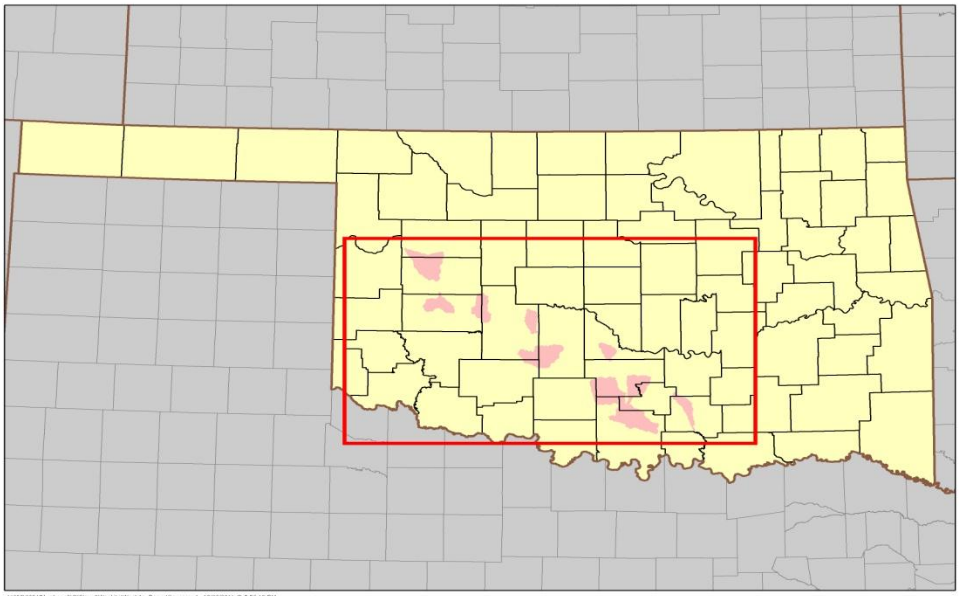
FINAL2012 BACTERIA TOTAL MAXIMUM DAILY LOADS FOR THE WASHITA RIVER, OKLAHOMA (OK310800, OK310810, OK310820, OK310830)



Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

PARSONS

AUGUST 2012

FINAL

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OKWBID

OK310830030210_00, OK310830030230_00, OK310830030100_00, OK310830060050_00, OK310830060080_00, OK310830040010_00, OK310820020010_00, OK310810020020_00, OK310810030080_00, OK310810030010_00, OK310800030010_00

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AUGUST 2012

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ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
ASAE	American Society of Agricultural Engineers
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
LA	Load allocation
LDC	Load duration curve
mgd	Million gallons per day
mg/L	Milligram per liter
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
DEQ	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
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow
TMDL	Total maximum daily load
USDA	U.S. Department of Agriculture
EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater treatment plant

Executive Summary

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli and* Enterococci] for selected waterbodies in the Washita River basin. (All future references to bacteria in this document imply these two classes of fecal pathogen indicator bacteria unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Data assessment and total maximum daily load (TMDL) calculations are conducted in accordance with requirements of Section 303(d) of the Clean Water Act (CWA), Water Quality Planning and Management Regulations (40 CFR Part 130), U.S. Environmental Protection Agency (EPA) guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to EPA for review. TMDLs for approved 303(d) listed waterbody-pollutant pairs or surrogates will receive notification of EPA's approval or disapproval action. Once the EPA 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 (EPA 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 instream 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). The LA is the fraction of the total pollutant load apportioned to nonpoint sources. MOS can be implicit and/or explicit. An implicit MOS is achieved by using conservative assumptions in the TMDL calculations. An explicit MOS is a percentage of the TMDL set aside to account for the lack of knowledge 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 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

This TMDL report focuses on waterbodies in the Washita River basin, identified in Table ES-1, that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of the primary body contact recreation (PBCR) designated use.

Elevated levels of bacteria above the WQS necessitates the development of a TMDL. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the PBCR beneficial use for each waterbody.

Table ES-1 Excerpt from the 2008 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Designated Use Primary Body Contact Recreation
Barnitz Creek, East	OK310830030210_00	26.48	2019	4	X	X	N
Barnitz Creek, West	OK310830030230_00	38.35	2019	4	X	X	N
Boggy Creek	OK310830030100_00	24.89	2019	4	X		N
Cobb Creek	OK310830060050_00	17.34	2010	1	X	X	N
Fivemile Creek	OK310830060080_00	12.22	2016	3	X	X	N
Spring Creek	OK310830040010_00	16.76	2019	4	X	X	N
Little Washita River	OK310820020010_00	36.98	2019	4	X		N
Finn Creek	OK310810020020_00	14.15	2019	4	X		N
Salt Creek	OK310810030080_00	19.05	2019	4	X		N
Wildhorse Creek	OK310810030010_00	22.30	2019	4	X		N
Washita River	OK310810010010_00	21.08	2019	4	X		N
Caddo Creek	OK310800030010_00	44.08	2016	3	X	X	N
Pennington Creek	OK310800010120_00	33.76	2013	2	X		N

ENT = enterococci; N = Not Attaining; X = Criterion Exceeded
Source: 2008 Integrated Report, DEQ 2008.

Table ES-2 summarizes water quality data collected during primary body contact recreation season from the water quality monitoring (WQM) stations between 2000 and 2009 for each of the two pathogen indicator bacteria classes: enterococci (ENT) and *E. coli* (EC). The data summary in Table ES-2 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data, collected during the primary contact recreation season, includes the data used to support the decision to place specific waterbodies within the Study Area on the DEQ 2008 303(d) list (DEQ 2008). It also includes new data collected after the data cutoff date for the 2008 303(d) list.

The definition of PBCR and the bacteria WQSs for PBCR are 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.

(c) Compliance with 785:45-5-16 shall be based upon meeting the requirements of one of the options specified in (1) or (2) of this subsection (c) for bacteria. Upon selection of one (1) group or test method, said method shall be used exclusively over the time period prescribed therefor. Provided, where concurrent data exist for multiple bacterial indicators on the

same waterbody or waterbody segment, no criteria exceedances shall be allowed for any indicator group.

(1) Escherichia coli (E. coli): The E. coli geometric mean criterion is 126/100 ml. For swimming advisory and permitting purposes, E. coli shall not exceed a monthly geometric mean of 126/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 235/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 406/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period. For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 126/100 milliliters compared to the geometric mean of all samples collected over the recreation period.

(2) Enterococci: The Enterococci geometric mean criterion is 33/100 ml. For swimming advisory and permitting purposes, Enterococci shall not exceed a monthly geometric mean of 33/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 61/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 108/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period. For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 33/100 milliliters compared to the geometric mean of all samples collected over the recreation period.

Table ES-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 2000-2009

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (count/100 ml)	Notes
OK310830030210_00	Barnitz Creek, East	EC	11	125	De-list, not impaired
		ENT	11	155	
OK310830030230_00	Barnitz Creek, West	EC	12	124	De-list, not impaired
		ENT	12	260	
OK310830030100_00	Boggy Creek	EC	11	201	Not listed, but geomean is exceeded
		ENT	11	269	
OK310830060050_00	Cobb Creek	EC	12	368	
		ENT	12	226	
OK310830060080_00	Fivemile Creek	EC	12	559	
		ENT	12	447	
OK310830040010_00	Spring Creek	EC	10	164	
		ENT	10	217	
OK310820020010_00	Little Washita River	ENT	11	192	
OK310810020020_00	Finn Creek	ENT	12	219	
OK310810030080_00	Salt Creek	ENT	12	103	
OK310810030010_00	Wildhorse Creek	ENT	12	55	
OK310810010010_00	Washita River				De-list, no data
OK310800030010_00	Caddo Creek	EC	12	143	
		ENT	12	109	
OK310800010120_00	Pennington Creek	ENT	13	26	De-list, not impaired

E. coli (EC) water quality criterion = Geometric Mean of 126 counts/100 mL
Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

To implement Oklahoma's WQS for PBCR, the Oklahoma Water Resources Board (OWRB) promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011a). 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) ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) 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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(c) ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) 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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

Compliance with the Oklahoma WQS is based on meeting requirements for both *E. coli* and Enterococci 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 2011). As stipulated in the WQS, only the geometric mean of all samples collected over the primary recreation period shall be used to assess the impairment status of a stream segment. Therefore, only the geometric mean criteria will be used to develop TMDLs for *E. coli* and Enterococci.

E.2 Pollutant Source Assessment

A pollutant 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 and sources may be point or nonpoint in nature.

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated sanitary wastewater are required to monitor fecal coliform under the current permits and will be required to monitor E coli when their permits come to renew. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from 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 permits are considered nonpoint sources. Table ES-3 summarizes the point sources that contribute bacteria to each respective waterbody.

Table ES-3 Point Source Discharges in the Study Area

OPDES Permit No.	Name	Stream Segment	Stream Name	Facility Type	SIC Code	County	Design Flow (mgd)[1]	Facility ID	Expiration Date	Max./Avg. FC[2] cfu/100mL	Outfall
OK0041467	Town of Cyril	OK310820020010_00	Little Washita River	Sewerage System	4952	Caddo	0.14	S10824	1/31/16	NA	001A
OK0038440	City of Ardmore	OK310800030010_00	Caddo Creek	Sewerage System	4952	Carter	5.9	S30804	3/31/12	400/200	001A

[1] Design flow in 208 Plan[2] FC = Fecal coliform

NA = not available.

