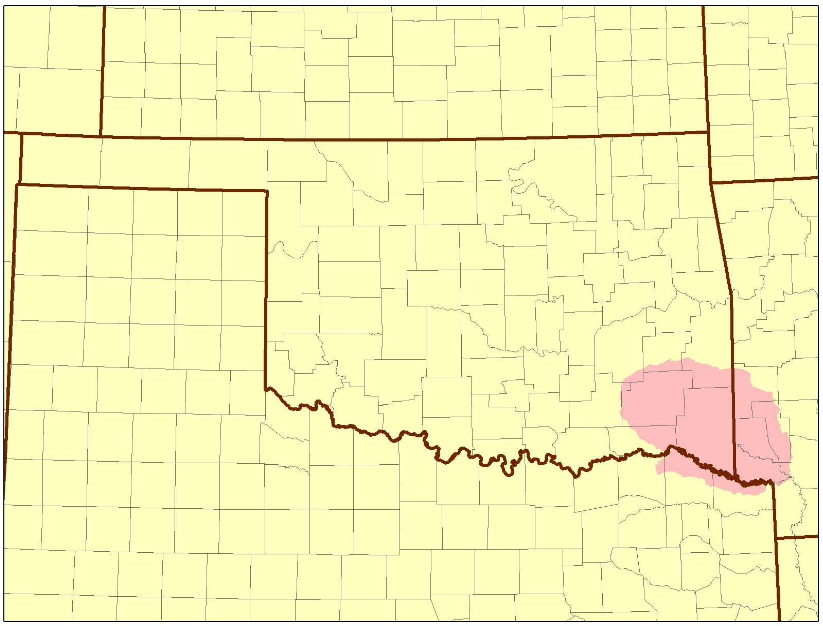
FINAL

BACTERIA TOTAL MAXIMUM DAILY LOADS FOR OK410210, OK410300, OK410310 IN THE LITTLE RIVER AREA, OKLAHOMA



Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

PARSONS

SEPTEMBER 10, 2007

DRAFT

BACTERIA TOTAL MAXIMUM DAILY LOADS FOR OK410210, OK410300, OK410310 IN THE LITTLE RIVER AREA, OKLAHOMA

OKWBID

OK410210020140, OK410210040010, OK410210080010, OK410300030010, OK410300030210, OK410300030270, OK410310010070, OK410310030090

Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

PARSONS

8000 Centre Park Drive, Suite 200
Austin, TX 78754

SEPTEMBER 10, 2007

Oklahoma Department of Environmental Quality: FY07 106 Grant (CA# I-006400-05) Project 24 – Bacteria TMDL Development

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ASAE	American Society of Agricultural Engineers
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
E.coli	*Escherichia coli*
GIS	geographic information system
LA	Load allocation
LDC	Load duration curve
mg	Million gallons
mgd	Million gallons per day
mL	Milliliter
MOS	Margin of safety
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
O.S.	Oklahoma statutes
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWRB	Oklahoma Water Resources Board
PBCR	Primary body contact recreation
PRG	Percent reduction goal
SH	State highway
SSO	Sanitary sewer overflow
TMDL	Total maximum daily load
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater treatment plant

Executive Summary

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria fecal coliform, *Escherichia coli (E. coli),* or Enterococci for certain waterbodies in the Little River area of the Red River Basin. Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a receiving water is contaminated with human or animal feces and that there is a potential health risk for individuals exposed to the water. Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and Oklahoma Department of Environmental Quality (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this report is to establish pollutant load allocations for indicator bacteria in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the uncertainty associated with natural process in aquatic systems, model assumptions, and data limitations.

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria loadings within each watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process.

E.1 Problem Identification and Water Quality Target

A decision was made to place specific waterbodies in this Study Area, listed in Table ES-1, on the ODEQ 2004 303(d) list because evidence of nonsupport of primary body contact recreation (PBCR) was observed.

Elevated levels of bacteria above the WQS for one or more of the bacterial indicators result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the bacteria loading controls needed to restore the primary body contact recreation use designated for each waterbody.

Table ES-1 Excerpt from the 2004 Integrated Report – Comprehensive Waterbody Assessment Category List

Waterbody ID	Waterbody Name	Stream Miles	Category	TMDL Date	Primary Body Contact Recreation
OK410210020140_00	Little River	29.14	5	2005	N
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	9.87	5	2005	N
OK410210080010_00	Glover River	33.95	5	2005	N
OK410300030010_10	Kiamichi River	10.298	5	2005	N
OK410300030210_00	Dumpling Creek	13.73	5	2008	N
OK410300030270_00	Tenmile Creek	35.75	5	2008	N
OK410310010070_00	Dry Creek	6.45	5	2008	N
OK410310030090_00	Bolen Creek	8.54	5	2008	N

N = Not Supporting

Source: 2004 Integrated Report, ODEQ 2004

For the data collected between 1999 and 2003, evidence of nonsupport of the PBCR use based on fecal coliform concentrations was observed in four waterbodies: Dumpling Creek (OK410300030210), Tenmile Creek (OK410300030270), Dry Creek (OK410310010070) and Bolen Creek (OK410310030090). Evidence of nonsupport of the PBCR use based on Enterococci concentrations was observed in four waterbodies: Little River (OK410210020140), Little River-Mountain Fork (OK410210040010_00, OK410210040010_10), Glover River (OK410210080010) and Kiamichi River (OK410300030010). There was no evidence of nonsupport of the PBCR used based on *E. coli* for any of the waterbodies in the Little River Study Area. Table ES-2 summarizes the waterbodies requiring TMDLs for not supporting PBCR.

Table ES-2 Waterbodies Requiring TMDLs for Not Supporting Primary Body Contact Recreation Use

WQM Station	Waterbody ID	Waterbody Name	Indicator Bacteria		
			FC	ENT	*E. coli*
OK410210020140-001AT	OK410210020140_00	Little River		X	
OK410210040010-001AT	OK410210040010_00, OK410210040040_10	Little River-Mountain Fork		X	
OK410210080010-001AT	OK410210080010_00	Glover River		X	
OK410300030010-001AT	OK410300030010_10	Kiamichi River		X	
OK410300030210C	OK410300030210_00	Dumpling Creek	X		
OK410300030270M	OK410300030270_00	Tenmile Creek	X		
OK410310010070C	OK410310010070_00	Dry Creek	X		
OK410310030090G	OK410310030090_00	Bolen Creek	X		

ENT = enterococci; FC = fecal coliform

The definition of PBCR is summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

(a) *Primary Body Contact Recreation involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.*

(b) *In waters designated for Primary Body Contact Recreation...limits...shall apply only during the recreation period of May 1 to September 30. The criteria for Secondary Body Contact Recreation will apply during the remainder of the year.*

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2007). The excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

(a) Scope. The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.

(b) Screening levels:

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 108 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) Fecal coliform:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(2) The parameter of fecal coliform is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that

waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of E. coli is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

(e) Enterococci:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of enterococci is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

Compliance with the Oklahoma WQS is based on meeting requirements for all three bacterial indicators. Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2006).

As stipulated in the WQS, utilization of the geometric mean to determine compliance for any of the three indicator bacteria depends on the collection of five samples within a 30-day period. For most WQM stations in Oklahoma there are insufficient data available to calculate the 30-day geometric mean since most water quality samples are collected once a month. As a result, waterbodies placed on the 303(d) list for not supporting the PBCR are the result of individual samples exceeding the instantaneous criteria or the long-term geometric mean of individual samples exceeding the geometric mean criteria for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1st to September 30th) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no more than 10% of samples may exceed instantaneous criteria. Since the attainability of stream beneficial uses for *E. coli* and Enterococci is based on the compliance of either the instantaneous or a long-term geometric mean criterion, percent reductions goals will be calculated for both criteria. TMDLs will be based on the percent reduction required to meet either the instantaneous or the long-term geometric mean criterion, whichever is less.

E.2 Pollutant Source Assessment

There are no NPDES-permitted facilities of any type in the contributing watersheds of Little River, Glover River, Kiamichi River, Dumpling Creek, Tenmile Creek, Dry Creek, and Bolen Creek. One watershed, Little River-Mountain Fork, has an NPDES-permitted continuous point source discharger, although it is not a municipal wastewater treatment plant. For the purposes of these TMDLs, only facility types identified as Sewerage Systems are assumed to contribute bacteria loads within the watersheds of the impaired waterbodies. Thus, nonpoint sources are considered to be the major source of bacteria loading in each watershed.

Nonpoint source bacteria loading to the receiving streams of each waterbody emanate from a number of different sources including wildlife, various agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems, and domestic pets.. Therefore, nonsupport of PBCR use is almost exclusively caused by nonpoint sources of bacteria. The data analysis and the load duration curves (LDC) demonstrate that exceedances at the WQM stations are the result of a variety of nonpoint source loading.

E.3 Using Load Duration curves to Develop TMDLs

The TMDL calculations presented in this report are derived from LDCs. LDCs facilitate rapid development of TMDLs and as a TMDL development tool, are effective in identifying whether impairments are associated with point or nonpoint sources.

Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when treatment plant effluents would dominate the base flow of the impaired water.

The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the USGS;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;

- obtaining the water quality data from the primary contact recreation season (May 1 through September 30);
- matching the water quality observations with the flow data from the same date;
- display a curve on a plot that represents the allowable load multiply the actual or estimated flow by the WQS for each respective indicator;
- multiplying the flow by the water quality parameter concentration to calculate daily loads; then
- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by the water quality criterion. The TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition.

E.4 TMDL Calculations

As indicated above, the bacteria TMDLs for the 303(d)-listed WQM stations covered in this report were derived using LDCs. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for uncertainty concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS$$

For each waterbody the TMDLs presented in this report are expressed as a percent reduction across the full range of flow conditions (See Table ES-3). The difference between existing loading and the water quality target is used to calculate the loading reductions required. Percent reduction goals (PRG) are calculated for each WQM site and bacterial indicator species as the reductions in load required in order that no more than 25 percent of the existing instantaneous fecal coliform observations and no more than 10 percent of the existing instantaneous *E. coli* or Enterococci observations would exceed the water quality target.

Table ES-3 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area. Attainment of WQSs in response to TMDL implementation will be based on results measured at each of these WQM stations. Selection of the appropriate PRG for each waterbody in Table ES-3 is denoted by the bold text. The TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria for *E. coli* and Enterococci because WQ standards are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no more than 10% of samples exceed the instantaneous criteria. Based on this table, the TMDL PRGs for Little River, Little River-Mountain Fork, Glover River, and Kiamichi River will be based on Enterococci; the TMDL PRGs for Dumpling Creek, Tenmile Creek, Dry Creek, and Bolen Creek will be based on fecal coliform.

Table ES-3 TMDL Percent Reduction Goals Required to Meet Water Quality Standards for Impaired Waterbodies in the Little River Area

Waterbody ID	WQM Station	Waterbody Name	Percent Reduction Goal Required		
			FC	ENT	
			Instant-aneous	Instant-aneous	Geo-mean
OK410210020140_00	OK410210020140-001AT	Little River		86%	**79%**
OK410210040010_00 OK410210040010_10	OK410210040010-001AT	Little River-Mountain Fork		97%	**87%**
OK410210080010_00	OK410210080010-001AT	Glover River		65%	**10%**
OK410300030010_10	OK410300030010-001AT	Kiamichi River		88%	**52%**
OK410300030210_00	OK410300030210C	Dumpling Creek	**55%**		
OK410300030270_00	OK410300030270M	Tenmile Creek	**80%**		
OK410310010070_00	OK410310010070C	Dry Creek	**28%**		
OK410310030090_00	OK410310030090G	Bolen Creek	**95%**		

The TMDL, WLA, LA, and MOS vary with flow condition, and can be calculated at every 5th flow interval percentile. For illustrative purposes, the TMDL, WLA, LA, and MOS are calculated for the median flow at each site in Table ES-4. The WLA component of each TMDL is the sum of all WLAs within the contributing watershed of each WQM station. The sum of the WLAs can be represented as a single line below the LDC. The LDC and the simple equation of:

$$\textit{Average LA} = \textit{average TMDL} - \textit{MOS} - \sum \textit{WLA}$$

can provide an individual value for the LA in counts per day which represents the area under the TMDL target line and above the WLA line. Where there are no point sources the WLA is zero. The LDCs and TMDL calculations for additional bacterial indicators are provided in Appendix D.

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include a MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable pollutant loading to ensure WQSs are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the MOS is considered explicit.

For the explicit MOS the water quality target was set at 10 percent lower than the water quality criterion for each pathogen which equates to 360 cfu/100 mL, 365.4 cfu/100 mL, and 97.2/100 mL for fecal coliform, *E. coli*, and Enterococci, respectively. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each waterbody is slightly reduced. These TMDLs incorporate an explicit MOS by using a curve representing 90 percent of the TMDL as the average MOS. The MOS at any given percent flow exceedance, therefore, can be defined as the difference in loading between the TMDL and the TMDL with MOS. The use of instream bacteria concentrations to estimate existing loading is another conservative element utilized in these TMDLs that can be recognized as an implicit

MOS. This conservative approach to establishing the MOS will ensure that both the 30-day geometric mean and instantaneous bacteria standards can be achieved and maintained.

Table ES-4 TMDL Summary Examples

Waterbody	Indicator Bacteria Species	TMDL† (cfu/day)	WLA† (cfu/day)	LA† (cfu/day)	MOS† (cfu/day)
Little River	Enterococci	3.84E+11	0	3.45E+11	3.84E+10
Little River-Mountain Fork	Enterococci	1.62E+12	0	1.45E+12	1.62E+11
Glover River	Enterococci	3.14E+11	0	2.83E+11	3.14E+10
Kiamichi River	Enterococci	8.64E+11	0	7.78E+11	8.64E+11
Dumpling Creek	Fecal Coliform	2.88E+10	0	2.59E+10	2.88E+09
Tenmile Creek	Fecal Coliform	5.58E+10	0	5.02E+10	5.58E+09
Dry Creek	Fecal Coliform	2.83E+10	0	2.55E+10	2.83E+09
Bolen Creek	Fecal Coliform	5.87E+10	0	5.29E+10	5.87E+09

E.5 Reasonable Assurance

As authorized by Section 402 of the CWA, ODEQ has delegation of NPDES in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by the Oklahoma Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act, and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES program. Implementation of WLAs for point sources is done through permits issued under the OPDES program.

SECTION 1
INTRODUCTION

1.1 TMDL Program Background

Section 303(d) of the Clean Water Act (CWA) and U.S. Environmental Protection Agency (USEPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) require states to develop total maximum daily loads (TMDL) for waterbodies not meeting designated uses where technology-based controls are in place. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so states can implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (USEPA 1991).

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria fecal coliform, *Escherichia coli (E. coli),* or Enterococci for certain waterbodies in the Little River area of the Red River Basin. Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a receiving water is contaminated with human or animal feces and that there is a potential health risk for individuals exposed to the water. Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and Oklahoma Department of Environmental Quality (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and in-stream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the uncertainty associated with natural process in aquatic systems, model assumptions, and data limitations.

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria loadings within each watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process involving stakeholders who live and work in the watersheds, tribes, and local, state, and federal government agencies.

This TMDL report focuses on eight waterbodies that ODEQ placed in Category 5 of the 2004 Integrated Report [303(d) list] for nonsupport of primary body contact recreation (PBCR):

- Little River (OK410210020140_00),
- Little River-Mountain Fork River (OK410210040010_00, OK410210040010_10),
- Glover River (OK410210080010_00),
- Kiamichi River (OK410300030010_10),
- Dumpling Creek (OK410300030210_00),
- Tenmile Creek (OK410300030270_00),
- Dry Creek (OK410310010070_00), and
- Bolen Creek (OK410310030090_00).

Figure 1-1 is a location map showing these Oklahoma waterbodies and their contributing watersheds. This map also displays the locations of the water quality monitoring (WQM) stations used as the basis for placement of these waterbodies on the Oklahoma 303(d) list. These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

Elevated levels of bacteria above the WQS result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the bacteria loading controls needed to restore the contact recreation use designated for each waterbody. Table 1-1 provides a description of the locations of the WQM stations on the 303(d)-listed waterbodies.

Table 1-1 Water Quality Monitoring Stations used for 2004 303(d) Listing Decision

Waterbody Name	Waterbody ID	WQM Station	WQM Station Locations Descriptions
Little River	OK410210020140_00	OK410210020140-001AT	Little River off State Highway (SH) 3 near Cloudy, OK
Little River-Mountain Fork	OK410210040010_00, OK410210040010_10	OK410210040010-001AT	Little River-Mountain Fork at US 70 near Eagletown, OK
Glover River	OK410210080010_00	OK410210080010-001AT	Glover River at SH 3 near Glover, OK
Kiamichi River	OK410300030010_10	OK410300030010-001AT	Kiamichi River at US 271 near Antlers, OK
Dumpling Creek	OK410300030210_00	OK410300030210C	Dumpling Creek (near SH 3)
Tenmile Creek	OK410300030270_00	OK410300030270M	Tenmile Creek near Miller, OK
Dry Creek	OK410310010070_00	OK410310010070C	Dry Creek (at US 71)
Bolen Creek	OK410310030090_00	OK410310030090G	Bolen Creek (Pittsburg County)

1.2 Watershed Description

General. The Red River Basin is located in the southeastern portion of Oklahoma. The majority of the eight waterbodies included in this report are located in Pittsburg, Pushmataha and McCurtain Counties. A small portion of Dumpling Creek watershed falls in both Choctaw and Bryan Counties, a small portion of Tenmile Creek watershed falls in Atoka County, and a small portion of Bolen Creek watershed falls in Latimer County.

Pittsburg County is part of the Hardwood Forest to the north and the Ouachita Mountains to the South. Pushmataha and McCurtain Counties are part of the Ouachita Mountains to the north and the Cypress Swamps and Forest to the south. These counties are part of the South Central Plains, Ouachita Mountains, and Arkansas Valley ecoregions. Tenmile Creek, Kiamichi River, Little River, Bolen Creek, Dry Creek, and the northern portion of Glover River are situated in the Ouachita Mountain Uplift geologic province. The southern portion of Glover River, Little River-Mountain Fork, and Dumpling Creek falls within the Gulf Coastal Plains geologic province. Table 1-2, derived from the 2000 U.S. Census, demonstrates that the counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2000).

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Population Density (per square mile)
Pittsburg	43,953	34
Pushmataha	11,667	8
McCurtain	34,402	19

Climate. Table 1-3 summarizes the average annual precipitation for each WQM station. Average annual precipitation values among the WQM stations in this portion of Oklahoma range between 46.9 and 53.6 inches (Oklahoma Climate Survey 2005).

Table 1-3 Average Annual Precipitation by WQM Station

Little River Precipitation Summary		
Waterbody Name	**Waterbody ID**	**Average Annual (Inches)**
Little River	OK410210020140_00	53.1
Little River-Mountain Fork	OK410210040010_00, OK410210040010_10	53.6
Glover River	OK410210080010_00	53.5
Kiamichi River	OK410300030010_10	47.0
Dumpling Creek	OK410300030210_00	46.9
Tenmile Creek	OK410300030270_00	47.6
Dry Creek	OK410310010070_00	51.8
Bolen Creek	OK410310030090_00	50.6

Land Use. Table 1-4 summarizes the acreages and the corresponding percentages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2001 National Land Cover Dataset (USGS 2007). The land use categories are displayed in Figure 1-2.

The dominant land use throughout most of the Study Area is forest (deciduous or evergreen); however, Little River-Mountain Fork and Tenmile Creek watersheds are primarily pasture/hay. The second most prevalent land use in each watershed is pasture/hay, except for Little River-Mountain Fork and Tenmile Creek, where forest is the second most prevalent land use. The only city located within any of the eight watersheds is Antlers, which falls within the Kiamichi River watershed. The other seven watersheds have no urban areas. Low, medium, and high intensity developed land account for less that one percent of the land use in each watershed.

Table 1-4 Land Use Summaries by Watershed

Landuse Category	Watershed							
	Little River	Little River-Mountain Fork	Glover River	Kiamichi River	Dumpling Creek	Tenmile Creek	Dry Creek	Bolen Creek
Waterbody ID	OK410210020140_00	OK410210040010_00, OK410210040010_10	OK410210080010_00	OK410300030010_20	OK410300030210_00	OK410300030270_00	OK410310010070_00	OK410310030090_00
Percent of Open Water	0.3	1.2	0.3	1.6	0.2	0.1	0.1	0.0
Percent of Developed, Open Space	3.4	4.9	5.6	4.3	4.6	3.1	1.7	0.4
Percent of Developed, Low Intensity	0.1	1.1	0.3	0.6	0.2	0.4	0.0	0.0
Percent of Developed, Medium Intensity	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Percent of Developed, High Intensity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent of Barren Land (Rock/Sand/Clay)	0.0	0.2	0.0	0.1	0.0	0.0	0.1	0.0
Percent of Deciduous Forest	18.9	18.6	18.8	34.6	47.1	29.4	58.5	55.9
Percent of Evergreen Forest	55.6	20.9	46.9	10.9	2.3	16.2	5.6	21.2
Percent of Mixed Forest	6.2	14.1	14.5	8.9	1.9	6.8	10.0	11.2
Percent of Shrub/Scrub	1.9	2.8	0.1	3.1	0.0	2.5	1.5	1.1
Percent of Grassland/Herbaceous	12.8	8.3	2.9	7.8	13.9	10.3	10.7	5.5
Percent of Pasture/Hay	0.2	24.4	9.6	27.5	29.5	30.7	11.3	3.9
Percent of Cultivated Crops	0.0	0.1	0.1	0.0	0.0	0.0	0.3	0.0
Percent of Woody Wetlands	0.3	3.3	0.8	0.5	0.1	0.4	0.1	0.6
Percent of Emergent Herbaceous Wetlands	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Acres Open Water	546	267	333	254	51	36	6	0
Acres Developed, Open Space	5,721	1,126	6,175	671	1,026	1,998	112	68
Acres Developed, Low Intensity	232	254	318	87	43	286	0	4
Acres Developed, Medium Intensity	0	7	9	8	9	117	0	0
Acres Developed, High Intensity	0	1	0	1	11	0	0	0
Acres Barren Land (Rock/Sand/Clay)	3	55	16	19	10	0	4	0
Acres Deciduous Forest	31,827	4,309	20,556	5,367	10,547	19,193	3,734	9,444
Acres Evergreen Forest	93,564	4,834	51,292	1,698	508	10,544	359	3,586
Acres Mixed Forest	10,407	3,273	15,825	1,372	433	4,430	636	1,893
Acres Shrub/Scrub	3,268	641	117	474	0	1,621	96	190
Acres Grassland/Herbaceous	21,562	1,920	3,219	1,215	3,120	6,722	685	934
Acres Pasture/Hay	393	5,651	10,494	4,256	6,600	20,028	722	656
Acres Cultivated Crops	10	23	128	8	0	21	22	0

Landuse Category	Watershed							
	Little River	Little River-Mountain Fork	Glover River	Kiamichi River	Dumpling Creek	Tenmile Creek	Dry Creek	Bolen Creek
Waterbody ID	OK410210020140_00	OK410210040010_00, OK410210040010_10	OK410210080010_00	OK410300030010_20	OK410300030210_00	OK410300030270_00	OK410310010070_00	OK410310030090_00
Acres Woody Wetlands	580	766	876	74	18	286	8	109
Acres Emergent Herbaceous Wetlands	61	19	69	0	11	2	0	0
Total (Acres)	**168,172**	**23,148**	**109,429**	**15,503**	**22,389**	**65,284**	**6,383**	**16,884**

Figure 1-1 Watersheds Not Supporting Primary Body Contact Recreation Use within the Study Area

