	5.92	11	0.65
06/17/2002	3.7	6.73	12	0.07	03/05/2008	270	166.67	210	121.05
07/30/2002	3.1	10.00	15	0.08	04/07/2008	166	35.00	45	15.63
08/26/2002	1.7	5.11	10	0.02	05/06/2008	46	12.00	13	1.48
09/16/2002	3.8	15.61	23	0.16	06/03/2008	22	7.50	10	0.44
10/23/2002	12	4.00	10	0.13	07/07/2008	24	24.00	50	1.55
11/19/2002	96	17.23	25	4.45	08/06/2008	7.9	5.11	10	0.11
12/16/2002	120	16.42	24	5.30	09/03/2008	28	9.20	11	0.69
01/27/2003	44	16.00	24	1.89	10/06/2008	26	2.04	6.2	0.14
02/20/2003	111	14.81	22	4.42	11/04/2008	27	1.64	5.7	0.12
03/17/2003	325	57.62	75	50.37	12/02/2008	63	13.00	29	2.20
04/07/2003	800	160.00	450	344.32	01/20/2009	60	9.50	12	1.53
05/06/2003	680	223.22	280	408.31	02/03/2009	54	8.00	15	1.16
06/19/2003	282	57.62	75	43.71	03/10/2009	86	16.00	19	3.70
07/01/2003	79	9.15	15	1.94	04/16/2009	130	27.00	27	9.44
08/18/2003	90	19.65	28	4.76	05/14/2009	52	13.00	14	1.82
09/08/2003	92	9.96	16	2.46	06/03/2009	37	23.00	23	2.29
10/07/2003	62	8.00	10	1.33	07/07/2009	30	11.00	14	0.89
11/03/2003	61	2.20	6.4	0.36	08/11/2009	14	4.95	9.8	0.19
12/01/2003	59	2.28	6.5	0.36	09/09/2009	21	4.79	9.6	0.27
01/07/2004	61	8.00	13	1.31	10/13/2009	39	10.00	15	1.05
02/03/2004	193	93.97	120	48.79	11/30/2009	78	8.00	11	1.68
03/08/2004	86	9.15	15	2.12	12/29/2009	162	28.00	40	12.20
04/14/2004	270	43.00	60	31.23					
05/04/2004	90	21.27	30	5.15					
06/02/2004	35	9.96	16	0.94					
07/08/2004	27	18.00	13	1.31					
08/04/2004	22	12.38	19	0.73					
09/09/2004	301	57.62	75	46.65					
11/01/2004	56	0.91	4.8	0.14					
12/02/2004	96	7.54	13	1.95					
01/04/2005	68	10.00	12	1.83					
02/14/2005	74	3.82	8.4	0.76					
03/03/2005	129	14.00	21	4.86					
04/05/2005	105	30.00	28	8.47					
05/04/2005	64	8.34	14	1.44					
06/07/2005	126	14.81	22	5.02					
07/07/2005	52	32.00	40	4.48					
08/04/2005	38	16.42	24	1.68					
10/05/2005	14	6.80	8.9	0.26					
11/02/2005	35	1.23	5.2	0.12					
12/06/2005	358	93.97	120	90.50					

South Deep Creek DWQ Stations Averaged (see text) and USGS station 02118500									
Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)	Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)
01/11/2000	173.4	269.82	240	125.87	10/17/2005	56.774	13.17	15	2.01
02/02/2000	61.42	19.09	20	3.15	11/14/2005	44.387	0.46	4.3	0.05
03/03/2000	51.61	10.20	12.5	1.42	12/12/2005	72.774	8.42	11	1.65
04/12/2000	65.55	29.61	28.9	5.22	01/23/2006	102.71	60.27	55	16.65
05/08/2000	58.32	52.54	48.4	8.24	02/20/2006	73.806	11.98	14	2.38
06/12/2000	34.58	28.31	27.8	2.63	03/13/2006	63.484	5.21	8.3	0.89
07/10/2000	32	56.53	51.8	4.87	04/10/2006	57.806	3.79	7.1	0.59
08/15/2000	22.19	22.87	23.2	1.37	05/08/2006	70.194	19.09	20	3.60
09/28/2000	51.61	75.10	67.7	10.43	06/12/2006	56.774	135.46	120	20.69
10/30/2000	28.39	1.09	4.83	0.08	07/17/2006	26.839	21.46	22	1.55
11/21/2000	31.48	0.93	4.7	0.08	08/14/2006	43.355	13.17	15	1.54
12/20/2000	40.77	4.86	8	0.53	09/11/2006	40.258	100.97	90	10.93
01/09/2001	33.03	0.69	4.5	0.06	10/16/2006	28.903	9.61	12	0.75
02/19/2001	42.84	17.91	19	2.06	11/13/2006	68.645	10.79	13	1.99
03/28/2001	58.32	0.57	4.4	0.09	12/11/2006	49.032	10.79	13	1.42
04/23/2001	48.52	4.26	3.7	0.56	01/22/2007	110.45	60.27	55	17.91
05/18/2001	46.45	4.86	8	0.61	02/12/2007	59.871	9.61	12	1.55
06/13/2001	27.87	7.23	10	0.54	03/12/2007	84.129	42.68	40	9.66
07/16/2001	20.65	10.79	13	0.60	04/16/2007	289.03	180.89	160	140.64
08/06/2001	24.77	4.26	7.5	0.28	05/07/2007	68.129	11.98	14	2.20
09/10/2001	20.13	8.42	11	0.46	06/11/2007	36.129	19.09	20	1.86
10/08/2001	14.97	4.74	7.9	0.19	07/09/2007	29.935	43.86	41	3.53
11/12/2001	20.65	3.57	3.1	0.20	08/27/2007	13.935	34.44	33	1.29
12/03/2001	23.23	3.92	3.4	0.24	09/10/2007	11.871	32.09	31	1.02
01/14/2002	30.45	2.83	6.3	0.23	10/08/2007	21.677	13.17	15	0.77
02/11/2002	65.55	6.52	9.4	1.15	11/12/2007	32.516	13.17	15	1.15
03/04/2002	65.55	16.72	18	2.95	12/10/2007	31.484	7.23	10	0.61
04/08/2002	46.97	1.05	4.8	0.13	01/14/2008	41.29	10.79	13	1.20
05/06/2002	34.06	7.23	10	0.66	02/18/2008	55.226	14.35	16	2.13
06/10/2002	17.03	10.79	13	0.49	03/10/2008	88.774	21.46	22	5.12
07/08/2002	8.258	16.72	18	0.37	04/21/2008	71.742	8.42	11	1.62
08/05/2002	6.194	8.42	11	0.14	05/05/2008	46.968	7.23	10	0.91
09/23/2002	13.94	6.04	9	0.23	06/09/2008	22.71	20.27	21	1.24
10/07/2002	11.87	4.50	7.7	0.14	07/14/2008	42.839	35.62	34	4.10
11/04/2002	30.97	4.50	7.7	0.37	08/11/2008	10.323	36.80	35	1.02
12/02/2002	36.65	8.42	11	0.83	09/08/2008	16.516	13.17	15	0.59
01/06/2003	80	34.44	33	7.41	10/06/2008	24.774	9.61	12	0.64
02/10/2003	61.94	7.23	10	1.20	11/03/2008	28.387	1.05	4.8	0.08
03/17/2003	330.3	106.74	95	94.85	12/08/2008	34.065	2.83	6.3	0.26
04/07/2003	206.5	100.97	90	56.07	01/26/2009	40.258	10.79	13	1.17
05/12/2003	128.5	14.35	16	4.96	02/16/2009	36.129	5.21	8.3	0.51
06/09/2003	1265	336.99	302	1146.29	03/16/2009	208	135.46	120	75.79
07/14/2003	151.2	41.51	39	16.89	04/20/2009	72.774	19.09	20	3.74
08/25/2003	105.3	17.91	19	5.07	05/04/2009	53.161	541.19	500	77.39
09/22/2003	85.68	14.35	16	3.31	06/08/2009	178.06	124.00	110	59.40
10/27/2003	121.3	6.76	9.6	2.21	07/13/2009	58.323	22.64	23	3.55
11/17/2003	79.48	7.11	9.9	1.52	08/10/2009	42.323	17.91	19	2.04
12/08/2003	89.29	7.23	10	1.74	09/14/2009	40.774	13.17	15	1.44
01/12/2004	76.39	4.97	8.1	1.02	10/19/2009	44.903	7.23	10	0.87
02/09/2004	163.6	135.46	120	59.62	11/16/2009	107.35	66.12	60	19.09
03/08/2004	90.84	21.46	22	5.24	12/14/2009	205.94	124.00	110	68.69
04/05/2004	85.16	14.35	16	3.29					
05/10/2004	72.77	22.64	23	4.43					
06/07/2004	55.74	26.18	26	3.93					
07/12/2004	50.06	28.55	28	3.84					
08/09/2004	30.45	20.27	21	1.66					
09/20/2004	67.61	27.37	27	4.98					
10/25/2004	69.68	14.35	16	2.69					
11/15/2004	108.9	34.44	33	10.09					
12/13/2004	142.5	54.42	50	20.85					
01/24/2005	91.87	39.15	37	9.68					
02/14/2005	81.55	19.09	20	4.19					
03/14/2005	95.48	10.79	13	2.77					
04/11/2005	102.7	20.27	21	5.60					
05/09/2005	76.39	13.17	15	2.71					
06/13/2005	74.84	35.62	34	7.17					
07/11/2005	124.4	158.25	140	52.95					
08/15/2005	59.87	15.54	17	2.50					
09/19/2005	34.06	13.17	15	1.21					