E.3 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 can provide some information for identifying whether impairments are associated with point or nonpoint sources. The efficiency and simplicity of the LDC method should not be considered as limitations of this powerful tool for displaying the changing water quality over changing flows that provides information as to the sources of the pollutant that is not apparent in the raw data. The LDC has additional valuable uses in the post-TMDL implementation phase of the restoration of the water quality for a segment. Plotting future monitoring information on the LDC will show trends of improvement to sources that will identify areas for revision to the segment restoration plan. The low cost of the LDC method allows the development of TMDL plans on more segments and the evaluation of the implementation of WLAs and BMPs on more segments. The technical approach for using LDCs for TMDL development includes the following steps:

- Preparing flow duration curves for gaged and ungaged WQM stations;

Estimating existing bacteria loading in the waterbody using ambient bacteria water quality data; and

Using LDCs to identify the critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

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 wastewater treatment plant (WWTP) effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. Water quality criteria exceedances have been noted under low flow conditions in some watersheds that contain no point sources.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by a 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.

The basic steps to generating an LDC involve:

- obtaining daily flow data measured for the site of interest from the USGS, or if unavailable, projected from a nearby USGS site;
- 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);

- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS (geometric mean) for each respective bacteria indicator; and,
- displaying and differentiating another curve derived by plotting the geometric mean of all existing bacteria samples continuously along the full spectrum of flow exceedance percentiles which represents the observed load in the stream.

For bacteria TMDLs 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 = 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

unit conversion factor = 24,465,525

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. *E. coli*/Enterococci loads are represented by the geometric mean of all samples aligned with the flow duration curve which creates a line displaying estimated existing loads above the water quality criterion line. Regarding bacteria data, it is noted that 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 geometric mean water quality criterion in the LDC; therefore individual bacteria samples are not plotted on the LDCs.

E.4 TMDL Calculations

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 the lack of knowledge concerning the relationship between pollutant loading and water quality.

This definition can be expressed by the following equation:

$$\boldsymbol{TMDL = \Sigma\, WLA + LA + MOS}$$

For each waterbody the TMDLs presented in this report are expressed as colony forming units per day across the full range of flow conditions. For general understanding and information purposes, percent reductions are also provided. The difference between existing loading and the water quality target is used to calculate the loading reductions required. Percent reduction goals are calculated through an iterative process of taking a series of percent reduction values applying each value uniformly to the concentrations of samples and verifying if the geometric mean of the reduced values of all samples is less than the geomean standards.

Table ES-4 presents the percent reductions necessary for each pathogen indicator causing nonsupport of the PBCR use in each waterbody of the Study Area. The PRGs range from 21% to 93%.

Table ES-4 Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate	
		EC	ENT
OK310830030210_00	Barnitz Creek, East		81%
OK310830030230_00	Barnitz Creek, West		89%
OK310830030100_00	Boggy Creek	44%	89%
OK310830060050_00	Cobb Creek	69%	87%
OK310830060080_00	Fivemile Creek	80%	93%
OK310830040010_00	Spring Creek	31%	86%
OK310820020010_00	Little Washita River		85%
OK310810020020_00	Finn Creek		86%
OK310810030080_00	Salt Creek		71%
OK310810030010_00	Wildhorse Creek		46%
OK310800030010_00	Caddo Creek	21%	73%

The TMDL, WLA, LA, and MOS vary with flow condition, and are calculated at every 5th flow interval percentile. The WLA component of each TMDL is the sum of all WLAs within each contributing watershed. The LA can then be calculated as follows:

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

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include a MOS and account for seasonal variability. The MOS, which can be implicit or explicit, is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained.

For bacteria TMDLs, an explicit MOS was set at 10%.

The bacteria TMDLs established in this report adhere to the seasonal application of Oklahoma WQS, which limit 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 five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

E.5 Reasonable Assurance

Reasonable assurance is required by the EPA rules for a TMDL to be approvable only when a waterbody is impaired by both point and non-point sources and where a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. In such a case, “reasonable assurance” that the NPS load reductions will actually occur must be demonstrated. In this report, all point source discharges either already have or will be given discharge limitations less than or equal to the water quality standard numerical criteria. This ensures that the impairments of the waterbodies in this report will not be caused by point sources. Since the point source WLAs in this TMDL report are not dependent on NPS load reduction, reasonable assurance does not apply.

SECTION 1
INTRODUCTION

1.1 TMDL Program Background

Section 303(d) of the Clean Water Act (CWA) and U.S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) require states to develop total maximum daily loads (TMDL) for all segments and pollutants identified by the Regional Administrator as suitable for TMDL calculation. Segments and pollutants identified on the approved 303(d) list as not meeting designated uses where technology-based controls are in place will be given a higher priority for development of TMDLs. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream 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 (EPA 1991).

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli),* Enterococci] for selected waterbodies in the Washita River basin. (All future references to bacteria in this document imply these two fecal pathogen indicator bacteria groups unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody 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 in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), EPA guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to EPA for review. TMDLs for approved 303(d) listed waterbody-pollutant pairs or surrogates will receive notification of EPA's approval or disapproval action. Once the EPA 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 (EPA 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 instream 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). The LA is the fraction of the total pollutant load apportioned to nonpoint sources. MOS can be implicit and/or explicit. An implicit MOS is achieved by using conservative assumptions in the TMDL calculations. An explicit MOS is a percentage of the TMDL set aside to account for the lack of knowledge 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 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, along with tribes, and local, state, and federal government agencies.

This TMDL report focuses on waterbodies that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of the primary body contact recreation (PBCR) or Fish and Wildlife Propagation beneficial uses. The waterbodies considered for TMDL development in this report, which are presented upstream to downstream, include:

- Barnitz Creek, East OK310830030210_00
- Barnitz Creek, West OK310830030230_00
- Boggy Creek OK310830030100_00
- Cobb Creek OK310830060050_00
- Fivemile Creek OK310830060080_00
- Spring Creek OK310830040010_00
- Little Washita River OK310820020010_00
- Finn Creek OK310810020020_00
- Salt Creek OK310810030080_00
- Wildhorse Creek OK310810030010_00
- Washita River OK310810010010_00
- Caddo Creek OK310800030010_00
- Pennington Creek OK310800010120_00

Figures 1-1 and 1-2 show these Oklahoma waterbodies and their contributing watersheds. These maps also display 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.

Figure 1-1 Washita River Watersheds (upper) Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation Use

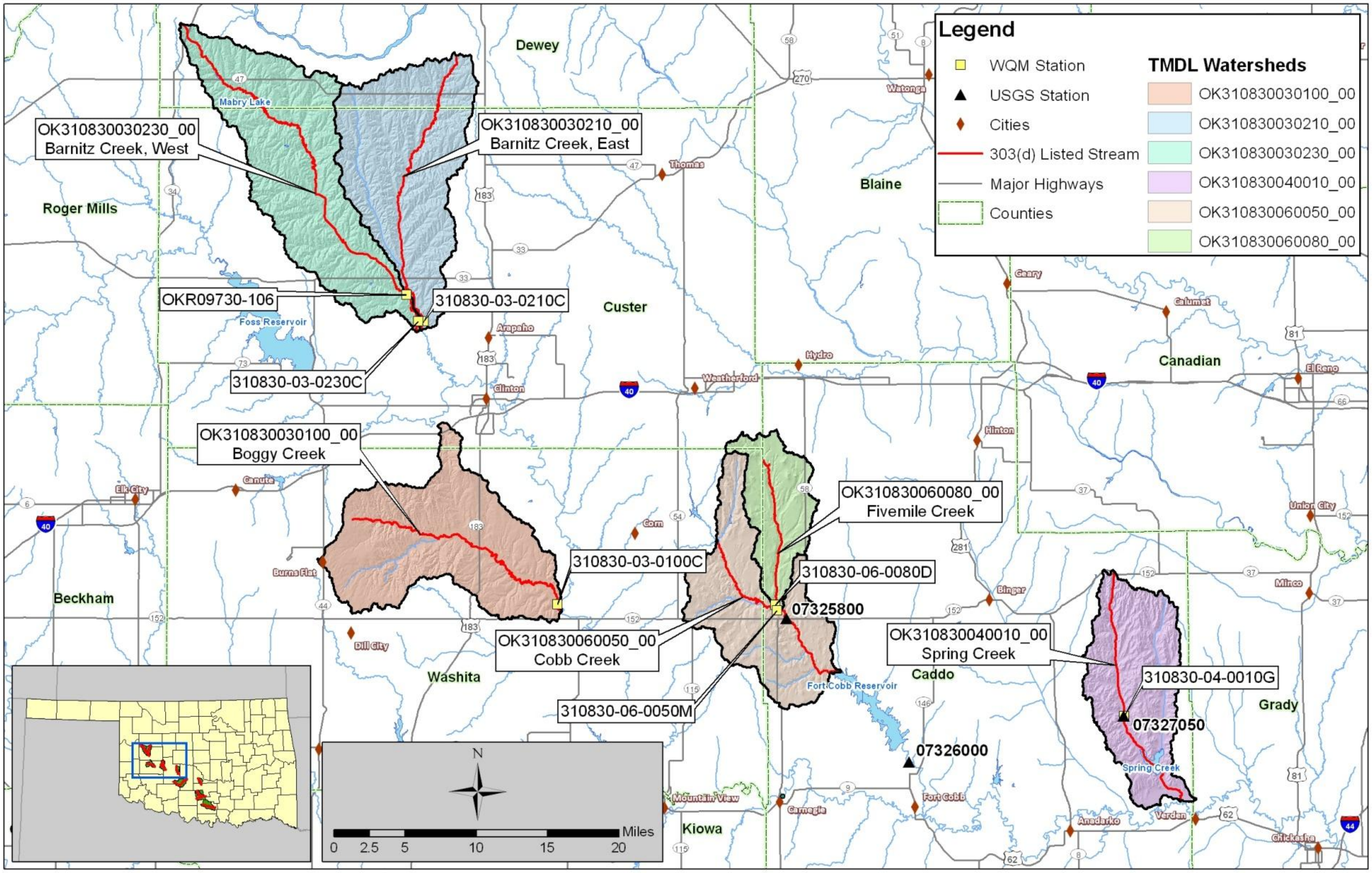
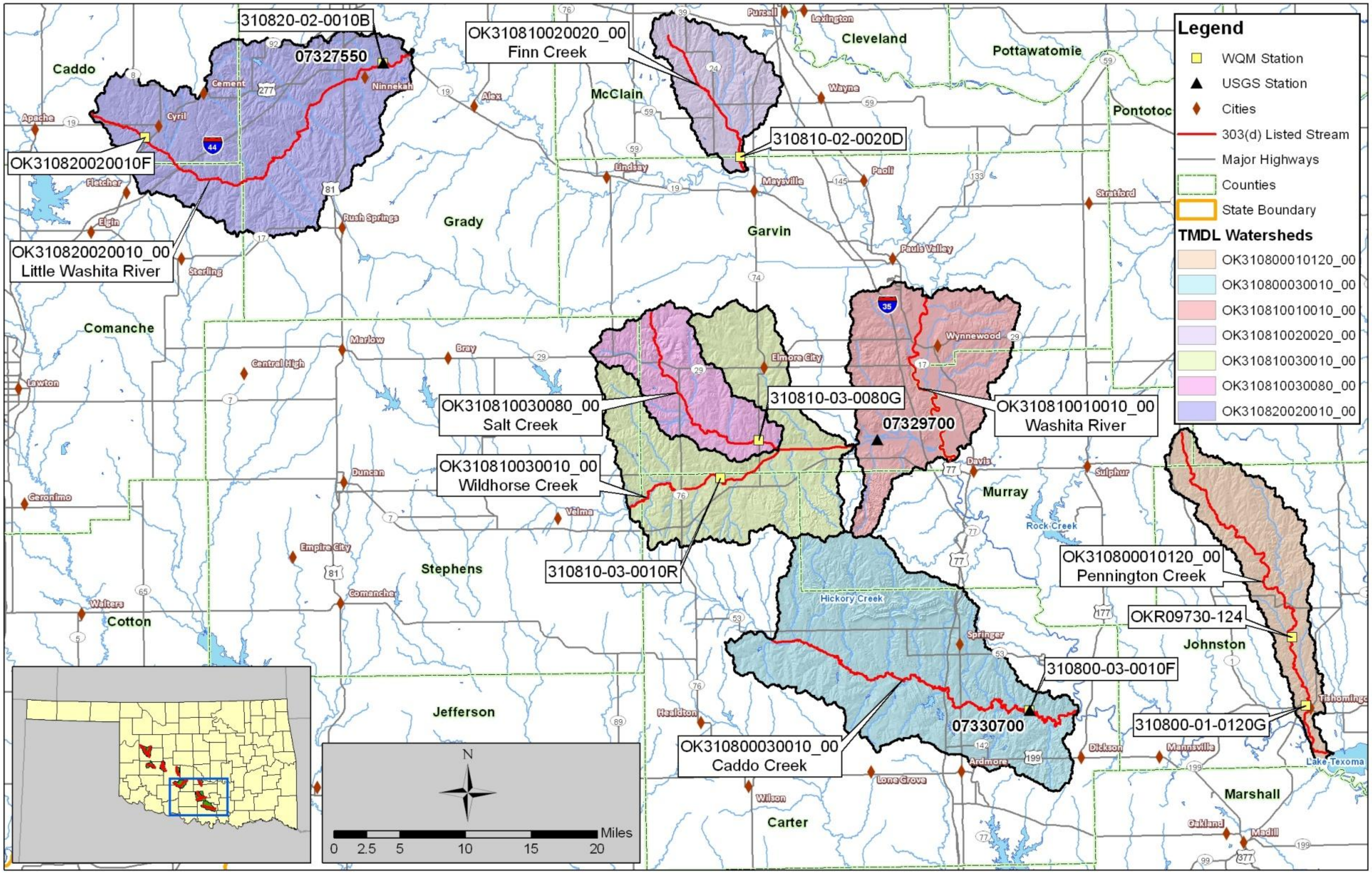


