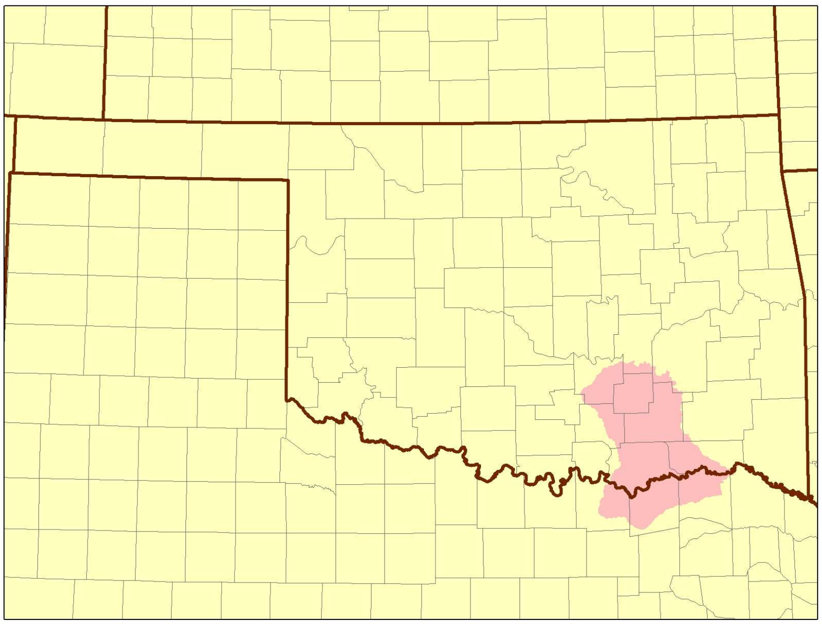
FINAL

BACTERIA TOTAL MAXIMUM DAILY LOADS FOR OK410400, OK410600, OK410700 IN THE BOGGY CREEK AREA, OKLAHOMA



Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

PARSONS

SEPTEMBER 10, 2007

FINAL

BACTERIA TOTAL MAXIMUM DAILY LOADS FOR OKWBID OK410400, OK410600, OK410700 IN THE BOGGY CREEK AREA, OKLAHOMA

OKWBID

OK410400010010, OK410400010070, OK410400030010, OK410400050270, OK410600010010, OK410700000230

Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

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SEPTEMBER 10, 2007

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

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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
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
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

Comment #1: The Blue River appears to be located in two vastly different types of environments. The stretch of Blue River from its head in Pontotoc County to where it crosses highway 48-A near Milburn could be considered the pristine, upstream stretch of the river and below 48-A the other stretch. Above 48-A contains the Blue River Public Hunting and Fishing Area and is the only public access to the river, containing more than 6 miles of river. This is the primary swimming area that, since the TMDL seems to concern itself with clean swimming water, should be of greatest concern.

Upstream from 48-A there are no public waterworks and a very light population. Also, few agricultural activities, other than ranching, occur in this stretch and therefore pollution from fertilizer runoff should be rather light. The water in Blue on this stretch is primarily spring flow. The rocky nature of the terrain (primarily limestone) further filters and purifies water runoff into Blue.

This does not mean that the DEQ should not be concerned with upstream water quality. To the contrary, it is important to ensure that the upstream portion of Blue does not degrade the quality of public water at the Blue River public area.

I urge DEQ to take charge of evaluating all source of pollution to all of the watersheds being considered. It seems to me that there are many economic incentives to pollute (e.g. permitting concentrated animal waste to wash directly into the watershed) and the economic incentives of a few should not create an economic waste (polluted water) for many.

Response #1: First of all, thanks for your comment. The TMDL is developed for the impaired stream segments only. We do not have any evidence suggesting the upper portion of Blue River is impaired or threatened. Therefore, the upper portion of Blue River will not be included in this report.

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 Boggy Creek 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

OKWBID	Waterbody Name	Stream Miles	Category	TMDL Date	Primary Body Contact Recreation
OK410400010010_20	Red River	4.86	5	2005	N
OK410400010070_00	Muddy Boggy Creek	21.59	5	2005	N
OK410400030010_00	Clear Boggy Creek	22.76	5	2005	N
OK410400050270_00	Muddy Boggy Creek 400	25	5	2008	N
OK410600010010_00	Blue River	48.17	5	2004	N
OK410700000230_00	Eastman Creek	7.19	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 five waterbodies: Red River (OK410400010010), Muddy Boggy Creek (OK410400010070), Clear Boggy Creek (OK410400030010), Muddy Boggy Creek 400 (OK410400050270), and Eastman Creek (OK410700000230). Evidence of nonsupport of the PBCR use based on Enterococci concentrations was observed in five waterbodies: Red River (OK410400010010), Muddy Boggy Creek (OK410400010070), Clear Boggy Creek (OK410400030010), Muddy Boggy Creek 400 (OK410400050270), and Blue River (OK410600010010). There was no evidence of nonsupport of the PBCR used based on *E. coli* for any of the waterbodies in the Boggy Creek 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*
OK410400010010-001AT	OK410400010010_20	Red River	X	X	
OK410400010070-001AT	OK410400010070_00	Muddy Boggy Creek	X	X	
OK410400030010-001AT	OK410400030010_00	Clear Boggy Creek	X	X	
OK410400050270-001AT	OK410400050270_00	Muddy Boggy Creek 400	X	X	
OK410600010010-001AT	OK410600010010_00	Blue River		X	
OK410700000230D	OK410700000230_00	Eastman 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 1^{st} to September 30^{th}) 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 Muddy Boggy Creek and Eastman Creek. Four of the watersheds in the Study Area, Red River (OK410400010010_20), Clear Boggy Creek (OK410400030010_00), Muddy Boggy Creek 400 (OK410400050270_00), and Blue River (OK410600010010_00) have NPDES-permitted facilities. Since NPDES-permitted facilities are absent from most of the watersheds in the Study Area, and the few point sources are relatively minor and for the most part, tend to meet instream water quality criteria in their effluent, 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. 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 WQS 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 PRGs for the Red River, both Muddy Boggy Creek segments, Clear Boggy Creek, and the Blue River will be based on Enterococci and the PRGs for Eastman Creek will be based on fecal coliform. All of the PRGs are significant, ranging from 54% to 82%.

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

Waterbody ID	WQM Station	Waterbody Name	Percent Reduction Goal Required		
			FC	ENT	
			Instant-aneous	Instant-aneous	Geo-mean
OK410400010010_20	OK410400010010-001AT	Red River	28%	89%	**54%**
OK410400010070_00	OK410400010070-001AT	Muddy Boggy Creek	60%	98%	**74%**
OK410400030010_00	OK410400030010-001AT	Clear Boggy Creek	55%	89%	**82%**
OK410400050270_00	OK410400050270-001AT	Muddy Boggy Creek 400	60%	93%	**82%**
OK410600010010_00	OK410600010010-001AT	Blue River		95%	**82%**
OK410700000230_00	OK410700000230D	Eastman Creek	**55%**		

The TMDL, WLA, LA, and MOS vary with flow condition, and are calculated at every 5^{th} 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.

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 Summaries Examples

WQM Segment	Indicator Bacteria Species	TMDL† (cfu/day)	WLA† (cfu/day)	LA† (cfu/day)	MOS† (cfu/day)
OK410400010010_20	Enterococci	1.37E+13	3.75E+07	1.23E+13	1.37E+12
OK410400010070_00	Enterococci	1.08E+12	0	9.69E+11	1.08E+11
OK410400030010_00	Enterococci	2.11E+11	0	1.90E+11	2.11E+10
OK410400050270_00	Enterococci	2.67E+11	0	2.40E+11	2.67E+10
OK410600010010_00	Enterococci	2.30E+11	2.46E+08	2.07E+11	2.30E+10
OK410700000230_00	Fecal Coliform	2.16E+10	0	1.94E+10	2.16E+09

† Derived for illustrative purposes at the median flow value

E.5 Reasonable Assurance

As authorized by Section 402 of the CWA, ODEQ has delegation of the 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 Boggy Creek 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 a potential health risk exists for individuals exposed to the water. Data assessment and TMDL calculations are conducted 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 six waterbodies that ODEQ placed in Category 5 of the 2004 Integrated Report [303(d) list] for nonsupport of primary body contact recreation (PBCR):

- Red River (OK410400010010_20),
- Muddy Boggy Creek (OK410400010070_00),
- Clear Boggy Creek (OK410400030010_00),
- Muddy Boggy Creek 400 (OK410400050270_00),
- Blue River (OK410600010010_00), and
- Eastman Creek (OK410700000230_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 Decriptions
Red River	OK410400010010_20	OK410400010010-001AT	Red River at U.S. 259 near De Kalb, TX and Harris, OK
Muddy Boggy Creek	OK410400010070_00	OK410400010070-001AT	Muddy Boggy Creek at U.S. 70 near Unger, OK
Clear Boggy Creek	OK410400030010_00	OK410400030010-001AT	Clear Boggy Creek off U.S. 69 near Caney, OK
Muddy Boggy Creek 400	OK410400050270_00	OK410400050270-001AT	Muddy Boggy Creek at U.S. 69 at Atoka, OK
Blue River	OK410600010010_00	OK410600010010-001AT	Blue River at U.S. 70 near Blue/Durant, OK
Eastman Creek	OK410700000230_00	OK410700000230D	Eastman Creek (near State Route 78)

1.2 Watershed Description

General. The Red River Basin is located in the southeastern portion of Oklahoma. The majority of the six waterbodies addressed in this report are located in Atoka, Bryan, and Choctaw Counties. A small portion of Clear Boggy Creek watershed falls in Johnston County and Coal County. These counties are part of the Central Oklahoma/Texas Plains, South Central Plains and Ouachita Mountain ecoregions. Muddy Boggy Creek (OK410400010070), Blue River (OK410600010010), and Eastman Creek (OK410700000230), and the portion of the Red River targeted for TMDL development are situated in the Gulf Coast Plain geologic province. Clear Boggy Creek (OK410400030010) and the upper portion of Muddy Boggy Creek 400 (OK41040050270_00) fall within the Ouachita Mountain Uplift 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)
Atoka	13,879	14
Bryan	38,395*	40
Choctaw	15,342	20

* Census updated in 2006

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 43.0 and 48.5 inches (Oklahoma Climate Survey 2007).

Table 1-3 Average Annual Precipitation by WQM Station

Boggy Creek Precipitation Summary		
Waterbody Name	WQM Station	Average Annual (Inches)
Red River	OK410400010010_20	48.5
Muddy Boggy Creek	OK410400010070_00	46.8
Clear Boggy Creek	OK410400030010_00	44.3
Muddy Boggy Creek 400	OK410400050270_00	45.6
Blue River	OK410600010010_00	44.7
Eastman Creek	OK410700000230_00	43.0

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 Boggy Creek area is primarily pasture/hay and row crops (57%) and forested (22%). The combination of pasture/hay, row crops, and grassland are the primary land use category in Muddy Boggy Creek (OK410400010070), Clear Boggy Creek (OK410400030010), Blue River (OK410600010010), and Eastman Creek (OK410700000230) watersheds. Deciduous forest is the second largest land use category in Muddy Boggy Creek, Clear Boggy Creek, Blue River, and Eastman Creek watersheds (24, 39, 30, and 32%, respectively). Muddy Boggy Creek 400 (OK410400050270) is 53 percent forested and 37 percent pasture/hay and row crops. Bokchito and Bennington are two small towns located in the Blue River watershed, and Caney and Caddo are located in the Clear Boggy Creek watershed. The other four watersheds have no urban areas. Low, medium, and high intensity developed land account for less than 4 percent of the land use in each watershed.

Table 1-4 Land Use Summaries by Watershed

Landuse Category	Watershed					
	Red River	Muddy Boggy Creek	Clear Boggy Creek	Muddy Boggy Creek 400	Blue River	Eastman Creek
Waterbody ID	OK410400010010_20	OK410400010070_00	OK410400030010_00	OK410400050270_00	OK410600010010_00	OK410700000230_00
Percent of Open Water	4.2	0.5	0.6	0.7	0.6	1.1
Percent of Developed, Open Space	2.7	3.7	3.2	3.0	3.9	3.9
Percent of Developed, Low Intensity	3.8	0.1	0.2	0.2	0.2	0.3
Percent of Developed, Medium Intensity	0.2	0.0	0.1	0.0	0.0	0.0
Percent of Developed, High Intensity	0.0	0.0	0.0	0.0	0.0	0.0
Percent of Barren Land (Rock/Sand/Clay)	1.6	0.0	0.2	0.0	0.0	0.0
Percent of Deciduous Forest	15.4	24.3	39.4	38.9	28.9	28.5
Percent of Evergreen Forest	2.3	0.2	0.7	10.2	0.4	4.0
Percent of Mixed Forest	1.9	0.8	0.0	4.0	0.0	0.0
Percent of Shrub/Scrub	2.0	0.1	0.0	5.2	0.0	0.0
Percent of Grassland/Herbaceous	0.3	11.8	32.6	14.7	31.0	25.6
Percent of Pasture/Hay	46.7	57.2	21.4	22.6	33.2	28.1
Percent of Cultivated Crops	10.4	0.8	1.4	0.1	1.5	8.3
Percent of Woody Wetlands	8.4	0.1	0.1	0.4	0.1	0.1
Percent of Emergent Herbaceous Wetlands	0.0	0.4	0.1	0.0	0.1	0.0
Acres Open Water	419	484	893	403	1,017	74
Acres Developed, Open Space	271	3,849	4,351	1,762	6,161	256
Acres Developed, Low Intensity	374	151	324	91	302	18

Landuse Category	Watershed					
	Red River	Muddy Boggy Creek	Clear Boggy Creek	Muddy Boggy Creek 400	Blue River	Eastman Creek
Waterbody ID	**OK410400010010_20**	**OK410400010070_00**	**OK410400030010_00**	**OK410400050270_00**	**OK410600010010_00**	**OK410700000230_00**
Acres Developed, Medium Intensity	22	18	95	14	73	0
Acres Developed, High Intensity	4	2	4	0	14	0
Acres Barren Land (Rock/Sand/Clay)	158	26	248	16	4	0
Acres Deciduous Forest	1,529	25,106	54,291	22,839	46,229	1,856
Acres Evergreen Forest	223	180	977	5,960	565	260
Acres Mixed Forest	189	795	0	2,344	0	0
Acres Shrub/Scrub	197	97	0	3,022	23	0
Acres Grassland/Herbaceous	31	12,121	44,981	8,641	49,535	1,668
Acres Pasture/Hay	4,623	58,992	29,515	13,287	53,100	1,827
Acres Cultivated Crops	1,030	830	1,926	31	2,426	541
Acres Woody Wetlands	828	91	99	234	95	5
Acres Emergent Herbaceous Wetlands	1	382	115	28	224	0
Total (Acres)	**9,899**	**103,123**	**137,818**	**58,672**	**159,767**	**6,503**

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

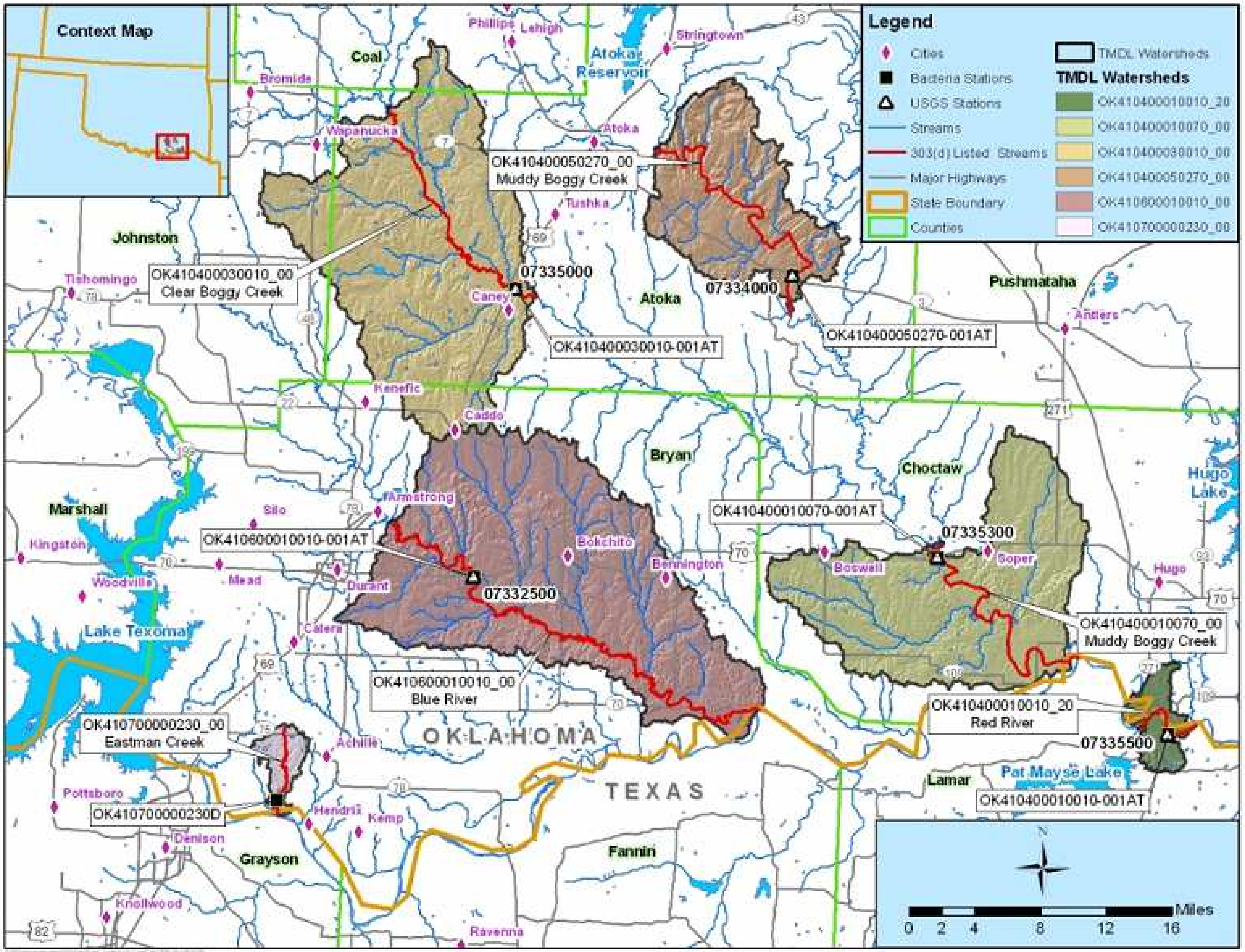
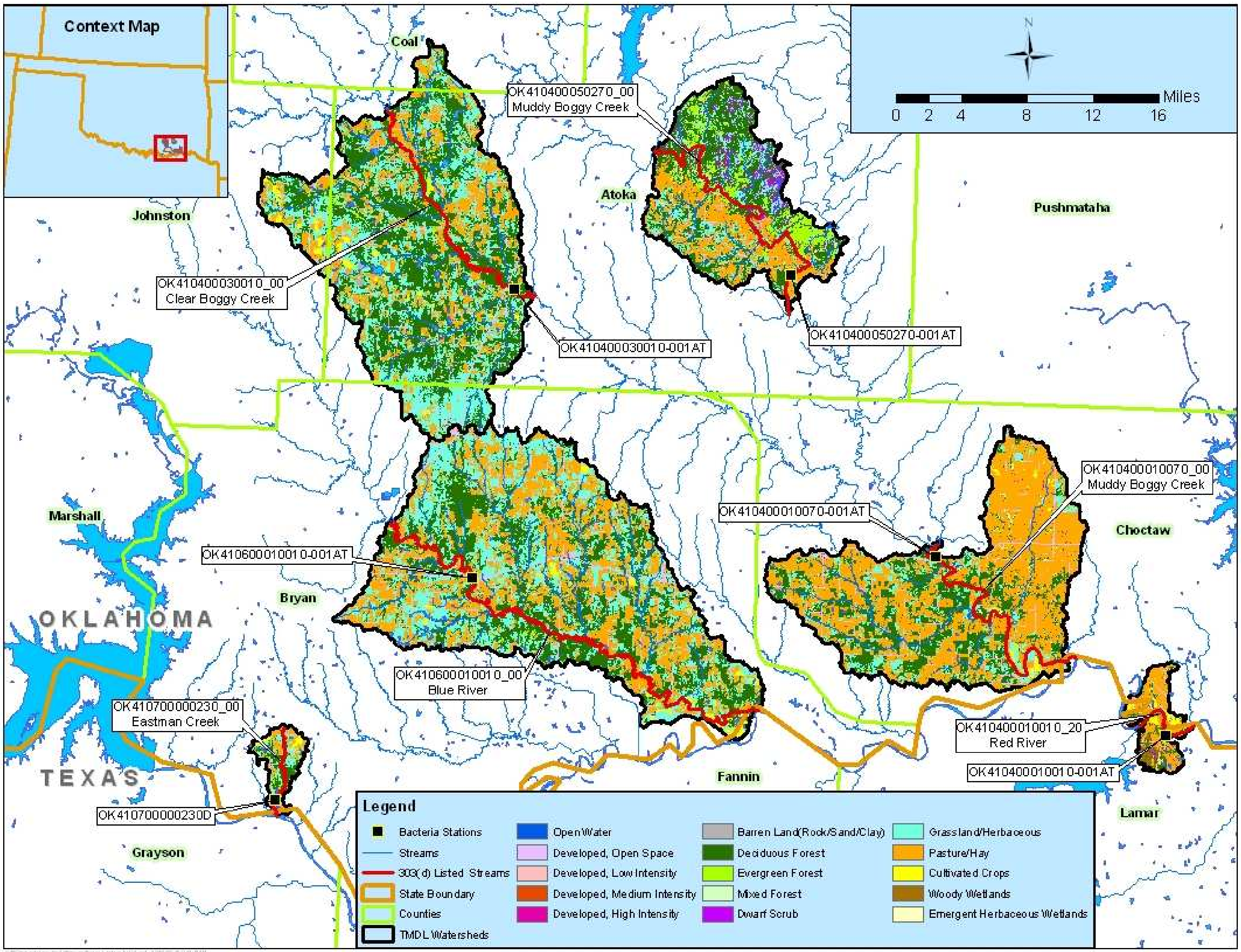