South Yadkin River DWQ Station Q3460000 and USGS station 02118000									
Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)	Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)
01/03/2000	128	7.00	6.4	2.41	08/08/2005	189	70.00	75	35.59
02/01/2000	258	13.00	20	9.02	08/23/2005	162	34.00	32	14.82
03/01/2000	181	13.00	17	6.33	09/22/2005	82	17.00	13	3.75
04/06/2000	399	71.00	50	76.21	10/18/2005	151	16.00	17	6.50
05/01/2000	377	84.00	40	85.19	10/27/2005	120	6.20	6.2	2.00
07/05/2000	72	11.42	12	2.21	11/16/2005	124	6.00	5.5	2.00
08/09/2000	97	33.50	32	8.74	11/28/2005	150	3.20	4.1	1.29
09/06/2000	109	53.37	50	15.65	12/13/2005	228	5.20	8.1	3.19
10/12/2000	62	6.01	7.1	1.00	01/03/2006	1080	318.00	310	923.85
11/14/2000	89	4.35	5.6	1.04	01/17/2006	455	24.00	45	29.37
12/20/2000	132	18.04	18	6.41	02/02/2006	244	14.00	14	9.19
01/24/2001	180	10.32	11	4.99	02/16/2006	229	7.50	5.9	4.62
02/20/2001	145	11.00	18	4.29	03/02/2006	206	14.00	12	7.76
04/30/2001	115	8.33	9.2	2.58	03/16/2006	186	14.00	14	7.00
05/30/2001	99	31.00	15	8.26	03/29/2006	191	8.80	8.7	4.52
06/26/2001	208	97.53	90	54.57	04/11/2006	183	15.00	18	7.38
07/25/2001	56	19.15	19	2.88	04/25/2006	203	50.00	45	27.30
08/27/2001	38	20.00	17	2.04	05/18/2006	150	26.00	24	10.49
09/25/2001	140	53.37	50	20.10	05/31/2006	105	29.00	27	8.19
10/11/2001	25	7.89	8.8	0.53	06/14/2006	155	52.00	24	21.68
11/15/2001	61	9.21	10	1.51	06/26/2006	106	34.00	19	9.69
12/10/2001	68	13.63	14	2.49	07/11/2006	101	24.00	22	6.52
01/07/2002	135	36.81	35	13.37	07/26/2006	119	35.00	55	11.20
02/12/2002	182	12.00	17	5.87	08/07/2006	73	11.00	13	2.16
03/21/2002	222	33.50	32	20.01	08/24/2006	108	48.00	60	13.94
04/30/2002	77	16.94	17	3.51	09/28/2006	90	16.94	17	4.10
05/30/2002	57	19.00	24	2.91	10/16/2006	78	7.11	8.1	1.49
06/13/2002	27	35.71	34	2.59	11/07/2006	152	2.15	3.6	0.88
07/17/2002	27	24.67	24	1.79	12/19/2006	154	6.20	7.1	2.57
08/14/2002	3	8.00	13	0.06	01/24/2007	291	18.04	18	14.12
09/16/2002	23	41.23	39	2.55	02/20/2007	226	7.00	10	4.26
10/09/2002	25	11.42	12	0.77	03/21/2007	315	31.29	30	26.51
11/07/2002	179	24.00	28	11.56	04/19/2007	324	37.92	36	33.05
12/10/2002	252	8.22	9.1	5.57	05/22/2007	133	20.00	23	7.16
01/14/2003	145	6.89	7.9	2.69	06/26/2007	131	274.17	250	96.62
02/03/2003	154	6.00	7.5	2.49	07/25/2007	147	75.45	70	29.84
03/13/2003	262	15.84	16	11.16	09/04/2007	33	18.00	19	1.60
04/08/2003	906	108.57	100	264.60	09/13/2007	23	35.71	34	2.21
06/11/2003	1030	119.61	110	331.41	10/30/2007	115	18.04	18	5.58
07/01/2003	350	35.71	34	33.62	11/26/2007	94	2.81	4.2	0.71
08/04/2003	512	51.00	34	70.24	12/19/2007	106	3.91	5.2	1.12
09/25/2003	252	33.50	32	22.71	01/30/2008	117	4.24	5.5	1.34
10/20/2003	198	8.33	9.2	4.44	02/20/2008	170	9.21	10	4.21
11/24/2003	253	12.00	9.9	8.17	03/19/2008	197	13.63	14	7.22
12/09/2003	229	7.89	8.8	4.86	04/17/2008	194	26.00	25	13.57
01/14/2004	215	3.69	5	2.13	05/13/2008	135	24.00	22	8.72
02/11/2004	448	37.00	30	44.59	06/12/2008	61	24.00	25	3.94
03/10/2004	252	8.33	9.2	5.65	07/10/2008	90	44.00	45	10.65
04/22/2004	261	24.67	24	17.32	08/07/2008	40	24.00	32	2.58
06/01/2004	169	43.00	27	19.55	09/10/2008	246	222	120	146.91
06/30/2004	151	27.98	27	11.36	10/09/2008	92	14	20	3.46
07/20/2004	122	42.33	40	13.89	11/12/2008	84	5.016	6.2	1.13
08/24/2004	99	22.00	20	5.86	12/08/2008	105	2.5872	4	0.73
09/14/2004	189	39.02	37	19.84	01/28/2009	172	11.4192	12	5.28
10/06/2004	200	31.29	30	16.83	02/05/2009	146	7.1136	8.1	2.79
11/23/2004	204	12.52	13	6.87	03/10/2009	265	32	29	22.81
12/01/2004	269	20.25	20	14.65	04/15/2009	369	38	32	37.72
01/04/2005	227	3.58	4.9	2.19	05/26/2009	668	166	170	298.29
02/14/2005	231	10.00	6.9	6.21	06/11/2009	667	120	100	215.31
03/10/2005	284	13.00	6.8	9.93	07/22/2009	184	35	60	17.32
03/31/2005	650	68.00	90	118.90	08/27/2009	154	34	45	14.08
04/12/2005	293	36.81	35	29.01	09/21/2009	197	44	45	23.32
04/25/2005	275	20.00	14	14.80	10/05/2009	146	20	23	7.85
05/05/2005	229	26.00	13	16.02	11/16/2009	438	46	45	54.20
06/02/2005	235	62.00	55	39.19	12/21/2009	431	17	24	19.71
06/16/2005	170	23.00	40	10.52					
06/28/2005	133	48.00	45	17.17					
07/13/2005	237	58.00	45	36.98					
07/27/2005	131	28.00	34	9.87					