Figure 1-2 Washita River Watersheds (lower) Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation Use



Elevated levels of pathogen indicator bacteria above the WQS numeric criterion 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 pollutant loading controls needed to restore the PBCR use designated for each waterbody. Table 1-1 provides a description of the locations of WQM stations on the 303(d)-listed waterbodies.

Table 1-1 Water Quality Monitoring Stations used for Assessment of Stream Segments

Station ID	Waterbody Name	Description	Waterbody ID
OK310830-03-0210C	Barnitz Creek, East	East Barnitz Creek, off E0980 Rd.	OK310830030210_00
OK310830-03-0230C	Barnitz Creek, West	West Barnitz Creek, off E0980 Rd.	OK310830030230_00
OKR09730-106	Barnitz Creek, West	West Barnitz Creek, off N2210 Rd.	OK310830030230_00
OK310830-03-0100C	Boggy Creek	Boggy Creek, off E1180 Rd.	OK310830030100_00
OK310830-06-0050M	Cobb Creek	Cobb Creek, off N2460 Rd.	OK310830060050_00
OK310830-06-0080D	Fivemile Creek	Fivemile Creek, off E1180 Rd.	OK310830060080_00
OK310830-04-0010G	Spring Creek	Spring Creek, off E1260 Rd.	OK310830040010_00
OK310820-02-0010B	Little Washita River	Little Washita River, off N2860 Rd., near Ninnekah	OK310820020010_00
OK310820-02-0010F	Little Washita River	Little Washita River, off E1470 Rd., near Cyril	OK310820020010_00
OK310810-02-0020D	Finn Creek	Finn Creek, off SH 24	OK310810020020_00
OK310810-03-0080G	Salt Creek	Salt Creek, off SH 74	OK310810030080_00
OK310810-03-0010R	Wildhorse Creek	Wildhorse Creek, off Cemetery Rd.	OK310810030010_00
	Washita River[1]		OK310810010010_00
OK310800-03-0010F	Caddo Creek	Caddo Creek, off Gene Autry Rd.	OK310800030010_00
OK310800-01-0120G	Pennington Creek	Pennington Creek, off W. Main St., Tishomingo	OK310800010120_00
OKR09730-124	Pennington Creek	Pennington Creek, off E1860 Rd.	OK310800010120_00

[1] No WQM Stations exist on this waterbody, therefore this portion of the Washita River was incorrectly placed on the Oklahoma 2008 §303(d) List for elevated levels of Enterococcus and Turbidity.

1.2 Watershed Description

General. The Washita River basin is located in the southwestern portion of Oklahoma. The majority of the waterbodies addressed in this report are located in Caddo, Carter, Comanche, Custer, Dewey, Garvin, Grady, McClain, Murray, Pontotoc, Stephens Johnston, and Washita Counties. These counties are part of the Central Great Plains and Cross Timbers Level III ecoregions (Woods, A.J, Omerik, J.M., et al 2005). The watersheds in the Study Area are located in the Anadarko Basin geological province. Table 1-2, derived from the 2010 U.S. Census, demonstrates that the counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2010). Table 1-3 identifies the towns and cities located in each watershed.

Table 1-2 County Population and Density

County Name	Population (2010 Census)	Population Density (per square mile)
Caddo	29,600	23
Carter	47,557	57
Comanche	124,098	115
Custer	27,469	27
Dewey	4,810	5
Garvin	27,576	34
Grady	52,431	47
McClain	34,506	60
Pontotoc	37,492	52
Murray	13,488	32
Stephens	45,048	51
Johnston	10,957	17
Washita	11,629	12

Table 1-3 Towns and Cities by Watershed

Waterbody Name	Waterbody ID	Municipalities
Boggy Creek	OK310830030100_00	Bessie, Burns Flat
Cobb Creek	OK310830060050_00	Colony
Little Washita River	OK310820020010_00	Cement, Cyril, Ninnekah
Wildhorse Creek	OK310810030010_00	Elmore City, Ratliff City, Tatums
Washita River	OK310810010010_00	Wynnewood
Caddo Creek	OK310800030010_00	Springer
Pennington Creek	OK310800010120_00	Tishomingo

Climate. Table 1-4 summarizes the average annual precipitation for each Oklahoma waterbody derived from a geospatial layer developed to display annual precipitation using data collected from Oklahoma weather stations between 1971 through 2000. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 29 and 41 inches (Oklahoma Mesonet 2010).

Table 1-4 Average Annual Precipitation by Watershed

Waterbody Name	Waterbody ID	Average Annual Precipitation (inches)
Barnitz Creek, East	OK310830030210_00	30.4
Barnitz Creek, West	OK310830030230_00	28.8
Boggy Creek	OK310830030100_00	31.3
Cobb Creek	OK310830060050_00	30.9
Fivemile Creek	OK310830060080_00	30.1
Spring Creek	OK310830040010_00	31.6
Little Washita River	OK310820020010_00	33.6
Finn Creek	OK310810020020_00	41.1
Salt Creek	OK310810030080_00	37.2
Wildhorse Creek	OK310810030010_00	37.7
Washita River	OK310810010010_00	39.2
Caddo Creek	OK310800030010_00	38.0
Pennington Creek	OK310800010120_00	41.1

Land Use. Tables 1-5a and 1-5b summarize the percentages and acreages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody addressed in the Study Area. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2001 National Land Cover Dataset (USGS 2007). The percentages provided in Tables 1-5a and 1-5b are rounded so in some cases may not total exactly 100%. The land use categories are displayed in Figure 1-3. The most dominant land use category of the watersheds within the Study Area is grasslands/herbaceous. Three watersheds in the Study Area have a significant percentage of land use classified as cultivated crops including Boggy Creek (OK310830030100_00), Cobb Creek (OK310830060050_00), and Fivemile Creek (OK310830060080_00). The aggregated total of low, medium, and high intensity developed land accounts for less than 2% of the land use in each watershed. The watersheds targeted for TMDL development in this Study Area range in size from 27,549 acres (Fivemile Creek, OK310830060080_00) to 168,447 acres (Caddo Creek (OK310800030010_00).