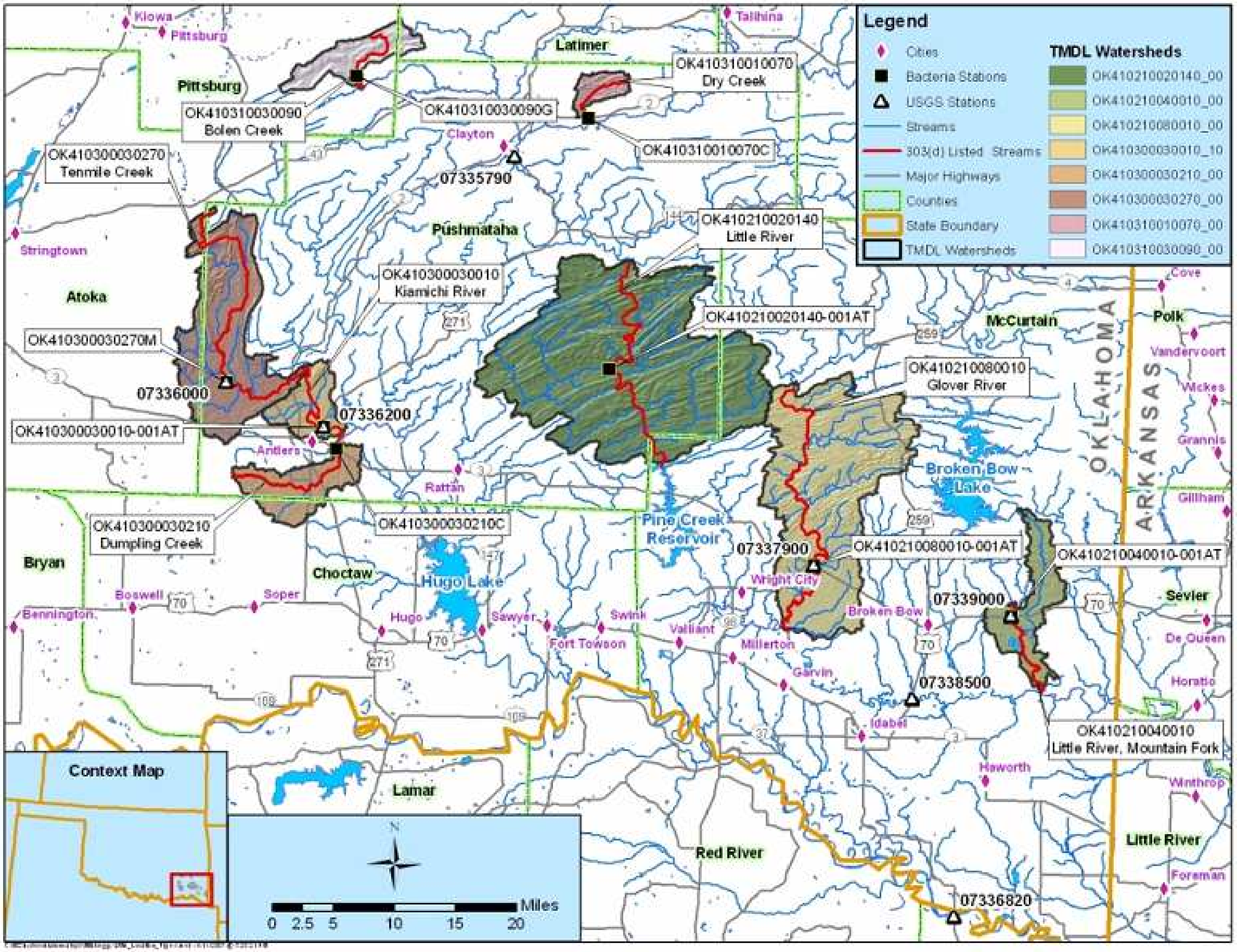
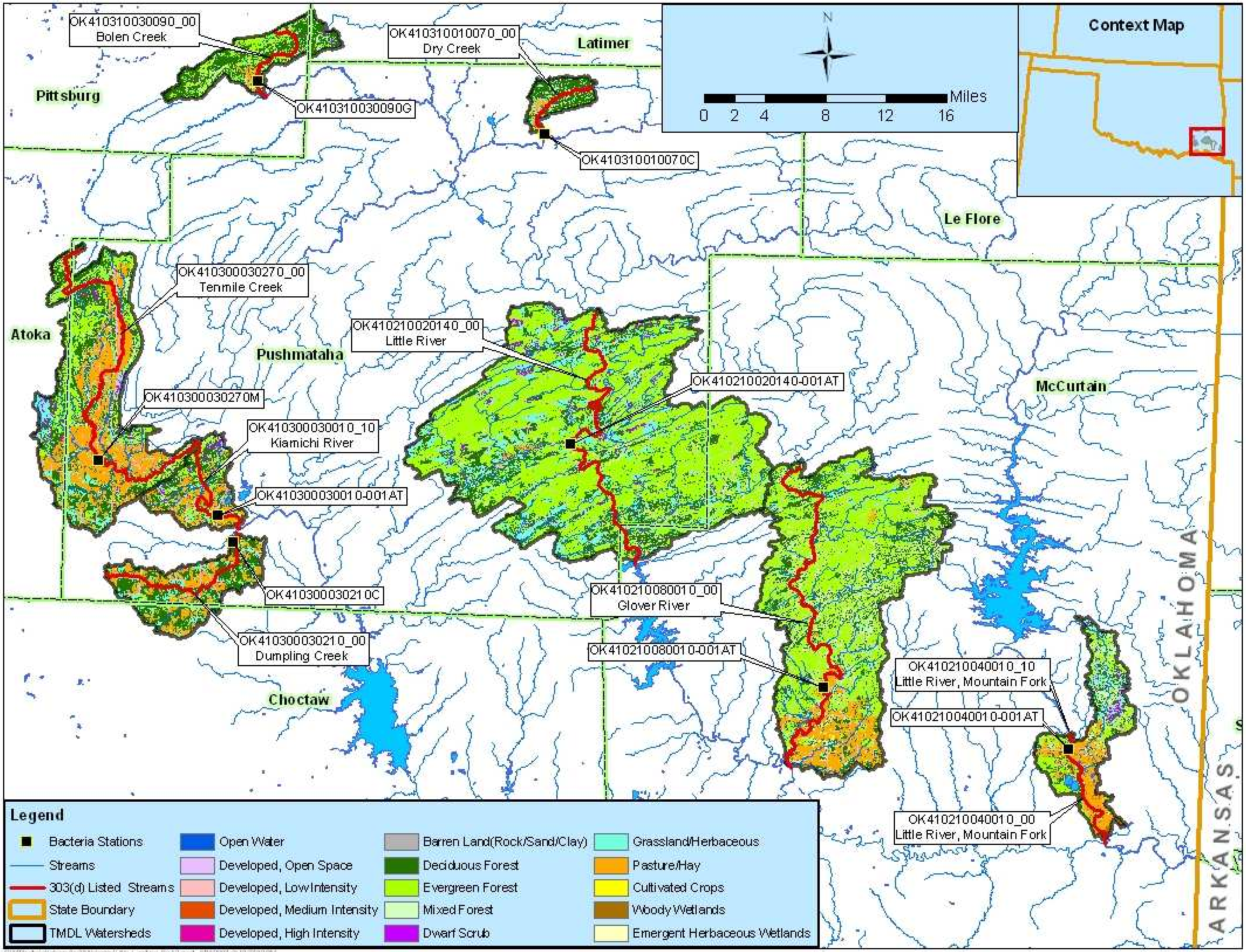


Figure 1-2 Land Use Map by Watershed



SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code authorizes the Oklahoma Water Resources Board (OWRB) to promulgate Oklahoma's water quality standards and implementation procedures (OWRB 2006). The OWRB has statutory authority and responsibility concerning establishment of state water quality standards, as provided for under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.* [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2006). The beneficial uses designated for the Little River, Little River-Mountain Fork, Glover River, Kiamichi River, Dumping Creek, Tenmile Creek, Dry Creek, and Bolen Creek include PBCR, public/private water supply, warm water aquatic community, industrial and municipal process and cooling water, hydropower, agricultural water supply, cool water aquatic community, trout fishery, fish consumption, outstanding resource, high quality water and aesthetics. The TMDLs in this report only address the PBCR-designated use. Table 2-1, an excerpt from Appendix B of the 2004 Integrated Report (ODEQ 2004), summarizes the PBCR use attainment status for the waterbodies of the Study Area. The priority for targeting TMDL development and implementation is derived from the chronological order of the dates listed in the TMDL Date column of Table 2-1. The TMDLs established in this report are a necessary step in the process to restore the PBCR use designation for each waterbody.

Table 2-1 Excerpt from the 2004 Integrated Report – Comprehensive Waterbody Assessment Category List

Waterbody ID	Waterbody Name	Stream Miles	Category	TMDL Date	Primary Body Contact Recreation
OK410210020140_00	Little River	29.14	5	2005	N
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	9.87	5	2005	N
OK410210080010_00	Glover River	33.95	5	2005	N
OK410300030010_10	Kiamichi River	10.298	5	2005	N
OK410300030210_00	Dumpling Creek	13.73	5	2008	N
OK410300030270_00	Tenmile Creek	35.75	5	2008	N
OK410310010070_00	Dry Creek	6.45	5	2008	N
OK410310030090_00	Bolen Creek	8.54	5	2008	N

N = Not Supporting

Source: 2004 Integrated Report, ODEQ 2004

The definition of PBCR is summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

(a) Primary Body Contact Recreation involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.

(b) In waters designated for Primary Body Contact Recreation...limits...shall apply only during the recreation period of May 1 to September 30. The criteria for Secondary Body Contact Recreation will apply during the remainder of the year.

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2007). The excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

(a) Scope. The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.

(b) Screening levels.

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 108 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) Fecal coliform:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(2) The parameter of fecal coliform is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that

waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of E. coli is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

(e) Enterococci:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of enterococci is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

Compliance with the Oklahoma WQS is based on meeting requirements for all three bacterial indicators. Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2006).

As stipulated in the WQS, utilization of the geometric mean to determine compliance for any of the three indicator bacteria depends on the collection of five samples within a 30-day period. For most WQM stations in Oklahoma there are insufficient data available to calculate the 30-day geometric mean since most water quality samples are collected once a month. As a result, waterbodies placed on the 303(d) list for not supporting the PBCR are the result of individual samples exceeding the instantaneous criteria or the long-term geometric mean of individual samples exceeding the geometric mean criteria for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1st to September 30th) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

The specific data assessment method for listing indicator bacteria based on instantaneous or single sample criterion is detailed in Oklahoma's 2004 Integrated Report. As stated in the report, a minimum of 10 samples collected between May 1st and September 30th (during the primary recreation season) are required to list a segment for *E. coli* and Enterococci.

A sample quantity exception exists for fecal coliform that allows waterbodies to be listed for nonsupport of PBCR if there are less than 10 samples. The assessment method states that if there are less than 10 samples and the existing sample set already assures a nonsupport determination then the waterbody should be listed for TMDL development. This condition is true in any case where the small sample set demonstrates that at least three out of six samples exceed the single sample fecal coliform criterion. In this case if four more samples were available to meet minimum of 10 samples, this would still translate to >25 percent exceedance or nonsupport of PBCR (i.e. three out of 10 samples = 33 percent exceedance). For *E. coli* and Enterococci, the 10-sample minimum was used, without exception, in attainment determination.

2.2 Problem Identification

Using the assessment methodology described in the previous section, all of the 2004 303(d) stream segments in Table 1-1 were re-evaluated with all available data for the bacteria impairment status. Since we have additional monitoring data now than when the 2004 303(d) list was compiled, stream segments and/or bacteria indicators may be added or removed from the 303(d) list as a result of the reevaluation. Table 2-2 summarizes instances where waterbodies or bacterial indicators are recommended for removal from or addition to the 303(d) list based on further data analysis associated with the preparation of this report. TMDLs will be calculated only for the confirmed stream segments and bacteria indicators. For streams and bacteria indicators originally listed in 2004 303(d) list but removed due to the reevaluation, no TMDLs will be calculated.

Table 2-2 summarizes water quality data collected during primary contact recreation season from the WQM stations between 1999 and 2003 for each indicator bacteria. The subset of this data collected during the primary contact recreation season was used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2004 303(d) list (ODEQ 2004). Water quality data from the primary and secondary contact recreation seasons are provided in Appendix A. For the data collected between 1999 and 2003, evidence of nonsupport of the PBCR use based on fecal coliform concentrations was observed in four waterbodies: Dumpling Creek (OK410300030210), Tenmile Creek (OK410300030270), Dry Creek (OK410310010070) and Bolen Creek (OK410310030090). Evidence of nonsupport of the PBCR use based on Enterococci concentrations was observed in four waterbodies: Little River (OK410210020140), Little River-Mountain Fork (OK410210040010_00, OK410210040010_10), Glover River (OK410210080010) and Kiamichi River (OK410300030010). There was no evidence of nonsupport of the PBCR used based on *E. coli* for any of the waterbodies in the Little River Study Area. In Appendix C of the ODEQ 2004

Integrated Report total fecal coliform is also identified as a pollutant of concern for some 303(d) listed waterbodies. This indicator is typically associated with evaluating use impairment for waterbodies with drinking water as a designated use. However, because there are no drinking water intakes within five miles downstream of the stream segment, total coliform listing should be delisted from the 2004 303(d) list. Therefore, TMDL development for total coliform is not required.

Table 2-3 summarizes the waterbodies requiring TMDLs for not supporting PBCR.

2.3 Water Quality Target

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." For the WQM stations requiring TMDLs in this report, defining the water quality target is somewhat complicated by the use of three different bacterial indicators with three different numeric criterion for determining attainment of PBCR use as defined in the Oklahoma WQSs. An individual water quality target is established for each bacterial indicator since each indicator group must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2006). As previously stated, because available bacteria data were collected on an approximate monthly basis (see Appendix A) instead of at least five samples over a 30–day period, data for these TMDLs are analyzed and presented in relation to the instantaneous criteria for fecal coliform and both the instantaneous and a long-term geometric mean for both *E. coli* and Enterococci.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no more than 10% of samples may exceed instantaneous criteria. Since the attainability of stream beneficial uses for *E. coli* and Enterococci is based on compliance with either the instantaneous or a long-term geometric mean criterion, percent reductions goals will be calculated for both criteria. TMDLs will be based on the percent reduction required to meet either the instantaneous or the long-term geometric mean criterion, whichever is less.

The water quality target for each waterbody will also incorporate an explicit 10 percent MOS. For example, if fecal coliform is utilized to establish the TMDL, then the water quality target is 360 organisms per 100 milliliters (mL), 10 percent lower than the instantaneous water quality criteria (400/100 mL). For *E. coli* the instantaneous water quality target is 365 organisms/100 mL, which is 10 percent lower than the criterion value (406/100 mL), and the geometric mean water quality target is 113 organisms/100 mL, which is 10 percent lower than the criterion value (126/100 mL). For Enterococci the instantaneous water quality target is 97/100 mL, which is 10 percent lower than the criterion value (108/100 mL) and the geometric mean water quality target is 30 organisms/100 mL, which is 10 percent lower than the criterion value (33/100 mL).

Each water quality target will be used to determine the allowable bacteria load which is derived by using the actual or estimated flow record multiplied by the instream criteria minus a 10 percent MOS. The line drawn through the allowable load data points is the water quality target which represents the maximum load for any given flow that still satisfies the WQS.

Table 2-2 Summary of Indicator Bacteria Samples from Primary Contact Recreation Season, 1999-2003

Waterbody ID	Waterbody Name	Indicator Bacteria	Single Sample Water Quality Criterion (#/100ml)	Geometric Mean Concentration (count/100ml)	Number of Samples	Number of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	Reason for Listing Change
OK410210020140_00	Little River	FC	400	77	22	3	14%	
		EC	406	32	23	2	9%	
		ENT	108	139	23	12	52%	
OK410210040010_00, OK410210040040_10	Little River-Mountain Fork	FC	400	90	17	2	12%	
		EC	406	39	19	1	5%	
		ENT	108	222	19	11	58%	
OK410210080010_00	Glover River	FC	400	48	18	2	11%	
		EC	406	31	18	0	0%	
		ENT	108	33	18	4	22%	
OK410300030010_10	Kiamichi River	FC	400	38	25	2	8%	
		EC	406	30	25	2	8%	
		ENT	108	62	25	8	32%	
OK410300030210_00	Dumpling Creek	FC	400	201	10	3	30%	
		EC	406	10	2	0	0%	
		ENT	108	10	1	0	0%	
OK410300030270_00	Tenmile Creek	FC	400	487	9	4	44%	List: >25%
		EC	406	10	1	0	0%	
OK410310010070_00	Dry Creek	FC	400	257	7	2	29%	List >25%
		EC	406	1259	2	1	50%	Delist: Low Sample Count
		ENT	108	8000	1	1	100%	
OK410310030090_00	Bolen Creek	FC	400	637	7	3	43%	
		EC	406	9804	1	1	100%	Delist: Low Sample Count
		ENT	108	7000	1	1	100%	

ENT = enterococci; FC = fecal coliform

Highlighted bacterial indicators require TMDL

Table 2-3 Waterbodies Requiring TMDLs for Not Supporting Primary Body Contact Recreation Use

WQM Station	Waterbody ID	Waterbody Name	Indicator Bacteria		
			FC	ENT	*E. coli*
OK410210020140-001AT	OK410210020140_00	Little River		X	
OK410210040010-001AT	OK410210040010_00, OK410210040040_10	Little River-Mountain Fork		X	
OK410210080010-001AT	OK410210080010_00	Glover River		X	
OK410300030010-001AT	OK410300030010_10	Kiamichi River		X	
OK410300030210C	OK410300030210_00	Dumpling Creek	X		
OK410300030270M	OK410300030270_00	Tenmile Creek	X		
OK410310010070C	OK410310010070_00	Dry Creek	X		
OK410310030090G	OK410310030090_00	Bolen Creek	X		

ENT = enterococci; FC = fecal coliform

SECTION 3
POLLUTANT SOURCE ASSESSMENT

A source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Bacteria originate from warm-blooded animals; some plant life and sources may be point or nonpoint in nature.

Point sources are permitted through the National Pollutant Discharge Elimination System program. NPDES-permitted facilities that discharge treated wastewater are required to monitor for one of the three bacterial indicators (fecal coliform, *E coli*, or Enterococci) in accordance with its permit. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources may involve land activities that contribute bacteria to surface water as a result of rainfall runoff. For the TMDLs in this report, all sources of pollutant loading not regulated by NPDES are considered nonpoint sources. The following discussion describes what is known regarding point and nonpoint sources of bacteria in the impaired watersheds.

3.1 NPDES-Permitted Facilities

Under 40 CFR, §122.2, a point source is described as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Certain NPDES-permitted municipal plants are classified as no-discharge facilities. NPDES-permitted facilities classified as point sources that may contribute bacteria loading include:

- NPDES municipal wastewater treatment plants (WWTP);
- NPDES municipal no-discharge WWTP;
- NPDES municipal separate storm sewer discharge (MS4); and
- NPDES Concentrated Animal Feeding Operation (CAFO).

Continuous point source discharges such as WWTPs, could result in discharge of elevated concentrations of fecal coliform bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates are above the disinfection capacity. While the no-discharge facilities do not discharge wastewater directly to a waterbody, it is possible that the collection systems associated with each facility may be a source of bacteria loading to surface waters. Stormwater runoff from MS4 areas, which is now regulated under the USEPA NPDES Program, can also contain high fecal coliform bacteria concentrations. However, there are no urbanized areas designated as MS4s within this Study Area. Concentrated Animal Feeding Operations are recognized by USEPA as significant sources of pollution, and may have the potential to cause serious impacts to water quality if not properly managed. There are no NPDES-permitted CAFO facilities within the Study Area.

There are no NPDES-permitted facilities of any type in the contributing watersheds of Little River, Glover River, Kiamichi River, Dumpling Creek, Tenmile Creek, Dry Creek, and Bolen Creek. One watershed, Little River-Mountain Fork, has an NPDES-permitted facility.

3.1.1 Continuous Point Source Discharges

The location of the NPDES-permitted facility that discharges wastewater to Little River-Mountain Fork is listed in Table 3-1 and shown in Figure 3-1. For the purposes of the TMDLs calculated in Chapter 5 only facility types identified in Table 3-1 as Sewerage Systems are assumed to contribute bacteria loads within the watersheds of the impaired waterbodies.

Table 3-1 Point Source Discharges in the Study Area

NPDES Permit No.	Name	Receiving Water	Facility Type	County Name	Design Flow (mgd)
OK0000736	Weyerhaeuser Co. - Craig Facility	Little River-Mountain Fork	Reconstituted Wood Products	McCurtain	1

Discharge Monitoring Reports (DMR) for fecal coliform analyses were not available for the Weyerhaeuser Co.–Craig Facility. However, flow discharge reports from January 1988 to December 2004 are provided in Appendix B.

3.1.2 NPDES No-Discharge Facilities and Sanitary Sewer Overflows

There are no NPDES-permitted no-discharge facilities within the Study Area. Sanitary sewer overflows (SSO) from wastewater collection systems, although infrequent, can be a major source of fecal coliform loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. There have been no SSOs reported in the Study Area.

3.1.3 Concentrated Animal Feeding Operations

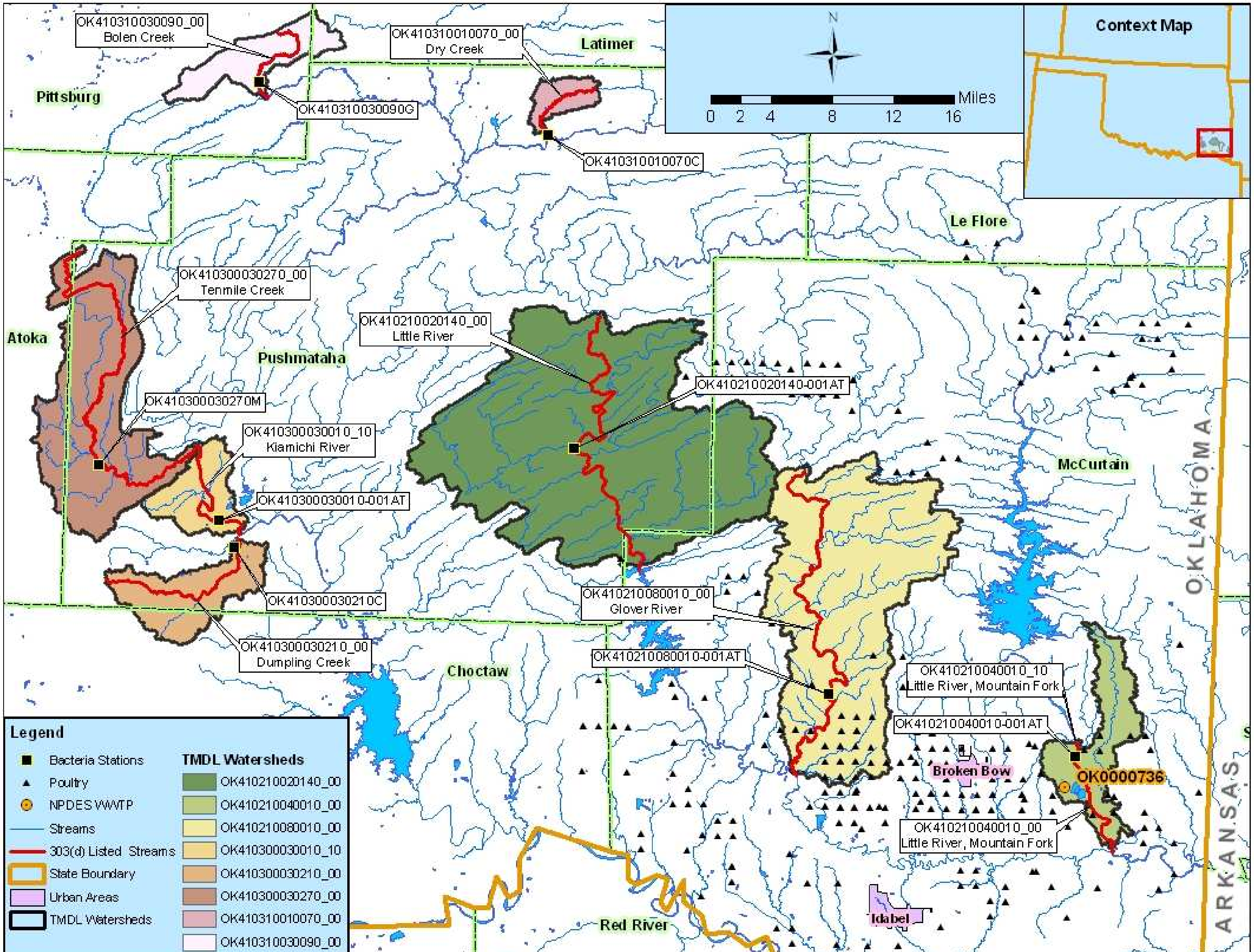
There are no NPDES-permitted CAFO facilities within the Study Area.

3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the waterbody at a specific location. Bacteria originate from rural, suburban, and urban areas. The following section describes possible major nonpoint sources contributing fecal coliform loading within the Study Area.

Nonpoint sources include wildlife, various agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems, and domestic pets. As previously stated, there are no NPDES-permitted facilities of any type in the contributing watersheds of Little River, Glover River, Kiamichi River, Dumpling Creek, Tenmile Creek, Dry Creek, and Bolen Creek, and only one NPDES point source discharger located in the Little River-Mountain Fork watershed. Therefore, nonsupport of PBCR use is almost exclusively caused by nonpoint sources of bacteria.

Figure 3-1 Locations of NPDES-Permitted Facilities and Poultry Operations in the Study Area



Bacteria associated with urban runoff can emanate from humans, wildlife, livestock, and domestic pets. Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's instantaneous standards. A study under USEPA's National Urban Runoff Project indicated that the average fecal coliform concentration from 14 watersheds in different areas within the United States was approximately 15,000 /100 mL in stormwater runoff (USEPA 1983). Best management practices (BMP) such as buffer strips and proper disposal of domestic animal waste reduce bacteria loading to waterbodies.

3.2.1 Wildlife

Fecal coliform bacteria are produced by all warm-blooded animals, including birds. Wildlife is naturally attracted to riparian corridors of streams and rivers. In developing bacteria TMDLs it is important to identify the potential for bacteria contributions from wildlife by watershed. With direct access to the stream channel, wildlife can be a concentrated source of bacteria loading to a waterbody. Fecal coliform bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. Currently there are insufficient data available to estimate populations and spatial distribution of wildlife and avian species by watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

However, adequate data are available by county to estimate the number of deer by watershed. This report assumes that deer habitat includes forests, croplands, and pastures. Using Oklahoma Department of Wildlife and Conservation county data, the population of deer can be roughly estimated from the actual number of deer harvested and harvest rate estimates. Because harvest success varies from year to year based on weather and other factors, the average harvest from 1999 to 2003 was combined with an estimated annual harvest rate of 20 percent to predict deer population by county. Using the estimated deer population by county and the percentage of the watershed area within each county, a wild deer population can be calculated for each watershed. Table 3-2 provides the estimated number of deer for each watershed.

Table 3-2 Estimated Deer Populations

Waterbody ID	Waterbody Name	Deer	Acre
OK410210020140_00	Little River	1,136	168,161
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	82	23,140
OK410210080010_00	Glover River	386	109,439
OK410300030010_10	Kiamichi River	113	15,497
OK410300030210_00	Dumpling Creek	167	22,384
OK410300030270_00	Tenmile Creek	563	65,293
OK410310010070_00	Dry Creek	46	6,378
OK410310030090_00	Bolen Creek	194	16,879

According to a livestock study conducted by the American Society of Agricultural Engineers (ASAE), deer release approximately $5x10^8$ fecal coliform units per animal per day (ASAE 1999). Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production for deer provided in Table 3-3 in colony-forming units per day (cfu/day) provides a relative magnitude of loading in each watershed.

Table 3-3 Estimated Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 10^8cfu/day) of Deer Population
OK410210020140_00	Little River	168,161	1,136	0.007	5,681
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	23,140	82	0.004	409
OK410210080010_00	Glover River	109,439	386	0.004	1,930
OK410300030010_10	Kiamichi River	15,497	113	0.007	563
OK410300030210_00	Dumpling Creek	22,384	167	0.007	833
OK410300030270_00	Tenmile Creek	65,293	563	0.009	2,814
OK410310010070_00	Dry Creek	6,378	46	0.007	231
OK410310030090_00	Bolen Creek	16,879	194	0.012	972

3.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

There are a number of non-permitted agricultural activities that can also be sources of fecal bacteria loading. Agricultural activities of greatest concern are typically those associated with livestock operations (Drapcho and Hubbs 2002). Examples of livestock activities that can contribute to bacteria sources include:

- Processed manure from livestock operations such as poultry facilities - often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff.
- Livestock grazing in pastures - deposits manure containing fecal bacteria onto land surfaces. These bacteria may be washed into waterbodies by runoff.
- Direct access to waterbodies by livestock - can provide a concentrated source of fecal bacteria loading directly into streams.