Figure 1-2 Land Use Map by Watershed



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 Red River (OK410400010010), Muddy Boggy Creek (OK410400010070), Clear Boggy Creek (OK410400030010), Muddy Boggy Creek 400 (OK410400050270), Blue River (OK410600010010), and Eastman Creek (OK410700000230) include PBCR, public/private water supply, warm water aquatic community, industrial and municipal process and cooling water, agricultural water supply, public and private water supply, fish consumption 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

OKWBID	Waterbody Name	Stream Miles	Category	TMDL Date	Primary Body Contact Recreation
OK410400010010_20	Red River	4.86	5	2005	N
OK410400010070_00	Muddy Boggy Creek	21.59	5	2005	N
OK410400030010_00	Clear Boggy Creek	22.76	5	2005	N
OK410400050270_00	Muddy Boggy Creek 400	25	5	2008	N
OK410600010010_00	Blue River	48.17	5	2004	N
OK410700000230_00	Eastman Creek	7.19	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) is 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 five waterbodies: Red River (OK410400010010), Muddy Boggy Creek (OK410400010070), Clear Boggy Creek (OK410400030010), Muddy Boggy Creek 400 (OK410400050270), and Eastman Creek (OK410700000230). Evidence of nonsupport of the PBCR use based on Enterococci concentrations was observed in five waterbodies: Red River (OK410400010010), Muddy Boggy Creek (OK410400010070), Clear Boggy Creek (OK410400030010), Muddy Boggy Creek 400 (OK410400050270), and Blue River (OK410600010010). There was no evidence of nonsupport of the PBCR used based on *E. coli* for any of the waterbodies in the Boggy

Creek Study Area. 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 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.

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 Body 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
OK410400010010_20	Red River	FC	400	105	16	6	38%	
		EC	406	43	17	4	24%	Delist: <GeoMean Criterion
		ENT	108	64	17	8	47%	
OK410400010070_00	Muddy Boggy Creek	FC	400	182	15	8	53%	
		EC	406	75	15	4	27%	
		ENT	108	113	14	6	43%	
OK410400030010_00	Clear Boggy Creek	FC	400	246	23	8	35%	
		EC	406	123	24	5	21%	
		ENT	108	162	22	14	64%	
OK410400050270_00	Muddy Boggy Creek 400	FC	400	216	21	8	38%	
		EC	406	78	21	4	19%	
		ENT	108	168	20	10	50%	
OK410600010010_00	Blue River	FC	400	203	24	6	25%	
		EC	406	104	25	2	8%	
		ENT	108	166	24	15	63%	
OK410700000230_00	Eastman Creek	FC	400	380	10	3	30%	
		EC	406	23	2	0	0%	
		ENT	108	460	1	1	100%	

EC = *E. coli;* 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*
OK410400010010-001AT	OK410400010010_20	Red River	X	X	
OK410400010070-001AT	OK410400010070_00	Muddy Boggy Creek	X	X	
OK410400030010-001AT	OK410400030010_00	Clear Boggy Creek	X	X	
OK410400050270-001AT	OK410400050270_00	Muddy Boggy Creek 400	X	X	
OK410600010010-001AT	OK410600010010_00	Blue River		X	
OK410700000230D	OK410700000230_00	Eastman 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 Muddy Boggy Creek and Eastman Creek. Four of the watersheds in the Study Area, Red River (OK410400010010_20), Clear Boggy Creek (OK410400030010_00), Muddy Boggy Creek 400 (OK410400050270_00), and Blue River (OK410600010010_00) have NPDES-permitted facilities.

3.1.1 Continuous Point Source Discharges

The locations of the NPDES permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed 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

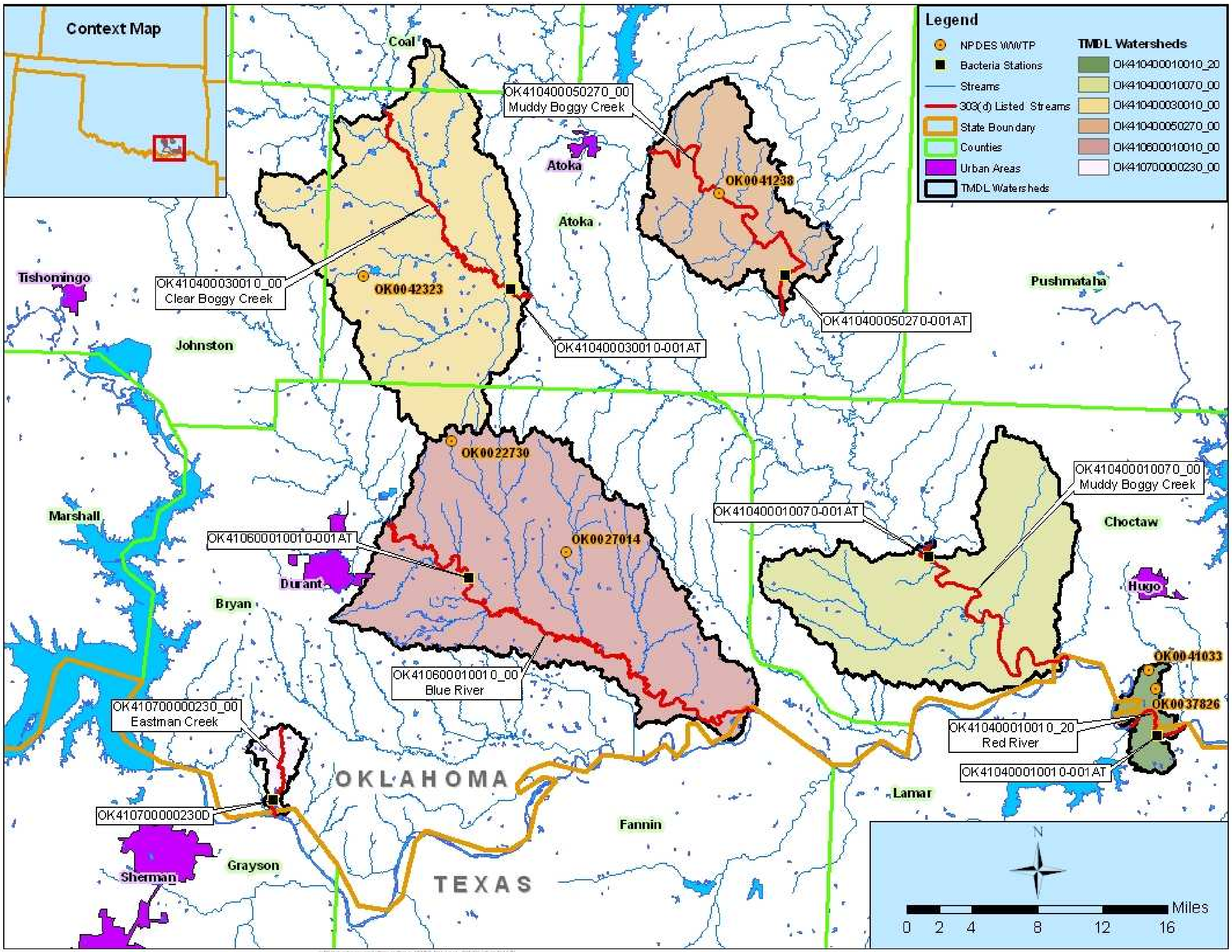
NPDES	Name	Receiving Waters	Facility Type	County Name	Design Flow mgd
OK0027014	City of Bokchito	OK410600010010_00 Bokchito Ck Unnamed Tributary to Blue River	Sewerage Systems	Bryan	0.065
OK0022730	Caddo Public Works Authority	OK410600010010_00 Caddo Creek, Blue River Tributary	Sewerage Systems	Bryan	0.132
OK0037826	Choctaw Co. Rw&Sd #1-Grant	OK410400010010_20 Unnamed Tributary To Red River	Sewerage Systems	Choctaw	0.03
OK0042323	Dolese-Coleman Quarry	Rock Creek Unnamed Tributary	Crushed and Broken Stone	Johnson	
OK0041238	Natural Gas PPLN Co. of America	Muddy Boggy Creek	Natural Gas Transmission	Atoka	
OK0041033	Hallett Materials-Hugo Plant	Red River	Construction Sand and Gravel	Choctaw	

Discharge Monitoring Reports for fecal coliform analyses were not available for the City of Bokchito and Choctaw County. However, flow discharge reports for the City of Bokchito 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. The reporting of SSOs over the last 6 years has been strongly encouraged by USEPA, primarily through enforcement and fines. While not all sewer overflows are reported, ODEQ has some data on SSOs available. There were 11 SSOs, ranging from 500 to 30,000 gallons, reported by the City of Bokchito (OK0027014) between November 1996 and March 2007. Choctaw County (OK0037826) reported 15 SSOs between October 1991 and January 2002, ranging from 0 to 100,000 gallons, although most of the overflow data were not available. The reported SSOs in the Boggy Creek watershed are provided in Appendix B.

Figure 3-1 Locations of NPDES-Permitted Facilities and Poultry Operations 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 watershed of Muddy Boggy Creek and Eastman Creek; therefore, nonsupport of PBCR use is caused by nonpoint sources of bacteria only.

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
OK410400010010_20	Red River	32	9,896
OK410400010070_00	Muddy Boggy Creek	822	103,146
OK410400030010_00	Clear Boggy Creek	1,906	137,797
OK410400050270_00	Muddy Boggy Creek 400	863	58,678
OK410600010010_00	Blue River	1,009	159,758
OK410700000230_00	Eastman Creek	40	6,507

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 10^8 cfu/day) of Deer Population
OK410400010010_20	Red River	32	9,896	0.003	49,482
OK410400010070_00	Muddy Boggy Creek	822	103,146	0.008	515,729
OK410400030010_00	Clear Boggy Creek	1,906	137,797	0.014	688,984
OK410400050270_00	Muddy Boggy Creek 400	863	58,678	0.015	293,388
OK410600010010_00	Blue River	1,009	159,758	0.006	798,790
OK410700000230_00	Eastman Creek	40	6,507	0.006	32,533

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 is 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 deposit 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. Beef cattle are the most abundant species of livestock in the Study Area. Since cattle often have direct access to tributaries within the Study Area they may in fact contribute the greatest load of fecal coliform to the stream as suggested in Table 3-4.

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 of land application acreage are also based on the county level reports from the 2002 USDA county agricultural census. 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 Boggy Creek 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 the 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, again, appear to represent the most likely livestock source of fecal bacteria.

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
OK410400010010_20	Red River	1462	16	23	11	7	6	2	42	2
OK410400010070_00	Muddy Boggy Creek	13789	34	463	253	60	67	38	251	22
OK410400030010_00	Clear Boggy Creek	16251	135	423	410	122	92	206	497	23
OK410400050270_00	Muddy Boggy Creek 400	6692	21	177	119	21	26	100	225	7
OK410600010010_00	Blue River	28130	1110	655	691	756	199	160	735	118
OK410700000230_00	Eastman Creek	1124	44	26	27	30	8	6	30	5

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	Total
OK410400010010_20	Red River	15,210	164	1	N/A	8	7	1	1	15,392
OK410400010070_00	Muddy Boggy Creek	143,402	345	19	N/A	72	73	18	3	143,932
OK410400030010_00	Clear Boggy Creek	169,008	1,365	18	N/A	147	99	119	7	170,762
OK410400050270_00	Muddy Boggy Creek 400	69,601	210	7	N/A	26	28	53	3	69,928
OK410600010010_00	Blue River	292,555	11,212	28	N/A	907	215	171	10	305,098
OK410700000230_00	Eastman Creek	11,691	447	1	N/A	36	9	7	0	12,191

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 onsite sewage disposal systems (ODEQ 2004). 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 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 3-6 summarizes estimates of sewered and unsewered households for each watershed in the Study Area.

Table 3-6 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK410400010010_20	Red River	7	86	4	98	8
OK410400010070_00	Muddy Boggy Creek	238	453	25	716	33
OK410400030010_00	Clear Boggy Creek	245	864	28	1,137	22
OK410400050270_00	Muddy Boggy Creek 400	10	342	26	378	3
OK410600010010_00	Blue River	1,127	1,159	28	2,314	49
OK410700000230_00	Eastman Creek	36	76	3	115	31

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):

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

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 3-7.

Table 3-7 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)
OK410400010010_20	Red River	9,896	86	10	67
OK410400010070_00	Muddy Boggy Creek	103,146	453	54	351
OK410400030010_00	Clear Boggy Creek	137,797	864	104	670
OK410400050270_00	Muddy Boggy Creek 400	58,678	342	41	265
OK410600010010_00	Blue River	159,758	1,159	139	899
OK410700000230_00	Eastman Creek	6,507	76	9	59

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 3-8 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-8 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK410400010010_20	Red River	55	64
OK410400010070_00	Muddy Boggy Creek	401	473
OK410400030010_00	Clear Boggy Creek	637	750
OK410400050270_00	Muddy Boggy Creek 400	212	249
OK410600010010_00	Blue River	1,296	1,527
OK410700000230_00	Eastman Creek	64	76

Table 3-9 provides an estimate of the fecal coliform load from pets. These estimates are based on estimated fecal coliform production rates of $5.4x10^8$ per day for cats and $3.3x10^9$ per day for dogs (Schueler 2000).

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

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK410400010010_20	Red River	18	3	215
OK410400010070_00	Muddy Boggy Creek	132	26	1,579
OK410400030010_00	Clear Boggy Creek	210	41	2,506
OK410400050270_00	Muddy Boggy Creek 400	70	13	833
OK410600010010_00	Blue River	428	82	5,101
OK410700000230_00	Eastman Creek	21	4	253

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 3-10 summarizes the suspected sources of bacteria loading in each impaired watershed.

Table 3-10 Estimated Major Source of Bacteria Loading by Watershed

Waterbody ID	Waterbody Name	Point Sources	Nonpoint Sources	Major Source
OK410400010010_20	Red River	Yes	Yes	Nonpoint
OK410400010070_00	Muddy Boggy Creek	No	Yes	Nonpoint
OK410400030010_00	Clear Boggy Creek	Yes	Yes	Nonpoint
OK410400050270_00	Muddy Boggy Creek 400	Yes	Yes	Nonpoint
OK410600010010_00	Blue River	Yes	Yes	Nonpoint
OK410700000230_00	Eastman Creek	No	Yes	Nonpoint

Table 3-11 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.

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.

Table 3-11 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
OK410400010010_20	Red River	153,918	215	16	67
OK410400010070_00	Muddy Boggy Creek	1,439,323	1,579	411	351
OK410400030010_00	Clear Boggy Creek	1,707,619	2,506	953	670
OK410400050270_00	Muddy Boggy Creek 400	699,278	833	432	265
OK410600010010_00	Blue River	3,050,977	5,101	505	899
OK410700000230_00	Eastman Creek	121,906	253	20	59

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:

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

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 which 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.

The flow duration curve for Red River segment OK410400010010_20 (Figure 4-1) was based on measured flows at USGS gage station 07335500 (Red River at U.S. Highway 271 near Arthur City/Hugo, TX). This gage is co-located with WQM station OK410400010010-001AT. Because the impoundment of McGee Creek in 1990 may have altered the flow regime, measured flows from 1990 through 2006 were used to develop the flow duration curve.