Figure 1-3 Land Use Map

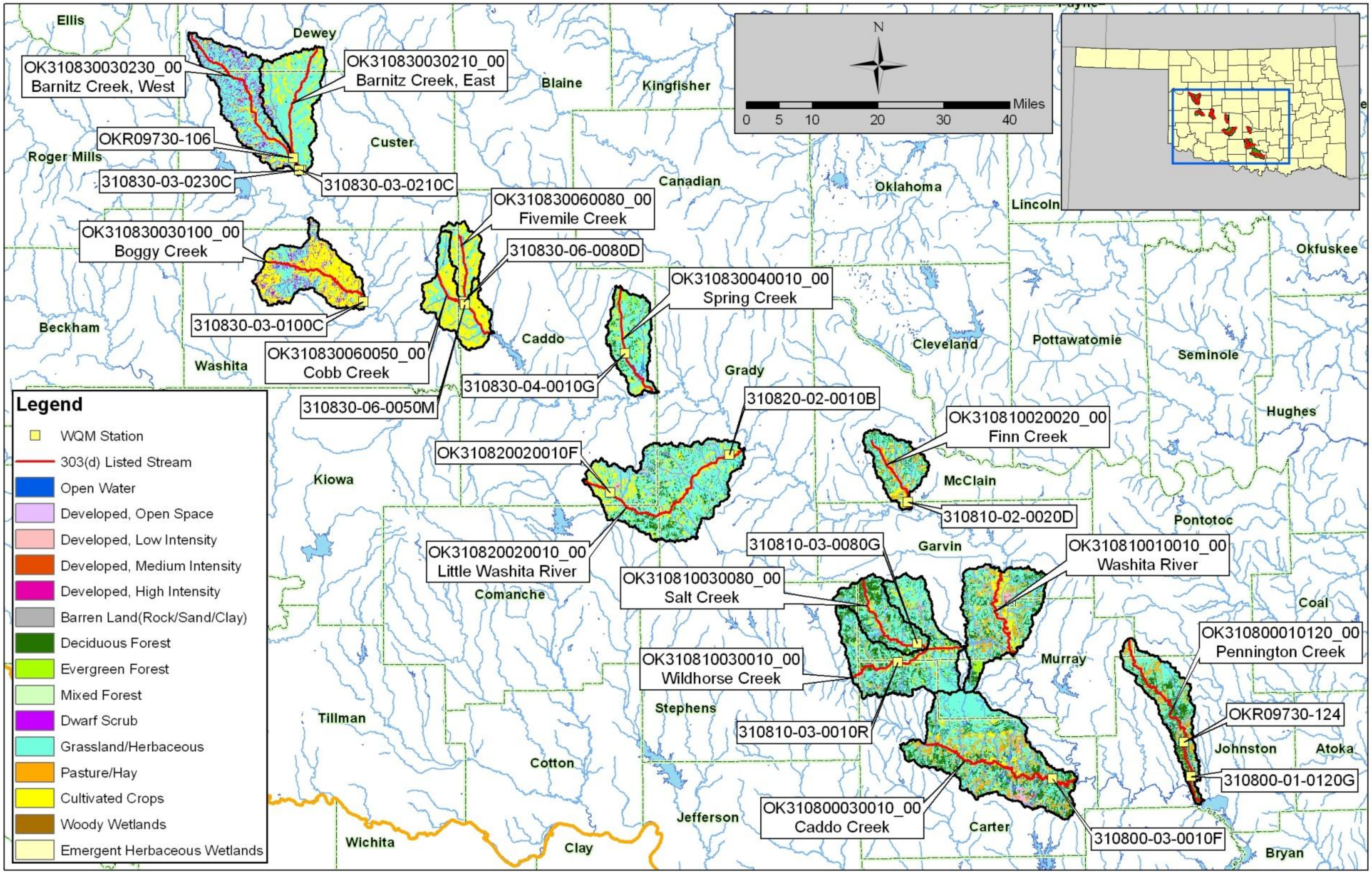


Table 1-5a Land Use Summaries by Watershed

Landuse Category	Watershed						
	Barnitz Creek, East	Barnitz Creek, West	Boggy Creek	Cobb Creek	Fivemile Creek	Spring Creek	Little Washita River
Waterbody ID	**OK310830030210_00**	**OK310830030230_00**	**OK310830030100_00**	**OK310830060050_00**	**OK310830060080_00**	**OK310830040010_00**	**OK310820020010_00**
Percent of Open Water	0.53	0.51	0.35	0.28	0.51	2.92	0.63
Percent of Developed, Open Space	3.96	1.13	2.93	4.73	4.98	4.05	5.48
Percent of Developed, Low Intensity	0.01	0.01	0.17	0.11	0.04	0.02	0.60
Percent of Developed, Medium Intensity	0.00	0.00	0.01	0.03	0.00	0.01	0.39
Percent of Developed, High Intensity	0.00	0.00	0.00	0.01	0.00	0.00	0.05
Percent of Barren Land (Rock/Sand/Clay)	0.00	0.02	0.01	0.07	0.00	0.00	0.12
Percent of Deciduous Forest	0.00	0.00	0.00	1.75	1.15	8.98	11.89
Percent of Evergreen Forest	2.79	0.08	0.00	0.07	0.63	7.27	0.30
Percent of Mixed Forest	0.08	0.99	1.40	0.00	0.01	0.00	0.00
Percent of Shrub/Scrub	1.33	17.35	13.70	0.10	0.00	0.08	0.18
Percent of Grassland/Herbaceous	66.00	63.77	26.66	31.92	35.84	62.49	61.74
Percent of Pasture/Hay	0.11	0.00	0.00	0.00	0.70	0.40	0.58
Percent of Cultivated Crops	25.19	16.12	54.72	60.91	56.14	13.78	18.05
Percent of Woody Wetlands	0.00	0.01	0.05	0.00	0.00	0.00	0.00
Percent of Emergent Herbaceous Wetlands	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Acres Open Water	408	432	275	153	141	1,535	974
Acres Developed, Open Space	3,019	967	2,307	2,610	1,371	2,126	8,510
Acres Developed, Low Intensity	5	6	134	60	10	8	936
Acres Developed, Medium Intensity	1	1	11	18	0	6	600
Acres Developed, High Intensity	0	0	0	7	0	0	82
Acres Barren Land (Rock/Sand/Clay)	3	20	6	37	0	0	194
Acres Deciduous Forest	2	0	2	968	318	4,716	18,464
Acres Evergreen Forest	2,127	70	0	36	172	3,815	472
Acres Mixed Forest	61	841	1,101	2	3	0	0
Acres Shrub/Scrub	1,015	14,786	10,794	55	0	41	272
Acres Grassland/Herbaceous	50,374	54,348	21,002	17,615	9,874	32,805	95,893
Acres Pasture/Hay	85	0	0	0	194	211	894
Acres Cultivated Crops	19,224	13,735	43,106	33,611	15,465	7,235	28,032
Acres Woody Wetlands	0	10	40	0	0	0	0
Acres Emergent Herbaceous Wetlands	0	0	0	7	0	2	0
Total (Acres)	**76,322**	**85,218**	**78,776**	**55,179**	**27,549**	**52,499**	**155,324**

Table 1-5b Land Use Summaries by Watershed

Landuse Category	Watershed					
	Finn Creek	Salt Creek	Wildhorse Creek	Washita River	Caddo Creek	Pennington Creek
Waterbody ID	**OK310810020020_00**	**OK310810030080_00**	**OK310810030010_00**	**OK310810010010_00**	**OK310800030010_00**	**OK310800010120_00**
Percent of Open Water	1.85	0.47	0.63	1.37	1.50	0.53
Percent of Developed, Open Space	3.91	3.76	3.85	5.78	3.67	3.46
Percent of Developed, Low Intensity	0.05	0.08	0.56	1.32	1.48	0.35
Percent of Developed, Medium Intensity	0.05	0.02	0.07	0.19	0.31	0.14
Percent of Developed, High Intensity	0.00	0.03	0.02	0.10	0.08	0.03
Percent of Barren Land (Rock/Sand/Clay)	0.01	0.03	0.04	0.18	0.07	0.01
Percent of Deciduous Forest	12.42	30.08	21.40	19.64	21.61	28.49
Percent of Evergreen Forest	0.00	0.00	0.14	2.23	0.05	0.93
Percent of Mixed Forest	0.00	0.00	0.00	0.00	0.00	0.00
Percent of Shrub/Scrub	0.00	0.00	0.00	0.00	0.00	0.00
Percent of Grassland/Herbaceous	50.65	54.87	60.96	45.63	51.62	48.47
Percent of Pasture/Hay	13.66	6.28	5.00	13.34	14.55	16.47
Percent of Cultivated Crops	17.39	4.38	7.34	10.22	5.05	0.55
Percent of Woody Wetlands	0.00	0.00	0.00	0.00	0.00	0.53
Percent of Emergent Herbaceous Wetlands	0.00	0.00	0.00	0.00	0.00	0.02
Acres Open Water	789	239	744	1,355	2,531	340
Acres Developed, Open Space	1,666	1,933	4,553	5,696	6,190	2,203
Acres Developed, Low Intensity	22	41	657	1,300	2,488	224
Acres Developed, Medium Intensity	20	12	82	192	515	92
Acres Developed, High Intensity	2	13	26	96	140	20
Acres Barren Land (Rock/Sand/Clay)	2	15	44	181	124	7
Acres Deciduous Forest	5,287	15,447	25,288	19,367	36,400	18,157
Acres Evergreen Forest	0	0	170	2,201	90	594
Acres Mixed Forest	0	0	0	0	0	0
Acres Shrub/Scrub	0	0	0	0	0	0
Acres Grassland/Herbaceous	21,561	28,179	72,045	44,989	86,960	30,887
Acres Pasture/Hay	5,814	3,226	5,904	13,148	24,505	10,495
Acres Cultivated Crops	7,403	2,247	8,674	10,074	8,501	352
Acres Woody Wetlands	0	0	0	0	0	340
Acres Emergent Herbaceous Wetlands	0	0	0	0	3	11
Total (Acres)	**42,566**	**51,352**	**118,186**	**98,600**	**168,447**	**63,720**

1.3 Stream Flow Conditions

Stream flow characteristics and data are key information when conducting water quality assessments such as TMDLs. The USGS operates flow gages throughout Oklahoma, from which long-term stream flow records can be obtained. At various WQM stations additional flow measurements are available which were collected at the same time bacteria water quality samples were collected. Not all of the waterbodies in this Study Area have historical flow data available. Flow data from the surrounding USGS gage stations and the instantaneous flow measurement data, taken with water quality samples have been used to estimate flows for ungaged streams. Flow data collected at the time of water quality sampling are included in Appendix A along with corresponding water chemistry data results. A summary of the method used to project flows for ungaged streams and flow exceedance percentiles from projected flow data are provided in Appendix B.

SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code contains Oklahoma's water quality standards and implementation procedures (OWRB 2011). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state water quality standards, as provided 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 2011). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegredation Policy is provided in Appendix C. Table 2-1, an excerpt from the 2008 Integrated Report (DEQ 2008), lists beneficial uses designated for each bacteria impaired stream segment in the Study Area. The beneficial uses are:

- AES – Aesthetics
- AG – Agriculture Water Supply
- Fish and Wildlife Propagation
    - o WWAC – Warm Water Aquatic Community
- FISH – Fish Consumption
- PBCR – Primary Body Contact Recreation
- PPWS – Public & Private Water Supply

Table 2-1 Designated Beneficial Uses for Each Stream Segment in This Report

Waterbody ID	Waterbody Name	AES	AG	WWAC	FISH	PBCR	PPWS
Barnitz Creek, East	OK310830030210_00	F	N	F	X	N	X
Barnitz Creek, West	OK310830030230_00	N	N	N	X	N	I
Boggy Creek	OK310830030100_00	F	N	I	X	N	
Cobb Creek	OK310830060050_00	F	F	N	X	N	I
Fivemile Creek	OK310830060080_00	F	F	F	X	N	I
Spring Creek	OK310830040010_00	F	N	I	X	N	I
Little Washita River	OK310820020010_00	F	F	I	X	N	F
Finn Creek	OK310810020020_00	F	F	N	X	N	I
Salt Creek	OK310810030080_00	F	N	F	X	N	I
Wildhorse Creek	OK310810030010_00	F	N	N	X	N	I
Washita River	OK310810010010_00	I	N	N	I	N	I
Caddo Creek	OK310800030010_00	I	N	N	X	N	I
Pennington Creek	OK310800010120_00	I	F	X	X	N	I

F = Fully Supporting; N = Not Supporting; I = Insufficient Information; X = Not Assessed

Table 2-2 summarizes the bacteria impairment status for streams in the Study Area. The TMDL priority shown in Table 2-2 is directly related to the TMDL target date. The TMDLs established in this report, which are a necessary step in the process of restoring water quality, only address bacteria impairments that affect the PBCR-beneficial uses.

The definition of PBCR and the bacteria WQSs for PBCR are 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.

(c) Compliance with 785:45-5-16 shall be based upon meeting the requirements of one of the options specified in (1) or (2) of this subsection (c) for bacteria. Upon selection of one (1) group or test method, said method shall be used exclusively over the time period prescribed therefor. Provided, where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, no criteria exceedances shall be allowed for any indicator group.

(1) Escherichia coli (E. coli): The E. coli geometric mean criterion is 126/100 ml. For swimming advisory and permitting purposes, E. coli shall not exceed a monthly geometric mean of 126/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 235/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 406/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period. For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 126/100 milliliters compared to the geometric mean of all samples collected over the recreation period.

(2) Enterococci: The Enterococci geometric mean criterion is 33/100 ml. For swimming advisory and permitting purposes, Enterococci shall not exceed a monthly geometric mean of 33/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 61/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 108/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period. For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 33/100 milliliters compared to the geometric mean of all samples collected over the recreation period.

Table 2-2 Excerpt from the 2008 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Turbidity	Designated Use Primary Body Contact Recreation
Barnitz Creek, East	OK310830030210_00	26.48	2019	4	X	X		N
Barnitz Creek, West	OK310830030230_00	38.35	2019	4	X	X		N
Boggy Creek	OK310830030100_00	24.89	2019	4	X			N
Cobb Creek	OK310830060050_00	17.34	2010	1	X	X		N
Fivemile Creek	OK310830060080_00	12.22	2016	3	X	X		N
Spring Creek	OK310830040010_00	16.76	2019	4	X	X		N
Little Washita River	OK310820020010_00	36.98	2019	4	X			N
Finn Creek	OK310810020020_00	14.15	2019	4	X			N
Salt Creek	OK310810030080_00	19.05	2019	4	X			N
Wildhorse Creek	OK310810030010_00	22.30	2019	4	X			N
Washita River	OK310810010010_00	21.08	2019	4	X		X	N
Caddo Creek	OK310800030010_00	44.08	2016	3	X	X		N
Pennington Creek	OK310800010120_00	33.76	2013	2	X			N

ENT = enterococci; N = Not Attaining; X = Criterion Exceeded
Source: 2008 Integrated Report, DEQ 2008.

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011). 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) ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) 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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(c) ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) 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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

Compliance with the Oklahoma WQS is based on meeting requirements for both *E. coli* and Enterococci bacterial indicators in addition to the minimum sample requirements for assessment. 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 2011).

As stipulated in the WQS, only the geometric mean of all samples collected over the primary recreation period shall be used to assess the impairment status of a stream segment. Therefore, only the geometric mean criteria will be used to develop TMDLs for *E. coli* and Enterococci.

It is worth noting that the Oklahoma WQS prior to July 1, 2011 contains three bacteria indicators (fecal coliform, *E. coli* and Enterococci) and the new Oklahoma WQS effective on July 1, 2011 contains only *E. coli* and Enterococci. Because the new Oklahoma WQS no longer have a standard for fecal coliform, fecal coliform TMDLs will not be developed for any stream segment in this report even though the stream segments were listed for fecal coliform impairment in the 2008 303(d) list. Bacteria TMDLs will be developed only for *E. coli* and/or Enterococci impaired streams.

The beneficial use of WWAC is one of several subcategories of the Fish and Wildlife Propagation use established to manage the variety of communities of fish and shellfish throughout the state (OWRB 2011). The numeric criteria for turbidity to maintain and protect the use of "Fish and Wildlife Propagation" from Title 785:45-5-12 (f) (7) is as follows:

(A) Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits:

i. Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;

ii. Lakes: 25 NTU; and

iii. Other surface waters: 50 NTUs.

(B) In waters where background turbidity exceeds these values, turbidity from point sources will be restricted to not exceed ambient levels.

(C) Numerical criteria listed in (A) of this paragraph apply only to seasonal base flow conditions.

(D) Elevated turbidity levels may be expected during, and for several days after, a runoff event.

To implement Oklahoma's WQS for Fish and Wildlife Propagation, promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011a). The excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

(a) Scope. The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

(1) Short term average numerical parameters are based upon exposure periods of less than seven days. Short term average parameters to which this Section applies include, but are not limited to, sample standards and turbidity.

(2) A beneficial use shall be deemed to be fully supported for a given parameter whose criterion is based upon a short term average if 10% or less of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

(3) A beneficial use shall be deemed to be fully supported but threatened if the use is supported currently but the appropriate state environmental agency determines that available data indicate that during the next five years the use may become not supported due to anticipated sources or adverse trends of pollution not prevented or controlled. If data from the preceding two year period indicate a trend away from impairment, the appropriate agency shall remove the threatened status.

(4) A beneficial use shall be deemed to be not supported for a given parameter whose criterion is based upon a short term average if at least 10% of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

2.2 Problem Identification

In this subsection water quality data summarizing waterbody impairments caused by elevated levels of bacteria are summarized.

2.2.1 Bacteria Data Summary

Table 2-3 summarizes water quality data collected during primary contact recreation season from the WQM stations between 2000 and 2009 for each indicator bacteria. The data summary in Table 2-3 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. 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 DEQ 2008 303(d) list (DEQ 2008). Water quality data from the primary contact recreation season are provided in Appendix A. For the data collected between 2000 and 2009, evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci exceedances was verified in five waterbodies: Boggy Creek (OK310830030100_00), Cobb Creek (OK310830060050_00), Fivemile Creek (OK310830060080_00), and Caddo Creek (OK310800030010_00), Spring Creek (OK310830040010_00). Evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci exceedances originally included two additional waterbodies: East Barnitz Creek (OK310830030210_00), West Barnitz Creek (OK310830030230_00), and although after examining the data, none of these waterbodies had *E. coli* exceedances. Evidence of nonsupport of the PBCR use based on Enterococci concentrations was observed in four waterbodies: Little Washita River (OK310820020010_00), Finn Creek (OK310810020020_00), Salt Creek (OK310810030080_00), and Wildhorse Creek (OK310810030010_00). Rows highlighted in green in Table 2-3 require TMDLs.

Two waterbodies within the Study Area have been removed from further consideration for TMDL development in this report. Detailed review of data collected between 2000 and 2009 for Pennington Creek OK310800010120_00) revealed full support for both *E. coli* and Enterococci and therefore no TMDL will be calculated. Further review of the 2008 rationale for listing Washita River (OK310810010010_00) determined that this waterbody was erroneously identified as impaired using a data set for the upstream portion of the Washita River which has a different WBID; furthermore a TMDL has already been completed for the upstream waterbody.