Table 3-4 provides estimated numbers of selected livestock by watershed based on the 2002 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2002). The estimated livestock populations in Table 3-4 were derived by using the percentage of the watershed within each county. Because the watersheds are generally much smaller than the counties, and livestock are not evenly distributed across counties or constant with time, these are rough estimates only. Poultry are the most abundant species of livestock in the Study Area, however, beef cattle generate the largest amount of fecal coliform and often have direct access to tributaries within the Study Area.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application of manure from livestock. The estimated acreage by watershed where manure was applied in 2002 is shown in Table 3-4. These estimates are also based on the county level reports from the 2002 USDA county agricultural census, and represent approximations of the livestock populations in each watershed. Despite the lack of specific data, for the purpose of these TMDLs, land application of livestock manure is considered a potential source of bacteria loading to the Little River watershed.

According to a livestock study conducted by the ASAE, the daily fecal coliform production rates by livestock species were estimated as follows (ASAE 1999):

- Beef cattle release approximately 1.04E+11 fecal coliform counts per animal per day
- Dairy cattle release approximately 1.01E+11 per animal per day
- Swine release approximately 1.08E+10 per animal per day
- Chickens release approximately 1.36E+08 per animal per day
- Sheep release approximately 1.20E+10 per animal per day
- Horses release approximately 4.20E+08 per animal per day;
- Turkey release approximately 9.30E+07 per animal per day
- Ducks release approximately 2.43E+09 per animal per day
- Geese release approximately 4.90E+10 per animal per day

Using the estimated livestock populations and fecal coliform production rates from ASAE, Table 3-5 gives an estimate of fecal coliform production from each group of livestock calculated in each watershed of the Study Area. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into streams by runoff or by direct deposition from wading animals. Cattle appear to represent the most likely livestock source of fecal bacteria. For informational purposes, data on poultry operations provided by the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) are provided in Table 3-6. Table 3-6 lists the estimated number of birds within select watersheds for which data are available. These numbers are considered more representative since they are based on the number of contract poultry operations within the select watershed and because they are derived from an ODAFF geographic information system (GIS) inventory. The general location of poultry operations are shown in Figure 3-1. However, for consistency, estimated fecal coliform production for the general category of poultry is based on USDA county agriculture census numbers summarized in Table 3-5.

Table 3-4 Livestock and Manure Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Acres of Manure Application
OK410210020140_00	Little River	7,188	21	341	162	40	209	77	185,545	48
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	1,488	12	63	13	5	157	5	187,435	26
OK410210080010_00	Glover River	7,014	56	297	64	25	369	22	883,622	123
OK410300030010_10	Kiamichi River	609	1	30	16	4	5	8	10	2
OK410300030210_00	Dumpling Creek	1,379	3	57	31	7	12	11	24	4
OK410300030270_00	Tenmile Creek	3,460	8	138	79	17	33	47	80	10
OK410310010070_00	Dry Creek	250	0	12	7	2	6	3	4	1
OK410310030090_00	Bolen Creek	1,616	7	58	23	13	48	7	333	6

Table 3-5 Fecal Coliform Production Estimates for Selected Livestock ($x10^{10}$ number/day)

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Totals
OK410210020140_00	Little River	74,755	209	14	N/A	49	226	191	2,523	77,968
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	15,473	120	3	N/A	6	170	7	2,549	18,327
OK410210080010_00	Glover River	72,944	565	12	N/A	30	399	32	12,017	85,999
OK410300030010_10	Kiamichi River	6,337	10	1	N/A	5	6	20	0	6,378
OK410300030210_00	Dumpling Creek	14,340	28	2	N/A	9	13	23	0	14,415
OK410300030270_00	Tenmile Creek	35,981	76	6	N/A	21	36	78	1	36,199
OK410310010070_00	Dry Creek	2,603	4	1	N/A	2	7	8	0	2,624
OK410310030090_00	Bolen Creek	16,807	70	2	N/A	16	52	10	5	16,961

Table 3-6 Estimated Poultry Numbers for Contract Growers Inventoried by ODAFF

Waterbody ID	Waterbody Name	County	Type	Estimated Birds
OK410210020140_00	Little River	McCurtain	Broilers	10,000
OK410210080010_00	Glover River	McCurtain	Broilers	1,292,400
OK410210080010_00	Glover River	McCurtain	Layers	29,845
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	McCurtain	Broilers	360,000

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

ODEQ is responsible for implementing the regulations of Title 252, Chapter 641 of the Oklahoma Administrative Code, which defines design standards for individual and small public OSWD systems (ODEQ 2004a). OSWD systems and illicit discharges can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSWD systems can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater discharges to creeks through springs and seeps.

To estimate the potential magnitude of OSWDs fecal bacteria loading, the number of OSWD systems was estimated for each watershed. The estimate of OSWD systems was derived by using data from the 1990 U.S. Census (U.S. Census Bureau 2000). The density of OSWD systems within each watershed was estimated by dividing the number of OSWD systems in each census block by the number of acres in each census block. This density was then applied to the number of acres of each census block within a WQM station watershed. Census blocks crossing a watershed boundary required additional calculation to estimate the number of OSWD systems based on the proportion of the census tracking falling within each watershed. This step involved adding all OSWD systems for each whole or partial census block.

Over time, most OSWD systems operating at full capacity will fail. OSWD system failures are proportional to the adequacy of a state's minimum design criteria (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSWD systems experience malfunctions during the year (U.S. Census Bureau 1995). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSWD systems in the northeast Texas (adjacent to the Study Area) were chronically malfunctioning. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSWD systems per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1986). Table 3-7 summarizes estimates of sewered and unsewered households for each watershed in the Study Area.

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 12 percent was used. Using this 12 percent failure rate, calculations were made to characterize fecal coliform loads in each watershed.

Fecal coliform loads were estimated using the following equation (USEPA 2001):

$$\#\frac{counts}{day} = \left(\#\,Failing\_systems\right) \times \left(\frac{10^6\,counts}{100ml}\right) \times \left(\frac{70gal}{personday}\right) \times \left(\#\frac{person}{household}\right) \times \left(3785.2\frac{ml}{gal}\right)$$

Table 3-7 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK410210020140_00	Little River	36	425	68	528	7
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	8	196	11	215	4
OK410210080010_00	Glover River	99	516	48	663	15
OK410300030010_10	Kiamichi River	94	104	7	204	46
OK410300030210_00	Dumpling Creek	148	159	9	316	47
OK410300030270_00	Tenmile Creek	390	453	26	869	45
OK410310010070_00	Dry Creek	6	18	2	26	21
OK410310030090_00	Bolen Creek	35	27	1	63	56

The average of number of people per household was calculated to be 2.44 for counties in the Study Area (U.S. Census Bureau 2000). Approximately 70 gallons of wastewater were estimated to be produced on average per person per day (Metcalf and Eddy 1991). The fecal coliform concentration in septic tank effluent was estimated to be 10^6 per 100 mL of effluent based on reported concentrations from a number of published reports (Metcalf and Eddy 1991; Canter and Knox 1985; Cogger and Carlile 1984). Using this information, the estimated load from failing septic systems within the watersheds is summarized in Table 3-8.

Table 3-8 Estimated Fecal Coliform Load from OSWD Systems

Waterbody ID	Waterbody Name	Acres	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day)
OK410210020140_00	Little River	168,161	425	51	329
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	23,140	196	24	152
OK410210080010_00	Glover River	109,439	516	62	400
OK410300030010_10	Kiamichi River	15,497	104	12	81
OK410300030210_00	Dumpling Creek	22,384	159	19	123
OK410300030270_00	Tenmile Creek	65,293	453	54	351
OK410310010070_00	Dry Creek	6,378	18	2	14
OK410310030090_00	Bolen Creek	16,879	27	3	21

3.2.4 Domestic Pets

Fecal matter from dogs and cats transported to streams by runoff from urban and suburban areas can be a potential source of bacteria loading. On average nationally, there are 0.58 dogs per household and 0.66 cats per household (American Veterinary Medical Association 2004). Using the U.S. census data at the block level (U.S. Census Bureau 2000), dog and cat populations can be estimated for each watershed. Table 3-9 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-9 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK410210020140_00	Little River	296	348
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	120	142
OK410210080010_00	Glover River	371	438
OK410300030010_10	Kiamichi River	114	135
OK410300030210_00	Dumpling Creek	177	208
OK410300030270_00	Tenmile Creek	486	573
OK410310010070_00	Dry Creek	15	17
OK410310030090_00	Bolen Creek	35	42

Table 3-10 provides an estimate of the fecal coliform load from pets. These estimates are based on estimated fecal coliform production rates of 5.4×10^8 per day for cats and 3.3×10^9 per day for dogs (Schueler 2000).

Table 3-10 Estimated Fecal Coliform Daily Production by Pets (x 10^9 number/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK410210020140_00	Little River	976	188	1164
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	397	76	473
OK410210080010_00	Glover River	1225	236	1461
OK410300030010_10	Kiamichi River	377	73	450
OK410300030210_00	Dumpling Creek	584	113	696
OK410300030270_00	Tenmile Creek	1605	310	1915
OK410310010070_00	Dry Creek	48	9	58
OK410310030090_00	Bolen Creek	117	23	139

3.3 Summary of Bacteria Sources

NPDES-permitted facilities are absent from most of the watersheds in the Study Area, and most point sources are relatively minor and, for the most part, tend to meet instream water quality criteria in their effluent. Thus, nonpoint sources are considered to be the major origin of bacteria loading in each watershed. Table 3-11 summarizes the suspected sources of bacteria loading in each impaired watershed.

Table 3-11 Estimated Major Source of Bacteria Loading by Watershed

Waterbody ID	Waterbodty Name	Point Sources	Nonpoint Sources	Major Source
OK410210020140_00	Little River	No	Yes	Nonpoint
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	No	Yes	Nonpoint
OK410210080010_00	Glover River	No	Yes	Nonpoint
OK410300030010_10	Kiamichi River	No	Yes	Nonpoint
OK410300030210_00	Dumpling Creek	No	Yes	Nonpoint
OK410300030270_00	Tenmile Creek	No	Yes	Nonpoint
OK410310010070_00	Dry Creek	No	Yes	Nonpoint
OK410310030090_00	Bolen Creek	No	Yes	Nonpoint

Table 3-12 below provides a summary of the estimated fecal coliform loads in cfu/day for the four major nonpoint source categories (livestock, pets, deer, and septic tanks) that are contributing to the elevated bacteria concentrations in each watershed. Livestock is estimated to be the largest contributor of fecal coliform loading to land surfaces. It must be noted that while no data are available to estimate populations and fecal loading of wildlife other than deer, a number of bacteria source tracking studies have demonstrated that wild birds and mammals represent a major source of the fecal bacteria found in streams.

Table 3-12 Summary of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces (x 10^9 counts/day)

Waterbody ID	Waterbody Name	All Livestock	Pets	Deer	Estimated Loads from Septic Tanks
OK410210020140_00	Little River	7,797	1,164	568	329
OK410210040010_00, OK410210040010_10	Little River-Mountain Fork	1,833	473	41	152
OK410210080010_00	Glover River	8,600	1,461	193	400
OK410300030010_10	Kiamichi River	638	450	56	81
OK410300030210_00	Dumpling Creek	1,442	696	83	123
OK410300030270_00	Tenmile Creek	3,620	1,915	281	351
OK410310010070_00	Dry Creek	262	58	23	14
OK410310030090_00	Bolen Creek	1,696	139	97	21

The magnitude of loading to a stream may not reflect the magnitude of loading to land surfaces. While no studies have quantified these effects, bacteria may die off or survive at different rates depending on the manure characteristics. Also, the structural properties of some manures, such as cow patties, may limit their washoff into streams by runoff. In contrast, malfunctioning septic tank effluent may be present in pools on the surface, or in shallow groundwater, which may enhance its conveyance to streams.

SECTION 4
TECHNICAL APPROACH AND METHODS

The objective of a TMDL is to estimate allowable pollutant loads and to allocate these loads to the known pollutant sources in the watershed so appropriate control measures can be implemented and the WQS achieved. A TMDL is expressed as the sum of three elements as described in the following mathematical equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS$$

The WLA is the proportion of the TMDL allocated to existing and future point sources. The LA is the portion of the TMDL allocated to nonpoint sources, including natural background sources. The MOS is intended to ensure that WQSs will be met. Thus, the allowable pollutant load that can be allocated to point and nonpoint sources can then be defined as the TMDL minus the MOS.

40 CFR, §130.2(1), states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For fecal coliform, *E. coli*, or Enterococci bacteria, TMDLs are expressed as colony-forming units per day, where possible, or as a percent reduction goal (PRG), and represent the maximum one-day load the stream can assimilate while still attaining the WQS.

4.1 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool are effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the four following steps that are described in Subsections 4.2 through 4.4 below:

- Preparing flow duration curves for gaged and ungaged WQM stations;
- Estimating existing bacteria loading in the receiving water using ambient water quality data;
- Using LDCs to identify the critical condition that will dictate loading reductions necessary to attain WQS; and
- Interpreting LDCs to derive TMDL elements – WLA, LA, MOS, and PRG.

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure adequate water quality across a range of flow conditions. Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when WWTP effluents would dominate the base flow of the impaired water.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by the water quality criterion. The TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition.

4.2 Development of Flow Duration Curves

Flow duration curves serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream gages to forecast future recurrence frequencies. Many WQM stations throughout Oklahoma do not have long term flow data and therefore, flow frequencies must be estimated. The most basic method to estimate flows at an ungaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the ungaged sites and the flow gage; and 3) calculating daily flows at the ungaged site by using the flow at the gaged site multiplied by the drainage area ratio. The more complex approach used here also considers watershed differences in rainfall, land use, and the hydrologic properties of soil that govern runoff and retention. More than one upstream flow gage may also be considered. A more detailed explanation of the methods for estimating flow at ungaged WQM stations is provided in Appendix C.

Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the ordinate (y-axis), which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the abscissa, which is numbered from 0 to 100 percent, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent. The flow exceedance percentiles for each WQM station addressed in this report are provided in Appendix C.

While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 1 year of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gaging stations operated by the USGS are utilized (USGS 2007a).

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100 percent. As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a “stair step” effect due to the USGS flow data rounding conventions near the limits of quantitation.

Figures 4-1 through 4-8 are flow duration curves for each impaired waterbody. No flow gage exists on Little River, segment OK410210020140_00, or Pine Creek Lake impounding

Little River downstream of WQM station OK410210020140-001AT (Little River off SH 3 near Cloudy, OK), and flow could not be predicted based on downstream gages. Thus, the flow duration curve for this site was estimated from measured flows on an adjacent waterbody at USGS gage 07337900 (Glover River near Glover, OK) using the drainage area ratio method. The flow period used for this station was 1961 through 2006.

The flow duration curve for Little River-Mountain Fork, segment OK410210040010_00, was based on measured flows at USGS gage station 07339000 (Little River-Mountain Fork near Eagletown, OK). This gage is co-located with WQM station OK410210040010-001AT. Because the impoundment of Broken Bow Lake in 1968 likely altered the flow regime, measured flows from 1968 through 2006 were used to develop the flow duration curve.

The flow duration curve for Glover River, segment OK410210080010_00, was based on measured flows at USGS gage station 07337900 (Glover River near Glover, OK). This gage is co-located with WQM station OK410210080010-001AT. The complete flow period of record (1961 through 2006) was used to develop the flow duration curve.

The flow duration curve for Kiamichi River, segment OK410300030010_20, was based on measured flows at USGS gage station 07336200 (Kiamichi River near Antlers, OK). This gage is co-located with WQM station OK410300030010-001AT. The flow duration curve was based on measured flows from 1982 through 2006, as the impoundment of Jack Fork Creek to form Sardis Lake in 1982 may have affected flows.

No flow gage exists on Dumpling Creek, segment OK41030030210_00, and the impoundment of the Kiamichi River at Hugo Lake, just downstream, precludes prediction of flow from downstream gages. Thus, flows for this waterbody were projected using the watershed area ratio method from the adjacent Kiamichi River incremental watershed between USGS gage 07336200 (Kiamichi River near Antlers, OK) and USGS gage 07335790 (Kiamichi River near Clayton, OK), and measured flows at these two gages from 1982 through 2006.

The flow duration curve for Tenmile Creek, segment OK410300030270_00, was based on measured flows at USGS gage station 07336000 (Tenmile Creek near Miller, OK). This gage is co-located with WQM station OK410300030270M. The flow duration curve was based on measured flows from 1955 through the time the gage was de-activated in 1970.

No flow gages exist on Dry Creek, segment OK410310010070_00, or Bolen Creek, segment OK410310030090_00. Flows for these waterbodies were projected using the watershed area ratio method from the adjacent watershed based on the downstream Kiamichi River incremental watershed between USGS gage 07335790 (Kiamichi River near Clayton, OK) and USGS gage 07335700 (Kiamichi River near Big Cedar, OK), and measured flows at these two gages from 1982 through 2006.

Figure 4-1 Flow Duration Curve for Little River (OK410210020140_00)

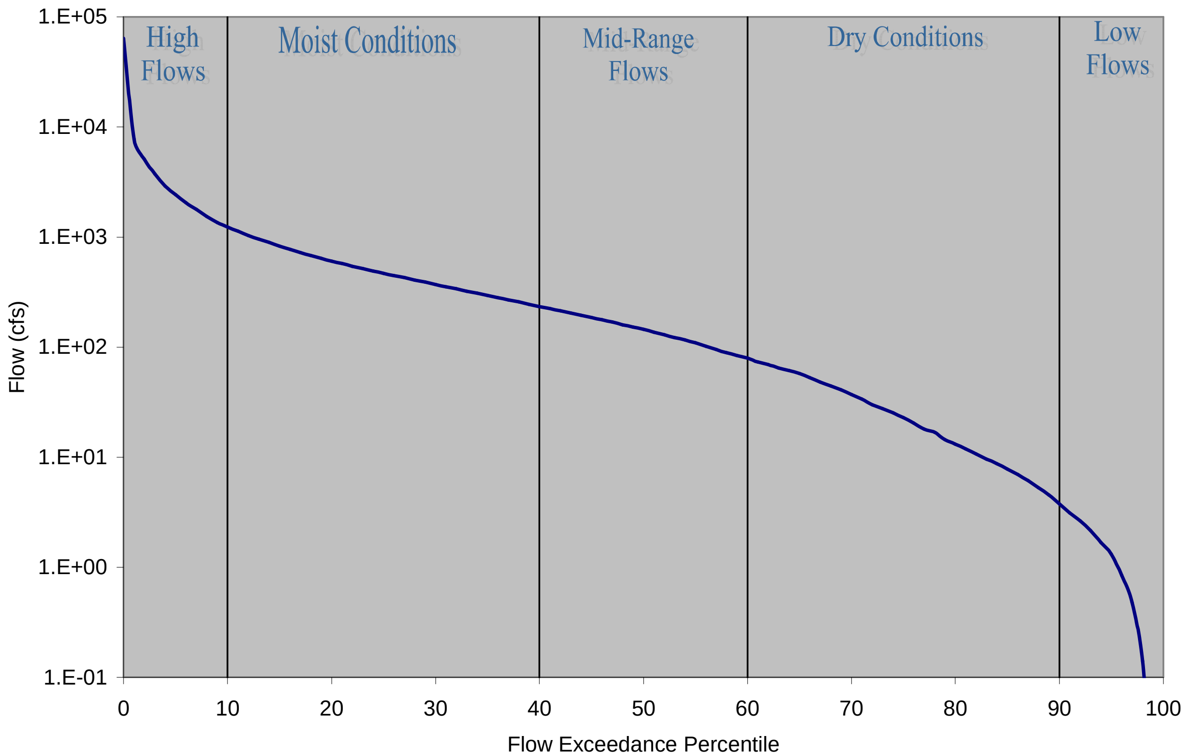


Figure 4-2 Flow Duration Curve for Little River-Mountain Fork (OK410210040010_00)

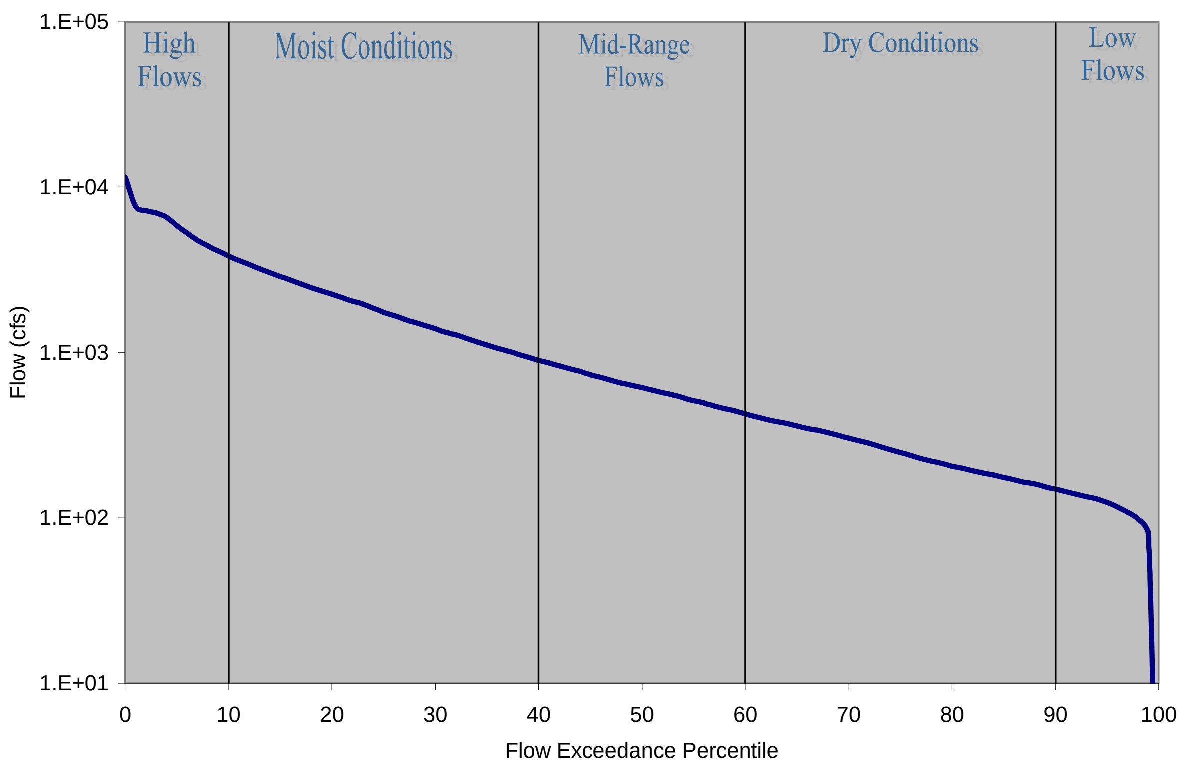


Figure 4-3 Flow Duration Curve for Glover River (OK410210080010_00)

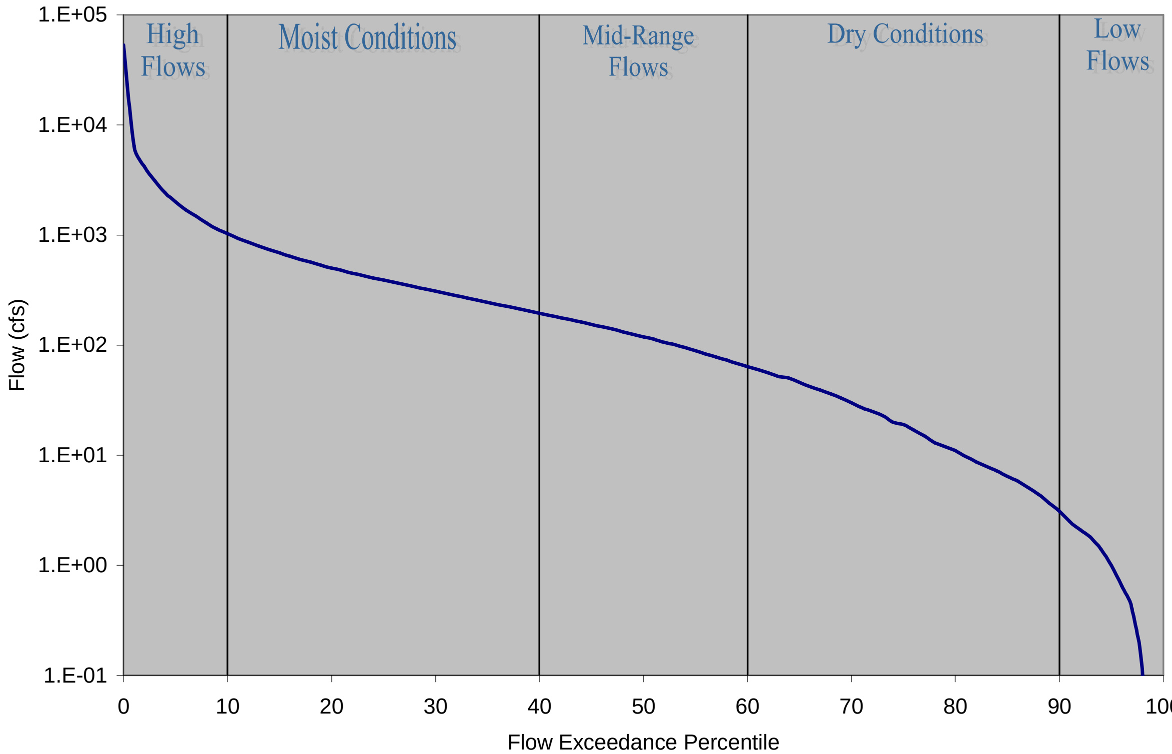


Figure 4-4 Flow Duration Curve for Kiamichi River (OK410300030010_20)