The flow duration curve for Muddy Boggy Creek segment OK410400010070_00 (Figure 4-2) was based on measured flows at USGS gage station 07335300 (Muddy Boggy Creek at U.S. Highway 70 near Unger, OK). This gage is co-located with WQM station OK410400010070-001AT. Because the impoundment of McGee Creek in 1990 may have altered the flow regime, measured flows from 1990 through 2006 were used to develop the flow duration curve.

The flow duration curve for Muddy Boggy Creek 400 segment OK410400050270_00 (Figure 4-3) was based on measured flows at USGS gage station 07334000 (Muddy Boggy Creek near Farris, OK). This gage is co-located with WQM station OK410400050270-001AT. Because the impoundment of McGee Creek in 1990 may have altered the flow regime, measured flows from 1990 through 2006 were used to develop the flow duration curve.

The flow duration curve for Clear Boggy Creek segment OK410400030010_00 (Figure 4-4) was based on measured flows at USGS gage station 07335000 (Clear Boggy Creek off U.S. Highway 69 near Caney, OK). This gage is co-located with WQM station OK410400030010-001AT. Measured flows from the complete period of record (1942 through 1989) were used to develop the flow duration curve.

The flow duration curve for Blue River segment OK410600010010_00 (Figure 4-5) was based on measured flows at USGS gage station 07332500 (Blue River at U.S. Highway 70 near Blue/Durant, OK). This gage is co-located with WQM station OK410600010010-001AT. Measured flows from the complete period of record (1936 through 2004) were used to develop the flow duration curve.

No flow gage exists on Eastman Creek segment OK410700000230_00, and flow could not accurately be predicted from the nearest downstream gage (on the Red River) because it drains a very large watershed and its flow is regulated by dams. Instead, flow projections to derive the flow duration curve (Figure 4-6) were based on measured flows at the nearest USGS gage station (07332500), on the Blue River using the drainage area ratio approach.

Figure 4-1 Flow Duration Curve for Red River (OK410400010010_20)

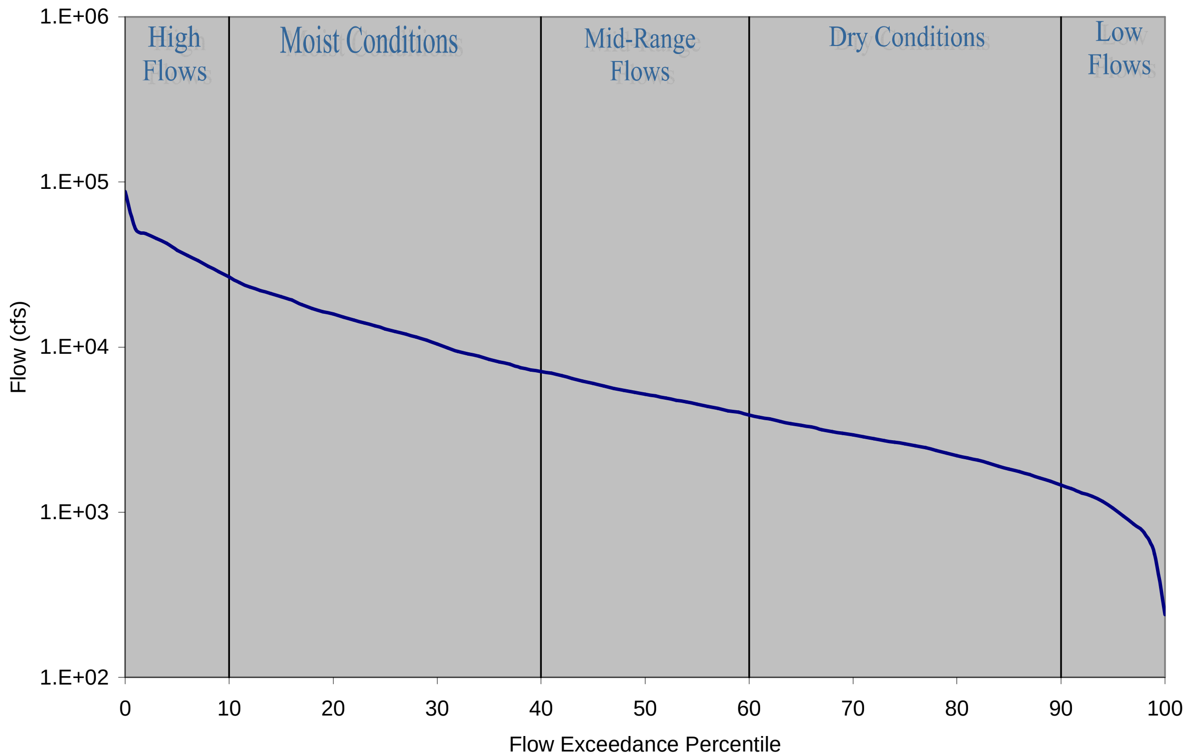


Figure 4-2 Flow Duration Curve for Muddy Boggy Creek (OK410400010070_00)

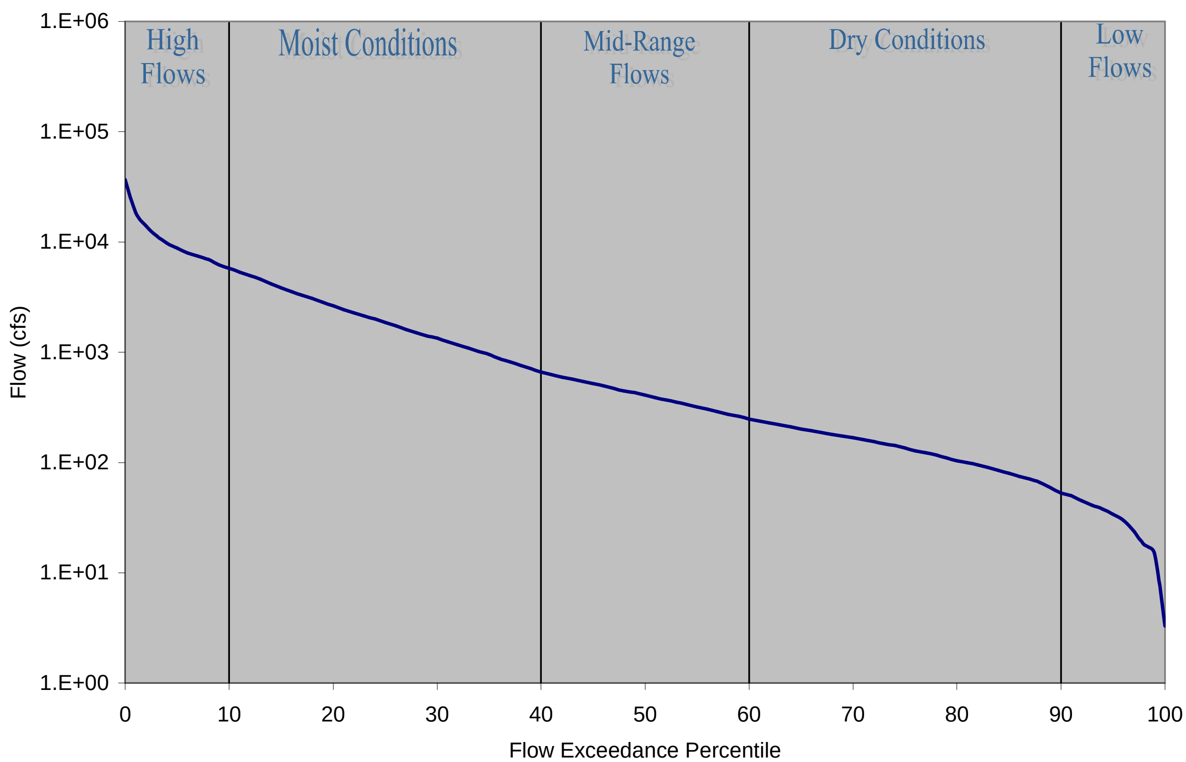


Figure 4-3 Flow Duration Curve for Muddy Boggy Creek 400 (OK410400050270_00)

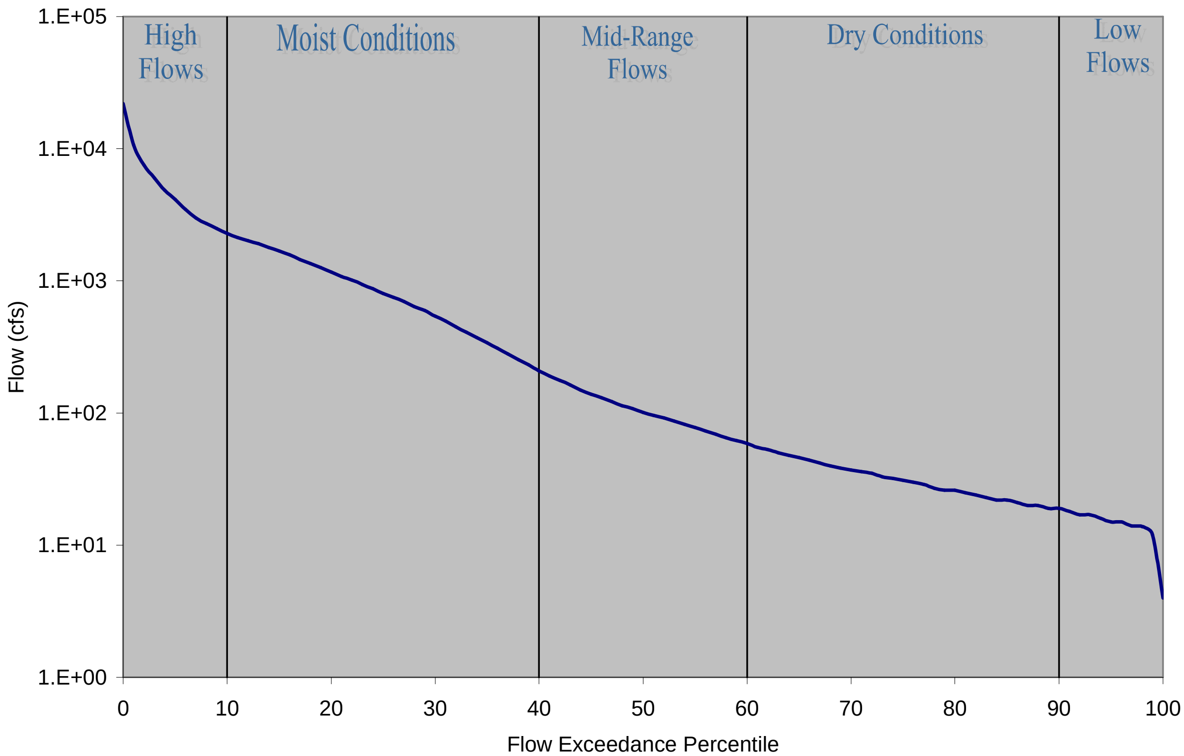


Figure 4-4 Flow Duration Curve for Clear Boggy Creek (OK410400030010_00)

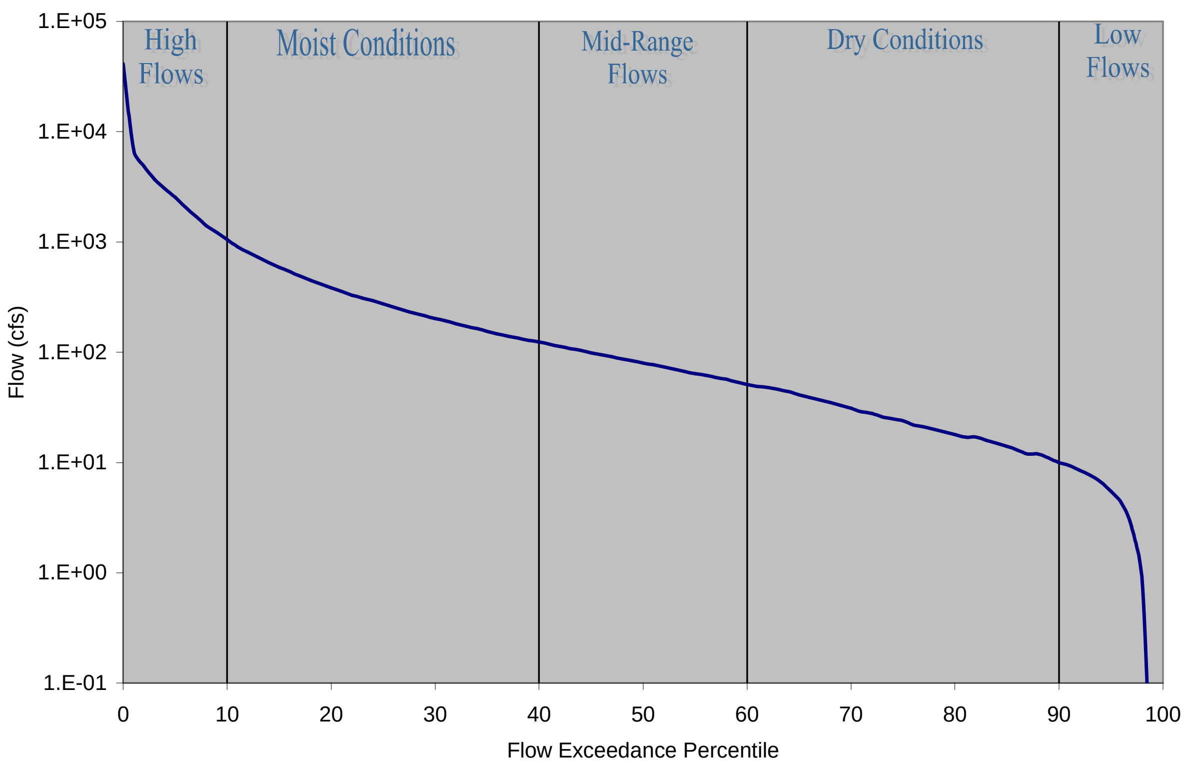


Figure 4-5 Flow Duration Curve for Blue River (OK410600010010_00)

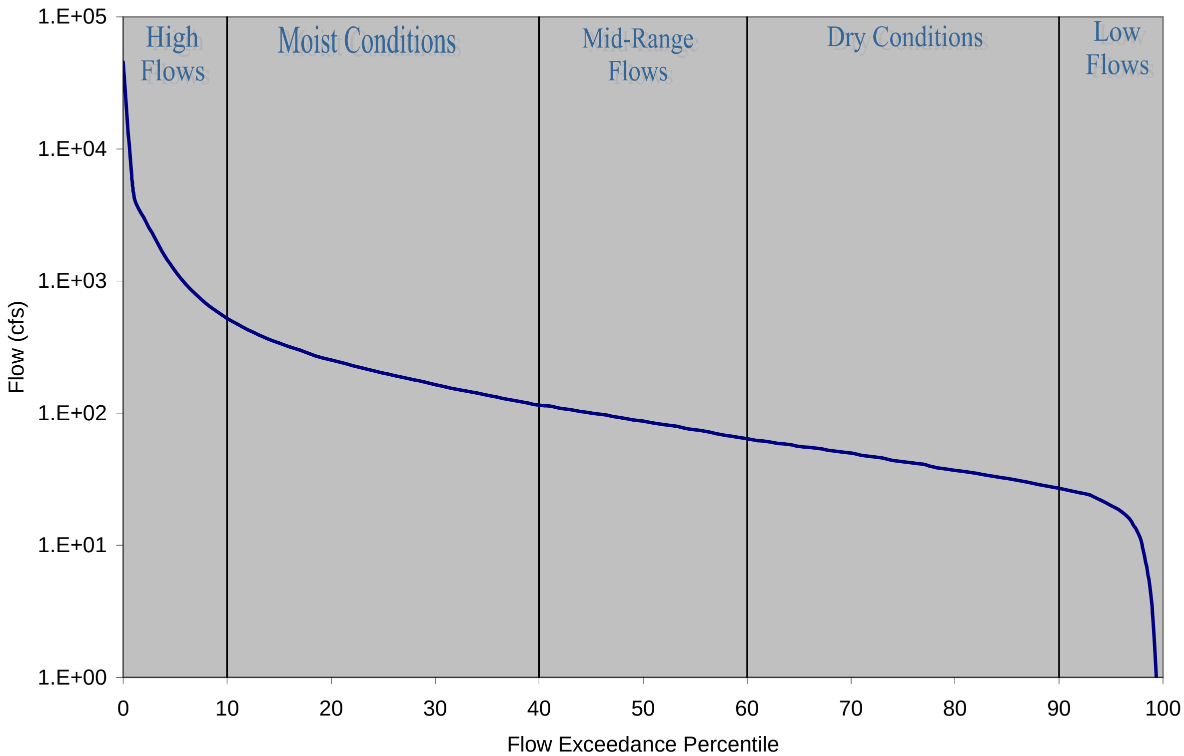
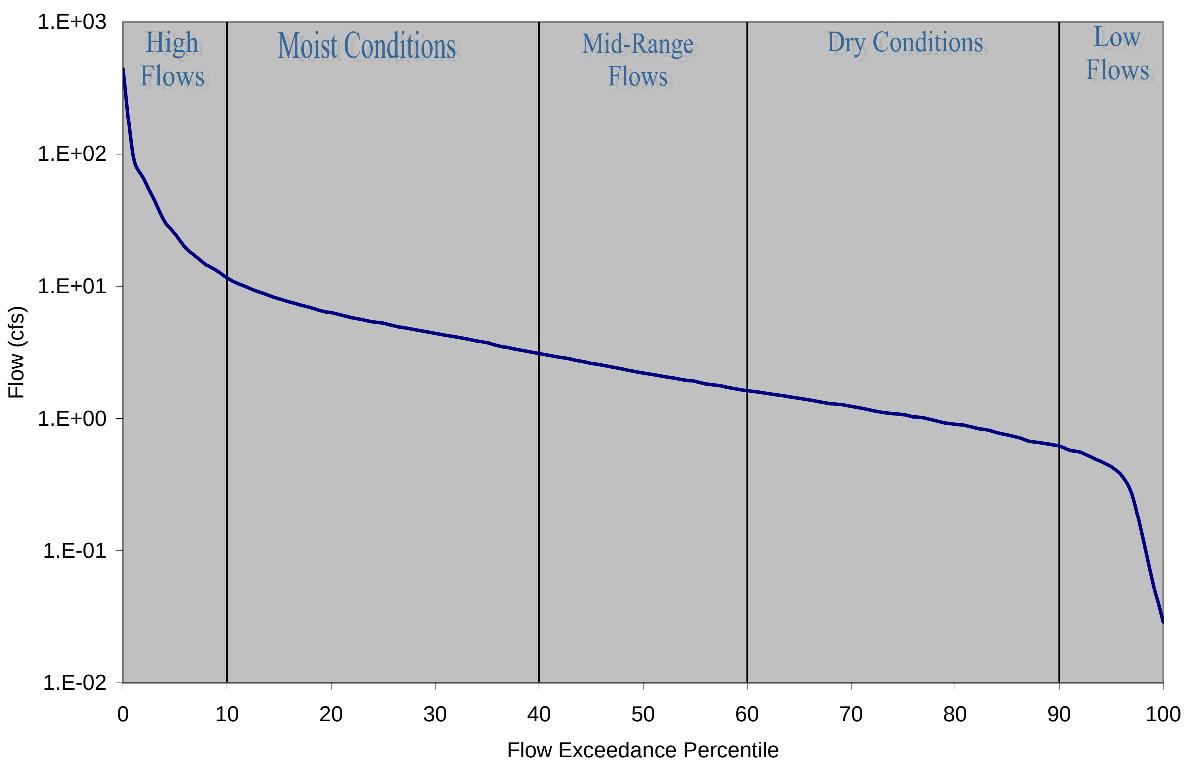


Figure 4-6 Flow Duration Curve for Eastman Creek (OK410700000230_00)



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 90th 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 1st through September 30th) 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 measured 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 contact recreation 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 WQS 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 PRGs for the Red River, both Muddy Boggy Creek segments, Clear Boggy Creek, and the Blue River will be based on Enterococci and the PRGs for Eastman Creek will be based on fecal coliform. All of the PRGs are significant, ranging from 54% to 82%.