Third Creek DWQ Station Q3934500 and drainage area ratio estimated flow from USGS station 02120780									
Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)	Sample Date	Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	TSS Load (tons/day)
02/15/2000	144.7	110.00	110	42.83	07/07/2005	45.614	22.00	21	2.70
03/13/2000	41.23	9.00	10	1.00	08/04/2005	33.333	31.01	26	2.78
04/17/2000	81.58	51.00	23	11.19	10/05/2005	12.281	7.50	11	0.25
05/15/2000	24.56	17.00	9.3	1.12	11/02/2005	30.702	10.16	9.6	0.84
06/07/2000	17.54	29.00	17	1.37	12/06/2005	314.04	150.49	120	127.13
07/24/2000	23.68	36.00	27	2.29	01/09/2006	81.579	22.00	25	4.83
08/15/2000	7.018	11.00	9.4	0.21	02/02/2006	68.421	18.30	16	3.37
09/12/2000	6.667	2.15	3.3	0.04	03/06/2006	62.281	9.02	8.7	1.51
10/05/2000	6.93	6.00	7.6	0.11	04/06/2006	53.509	16.00	16	2.30
11/06/2000	11.4	1.90	3.1	0.06	05/08/2006	59.649	93.29	75	14.97
12/11/2000	14.91	5.08	5.6	0.20	06/08/2006	25.439	37.36	31	2.56
01/17/2001	15.79	6.00	7.2	0.25	07/06/2006	41.228	55.00	45	6.10
02/12/2001	26.32	8.64	8.4	0.61	08/09/2006	19.298	38.63	32	2.01
04/17/2001	37.72	10.00	9.5	1.01	09/07/2006	17.544	28.46	24	1.34
05/23/2001	19.3	13.21	12	0.69	10/11/2006	14.035	7.00	9.3	0.26
06/25/2001	8.772	31.01	26	0.73	11/06/2006	25.439	4.57	5.2	0.31
07/25/2001	6.754	11.00	12	0.20	12/05/2006	46.491	11.94	11	1.49
08/13/2001	10.53	8.25	8.1	0.23	01/09/2007	278.95	61.00	150	45.77
09/13/2001	3.947	5.08	5.6	0.05	02/07/2007	59.649	13.21	12	2.12
10/09/2001	6.053	2.50	2.6	0.04	03/08/2007	122.81	47.53	39	15.70
11/28/2001	8.07	8.13	8	0.18	04/03/2007	55.263	20.00	15	2.97
12/27/2001	17.54	11.94	11	0.56	05/02/2007	48.246	18.30	16	2.37
01/23/2002	467.5	1100.00	850	1383.46	06/06/2007	21.93	28.46	24	1.68
02/27/2002	21.05	9.52	9.1	0.54	07/09/2007	13.158	32.00	24	1.13
03/20/2002	44.74	34.82	29	4.19	08/08/2007	3.6842	13.21	12	0.13
04/24/2002	13.16	17.00	23	0.60	09/06/2007	1.5789	7.36	7.4	0.03
05/23/2002	8.509	14.48	13	0.33	10/02/2007	1.0526	12.00	12	0.03
06/17/2002	3.246	14.48	13	0.13	11/01/2007	3.5965	14.48	13	0.14
07/30/2002	2.719	8.00	13	0.06	12/04/2007	7.5439	4.19	4.9	0.08
08/26/2002	1.491	10.67	10	0.04	01/08/2008	18.421	9.00	12	0.45
09/16/2002	3.333	52.62	43	0.47	02/05/2008	35.965	23.38	20	2.26
10/23/2002	10.53	7.00	16	0.20	03/05/2008	236.84	226.76	180	144.47
11/19/2002	84.21	74.22	60	16.81	04/01/2008	56.14	19.00	20	2.87
12/16/2002	105.3	112.36	90	31.81	05/06/2008	40.351	28.46	24	3.09
01/27/2003	38.6	9.00	10	0.93	06/02/2008	17.544	22.11	19	1.04
02/20/2003	97.37	23.38	20	6.12	07/01/2008	8.7719	40.00	50	0.94
03/17/2003	285.1	118.71	95	91.04	08/05/2008	7.5439	22.11	19	0.45
04/07/2003	701.8	350.00	260	660.70	09/02/2008	28.07	29.74	25	2.25
05/08/2003	262.3	61.51	50	43.40	10/02/2008	32.456	13.00	17	1.13
06/19/2003	247.4	201.33	160	133.97	11/03/2008	22.807	5.08	5.6	0.31
07/16/2003	62.28	31.01	26	5.19	12/01/2008	121.93	67.87	55	22.26
08/21/2003	64.91	31.01	26	5.41	01/06/2009	193.86	327.00	300	170.52
09/08/2003	80.7	29.74	25	6.46	02/02/2009	42.982	18.30	16	2.12
10/06/2003	53.51	13.00	10	1.87	03/03/2009	291.23	188.62	150	147.77
11/03/2003	53.51	9.14	8.8	1.32	04/01/2009	97.368	28.00	26	7.33
12/01/2003	51.75	15.75	14	2.19	05/04/2009	47.368	13.21	12	1.68
01/07/2004	53.51	11.00	14	1.58	06/02/2009	35.088	80.58	65	7.61
02/03/2004	169.3	188.62	150	85.90	07/06/2009	27.193	14.00	16	1.02
03/08/2004	75.44	14.48	13	2.94	08/04/2009	16.667	24.65	21	1.11
04/14/2004	236.8	190.00	150	121.05	09/02/2009	42.105	125.07	100	14.17
05/04/2004	78.95	36.09	30	7.66	10/01/2009	26.316	12.00	14	0.85
06/02/2004	30.7	29.74	25	2.46	11/02/2009	241.23	201.33	160	130.65
07/08/2004	23.68	21.00	13	1.34	12/01/2009	70.175	17.02	15	3.21
08/04/2004	19.3	32.28	27	1.68					
09/09/2004	264	137.78	110	97.86					
11/02/2004	49.12	7.75	7.7	1.02					
12/02/2004	84.21	19.57	17	4.43					
01/04/2005	59.65	12.00	13	1.93					
02/14/2005	64.91	8.51	8.3	1.49					
03/03/2005	113.2	34.82	29	10.60					
04/05/2005	92.11	36.00	37	8.92					
05/04/2005	56.14	17.02	15	2.57					
06/07/2005	110.5	33.55	28	9.97					

Appendix C. Load Reduction Estimations

Estimation of Load Reduction Required for TSS for Abbotts Creek at Station Q5930000.

% Flow Exceedance	Allowable Load (tons/day	Estimated Exceeding Load (tons/day)
10.000%	30.38	137.09
15.000%	22.01	65.99
20.000%	17.54	39.29
25.000%	14.60	26.27
30.000%	12.27	18.91
35.000%	10.24	14.32
40.000%	8.92	11.26
45.000%	7.91	9.10
50.000%	7.00	7.53
55.000%	5.98	6.34
60.000%	5.07	5.42
65.000%	4.16	4.69
70.000%	3.45	4.10
75.000%	2.84	3.62
80.000%	2.23	3.23
85.000%	1.83	2.89
90.000%	1.52	2.61
Average	**9.3**	**21.3**
Load Reduction = 56%		

Estimation of Load Reduction Required for TSS for the Ararat River at Station Q1780000.

% Flow Exceedance	Allowable Load (tons/day	Estimated Exceeding Load (tons/day)
10.00%	25.99	71.14
15.00%	22.28	61.44
20.00%	19.94	53.07
25.00%	18.08	45.84
30.00%	16.43	39.59
35.00%	15.08	34.20
40.00%	13.78	29.54
45.00%	12.43	25.51
50.00%	11.55	22.03
55.00%	10.73	19.03
60.00%	10.00	16.44
65.00%	9.32	14.20
70.00%	8.65	12.26
75.00%	7.97	10.59
80.00%	7.17	9.15
85.00%	6.16	7.90
90.00%	5.20	6.83
Average	**12.98589**	**28.16262**
Load Reduction = 54%		

Estimation of Load Reduction Required for TSS for Hunting Creek at Station Q3484000.

% Flow Exceedance	Allowable Load (tons/day	Estimated Exceeding Load (tons/day)
10.00%	24.27	51.52
15.00%	19.87	40.43
20.00%	17.31	34.04
25.00%	15.46	29.79
30.00%	14.20	26.71
35.00%	13.13	24.36
40.00%	11.79	22.49
45.00%	10.88	20.96
50.00%	10.07	19.68
55.00%	9.17	18.59
60.00%	8.36	17.65
65.00%	7.73	16.82
70.00%	6.92	16.09
75.00%	6.20	15.44
80.00%	5.57	14.86
85.00%	5.03	14.33
90.00%	4.14	13.85
Average	**11.18**	**23.39**
Load Reduction Needed = 52%		

Estimation of Load Reduction Required for TSS for Second Creek at Station Q2600000. Only two data points exceeded the allowable load in the TMLD calculation which occurred in the 50 to 70 percent flow exceedance. Therefore only the 50-70 percent flow exceedance range was used in the TMDL calculation and reduction needed.