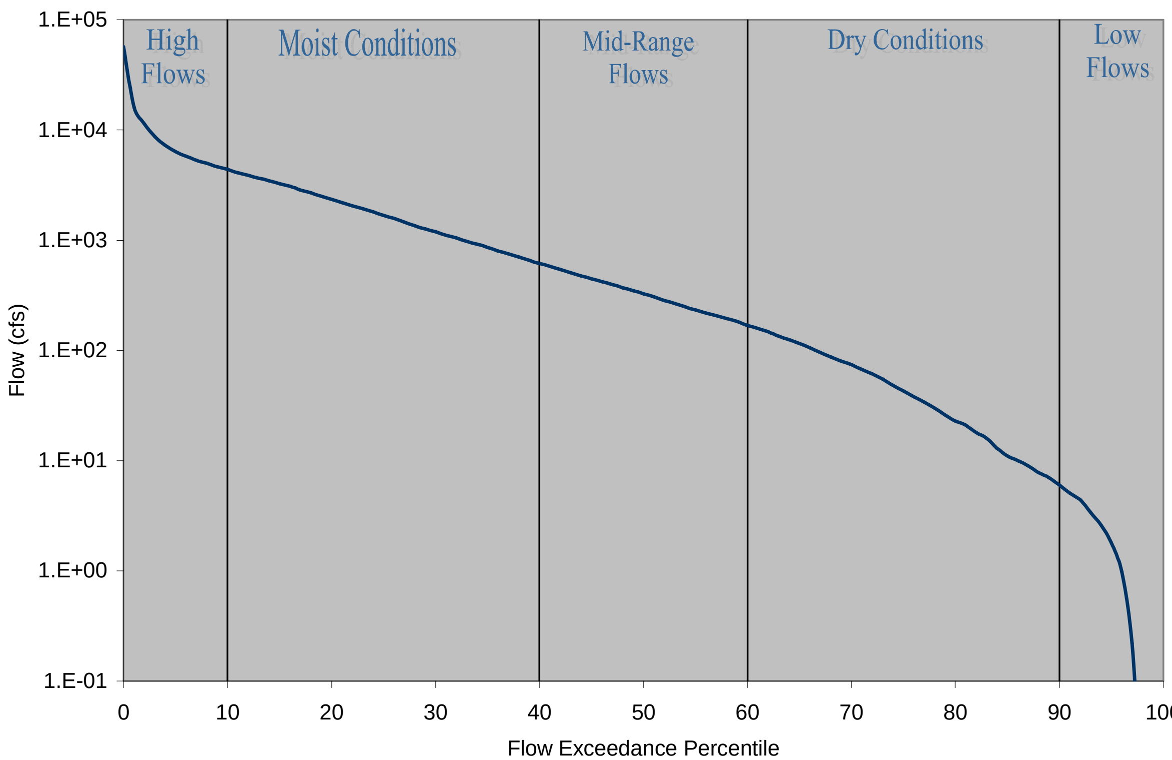


Figure 4-5 Flow Duration Curve for Dumpling Creek (OK410300030210_00)

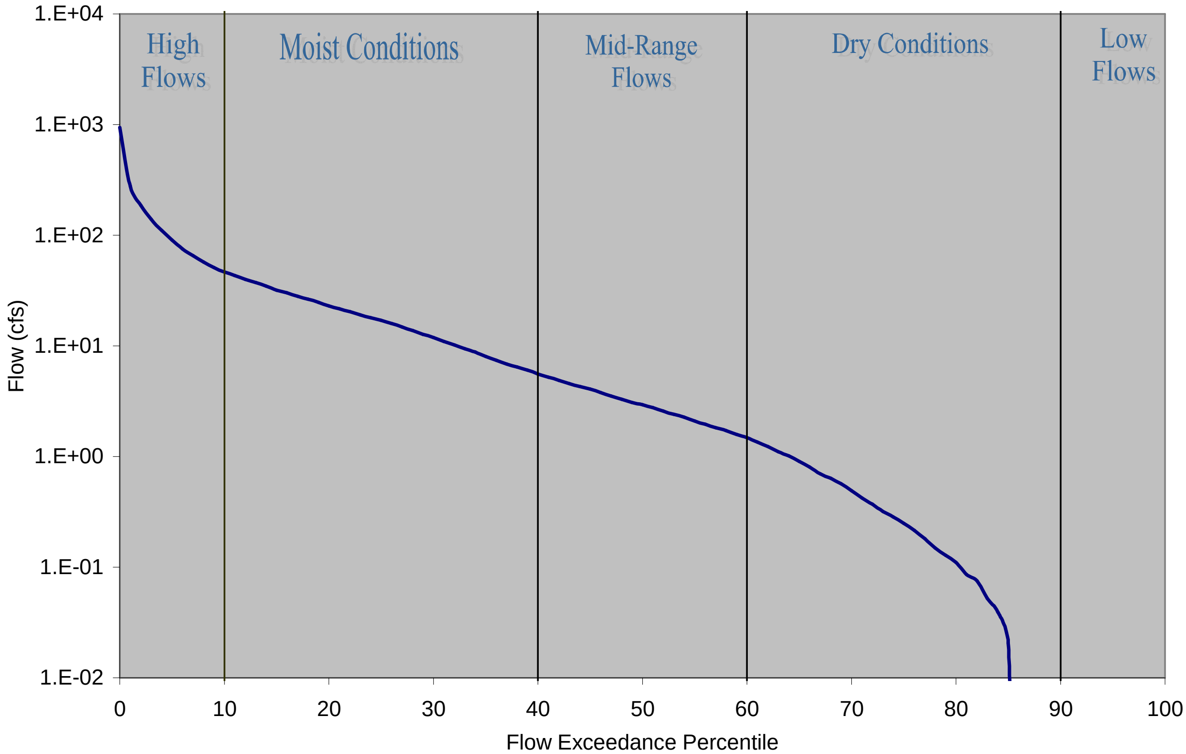
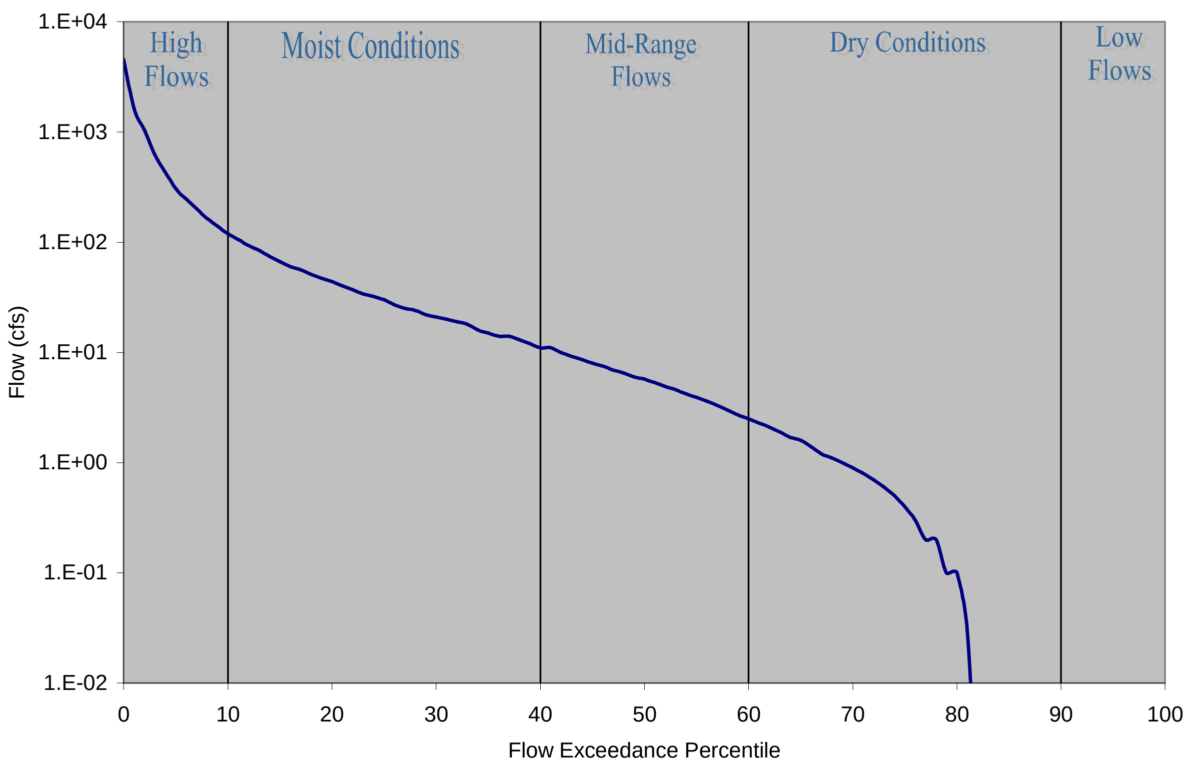


Figure 4-6 Flow Duration Curve for Tenmile Creek (OK410300030270_00)



Note: The stepped curve is caused by extremely low flow conditions near the limit of quantitation, as well as data rounding conventions.

Figure 4-7 Flow Duration Curve for Dry Creek (OK410310010070_00)

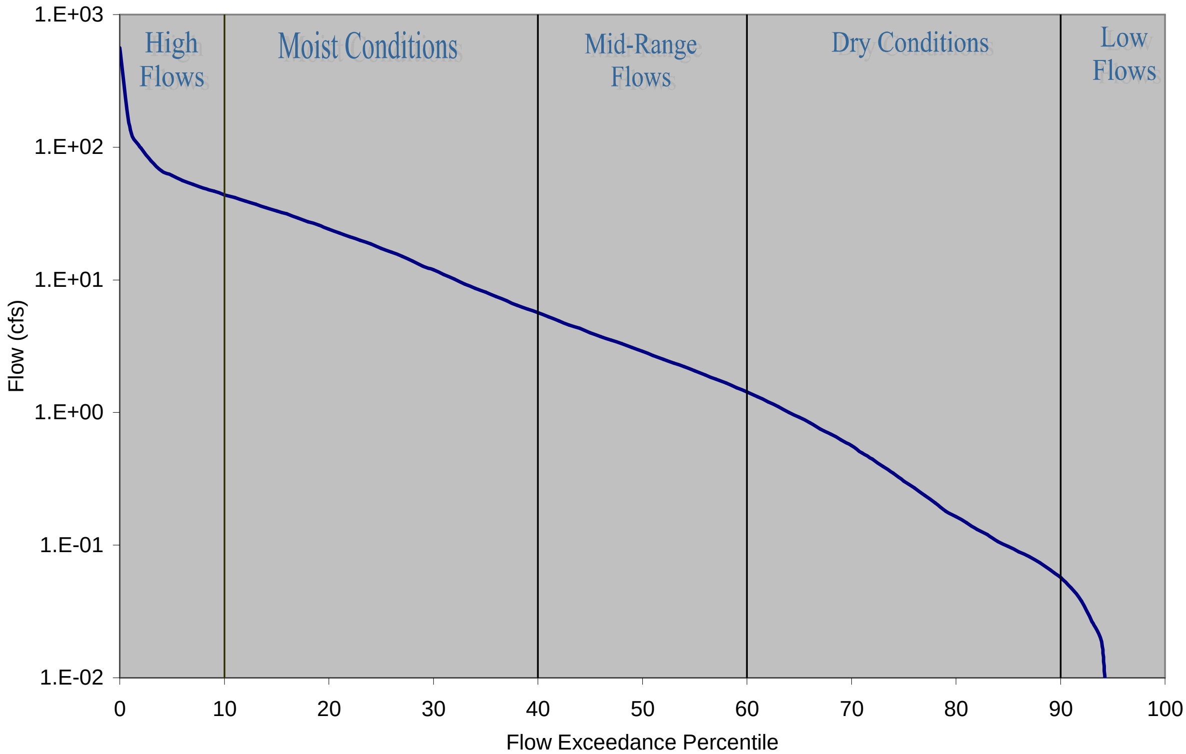
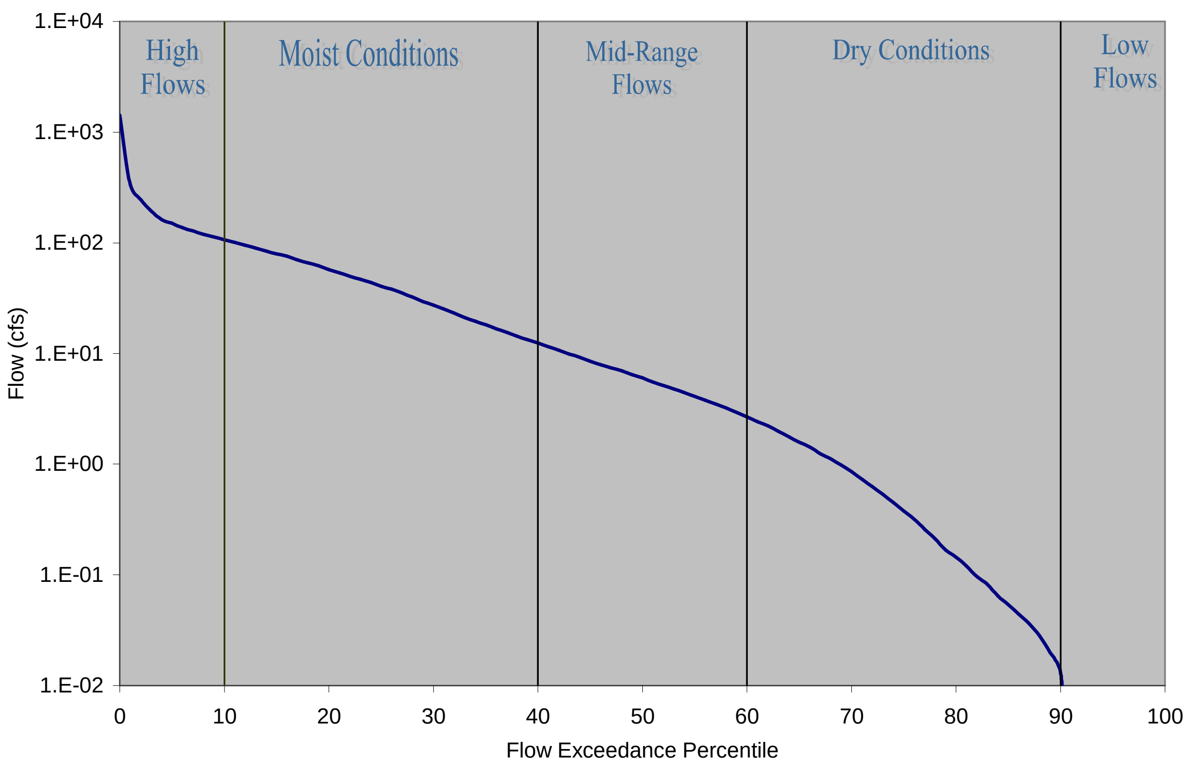


Figure 4-8 Flow Duration Curve for Bolen Creek (OK410310030090_00)



Flow duration curves can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of flow and LDCs. The hydrologic classification scheme utilized in this application is similar to that described by Cleland (2003):

Table 4-1 Hydrologic Classification Scheme

Flow Exceedance Percentile	Hydrologic Condition Class
0-10	High flows
10-40	Moist Conditions
40-60	Mid-Range Conditions
60-90	Dry Conditions
90-100	Low Flows

Flow duration curves are generated using an ODEQ automated application referred to as the bacteria LDC toolbox. A step-by-step procedure on how to generate flow duration curves and flow exceedance percentiles is provided in Appendix C.

The USGS National Water Information System serves as the primary source of flow measurements for the application. All available daily average flow values for all gages in Oklahoma, as well as the nearest upstream and downstream gages in adjacent states, were retrieved for use in the application. The application includes a data update module that automatically downloads the most recent USGS data and appends it to the existing flow database.

Some instantaneous flow measurements were available from various agencies. These were not combined with the daily average flows or used in calculating flow percentiles, but were matched to bacteria grab measurements collected at the same site and time. When available, these instantaneous flow measurements were used in lieu of the daily average flow to calculate instantaneous bacteria loads.

4.3 Estimating Current Point and Nonpoint Loading

Another key step in the use of LDCs for TMDL development is the estimation of existing bacteria loading from point and nonpoint sources and the display of this loading in relation to the TMDL. In Oklahoma, WWTPs that discharge treated sanitary wastewater must meet the state WQSs for fecal bacteria at the point of discharge. However, for TMDL analysis it is necessary to understand the relative contribution of WWTPs to the overall pollutant loading and its general compliance with required effluent limits. The monthly bacteria load for continuous point source dischargers is estimated by multiplying the monthly average flow rates by the monthly geometric mean using a conversion factor. Where available, data necessary for this calculation were extracted from each point source's discharge monitoring reports from 1997 through 2006. The 90^{th} percentile value of the monthly loads was used to express the estimated existing point source load in counts/day. The current pollutant loading from each permitted point source discharge is calculated using the equation below.

Point Source Loading = monthly average flow rates (mgd) * geometric mean of corresponding fecal coliform concentration * unit conversion factor

Where:

unit conversion factor = 37,854,120 100-ml/million gallons (mg)

It is difficult to estimate current nonpoint loading due to lack of specific water quality and flow information that would assist in estimating the relative proportion of non-specific sources within the watershed. Therefore, existing instream loads were used as a conservative surrogate for nonpoint loading. Existing instream loads were calculated as the 90^{th} percentile of measured bacteria concentrations multiplied by the flow rate under various flow conditions.

4.4 Development of TMDLs Using Load Duration Curves

The final step in the TMDL calculation process involves a group of additional computations derived from the preparation of LDCs. These computations are necessary to derive a PRG (which is one method of presenting how much bacteria loading must be reduced to meet WQSs in the impaired watershed).

Step 1: Generate Bacteria LDCs. LDCs are similar in appearance to flow duration curves; however, the ordinate is expressed in terms of a bacteria load in cfu/day. The curve represents the single sample water quality criterion for fecal coliform (400 cfu/100 mL), *E. coli* (406 cfu/100 mL), or Enterococci (108 cfu/100 mL) expressed in terms of a load through multiplication by the continuum of flows historically observed at this site. The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the USGS;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30);
- matching the water quality observations with the flow data from the same date;
- display a curve on a plot that represents the allowable load multiply the actual or estimated flow by the WQS for each respective indicator;
- multiplying the flow by the water quality parameter concentration to calculate daily loads; then
- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

The culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (cfu/day) = WQS * flow (cfs) * unit conversion factor

Where: WQS = 400 cfu /100 ml (Fecal coliform); 406 cfu/100 ml (E. coli); or 108 cfu/100 ml (Enterococci)

unit conversion factor = 24,465,525 ml*s / ft3*day

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow, in other words, the percent of historical observations that equal or exceed the measured or estimated flow. Historical observations of bacteria concentration are paired with flow data and are plotted on the LDC. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform concentration (colonies/100 mL) by the instantaneous flow (cubic feet per second) at the same site and time, with appropriate volumetric and time unit conversions. Fecal coliform/*E. coli*/Enterococci loads representing exceedance of water quality criteria fall above the water quality criterion line.

Only those flows and water quality samples observed in the months comprising the primary contact recreation season are used to generate the LDCs. It is inappropriate to compare single sample bacteria observations and instantaneous or daily flow durations to a 30-day geometric mean water quality criterion in the LDC.

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. Yet flows do not always correspond directly to runoff; high flows may occur in dry weather and runoff influence may be observed with low or moderate flows.

Step 2: Develop LDCs with MOS. An LDC depicting slightly lower estimates than the TMDL is developed to represent the TMDL with MOS. The MOS may be defined explicitly or implicitly. A typical explicit approach would reserve some fraction of the TMDL (*e.g.*, 10%) as the MOS. In an implicit approach, conservative assumptions used in developing the TMDL are relied upon to provide an MOS to assure that WQSs are attained.

For the TMDLs in this report, an explicit MOS of 10 percent of the TMDL value (10% of the instantaneous water quality criterion) has been selected to slightly reduce assimilative capacity in the watershed. The MOS at any given percent flow exceedance, therefore, is defined as the difference in loading between the TMDL and the TMDL with MOS.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for point sources is defined by the WLA. A point source can be either a wastewater (continuous) or stormwater (MS4) discharge. Stormwater point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes NPDES-permitted stormwater discharges as point source discharges and, therefore, part of the WLA.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading will vary with flow condition. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. This concentration-based approach meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs “in terms of mass per time, toxicity, or other appropriate measures” and is consistent with USEPA’s Protocol for Developing Pathogen TMDLs (USEPA 2001).

WLA for WWTP. WLAs may be set to zero in cases of watersheds with no existing or planned continuous permitted point sources. For watersheds with permitted point sources, wasteloads may be derived from NPDES permit limits. A WLA may be calculated for each active NPDES wastewater discharger using a mass balance approach as shown in the equation below. The permitted average flow rate used for each point source discharge and the water quality criterion concentration are used to estimate the WLA for each wastewater facility. All WLA values for each NPDES wastewater discharger are then summed to represent the total WLA for the watershed.

WLA (cfu/day) = WQS * flow * unit conversion factor

Where: WQS = 200 cfu /100 ml (Fecal coliform); 126 cfu/100 ml (E. coli); or 33 cfu/100 ml (Enterococci)

flow (10^6 gal/day) = permitted flow or design flow (if unavailable)

unit conversion factor = 37,854,120-10^6 gal/day

Step 4: Calculate LA. LAs can be calculated under different flow conditions as the water quality target load minus the WLA. The LA is represented by the area under the LDC but above the WLA. The LA at any particular flow exceedance is calculated as shown in the equation below.

LA = TMDL – MOS - ∑WLA

Step 5: Estimate WLA Load Reduction. The WLA load reduction was not calculated as it was assumed that continuous dischargers (NPDES-permitted WWTPs) are adequately regulated under existing permits to achieve water quality standards at the end-of-pipe and, therefore, no WLA reduction would be required.

Step 6: Estimate LA Load Reduction.

After existing loading estimates are computed for each bacterial indicator, nonpoint load reduction estimates for each WQM station are calculated by using the difference between estimated existing loading and the allowable load expressed by the LDC (TMDL-MOS). This difference is expressed as the overall percent reduction goal for the impaired waterbody. For fecal coliform the PRG ensures that no more than 25 percent of the samples exceed the TMDL based on the instantaneous criteria and allocates the loads in manner that is also protective of the geometric mean criterion. For *E. coli* and Enterococci, because WQ standards are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no more than 10% of samples exceed the instantaneous criteria, the TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria.

SECTION 5
TMDL CALCULATIONS

5.1 Estimated Loading and Critical Conditions

USEPA regulations at 40 CFR 130.7(c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and all applicable water quality standards. To accomplish this, available instream WQM data were evaluated with respect to flows and magnitude of water quality criteria exceedance using LDCs. Furthermore, TMDLs are derived for all bacterial indicators at any given WQM station placed on the 303(d) list.

To calculate the bacteria load at the WQS, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*24,465,525 ml*s /* ft^3**day*) and the criterion specific to each bacterial indicator. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions. The allowable bacteria (fecal coliform, *E. coli*, or Enterococci) loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a bacteria load.

To estimate existing loading, bacteria observations for the primary contact recreation season (May 1^{st} through September 30^{th}) from 1999 to 2003 are paired with the flows measured or estimated in that segment on the same date. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and a unit conversion factor of *24,465,525 ml*s /* ft^3**day*. The associated flow exceedance percentile is then matched with the flow from the tables provided in Appendix C. The observed bacteria loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of bacteria. Points above the LDC indicate the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the WQS.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading, and load reductions required to meet the TMDL water quality target can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. Percent reduction goals are calculated for each WQM site and bacterial indicator species as the reductions in load required in order that no more than 25 percent of the existing instantaneous fecal coliform observations and no more than 10 percent of the existing instantaneous *E. coli* or Enterococci observations would exceed the water quality target. This is because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

Table 5-1 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area. Attainment of WQSs in response to TMDL implementation will be based on results measured at each of these WQM stations. Selection of the appropriate PRG for each waterbody in Table 5-1 is denoted by the bold text. The TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria for *E. coli* and Enterococci because WQ standards are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no more than 10% of samples exceed the instantaneous criteria. Based on this table, the TMDL PRGs for Little River, Little River-Mountain Fork, Glover River, and Kiamichi River will be based on

Enterococci; the TMDL PRGs for Dumpling Creek, Tenmile Creek, Dry Creek, and Bolen Creek will be based on fecal coliform.

Table 5-1 TMDL Percent Reduction Goals Required to Meet Water Quality Standards for Impaired Waterbodies in the Little River Area

Waterbody ID	WQM Station	Waterbody Name	Percent Reduction Goal Required		
			FC	ENT	
			Instantaneous	Instantaneous	Geo-mean
OK410210020140_00	OK410210020140-001AT	Little River		86%	**79%**
OK410210040010_00 OK410210040010_10	OK410210040010-001AT	Little River-Mountain Fork		97%	**87%**
OK410210080010_00	OK410210080010-001AT	Glover River		65%	**10%**
OK410300030010_10	OK410300030010-001AT	Kiamichi River		88%	**52%**
OK410300030210_00	OK410300030210C	Dumpling Creek	**55%**		
OK410300030270_00	OK410300030270M	Tenmile Creek	**80%**		
OK410310010070_00	OK410310010070C	Dry Creek	**28%**		
OK410310030090_00	OK410310030090G	Bolen Creek	**95%**		

LDCs for the appropriate bacterial indicator species that will ensure all criteria for PBCR in each impaired waterbody should be attained are shown in Figures 5-1 through 5-8.

The LDC for Little River (Figure 5-1) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410210020140-001AT (Little River off SH 3 near Cloudy, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria during all flow conditions, indicative of nonpoint sources.

The LDC for Little River-Mountain Fork (Figure 5-2) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410210040010-001AT (Little River-Mountain Fork at U.S. Highway 70 near Eagletown, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria over a wide range of flow conditions, indicative of nonpoint sources.

The LDC for Glover River (Figure 5-3) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410210080010-001AT (Glover River at SH3 near Glover, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria primarily under high flow and moist conditions, indicative of nonpoint sources.

The LDC for Kiamichi River segment (Figure 5-4) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410300030010-001AT (Kiamichi River at US Highway 271 near Antlers, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria, primarily under all but dry conditions, indicative of nonpoint sources.