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

Waterbody ID	WQM Station	Waterbody Name	Percent Reduction Goal Required		
			FC	ENT	
			Instant-aneous	Instant-aneous	Geo-mean
OK410400010010_20	OK410400010010-001AT	Red River	28%	89%	**54%**
OK410400010070_00	OK410400010070-001AT	Muddy Boggy Creek	60%	98%	**74%**
OK410400030010_00	OK410400030010-001AT	Clear Boggy Creek	55%	89%	**82%**
OK410400050270_00	OK410400050270-001AT	Muddy Boggy Creek 400	60%	93%	**82%**
OK410600010010_00	OK410600010010-001AT	Blue River		95%	**82%**
OK410700000230_00	OK410700000230D	Eastman Creek	**55%**		

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 5-6. The LDCs for other bacterial indicator exceeding the numeric criterion for PBCR are provided in subsection 5.7..

The LDC for Red River segment OK410400010010_20 (Figure 5-1) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410400010010-001AT (Red River at US Highway 271 near Hugo, 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 Muddy Boggy Creek segment OK410400010070_00 (Figure 5-2) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410400010070-001AT (Muddy Boggy Creek at US Highway 70 near Unger, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria under moist to dry conditions, but meet criteria under extremely low flow conditions, indicative of nonpoint sources.

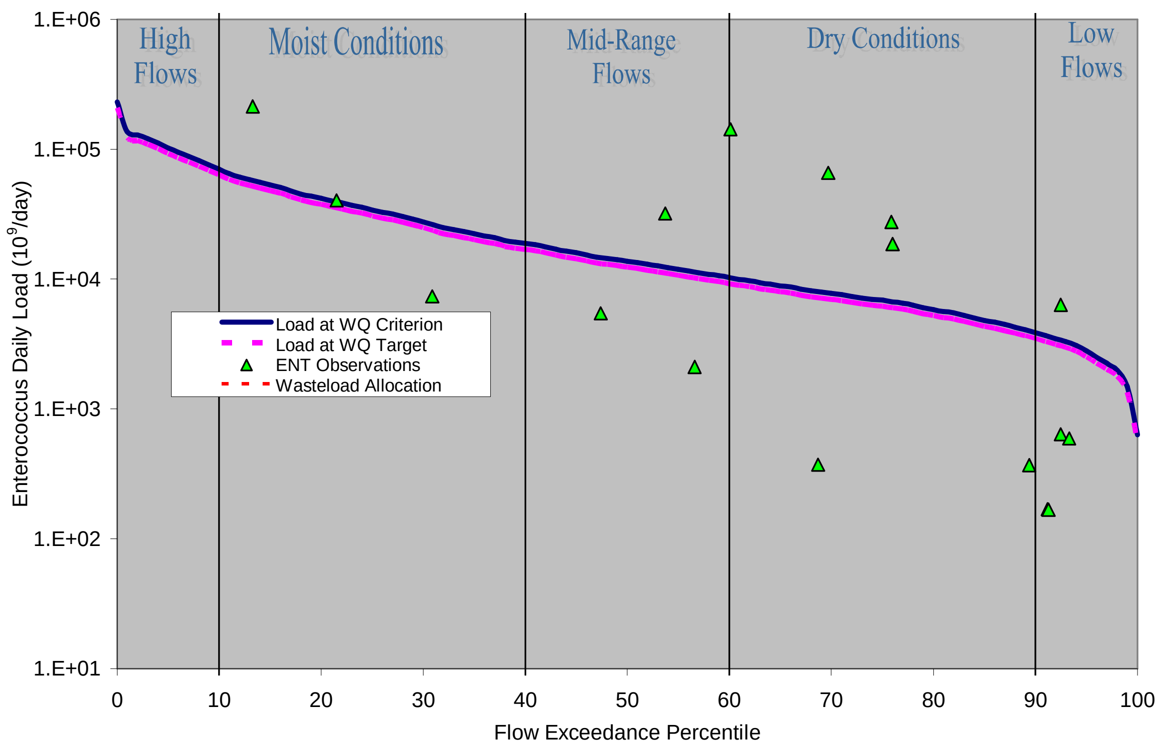
The LDC for Clear Boggy Creek segment OK410400030010_00 (Figure 5-3) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410400030010-001AT (Clear Boggy Creek off US Highway 69 near Caney, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria under a wide range of flow conditions, but exceedances are greatest under moist and mid-range conditions, indicating nonpoint sources.

The LDC for Muddy Boggy Creek segment OK410400050270_00 (Figure 5-4) is based on Enterococci bacteria measurements during primary contact recreation season at WQM station OK410400050270-001AT (Muddy Boggy Creek at State Highway 3 near Farris, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria under a wide range of flow conditions, but exceedances are greatest under moist and mid-range conditions, indicating nonpoint sources.

The LDC for Blue River segment OK410600010010_00 (Figure 5-5) is based on Enterococci measurements during primary contact recreation season at WQM station OK410600010010-001AT (Blue River at US Highway 70 near Durant, OK). The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria over a wide range of flow conditions, indicating nonpoint sources.

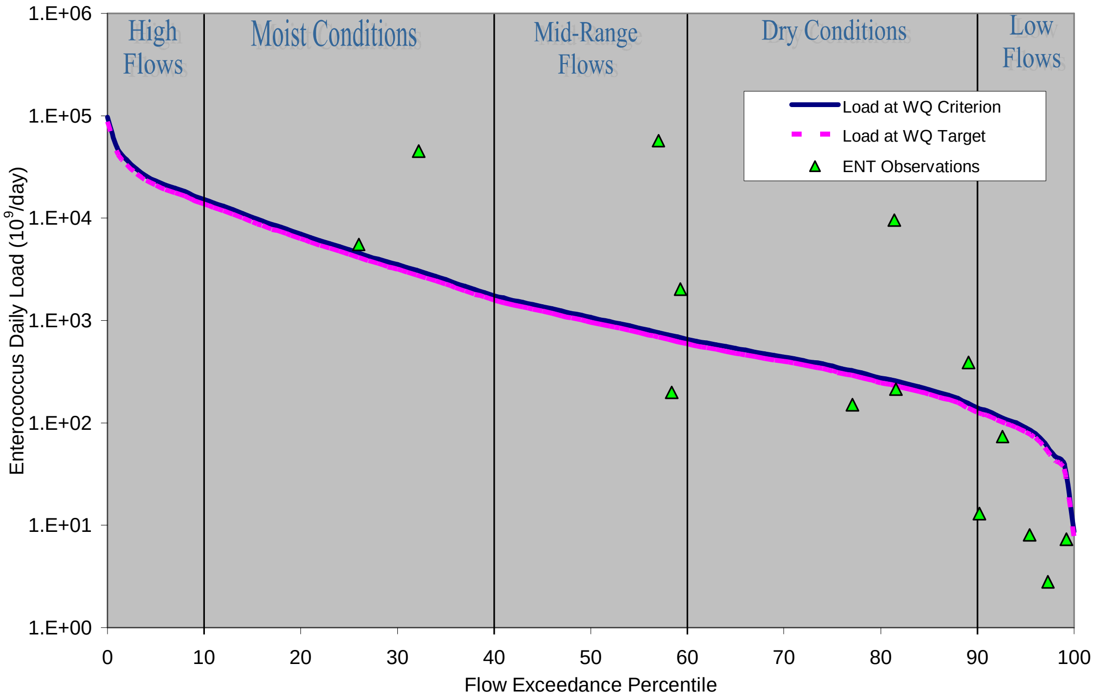
The LDC for Eastman Creek segment OK410700000230_00 (Figure 5-6) is based on fecal coliform measurements during primary contact recreation season at WQM station OK410700000230D (Eastman Creek). Fecal coliform measurements collected during secondary contact recreation season (October – April) are also displayed on the figure, although the load at the secondary contact recreation criterion is not shown. The PRG is calculated such that 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 primarily under a wide range of flow conditions, indicative of nonpoint sources.

Figure 5-1 Load Duration Curve for Enterococci in Red River Segment (OK410400010010_20)



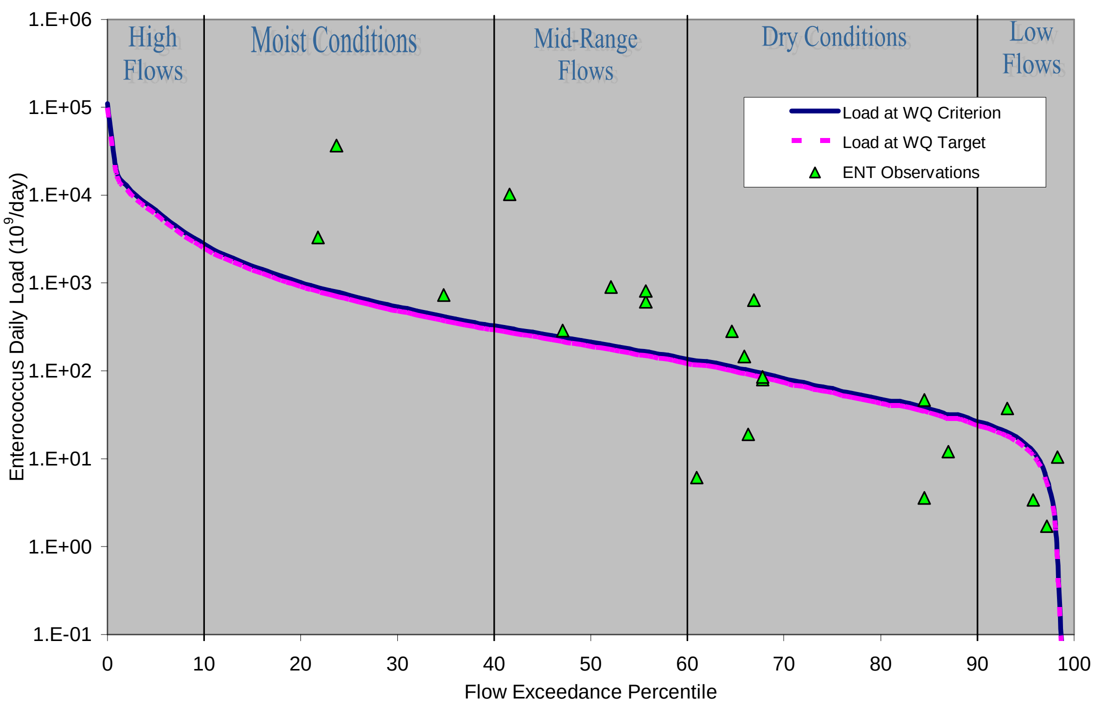
*the wasteload allocation is off the scale of this plot (low)

Figure 5-2 Load Duration Curve for Enterococci in Muddy Boggy Creek Segment (OK410400010070_00)



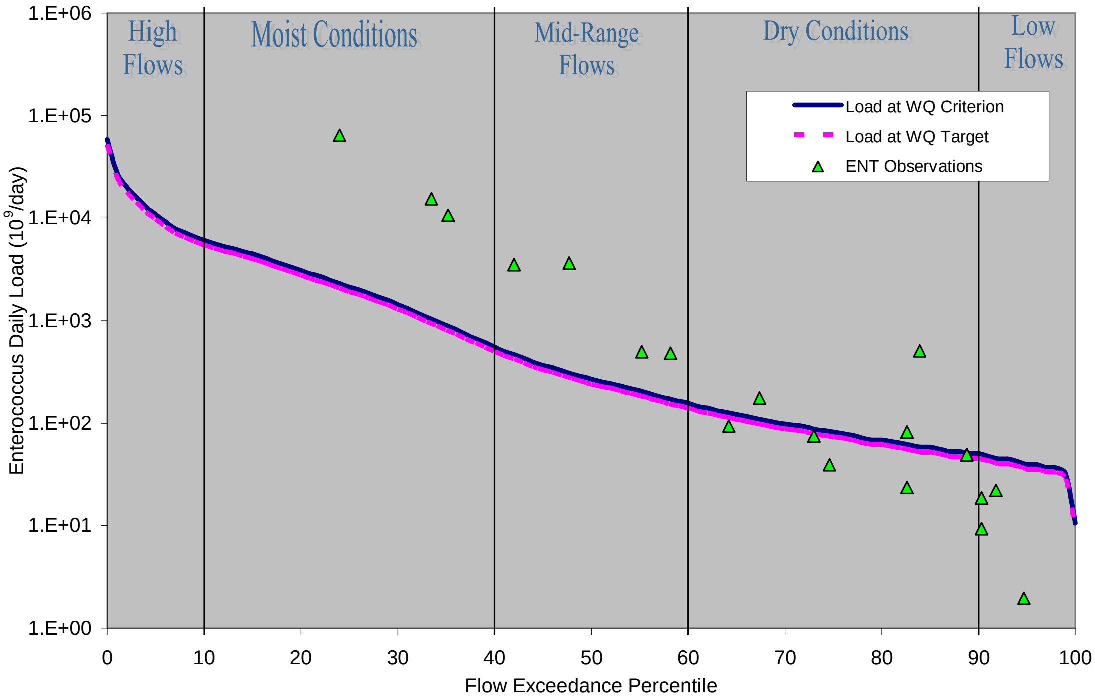
* there is no wasteload allocation for this waterbody

Figure 5-3 Load Duration Curve for Enterococci in Clear Boggy Creek Segment (OK410400030010_00)



*there is no wasteload allocation for this waterbody

Figure 5-4 Load Duration Curve for Enterococci in Muddy Boggy Creek Segment (OK410400050270_00)



* there is no wasteload allocation for this waterbody

Figure 5-5 Load Duration Curve for Enterococci in Blue River Segment (OK410600010010_00)

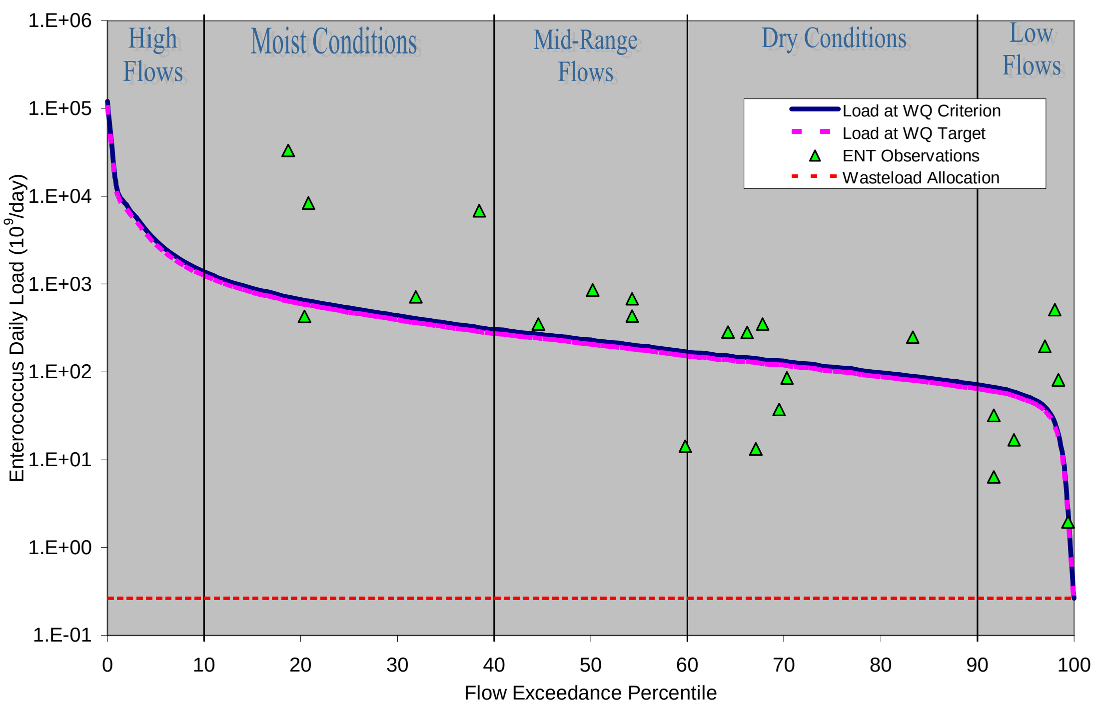
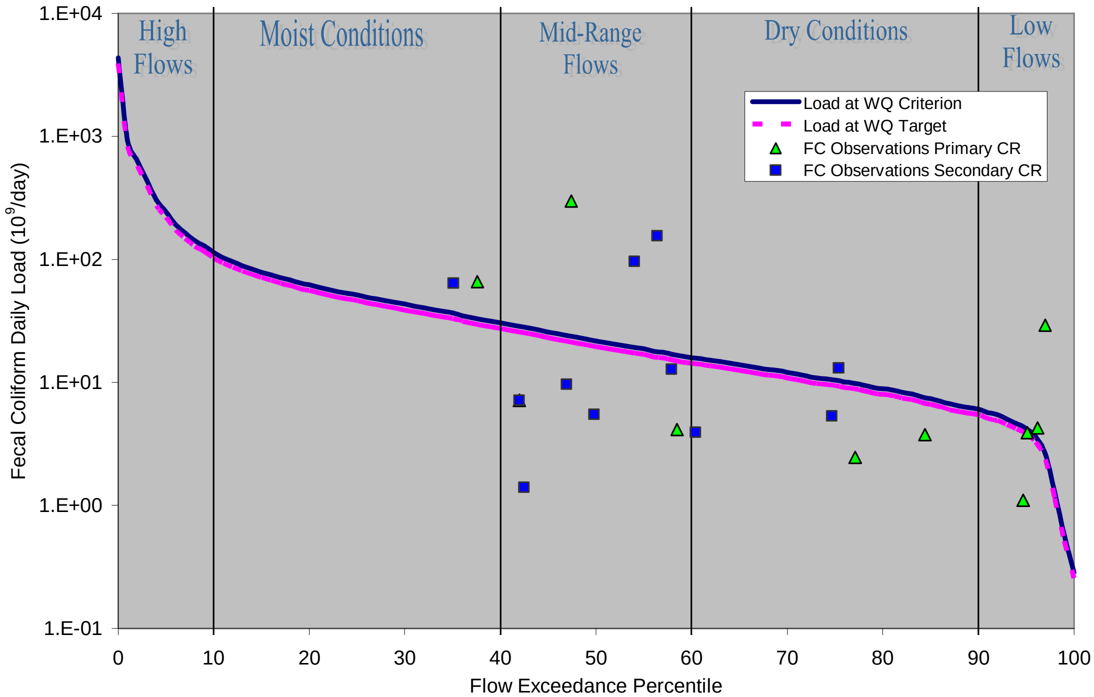


Figure 5-6 Load Duration Curve for Fecal Coliform in Eastman Creek Segment (OK410700000230_00)



* 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. In other words, the facilities are required to meet instream criteria in their discharge. Table 5-2 summarizes the WLA of the NPDES-permitted facilities within the Study Area. The WLA for each facility is derived from the following equation:

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

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

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

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.