% Flow Exceedance	Allowable Load (tons/day	Estimated Exceeding Load (tons/day)
10.00%	12.99	513.93
15.00%	10.15	179.23
20.00%	8.69	84.88
25.00%	7.59	47.54
30.00%	6.68	29.60
35.00%	5.94	19.83
40.00%	5.40	14.02
45.00%	4.79	10.32
50.00%	4.21	7.85
55.00%	3.57	6.13
60.00%	3.11	4.89
65.00%	2.56	3.97
70.00%	2.29	3.28
75.00%	1.83	2.74
80.00%	1.46	2.32
85.00%	1.10	1.98
90.00%	0.74	1.71
Average	**3.15**	**5.22**
Load Reduction Needed = 40%		

Estimation of load reduction required for TSS for South Deep Creek using average TSS values from DWQ water quality monitoring stations. These stations include Q5930000, Q3484000, Q2600000, Q2720000, Q4120000, and Q3934500.

% Flow Exceedance	Allowable Load (tons/day	Estimated Exceeding Load (tons/day)
10.00%	18.37	29.31
15.00%	15.03	27.00
20.00%	13.10	24.87
25.00%	11.70	22.90
30.00%	10.75	21.10
35.00%	9.93	19.43
40.00%	8.93	17.90
45.00%	8.23	16.48
50.00%	7.62	15.18
55.00%	6.94	13.98
60.00%	6.33	12.88
65.00%	5.85	11.86
70.00%	5.24	10.93
75.00%	4.69	10.06
80.00%	4.22	9.27
85.00%	3.81	8.54
90.00%	3.13	7.86
Average	**8.46**	**16.44**
Load Reduction Needed = 49%		

Estimation of Load Reduction Required for TSS for the South Yadkin River at DWQ Station Q3460000

% Flow Exceedance	Allowable Load (tons/day	Estimated Exceeding Load (tons/day)
10.00%	58.9	98.19
15.00%	46.9	80.17
20.00%	39.5	69.43
25.00%	34.8	62.10
30.00%	31.9	56.69
35.00%	29.4	52.49
40.00%	27.0	49.10
45.00%	25.2	46.29
50.00%	23.0	43.91
55.00%	20.9	41.87
60.00%	19.2	40.09
65.00%	17.3	38.51
70.00%	15.2	37.11
75.00%	13.2	35.85
80.00%	11.5	34.72
85.00%	10.2	33.68
90.00%	8.0	32.73
Average	**25.42**	**50.17**
Load Reduction Needed = 49%		

Estimation of Load Reduction Required for TSS for Third Creek at DWQ Station Q3934500

% Flow Exceedance	Allowable Load (tons/day	Estimated Exceeding Load (tons/day)
10.00%	18.43	34.94
15.00%	14.41	25.74
20.00%	12.33	20.73
25.00%	10.77	17.52
30.00%	9.47	15.28
35.00%	8.44	13.60
40.00%	7.66	12.30
45.00%	6.79	11.26
50.00%	5.97	10.40
55.00%	5.06	9.68
60.00%	4.41	9.06
65.00%	3.63	8.53
70.00%	3.24	8.07
75.00%	2.60	7.66
80.00%	2.08	7.30
85.00%	1.56	6.97
90.00%	1.05	6.68
Average	**6.94**	**13.28**
Load Reduction Needed = 48%		

Appendix D: Public Notification of TMDL for Yadkin River Basin Turbidity TMDLS

NCDENR

North Carolina Department of Environment and Natural Resources

Division of Water Quality

Beverly Eaves Perdue
Governor

Coleen H. Sullins
Director

July 26, 2011
North Carolina Department of Environment and Natural Resources
Division of Water Quality

DRAFT Total Maximum Daily Load for Turbidity for *Abbotts Creek, Ararat River, Hunting Creek, Muddy Creek, Second Creek, South Deep Creek, South Yadkin River, Third Creek and the Yadkin River,* in the Yadkin River Basin, North Carolina

Now Available for Public Comment

This draft TMDL report was prepared as a requirement of the Federal Water Pollution Control Act, Section 303(d). Interested parties are invited to comment on the draft TMDL report by August 25, 2011. Comments concerning the report should be directed to Andy Painter at andy.painter@ncdenr.gov or write to:

Andy Painter
NC Division of Water Quality
Planning Section
1617 Mail Service Center
Raleigh, NC 27699

The draft TMDL can be downloaded from the following website:
http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls#Draft

App endix E: Public Comments

2011 Yadkin River Basin Turbidity TMDLs
Public Comment Response Summary

The comments received for this TMDL were based on the public comment version which included assessment units for Muddy Creek and the Yadkin River. These two waterbodies were not included in the final TMDL presented here in order to allow time to meet with and explain the TMDL process to the MS4 permittees that would be impacted by these TMDLs. However, the comments received regarding Muddy Creek and the Yadkin River were left in the response summary and are addressed below.

Comments were received from:

- Piedmont Triad Regional Council (PTRC)
- Town of Lewisville
- Salisbury-Rowan Utilities
- Winston-Salem
- Village of Clemmons
- North Carolina Department of Transportation (NCDOT)
- North Carolina Conservation Network

1) PTRC:

This turbidity TMDL is for nine large watersheds, yet only identifies four (4) entities total that are responsible for reducing total suspended solids (TSS) loading to receiving waters. The waste load allocations (WLAs) identified in this TMDL may be able to restore receiving waters to conditions where they can meet the turbidity water quality standard if applied broadly across all sectors, however the ability of four entities to achieve this goal is doubtful, especially when considering the land uses and other likely sources of TSS in these nine watersheds. How does NC DWQ or the US EPA realistically expect these entities to be able to restore supportive water quality conditions when they occupy a small area of these watersheds and represent a fraction of the total mass of TSS loaded to receiving waters?

Response: Each TMDL has a Load Allocation, Wasteload Allocation and Margin of Safety. The TMDL Load Allocations show the reductions needed from nonpoint sources. The TMDL does not suggest that the wasteload allocations alone will achieve water quality standard attainment. Reductions for the identified jurisdictions are identical to the reductions for nonpoint sources.

2) PTRC , Town of Lewisville, Winston-Salem, Village of Clemmons:

The commenters mentioned that the Village of Clemmons and the Town of Lewisville have only been NPDES Phase II communities since 2005, and Winston-Salem since 2001. The commenters suggested that the DWQ acknowledge new stormwater ordinances and development regulations in this time period and the impacts of these requirements on the receiving streams have not had time to be assessed. Further, the need for additional expenses to mitigate stormwater sources of water quality pollutants is not readily apparent.

Response: The data used in the TMDL was from years 2000-2009. Implementation of the TMDL will not necessarily incur additional significant costs to the affected NPDES permit holders. The DWQ Stormwater Permitting Unit will consider recent improvements and determine further permit requirements in the next permit renewal.

3) PTRC , Town of Lewisville, Village of Clemmons:

The fiscal year has almost completed its first quarter, and the stormwater and public works budgets are final through June 2012. What will be the Implementation Timeline NC DWQ expects of entities given WLAs?

We are very concerned about the ramifications of these TMDL to growth in the Yadkin River basin. With these communities requiring greater on-site controls for TSS management, and non-permitted communities and rural areas not having these restrictions, there is a high potential to promote sprawl around urbanized areas, which will only add to the non-point source pollutant burden in these watersheds. This is of particular concern in Forsyth County around the communities of Winston-Salem, Clemmons, and Lewisville. How does NC DWQ intend to prevent these impacts to water quality?

Response: The implementation timeline will depend on your water quality recovery plan that you will submit as required under your stormwater permit. We expect the fulfillment of your water quality recovery plan to take several permit cycles. Because this TMDL can be implemented along with various existing permit requirements, and it only requires reductions in the named TMDL subwatersheds, it is not expected to trigger sprawl outside of MS4 jurisdictions.

4) PTRC, Town of Lewisville, Winston-Salem:

The commenters acknowledged that a TMDL Load Allocation has no regulatory authority to require a reduction from nonpoint sources. However, the commenters requested a clearer representation of the presence of animal and forestry operations and communities enrolled in cost-share programs to manage runoff. The commenters also requested greater acknowledgement that rural land uses are contributing to the impairment.