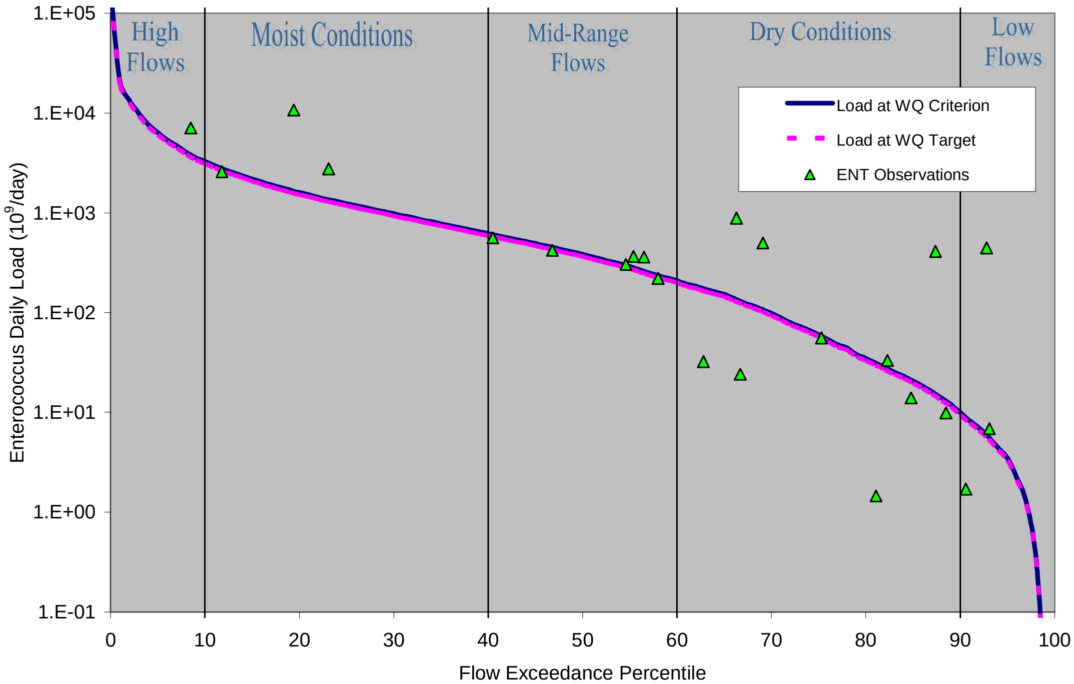
The LDC for Dumpling Creek (Figure 5-5) is based on fecal coliform measurements during primary contact recreation season at WQM station OK410300030210C (Dumpling Creek). Fecal coliform measurements collected during secondary contact recreation season (October – April) are also displayed on the figure, although the load at the secondary contact recreation criterion is not shown. The PRG is calculated so the measurements under primary contact recreation season are met; however, this percent reduction is sufficient to ensure that secondary contact recreation criteria are also met. Note the LDC indicates that fecal coliform levels exceed the instantaneous water quality criteria, primarily under moist and high flow conditions, indicative of nonpoint sources.

The LDC for Tenmile Creek (Figure 5-6) is based on fecal coliform measurements during primary contact recreation season at WQM station OK410300030270M (Tenmile Creek near Miller, OK). Fecal coliform measurements collected during secondary contact recreation season (October – April) are also displayed on the figure, although the load at the secondary contact recreation criterion is not shown. The PRG is calculated so the measurements under primary contact recreation season are met; however, this percent reduction is sufficient to ensure that secondary contact recreation criteria are also met. Note the LDC indicates that fecal coliform levels exceed the instantaneous water quality criteria primarily under all flow conditions, indicative of nonpoint sources.

The LDC for Dry Creek (Figure 5-7) is based on fecal coliform measurements during primary contact recreation season at WQM station OK410310010070C (Dry Creek). Fecal coliform measurements collected during secondary contact recreation season (October – April) are also displayed on the figure, although the load at the secondary contact recreation criterion is not shown. The PRG is calculated so the measurements under primary contact recreation season are met; however, this percent reduction is sufficient to ensure that secondary contact recreation criteria are also met. Note that the LDC indicates that fecal coliform levels exceed the instantaneous water quality criteria under dry conditions and low flows as well as extremely high flows, indicating possible point and nonpoint sources.

The LDC for Bolen Creek (Figure 5-8) is based on fecal coliform measurements during primary contact recreation season at WQM station OK410310030090G (Bolen Creek). Fecal coliform measurements collected during secondary contact recreation season (October – April) are also displayed on the figure, although the load at the secondary contact recreation criterion is not shown. The PRG is calculated so the measurements under primary contact recreation season are met; however, this percent reduction is sufficient to ensure that secondary contact recreation criteria are also met. Note the LDC indicates that fecal coliform levels exceed the instantaneous water quality criteria under a wide range of flow conditions, indicating possible point and nonpoint sources.

Figure 5-1 Load Duration Curve for Enterococci in Little River (OK410210020140_00)



* there is no wasteload allocation for this waterbody

Figure 5-2 Load Duration Curve for Enterococci in the Little River -Mountain Fork (OK410210040010_00, OK410210040010_10)

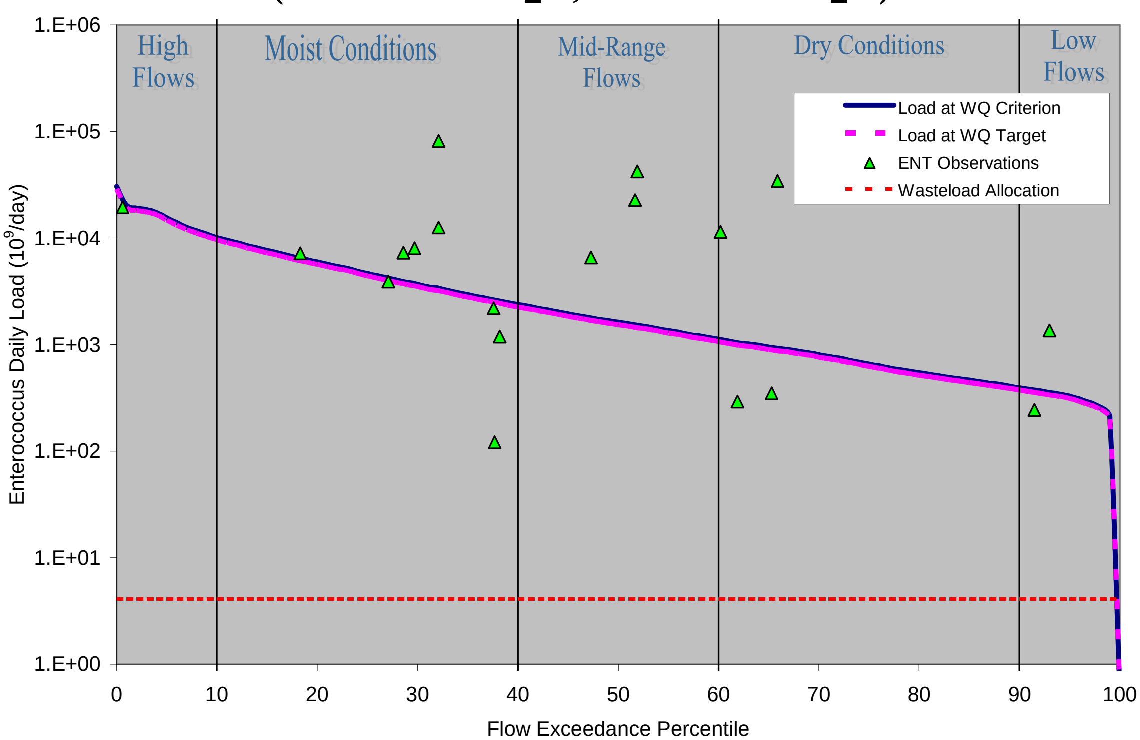
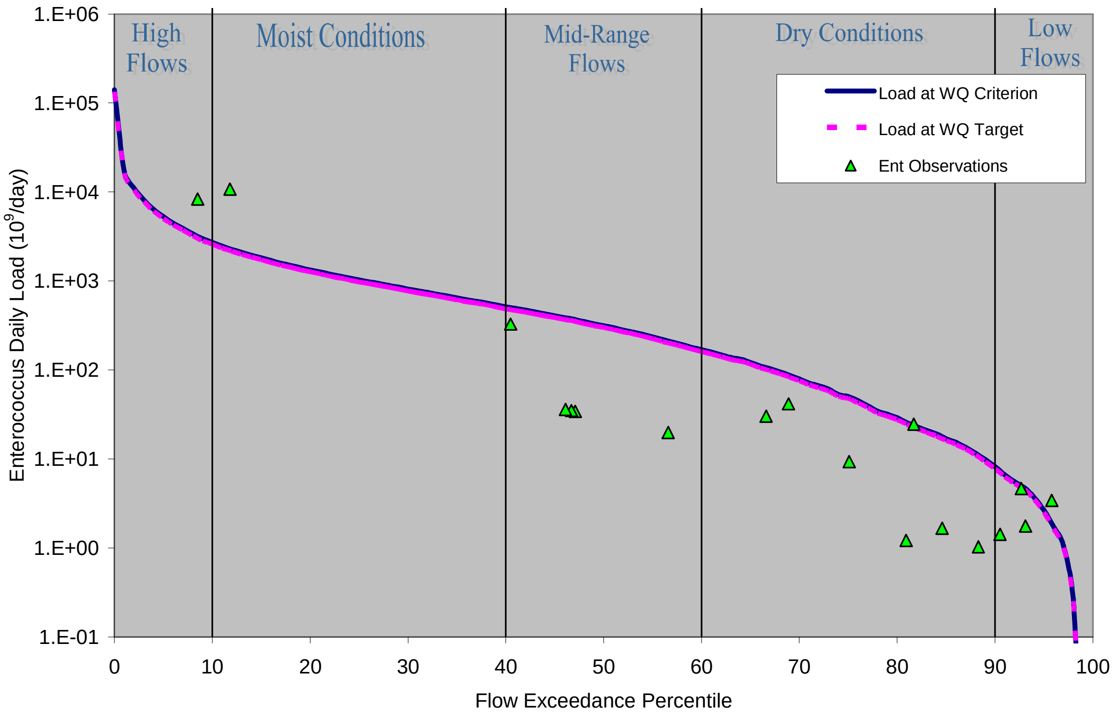
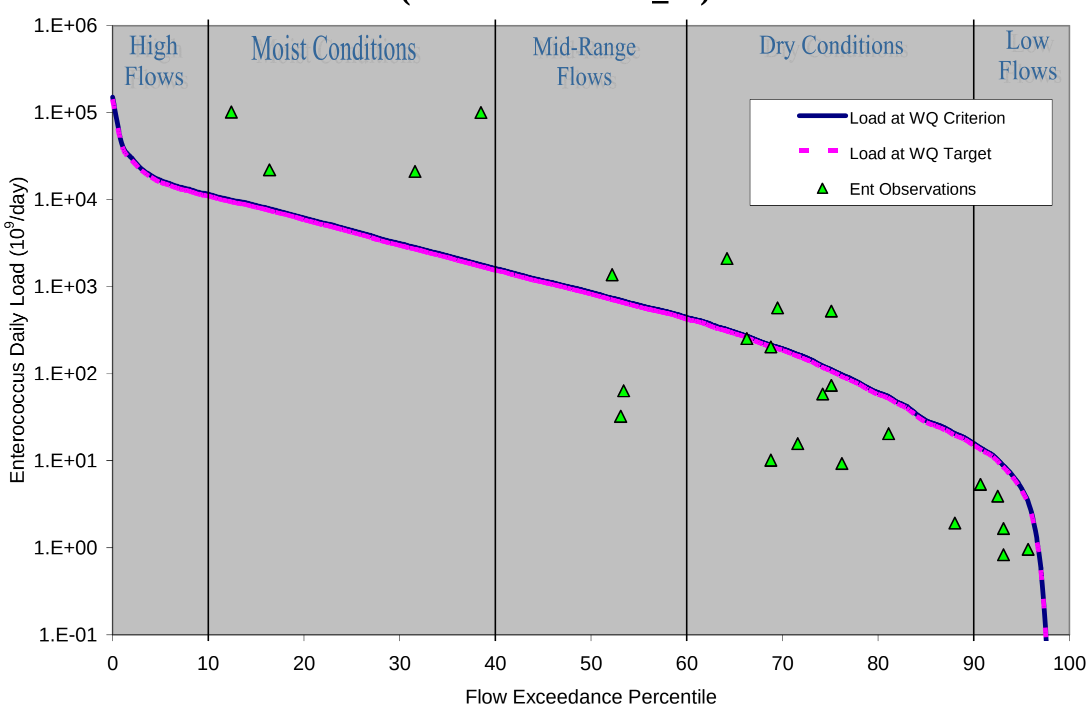


Figure 5-3 Load Duration Curve for Enterococci in Glover River (OK410210080010_00)



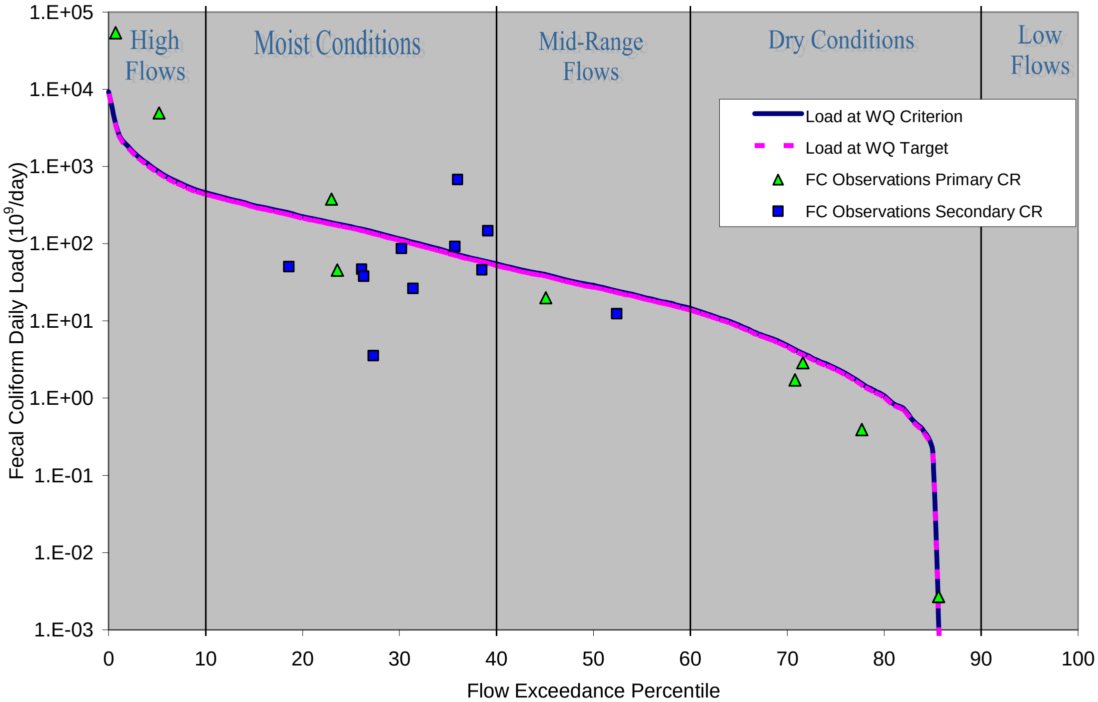
* there is no wasteload allocation for this waterbody

Figure 5-4 Load Duration Curve for Enterococci in Kiamichi River (OK410300030010_20)



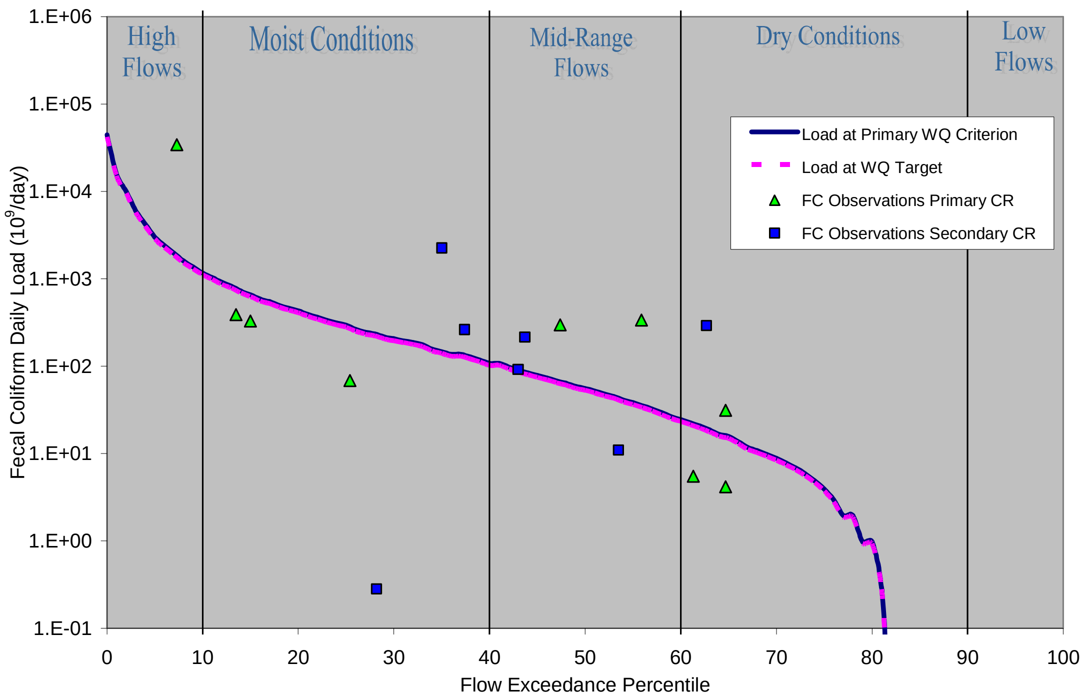
* there is no wasteload allocation for this waterbody

Figure 5-5 Load Duration Curve for Fecal Coliform in Dumpling Creek (OK410300030210_00)



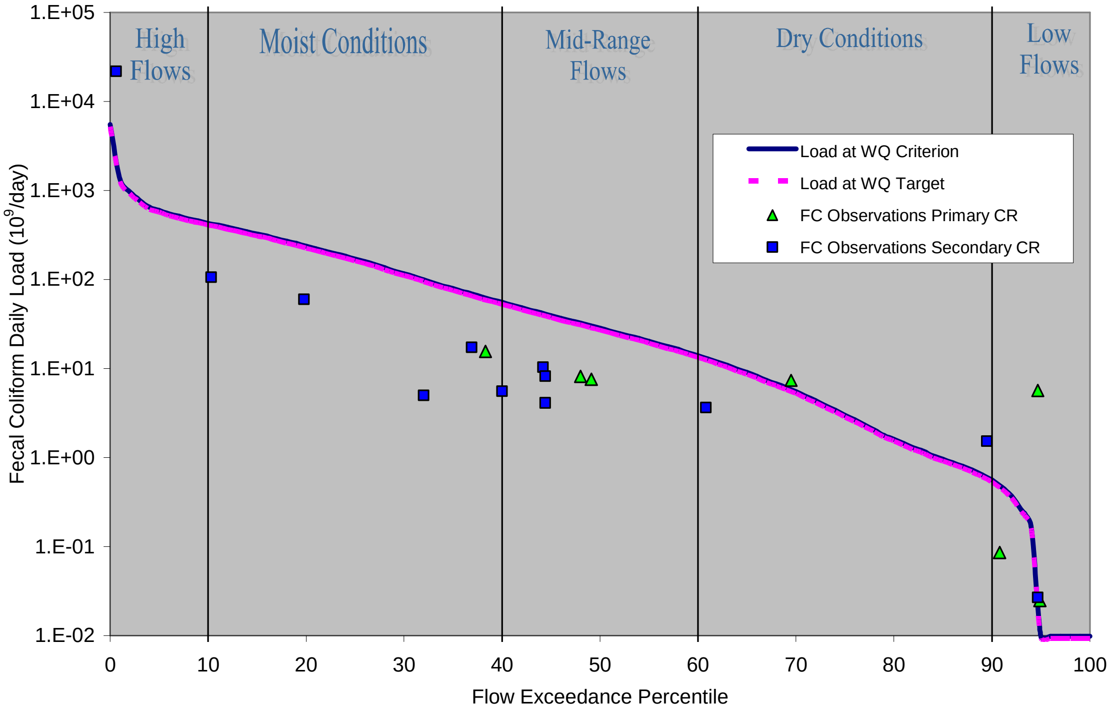
* there is no wasteload allocation for this waterbody

Figure 5-6 Load Duration Curve for Fecal Coliform in Tenmile Creek (OK410300030270_00)



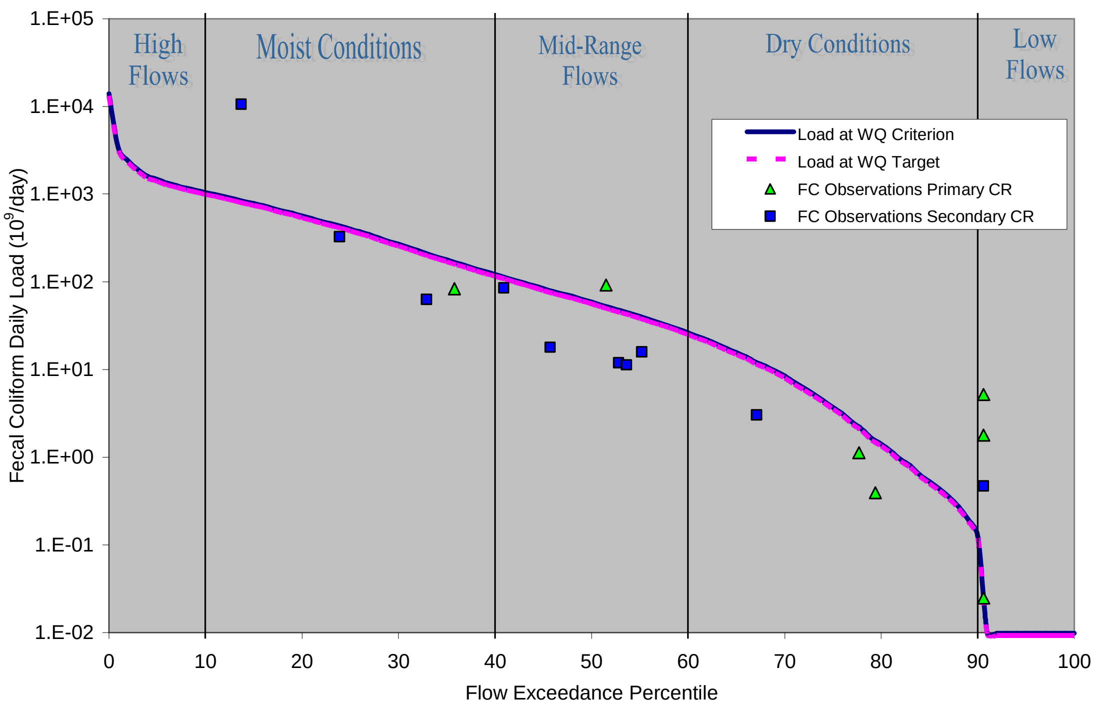
* there is no wasteload allocation for this waterbody

Figure 5-7 Load Duration Curve for Fecal Coliform in Dry Creek (OK410310010070_00)



* there is no wasteload allocation for this waterbody

Figure 5-8 Load Duration Curve for Fecal Coliform in Bolen Creek (OK410310030090_00)



* there is no wasteload allocation for this waterbody

5.2 Wasteload Allocation

NPDES-permitted facilities are allocated a daily wasteload calculated as their permitted maximum discharge flow rate multiplied by their monthly average permit limit which is equal to the appropriate geometric mean water quality criterion.

For the purposes of the TMDLs calculated in this chapter only facility types identified in Table 3-1 as Sewerage Systems are assumed to contribute bacteria loads within the watersheds of the impaired waterbodies. There are no Sewerage Systems in this Study Area.

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES WWTPs discharging into the contributing watershed of a WQM station, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform limits and disinfection requirements of NPDES permits.

Permitted stormwater discharges are considered as point sources. However, there are no permitted stormwater discharges in the Study Area.

5.3 Load Allocation

As discussed in Section 3, nonpoint source bacteria loading to the receiving streams of each waterbody emanate from a number of different sources. The data analysis and the LDCs demonstrate that exceedances at the WQM stations are the result of a variety of nonpoint source loading. The LAs for each stream segment are calculated as the difference between the TMDL, MOS, and WLA, as follows:

$$LA = TMDL - \sum WLA - MOS$$

5.4 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS which limits the PBCR use to the period of May 1st through September 30th. Seasonal variation was also accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.5 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include a MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable pollutant loading to ensure WQSs are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the MOS is considered explicit.

For the explicit MOS the water quality target was set at 10 percent lower than the water quality criterion for each pathogen which equates to 360 cfu/100 mL, 365.4 cfu/100 mL, and

97.2/100 mL for fecal coliform, *E. coli*, and Enterococci, respectively. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each waterbody is slightly reduced. These TMDLs incorporate an explicit MOS by using a curve representing 90 percent of the TMDL as the average MOS. The MOS at any given percent flow exceedance, therefore, can be defined as the difference in loading between the TMDL and the TMDL with MOS. The use of instream bacteria concentrations to estimate existing loading is another conservative element utilized in these TMDLs that can be recognized as an implicit MOS. This conservative approach to establishing the MOS will ensure that both the 30-day geometric mean and instantaneous bacteria standards can be achieved and maintained.

5.6 TMDL Calculations

The bacteria TMDLs for the 303(d)-listed WQM stations covered in this report were derived using LDCs. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for uncertainty concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS$$

For each stream segment the TMDLs presented in this report are expressed as a percent reduction across the full range of flow conditions. The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5th flow interval percentile (Tables 5-3 through 5-10). For illustrative purposes, the TMDL, WLA, LA, and MOS are calculated for the median flow at each site in Table 5-2. The WLA component of each TMDL is the sum of all WLAs within the contributing watershed of each WQM station. The sum of the WLAs can be represented as a single line below the LDC. The LDC and the simple equation of:

$$Average\ LA = average\ TMDL - MOS - \sum WLA$$

can provide an individual value for the LA in counts per day, which represents the area under the TMDL target line and above the WLA line. Where there are no point sources the WLA is zero. The LDCs and TMDL calculations for additional bacterial indicators are provided in Appendix D.