Table 5-2 Wasteload Allocations for NPDES Permitted Facilities

Waterbody ID	NPDES Permit Number	Facility Name	Flow (mgd)	Wasteload Allocation (cfu/day)
				Enterococci
OK410400010010_20 Red River	OK0037826	Choctaw Co. RW&SD #1-Grant	0.03	3.75E+07
OK410600010010_00 Blue River	OK0027014	City of Bokchito	0.065	8.12E+07
OK410600010010_00 Blue River	OK0022730	Caddo Public Works Authority	0.132	1.65E+08

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 5-4 through 5-9). For illustrative purposes, the TMDL, WLA, LA, and MOS are calculated for the median flow at each site in Table 5-3. 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 Subsection 5.7.

Table 5-3 TMDL Summary Examples

WQM Segment	Indicator Bacteria Species	TMDL† (cfu/day)	WLA† (cfu/day)	LA† (cfu/day)	MOS† (cfu/day)
OK410400010010_20	Enterococci	1.37E+13	3.75E+07	1.23E+13	1.37E+12
OK410400010070_00	Enterococci	1.08E+12	0	9.69E+11	1.08E+11
OK410400030010_00	Enterococci	2.11E+11	0	1.90E+11	2.11E+10
OK410400050270_00	Enterococci	2.67E+11	0	2.40E+11	2.67E+10
OK410600010010_00	Enterococci	2.30E+11	2.46E+08	2.07E+11	2.30E+10
OK410700000230_00	Fecal Coliform	2.16E+10	0	1.94E+10	2.16E+09

† Derived for illustrative purposes at the median flow value

Table 5-4 Enterococci TMDL Calculations for Red River (OK410400010010_20)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	87,600	2.31E+14	3.75E+07	2.08E+14	2.31E+13
5	38,585	1.02E+14	3.75E+07	9.18E+13	1.02E+13
10	26,600	7.03E+13	3.75E+07	6.33E+13	7.03E+12
15	20,200	5.34E+13	3.75E+07	4.80E+13	5.34E+12
20	15,840	4.19E+13	3.75E+07	3.77E+13	4.19E+12
25	12,900	3.41E+13	3.75E+07	3.07E+13	3.41E+12
30	10,400	2.75E+13	3.75E+07	2.47E+13	2.75E+12
35	8,440	2.23E+13	3.75E+07	2.01E+13	2.23E+12
40	7,100	1.88E+13	3.75E+07	1.69E+13	1.88E+12
45	6,027	1.59E+13	3.75E+07	1.43E+13	1.59E+12
50	5,185	1.37E+13	3.75E+07	1.23E+13	1.37E+12
55	4,510	1.19E+13	3.75E+07	1.07E+13	1.19E+12
60	3,880	1.03E+13	3.75E+07	9.23E+12	1.03E+12
65	3,360	8.88E+12	3.75E+07	7.99E+12	8.88E+11
70	2,940	7.77E+12	3.75E+07	6.99E+12	7.77E+11
75	2,600	6.87E+12	3.75E+07	6.18E+12	6.87E+11
80	2,200	5.81E+12	3.75E+07	5.23E+12	5.81E+11
85	1,820	4.81E+12	3.75E+07	4.33E+12	4.81E+11
90	1,460	3.86E+12	3.75E+07	3.47E+12	3.86E+11
95	1,060	2.80E+12	3.75E+07	2.52E+12	2.80E+11
100	240	6.34E+11	3.75E+07	5.71E+11	6.34E+10

Table 5-5 Enterococci TMDL Calculations for Muddy Boggy Creek (OK410400010070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	36,800	9.72E+13	0.00E+00	8.75E+13	9.72E+12
5	8,767	2.32E+13	0.00E+00	2.08E+13	2.32E+12
10	5,767	1.52E+13	0.00E+00	1.37E+13	1.52E+12
15	3,856	1.02E+13	0.00E+00	9.17E+12	1.02E+12
20	2,640	6.98E+12	0.00E+00	6.28E+12	6.98E+11
25	1,870	4.94E+12	0.00E+00	4.45E+12	4.94E+11
30	1,340	3.54E+12	0.00E+00	3.19E+12	3.54E+11
35	955	2.52E+12	0.00E+00	2.27E+12	2.52E+11
40	662	1.75E+12	0.00E+00	1.57E+12	1.75E+11
45	520	1.37E+12	0.00E+00	1.24E+12	1.37E+11
50	408	1.08E+12	0.00E+00	9.69E+11	1.08E+11
55	320	8.46E+11	0.00E+00	7.61E+11	8.46E+10
60	249	6.58E+11	0.00E+00	5.92E+11	6.58E+10
65	202	5.34E+11	0.00E+00	4.80E+11	5.34E+10
70	168	4.44E+11	0.00E+00	3.99E+11	4.44E+10
75	136	3.59E+11	0.00E+00	3.23E+11	3.59E+10
80	104	2.75E+11	0.00E+00	2.47E+11	2.75E+10
85	80	2.11E+11	0.00E+00	1.90E+11	2.11E+10
90	53	1.40E+11	0.00E+00	1.26E+11	1.40E+10
95	34	8.98E+10	0.00E+00	8.09E+10	8.98E+09
100	3	8.72E+09	0.00E+00	7.85E+09	8.72E+08

Table 5-6 Enterococci TMDL Calculations for Clear Boggy Creek (OK410400030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	41,500	1.10E+14	0.00E+00	9.87E+13	1.10E+13
5	2,540	6.71E+12	0.00E+00	6.04E+12	6.71E+11
10	1,050	2.77E+12	0.00E+00	2.50E+12	2.77E+11
15	589	1.56E+12	0.00E+00	1.40E+12	1.56E+11
20	384	1.01E+12	0.00E+00	9.13E+11	1.01E+11
25	275	7.27E+11	0.00E+00	6.54E+11	7.27E+10
30	202	5.34E+11	0.00E+00	4.80E+11	5.34E+10
35	155	4.10E+11	0.00E+00	3.69E+11	4.10E+10
40	124	3.28E+11	0.00E+00	2.95E+11	3.28E+10
45	99	2.62E+11	0.00E+00	2.35E+11	2.62E+10
50	80	2.11E+11	0.00E+00	1.90E+11	2.11E+10
55	64	1.69E+11	0.00E+00	1.52E+11	1.69E+10
60	51	1.35E+11	0.00E+00	1.21E+11	1.35E+10
65	41	1.09E+11	0.00E+00	9.77E+10	1.09E+10
70	31	8.19E+10	0.00E+00	7.37E+10	8.19E+09
75	24	6.34E+10	0.00E+00	5.71E+10	6.34E+09
80	18	4.76E+10	0.00E+00	4.28E+10	4.76E+09
85	14	3.70E+10	0.00E+00	3.33E+10	3.70E+09
90	10	2.64E+10	0.00E+00	2.38E+10	2.64E+09
95	6	1.45E+10	0.00E+00	1.31E+10	1.45E+09
100	0	2.64E+07	0.00E+00	2.38E+07	2.64E+06

Table 5-7 Enterococci TMDL Calculations for Muddy Boggy Creek (OK410400050270_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	22,000	5.81E+13	0.00E+00	5.23E+13	5.81E+12
5	4,121	1.09E+13	0.00E+00	9.80E+12	1.09E+12
10	2,287	6.04E+12	0.00E+00	5.44E+12	6.04E+11
15	1,686	4.45E+12	0.00E+00	4.01E+12	4.45E+11
20	1,170	3.09E+12	0.00E+00	2.78E+12	3.09E+11
25	802	2.12E+12	0.00E+00	1.91E+12	2.12E+11
30	540	1.43E+12	0.00E+00	1.28E+12	1.43E+11
35	340	8.98E+11	0.00E+00	8.09E+11	8.98E+10
40	209	5.52E+11	0.00E+00	4.97E+11	5.52E+10
45	139	3.67E+11	0.00E+00	3.31E+11	3.67E+10
50	101	2.67E+11	0.00E+00	2.40E+11	2.67E+10
55	78	2.06E+11	0.00E+00	1.85E+11	2.06E+10
60	59	1.56E+11	0.00E+00	1.40E+11	1.56E+10
65	46	1.22E+11	0.00E+00	1.09E+11	1.22E+10
70	37	9.78E+10	0.00E+00	8.80E+10	9.78E+09
75	31	8.19E+10	0.00E+00	7.37E+10	8.19E+09
80	26	6.87E+10	0.00E+00	6.18E+10	6.87E+09
85	22	5.81E+10	0.00E+00	5.23E+10	5.81E+09
90	19	5.02E+10	0.00E+00	4.52E+10	5.02E+09
95	15	3.96E+10	0.00E+00	3.57E+10	3.96E+09
100	4	1.06E+10	0.00E+00	9.51E+09	1.06E+09

Table 5-8 Enterococci TMDL Calculations for Blue River (OK410600010010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	45,500	1.20E+14	2.46E+08	1.08E+14	1.20E+13
5	1,190	3.14E+12	2.46E+08	2.83E+12	3.14E+11
10	523	1.38E+12	2.46E+08	1.24E+12	1.38E+11
15	339	8.96E+11	2.46E+08	8.06E+11	8.96E+10
20	252	6.66E+11	2.46E+08	5.99E+11	6.66E+10
25	201	5.31E+11	2.46E+08	4.78E+11	5.31E+10
30	165	4.36E+11	2.46E+08	3.92E+11	4.36E+10
35	137	3.62E+11	2.46E+08	3.26E+11	3.62E+10
40	115	3.04E+11	2.46E+08	2.73E+11	3.04E+10
45	100	2.64E+11	2.46E+08	2.38E+11	2.64E+10
50	87	2.30E+11	2.46E+08	2.07E+11	2.30E+10
55	75	1.98E+11	2.46E+08	1.78E+11	1.98E+10
60	64	1.69E+11	2.46E+08	1.52E+11	1.69E+10
65	56	1.48E+11	2.46E+08	1.33E+11	1.48E+10
70	50	1.32E+11	2.46E+08	1.19E+11	1.32E+10
75	43	1.14E+11	2.46E+08	1.02E+11	1.14E+10
80	37	9.78E+10	2.46E+08	8.77E+10	9.78E+09
85	32	8.46E+10	2.46E+08	7.59E+10	8.46E+09
90	27	7.13E+10	2.46E+08	6.40E+10	7.13E+09
95	20	5.28E+10	2.46E+08	4.73E+10	5.28E+09
100	0	0.00E+00	2.46E+08	0.00E+00	0.00E+00

Table 5-9 Fecal Coliform TMDL Calculations for Eastman Creek (OK410700000230_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	443	4.34E+12	0.00E+00	3.90E+12	4.34E+11
5	25	2.44E+11	0.00E+00	2.19E+11	2.44E+10
10	12	1.14E+11	0.00E+00	1.02E+11	1.14E+10
15	8.1	7.88E+10	0.00E+00	7.10E+10	7.88E+09
20	6.3	6.19E+10	0.00E+00	5.57E+10	6.19E+09
25	5.3	5.14E+10	0.00E+00	4.63E+10	5.14E+09
30	4.4	4.31E+10	0.00E+00	3.88E+10	4.31E+09
35	3.8	3.67E+10	0.00E+00	3.30E+10	3.67E+09
40	3.1	3.05E+10	0.00E+00	2.74E+10	3.05E+09
45	2.6	2.56E+10	0.00E+00	2.30E+10	2.56E+09
50	2.2	2.16E+10	0.00E+00	1.94E+10	2.16E+09
55	1.9	1.88E+10	0.00E+00	1.69E+10	1.88E+09
60	1.6	1.59E+10	0.00E+00	1.43E+10	1.59E+09
65	1.4	1.39E+10	0.00E+00	1.25E+10	1.39E+09
70	1.2	1.21E+10	0.00E+00	1.09E+10	1.21E+09
75	1.1	1.05E+10	0.00E+00	9.43E+09	1.05E+09
80	0.9	8.88E+09	0.00E+00	7.99E+09	8.88E+08
85	0.8	7.35E+09	0.00E+00	6.61E+09	7.35E+08
90	0.6	6.05E+09	0.00E+00	5.44E+09	6.05E+08
95	0.4	4.24E+09	0.00E+00	3.81E+09	4.24E+08
100	0	0.00E+00	0	0.00E+00	0.00E+00

5.7 LDCs and TMDL Calculations for Additional Bacterial Indicators

As mentioned previously in Subsection 5.1, 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 as required, TMDL calculations from LDCs for all bacterial indicators not supporting the PBCR use were prepared. The remaining LDCs and TMDL calculations for additional bacterial indicators are shown in Figures 5-7 through 5-10 and Tables 5-10 through 5-13 respectively.

Figure 5-7 Load Duration Curve for Fecal Coliform in Red River Segment (OK410400010010_20)

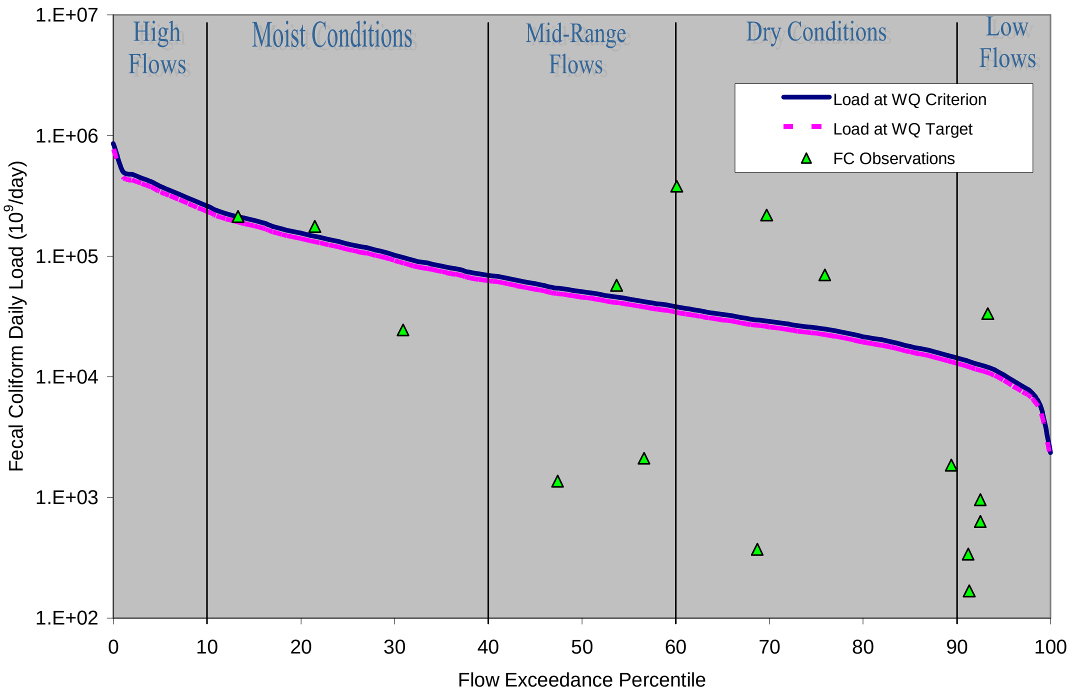


Table 5-10 Fecal Coliform TMDL Calculations for Red River (OK410400010010_20)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	87,600	8.57E+14	1.43E+08	7.72E+14	8.57E+13
5	38,585	3.78E+14	1.43E+08	3.40E+14	3.78E+13
10	26,600	2.60E+14	1.43E+08	2.34E+14	2.60E+13
15	20,200	1.98E+14	1.43E+08	1.78E+14	1.98E+13
20	15,840	1.55E+14	1.43E+08	1.40E+14	1.55E+13
25	12,900	1.26E+14	1.43E+08	1.14E+14	1.26E+13
30	10,400	1.02E+14	1.43E+08	9.16E+13	1.02E+13
35	8,440	8.26E+13	1.43E+08	7.43E+13	8.26E+12
40	7,100	6.95E+13	1.43E+08	6.25E+13	6.95E+12
45	6,027	5.90E+13	1.43E+08	5.31E+13	5.90E+12
50	5,185	5.07E+13	1.43E+08	4.57E+13	5.07E+12
55	4,510	4.41E+13	1.43E+08	3.97E+13	4.41E+12
60	3,880	3.80E+13	1.43E+08	3.42E+13	3.80E+12
65	3,360	3.29E+13	1.43E+08	2.96E+13	3.29E+12
70	2,940	2.88E+13	1.43E+08	2.59E+13	2.88E+12
75	2,600	2.54E+13	1.43E+08	2.29E+13	2.54E+12
80	2,200	2.15E+13	1.43E+08	1.94E+13	2.15E+12
85	1,820	1.78E+13	1.43E+08	1.60E+13	1.78E+12
90	1,460	1.43E+13	1.43E+08	1.29E+13	1.43E+12
95	1,060	1.04E+13	1.43E+08	9.34E+12	1.04E+12
100	240	2.35E+12	1.43E+08	2.11E+12	2.35E+11

Figure 5-8 Load Duration Curve for Fecal Coliform in Muddy Boggy Creek Segment (OK410400010070_00)