Table 2-3 Summary of Assessment of Indicator Bacteria Samples from Primary Body Contact Recreation subcategory Season May 1 to September 30, 2000-2009

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (count/100 ml)	Notes
OK310830030210_00	Barnitz Creek, East	EC	11	125	De-list, not impaired
		ENT	11	155	
OK310830030230_00	Barnitz Creek, West	EC	12	124	De-list, not impaired
		ENT	12	260	
OK310830030100_00	Boggy Creek	EC	11	201	Not listed, but geomean is exceeded
		ENT	11	269	
OK310830060050_00	Cobb Creek	EC	12	368	
		ENT	12	226	
OK310830060080_00	Fivemile Creek	EC	12	559	
		ENT	12	447	
OK310830040010_00	Spring Creek	EC	10	164	
		ENT	10	217	
OK310820020010_00	Little Washita River	ENT	11	192	
OK310810020020_00	Finn Creek	ENT	12	219	
OK310810030080_00	Salt Creek	ENT	12	103	
OK310810030010_00	Wildhorse Creek	ENT	12	55	
OK310810010010_00	Washita River				De-list, no data
OK310800030010_00	Caddo Creek	EC	12	143	
		ENT	12	109	
OK310800010120_00	Pennington Creek	ENT	13	26	De-list, not impaired

E. coli (EC) water quality criterion = Geometric Mean of 126 counts/100 mL
Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

2.2.2 Turbidity Data Summary

Washita River (OK310810010010_00) was listed in the Oklahoma 2008 303(d) list. However, it was found that the data used to place this segment of Washita River on 2008 303(d) list was collected in the next segment of Washita River (OK310810010010_10). Therefore, Washita River (OK310810010010_00) was listed in error. As a result, there will be no turbidity TMDL developed in this report.

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." The water quality targets for E. coli and enterococci are geometric mean standards of 126 cfu/100ml and 33 cfu/100ml, respectively.

The TMDL for bacteria will incorporate an explicit 10% margin of safety.

SECTION 3
POLLUTANT SOURCE ASSESSMENT

A pollutant 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. Pathogen indicator bacteria originate from the digestive tract of warm-blooded animals, and sources may be point or nonpoint in nature.

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated wastewater are currently required to monitor for fecal coliform. These discharges will be required to monitor for E coli as their permits are renewed. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from 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 permits are considered nonpoint sources. The following discussion describes what is known regarding point and nonpoint sources of bacteria in the impaired watersheds.

The potential non-point sources for bacteria were compared based on the fecal coliform load produced in each sub-watershed. Although fecal coliform is no longer used as a bacteria indicator in the Oklahoma WQS, it is still valid to use fecal coliform load to compare the potential non-point sources because E coli is a subset of fecal coliform. Not enough references on E coli can be found to do the same comparison directly.

The following non-point sources were considered in this report:

- Wildlife (deer)
- Non-Permitted Agricultural Activities and Domesticated Animals
- Failing Onsite Wastewater Disposal Systems and Illicit Discharges
- Pets (dogs and cats)

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 municipal plants are classified as no-discharge facilities. These facilities are required to sign an affidavit of no discharge. NPDES-permitted facilities classified as point sources that may contribute bacteria include:

NPDES municipal wastewater treatment plant (WWTP);

NPDES Industrial WWTP Discharges;

Municipal no-discharge WWTP;

NPDES Concentrated Animal Feeding Operation (CAFO);

NPDES municipal separate storm sewer system (MS4) discharges; and

NPDES multi-sector general permits.

Continuous point source discharges such as WWTPs, could result in discharge of elevated concentrations of 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 EPA NPDES Program, can also contain high bacteria concentrations. 40 C.F.R. § 130.2(h) requires that NPDES-regulated stormwater discharges must be addressed by the wasteload allocation component of a TMDL. CAFOs are recognized by EPA as potential significant sources of pollution, and may have the potential to cause serious impacts to water quality if not properly managed.

There is one NPDES-permitted facility in each of the contributing watersheds of Little Washita River (OK310820020010_00) and Caddo Creek (OK310800030010_00). The remaining watersheds in the Study Area have no continuous NPDES-permitted facilities. There are no MS4 permitted entities within the watersheds addressed in the Study Area.

3.1.1 Continuous Point Source Dischargers

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 the lower portion of the Study Area, Figure 3-2. For the purposes of the TMDLs calculated in Chapter 5, only facility types identified in Table 3-1 as Sewerage Systems (Standard Industrial Code number 4952) are assumed to contribute bacteria loads within the watersheds of the impaired waterbodies. There are two continuous point source discharging facilities within the Study Area. WWTP dischargers for bacteria impaired watersheds were reviewed for availability of Discharge Monitoring Reports (DMR) data. Monthly DMRs for fecal coliform analyses were not available for the Town of Cyril (OK0041467) because the Town of Cyril does not have a bacteria limit. Available DMR data for both NPDES-permitted facilities are provided in Appendix D.

Table 3-1 Point Source Discharges in the Study Area

OPDES Permit No.	Name	Stream Segment	Stream Name	Facility Type	SIC Code	County	Design Flow (mgd)[1]	Facility ID	Expiration Date	Max./Avg. FC cfu/100mL	Outfall
OK0041467	Town of Cyril	OK310820020010_00	Little Washita River	Sewerage System	4952	Caddo	0.14	S10824	1/31/16	NA	001A
OK0038440	City of Ardmore	OK310800030010_00	Caddo Creek	Sewerage System	4952	Carter	5.9	S30804	3/31/12	400/200	001A

[1] Design Flow in 208 Plan
NA = not available.

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

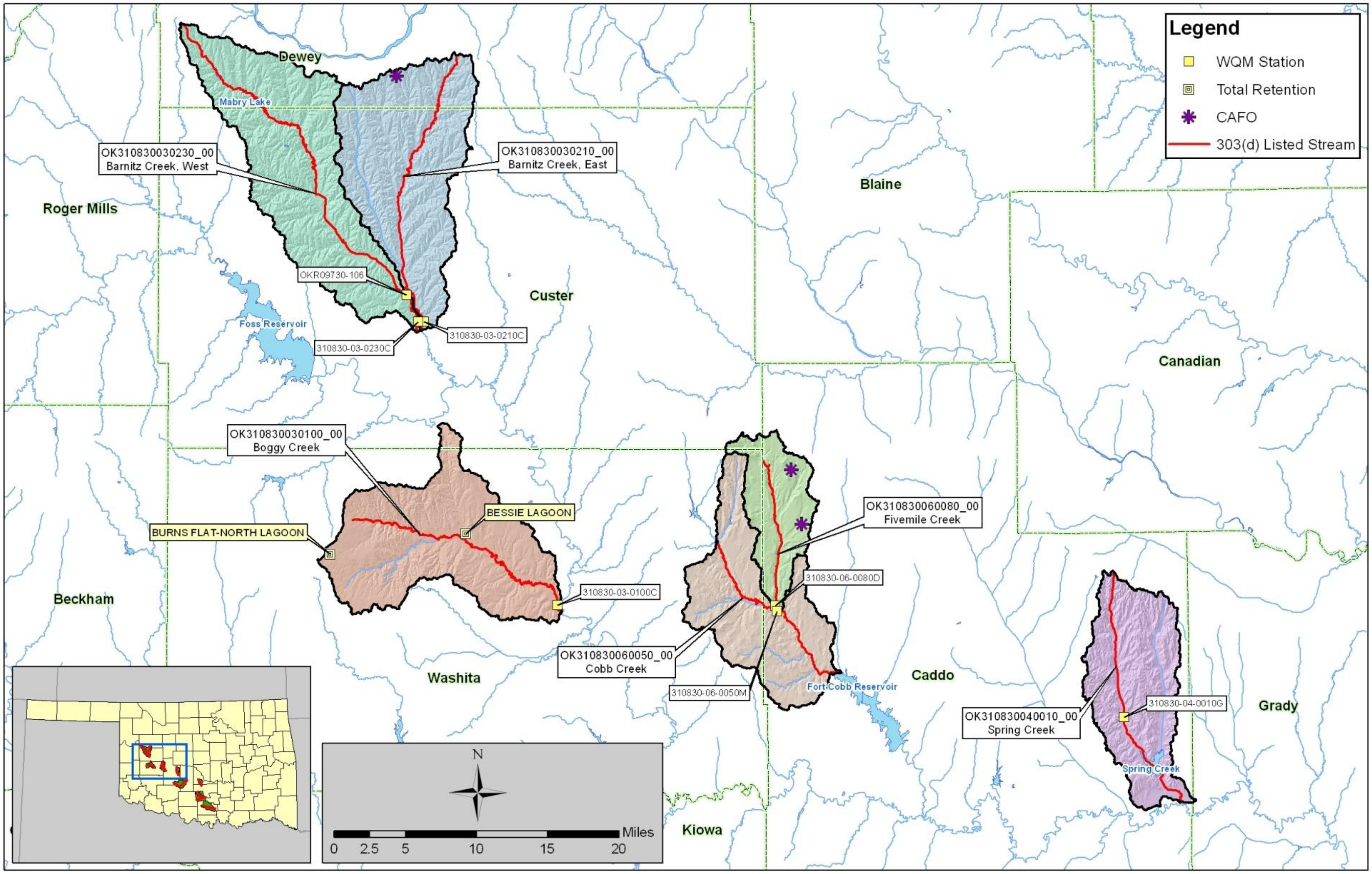
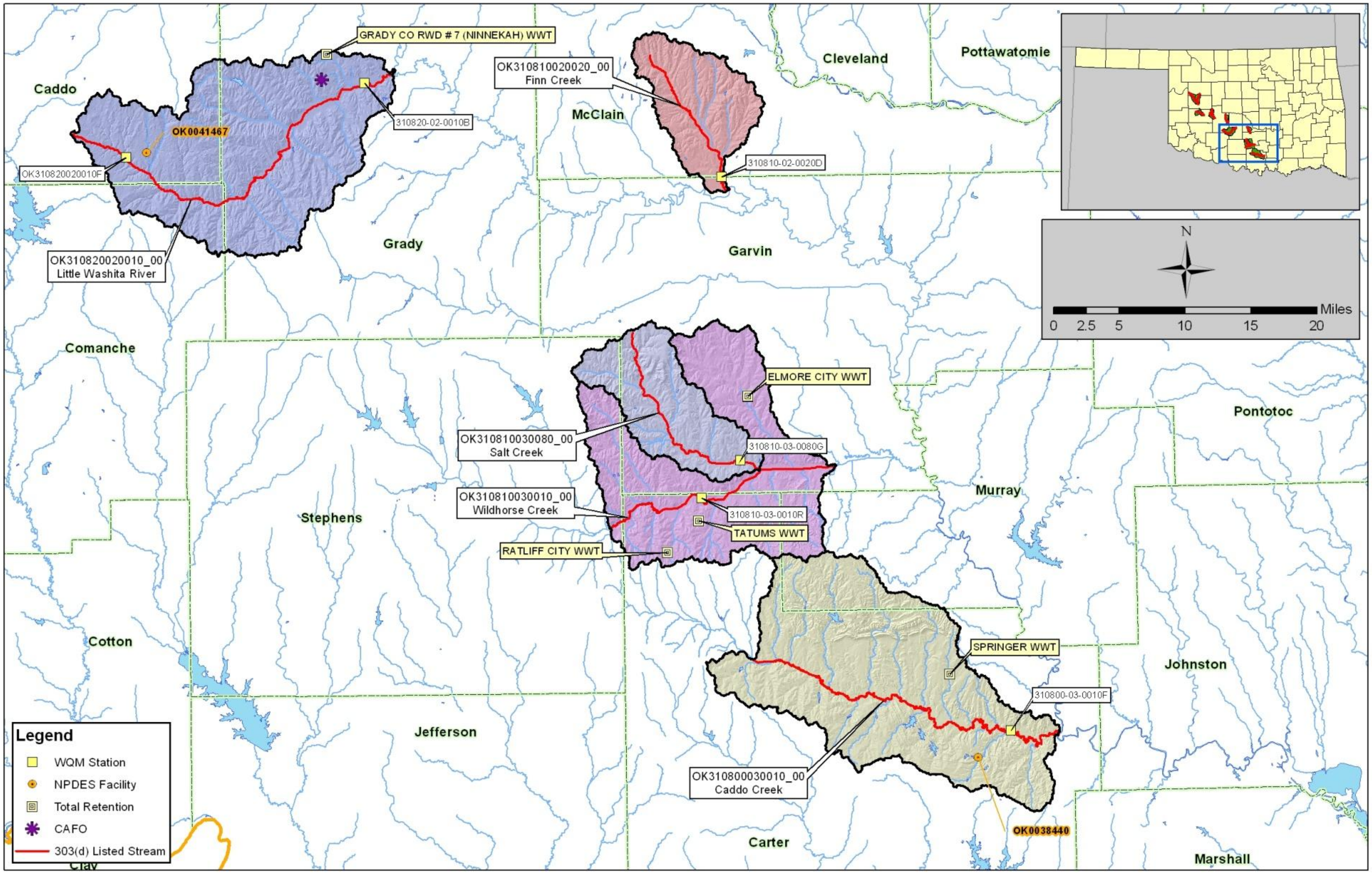