Table 5-2 TMDL Summary Examples

Waterbody	Indicator Bacteria Species	TMDL† (cfu/day)	WLA† (cfu/day)	LA† (cfu/day)	MOS† (cfu/day)
Little River	Enterococci	3.84E+11	0	3.45E+11	3.84E+10
Little River-Mountain Fork	Enterococci	1.62E+12	0	1.45E+12	1.62E+11
Glover River	Enterococci	3.14E+11	0	2.83E+11	3.14E+10
Kiamichi River	Enterococci	8.64E+11	0	7.78E+11	8.64E+11
Dumpling Creek	Fecal Coliform	2.88E+10	0	2.59E+10	2.88E+09
Tenmile Creek	Fecal Coliform	5.58E+10	0	5.02E+10	5.58E+09
Dry Creek	Fecal Coliform	2.83E+10	0	2.55E+10	2.83E+09
Bolen Creek	Fecal Coliform	5.87E+10	0	5.29E+10	5.87E+09

† Derived for illustrative purposes at the median flow value

Table 5-3 Enterococci TMDL Calculations for Little River (OK410210020140_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	63720	1.68E+14	0	1.52E+14	1.68E+13
5	2412	6.37E+12	0	5.74E+12	6.37E+11
10	1236	3.27E+12	0	2.94E+12	3.27E+11
15	827	2.18E+12	0	1.97E+12	2.18E+11
20	604	1.59E+12	0	1.44E+12	1.59E+11
25	468	1.24E+12	0	1.11E+12	1.24E+11
30	371	9.80E+11	0	8.82E+11	9.80E+10
35	294	7.77E+11	0	6.99E+11	7.77E+10
40	234	6.18E+11	0	5.56E+11	6.18E+10
45	186	4.91E+11	0	4.42E+11	4.91E+10
50	145	3.84E+11	0	3.45E+11	3.84E+10
55	109	2.89E+11	0	2.60E+11	2.89E+10
60	79.2	2.09E+11	0	1.88E+11	2.09E+10
65	57.6	1.52E+11	0	1.37E+11	1.52E+10
70	37.2	9.83E+10	0	8.85E+10	9.83E+09
75	22.8	6.02E+10	0	5.42E+10	6.02E+09
80	13.2	3.49E+10	0	3.14E+10	3.49E+09
85	7.8	2.06E+10	0	1.85E+10	2.06E+09
90	3.8	9.96E+09	0	8.96E+09	9.96E+08
95	1.3	3.49E+09	0	3.14E+09	3.49E+08
95	1.3	3.49E+09	0	3.14E+09	3.49E+08
100	0	0.00E+00	0	0.00E+00	0.00E+00

Table 5-4 Enterococci TMDL Calculations for Little River -Mountain Fork (OK410210040010_00, OK410210040010_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	11500	3.04E+13	4.09E+09	2.73E+13	3.04E+12
5	5842	1.54E+13	4.09E+09	1.39E+13	1.54E+12
10	3820	1.01E+13	4.09E+09	9.08E+12	1.01E+12
15	2880	7.61E+12	4.09E+09	6.84E+12	7.61E+11
20	2250	5.95E+12	4.09E+09	5.35E+12	5.95E+11
25	1750	4.62E+12	4.09E+09	4.16E+12	4.62E+11
30	1390	3.67E+12	4.09E+09	3.30E+12	3.67E+11
35	1110	2.93E+12	4.09E+09	2.64E+12	2.93E+11
40	896.8	2.37E+12	4.09E+09	2.13E+12	2.37E+11
45	733	1.94E+12	4.09E+09	1.74E+12	1.94E+11
50	612	1.62E+12	4.09E+09	1.45E+12	1.62E+11
55	511	1.35E+12	4.09E+09	1.21E+12	1.35E+11
60	425	1.12E+12	4.09E+09	1.01E+12	1.12E+11
65	358	9.46E+11	4.09E+09	8.47E+11	9.46E+10
70	303	8.01E+11	4.09E+09	7.16E+11	8.01E+10
75	248	6.55E+11	4.09E+09	5.86E+11	6.55E+10
80	205	5.42E+11	4.09E+09	4.83E+11	5.42E+10
85	175	4.62E+11	4.09E+09	4.12E+11	4.62E+10
90	149	3.94E+11	4.09E+09	3.50E+11	3.94E+10
95	124	3.28E+11	4.09E+09	2.91E+11	3.28E+10
100	0.21	5.55E+08	4.99E+08	0.00E+00	5.55E+07

Table 5-5 Enterococci TMDL Calculations for Glover River (OK410210080010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	53100	1.40E+14	0	1.26E+14	1.40E+13
5	2000	5.28E+12	0	4.76E+12	5.28E+11
10	1030	2.72E+12	0	2.45E+12	2.72E+11
15	688	1.82E+12	0	1.64E+12	1.82E+11
20	502	1.33E+12	0	1.19E+12	1.33E+11
25	389	1.03E+12	0	9.25E+11	1.03E+11
30	308	8.13E+11	0	7.31E+11	8.13E+10
35	244	6.45E+11	0	5.80E+11	6.45E+10
40	194	5.13E+11	0	4.61E+11	5.13E+10
45	154	4.07E+11	0	3.66E+11	4.07E+10
50	119	3.14E+11	0	2.83E+11	3.14E+10
55	89	2.35E+11	0	2.12E+11	2.35E+10
60	64	1.69E+11	0	1.52E+11	1.69E+10
65	46	1.22E+11	0	1.09E+11	1.22E+10
70	30	7.93E+10	0	7.13E+10	7.93E+09
75	19	5.02E+10	0	4.52E+10	5.02E+09
80	11	2.91E+10	0	2.62E+10	2.91E+09
85	6.4	1.69E+10	0	1.52E+10	1.69E+09
90	3.1	8.19E+09	0	7.37E+09	8.19E+08
95	1	2.64E+09	0	2.38E+09	2.64E+08
100	0	0.00E+00	0	0.00E+00	0.00E+00

Table 5-6 Enterococci TMDL Calculations for Kiamichi River (OK410300030010_20)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	57000	1.51E+14	0	1.36E+14	1.51E+13
5	6340	1.68E+13	0	1.51E+13	1.68E+12
10	4375	1.16E+13	0	1.04E+13	1.16E+12
15	3250	8.59E+12	0	7.73E+12	8.59E+11
20	2340	6.18E+12	0	5.56E+12	6.18E+11
25	1680	4.44E+12	0	4.00E+12	4.44E+11
30	1190	3.14E+12	0	2.83E+12	3.14E+11
35	861	2.28E+12	0	2.05E+12	2.28E+11
40	613	1.62E+12	0	1.46E+12	1.62E+11
45	447	1.18E+12	0	1.06E+12	1.18E+11
50	327	8.64E+11	0	7.78E+11	8.64E+10
55	233.25	6.16E+11	0	5.55E+11	6.16E+10
60	168	4.44E+11	0	4.00E+11	4.44E+10
65	115	3.04E+11	0	2.73E+11	3.04E+10
70	74	1.96E+11	0	1.76E+11	1.96E+10
75	43	1.14E+11	0	1.02E+11	1.14E+10
80	23	6.08E+10	0	5.47E+10	6.08E+09
85	11	2.91E+10	0	2.62E+10	2.91E+09
90	6	1.59E+10	0	1.43E+10	1.59E+09
95	1.8	4.76E+09	0	4.28E+09	4.76E+08
100	0	0.00E+00	0	0.00E+00	0.00E+00

Table 5-7 Fecal Coliform TMDL Calculations for Dumpling Creek (OK410300030210_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	943	9.23E+12	0	8.31E+12	9.23E+11
5	90.4	8.85E+11	0	7.97E+11	8.85E+10
10	46.6	4.56E+11	0	4.11E+11	4.56E+10
15	31.8	3.11E+11	0	2.80E+11	3.11E+10
20	22.9	2.24E+11	0	2.02E+11	2.24E+10
25	16.9	1.66E+11	0	1.49E+11	1.66E+10
30	11.9	1.16E+11	0	1.05E+11	1.16E+10
35	8.0	7.85E+10	0	7.06E+10	7.85E+09
40	5.6	5.46E+10	0	4.92E+10	5.46E+09
45	4.1	4.00E+10	0	3.60E+10	4.00E+09
50	2.9	2.88E+10	0	2.59E+10	2.88E+09
55	2.1	2.05E+10	0	1.84E+10	2.05E+09
60	1.5	1.45E+10	0	1.30E+10	1.45E+09
65	0.90	8.83E+09	0	7.94E+09	8.83E+08
70	0.49	4.81E+09	0	4.33E+09	4.81E+08
75	0.25	2.44E+09	0	2.20E+09	2.44E+08
80	0.11	1.08E+09	0	9.71E+08	1.08E+08
85	0.02	2.03E+08	0	1.83E+08	2.03E+07
90	0	0.00E+00	0	0.00E+00	0.00E+00
95	0	0.00E+00	0	0.00E+00	0.00E+00
100	0	0.00E+00	0	0.00E+00	0.00E+00

Table 5-8 Fecal Coliform TMDL Calculations for Tenmile Creek (OK410300030270_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	4540	4.44E+13	0	4.00E+13	4.44E+12
5	306	2.99E+12	0	2.70E+12	2.99E+11
10	119	1.17E+12	0	1.05E+12	1.17E+11
15	67	6.56E+11	0	5.90E+11	6.56E+10
20	44	4.31E+11	0	3.88E+11	4.31E+10
25	30	2.94E+11	0	2.64E+11	2.94E+10
30	21	2.06E+11	0	1.85E+11	2.06E+10
35	15	1.47E+11	0	1.32E+11	1.47E+10
40	11	1.08E+11	0	9.69E+10	1.08E+10
45	8.0	7.83E+10	0	7.05E+10	7.83E+09
50	5.7	5.58E+10	0	5.02E+10	5.58E+09
55	3.9	3.82E+10	0	3.43E+10	3.82E+09
60	2.5	2.45E+10	0	2.20E+10	2.45E+09
65	1.6	1.57E+10	0	1.41E+10	1.57E+09
70	0.9	8.81E+09	0	7.93E+09	8.81E+08
75	0.4	3.91E+09	0	3.52E+09	3.91E+08
80	0.1	9.79E+08	0	8.81E+08	9.79E+07
85	0	0.00E+00	0	0.00E+00	0.00E+00
90	0	0.00E+00	0	0.00E+00	0.00E+00
95	0	0.00E+00	0	0.00E+00	0.00E+00
100	0	0.00E+00	0	0.00E+00	0.00E+00

Table 5-9 Fecal Coliform TMDL Calculations for Dry Creek (OK410310010070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	562	5.50E+12	0	4.95E+12	5.50E+11
5	61	6.00E+11	0	5.40E+11	6.00E+10
10	44	4.28E+11	0	3.86E+11	4.28E+10
15	33	3.24E+11	0	2.91E+11	3.24E+10
20	24	2.36E+11	0	2.12E+11	2.36E+10
25	17	1.69E+11	0	1.53E+11	1.69E+10
30	12	1.16E+11	0	1.05E+11	1.16E+10
35	8.1	7.91E+10	0	7.12E+10	7.91E+09
40	5.7	5.53E+10	0	4.98E+10	5.53E+09
45	4.0	3.91E+10	0	3.52E+10	3.91E+09
50	2.9	2.83E+10	0	2.55E+10	2.83E+09
55	2.1	2.02E+10	0	1.82E+10	2.02E+09
60	1.4	1.40E+10	0	1.26E+10	1.40E+09
65	0.9	9.01E+09	0	8.11E+09	9.01E+08
70	0.56	5.49E+09	0	4.94E+09	5.49E+08
75	0.30	2.98E+09	0	2.68E+09	2.98E+08
80	0.16	1.61E+09	0	1.44E+09	1.61E+08
85	0.10	9.55E+08	0	8.60E+08	9.55E+07
90	0.06	5.56E+08	0	5.01E+08	5.56E+07
95	0	0.00E+00	0	0.00E+00	0.00E+00
100	0	0.00E+00	0	0.00E+00	0.00E+00

Table 5-10 Fecal Coliform TMDL Calculations for Bolen Creek (OK410310030090_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1422	1.39E+13	0	1.25E+13	1.39E+12
5	150	1.47E+12	0	1.32E+12	1.47E+11
10	106	1.04E+12	0	9.35E+11	1.04E+11
15	80	7.78E+11	0	7.01E+11	7.78E+10
20	57	5.61E+11	0	5.05E+11	5.61E+10
25	41	3.97E+11	0	3.57E+11	3.97E+10
30	27	2.69E+11	0	2.42E+11	2.69E+10
35	18	1.78E+11	0	1.60E+11	1.78E+10
40	12	1.22E+11	0	1.09E+11	1.22E+10
45	8.5	8.33E+10	0	7.50E+10	8.33E+09
50	6.0	5.87E+10	0	5.29E+10	5.87E+09
55	4.1	4.02E+10	0	3.62E+10	4.02E+09
60	2.7	2.63E+10	0	2.36E+10	2.63E+09
65	1.6	1.55E+10	0	1.40E+10	1.55E+09
70	0.86	8.39E+09	0	7.55E+09	8.39E+08
75	0.38	3.69E+09	0	3.32E+09	3.69E+08
80	0.14	1.41E+09	0	1.27E+09	1.41E+08
85	0.05	5.26E+08	0	4.73E+08	5.26E+07
90	0.01	1.25E+08	0	1.13E+08	1.25E+07
95	0	0.00E+00	0	0.00E+00	0.00E+00
100	0	0.00E+00	0	0.00E+00	0.00E+00

5.7 Reasonable Assurances

ODEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources provide reasonable assurance that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. ODEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (ODEQ 2002). The CPP can be viewed from ODEQ's website at http://www.deq.state.ok.us/WQDnew/pubs/2002_cpp_final.pdf. Table 5-11 provides a partial list of the state partner agencies ODEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-11 Partial List of Oklahoma Water Quality Management Agencies

Agency	Web Link
Oklahoma Conservation Commission	http://www.okcc.state.ok.us/WQ/WQ_home.htm
Oklahoma Department of Wildlife Conservation	http://www.wildlifedepartment.com/watchabl.htm
Oklahoma Department of Agriculture, Food, and Forestry	http://www.oda.state.ok.us/water-home.htm
Oklahoma Water Resources Board	http://www.owrb.state.ok.us/quality/index.php

Nonpoint source pollution is regulated by the Oklahoma Conservation Commission. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach. Other programs include regulations and permits for CAFOs. The CAFO Act, as administered by the ODAFF, provides CAFO operators the necessary tools and information to deal with the manure and wastewater animals produce so streams, lakes, ponds, and groundwater sources are not polluted.

As authorized by Section 402 of the CWA, the ODEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by State Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES Program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES Program. Implementation of point source WLAs is done through permits issued under the OPDES program.

The reduction rates called for in this TMDL report are as high as 95 percent. The ODEQ recognizes that achieving such high reductions may not be realistic, especially since unregulated nonpoint sources are a major cause of the impairment. The high reduction rates are not uncommon for pathogen-impaired waters. Similar reduction rates are often found in other pathogen TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of the receiving stream should be reviewed. For example, the Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the USEPA. Additionally, USEPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the near future.

Revisions to the current pathogen provisions of Oklahoma's WQSs should be considered. There are three basic approaches to such revisions that may apply.

- **Removing the PBCR use:** This revision would require documentation in a Use Attainability Analysis that the use is not existing and cannot be attained. It is unlikely that this approach would be successful since there is evidence that people do swim in this segment of the river, thus constituting an existing use. Existing uses cannot be removed.

- **Modifying application of the existing criteria:** This approach would include considerations such as an exemption under certain high flow conditions, an allowance for wildlife or "natural conditions," a sub-category of the use or other special provision for urban areas, or other special provisions for storm flows. Since large bacteria violations occur over all flow ranges, it is likely that large reductions would still be necessary. However, this approach may have merit and should be considered.
- **Revising the existing numeric criteria:** Oklahoma's current pathogen criteria are based on USEPA guidelines (See Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft; and Ambient Water Quality Criteria for Bacteria-1986, January 1986). However, those guidelines have received much criticism and USEPA studies that could result in revisions to their recommendations are ongoing. The use of the three indicators specified in Oklahoma's standards should be evaluated. The numeric criteria values should also be evaluated using a risk-based method such as that found in USEPA guidance.

Unless or until the WQSs are revised and approved by USEPA, federal rules require that the TMDLs in this report must be based on attainment of the current standards. If revisions to the pathogen standards are approved in the future, reductions specified in these TMDLs will be re-evaluated.

SECTION 6
PUBLIC PARTICIPATION

This TMDL report was sent to other related state agencies and local government agencies for peer review and was also submitted to the EPA for technical review. There is no comments received from peer review. The report was technically approved by the EPA on July 3, 2007 with one comment on priority ranking of impaired stream segment. After updating the report according to the EPA's comment, the TMDL report was made available for public from July 27, 2007 through September 10, 2007. A public meeting was held in Antlers, Oklahoma on August 21, 2007. Seven people attended the public meeting.

At the end of public comment period, no comments were received.

SECTION 7
REFERENCES

American Veterinary Medical Association 2002. U.S. Pet Ownership and Demographics Sourcebook (2002 Edition). Schaumberg, IL.

ASAE (American Society of Agricultural Engineers). 1999. ASAE standards, 46th edition: standards, engineering practices, data. St. Joseph, MI.

Canter, LW and RC Knox 1985. Septic tank system effects on ground water quality. Lewis Publishers, Boca Raton, FL.

Cleland 2003. Cleland, B. TMDL Development from the "Bottom Up" – Part III: Duration Curves and Wet-Weather Assessments. Water Environment Federation National TMDL Science and Policy Conference 2003. Chicago, IL.

Cogger, CG and BL Carlile 1984. Field performance of conventional and alternative septic systems in wet soils. *J. Environ. Qual*. 13 (1).

Drapcho, C.M. and A.K.B. Hubbs 2002. Fecal Coliform Concentration in Runoff from Fields with Applied Dairy Manure. http://www.lwrri.lsu.edu/downloads/drapcho Annual%20report01.02.pdf

Hall, S. 2002. Washington State Department of Health, Wastewater Management Program Rule Development Committee, Issue Research Report - Failing Systems, June 2002.

Metcalf and Eddy 1991. Wastewater Engineering: Treatment, Disposal, Reuse: 2nd Edition.

ODAFF 2005. http://www.state.ok.us/~okag/water-home.htm

ODEQ 2002. The State of Oklahoma 2002 Continuing Planning Process. 2002.

ODEQ 2004. *The State of Oklahoma 2004 Water Quality Assessment Integrated Report*. 2004.

ODEQ 2004a. Oklahoma Department of Environmental Quality. *Individual and Small Public On-site Sewage Treatment Systems* Title 252, Chapter 641, 2004.

Oklahoma Climate Survey 2005. Viewed August 29, 2005 in http://climate.ocs.ou.edu/county climate/Products/County_Climatologies/

OWRB 2006. Oklahoma Water Resources Board. *2006 Water Quality Standards*.

OWRB 2007. Oklahoma Water Resources Board. Viewed June 1, 2007. Implementation of Oklahoma's Water Quality Standards (Chapter 46)

Reed, Stowe &Yanke, LLC 2001. *Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas*. September 2001.

Schueler, TR 2000. Microbes and Urban Watersheds: Concentrations, Sources, and Pathways. In *The Practice of Watershed Protection*, TR Schueler and HK Holland, eds. Center for Watershed Protection, Ellicott City, MD.

University of Florida 1987. Institute of Food and Agricultural Sciences, University Of Florida, Florida Cooperative Extension Service, No. 31, December, 1987.

U.S. Census Bureau 1995. http://www.census.gov/.

U.S. Census Bureau 2000. http://www.census.gov/main/www/cen2000.html

USDA 2002, Census of Agriculture, National Agricultural Statistics Service, United States Department of Agriculture.

USEPA 1983. Final Report of the Nationwide Urban Runoff Program. U.S. Environmental Protection Agency, Water Planning Division.

USEPA 1991. Guidance for Water Quality-. Based Decisions: The TMDL Process. Office of Water, USEPA 440/4-91-001.

USEPA 2001. 2001 Protocol for Developing Pathogen TMDLs. First Edition. Office of Water, USEPA 841-R-00-002.

USEPA 2003. Guidance for 2004 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d) and 305(b) of the Clean Water Act, TMDL -01-03 - Diane Regas-- July 21, 2003.

USGS 2007. Multi-Resolution Land Characteristics Consortium. http://www.mrlc.gov/index.asp

USGS 2007a. USGS Daily Streamflow Data. http://waterdata.usgs.gov/nwis/sw

APPENDIX A
AMBIENT WATER QUALITY BACTERIA DATA – 1999 TO 2003

Appendix A

Ambient Water Quality Bacteria Data – 1999 to 2003

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410210020140-001AT	Little River	6/23/1999	40	FC	400
OK410210020140-001AT	Little River	7/7/1999	180	FC	400
OK410210020140-001AT	Little River	8/4/1999	40	FC	400
OK410210020140-001AT	Little River	9/8/1999	37000	FC	400
OK410210020140-001AT	Little River	5/9/2000	310	FC	400
OK410210020140-001AT	Little River	6/6/2000	240	FC	400
OK410210020140-001AT	Little River	7/11/2000	20	FC	400
OK410210020140-001AT	Little River	8/22/2000	110	FC	400
OK410210020140-001AT	Little River	6/20/2001	10	FC	400
OK410210020140-001AT	Little River	7/25/2001	5	FC	400
OK410210020140-001AT	Little River	8/21/2001	10	FC	400
OK410210020140-001AT	Little River	9/18/2001	500	FC	400
OK410210020140-001AT	Little River	7/24/2002	20	FC	400
OK410210020140-001AT	Little River	9/11/2002	700	FC	400
OK410210020140-001AT	Little River	5/5/2003	20	FC	400
OK410210020140-001AT	Little River	5/21/2003	20	FC	400
OK410210020140-001AT	Little River	6/9/2003	130	FC	400
OK410210020140-001AT	Little River	6/25/2003	90	FC	400
OK410210020140-001AT	Little River	7/14/2003	50	FC	400
OK410210020140-001AT	Little River	8/18/2003	70	FC	400
OK410210020140-001AT	Little River	9/3/2003	100	FC	400
OK410210020140-001AT	Little River	9/22/2003	30	FC	400
OK410210020140-001AT	Little River	6/23/1999	189	EC	406
OK410210020140-001AT	Little River	7/7/1999	110	EC	406
OK410210020140-001AT	Little River	8/4/1999	5	EC	406
OK410210020140-001AT	Little River	9/8/1999	432	EC	406
OK410210020140-001AT	Little River	5/9/2000	145	EC	406
OK410210020140-001AT	Little River	6/6/2000	161	EC	406
OK410210020140-001AT	Little River	7/11/2000	5	EC	406
OK410210020140-001AT	Little River	8/22/2000	5	EC	406
OK410210020140-001AT	Little River	5/23/2001	262	EC	406
OK410210020140-001AT	Little River	6/20/2001	20	EC	406
OK410210020140-001AT	Little River	7/25/2001	5	EC	406
OK410210020140-001AT	Little River	8/21/2001	5	EC	406
OK410210020140-001AT	Little River	9/18/2001	457	EC	406
OK410210020140-001AT	Little River	7/24/2002	10	EC	406
OK410210020140-001AT	Little River	9/11/2002	10	EC	406
OK410210020140-001AT	Little River	5/5/2003	10	EC	406
OK410210020140-001AT	Little River	5/21/2003	10	EC	406
OK410210020140-001AT	Little River	6/9/2003	105	EC	406
OK410210020140-001AT	Little River	6/25/2003	74	EC	406

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410210020140-001AT	Little River	7/14/2003	10	EC	406
OK410210020140-001AT	Little River	8/18/2003	127	EC	406
OK410210020140-001AT	Little River	9/3/2003	10	EC	406
OK410210020140-001AT	Little River	9/22/2003	30	EC	406
OK410210020140-001AT	Little River	6/23/1999	110	ENT	108
OK410210020140-001AT	Little River	7/7/1999	100	ENT	108
OK410210020140-001AT	Little River	8/4/1999	5	ENT	108
OK410210020140-001AT	Little River	9/8/1999	130	ENT	108
OK410210020140-001AT	Little River	5/9/2000	220	ENT	108
OK410210020140-001AT	Little River	6/6/2000	200	ENT	108
OK410210020140-001AT	Little River	7/11/2000	100	ENT	108
OK410210020140-001AT	Little River	8/22/2000	8000	ENT	108
OK410210020140-001AT	Little River	5/23/2001	100	ENT	108
OK410210020140-001AT	Little River	6/20/2001	20	ENT	108
OK410210020140-001AT	Little River	7/25/2001	80	ENT	108
OK410210020140-001AT	Little River	8/21/2001	70	ENT	108
OK410210020140-001AT	Little River	9/18/2001	500	ENT	108
OK410210020140-001AT	Little River	7/24/2002	130	ENT	108
OK410210020140-001AT	Little River	9/11/2002	20	ENT	108
OK410210020140-001AT	Little River	5/5/2003	100	ENT	108
OK410210020140-001AT	Little River	5/21/2003	100	ENT	108
OK410210020140-001AT	Little River	6/9/2003	150	ENT	108
OK410210020140-001AT	Little River	6/25/2003	140	ENT	108
OK410210020140-001AT	Little River	7/14/2003	700	ENT	108
OK410210020140-001AT	Little River	8/18/2003	2800	ENT	108
OK410210020140-001AT	Little River	9/3/2003	700	ENT	108
OK410210020140-001AT	Little River	9/22/2003	20	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	6/8/1999	710	FC	400
OK410210040010-001AT	Little River-Mountain Fork	7/7/1999	80	FC	400
OK410210040010-001AT	Little River-Mountain Fork	8/4/1999	20	FC	400
OK410210040010-001AT	Little River-Mountain Fork	9/8/1999	360	FC	400
OK410210040010-001AT	Little River-Mountain Fork	5/2/2000	140	FC	400
OK410210040010-001AT	Little River-Mountain Fork	6/6/2000	50	FC	400
OK410210040010-001AT	Little River-Mountain Fork	7/11/2000	150	FC	400
OK410210040010-001AT	Little River-Mountain Fork	8/22/2000	70	FC	400
OK410210040010-001AT	Little River-Mountain Fork	9/7/2000	5	FC	400
OK410210040010-001AT	Little River-Mountain Fork	5/23/2001	3000	FC	400
OK410210040010-001AT	Little River-Mountain Fork	6/20/2001	300	FC	400
OK410210040010-001AT	Little River-Mountain Fork	7/25/2001	40	FC	400
OK410210040010-001AT	Little River-Mountain Fork	5/22/2002	20	FC	400
OK410210040010-001AT	Little River-Mountain Fork	6/18/2002	70	FC	400
OK410210040010-001AT	Little River-Mountain Fork	7/23/2002	30	FC	400
OK410210040010-001AT	Little River-Mountain Fork	9/11/2002	200	FC	400