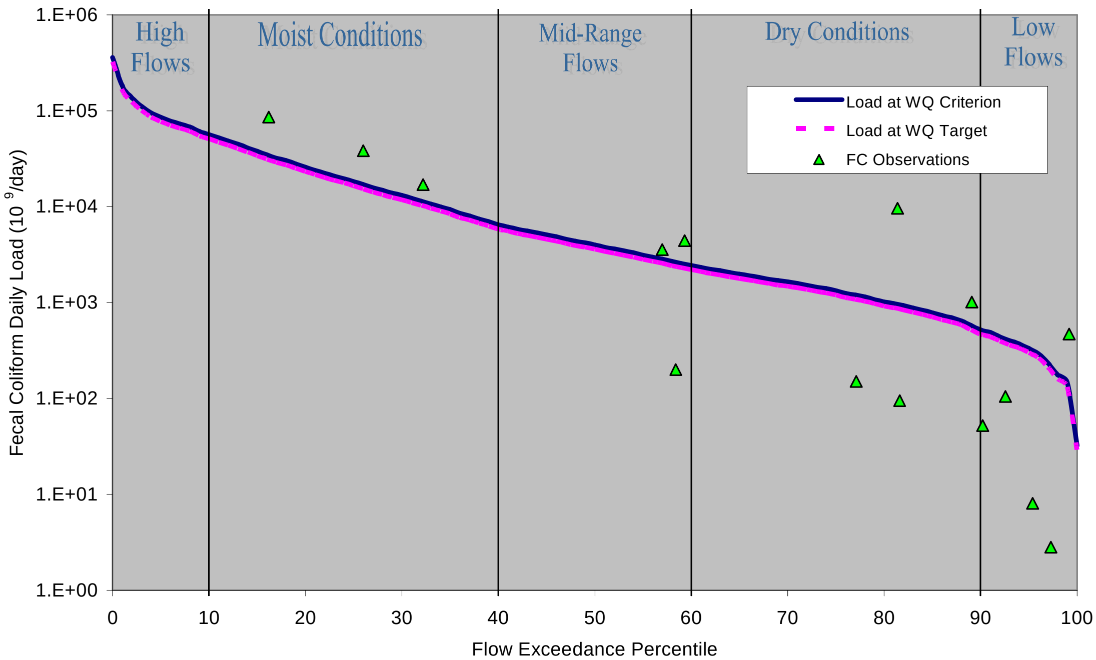


Table 5-11 Fecal Coliform TMDL Calculations for Muddy Boggy Creek (OK410400010070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	36,800	3.60E+14	0.00E+00	3.24E+14	3.60E+13
5	8,767	8.58E+13	0.00E+00	7.72E+13	8.58E+12
10	5,767	5.64E+13	0.00E+00	5.08E+13	5.64E+12
15	3,856	3.77E+13	0.00E+00	3.40E+13	3.77E+12
20	2,640	2.58E+13	0.00E+00	2.33E+13	2.58E+12
25	1,870	1.83E+13	0.00E+00	1.65E+13	1.83E+12
30	1,340	1.31E+13	0.00E+00	1.18E+13	1.31E+12
35	955	9.34E+12	0.00E+00	8.41E+12	9.34E+11
40	662	6.48E+12	0.00E+00	5.83E+12	6.48E+11
45	520	5.09E+12	0.00E+00	4.58E+12	5.09E+11
50	408	3.99E+12	0.00E+00	3.59E+12	3.99E+11
55	320	3.13E+12	0.00E+00	2.82E+12	3.13E+11
60	249	2.44E+12	0.00E+00	2.19E+12	2.44E+11
65	202	1.98E+12	0.00E+00	1.78E+12	1.98E+11
70	168	1.64E+12	0.00E+00	1.48E+12	1.64E+11
75	136	1.33E+12	0.00E+00	1.20E+12	1.33E+11
80	104	1.02E+12	0.00E+00	9.16E+11	1.02E+11
85	80	7.83E+11	0.00E+00	7.05E+11	7.83E+10
90	53	5.19E+11	0.00E+00	4.67E+11	5.19E+10
95	34	3.33E+11	0.00E+00	2.99E+11	3.33E+10
100	3	3.23E+10	0.00E+00	2.91E+10	3.23E+09

Figure 5-9 Load Duration Curve for Fecal Coliform in Clear Boggy Creek Segment (OK410400030010_00)

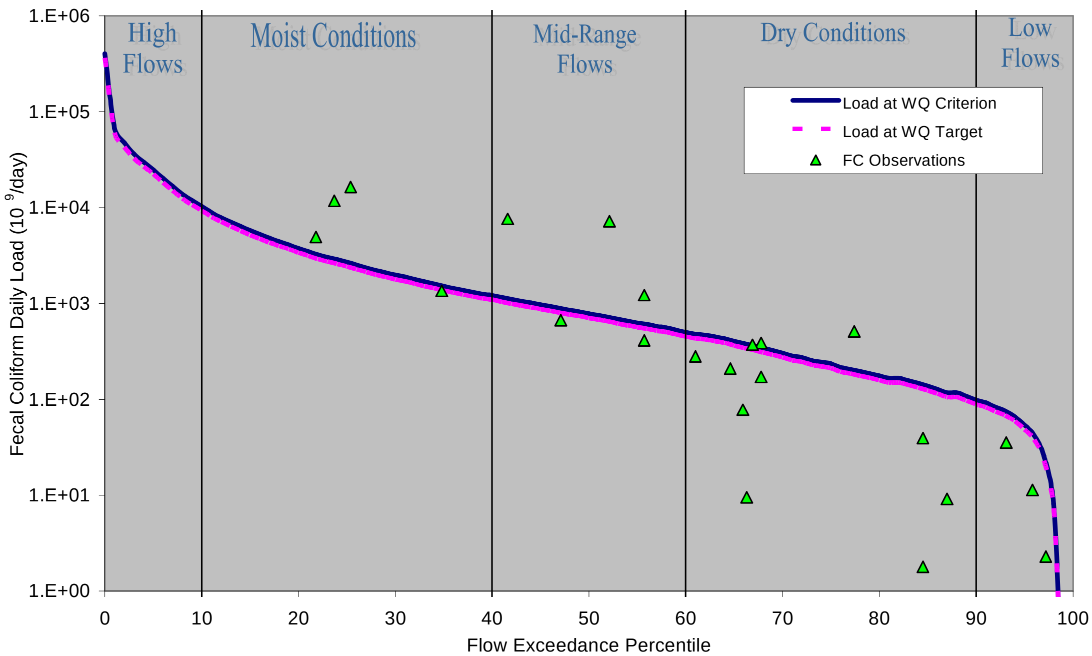


Table 5-12 Fecal Coliform TMDL Calculations for Clear Boggy Creek (OK410400030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	41,500	4.06E+14	0.00E+00	3.66E+14	4.06E+13
5	2,540	2.49E+13	0.00E+00	2.24E+13	2.49E+12
10	1,050	1.03E+13	0.00E+00	9.25E+12	1.03E+12
15	589	5.76E+12	0.00E+00	5.19E+12	5.76E+11
20	384	3.76E+12	0.00E+00	3.38E+12	3.76E+11
25	275	2.69E+12	0.00E+00	2.42E+12	2.69E+11
30	202	1.98E+12	0.00E+00	1.78E+12	1.98E+11
35	155	1.52E+12	0.00E+00	1.37E+12	1.52E+11
40	124	1.21E+12	0.00E+00	1.09E+12	1.21E+11
45	99	9.69E+11	0.00E+00	8.72E+11	9.69E+10
50	80	7.83E+11	0.00E+00	7.05E+11	7.83E+10
55	64	6.26E+11	0.00E+00	5.64E+11	6.26E+10
60	51	4.99E+11	0.00E+00	4.49E+11	4.99E+10
65	41	4.02E+11	0.00E+00	3.62E+11	4.02E+10
70	31	3.03E+11	0.00E+00	2.73E+11	3.03E+10
75	24	2.35E+11	0.00E+00	2.11E+11	2.35E+10
80	18	1.76E+11	0.00E+00	1.59E+11	1.76E+10
85	14	1.37E+11	0.00E+00	1.23E+11	1.37E+10
90	10	9.79E+10	0.00E+00	8.81E+10	9.79E+09
95	6	5.38E+10	0.00E+00	4.84E+10	5.38E+09
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Figure 5-10 Load Duration Curve for Fecal Coliform in Muddy Boggy Creek Segment (OK410400050270_00)

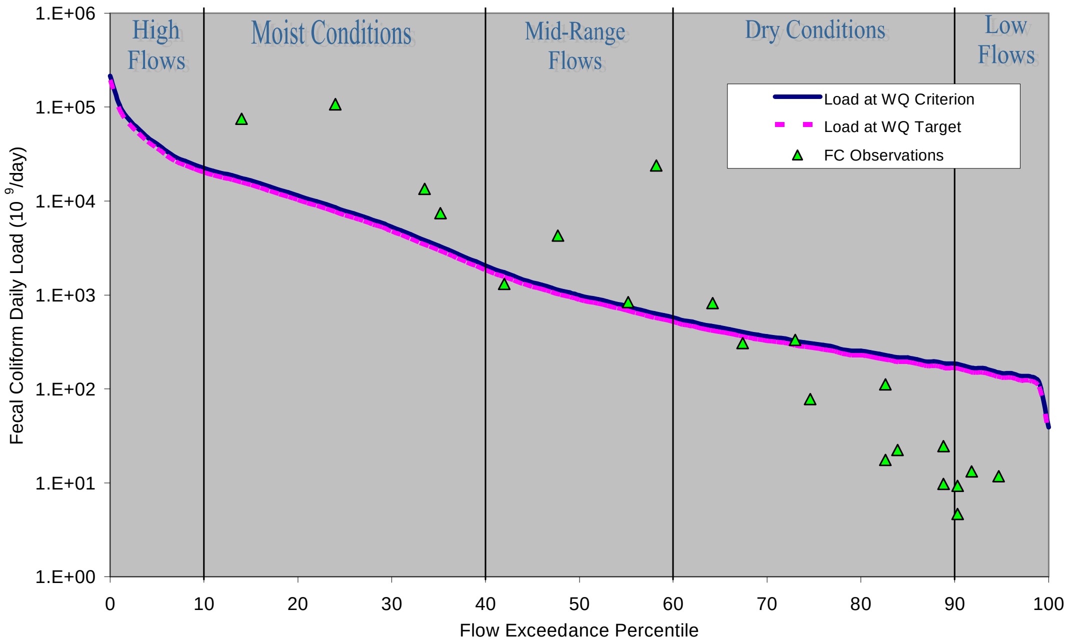


Table 5-13 Fecal Coliform TMDL Calculations for Muddy Boggy Creek (OK410400050270_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	22,000	2.15E+14	0.00E+00	1.94E+14	2.15E+13
5	4,121	4.03E+13	0.00E+00	3.63E+13	4.03E+12
10	2,287	2.24E+13	0.00E+00	2.01E+13	2.24E+12
15	1,686	1.65E+13	0.00E+00	1.48E+13	1.65E+12
20	1,170	1.14E+13	0.00E+00	1.03E+13	1.14E+12
25	802	7.84E+12	0.00E+00	7.06E+12	7.84E+11
30	540	5.29E+12	0.00E+00	4.76E+12	5.29E+11
35	340	3.33E+12	0.00E+00	2.99E+12	3.33E+11
40	209	2.04E+12	0.00E+00	1.84E+12	2.04E+11
45	139	1.36E+12	0.00E+00	1.22E+12	1.36E+11
50	101	9.88E+11	0.00E+00	8.90E+11	9.88E+10
55	78	7.63E+11	0.00E+00	6.87E+11	7.63E+10
60	59	5.77E+11	0.00E+00	5.20E+11	5.77E+10
65	46	4.50E+11	0.00E+00	4.05E+11	4.50E+10
70	37	3.62E+11	0.00E+00	3.26E+11	3.62E+10
75	31	3.03E+11	0.00E+00	2.73E+11	3.03E+10
80	26	2.54E+11	0.00E+00	2.29E+11	2.54E+10
85	22	2.15E+11	0.00E+00	1.94E+11	2.15E+10
90	19	1.86E+11	0.00E+00	1.67E+11	1.86E+10
95	15	1.47E+11	0.00E+00	1.32E+11	1.47E+10
100	4.0	3.91E+10	0.00E+00	3.52E+10	3.91E+09

5.8 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 5-10 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 5-10 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 ground water 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 82 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, 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 on-going. 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. The TMDL report was made available for public from July 27, 2007 through September10, 2007. A public meeting was held in Antlers, Oklahoma on August 21, 2007. Seven people attended the public meeting and no oral comment was received at the meeting.

At the end of public comment period, only one comment was received. The response to the comment was prepared and included as part of the report. No change was made to the report.

SECTION 7
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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)
OK410400010010-001AT	Red River	6/28/1999	480	FC	400
OK410400010010-001AT	Red River	7/26/1999	5	FC	400
OK410400010010-001AT	Red River	8/10/1999	10	FC	400
OK410400010010-001AT	Red River	9/28/1999	30	FC	400
OK410400010010-001AT	Red River	6/6/2000	1120	FC	400
OK410400010010-001AT	Red River	7/11/2000	50	FC	400
OK410400010010-001AT	Red River	8/8/2000	5	FC	400
OK410400010010-001AT	Red River	9/13/2000	1130	FC	400
OK410400010010-001AT	Red River	5/29/2001	400	FC	400
OK410400010010-001AT	Red River	6/13/2001	100	FC	400
OK410400010010-001AT	Red River	7/18/2001	10	FC	400
OK410400010010-001AT	Red River	8/15/2001	20	FC	400
OK410400010010-001AT	Red River	5/13/2002	4000	FC	400
OK410400010010-001AT	Red River	6/10/2002	500	FC	400
OK410400010010-001AT	Red River	7/15/2002	20	FC	400
OK410400010010-001AT	Red River	9/9/2002	3000	FC	400
OK410400010010-001AT	Red River	6/28/1999	256	EC	406
OK410400010010-001AT	Red River	7/26/1999	5	EC	406
OK410400010010-001AT	Red River	8/10/1999	20	EC	406
OK410400010010-001AT	Red River	9/28/1999	41	EC	406
OK410400010010-001AT	Red River	6/6/2000	743	EC	406
OK410400010010-001AT	Red River	7/11/2000	31	EC	406
OK410400010010-001AT	Red River	8/8/2000	5	EC	406
OK410400010010-001AT	Red River	9/13/2000	10	EC	406
OK410400010010-001AT	Red River	5/29/2001	504	EC	406
OK410400010010-001AT	Red River	6/13/2001	5	EC	406
OK410400010010-001AT	Red River	7/18/2001	5	EC	406
OK410400010010-001AT	Red River	8/15/2001	5	EC	406
OK410400010010-001AT	Red River	9/4/2001	437	EC	406
OK410400010010-001AT	Red River	5/13/2002	1607	EC	406
OK410400010010-001AT	Red River	6/10/2002	52	EC	406
OK410400010010-001AT	Red River	7/15/2002	10	EC	406
OK410400010010-001AT	Red River	9/9/2002	199	EC	406
OK410400010010-001AT	Red River	6/28/1999	110	ENT	108
OK410400010010-001AT	Red River	7/26/1999	5	ENT	108
OK410400010010-001AT	Red River	8/10/1999	5	ENT	108
OK410400010010-001AT	Red River	9/28/1999	20	ENT	108
OK410400010010-001AT	Red River	6/6/2000	440	ENT	108
OK410400010010-001AT	Red River	7/11/2000	10	ENT	108
OK410400010010-001AT	Red River	8/8/2000	5	ENT	108
OK410400010010-001AT	Red River	9/13/2000	20	ENT	108

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK410400010010-001AT	Red River	5/29/2001	400	ENT	108
OK410400010010-001AT	Red River	6/13/2001	30	ENT	108
OK410400010010-001AT	Red River	7/18/2001	40	ENT	108
OK410400010010-001AT	Red River	8/15/2001	200	ENT	108
OK410400010010-001AT	Red River	9/4/2001	300	ENT	108
OK410400010010-001AT	Red River	5/13/2002	1500	ENT	108
OK410400010010-001AT	Red River	6/10/2002	280	ENT	108
OK410400010010-001AT	Red River	7/15/2002	20	ENT	108
OK410400010010-001AT	Red River	9/9/2002	900	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	7/11/1999	900	FC	400
OK410400010070-001AT	Muddy Boggy Creek	8/4/1999	40	FC	400
OK410400010070-001AT	Muddy Boggy Creek	9/8/1999	10	FC	400
OK410400010070-001AT	Muddy Boggy Creek	6/6/2000	700	FC	400
OK410400010070-001AT	Muddy Boggy Creek	7/11/2000	50	FC	400
OK410400010070-001AT	Muddy Boggy Creek	8/8/2000	100	FC	400
OK410400010070-001AT	Muddy Boggy Creek	9/13/2000	1280	FC	400
OK410400010070-001AT	Muddy Boggy Creek	5/30/2001	1000	FC	400
OK410400010070-001AT	Muddy Boggy Creek	6/13/2001	30	FC	400
OK410400010070-001AT	Muddy Boggy Creek	7/18/2001	40	FC	400
OK410400010070-001AT	Muddy Boggy Creek	8/15/2001	5	FC	400
OK410400010070-001AT	Muddy Boggy Creek	9/4/2001	700	FC	400
OK410400010070-001AT	Muddy Boggy Creek	5/13/2002	500	FC	400
OK410400010070-001AT	Muddy Boggy Creek	6/10/2002	600	FC	400
OK410400010070-001AT	Muddy Boggy Creek	9/9/2002	4000	FC	400
OK410400010070-001AT	Muddy Boggy Creek	7/11/1999	776	EC	406
OK410400010070-001AT	Muddy Boggy Creek	8/4/1999	63	EC	406
OK410400010070-001AT	Muddy Boggy Creek	9/8/1999	52	EC	406
OK410400010070-001AT	Muddy Boggy Creek	6/6/2000	479	EC	406
OK410400010070-001AT	Muddy Boggy Creek	7/11/2000	10	EC	406
OK410400010070-001AT	Muddy Boggy Creek	8/8/2000	10	EC	406
OK410400010070-001AT	Muddy Boggy Creek	9/13/2000	30	EC	406
OK410400010070-001AT	Muddy Boggy Creek	5/30/2001	2382	EC	406
OK410400010070-001AT	Muddy Boggy Creek	6/13/2001	63	EC	406
OK410400010070-001AT	Muddy Boggy Creek	7/18/2001	10	EC	406
OK410400010070-001AT	Muddy Boggy Creek	8/15/2001	10	EC	406
OK410400010070-001AT	Muddy Boggy Creek	9/4/2001	307	EC	406
OK410400010070-001AT	Muddy Boggy Creek	5/13/2002	160	EC	406
OK410400010070-001AT	Muddy Boggy Creek	6/10/2002	10	EC	406
OK410400010070-001AT	Muddy Boggy Creek	9/9/2002	529	EC	406
OK410400010070-001AT	Muddy Boggy Creek	7/11/1999	130	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	8/4/1999	10	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	9/8/1999	10	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	6/6/2000	320	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	7/11/2000	50	ENT	108