Figure 3-2 Locations of NPDES-Permitted Facilities in the Study Area



3.1.2 No-Discharge Facilities and Sanitary Sewer Overflows

For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute indicator bacteria. However, it is possible the wastewater collection systems associated with these no-discharge facilities could be a source of indicator bacteria loading, or that discharges from the wastewater plant may occur during large rainfall events that exceed the systems' storage capacities. There are eight municipal no-discharge facilities in the Study Area which are listed in Table 3-2. The no-discharge facilities located in Boggy Creek (OK310830030100_00), Little Washita River (OK310820020010_00), Wildhorse Creek (OK310810030010_00) and Caddo Creek (OK310800030010_00) watersheds could be contributing to the elevated levels of instream indicator bacteria.

Table 3-2 NPDES No-Discharge Facilities in the Study Area

Facility	Facility	County	Facility Type	Type	Waterbody ID and Name
Burns Flat-North Lagoon	10809	Washita	Lagoon (total retention)	Municipal	OK310830030100_00 Boggy Creek
Bessie LAGOON	10810	Washita	Lagoon (total retention)	Municipal	OK310830030100_00 Boggy Creek
GRADY CO RWD # 7 (NINNEKAH) WWT	10868	Grady	Lagoon (total retention)	Municipal	OK310820020010_00 Little Washita River
Elmore City WWT	10835	Garvin	Lagoon (total retention)	Municipal	OK310810030010_00 Wildhorse Creek
Ratliff City WWT	10892	Carter	Lagoon (total retention)	Municipal	OK310810030010_00 Wildhorse Creek
Tatums WWT	10889	Carter	Lagoon (total retention)	Municipal	OK310810030010_00 Wildhorse Creek
Longmire Rec Area A WWT	30814	Garvin	Lagoon (total retention)	Municipal	OK310810010010_00 Wildhorse Creek
Springer WWT	10880	Carter	Lagoon (total retention)	Municipal	OK310800030010_00 Caddo Creek

Sanitary sewer overflows (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacteria 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 has been strongly encouraged by EPA, primarily through enforcement and fines. While not all sewer overflows are reported, DEQ has some data on SSOs available. SSOs were reported between 1993 and 2007. During that period 467 overflows were reported from systems within the watersheds of the Study Area ranging from 0 to 4 million gallons. Table 3-3 summarizes the SSO occurrences by NPDES facility.

Table 3-3 Sanitary Sewer Overflow (SSO) Summary

Facility Name	NPDES Permit No.	Receiving Water	Facility ID	Number of Occurrences	Date Range		Amount (Gallons)	
					From	To	Min	Max
Town of Cyril	OK0041467	OK310820020150_00	S10824	17	2/8/1993	10/28/2000	0	4,000
City of Ardmore	OK0038440	OK310800030020_00	S30804	422	12/21/1989	3/28/2007	0	1,128,000
Burns Flat - North Lagoon		OK310830030100_00	S10809	4	5/16/1993	3/16/1998	1,500	50,000
Grady CO RWD # 7 WWT		OK310820020010_00	S10868	1	6/1/1995	6/3/1995	0	10,000
Elmore City WWT		OK310810030010_00	S10835	16	5/19/11994	2/21/2007	0	10,000
Ratliff City WWT		OK310810030010_00	S10892	2	6/11/1997	1/9/1998	N/A	N/A
Springer WWT		OK310800030010_00	S10880	5	5/18/1993	3/30/1998	0	4,000,000

3.1.3 NPDES Municipal Separate Storm Sewer System

Phase I MS4

In 1990 the EPA developed rules establishing Phase I of the NPDES Stormwater Program, designed to prevent harmful pollutants from being washed by stormwater runoff into MS4s (or from being dumped directly into the MS4) and then discharged into local water bodies (EPA 2005). Phase I of the program required operators of medium and large MS4s (those generally serving populations of 100,000 or greater) to implement a stormwater management program as a means to control polluted discharges. Approved stormwater management programs for medium and large MS4s are required to address a variety of water quality-related issues, including roadway runoff management, municipal-owned operations, and hazardous waste treatment. There are no Phase I MS4 permits in the Study Area.

Phase II MS4

Phase II of the rule extends coverage of the NPDES stormwater program to certain small MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Stormwater Program. Phase II requires operators of regulated small MS4s to obtain NPDES permits and develop a stormwater management program. Programs are designed to reduce discharges of pollutants to the “maximum extent practicable,” protect water quality, and satisfy appropriate water quality requirements of the CWA. Small MS4 stormwater programs must address the following minimum control measures:

- Public Education and Outreach;
- Public Participation/Involvement;
- Illicit Discharge Detection and Elimination;
- Construction Site Runoff Control;
- Post- Construction Runoff Control; and
- Pollution Prevention/Good Housekeeping.

The small MS4 General Permit for communities in Oklahoma became effective on February 8, 2005. DEQ provides information on the current status of the MS4 program on its website, which can be found at: http://www.deq.state.ok.us/WQDnew/stormwater/ms4/.

There are no permitted MS4s in the study area.

3.1.4 Concentrated Animal Feeding Operations

The Agricultural Environmental Management Services (AEMS) of the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) was created to help develop, coordinate, and oversee environmental policies and programs aimed at protecting the Oklahoma environment from pollutants associated with agricultural animals and their waste. Through regulations established by the Oklahoma Concentrated Animal Feeding Operation (CAFO) Act, Swine Feeding Operation (SFO) Act and Poultry Feeding Operation (PFO) Registration Act, AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the state.

(1) CAFOs

A CAFO is an animal feeding operation that confines and feeds at least 1,000 animal units for 45 days or more in a 12-month period (ODAFF 2009). The CAFO Act is designed to protect water quality through the use of best management practices (BMP) such as dikes, berms, terraces, ditches, or other similar structures used to isolate animal waste from outside surface drainage, except for a 25-year, 24–hour rainfall event (ODAFF 2009). CAFOs are considered no-discharge facilities for the purpose of the TMDL calculations in this report.

CAFOs are designated by EPA as significant sources of pollution (ODAFF 2009), and may have the potential to cause serious impacts to water quality if not managed properly. Potential problems for CAFOs can include animal waste discharges to waters of the state and failure to properly operate wastewater lagoons. The location of each CAFO is shown in Figure 3-1 and Figure 3-2 and is listed in Table 3-4.

Regulated CAFOs within the Study Area operate under state CAFO licenses issued and overseen by ODAFF and NPDES permits by EPA. In order to comply with this TMDL, those CAFO permits in the watershed and their associated management plans must be reviewed and evaluated. Further actions to reduce bacteria loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA and ODAFF for follow up.