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410210040010-001AT	Little River-Mountain Fork	5/20/2003	40	FC	400
OK410210040010-001AT	Little River-Mountain Fork	6/8/1999	327	EC	406
OK410210040010-001AT	Little River-Mountain Fork	7/7/1999	85	EC	406
OK410210040010-001AT	Little River-Mountain Fork	8/4/1999	5	EC	406
OK410210040010-001AT	Little River-Mountain Fork	9/8/1999	41	EC	406
OK410210040010-001AT	Little River-Mountain Fork	5/2/2000	52	EC	406
OK410210040010-001AT	Little River-Mountain Fork	6/6/2000	63	EC	406
OK410210040010-001AT	Little River-Mountain Fork	7/11/2000	10	EC	406
OK410210040010-001AT	Little River-Mountain Fork	8/22/2000	31	EC	406
OK410210040010-001AT	Little River-Mountain Fork	9/7/2000	52	EC	406
OK410210040010-001AT	Little River-Mountain Fork	5/23/2001	52	EC	406
OK410210040010-001AT	Little River-Mountain Fork	6/20/2001	86	EC	406
OK410210040010-001AT	Little River-Mountain Fork	7/25/2001	10	EC	406
OK410210040010-001AT	Little River-Mountain Fork	8/21/2001	1956	EC	406
OK410210040010-001AT	Little River-Mountain Fork	9/18/2001	130	EC	406
OK410210040010-001AT	Little River-Mountain Fork	5/22/2002	10	EC	406
OK410210040010-001AT	Little River-Mountain Fork	6/18/2002	10	EC	406
OK410210040010-001AT	Little River-Mountain Fork	7/23/2002	31	EC	406
OK410210040010-001AT	Little River-Mountain Fork	9/11/2002	20	EC	406
OK410210040010-001AT	Little River-Mountain Fork	5/20/2003	10	EC	406
OK410210040010-001AT	Little River-Mountain Fork	6/8/1999	230	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	7/7/1999	100	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	8/4/1999	5	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	9/8/1999	50	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	5/2/2000	410	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	6/6/2000	100	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	7/11/2000	120	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	8/22/2000	1600	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	9/7/2000	400	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	5/23/2001	70	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	6/20/2001	90	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	7/25/2001	30	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	8/21/2001	4000	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	9/18/2001	200	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	5/22/2002	1100	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	6/18/2002	40	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	7/23/2002	2600	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	9/11/2002	3000	ENT	108
OK410210040010-001AT	Little River-Mountain Fork	5/20/2003	400	ENT	108
OK410210080010-001AT	Glover River	6/8/1999	50	FC	400
OK410210080010-001AT	Glover River	7/7/1999	120	FC	400
OK410210080010-001AT	Glover River	8/4/1999	30	FC	400
OK410210080010-001AT	Glover River	9/8/1999	380	FC	400

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410210080010-001AT	Glover River	6/6/2000	560	FC	400
OK410210080010-001AT	Glover River	7/11/2000	40	FC	400
OK410210080010-001AT	Glover River	8/22/2000	100	FC	400
OK410210080010-001AT	Glover River	9/7/2000	5	FC	400
OK410210080010-001AT	Glover River	5/23/2001	1000	FC	400
OK410210080010-001AT	Glover River	6/20/2001	5	FC	400
OK410210080010-001AT	Glover River	7/25/2001	10	FC	400
OK410210080010-001AT	Glover River	8/21/2001	100	FC	400
OK410210080010-001AT	Glover River	9/18/2001	100	FC	400
OK410210080010-001AT	Glover River	5/22/2002	40	FC	400
OK410210080010-001AT	Glover River	6/18/2002	20	FC	400
OK410210080010-001AT	Glover River	7/23/2002	50	FC	400
OK410210080010-001AT	Glover River	9/11/2002	10	FC	400
OK410210080010-001AT	Glover River	5/21/2003	10	FC	400
OK410210080010-001AT	Glover River	6/8/1999	51	EC	406
OK410210080010-001AT	Glover River	7/7/1999	74	EC	406
OK410210080010-001AT	Glover River	8/4/1999	10	EC	406
OK410210080010-001AT	Glover River	9/8/1999	197	EC	406
OK410210080010-001AT	Glover River	6/6/2000	332	EC	406
OK410210080010-001AT	Glover River	7/11/2000	20	EC	406
OK410210080010-001AT	Glover River	8/22/2000	20	EC	406
OK410210080010-001AT	Glover River	9/7/2000	74	EC	406
OK410210080010-001AT	Glover River	5/23/2001	238	EC	406
OK410210080010-001AT	Glover River	6/20/2001	10	EC	406
OK410210080010-001AT	Glover River	7/25/2001	5	EC	406
OK410210080010-001AT	Glover River	8/21/2001	5	EC	406
OK410210080010-001AT	Glover River	9/18/2001	41	EC	406
OK410210080010-001AT	Glover River	5/22/2002	30	EC	406
OK410210080010-001AT	Glover River	6/18/2002	10	EC	406
OK410210080010-001AT	Glover River	7/23/2002	10	EC	406
OK410210080010-001AT	Glover River	9/11/2002	74	EC	406
OK410210080010-001AT	Glover River	5/21/2003	20	EC	406
OK410210080010-001AT	Glover River	6/8/1999	10	ENT	108
OK410210080010-001AT	Glover River	7/7/1999	10	ENT	108
OK410210080010-001AT	Glover River	8/4/1999	5	ENT	108
OK410210080010-001AT	Glover River	9/8/1999	40	ENT	108
OK410210080010-001AT	Glover River	6/6/2000	280	ENT	108
OK410210080010-001AT	Glover River	7/11/2000	20	ENT	108
OK410210080010-001AT	Glover River	8/22/2000	100	ENT	108
OK410210080010-001AT	Glover River	9/7/2000	180	ENT	108
OK410210080010-001AT	Glover River	5/23/2001	500	ENT	108
OK410210080010-001AT	Glover River	6/20/2001	30	ENT	108
OK410210080010-001AT	Glover River	7/25/2001	10	ENT	108
OK410210080010-001AT	Glover River	8/21/2001	10	ENT	108

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410210080010-001AT	Glover River	9/18/2001	50	ENT	108
OK410210080010-001AT	Glover River	5/22/2002	10	ENT	108
OK410210080010-001AT	Glover River	6/18/2002	10	ENT	108
OK410210080010-001AT	Glover River	7/23/2002	110	ENT	108
OK410210080010-001AT	Glover River	9/11/2002	20	ENT	108
OK410210080010-001AT	Glover River	5/21/2003	70	ENT	108
OK410300030010-001AT	Kiamichi River	6/8/1999	80	FC	400
OK410300030010-001AT	Kiamichi River	7/26/1999	40	FC	400
OK410300030010-001AT	Kiamichi River	8/10/1999	20	FC	400
OK410300030010-001AT	Kiamichi River	9/28/1999	30	FC	400
OK410300030010-001AT	Kiamichi River	6/6/2000	1400	FC	400
OK410300030010-001AT	Kiamichi River	7/11/2000	40	FC	400
OK410300030010-001AT	Kiamichi River	8/22/2000	5	FC	400
OK410300030010-001AT	Kiamichi River	9/7/2000	5	FC	400
OK410300030010-001AT	Kiamichi River	5/23/2001	1700	FC	400
OK410300030010-001AT	Kiamichi River	6/20/2001	10	FC	400
OK410300030010-001AT	Kiamichi River	7/25/2001	20	FC	400
OK410300030010-001AT	Kiamichi River	8/21/2001	5	FC	400
OK410300030010-001AT	Kiamichi River	9/18/2001	400	FC	400
OK410300030010-001AT	Kiamichi River	5/22/2002	10	FC	400
OK410300030010-001AT	Kiamichi River	6/18/2002	40	FC	400
OK410300030010-001AT	Kiamichi River	7/24/2002	50	FC	400
OK410300030010-001AT	Kiamichi River	9/11/2002	10	FC	400
OK410300030010-001AT	Kiamichi River	5/5/2003	20	FC	400
OK410300030010-001AT	Kiamichi River	5/21/2003	100	FC	400
OK410300030010-001AT	Kiamichi River	6/9/2003	10	FC	400
OK410300030010-001AT	Kiamichi River	6/25/2003	40	FC	400
OK410300030010-001AT	Kiamichi River	7/14/2003	40	FC	400
OK410300030010-001AT	Kiamichi River	8/18/2003	10	FC	400
OK410300030010-001AT	Kiamichi River	9/3/2003	200	FC	400
OK410300030010-001AT	Kiamichi River	9/22/2003	100	FC	400
OK410300030010-001AT	Kiamichi River	6/8/1999	20	EC	406
OK410300030010-001AT	Kiamichi River	7/26/1999	30	EC	406
OK410300030010-001AT	Kiamichi River	8/10/1999	5	EC	406
OK410300030010-001AT	Kiamichi River	9/28/1999	52	EC	406
OK410300030010-001AT	Kiamichi River	6/6/2000	669	EC	406
OK410300030010-001AT	Kiamichi River	7/11/2000	52	EC	406
OK410300030010-001AT	Kiamichi River	8/22/2000	5	EC	406
OK410300030010-001AT	Kiamichi River	9/7/2000	20	EC	406
OK410300030010-001AT	Kiamichi River	5/23/2001	650	EC	406
OK410300030010-001AT	Kiamichi River	6/20/2001	10	EC	406
OK410300030010-001AT	Kiamichi River	7/25/2001	10	EC	406
OK410300030010-001AT	Kiamichi River	8/21/2001	5	EC	406
OK410300030010-001AT	Kiamichi River	9/18/2001	121	EC	406

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410300030010-001AT	Kiamichi River	5/22/2002	20	EC	406
OK410300030010-001AT	Kiamichi River	6/18/2002	74	EC	406
OK410300030010-001AT	Kiamichi River	7/24/2002	10	EC	406
OK410300030010-001AT	Kiamichi River	9/11/2002	10	EC	406
OK410300030010-001AT	Kiamichi River	5/5/2003	63	EC	406
OK410300030010-001AT	Kiamichi River	5/21/2003	51	EC	406
OK410300030010-001AT	Kiamichi River	6/9/2003	10	EC	406
OK410300030010-001AT	Kiamichi River	6/25/2003	20	EC	406
OK410300030010-001AT	Kiamichi River	7/14/2003	52	EC	406
OK410300030010-001AT	Kiamichi River	8/18/2003	10	EC	406
OK410300030010-001AT	Kiamichi River	9/3/2003	86	EC	406
OK410300030010-001AT	Kiamichi River	9/22/2003	85	EC	406
OK410300030010-001AT	Kiamichi River	6/8/1999	5	ENT	108
OK410300030010-001AT	Kiamichi River	7/26/1999	10	ENT	108
OK410300030010-001AT	Kiamichi River	8/10/1999	40	ENT	108
OK410300030010-001AT	Kiamichi River	9/28/1999	40	ENT	108
OK410300030010-001AT	Kiamichi River	6/6/2000	300	ENT	108
OK410300030010-001AT	Kiamichi River	7/11/2000	5	ENT	108
OK410300030010-001AT	Kiamichi River	8/22/2000	30	ENT	108
OK410300030010-001AT	Kiamichi River	9/7/2000	5	ENT	108
OK410300030010-001AT	Kiamichi River	5/23/2001	1100	ENT	108
OK410300030010-001AT	Kiamichi River	6/20/2001	300	ENT	108
OK410300030010-001AT	Kiamichi River	7/25/2001	10	ENT	108
OK410300030010-001AT	Kiamichi River	8/21/2001	20	ENT	108
OK410300030010-001AT	Kiamichi River	9/18/2001	700	ENT	108
OK410300030010-001AT	Kiamichi River	5/22/2002	6000	ENT	108
OK410300030010-001AT	Kiamichi River	6/18/2002	200	ENT	108
OK410300030010-001AT	Kiamichi River	7/24/2002	10	ENT	108
OK410300030010-001AT	Kiamichi River	9/11/2002	10	ENT	108
OK410300030010-001AT	Kiamichi River	5/5/2003	100	ENT	108
OK410300030010-001AT	Kiamichi River	5/21/2003	800	ENT	108
OK410300030010-001AT	Kiamichi River	6/9/2003	100	ENT	108
OK410300030010-001AT	Kiamichi River	6/25/2003	10	ENT	108
OK410300030010-001AT	Kiamichi River	7/14/2003	50	ENT	108
OK410300030010-001AT	Kiamichi River	8/18/2003	40	ENT	108
OK410300030010-001AT	Kiamichi River	9/3/2003	500	ENT	108
OK410300030010-001AT	Kiamichi River	9/22/2003	70	ENT	108
OK410300030210C	Dumpling Creek	4/19/1999	3700	FC	2000
OK410300030210C	Dumpling Creek	5/17/1999	< 100	FC	400
OK410300030210C	Dumpling Creek	6/14/1999	2300	FC	400
OK410300030210C	Dumpling Creek	7/12/1999	200	FC	400
OK410300030210C	Dumpling Creek	8/16/1999	< 100	FC	400
OK410300030210C	Dumpling Creek	9/27/1999	300	FC	400
OK410300030210C	Dumpling Creek	11/1/1999	200	FC	2000

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410300030210C	Dumpling Creek	12/6/1999	500	FC	2000
OK410300030210C	Dumpling Creek	1/10/2000	300	FC	2000
OK410300030210C	Dumpling Creek	2/14/2000	300	FC	2000
OK410300030210C	Dumpling Creek	3/20/2000	< 100	FC	2000
OK410300030210C	Dumpling Creek	5/1/2000	6000	FC	400
OK410300030210C	Dumpling Creek	6/5/2000	800	FC	400
OK410300030210C	Dumpling Creek	7/10/2000	160	FC	400
OK410300030210C	Dumpling Creek	8/14/2000	< 10	FC	400
OK410300030210C	Dumpling Creek	9/18/2000	10	FC	400
OK410300030210C	Dumpling Creek	10/23/2000	1000	FC	2000
OK410300030210C	Dumpling Creek	11/27/2000	120	FC	2000
OK410300030210C	Dumpling Creek	1/8/2001	10	FC	2000
OK410300030210C	Dumpling Creek	2/12/2001	100	FC	2000
OK410300030210C	Dumpling Creek	3/19/2001	80	FC	2000
OK410300030210C	Dumpling Creek	8/14/2000	10	EC	406
OK410300030210C	Dumpling Creek	9/18/2000	10	EC	406
OK410300030210C	Dumpling Creek	10/23/2000	780	EC	2030
OK410300030210C	Dumpling Creek	11/27/2000	164	EC	2030
OK410300030210C	Dumpling Creek	1/8/2001	74	EC	2030
OK410300030210C	Dumpling Creek	2/12/2001	332	EC	2030
OK410300030210C	Dumpling Creek	3/19/2001	122	EC	2030
OK410300030210C	Dumpling Creek	9/18/2000	10	ENT	108
OK410300030210C	Dumpling Creek	10/23/2000	1400	ENT	540
OK410300030210C	Dumpling Creek	11/27/2000	110	ENT	540
OK410300030210C	Dumpling Creek	1/8/2001	40	ENT	540
OK410300030210C	Dumpling Creek	2/12/2001	600	ENT	540
OK410300030210C	Dumpling Creek	3/19/2001	10	ENT	540
OK410300030270M	Tenmile Creek	8/14/2000	10	EC	406
OK410300030270M	Tenmile Creek	3/19/2001	0	ENT	540
OK410300030270M	Tenmile Creek	4/19/1999	6100	FC	2000
OK410300030270M	Tenmile Creek	5/17/1999	200	FC	400
OK410300030270M	Tenmile Creek	6/14/1999	100	FC	400
OK410300030270M	Tenmile Creek	7/12/1999	200	FC	400
OK410300030270M	Tenmile Creek	8/16/1999	100	FC	400
OK410300030270M	Tenmile Creek	9/27/1999	100	FC	400
OK410300030270M	Tenmile Creek	11/1/1999	6000	FC	2000
OK410300030270M	Tenmile Creek	12/6/1999	1000	FC	2000
OK410300030270M	Tenmile Creek	1/10/2000	800	FC	2000
OK410300030270M	Tenmile Creek	2/14/2000	100	FC	2000
OK410300030270M	Tenmile Creek	3/20/2000	400	FC	2000
OK410300030270M	Tenmile Creek	5/1/2000	7500	FC	400
OK410300030270M	Tenmile Creek	6/5/2000	1800	FC	400
OK410300030270M	Tenmile Creek	7/10/2000	3800	FC	400

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410300030270M	Tenmile Creek	8/14/2000	750	FC	400
OK410300030270M	Tenmile Creek	3/19/2001	0	FC	2000
OK410310010070C	Dry Creek	4/26/1999	5000	FC	2000
OK410310010070C	Dry Creek	7/19/1999	100	FC	400
OK410310010070C	Dry Creek	8/23/1999	100	FC	400
OK410310010070C	Dry Creek	10/4/1999	100	FC	2000
OK410310010070C	Dry Creek	12/13/1999	100	FC	2000
OK410310010070C	Dry Creek	1/18/2000	100	FC	2000
OK410310010070C	Dry Creek	2/20/2000	100	FC	2000
OK410310010070C	Dry Creek	3/27/2000	100	FC	2000
OK410310010070C	Dry Creek	5/8/2000	100	FC	400
OK410310010070C	Dry Creek	6/12/2000	100	FC	400
OK410310010070C	Dry Creek	7/17/2000	500	FC	400
OK410310010070C	Dry Creek	8/21/2000	70	FC	400
OK410310010070C	Dry Creek	9/25/2000	21000	FC	400
OK410310010070C	Dry Creek	10/31/2000	1000	FC	2000
OK410310010070C	Dry Creek	12/6/2000	110	FC	2000
OK410310010070C	Dry Creek	1/17/2001	40	FC	2000
OK410310010070C	Dry Creek	1/17/2001	80	FC	2000
OK410310010070C	Dry Creek	2/21/2001	20	FC	2000
OK410310010070C	Dry Creek	3/27/2001	40	FC	2000
OK410310010070C	Dry Creek	8/21/2000	122	EC	406
OK410310010070C	Dry Creek	9/25/2000	12996	EC	406
OK410310010070C	Dry Creek	10/31/2000	677	EC	2030
OK410310010070C	Dry Creek	12/6/2000	10	EC	2030
OK410310010070C	Dry Creek	1/17/2001	41	EC	2030
OK410310010070C	Dry Creek	2/21/2001	30	EC	2030
OK410310010070C	Dry Creek	3/27/2001	41	EC	2030
OK410310010070C	Dry Creek	9/25/2000	8000	ENT	108
OK410310010070C	Dry Creek	10/31/2000	400	ENT	540
OK410310010070C	Dry Creek	12/6/2000	50	ENT	540
OK410310010070C	Dry Creek	1/17/2001	70	ENT	540
OK410310010070C	Dry Creek	1/17/2001	130	ENT	540
OK410310010070C	Dry Creek	2/21/2001	30	ENT	540
OK410310010070C	Dry Creek	3/27/2001	20	ENT	540
OK410310010070C	Dry Creek	3/27/2001	10	ENT	540
OK410310030090G	Bolen Creek	4/26/1999	5000	FC	2000
OK410310030090G	Bolen Creek	5/24/1999	200	FC	400
OK410310030090G	Bolen Creek	7/19/1999	100	FC	400
OK410310030090G	Bolen Creek	8/23/1999	100	FC	400
OK410310030090G	Bolen Creek	12/13/1999	300	FC	2000
OK410310030090G	Bolen Creek	1/18/2000	100	FC	2000
OK410310030090G	Bolen Creek	2/20/2000	100	FC	2000

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria* (#/100ml)
OK410310030090G	Bolen Creek	3/27/2000	300	FC	2000
OK410310030090G	Bolen Creek	5/8/2000	700	FC	400
OK410310030090G	Bolen Creek	6/12/2000	200	FC	400
OK410310030090G	Bolen Creek	7/17/2000	7200	FC	400
OK410310030090G	Bolen Creek	9/25/2000	21000	FC	400
OK410310030090G	Bolen Creek	10/31/2000	1900	FC	2000
OK410310030090G	Bolen Creek	12/6/2000	160	FC	2000
OK410310030090G	Bolen Creek	1/17/2001	120	FC	2000
OK410310030090G	Bolen Creek	2/21/2001	90	FC	2000
OK410310030090G	Bolen Creek	3/27/2001	100	FC	2000
OK410310030090G	Bolen Creek	9/25/2000	9804	EC	406
OK410310030090G	Bolen Creek	10/31/2000	328	EC	2030
OK410310030090G	Bolen Creek	12/6/2000	309	EC	2030
OK410310030090G	Bolen Creek	1/17/2001	262	EC	2030
OK410310030090G	Bolen Creek	2/21/2001	97	EC	2030
OK410310030090G	Bolen Creek	3/27/2001	135	EC	2030
OK410310030090G	Bolen Creek	9/25/2000	7000	ENT	108
OK410310030090G	Bolen Creek	10/31/2000	800	ENT	540
OK410310030090G	Bolen Creek	12/6/2000	160	ENT	540
OK410310030090G	Bolen Creek	1/17/2001	400	ENT	540
OK410310030090G	Bolen Creek	2/21/2001	300	ENT	540
OK410310030090G	Bolen Creek	3/27/2001	20	ENT	540

EC = E. coli; ENT = enterococci; FC = fecal coliform

Single sample criterion for secondary contact recreation season is shown for all samples collected between October 1st and April 30th.

APPENDIX B
NPDES PERMIT DISCHARGE MONITORING REPORT DATA – 1998 TO 2004

Appendix B

NPDES Permit Discharge Monitoring Report Data 1998-2004

NPDES	Report Date	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter Code	Parameter
OK0000736	1/31/1998	0.000009	0.000009	50050	FLOW
OK0000736	2/28/1998	7.63	8.35	50050	FLOW
OK0000736	3/31/1998	5.88	6.58	50050	FLOW
OK0000736	4/30/1998	0.06	0.072	50050	FLOW
OK0000736	5/31/1998	0.2583	1.764	50050	FLOW
OK0000736	6/30/1998	0.00864	0.00864	50050	FLOW
OK0000736	7/31/1998	0.00864	0.00864	50050	FLOW
OK0000736	8/31/1998	0	0	50050	FLOW
OK0000736	9/30/1998	0	0	50050	FLOW
OK0000736	10/31/1998	0	0	50050	FLOW
OK0000736	11/30/1998	0	0	50050	FLOW
OK0000736	12/31/1998	0	0	50050	FLOW
OK0000736	1/31/1999	7.326	9.072	50050	FLOW
OK0000736	2/28/1999	0	0	50050	FLOW
OK0000736	3/31/1999	0	0	50050	FLOW
OK0000736	4/30/1999	6.1632	8.208	50050	FLOW
OK0000736	5/31/1999	0.279	0.792	50050	FLOW
OK0000736	6/30/1999	0	0	50050	FLOW
OK0000736	7/31/1999	0	0	50050	FLOW
OK0000736	8/31/1999	0	0	50050	FLOW
OK0000736	9/30/1999	0	0	50050	FLOW
OK0000736	10/31/1999	0	0	50050	FLOW
OK0000736	11/30/1999	0	0	50050	FLOW
OK0000736	12/31/1999	0	0	50050	FLOW
OK0000736	1/31/2000	0	0	50050	FLOW
OK0000736	2/29/2000	0	0	50050	FLOW
OK0000736	3/31/2000	0	0	50050	FLOW
OK0000736	4/30/2000	0	0	50050	FLOW
OK0000736	5/31/2000	0	0	50050	FLOW
OK0000736	6/30/2000	0	0	50050	FLOW
OK0000736	7/31/2000	0	0	50050	FLOW
OK0000736	8/31/2000	1.728	1.728	50050	FLOW
OK0000736	9/30/2000	1.728	1.728	50050	FLOW
OK0000736	10/31/2000	0	0	50050	FLOW
OK0000736	11/30/2000	0	0	50050	FLOW
OK0000736	12/31/2000	2.034	2.232	50050	FLOW
OK0000736	1/31/2001	1.377	2.16	50050	FLOW
OK0000736	2/28/2001	0	0	50050	FLOW
OK0000736	3/31/2001	0	0	50050	FLOW
OK0000736	4/30/2001	2.196	2.304	50050	FLOW
OK0000736	5/31/2001	0.5904	1.224	50050	FLOW

NPDES	Report Date	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter Code	Parameter
OK0000736	6/30/2001	0.00432	0.000432	50050	FLOW
OK0000736	7/31/2001	0.01092	0.027	50050	FLOW
OK0000736	8/31/2001	0	0	50050	FLOW
OK0000736	9/30/2001	0	0	50050	FLOW
OK0000736	10/31/2001	0	0	50050	FLOW
OK0000736	11/30/2001	0	0	50050	FLOW
OK0000736	12/31/2001	0	0	50050	FLOW
OK0000736	1/31/2002			50050	FLOW
OK0000736	2/28/2002	0	0	50050	FLOW
OK0000736	3/31/2002	1.944	2.232	50050	FLOW
OK0000736	4/30/2002	1.14	1.728	50050	FLOW
OK0000736	5/31/2002	0	0	50050	FLOW
OK0000736	6/30/2002	0	0	50050	FLOW
OK0000736	7/31/2002	0	0	50050	FLOW
OK0000736	8/31/2002	0	0	50050	FLOW
OK0000736	9/30/2002	0	0	50050	FLOW
OK0000736	10/31/2002	0	0	50050	FLOW
OK0000736	11/30/2002	0	0	50050	FLOW
OK0000736	12/31/2002	0	0	50050	FLOW
OK0000736	1/31/2003	0	0	50050	FLOW
OK0000736	2/28/2003	0	0	50050	FLOW
OK0000736	3/31/2003	0	0	50050	FLOW
OK0000736	4/30/2003	0	0	50050	FLOW
OK0000736	5/31/2003	0	0	50050	FLOW
OK0000736	6/30/2003	0	0	50050	FLOW
OK0000736	7/31/2003	0	0	50050	FLOW
OK0000736	8/31/2003	0	0	50050	FLOW
OK0000736	9/30/2003	0	0	50050	FLOW
OK0000736	10/31/2003	0	0	50050	FLOW
OK0000736	11/30/2003	0	0	50050	FLOW
OK0000736	12/31/2003	0	0	50050	FLOW
OK0000736	1/31/2004	0	0	50050	FLOW
OK0000736	2/29/2004	0	0	50050	FLOW
OK0000736	3/31/2004	0	0	50050	FLOW
OK0000736	4/30/2004	0	0	50050	FLOW
OK0000736	5/31/2004	0	0	50050	FLOW
OK0000736	6/30/2004	0	0	50050	FLOW
OK0000736	7/31/2004	0	0	50050	FLOW
OK0000736	8/31/2004	0	0	50050	FLOW
OK0000736	9/30/2004	0	0	50050	FLOW
OK0000736	10/31/2004	0	0	50050	FLOW
OK0000736	11/30/2004	0	0	50050	FLOW
OK0000736	12/31/2004	1.776309	2.1888	50050	FLOW