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK410400010070-001AT	Muddy Boggy Creek	8/8/2000	70	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	9/13/2000	20	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	6/13/2001	30	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	7/18/2001	90	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	8/15/2001	5	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	9/4/2001	270	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	5/13/2002	8000	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	6/10/2002	1600	ENT	108
OK410400010070-001AT	Muddy Boggy Creek	9/9/2002	4000	ENT	108
OK410400030010-001AT	Clear Boggy Creek	6/28/1999	350	FC	400
OK410400030010-001AT	Clear Boggy Creek	7/26/1999	230	FC	400
OK410400030010-001AT	Clear Boggy Creek	8/10/1999	440	FC	400
OK410400030010-001AT	Clear Boggy Creek	9/28/1999	200	FC	400
OK410400030010-001AT	Clear Boggy Creek	6/6/2000	400	FC	400
OK410400030010-001AT	Clear Boggy Creek	7/11/2000	30	FC	400
OK410400030010-001AT	Clear Boggy Creek	8/8/2000	40	FC	400
OK410400030010-001AT	Clear Boggy Creek	5/30/2001	2500	FC	400
OK410400030010-001AT	Clear Boggy Creek	6/13/2001	300	FC	400
OK410400030010-001AT	Clear Boggy Creek	7/18/2001	80	FC	400
OK410400030010-001AT	Clear Boggy Creek	8/15/2001	5	FC	400
OK410400030010-001AT	Clear Boggy Creek	9/4/2001	1000	FC	400
OK410400030010-001AT	Clear Boggy Creek	5/15/2002	1600	FC	400
OK410400030010-001AT	Clear Boggy Creek	7/17/2002	270	FC	400
OK410400030010-001AT	Clear Boggy Creek	9/11/2002	600	FC	400
OK410400030010-001AT	Clear Boggy Creek	5/6/2003	200	FC	400
OK410400030010-001AT	Clear Boggy Creek	6/10/2003	4000	FC	400
OK410400030010-001AT	Clear Boggy Creek	6/25/2003	10	FC	400
OK410400030010-001AT	Clear Boggy Creek	7/15/2003	110	FC	400
OK410400030010-001AT	Clear Boggy Creek	7/30/2003	100	FC	400
OK410400030010-001AT	Clear Boggy Creek	8/19/2003	190	FC	400
OK410400030010-001AT	Clear Boggy Creek	9/3/2003	2700	FC	400
OK410400030010-001AT	Clear Boggy Creek	9/23/2003	800	FC	400
OK410400030010-001AT	Clear Boggy Creek	6/28/1999	233	EC	406
OK410400030010-001AT	Clear Boggy Creek	7/26/1999	98	EC	406
OK410400030010-001AT	Clear Boggy Creek	8/10/1999	143	EC	406
OK410400030010-001AT	Clear Boggy Creek	9/28/1999	41	EC	406
OK410400030010-001AT	Clear Boggy Creek	6/6/2000	520	EC	406
OK410400030010-001AT	Clear Boggy Creek	7/11/2000	20	EC	406
OK410400030010-001AT	Clear Boggy Creek	8/8/2000	10	EC	406
OK410400030010-001AT	Clear Boggy Creek	9/13/2000	156	EC	406
OK410400030010-001AT	Clear Boggy Creek	5/30/2001	1396	EC	406
OK410400030010-001AT	Clear Boggy Creek	6/13/2001	74	EC	406
OK410400030010-001AT	Clear Boggy Creek	7/18/2001	95	EC	406
OK410400030010-001AT	Clear Boggy Creek	8/15/2001	20	EC	406

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK410400030010-001AT	Clear Boggy Creek	9/4/2001	2333	EC	406
OK410400030010-001AT	Clear Boggy Creek	5/15/2002	619	EC	406
OK410400030010-001AT	Clear Boggy Creek	7/17/2002	121	EC	406
OK410400030010-001AT	Clear Boggy Creek	9/11/2002	169	EC	406
OK410400030010-001AT	Clear Boggy Creek	5/6/2003	63	EC	406
OK410400030010-001AT	Clear Boggy Creek	6/10/2003	197	EC	406
OK410400030010-001AT	Clear Boggy Creek	6/25/2003	10	EC	406
OK410400030010-001AT	Clear Boggy Creek	7/15/2003	121	EC	406
OK410400030010-001AT	Clear Boggy Creek	7/30/2003	10	EC	406
OK410400030010-001AT	Clear Boggy Creek	8/19/2003	350	EC	406
OK410400030010-001AT	Clear Boggy Creek	9/3/2003	573	EC	406
OK410400030010-001AT	Clear Boggy Creek	9/23/2003	382	EC	406
OK410400030010-001AT	Clear Boggy Creek	6/28/1999	190	ENT	108
OK410400030010-001AT	Clear Boggy Creek	7/26/1999	5	ENT	108
OK410400030010-001AT	Clear Boggy Creek	8/10/1999	90	ENT	108
OK410400030010-001AT	Clear Boggy Creek	9/28/1999	100	ENT	108
OK410400030010-001AT	Clear Boggy Creek	6/6/2000	690	ENT	108
OK410400030010-001AT	Clear Boggy Creek	7/11/2000	40	ENT	108
OK410400030010-001AT	Clear Boggy Creek	8/8/2000	30	ENT	108
OK410400030010-001AT	Clear Boggy Creek	9/13/2000	900	ENT	108
OK410400030010-001AT	Clear Boggy Creek	6/13/2001	130	ENT	108
OK410400030010-001AT	Clear Boggy Creek	7/18/2001	150	ENT	108
OK410400030010-001AT	Clear Boggy Creek	8/15/2001	10	ENT	108
OK410400030010-001AT	Clear Boggy Creek	5/15/2002	5000	ENT	108
OK410400030010-001AT	Clear Boggy Creek	7/17/2002	400	ENT	108
OK410400030010-001AT	Clear Boggy Creek	9/11/2002	400	ENT	108
OK410400030010-001AT	Clear Boggy Creek	5/6/2003	270	ENT	108
OK410400030010-001AT	Clear Boggy Creek	6/10/2003	500	ENT	108
OK410400030010-001AT	Clear Boggy Creek	6/25/2003	20	ENT	108
OK410400030010-001AT	Clear Boggy Creek	7/15/2003	130	ENT	108
OK410400030010-001AT	Clear Boggy Creek	7/30/2003	30	ENT	108
OK410400030010-001AT	Clear Boggy Creek	8/19/2003	200	ENT	108
OK410400030010-001AT	Clear Boggy Creek	9/3/2003	3600	ENT	108
OK410400030010-001AT	Clear Boggy Creek	9/23/2003	530	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	6/6/2000	440	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	7/11/2000	100	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	8/8/2000	10	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	9/13/2000	30	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	5/30/2001	1700	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	6/13/2001	15000	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	7/18/2001	300	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	8/15/2001	30	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	9/4/2001	190	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	5/15/2002	5000	FC	400

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK410400050270-001AT	Muddy Boggy Creek 400	6/10/2002	900	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	7/17/2002	300	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	9/11/2002	20	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	5/6/2003	30	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	6/10/2003	400	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	6/25/2003	700	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	7/15/2003	40	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	7/30/2003	50	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	8/19/2003	20	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	9/3/2003	1400	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	9/23/2003	1500	FC	400
OK410400050270-001AT	Muddy Boggy Creek 400	6/6/2000	262	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	7/11/2000	85	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	8/8/2000	20	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	9/13/2000	10	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	5/30/2001	727	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	6/13/2001	4106	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	7/18/2001	97	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	8/15/2001	5	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	9/4/2001	30	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	5/15/2002	2909	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	6/10/2002	309	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	7/17/2002	173	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	9/11/2002	20	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	5/6/2003	31	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	6/10/2003	41	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	6/25/2003	156	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	7/15/2003	10	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	7/30/2003	41	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	8/19/2003	10	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	9/3/2003	10	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	9/23/2003	1081	EC	406
OK410400050270-001AT	Muddy Boggy Creek 400	6/6/2000	260	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	7/11/2000	50	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	8/8/2000	20	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	9/13/2000	5	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	6/13/2001	300	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	7/18/2001	170	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	8/15/2001	50	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	9/4/2001	40	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	5/15/2002	3000	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	6/10/2002	1300	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	7/17/2002	800	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	9/11/2002	40	ENT	108

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK410400050270-001AT	Muddy Boggy Creek 400	5/6/2003	140	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	6/10/2003	90	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	6/25/2003	80	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	7/15/2003	900	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	7/30/2003	100	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	8/19/2003	100	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	9/3/2003	1600	ENT	108
OK410400050270-001AT	Muddy Boggy Creek 400	9/23/2003	1270	ENT	108
OK410600010010-001AT	Blue River	6/28/1999	1200	FC	400
OK410600010010-001AT	Blue River	7/26/1999	120	FC	400
OK410600010010-001AT	Blue River	8/10/1999	180	FC	400
OK410600010010-001AT	Blue River	9/28/1999	300	FC	400
OK410600010010-001AT	Blue River	6/6/2000	460	FC	400
OK410600010010-001AT	Blue River	7/11/2000	80	FC	400
OK410600010010-001AT	Blue River	8/8/2000	320	FC	400
OK410600010010-001AT	Blue River	9/13/2000	100	FC	400
OK410600010010-001AT	Blue River	6/13/2001	130	FC	400
OK410600010010-001AT	Blue River	7/18/2001	300	FC	400
OK410600010010-001AT	Blue River	8/15/2001	40	FC	400
OK410600010010-001AT	Blue River	9/4/2001	210	FC	400
OK410600010010-001AT	Blue River	5/15/2002	80	FC	400
OK410600010010-001AT	Blue River	6/10/2002	80	FC	400
OK410600010010-001AT	Blue River	7/17/2002	50	FC	400
OK410600010010-001AT	Blue River	9/11/2002	5000	FC	400
OK410600010010-001AT	Blue River	5/6/2003	50	FC	400
OK410600010010-001AT	Blue River	6/10/2003	1000	FC	400
OK410600010010-001AT	Blue River	6/25/2003	10	FC	400
OK410600010010-001AT	Blue River	7/15/2003	700	FC	400
OK410600010010-001AT	Blue River	7/30/2003	130	FC	400
OK410600010010-001AT	Blue River	8/19/2003	200	FC	400
OK410600010010-001AT	Blue River	9/3/2003	2900	FC	400
OK410600010010-001AT	Blue River	9/23/2003	200	FC	400
OK410600010010-001AT	Blue River	6/28/1999	379	EC	406
OK410600010010-001AT	Blue River	7/26/1999	52	EC	406
OK410600010010-001AT	Blue River	8/10/1999	148	EC	406
OK410600010010-001AT	Blue River	9/28/1999	145	EC	406
OK410600010010-001AT	Blue River	6/6/2000	305	EC	406
OK410600010010-001AT	Blue River	7/11/2000	74	EC	406
OK410600010010-001AT	Blue River	8/8/2000	10	EC	406
OK410600010010-001AT	Blue River	9/13/2000	30	EC	406
OK410600010010-001AT	Blue River	5/30/2001	336	EC	406
OK410600010010-001AT	Blue River	6/13/2001	97	EC	406
OK410600010010-001AT	Blue River	7/18/2001	41	EC	406
OK410600010010-001AT	Blue River	8/15/2001	41	EC	406

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK410600010010-001AT	Blue River	9/4/2001	187	EC	406
OK410600010010-001AT	Blue River	5/15/2002	51	EC	406
OK410600010010-001AT	Blue River	6/10/2002	185	EC	406
OK410600010010-001AT	Blue River	7/17/2002	63	EC	406
OK410600010010-001AT	Blue River	9/11/2002	450	EC	406
OK410600010010-001AT	Blue River	5/6/2003	97	EC	406
OK410600010010-001AT	Blue River	6/10/2003	173	EC	406
OK410600010010-001AT	Blue River	6/25/2003	10	EC	406
OK410600010010-001AT	Blue River	7/15/2003	259	EC	406
OK410600010010-001AT	Blue River	7/30/2003	30	EC	406
OK410600010010-001AT	Blue River	8/19/2003	74	EC	406
OK410600010010-001AT	Blue River	9/3/2003	907	EC	406
OK410600010010-001AT	Blue River	9/23/2003	373	EC	406
OK410600010010-001AT	Blue River	6/28/1999	190	ENT	108
OK410600010010-001AT	Blue River	7/26/1999	9	ENT	108
OK410600010010-001AT	Blue River	8/10/1999	30	ENT	108
OK410600010010-001AT	Blue River	9/28/1999	70	ENT	108
OK410600010010-001AT	Blue River	6/6/2000	270	ENT	108
OK410600010010-001AT	Blue River	7/11/2000	30	ENT	108
OK410600010010-001AT	Blue River	8/8/2000	500	ENT	108
OK410600010010-001AT	Blue River	9/13/2000	40	ENT	108
OK410600010010-001AT	Blue River	6/13/2001	140	ENT	108
OK410600010010-001AT	Blue River	7/18/2001	210	ENT	108
OK410600010010-001AT	Blue River	8/15/2001	10	ENT	108
OK410600010010-001AT	Blue River	9/4/2001	300	ENT	108
OK410600010010-001AT	Blue River	5/15/2002	70	ENT	108
OK410600010010-001AT	Blue River	6/10/2002	1400	ENT	108
OK410600010010-001AT	Blue River	7/17/2002	230	ENT	108
OK410600010010-001AT	Blue River	9/11/2002	5000	ENT	108
OK410600010010-001AT	Blue River	5/6/2003	200	ENT	108
OK410600010010-001AT	Blue River	6/10/2003	400	ENT	108
OK410600010010-001AT	Blue River	6/25/2003	10	ENT	108
OK410600010010-001AT	Blue River	7/15/2003	50	ENT	108
OK410600010010-001AT	Blue River	7/30/2003	1900	ENT	108
OK410600010010-001AT	Blue River	8/19/2003	500	ENT	108
OK410600010010-001AT	Blue River	9/3/2003	2300	ENT	108
OK410600010010-001AT	Blue River	9/23/2003	360	ENT	108
OK410700000230D	Eastman Creek	4/19/1999	3500	FC	2000
OK410700000230D	Eastman Creek	5/17/1999	5000	FC	400
OK410700000230D	Eastman Creek	6/14/1999	100	FC	400
OK410700000230D	Eastman Creek	7/12/1999	200	FC	400
OK410700000230D	Eastman Creek	8/16/1999	100	FC	400
OK410700000230D	Eastman Creek	9/27/1999	100	FC	400
OK410700000230D	Eastman Creek	11/1/1999	500	FC	2000

WQM Station	Water Body Name	Date	Bacteria Concentration (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK410700000230D	Eastman Creek	12/6/1999	300	FC	2000
OK410700000230D	Eastman Creek	1/10/2000	100	FC	2000
OK410700000230D	Eastman Creek	2/14/2000	200	FC	2000
OK410700000230D	Eastman Creek	3/20/2000	100	FC	2000
OK410700000230D	Eastman Creek	5/1/2000	800	FC	400
OK410700000230D	Eastman Creek	6/5/2000	100	FC	400
OK410700000230D	Eastman Creek	7/10/2000	380	FC	400
OK410700000230D	Eastman Creek	8/14/2000	4400	FC	400
OK410700000230D	Eastman Creek	9/18/2000	470	FC	400
OK410700000230D	Eastman Creek	10/23/2000	2000	FC	2000
OK410700000230D	Eastman Creek	11/27/2000	700	FC	2000
OK410700000230D	Eastman Creek	1/8/2001	20	FC	2000
OK410700000230D	Eastman Creek	2/12/2001	100	FC	2000
OK410700000230D	Eastman Creek	3/19/2001	160	FC	2000
OK410700000230D	Eastman Creek	8/14/2000	10	EC	406
OK410700000230D	Eastman Creek	9/18/2000	52	EC	406
OK410700000230D	Eastman Creek	10/23/2000	452	EC	2030
OK410700000230D	Eastman Creek	11/27/2000	669	EC	2030
OK410700000230D	Eastman Creek	1/8/2001	96	EC	2030
OK410700000230D	Eastman Creek	2/12/2001	211	EC	2030
OK410700000230D	Eastman Creek	3/19/2001	175	EC	2030
OK410700000230D	Eastman Creek	9/18/2000	460	ENT	108
OK410700000230D	Eastman Creek	10/23/2000	8000	ENT	540
OK410700000230D	Eastman Creek	11/27/2000	18000	ENT	540
OK410700000230D	Eastman Creek	1/8/2001	400	ENT	540
OK410700000230D	Eastman Creek	2/12/2001	400	ENT	540
OK410700000230D	Eastman Creek	3/19/2001	60	ENT	540

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

APPENDIX B
NPDES PERMIT DISCHARGE MONITORING REPORT DATA AND SANITARY SEWER OVERFLOW DATA

Appendix B

NPDES Permit Discharge Monitoring Report Data 1998-2007

NPDES	Outfall	Report Date	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter Code	Parameter
OK0027014	1	1/31/1998	0.143	0.394	50050	FLOW
OK0027014	1	2/28/1998	0.155	0.243	50050	FLOW
OK0027014	1	3/31/1998	0.101	0.395	50050	FLOW
OK0027014	1	4/30/1998	0.028	0.105	50050	FLOW
OK0027014	1	5/31/1998	0.014	0.044	50050	FLOW
OK0027014	1	6/30/1998	0.933	2	50050	FLOW
OK0027014	1	7/31/1998	0.0043	3	50050	FLOW
OK0027014	1	8/31/1998	0.0008	2	50050	FLOW
OK0027014	1	9/30/1998	0.0033	2.5	50050	FLOW
OK0027014	1	10/31/1998	0.0068	4	50050	FLOW
OK0027014	1	11/30/1998	0.0357	4	50050	FLOW
OK0027014	1	12/31/1998	0.07013	0.104	50050	FLOW
OK0027014	1	1/31/1999	0.0449	0.104	50050	FLOW
OK0027014	1	2/28/1999	0.0842	0.104	50050	FLOW
OK0027014	1	3/31/1999	0.053	0.104	50050	FLOW
OK0027014	1	4/30/1999	0.14	0.338	50050	FLOW
OK0027014	1	5/31/1999	0.029	0.104	50050	FLOW
OK0027014	1	6/30/1999	0.066	0.104	50050	FLOW
OK0027014	1	7/31/1999	0.023	0.06	50050	FLOW
OK0027014	1	8/31/1999	0	0	50050	FLOW
OK0027014	1	9/30/1999	0.045	0.104	50050	FLOW
OK0027014	1	10/31/1999	0.043	0.164	50050	FLOW
OK0027014	1	11/30/1999	0.013	0.06	50050	FLOW
OK0027014	1	12/31/1999	0.048	0.164	50050	FLOW
OK0027014	1	1/31/2000	0.027	0.06	50050	FLOW
OK0027014	1	2/29/2000	0.019	0.029	50050	FLOW
OK0027014	1	3/31/2000	0.023	0.104	50050	FLOW
OK0027014	1	4/30/2000	0.0095	0.029	50050	FLOW
OK0027014	1	5/31/2000	0.18	0.011	50050	FLOW
OK0027014	1	6/30/2000	0.05	0.164	50050	FLOW
OK0027014	1	7/31/2000	0.01	0.011	50050	FLOW
OK0027014	1	8/31/2000	0	0	50050	FLOW
OK0027014	1	9/30/2000	0	0	50050	FLOW
OK0027014	1	10/31/2000	0	0	50050	FLOW
OK0027014	1	11/30/2000	0.07	0.164	50050	FLOW
OK0027014	1	12/31/2000	0.08	0.242	50050	FLOW
OK0027014	1	1/31/2001	0.1	0.164	50050	FLOW
OK0027014	1	2/28/2001	0.2	0.454	50050	FLOW
OK0027014	1	3/31/2001	0.09	0.164	50050	FLOW
OK0027014	1	4/30/2001	0.04	0.06	50050	FLOW
OK0027014	1	5/31/2001	0.04	0.06	50050	FLOW
OK0027014	1	6/30/2001	0.01	0.029	50050	FLOW