Response: General sources of nonpoint source pollution are described in section 2.1. The TMDL shows land cover for each watershed as well as land cover adjacent to streams for each watershed, including the distribution of agricultural lands (pasture/hay and crop). Further source assessment, including how land is managed, will be useful for TMDL implementation. Reductions in both point and nonpoint sources of turbidity are needed to meet water quality standards as stated in section 12. Reductions for the identified jurisdictions are identical to the reductions for nonpoint sources.

5) PTRC, Town of Lewisville:

All communities are willing to collect data to more precisely pinpoint the sources of TSS loading to receiving waters. The Village of Clemmons, the Town of Lewisville, and the City of Winston-Salem are all willing to collect and analyze water quality data within their jurisdictions, fill out QAPPs to ensure that their practices and methods meet NC DWQ and US EPA Office Of Water standards, and be audited by a third party to ensure quality control in the data. They are happy to do this in-house, or to work with an approved third party laboratory to collect and analyze the data. However, they are only willing to do this if this data will be used by NC DWQ in determining use support decision making. So long as the Division insists that only its staff is capable of adequately collecting and analyzing water quality data for regulatory and policy determination, it is not an effective use of funds for local governments to enrich the datasets for these impaired waters.

Response: The jurisdictions are encouraged to conduct additional monitoring to gain further knowledge of the watersheds' pollution sources. In addition, DWQ indeed uses data from various outside sources; municipalities interested in collecting data to be used for use support assessment should contact DWQ. Please review this website on data sources and how to submit data http://portal.ncdenr.org/web/wq/ps/mtu/assessment#4.

6) PTRC, Town of Lewisville, Winston-Salem:

The regression analyses correlating wet weather events to TSS violations makes a very poor argument on Muddy Creek (R^2 = 0.23). Has NC DWQ considered other sources of TSS that could be contributing to elevated levels? Of the five data analyzed to develop the WLA, one (20%) was collected under dry weather conditions, and the regression analysis does not strongly support a causative relationship between wet weather events and elevated TSS levels. This all suggests another possible source of TSS that remains undiscussed in the TMDL. How can NC DWQ expect local governments to make investments to reduce TSS loadings with BMPs when they cannot show with confidence that the TSS loadings are due to wet weather events? The ramifications are too great to make these investments without more confidence that they will improve water quality conditions.

Response: This is not a correlation between wet weather and TSS. The equation of this line was used to determine the target reduction as describe in section 6.6. Figure 6.2 shows that no exceedances occurred during low flow events. The R^2 *of 0.23 for Muddy Creek refers to strength of the linear relationship between the calculated existing load exceedances in Figure 6.3. This response also addresses similar comments for the Yadkin River.*

7) PTRC and Winston-Salem:

In response to a Biological Integrity TMDL on Salem Creek, the City of Winston-Salem has invested significant resources in retrofits and restoration projects to mitigate stormwater runoff to this tributary to Muddy Creek. They have also invested in several regional BMPs in this watershed, and required new, more intensive BMPs for new development. Does this TMDL consider the benefits of the efforts on Salem Creek to reduce turbidity levels in Muddy Creek? It is not referenced in the text of the TMDL. With water quality monitoring analyzed for this TMDL ceasing in 2009, there has not been enough time to judge the impacts of these practices to downstream water quality, nor is there evidence that the potentially significant impacts of these investments on Salem Creek may be having in addressing turbidity levels downstream in Muddy Creek

Response: The Salem Creek TMDL targeted Fecal Coliform. If the retrofits to reduce fecal coliform were targeted at stormwater, and also achieved a reduction in turbidity, this can be reflected in your water quality recovery program for your stormwater permit and count towards compliance with this TMDL.

8) PTRC:

The Town of Lewisville mainly lies on two tributaries of the large Yadkin River watershed (as identified in this TMDL). There is one water quality monitoring station upstream of these tributaries (Q2040000). The next water quality monitoring station lies approximately seven miles downstream. How was the WLA for the Town determined with this indirectly sampled data?

Response: Ambient station Q2040000 was used to develop the TMDL for both impaired segments of the Yadkin River for several reasons. One reason is that it is co-located with a USGS gage, which is ideal to develop the load duration curve. Second, the correlation of Turbidity vs. TSS for the lower ambient monitoring site, Q2180000, has an R^2 of 0.579, which is less than the TSS vs turbidity R^2 value of 0.88 for the ambient station (Q2040000) used in the TMDL. Finally, the turbidity data comparison between the two stations show that the data is comparable with median NTU values for Q2040000 and Q2180000 at 16 and 18 respectively for years 2000-2009. The change in reductions between the two stations would likely be insignificant, and uncertainty would be higher due to estimating flow and using the lower TSS vs NTU correlation from site Q2180000.

9) PTRC, Town of Lewisville:

The NC DWQ acknowledges that actions on the Yadkin River may be unnecessary if water quality conditions on the South Yadkin River improve. It appears to be the most prudent use of resources to provide support and time to the communities within the South Yadkin River watershed to address the turbidity issues in that watershed before resources and funds and perhaps unnecessarily spent in the Yadkin River watershed. Is there a timeline of implementation and monitoring that will reflect this management strategy?

Response: Perhaps the commenters are referring to South Deep Creek. Reductions in South Deep Creek alone are not expected to attain the turbidity standard in the Yadkin River. Your water quality recovery program can reflect your implementation and monitoring timeline.

10) Town of Lewisville:

At current the Town of Lewisville employs one full time person to manage all storm water related requirements and activities, and funds the storm water budget out of the general fund. Although there is no consideration given to fiscal impacts, the time and monetary investments associated with implementing a plan or program that may or may not be able to reach the required reductions set forth in the TMDL report are unreasonable and not seen as being efficient and effective use of tax dollars.

Response: Reductions required in the TMDL for NPDES stormwater permittees will be implemented through the stormwater permit, in the form of a water quality recovery program submitted to DWQ by each permittee. This plan will outline how each permittee will improve water quality. Implementation of the TMDL will not necessarily incur additional significant costs to the affected NPDES permit holders. An implementation section has been added to the TMDL to clarify responsibilities of MS4 permittees.

11) Town of Lewisville:

The Town does not disagree that there is an elevated amount of turbidity within the Yadkin River, although there still is no evidence proving the Town has contributed to this condition nor the ability to obtain the required reduction. Therefore, the Town feels the TMDL needs to delayed and restructured before implementation.

Response: Your water quality recovery program will describe how the Town will implement the TMDL. The monitoring you propose (see Comment 5) can assist with source identification and tracking of reductions.

12) Salisbury-Rowan Utilities:

- Table 7.1 (pg 55) & Table 7.2 (pg 60) Second Creek WWTP permitted capacity is 30,000 gpd.
- Pg 55 – Methodology subheading refers to Hunting Creek rather than Second Creek.
- Table 7.5 appears to be labeled Table 7.6 (pg 61)

Response: Thank you. We have made these corrections in the text.

13) Winston-Salem:

Overall, with the pollutants of concern in the watershed being nutrients and turbidity and given the nature of nutrient bound sediments, the draft TMDL's for turbidity should be developed jointly with the High Rock Lake TMDL efforts as they are so interdependent. This should take place with the formation of a Technical Advisory Committee or Stake holder process.

Response: These TMDLs were developed to address localized turbidity impairments in the High Rock Lake watershed. A separate analysis will be conducted to determine how to address the turbidity impairment in High Rock Lake. Winston-Salem is represented on the High Rock Lake nutrient TAC.

14) Winston-Salem:

> On page 50 figure 6.3 shows TSS load exceedances within the 10% to 50% range approximately. We assume that there was a fair amount of extrapolation in estimating the required load reductions outside this interval. Is this appropriate in determining the load reduction?

Response: This TMDL approach estimates TSS reduction for any flow exceeded between 10% and 90%. Therefore, we developed Figure 6.3 to show the relationship between percent flow exceeded and daily TSS load to estimate an averaged TSS reduction for the flow exceedance between 10% to 90%. Any method used would require some percent reduction in turbidity. Implementation of this TMDL will involve adaptive management, with the ultimate measure of success attainment of the standard instream.

15) Village of Clemmons:

> The Village of Clemmons represents only 6 square miles (2%) of the watershed within Muddy Creek. Land disturbance from agriculture and County development has to be a primary contributor to turbidity problems in Muddy Creek. No allowance has been made for natural, agricultural, and/or County development contributions to the problem and no provision has been proposed to remedy the contributions from these sources.