APPENDIX C
ESTIMATED FLOW EXCEEDANCE PERCENTILES

Appendix C

Estimated Flow Exceedance Percentiles

WQ Station	OK410210020140-001AT	OK410210040010-001AT	OK410210080010-001AT	OK410300030010-001AT	OK410300030210C	OK410300030270M	OK410310010070C	OK410310030090G
	Little River	**Mountain Fork River**	**Glover River**	**Kiamichi River**	**Dumpling Creek**	**Tenmile Creek**	**Dry Creek**	**Bolen Creek**
WBID Segment	OK410210020140_00	OK410210040010_00	OK410210080010_00	OK410300030010_20	OK410300030210_00	OK410300030270_00	OK410310010070_00	OK410310030090_00
USGS Gage Reference	07338500	07339000	07337900	07336200	07336820	07336000	07335790	07335790
Watershed Area (Acres)	330,261	328,760	233,107	234,254	9,331	65,294	6,378	16,879
Mean Curve Number	69.7	68.8	70.3	69.0	69.2	70.1	62.8	64.4
Average Annual Rainfall (inches)	53.4	56.0	54.9	50.0	46.9	47.6	51.8	50.6
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
0	63,720	11,500	53,100	57,000	943	4,540	562	1,422
1	7,772	7,650	6,452	16,135	276	1,622	136	336
2	5,076	7,200	4,180	11,370	186	1,024	99	245
3	3,732	6,980	3,099	8,680	139	618	79	194
4	2,904	6,549	2,420	7,240	111	433	66	162
5	2,412	5,842	2,000	6,340	90	306	61	150
6	2,040	5,263	1,690	5,790	75	245	56	137
7	1,776	4,760	1,480	5,290	65	201	52	128
8	1,536	4,400	1,280	5,000	57	164	49	119
9	1,356	4,100	1,130	4,622	51	140	47	113
10	1,236	3,820	1,030	4,375	46.6	119	44	106
11	1,126	3,594	935	4,080	43.3	106	42	101
12	1,028	3,410	856	3,860	40.0	93	39	95
13	955	3,210	792	3,640	37.2	84	37	90
14	890	3,040	738	3,469	34.8	74	35	84
15	827	2,880	688	3,250	31.8	67	33	80
16	771	2,740	641	3,080	30.1	60	31	75
17	722	2,597	600	2,860	28.1	56	29	70
18	680	2,460	566	2,690	26.5	51	27	66

WQ Station	OK410210020140-001AT	OK410210040010-001AT	OK410210080010-001AT	OK410300030010-001AT	OK410300030210C	OK410300030270M	OK410310010070C	OK410310030090G
	Little River	**Mountain Fork River**	**Glover River**	**Kiamichi River**	**Dumpling Creek**	**Tenmile Creek**	**Dry Creek**	**Bolen Creek**
WBID Segment	OK410210020140_00	OK410210040010_00	OK410210080010_00	OK410300030010_20	OK410300030210_00	OK410300030270_00	OK410310010070_00	OK410310030090_00
USGS Gage Reference	07338500	07339000	07337900	07336200	07336820	07336000	07335790	07335790
Watershed Area (Acres)	330,261	328,760	233,107	234,254	9,331	65,294	6,378	16,879
Mean Curve Number	69.7	68.8	70.3	69.0	69.2	70.1	62.8	64.4
Average Annual Rainfall (inches)	53.4	56.0	54.9	50.0	46.9	47.6	51.8	50.6
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
19	640	2,350	531	2,510	24.8	47	26	62
20	604	2,250	502	2,340	22.9	44	24	57
21	575	2,140	477	2,190	21.7	40	23	54
22	542	2,040	450	2,050	20.3	37	21	50
23	516	1,960	429	1,930	19.1	34	20	47
24	491	1,850	408	1,800	18.0	32	19	44
25	468	1,750	389	1,680	16.9	30	17	41
26	446	1,670	372	1,571	15.9	27	16	38
27	427	1,590	356	1,460	14.8	25	15	35
28	407	1,520	338	1,350	13.7	24	14	32
29	389	1,450	323	1,262	12.7	22	13	29
30	371	1,390	308	1,190	11.9	21	12	27
31	353	1,320	294	1,110	11.0	20	11	25
32	338	1,280	281	1,050	10.2	19	10	23
33	322	1,220	268	977	9.4	18	9.3	21
34	308	1,160	256	920	8.8	16	8.6	20
35	294	1,110	244	861	8.0	15	8.1	18
36	281	1,060	233	802	7.4	14	7.5	17
37	269	1,020	224	752	6.8	14	7.0	16
38	257	976	214	703	6.4	13	6.4	14
39	245	934	203	657	6.0	12	6.0	13
40	234	897	194	613	5.6	11	5.7	12

WQ Station	OK410210020140-001AT	OK410210040010-001AT	OK410210080010-001AT	OK410300030010-001AT	OK410300030210C	OK410300030270M	OK410310010070C	OK410310030090G
	Little River	**Mountain Fork River**	**Glover River**	**Kiamichi River**	**Dumpling Creek**	**Tenmile Creek**	**Dry Creek**	**Bolen Creek**
WBID Segment	OK410210020140_00	OK410210040010_00	OK410210080010_00	OK410300030010_20	OK410300030210_00	OK410300030270_00	OK410310010070_00	OK410310030090_00
USGS Gage Reference	07338500	07339000	07337900	07336200	07336820	07336000	07335790	07335790
Watershed Area (Acres)	330,261	328,760	233,107	234,254	9,331	65,294	6,378	16,879
Mean Curve Number	69.7	68.8	70.3	69.0	69.2	70.1	62.8	64.4
Average Annual Rainfall (inches)	53.4	56.0	54.9	50.0	46.9	47.6	51.8	50.6
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
41	223	865	186	579	5.2	11	5.3	11
42	214	829	178	540	4.9	10	4.9	11
43	204	797	170	507	4.6	9.2	4.6	9.9
44	196	767	162	473	4.3	8.6	4.3	9.2
45	186	733	154	447	4.1	8.0	4.0	8.5
46	177	706	147	421	3.8	7.5	3.7	7.9
47	169	678	140	396	3.5	6.9	3.5	7.4
48	160	653	132	371	3.3	6.5	3.3	7.0
49	152	634	125	350	3.1	6.0	3.1	6.4
50	145	612	119	327	2.9	5.7	2.9	6.0
51	137	591	113	306	2.8	5.3	2.7	5.5
52	130	571	106	284	2.6	4.9	2.5	5.1
53	122	553	101	267	2.4	4.6	2.4	4.8
54	116	531	95	249	2.3	4.2	2.2	4.4
55	109	511	89	233	2.1	3.9	2.1	4.1
56	102	494	83	219	2.0	3.6	1.9	3.8
57	94.8	473	78	207	1.8	3.3	1.8	3.5
58	88.8	457	73	195	1.7	3.0	1.7	3.2
59	84	442	68	183	1.6	2.7	1.5	2.9
60	79.2	425	64	168	1.5	2.5	1.4	2.7
61	73.2	408	60	159	1.3	2.3	1.3	2.4
62	69.6	393	56	148	1.2	2.1	1.2	2.2

WQ Station	OK410210020140-001AT	OK410210040010-001AT	OK410210080010-001AT	OK410300030010-001AT	OK410300030210C	OK410300030270M	OK410310010070C	OK410310030090G
	Little River	**Mountain Fork River**	**Glover River**	**Kiamichi River**	**Dumpling Creek**	**Tenmile Creek**	**Dry Creek**	**Bolen Creek**
WBID Segment	OK410210020140_00	OK410210040010_00	OK410210080010_00	OK410300030010_20	OK410300030210_00	OK410300030270_00	OK410310010070_00	OK410310030090_00
USGS Gage Reference	07338500	07339000	07337900	07336200	07336820	07336000	07335790	07335790
Watershed Area (Acres)	330,261	328,760	233,107	234,254	9,331	65,294	6,378	16,879
Mean Curve Number	69.7	68.8	70.3	69.0	69.2	70.1	62.8	64.4
Average Annual Rainfall (inches)	53.4	56.0	54.9	50.0	46.9	47.6	51.8	50.6
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
63	64.8	383	52	134	1.1	1.9	1.1	2.0
64	61.2	371	50	125	1.0	1.7	1.0	1.8
65	57.6	358	46	115	0.90	1.6	0.92	1.6
66	52.8	347	42	106	0.80	1.4	0.84	1.4
67	48	338	39	96	0.70	1.2	0.75	1.2
68	44.4	327	36	87	0.63	1.1	0.69	1.1
69	40.8	316	33	80	0.57	1.0	0.62	0.98
70	37.2	303	30	74	0.49	0.9	0.56	0.86
71	33.6	293	27	67	0.42	0.8	0.50	0.73
72	30	282	25	61	0.37	0.7	0.44	0.63
73	27.6	270	23	55	0.32	0.6	0.39	0.53
74	25.2	259	20	48	0.28	0.5	0.35	0.45
75	22.8	248	19	43	0.25	0.4	0.30	0.38
76	20.4	239	17	38	0.21	0.3	0.27	0.32
77	18	228	15	34	0.18	0.2	0.24	0.26
78	16.8	220	13	30	0.15	0.2	0.21	0.21
79	14.4	213	12	26	0.13	0.10	0.18	0.17
80	13.2	205	11	23	0.11	0.10	0.16	0.14
81	11.9	199	9.7	21	0.09	0.03	0.15	0.12
82	10.7	192	8.7	18	0.07	0.01	0.13	0.10
83	9.6	186	7.9	16	0.05	0	0.12	0.08
84	8.8	181	7.2	13	0.04	0	0.11	0.06

WQ Station	OK410210020140-001AT	OK410210040010-001AT	OK410210080010-001AT	OK410300030010-001AT	OK410300030210C	OK410300030270M	OK410310010070C	OK410310030090G
	Little River	**Mountain Fork River**	**Glover River**	**Kiamichi River**	**Dumpling Creek**	**Tenmile Creek**	**Dry Creek**	**Bolen Creek**
WBID Segment	OK410210020140_00	OK410210040010_00	OK410210080010_00	OK410300030010_20	OK410300030210_00	OK410300030270_00	OK410310010070_00	OK410310030090_00
USGS Gage Reference	07338500	07339000	07337900	07336200	07336820	07336000	07335790	07335790
Watershed Area (Acres)	330,261	328,760	233,107	234,254	9,331	65,294	6,378	16,879
Mean Curve Number	69.7	68.8	70.3	69.0	69.2	70.1	62.8	64.4
Average Annual Rainfall (inches)	53.4	56.0	54.9	50.0	46.9	47.6	51.8	50.6
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
85	7.8	175	6.4	11	0.02	0	0.10	0.05
86	7.0	170	5.8	10	0	0	0.09	0.04
87	6.1	164	5.1	9	0	0	0.08	0.04
88	5.3	160	4.4	7.8	0	0	0.07	0.03
89	4.6	154	3.7	7	0	0	0.07	0.02
90	3.8	149	3.1	6	0	0	0.06	0.01
91	3.1	144	2.5	5.1	0	0	0.05	0
92	2.6	139	2.1	4.4	0	0	0.04	0
93	2.2	134	1.8	3.4	0	0	0.03	0
94	1.7	130	1.4	2.6	0	0	0.02	0
95	1.3	124	1.0	1.8	0	0	0	0
96	0.84	116	0.65	0.98	0	0	0	0
97	0.48	108	0.40	0.22	0	0	0	0
98	0.14	98	0.10	0	0	0	0	0
99	0	79	0	0	0	0	0	0
100	0	0.21	0	0	0	0	0	0

Appendix C
General Methodology for Estimating Flow at WQM Stations

Flows duration curve will be developed using existing USGS measured flow where the data exist from a gage on the stream segment of interest, or by estimating flow for stream segments with no corresponding flow record. Flow data to support flow duration curves and load duration curves will be derived for each Oklahoma stream segment in the following priority:

i) In cases where a USGS flow gage occurs on, or within one-half mile upstream or downstream of the Oklahoma stream segment.

a. If simultaneously-collected flow data matching the water quality sample collection date are available, these flow measurements will be used.

b. If flow measurements at the coincident gage are missing for some dates on which water quality samples were collected, the gaps in the flow record will be filled, or the record will be extended, by estimating flow based on measured streamflows at a nearby gage. First, the most appropriate nearby stream gage is identified. All flow data are first log-transformed to linearize the data because flow data are highly skewed. Linear regressions are then developed between 1) daily streamflow at the gage to be filled/extended, and 2) streamflow at all gages within 95 miles that have at least 300 daily flow measurements on matching dates. The station with the best flow relationship, as indicated by the highest r-squared value, is selected as the index gage. R-squared indicates the fraction of the variance in flow explained by the regression. The regression is then used to estimate flow at the gage to be filled/extended from flow at the index station. Flows will not be estimated based on regressions with r-squared values less than 0.25, even if that is the best regression. In some cases, it will be necessary to fill/extend flow records from two or more index gages. The flow record will be filled/extended to the extent possible based on the best index gage (highest r-squared value), and remaining gaps will be filled from the next best index gage (second highest r-squared value), and so forth.

c. Flow duration curves will be based on measured flows only, not on the filled or extended flow time series calculated from other gages using regression.

d. On a stream impounded by dams to form reservoirs of sufficient size to impact stream flow, only flows measured after the date of the most recent impoundment will be used to develop the flow duration curve. This also applies to reservoirs on major tributaries to the stream.

ii) In the case no coincident flow data are available for a stream segment, but flow gage(s) are present upstream and/or downstream without a major reservoir between, flows will be estimated for the stream segment from an upstream or downstream gage using a watershed area ratio method derived by delineating subwatersheds, and relying on the National Resources Conservation Service (NRCS) runoff curve numbers and antecedent rainfall condition. Drainage subbasins will first be delineated for all impaired 303(d)-listed WQM stations, along with all USGS flow stations located in the 8-digit HUCs with impaired streams. Parsons will then identify all the USGS gage stations upstream and downstream of the subwatersheds with 303(d) listed WQM stations.

a. Watershed delineations are performed using ESRI Arc Hydro with a 30 m resolution National Elevation Dataset (NED) digital elevation model, and National Hydrography Dataset (NHD) streams. The area of each watershed will be calculated following watershed delineation.

b. The watershed average curve number is calculated from soil properties and land cover as described in the U.S. Department of Agriculture (USDA) Publication *TR-55: Urban Hydrology for Small Watersheds*. The soil hydrologic group is extracted from NRCS STATSGO soil data, and land use category from the 2001 National Land Cover Dataset (NLCD). Based on land use and the hydrologic soil group, SCS curve numbers are estimated at the 30-meter resolution of the NLCD grid as shown in Table 7. The average curve number is then calculated from all the grid cells within the delineated watershed.

c. The average rainfall is calculated for each watershed from gridded average annual precipitation datasets for the period 1971-2000 (Spatial Climate Analysis Service, Oregon State University, http://www.ocs.oregonstate.edu/prism/, created 20 Feb 2004).

Table C-1 Runoff Curve Numbers for Various Land Use Categories and Hydrologic Soil Groups

NLCD Land Use Category	Curve number for hydrologic soil group			
	A	B	C	D
0 in case of zero	100	100	100	100
11 Open Water	100	100	100	100
12 Perennial Ice/Snow	100	100	100	100
21 Developed, Open Space	39	61	74	80
22 Developed, Low Intensity	57	72	81	86
23 Developed, Medium Intensity	77	85	90	92
24 Developed, High Intensity	89	92	94	95
31 Barren Land (Rock/Sand/Clay)	77	86	91	94
32 Unconsolidated Shore	77	86	91	94
41 Deciduous Forest	37	48	57	63
42 Evergreen Forest	45	58	73	80
43 Mixed Forest	43	65	76	82
51 Dwarf Scrub	40	51	63	70
52 Shrub/Scrub	40	51	63	70
71 Grasslands/Herbaceous	40	51	63	70
72 Sedge/Herbaceous	40	51	63	70
73 Lichens	40	51	63	70
74 Moss	40	51	63	70
81 Pasture/Hay	35	56	70	77
82 Cultivated Crops	64	75	82	85
90-99 Wetlands	100	100	100	100

d. Flow at the ungaged site is calculated from the gaged site. The NRCS runoff curve number equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (1)$$

where:

Q = runoff (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

If P < 0.2, Q = 0. Initial abstraction has been found to be empirically related to S by the equation

$$I_a = 0.2*S \qquad (2)$$

Thus, the runoff curve number equation can be rewritten:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (3)$$

S is related to the curve number (CN) by:

$$S = \frac{1000}{CN} - 10 \qquad (4)$$

e. First, S is calculated from the average curve number for the gaged watershed. Next, the daily historic flows at the gage are converted to depth basis (as used in equations 1 and 3) by dividing by its drainage area, then converted to inches. Equation 3 is then solved for daily precipitation depth of the gaged site, P_{gaged}. The daily precipitation depth for the ungaged site is then calculated as the precipitation depth of the gaged site multiplied by the ratio of the long-term average precipitation in the watersheds of the ungaged and gaged sites:

$$P_{ungaged} = P_{gaged}\left(\frac{M_{ungaged}}{M_{gaged}}\right) \qquad (5)$$

where M is the mean annual precipitation of the watershed in inches. The daily precipitation depth for the ungaged watershed, along with the average curve number of the ungaged watershed, are then used to calculate the depth equivalent daily flow Q of the ungaged site. Finally, the volumetric flow rate at the ungaged site is calculated by multiplying by the area of the watershed of the ungaged site and converted to cubic feet.

f. If any flow measurements are available on the stream segment of interest, the projected flows will be compared to the measured flows on each date. If there is poor agreement, projections will be repeated with a simpler approach, using only the watershed area ratio and the gaged site (thereby eliminating the influence of differences in curve number and precipitation between the gaged and ungaged stream watersheds). If this simpler approach provides better agreement with existing data, the projected flows based on the simpler approach will be used.

iii) In the rare case where no coincident flow data are available for a WQM station and no gages are present upstream or downstream, flows will be estimated for the WQM station from a gage on an adjacent watershed of similar size and properties, via the same procedure described above for upstream or downstream gages.

APPENDIX D
STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix D
State of Oklahoma Antidegradation Policy

785:45-3-1. Purpose; Antidegradation policy statement

(a) Waters of the state constitute a valuable resource and shall be protected, maintained and improved for the benefit of all the citizens.

(b) It is the policy of the State of Oklahoma to protect all waters of the state from degradation of water quality, as provided in OAC 785:45-3-2 and Subchapter 13 of OAC 785:46.

785:45-3-2. Applications of antidegradation policy

(a) Application to outstanding resource waters (ORW). Certain waters of the state constitute an outstanding resource or have exceptional recreational and/or ecological significance. These waters include streams designated "Scenic River" or "ORW" in Appendix A of this Chapter, and waters of the State located within watersheds of Scenic Rivers. Additionally, these may include waters located within National and State parks, forests, wilderness areas, wildlife management areas, and wildlife refuges, and waters which contain species listed pursuant to the federal Endangered Species Act as described in 785:45-5-25(c)(2)(A) and 785:46-13-6(c). No degradation of water quality shall be allowed in these waters.

(b) Application to high quality waters (HQW). It is recognized that certain waters of the state possess existing water quality which exceeds those levels necessary to support propagation of fishes, shellfishes, wildlife, and recreation in and on the water. These high quality waters shall be maintained and protected.

(c) Application to beneficial uses. No water quality degradation which will interfere with the attainment or maintenance of an existing or designated beneficial use shall be allowed.

(d) Application to improved waters. As the quality of any waters of the state improve, no degradation of such improved waters shall be allowed.

785:46-13-1. Applicability and scope

(a) The rules in this Subchapter provide a framework for implementing the antidegradation policy stated in OAC 785:45-3-2 for all waters of the state. This policy and framework includes three tiers, or levels, of protection.

(b) The three tiers of protection are as follows:

- (1) Tier 1. Attainment or maintenance of an existing or designated beneficial use.
- (2) Tier 2. Maintenance or protection of High Quality Waters and Sensitive Public and Private Water Supply waters.
- (3) Tier 3. No degradation of water quality allowed in Outstanding Resource Waters.

(c) In addition to the three tiers of protection, this Subchapter provides rules to implement the protection of waters in areas listed in Appendix B of OAC 785:45. Although Appendix B areas are not mentioned in OAC 785:45-3-2, the framework for protection of Appendix B areas is similar to the implementation framework for the antidegradation policy.

(d) In circumstances where more than one beneficial use limitation exists for a waterbody, the most protective limitation shall apply. For example, all antidegradation policy implementation rules applicable to Tier 1 waterbodies shall be applicable also to Tier 2 and Tier 3 waterbodies or areas, and implementation rules applicable to Tier 2 waterbodies shall be applicable also to Tier 3 waterbodies.

(e) Publicly owned treatment works may use design flow, mass loadings or concentration, as appropriate, to calculate compliance with the increased loading requirements of this section if those flows, loadings or concentrations were approved by the Oklahoma Department of Environmental Quality as a portion of Oklahoma's Water Quality Management Plan prior to the application of the ORW, HQW or SWS limitation.

785:46-13-2. Definitions

The following words and terms, when used in this Subchapter, shall have the following meaning, unless the context clearly indicates otherwise:

"Specified pollutants" means

(A) Oxygen demanding substances, measured as Carbonaceous Biochemical Oxygen Demand (CBOD) and/or Biochemical Oxygen Demand (BOD);

(B) Ammonia Nitrogen and/or Total Organic Nitrogen;

(C) Phosphorus;

(D) Total Suspended Solids (TSS); and

(E) Such other substances as may be determined by the Oklahoma Water Resources Board or the permitting authority.

785:46-13-3. Tier 1 protection; attainment or maintenance of an existing or designated beneficial use

(a) General.

(1) Beneficial uses which are existing or designated shall be maintained and protected.

(2) The process of issuing permits for discharges to waters of the state is one of several means employed by governmental agencies and affected persons which are designed to attain or maintain beneficial uses which have been designated for those waters. For example, Subchapters 3, 5, 7, 9 and 11 of this Chapter are rules for the permitting process. As such, the latter Subchapters not only implement numerical and narrative criteria, but also implement Tier 1 of the antidegradation policy.

(b) Thermal pollution. Thermal pollution shall be prohibited in all waters of the state. Temperatures greater than 52 degrees Centigrade shall constitute thermal pollution and shall be prohibited in all waters of the state.

(c) Prohibition against degradation of improved waters. As the quality of any waters of the state improves, no degradation of such improved waters shall be allowed.

785:46-13-4. Tier 2 protection; maintenance and protection of High Quality Waters and Sensitive Water Supplies

(a) General rules for High Quality Waters. New point source discharges of any pollutant after June 11, 1989, and increased load or concentration of any specified pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "HQW". Any discharge of any pollutant to a waterbody designated "HQW" which would, if it occurred, lower existing water quality shall be prohibited. Provided however, new point source discharges or increased load or concentration of any specified pollutant from a discharge existing as of June 11, 1989, may be approved by the permitting authority in circumstances where the discharger demonstrates to the satisfaction of the permitting authority that such new discharge or increased load or concentration would result in maintaining or improving the level of water quality which exceeds that necessary to support recreation and propagation of fishes, shellfishes, and wildlife in the receiving water.

(b) General rules for Sensitive Public and Private Water Supplies. New point source discharges of any pollutant after June 11, 1989, and increased load of any specified pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "SWS". Any discharge of any pollutant to a waterbody designated "SWS" which would, if it occurred, lower existing water quality shall be prohibited. Provided however, new point source discharges or increased load of any specified pollutant from a discharge existing as of June 11, 1989, may be approved by the permitting authority in circumstances where the discharger demonstrates to the satisfaction of the permitting authority that such new discharge or increased load will result in maintaining or improving the water quality in both the direct receiving water, if designated SWS, and any downstream waterbodies designated SWS.

(c) Stormwater discharges. Regardless of subsections (a) and (b) of this Section, point source discharges of stormwater to waterbodies and watersheds designated "HQW" and "SWS" may be approved by the permitting authority.

(d) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds of waterbodies designated "HQW" or "SWS" in Appendix A of OAC 785:45.

785:46-13-5. Tier 3 protection; prohibition against degradation of water quality in outstanding resource waters

(a) General. New point source discharges of any pollutant after June 11, 1989, and increased load of any pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "ORW" and/or "Scenic River", and in any waterbody located within the watershed of any waterbody designated with the limitation "Scenic River". Any discharge of any pollutant to a waterbody designated "ORW" or "Scenic River" which would, if it occurred, lower existing water quality shall be prohibited.

(b) Stormwater discharges. Regardless of 785:46-13-5(a), point source discharges of stormwater from temporary construction activities to waterbodies and watersheds designated "ORW" and/or "Scenic River" may be permitted by the permitting authority. Regardless of 785:46-13-5(a), discharges of stormwater to waterbodies and watersheds designated "ORW" and/or "Scenic River" from point sources existing as of June 25, 1992, whether or not such stormwater discharges were permitted as point sources prior to June 25, 1992, may be permitted by the permitting authority; provided, however, increased load of any pollutant from such stormwater discharge shall be prohibited.

(c) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds of waterbodies designated "ORW" in Appendix A of OAC 785:45, provided, however, that development of conservation plans shall be required in sub-watersheds where discharges or runoff from nonpoint sources are identified as causing or significantly contributing to degradation in a waterbody designated "ORW".

(d) LMFO's. No licensed managed feeding operation (LMFO) established after June 10, 1998 which applies for a new or expanding license from the State Department of Agriculture after March 9, 1998 shall be located...[w]ithin three (3) miles of any designated scenic river area as specified by the Scenic Rivers Act in 82 O.S. Section 1451 and following, or [w]ithin one (1) mile of a waterbody [2:9-210.3(D)] designated in Appendix A of OAC 785:45 as "ORW".

785:46-13-6. Protection for Appendix B areas

(a) General. Appendix B of OAC 785:45 identifies areas in Oklahoma with waters of recreational and/or ecological significance. These areas are divided into Table 1, which includes national and state parks, national forests, wildlife areas, wildlife management areas and wildlife refuges; and Table 2, which includes areas which contain threatened or endangered species listed as such by the federal government pursuant to the federal Endangered Species Act as amended.

(b) Protection for Table 1 areas. New discharges of pollutants after June 11, 1989, or increased loading of pollutants from discharges existing as of June 11, 1989, to waters within the boundaries of areas listed in Table 1 of Appendix B of OAC 785:45 may be approved by the permitting authority under such conditions as ensure that the recreational and ecological significance of these waters will be maintained.

(c) Protection for Table 2 areas. Discharges or other activities associated with those waters within the boundaries listed in Table 2 of Appendix B of OAC 785:45 may be restricted through agreements between appropriate regulatory agencies and the United States Fish and Wildlife Service. Discharges or other activities in such areas shall not substantially disrupt the threatened or endangered species inhabiting the receiving water.

(d) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds located within areas listed in Appendix B of OAC 785:45.