NPDES	Outfall	Report Date	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter Code	Parameter
OK0027014	1	7/31/2001	0.029	0.029	50050	FLOW
OK0027014	1	8/31/2001	0.029	0.1656	50050	FLOW
OK0027014	1	9/30/2001	0.094	0.454	50050	FLOW
OK0027014	1	10/31/2001	0.05	0.06	50050	FLOW
OK0027014	1	11/30/2001	0.037	0.064	50050	FLOW
OK0027014	1	12/31/2001	0.084	0.514	50050	FLOW
OK0027014	1	1/31/2002	0.082	0.394	50050	FLOW
OK0027014	1	2/28/2002	0.191	0.394	50050	FLOW
OK0027014	1	3/31/2002	0.158	0.454	50050	FLOW
OK0027014	1	4/30/2002	0.259	0.514	50050	FLOW
OK0027014	1	5/31/2002	0.095	0.164	50050	FLOW
OK0027014	1	6/30/2002	0.01775	0.029	50050	FLOW
OK0027014	1	7/31/2002	0.0266	0.06	50050	FLOW
OK0027014	1	8/31/2002	0.063	0.242	50050	FLOW
OK0027014	1	9/30/2002	0.036	0.164	50050	FLOW
OK0027014	1	10/31/2002	0.056	0.132	50050	FLOW
OK0027014	1	11/30/2002	0.065	0.201	50050	FLOW
OK0027014	1	12/31/2002	0.042	0.104	50050	FLOW
OK0027014	1	1/31/2003	0.064	0.132	50050	FLOW
OK0027014	1	2/28/2003	0.073	0.201	50050	FLOW
OK0027014	1	3/31/2003	0.094	0.242	50050	FLOW
OK0027014	1	4/30/2003	0.0018	0.043	50050	FLOW
OK0027014	1	5/31/2003	0.0037	0.029	50050	FLOW
OK0027014	1	6/30/2003	0.048	0.164	50050	FLOW
OK0027014	1	7/31/2003	0.023	0.132	50050	FLOW
OK0027014	1	8/31/2003	0.011	0.018	50050	FLOW
OK0027014	1	9/30/2003	0.035	0.164	50050	FLOW
OK0027014	1	10/31/2003	0.007	0.011	50050	FLOW
OK0027014	1	11/30/2003	0.013	0.029	50050	FLOW
OK0027014	1	12/31/2003	0.0148	0.029	50050	FLOW
OK0027014	1	1/31/2004	0.072	0.338	50050	FLOW
OK0027014	1	2/29/2004	0.104	0.242	50050	FLOW
OK0027014	1	3/31/2004	0.047	0.164	50050	FLOW
OK0027014	1	4/30/2004	0.035	0.242	50050	FLOW
OK0027014	1	5/31/2004	0.101	0.338	50050	FLOW
OK0027014	1	6/30/2004	0.06	0.164	50050	FLOW
OK0027014	1	7/31/2004	0.01485	0.06	50050	FLOW
OK0027014	1	8/31/2004	0.019	0.029	50050	FLOW
OK0027014	1	9/30/2004	0.029	0.029	50050	FLOW
OK0027014	1	10/31/2004	0.139	0.104	50050	FLOW
OK0027014	1	11/30/2004	0.202	0.454	50050	FLOW
OK0027014	1	12/31/2004	0.097	0.338	50050	FLOW
OK0027014	1	1/31/2005	0.166	0.499	50050	FLOW
OK0027014	1	2/28/2005	0.197	0.164	50050	FLOW
OK0027014	1	3/31/2005	0.066	0.242	50050	FLOW
OK0027014	1	4/30/2005	0.122	0.288	50050	FLOW

NPDES	Outfall	Report Date	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter Code	Parameter
OK0027014	1	5/31/2005	0.035	0.06	50050	FLOW
OK0027014	1	6/30/2005	0.032	0.08	50050	FLOW
OK0027014	1	7/31/2005	0.025	0.069	50050	FLOW
OK0027014	1	8/31/2005	0.0196	0.06	50050	FLOW
OK0027014	1	9/30/2005	0.027	0.06	50050	FLOW
OK0027014	1	10/31/2005	0.0049	0.011	50050	FLOW
OK0027014	1	12/31/2005	0.029	0.06	50050	FLOW
OK0027014	1	1/31/2006	0.052	0.132	50050	FLOW
OK0027014	1	2/28/2006	0.05	0.104	50050	FLOW
OK0027014	1	3/31/2006	0.144	0.454	50050	FLOW
OK0027014	1	4/30/2006	0.07	0.242	50050	FLOW
OK0027014	1	5/31/2006	0.061	0.164	50050	FLOW
OK0027014	1	6/30/2006	0.006	0.011	50050	FLOW
OK0027014	1	7/31/2006	0.004	0.011	50050	FLOW
OK0027014	1	8/31/2006	0.011	0.06	50050	FLOW
OK0027014	1	9/30/2006	0.04	0.098	50050	FLOW
OK0027014	1	10/31/2006	0.108	0.242	50050	FLOW
OK0027014	1	11/30/2006	0.073	0.251	50050	FLOW
OK0027014	1	12/31/2006	0.105	0.338	50050	FLOW
OK0027014	1	2/28/2007	0.032	0.164	50050	FLOW

ODEQ Summary of Available Reports of Sanitary Sewer Overflows

Facility Name	Date	Facility ID	Location	Amount (gal)	Cause	Type of Source
BOKCHITO	11/20/1996	S10604	Mh #14 S. of Main at no name st.; MH #3 at Kelly & Kelly	N/A	Rain	N/A
BOKCHITO	12/12/1999	S10604	Alley between Albright & Steakley St.	N/A	Damaged sewer line	N/A
BOKCHITO	08/31/2001	S10604	N. side of Norman St. & Heil St.	1,000	Bulldozer hit line	Pipe
BOKCHITO	11/08/2001	S10604	400 W. Main - S. Side of Hwy 70	3,000	Roots & grease	Manhole
BOKCHITO	12/23/2003	S10604	W. side of Heil St. by Heil Apts.	10,000	Grease & diapers	Manhole
BOKCHITO	10/24/2004	S10604	Block 39 lots 6-10 & Block 38 lots 1-6	1,000	Grease & diapers	Manhole
BOKCHITO	11/17/2004	S10604	400 West Main behind Mayes grocery	500	Rain	Manhole
BOKCHITO	11/23/2004	S10604	400 W. Main	1,000	I & I	Manhole
BOKCHITO	03/10/2005	S10604	606 E. Main	10,000	Stoppage	Manhole
BOKCHITO	10/15/2006	S10604	108 N. Brackett	30,000	Trash in MH	Manhole
BOKCHITO	03/27/2007	S10604	107 Heil St. west side of Apt. #3	1,500	Burned trash in manhole	Manhole
CHOCTAW	10/13/1991	S20592	827 Oak Park	15	Roots in the sewer line	N/A
CHOCTAW	10/15/1991	S20592	827 Oak Park	N/A	Stoppage	N/A
CHOCTAW	12/02/1991	S20592	2918 N. Choctaw Road	0	Grease and roots in the main line	N/A
CHOCTAW	12/20/1991	S20592	Overflow ponds	0	Rain	N/A
CHOCTAW	06/09/1995	S20592	Holding pond	0	Heavy rain & flood water	N/A
CHOCTAW	06/04/1996	S20592	3220 Clark	N/A	Grease	N/A
CHOCTAW	07/31/1996	S20592	Choctaw Treatment Plant holding pond	N/A	Rainfall	N/A
CHOCTAW WWTP	01/06/1998	S20592	Holding pond	N/A	Excessive rainfall	N/A
CHOCTAW	03/16/1998	S20592	Holding pond	N/A		N/A
CHOCTAW	05/08/1998	S20592	14550 N.E. 6th	N/A	Plugged main	N/A
CHOCTAW	11/01/1998	S20592	Holding pond	N/A	Rain	N/A
CHOCTAW	03/14/1999	S20592	Holding pond	100,000	Snowfall	N/A
CHOCTAW	01/07/2001	S20592	Holding pond	N/A	Snow	N/A
CHOCTAW	02/25/2001	S20592	Holding pond	N/A	Rain	N/A
CHOCTAW	01/31/2002	S20592	Holding pond	N/A	Rain	N/A

APPENDIX C
ESTIMATED FLOW EXCEEDANCE PERCENTILES

Appendix C

Estimated Flow Exceedance Percentiles

WQ Station	OK410400010010-001AT	OK410400010070-001AT	OK410400030010-001AT	OK410400050270-001AT	OK410600010010-001AT	OK410700000230D
	Red River	**Muddy Boggy Creek**	**Clear Boggy Creek**	**Muddy Boggy Creek**	**Blue River**	**Eastman Creek**
WBID Segment	OK410400010010_20	OK410400010070_00	OK410400030010_00	OK410400050270_00	OK410600010010_00	OK410700000230_00
USGS Gage Reference	07335500	07335300	07335000	07334000	07332500	7332500
Watershed Area (Acres)	1,324,459†	1,555,755	459,522	699,807	437,190	6,278
Mean Curve Number	68.8	66.5	67.6	65.3	68.8	66.5
Average Annual Rainfall (inches)	43.9	45.9	43.4	44.9	43.9	43.0
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
0	87,600	36,800	41,500	22,000	45,500	443
1	51,600	18,514	6,873	10,657	4,590	94
2	48,700	14,014	4,877	7,564	3,020	65
3	45,500	11,400	3,710	6,004	2,140	45
4	42,500	9,764	3,050	4,843	1,550	31
5	38,585	8,767	2,540	4,121	1,190	25
6	35,942	7,994	2,070	3,468	952	20
7	33,399	7,440	1,710	2,990	790	17
8	30,900	6,936	1,410	2,720	672	15
9	28,613	6,221	1,220	2,491	589	13
10	26,600	5,767	1,050	2,287	523	12
11	24,500	5,340	907	2,133	470	11
12	23,100	4,958	807	2,010	426	10
13	22,000	4,580	724	1,910	393	9.1
14	21,100	4,200	652	1,790	363	8.6
15	20,200	3,856	589	1,686	339	8.1
16	19,300	3,550	539	1,570	317	7.6
17	18,069	3,280	490	1,450	300	7.2
18	17,100	3,090	450	1,350	280	6.9

WQ Station	OK410400010010-001AT Red River	OK410400010070-001AT Muddy Boggy Creek	OK410400030010-001AT Clear Boggy Creek	OK410400050270-001AT Muddy Boggy Creek	OK410600010010-001AT Blue River	OK410700000230D Eastman Creek
WBID Segment	OK410400010010_20	OK410400010070_00	OK410400030010_00	OK410400050270_00	OK410600010010_00	OK410700000230_00
USGS Gage Reference	07335500	07335300	07335000	07334000	07332500	7332500
Watershed Area (Acres)	1,324,459†	1,555,755	459,522	699,807	437,190	6,278
Mean Curve Number	68.8	66.5	67.6	65.3	68.8	66.5
Average Annual Rainfall (inches)	43.9	45.9	43.4	44.9	43.9	43.0
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
19	16,400	2,850	418	1,258	265	6.6
20	15,840	2,640	384	1,170	252	6.3
21	15,200	2,440	357	1,080	241	6.0
22	14,600	2,280	330	1,015	229	5.8
23	14,000	2,130	310	940	219	5.6
24	13,500	2,000	293	872	210	5.4
25	12,900	1,870	275	802	201	5.3
26	12,400	1,738	257	752	194	5.0
27	12,000	1,610	241	698	186	4.9
28	11,500	1,510	226	641	179	4.7
29	11,000	1,410	214	597	172	4.6
30	10,400	1,340	202	540	165	4.4
31	9,910	1,247	193	497	158	4.3
32	9,412	1,170	182	450	152	4.1
33	9,088	1,090	172	410	147	4.0
34	8,790	1,020	164	373	142	3.9
35	8,440	955	155	340	137	3.8
36	8,140	874	147	310	132	3.6
37	7,870	820	140	279	127	3.4
38	7,507	762	134	254	123	3.3
39	7,290	711	128	231	119	3.2
40	7,100	662	124	209	115	3.1

WQ Station	OK410400010010-001AT **Red River**	OK410400010070-001AT **Muddy Boggy Creek**	OK410400030010-001AT **Clear Boggy Creek**	OK410400050270-001AT **Muddy Boggy Creek**	OK410600010010-001AT **Blue River**	OK410700000230D **Eastman Creek**
WBID Segment	OK410400010010_20	OK410400010070_00	OK410400030010_00	OK410400050270_00	OK410600010010_00	OK410700000230_00
USGS Gage Reference	07335500	07335300	07335000	07334000	07332500	7332500
Watershed Area (Acres)	1,324,459†	1,555,755	459,522	699,807	437,190	6,278
Mean Curve Number	68.8	66.5	67.6	65.3	68.8	66.5
Average Annual Rainfall (inches)	43.9	45.9	43.4	44.9	43.9	43.0
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
41	6,944	630	118	190	113	3.0
42	6,709	595	113	177	109	2.9
43	6,460	570	108	163	106	2.8
44	6,230	544	104	149	103	2.7
45	6,027	520	99	139	100	2.6
46	5,822	496	95	131	98	2.5
47	5,600	469	91	122	95	2.5
48	5,480	446	87	114	92	2.4
49	5,330	430	84	108	89	2.3
50	5,185	408	80	101	87	2.2
51	5,060	387	77	96	84	2.1
52	4,916	371	74	92	82	2.1
53	4,762	353	70	87	80	2.0
54	4,650	338	67	82	77	2.0
55	4,510	320	64	78	75	1.9
56	4,379	305	62	73	73	1.8
57	4,250	290	59	69	70	1.8
58	4,121	275	57	65	68	1.7
59	4,026	262	54	62	66	1.7
60	3,880	249	51	59	64	1.6
61	3,760	238	49	55	62	1.6
62	3,670	228	48	53	61	1.5

WQ Station	OK410400010010-001AT **Red River**	OK410400010070-001AT **Muddy Boggy Creek**	OK410400030010-001AT **Clear Boggy Creek**	OK410400050270-001AT **Muddy Boggy Creek**	OK410600010010-001AT **Blue River**	OK410700000230D **Eastman Creek**
WBID Segment	OK410400010010_20	OK410400010070_00	OK410400030010_00	OK410400050270_00	OK410600010010_00	OK410700000230_00
USGS Gage Reference	07335500	07335300	07335000	07334000	07332500	7332500
Watershed Area (Acres)	1,324,459†	1,555,755	459,522	699,807	437,190	6,278
Mean Curve Number	68.8	66.5	67.6	65.3	68.8	66.5
Average Annual Rainfall (inches)	43.9	45.9	43.4	44.9	43.9	43.0
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
63	3,540	220	46	50	59	1.5
64	3,450	210	44	48	58	1.5
65	3,360	202	41	46	56	1.4
66	3,280	195	39	44	55	1.4
67	3,162	187	37	42	54	1.3
68	3,070	180	35	40	52	1.3
69	3,010	173	33	38	51	1.3
70	2,940	168	31	37	50	1.2
71	2,865	162	29	36	48	1.2
72	2,790	155	28	35	47	1.2
73	2,710	148	26	33	46	1.1
74	2,650	143	25	32	44	1.1
75	2,600	136	24	31	43	1.1
76	2,530	128	22	30	42	1.0
77	2,460	123	21	29	41	1.0
78	2,370	117	20	27	39	0.97
79	2,280	110	19	26	38	0.93
80	2,200	104	18	26	37	0.91
81	2,130	100	17	25	36	0.89
82	2,070	95	17	24	35	0.85
83	1,990	90	16	23	34	0.82
84	1,900	85	15	22	33	0.78

WQ Station	OK410400010010-001AT **Red River**	OK410400010070-001AT **Muddy Boggy Creek**	OK410400030010-001AT **Clear Boggy Creek**	OK410400050270-001AT **Muddy Boggy Creek**	OK410600010010-001AT **Blue River**	OK410700000230D **Eastman Creek**
WBID Segment	OK410400010010_20	OK410400010070_00	OK410400030010_00	OK410400050270_00	OK410600010010_00	OK410700000230_00
USGS Gage Reference	07335500	07335300	07335000	07334000	07332500	7332500
Watershed Area (Acres)	1,324,459†	1,555,755	459,522	699,807	437,190	6,278
Mean Curve Number	68.8	66.5	67.6	65.3	68.8	66.5
Average Annual Rainfall (inches)	43.9	45.9	43.4	44.9	43.9	43.0
Percentile	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**	**Flow cfs**
85	1,820	80	14	22	32	0.75
86	1,760	75	13	21	31	0.72
87	1,690	71	12	20	30	0.68
88	1,610	66	12	20	29	0.66
89	1,540	59	11	19	28	0.64
90	1,460	53	10	19	27	0.62
91	1,390	50	9.4	18	26	0.58
92	1,310	45	8.5	17	25	0.56
93	1,250	41	7.7	17	24	0.52
94	1,166	38	6.7	16	22	0.47
95	1,060	34	5.5	15	20	0.43
96	946	30	4.3	15	18	0.37
97	848	24	2.6	14	15	0.27
98	752	18	0.8	14	10	0.13
99	562	15	0	12	3.1	0.06
100	240	3.3	0	4	0.1	0.03

† incremental watershed area below other gages

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 <u>and</u> 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.