Response: The Load Allocation reported in the TMDL sets a limit, or "allowance," for turbidity originating from nonpoint sources. An implementation plan is not included in this TMDL. Local governments and other stakeholders are encouraged to design and carry out implementation plans. The monitoring proposed in Comment 5 could assist with source identification and tracking of reductions. Your water quality recovery program can describe how you will differentiate contributions from the Village of Clemmons from other sources.

16) Village of Clemmons:

> We are aware of existing and former sand dredging operations located on Muddy Creek within and upstream of the impaired reach. These operations may have caused the reported turbidity violations and should be researched and evaluated for their potential contribution to turbidity problems.

Response: Sand dredging operations are not permitted to exceed the turbidity standard of 50 NTU in Muddy Creek. Sand dredging operations are permitted under general permit NCG520000. Please call the DWQ Winston-Salem Regional Office at 336-771-5000 if you observe a sand dredging operation causing excess turbidity in Muddy Creek.

17) Village of Clemmons:

> Muddy Creek is aptly named! Natural clay from the watershed soils is at least a major cause of turbidity problems. Long before the existence of Clemmons or any other modern development in the area, the stream had a reputation for turbidity. There are references to the stream being called "Muddy Creek" that date back to at least 1880, see: (http://dc.lib.unc.edu/cdm4/item_viewer.php?CISOROOT=/ncmaps&CISOPTR=1323&CISOBOX=1&REC=3)

Response: DWQ acknowledges that some soil types can make it more difficult to control erosion and turbidity. However Muddy Creek has met the turbidity standard in previous years. Muddy Creek was just added to the 303d list in 2010.

18) Village of Clemmons -

> With so many other likely contributors (natural conditions, agriculture, silviculture, sand dredging, transportation, County development, etc.) to turbidity problems in Muddy Creek, it is not appropriate to single out the Village of Clemmons as a primary polluter. Clemmons' contribution to the problem, while arguably present to some degree, has not been conclusively demonstrated or quantified and it is inappropriate to assign any quantitative responsibility without clear justification.

Response: It is currently difficult to quantify a justifiable load from stormwater outfalls within each municipality without monitoring those outfalls. However, MS4 permittees cannot be ignored when addressing a turbidity impairment, especially during wet weather events. The Village has not been "singled out." Nonpoint sources outside your jurisdiction have been assigned a load allocation. The monitoring proposed in Comment 5 could assist with source identification and tracking of reductions. Your water quality recovery program can describe how you will differentiate contributions from the Village of Clemmons from other sources.

19) Part 1 – NCDOT:

In the Source Assessment section for each of the nine named waterbodies in the report, the following paragraph is included for Point Sources:

Point Sources

NPDES wastewater and stormwater permittees upstream of the impairment that discharge above a water quality station that is not impaired for turbidity are not considered to be contributing to the impairment. They are not subject to the TMDL. Permittees considered to be contributing to the impairment are discussed below.

For each of the nine named waterbodies, the paragraph above implies that there exists a portion(s) of each watershed that is not subject to the TMDL from a point source discharge perspective. However, the portion(s) of each watershed not subject to the TMDL is not identified in the report. Since stream reaches and not water quality stations are the features that are labeled impaired in the 303(d) List, terms "impaired water quality stations" and "not impaired water quality stations" are undefined. Therefore, we interpret a *water quality station that is not impaired* as any instream point not falling within the twelve assessment units (AUs) described in Table 1.1 of the report.

Response: NPDES discharges not subject to the TMDLs are identified in the report by the description in the text (as repeated above). Water quality stations refer to Ambient Monitoring Sites as shown in the watershed maps in section 1.3 of the report. We have changed the term "water quality station" to "ambient monitoring site" in the text. Therefore an ambient monitoring site that is not impaired is shown on the watershed maps not falling within the 12 assessment units described in table 1.1 (also shown in red on the watershed maps in section 1.3). We would be happy to assist you with identifying areas of interest to you that are subject to the TMDL.

Part 2 - Comment Continued from 19 – Part 1

Under this interpretation, point source outfalls, by definition, fall into one of two categories: 1) those outfalls that directly discharge into an impaired reach, or 2) those outfalls that discharge upstream of an impaired reach (obviously, point source outfalls that discharge hydrologically downstream of an impaired reach never contribute pollutant loads to the impaired reach and, thus, could never contribute to the impairment). Hence, we interpret the paragraph above to mean that any NCDOT outfall that does not directly discharge into one of the twelve impaired AUs is an outfall above a water quality station that is not impaired for turbidity and, thus, not contributing to the impairment. If this interpretation is not DWQ's intent for how the TMDL regulated area is to be defined, then please include a map delineating the portion of the watershed considered to be contributing to the impairment and differentiate that area from those portions of the watershed not contributing to the impairment from a point source perspective. NCDOT considers this to be critically important information, especially given that we operate NPDES permitted outfalls that discharge upstream, downstream, and directly into the twelve impaired AUs.

Response: The paragraph above has been revised for clarification in the text as follows: "NPDES wastewater and stormwater permittees upstream of an Ambient Monitoring Site that is not impaired (not intersected by the impaired waterbody) are not subject to the TMDL. Permittees that discharge directly to, or upstream of the impairment, yet still downstream of an unimpaired ambient monitoring site are subject to the TMDL and are discussed below."

20) NCDOT:

For each of the nine named impaired waterbodies, NCDOT's wasteload allocation has been deemed not available, or "N/A", due to a purported lack of data to calculate existing and allowable TSS loadings from NCDOT roads and facilities. Despite the lack of data, the report claims that NCDOT is considered a "significant contributor", presumably based on professional judgment, but this is not stated in the report. Given that no supporting information is provided in support of this judgment call and given that NCDOT is in compliance with its NPDES permit as noted in the report, we believe the decision to label NCDOT as a significant contributor was made in an arbitrary fashion and, thus, not appropriate to include in this TMDL report. Since no supporting data is provided, we respectfully request that NCDOT not be labeled a significant contributor. Given NCDOT's strong compliance record with its NPDES permit, the basis for the implied percent load reduction requirements for NCDOT within each of the nine watersheds is not clear.

Response: DWQ is open to new ideas or methods to calculate wasteload allocations for DOT stormwater in TMDLs. It is possible for a permittee to be in compliance with its current permit, yet need to make further reductions to achieve water quality standards instream.

21) Part 1 – NCDOT:

Each of the nine TMDLs is based on a Load Duration Curve methodology using TSS as a surrogate for turbidity. A relatively long period of record (~10 years) for both flow and water quality monitoring was used in the analysis. DWQ represented existing TSS loading over the flow spectrum by fitting a curve represented by a dashed line through the monitored load points. For each of the nine watersheds, the existing load curve was below the allowable load, even with a margin of safety applied. Since the dashed existing load curve did not indicate a load reduction was necessary, DWQ used a variation of the Load Duration Curve methodology to recalculate the "existing load" by fitting a curve through a much smaller dataset that only included load points falling above the allowable curve. NCDOT has several concerns about this variation on the use of the Load Duration Curve methodology which are described using the Hunting Creek TMDL as an example, but the comments generally apply to each of the nine TMDLs. First, compared to the approximately 85 monitored load points falling between the 10th and 90th percentile flows, only three monitored data points were used as the basis for characterizing the "existing load" for Hunting Creek. In this case, only 3.5% of the available water quality data was used, which as a point of reference, is far less than DWQ's policy of indicating impairment by more than 10% of the data above the standard.

Response: The dashed line in the load duration curve figures represents the best fit for the entire data set. As shown in Table 1.2 in the text, 11 to 14 percent of the data has exceeded the turbidity standard. This is why the majority of the dashed lines in the load duration curve figures are below the allowable load line. The load duration curve methodology uses only the points exceeding the allowable load to provide a formula to estimate the exceeding load at a variety of flow ranges. This also enables data points that fall in ranges of extreme flow or drought conditions to be excluded from the TMDL calculation.

Part 2 – Continued from above

standard. Second, using such a small fraction of the available water quality data calls into question whether seasonality was adequately considered. In the case of Hunter Creek, Figure 5.2 suggests that only three samples, all collected during the summer, were used as the basis for calculating the load reduction requirement.

Response: Seasonality is included in the TMDL by using a long term 10 years of data for the TMDLs. This allows for a variety of flow conditions and seasonal variation to be captured in the data.

Part-3 Continued from above

Finally, and most importantly, NCDOT is concerned about the use of "manufactured" load exceedances in TMDL calculations and the subsequent regulations. The Hunting Creek load reduction calculation is based on an average of seventeen manufactured load exceedances labeled "Estimated Exceeding Load" in *Appendix C* and inappropriately labeled "Existing Load" in the *TMDL Allocation Summary* on page ii. We do not believe the labeling of these calculated load exceedances as "existing load" is appropriate because of the inherit bias in the methodology towards inflated loading estimates. By way of illustration, *Appendix C* reports the "existing load" of Hunting Creek at the 30th percentile flow to be 26.71 tons/day, whereas the numerous monitored loads on and immediately surrounding the 30th percentile flow suggest a measured existing load of around 5 tons/day. In summary, DWQ's methodology of recalculating existing loads based only on a small subset of the data results in inflated load estimates across the flow spectrum that are many times higher than the majority of the actual monitored loads.

Response: The equation from the best-fit line from the exceeding loads is used to calculated load exceedances across multiple flow ranges that are not represented by actual data points. This is a good method to estimate or model reductions needed across multiple flow ranges. An alternative method would be to take the TSS value from the highest exceeding point between the 90^{th} and 10^{th} percentile flow exceedance range and reduce it to the TSS standard. Any method used would require some percent reduction in turbidity. Implementation of this TMDL will involve adaptive management, with the ultimate measure of success attainment of the standard instream.

Part 4 – Continued from above

In addition, the existing load violation curves appear to only apply between certain flows; for example, Figure 5.3 implies that the existing load violation curve for Hunting Creek only applies between approximately the 20^{th} and 50^{th} percentile flow regimes. However, the data presented in *Appendix C* apply from the 10^{th} to the 90^{th} percentile flows. Each figure in the report depicting an existing load violation curve should be consistent in its extent with the load reduction calculations shown in *Appendix C*.

Response: The load duration curve methodology uses only the points exceeding the allowable load to provide a formula, in this case 20^{th} to 50^{th} percentile, to estimate the exceeding load at a flow ranges from 10^{th} to the 90^{th} percentile.

22) NCDOT:

There is a discrepancy between the load reduction percentages reported to be required for Muddy Creek presented in *Appendix C* (51%) and Table 6.3 (58%). Please clarify.

Response: The 51% reduction shown in Appendix C is the overall reduction needed based on the TMDL of 21.6 tons/day TSS. However, because NPDES WW discharges are not required to make a reduction, the reductions shown in the TMDL text are based on that of the load allocation only which does not include the wasteload allocation of 5.462 tons/day TSS.

23) NCDOT:

For each of the nine named waterbodies, a regression equation is presented describing the relationship between TSS and turbidity. The associated coefficient of determination (R-square) is cited as justification for using TSS as a surrogate for turbidity and the basis of the TMDL calculations. Given the importance of this justification to the validity of the TMDL calculation, we recommend that a plot showing the data and the regression relationship be presented along with the sample count.

Response: The turbidity and TSS data used in the TMDL can be found in Appendix B.

24) Part 1 NCDOT:

South Yadkin River – two separate AUs along the South Yadkin River appear to be each subject to a TMDL allocation equal to 25.4 tons TSS/day. This allocation seems to be calculated at a point along the upstream-most AU, 12-108-(14.5). However, the allocations conflict with three other TMDLs presented in the report. The TMDL calculations for the two South Yadkin River AUs were based on flow and water quality data collected near DWQ station Q3460000 located along AU 12-108-(14.5). Downstream of this AU is a reach of the South Yadkin River that is not impaired for turbidity, but downstream of this non-impaired reach is AU 12-108-(19.5)b which was assigned a TMDL allocation of 25.4 tons TSS/day. Since AUs 12-108-(14.5) and 12-108-(19.5)b each have an allowable loading of 25.4 tons TSS/day, NCDOT interprets the two TMDLs to mean that no additional TSS loading is allowable within the large intervening drainage area between the two AUs. Between station Q3460000 (TMDL calculation point along AU 12-108-(14.5)) and the downstream-most point along AU 12-108-(19.5)b is the large intervening drainage area in question.

Response: The South Yadkin River watershed is a large drainage area (906 sqmi) and contains other impaired streams included in this TMDL. Each stream received a unique TMDL. Reductions achieved from the impaired streams upstream of the South Yadkin River impairment will also count as reductions for the South Yadkin River TMDL. There is a 3.25 mile stretch of the South Yadkin River that is currently not impaired located between Aus 12-108-(14.5) and 12-108-(19.5)b. Two small unnamed tributaries flow in from the northeast to the South Yadkin River in this stretch; this approximately 7.75 square mile area is not a large intervening drainage area. This 3.5 mile stretch is *within the watershed draining to the impaired waters, and not above an unimpaired Ambient Monitoring Site, thus is subject to the TMDL.*

Part 2 – Continued from above

This drainage area is primarily composed of the TMDL watersheds of Hunting Creek, Third Creek, and Second Creek which have a combined TMDL loading of 21.2 tons TSS/day (11.2, 6.9, and 3.1 tons TSS/day, respectively). The allocation of 21.2 tons TSS/day to these three intervening drainage areas appears to be in conflict with the 25.4 tons TSS/day allocated to AU 12-108-(19.5)b and the 25.4 tons TSS/day allocated to AU 12-108-(14.5). Illustrated on Figure 1.14, DWQ ambient monitoring station Q3970000 appears to be located along AU 12-108-(19.5)b. Data for station Q3970000 is not presented in the report. Given the allocation conflict discussed above and the presence of station Q3970000, a separate TMDL calculation for AU 12-108-(19.5)b seems appropriate. Alternatively, DWQ could choose to not calculate a TMDL for AU 12-108-(19.5)b and move this AU from Category 5 to 4b of the Integrated Report citing that the TMDLs for AU 12-108-(14.5), as well as for Hunting Creek, Third Creek, and Second Creek are expected to result in attainment of the turbidity standard.

Response: The South Yadkin River watershed is a large drainage area (906 sqmi) and contains other impaired streams included in this TMDL. Each stream received a unique TMDL. Reductions achieved from the impaired streams upstream of the South Yadkin River impairment will also count as reductions for the South Yadkin River TMDL. Ambient monitoring station Q3970000 was not used to calculate the TMDL for the lower impaired section (12-108-(19.5)b because there is no flow gage located with that station. Second, the correlation of Turbidity vs. TSS has an R^2 of 0.552, which is less than the TSS vs NTU R^2 value of 0.88 for the upstream ambient station (Q3460000) used in the TMDL. Finally, the turbidity data comparison between the two stations shows that the data is comparable with median NTU values for Q3460000 and Q3970000 both at 22 for years 2000-2009. The change in reductions between the two stations would likely be insignificant, and uncertainty would be high due to estimating flow and using the lower TSS vs NTU correlation from site Q3970000.

25) NCDOT :

Yadkin River – similar to the South Yadkin River comments presented above, a TMDL allocation conflict also exists for the Yadkin River between AUs 12-(80.7) and 12-(86.7) which are separated by a reach of the Yadkin River that is not impaired for turbidity. AU 12-(80.7) and AU 12-(86.7) have each been assigned a TMDL allocation of 151.0 tons TSS/day. Again, NCDOT interprets the two Yadkin River TMDLs to mean that no additional loading is allowed between AUs 12-(80.7) and 12-(86.7). However, between the TMDL calculation point at station Q2040000 and AU12-(86.7) is the intervening drainage area of South Deep Creek which has been allocated a TMDL allowable load of 8.50 tons TSS/day. Since these TMDLs conflict with each other, DWQ should consider recalculating the TMDL for AU 12-(86.7) using data from station Q2180000 illustrated in Figure 1.18, or move AU 12-(86.7) from Category 5 to 4b as similarly discussed for the South Yadkin River situation.

Response: Ambient station Q2040000 was used to develop the TMDL for both impaired segments of the Yadkin River for several reasons. One reason is that it is co-located with a USGS gage used to develop the load duration curve. Second, the correlation of Turbidity vs. TSS for the lower ambient monitoring site, Q2180000, has an R^2 of 0.579, which is less than the TSS vs NTU R^2 value of 0.88 for the ambient station (Q2040000) used in the TMDL. Finally, the turbidity data comparison between the two stations show that the data is comparable with median NTU values for Q2040000 and Q2180000 at 16 and 18 respectively for years 2000-2009. The change in reductions between the two stations would likely be insignificant, and uncertainty would be high due to estimating flow and using the lower TSS vs NTU correlation from site Q2180000. Reductions achieved through the South Deep Creek TMDL will count towards reductions in both assessment units of the Yadkin River TMDL.

26) NCDOT :

Ararat River – similar to the South Yadkin River and Yadkin River situations discussed above, the Ararat River has two AUs, 12-72-(4.5)b and 12-72-(18), which appear to have each been allocated an allowable loading of 13.0 tons TSS/day based on a TMDL calculation point located along the upstream-most AU, 12-72-(4.5)b. Again, a large intervening drainage area contributes flow and presumably TSS loading between the TMDL calculation point at station Q1780000 and AU 12-72-(18), but this additional loading is not reflected in the TMDL for 12-72-(18). This conflicts with the wasteload allocation for the Pilot Mountain WWTP (NC0026646) and presumably with the allocation for the water treatment plant as well. Since Figure 1.4 indicates that DWQ ambient station Q1950000 is located along AU 12-72-(18), it is recommended that the TMDL for this AU be recalculated using data from this station in order to avoid the allocation conflicts.

Response: DWQ did not use data from ambient station Q1950000 because data collection at this station was discontinued in 2006.

27) North Carolina Conservation Network:

> *Exclusion of high flows*. The draft TMDL excludes loads in the highest flow periods as 'unmanageable' (p.29, 36, 43, 50, 58, 65, 73, 81, 89). It is true that many jurisdictions do not require development to manage or treat volumes beyond the 1 year, 24 hour storm. However, these unmanaged flows are not unmanageable; they just demand a different implementation strategy than DWQ has traditionally used. Specifically, high flows can be controlled through design standards for new and retrofitted development that protect the original hydrograph. The fact that the TMDLs consistently found that average loads exceeded the allowable load during high flows (for example, Abbotts Creek, p.29) indicates the need to develop allocations and strategies specifically targeting high flows.

Response: The highest 10% flows were excluded from the TMDL calculation to address extreme flows and this has been the general practice for most TMDLS developed using the LDC method so far. As the commenter suggested, if high flows are commonly occurring in an area a different implementation strategy can be employed to address these high flows. It should be noted that the load duration flow interval serves as an indicator of the hydrologic condition. Even though implementation is not a required element of the TMDL, the use of duration curve zones (e.g., high flow, moist, mid-range, dry, and low flow) presented in the TMDL provide useful information to direct potential implementation actions that most effectively address water quality concerns for various flow conditions.

28) North Carolina Conservation Network:

> *Lack of implementation plan*. The draft TMDL lacks an implementation plan, instead suggesting vaguely that stakeholders in the watershed should consider existing grant and incentive programs that have to date failed to prevent or cure impairment. That omission is a serious problem. We understand that there is a different between a TMDL model and an implementation plan; our argument is that the state cannot choose a non-arbitrary approach to calculating a TMDL and assigning load reductions without some minimal discussion of the approaches that will be relied upon in the implementation plan. For example, to the extent that volume control is a low cost way to reduce in-stream erosion (and therefore total loadings), the formula used to attribute the total load needs to include volume. So, the draft TMDL should outline the regulatory options the state envisions will be used to achieve the allocated reductions.

Response: An implementation section has been added to the TMDL explaining how the TMDL will be implemented through NPDES stormwater permits. Addressing nonpoint sources of turbidity beyond regulatory authority requires the will and cooperation among the community to voluntarily adjust land management practices and to use incentive programs listed in Section 12.1 of the report. An implementation plan, although very useful, is not required in a TMDL.

29) North Carolina Conservation Network:

> *Omission of MS4s and total volume.* Perhaps because it does not address total volume, the draft TMDL does not describe the contribution of or assign volume reductions (as a wasteload allocation) to municipal separate storm sewer systems (MS4s) in the watershed. The discussion of point sources of turbidity acknowledges that "large volumes of quickly flowing runoff erode stream banks, damage streamside vegetation, and widen stream channels," and affirms that MS4s are point sources (p.25). However, the draft TMDL does not take account of the in-stream erosion caused by excess volumes of water. Doing so might require a different approach to attributing loading, expanding the formula at the heart of the calculation to account for the in-stream erosion associated with different volumes of discharge, apart from the TSS load carried by those volumes. Another way of saying this is that each point discharge is carrying a load of suspended sediment, and also a load of kinetic energy, and the combination causes turbidity; as written, the draft TMDL only takes into account the TSS, and not the kinetic energy, in attributing loadings to different sources. That matters, because control of volumes may be a low-cost strategy to reduce downstream turbidity, or at least to prevent it from becoming worse. We recommend that the TMDL be revised to incorporate total volumes, and to assign wasteload allocations to upstream MS4s in the form of total volume reductions.

Response: DWQ agrees high volume and resulting stream bank erosion is likely to contribute a significant portion of turbidity and that using volume as a surrogate parameter would be useful for turbidity TMDLs. DWQ is open to discussing the use of flow, or other innovative approaches for future TMDLs.

30) North Carolina Conservation Network:

> *Cumulative contributions to impairment.* The draft TMDL states, for each of the nine waterbodies, that "permittees …that discharges above a water quality station that is not impaired for turbidity are not considered to be contributing to the impairment [further downstream]." (p.26, 33, 40, 47, 54, 62, 69, 77, 85). While that makes some sense for pollutants where impairment is purely a function of cumulative concentration, it is not a reasonable assumption where the downstream impairment is related nonlinearly to concentration, or is a function of a variable that is not appropriately expressed as a concentration. Both of those conditions are true for turbidity from in-stream erosion: overbank flooding may make it worse in non-linear increments; and the erosion is a function of total kinetic energy, not a concentration. To appropriately account for turbidity in impaired segments, the TMDL should incorporate the volume contributions of upstream MS4s, even above stations that are not impaired for turbidity.

Response: DWQ agrees that volume from upstream locations will contribute to stream bank erosion in the impaired sections. However this TMDL is not intended to address flow. The paragraph mentioned above has been changed in the text in response to comment 19-Part 2. DWQ is open to discussing the use of flow, or other innovative approaches for future TMDLs.

31) North Carolina Conservation Network:

Omission of construction stormwater. The draft TMDL omits another critical category of point source discharges that contribute to turbidity impairment: runoff from construction sites. Again, the draft acknowledges that NPDES stormwater permits are point source discharges, and presumably therefore should be addressed by the TMDL under 40 CFR 130.2(i). However, the draft TMDL does not discuss how runoff from construction sites has contributed to the observed impairment in any of the nine river or stream segments, and does not appear to take this runoff

into account in assigning load reductions. It seems likely that, at any given time, a significant share of the impairment in the watershed is a product of temporary land-disturbing activities. Indeed, the draft TMDL says as much: "violations of the turbidity standard did not occur during low flows when continuous dischargers' contributions would be greatest" (Abbott Creek p.32); "higher loads during high and transitional flows suggest the sources of turbidity could be from storm runoff and/or bank erosion" (Ararat River, p. 36); other segments include similar comments. Construction stormwater should receive a wasteload allocation for a reduction in loadings. In keeping with North Carolina's water quality standards for turbidity, in watersheds that are impaired for turbidity (>50 NTUs), the TMDL should acknowledge that the NCG 010000 can authorize *no* increase in turbidity, and therefore no loading.

In this connection, it is worth noting that the state water quality standard for turbidity, which unfortunately includes ambiguous language about the relationship between best management practices (BMPs) and turbidity, does not obviate the need to address construction stormwater in the TMDL. The state water quality standard includes the sentence, "[c]ompliance with this turbidity standard can be met when land management activities employ BMPs recommended by the Designated Nonpoint Source Agency", 15 NCAC 02B .0211. In different contexts, DWQ has maintained that this is either a hopeful prediction (one who complies with BMPs will usually avoid violating the turbidity standard) or an assurance (if a discharger complies with BMPs, DWQ will not enforce against any turbidity violations that occur). Either way, it is not a statement of scientific fact; experience has confirmed repeatedly that BMPs are not sufficient to prevent actual turbidity violations. Science must drive the TMDL process, and so the TMDL must into account the actual contribution of construction stormwater to the impairment of the nine waterbodies.

Response: DWQ believes that a TMDL is not the best tool to address stormwater from construction sites due to the relative short time period in which sites are actually under construction and vulnerable to erosion. DWQ does not require on-site monitoring of stormwater runoff for construction sites and the uncertainty would be very high to estimate a load from construction sites with varying BMPs if DWQ were to base loading on construction stormwater runoff studies alone.