Table 3-4 NPDES-Permitted CAFOs in Study Area

ODAFF Owner ID	EPA Facility	ODAFF ID	ODAFF License Number	Maximum Number of Swine Units at Facility	Maximum Number of Slaughter Feeder Cattle Units at Facility	Total # of Animal Units at Facility	County	Waterbody ID and Waterbody Name
AGN031858		90	1388	0	450	450	Dewey	OK310830030210_00, Barnitz Creek, East
AGN036276	OKG010049	139	1486	0	2700	2700	Caddo	OK310830060080_00, Fivemile Creek
WQ0000243	OKU000393	247	200102	3252	0	3252	Caddo	OK310830060080_00, Fivemile Creek
AGN032026	OKU000340	105	1432	0	1000	1000	Grady	OK310820020010_00, Little Washita River

(2) PFOs

Poultry feeding operations, whether regulated or not under CAFO permits must register with the State Board of Agriculture. A registered PFO is an animal feeding operation which raises poultry and generates more than 10 tons of poultry waste (litter) per year. PFOs are required to develop an Animal Waste Management Plan (AWMP) or an equivalent document such as a Nutrient Management Plan (NMP) to store, apply litter on land or transfer off site.

These plans describe how litter will be stored, land applied properly or transferred off site in order to protect water quality of streams and lakes located in the watershed. Applicable BMPs shall be included in the Plan. In order to comply with this TMDL, the registered PFOs in the watershed and their associated management plans must be reviewed and evaluated. Further actions to reduce bacteria loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA and ODAFF for follow up.

There is no PFO located in the watershed.

3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the waterbody at a specific location. The relatively homogeneous land use/land cover categories throughout the Study Area associated with rural agricultural, forest and range management activities has an influence on the origin and pathways of pollutant sources to surface water. Bacteria originate from warm-blooded animals in rural, suburban, and urban areas. These sources include wildlife, various agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems 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 water quality criterion. A study under EPA'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 (EPA 1983). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal coliform bacteria. Water quality data collected from streams draining many of the nonpermitted communities show a high level of fecal coliform bacteria. The following section provides general information on nonpoint sources contributing bacteria loading within the watersheds of the Study Area. The following subsections are presented as fecal coliform loads to assess the relative magnitude of loading between various sources of bacteria.

3.2.1 Wildlife

Fecal coliform bacteria are produced by all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs it is important to identify the potential for bacteria contributions from wildlife by watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers due to habitat and resource availability. 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 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 2005 to 2009 was combined with an estimated annual harvest rate of 20% 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.

According to a 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 based on the estimated deer population provided in Table 3-5 in cfu/day provides a relative magnitude of loading in each watershed.

Table 3-5 Estimated Population and Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 10^9 cfu/day) of Deer Population
OK310830030210_00	Barnitz Creek, East	75,808	504	0.007	252
OK310830030230_00	Barnitz Creek, West	84,622	580	0.007	290
OK310830030100_00	Boggy Creek	78,241	311	0.004	156
OK310830060050_00	Cobb Creek	54,816	376	0.007	188
OK310830060080_00	Fivemile Creek	27,375	252	0.009	126
OK310830040010_00	Spring Creek	52,212	566	0.011	283
OK310820020010_00	Little Washita River	154,573	1,191	0.008	595
OK310810020020_00	Finn Creek	42,419	287	0.007	144
OK310810030080_00	Salt Creek	51,144	392	0.008	196
OK310810030010_00	Wildhorse Creek	117,780	1,038	0.009	519
OK310800030010_00	Caddo Creek	167,996	1,749	0.010	874

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 bacteria loading. Agricultural activities of greatest concern are typically those associated with livestock operations (Drapcho and Hubbs 2002). Examples of commercially raised farm animal activities that can contribute to bacteria sources include:

Processed commercially raised farm animal manure is often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff.

Animals grazing in pastures deposit manure containing fecal bacteria onto land surfaces. These bacteria may be washed into waterbodies by runoff.

Animals often have direct access to waterbodies and can provide a concentrated source of fecal bacteria loading directly into streams.

Table 3-6 provides estimated numbers of selected livestock by watershed based on the 2007 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2007). The estimated commercially raised farm animal populations in Table 3-6 were derived by using the percentage of the watershed within each county. Because the watersheds are generally much smaller than the counties, and commercially raised farm animals are not evenly distributed across counties or constant with time, these are rough estimates only. Cattle are clearly the most abundant species of commercially raised farm animals in the Study Area and often have direct access to the waterbodies and their tributaries.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application or direct deposition of manure from commercially raised farm animal. The estimated acreage by watershed where manure was applied in 2007 is shown in Table 3-6. These estimates are also based on the county level reports from the 2007 USDA county agricultural census, and thus, represent approximations of the commercially raised farm animal populations in each watershed. Despite the lack of specific data, for the purpose of these TMDLs, land application of commercially raised farm animal manure is considered a potential source of bacteria loading to the watersheds in the Study Area.

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 animal populations and the fecal coliform production rates from ASAE, an estimate of fecal coliform production from each group of commercially raised farm animal was calculated in each watershed of the Study Area. These estimates are presented in Table 3-7. 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. Because of their numbers and animal unit production of bacteria, cattle again appear to represent the most likely commercially raised farm animal source of fecal bacteria.

Table 3-6 Commercially Raised Farm Animals and Manure Application Area Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves	Dairy Cows	Hogs & Pigs	Chickens	Sheep & Lambs	Horses & Ponies	Turkeys	Ducks	Geese	Acres of Manure Application
OK310830030210_00	Barnitz Creek, East	9,248	61	9	83	129	277	18	3	0	175
OK310830030230_00	Barnitz Creek, West	10,021	63	14	92	134	292	18	3	0	178
OK310830030100_00	Boggy Creek	13,045	1	0	84	57	109	0	0	1	148
OK310830060050_00	Cobb Creek	9,274	7	1,828	92	70	124	2	1	1	133
OK310830060080_00	Fivemile Creek	4,631	8	1,625	59	49	85	2	1	0	80
OK310830040010_00	Spring Creek	8,968	17	4,123	132	107	183	4	3	1	167
OK310820020010_00	Little Washita River	23,178	2,006	7,646	398	318	247	7	19	10	1,408
OK310810020020_00	Finn Creek	6,684	156	253	307	103	438	8	11	3	268
OK310810030080_00	Salt Creek	8,000	20	53	240	80	282	4	4	2	178
OK310810030010_00	Wildhorse Creek	15,552	31	116	678	150	713	10	19	6	598
OK310800030010_00	Caddo Creek	16,949	16	147	1,268	141	1,074	17	39	8	1,261

Table 3-7 Fecal Coliform Production Estimates for Commercially Raised Farm Animals ($x10^9$ number/day)

Waterbody ID	Waterbody Name	Cattle & Calves	Dairy Cows	Hogs & Pigs	Chickens	Sheep & Lambs	Horses & Ponies	Turkeys	Ducks	Geese	Total
OK310830030210_00	Barnitz Creek, East	961,780	6,205	102	11	1,542	116	2	6	11	969,776
OK310830030230_00	Barnitz Creek, West	1,042,132	6,349	149	13	1,602	123	2	8	17	1,050,394
OK310830030100_00	Boggy Creek	1,356,652	142	0	11	685	46	0	0	53	1,357,589
OK310830060050_00	Cobb Creek	964,525	745	19,743	13	836	52	0	3	42	985,958
OK310830060080_00	Fivemile Creek	481,580	791	17,546	8	583	36	0	3	22	500,569
OK310830040010_00	Spring Creek	932,647	1,723	44,525	18	1,281	77	0	7	47	980,325
OK310820020010_00	Little Washita River	2,410,479	202,586	82,572	54	3,812	104	1	46	506	2,700,160
OK310810020020_00	Finn Creek	695,187	15,757	2,731	42	1,231	184	1	26	143	715,302
OK310810030080_00	Salt Creek	832,018	2,064	575	33	962	119	0	10	102	835,883
OK310810030010_00	Wildhorse Creek	1,617,458	3,091	1,250	92	1,803	300	1	46	300	1,624,341
OK310800030010_00	Caddo Creek	1,762,711	1,607	1,589	172	1,686	451	2	95	391	1,768,704

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

DEQ 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 (DEQ 2011). 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 may discharge 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 which was the last year in which there were Census questions about plumbing facilities (U.S. Department of Commerce, Bureau of the Census 1990). 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 block 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 1990 American Housing Survey for Oklahoma conducted by the U.S. Census Bureau estimates that, nationwide, 10% of occupied homes with OSWD systems experience malfunctions during the year (U.S. Department of Commerce, Bureau of the Census 1990). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12% of the OSWD systems in east Texas and 8% in the Texas Panhandle 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 3-8 summarizes estimates of sewered and unsewered households and the average number of septic tanks per square mile for each watershed in the Study Area.

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 8% was used for all watersheds in this Study Area. Using 8% failure rates, calculations were made to characterize fecal coliform loads in each watershed.

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

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

Table 3-8 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	# of Septic Tanks / Mile^2
OK310830030210_00	Barnitz Creek, East	0	101	2	103	0.85
OK310830030230_00	Barnitz Creek, West	175	172	4	351	1.30
OK310830030100_00	Boggy Creek	447	230	6	683	1.88
OK310830060050_00	Cobb Creek	30	453	15	497	5.29
OK310830060080_00	Fivemile Creek	51	111	5	168	2.60
OK310830040010_00	Spring Creek	90	276	2	368	3.38
OK310820020010_00	Little Washita River	999	1,641	62	2,702	6.79
OK310810020020_00	Finn Creek	79	349	12	440	5.27
OK310810030080_00	Salt Creek	4	288	13	306	3.60
OK310810030010_00	Wildhorse Creek	366	863	35	1,264	4.69
OK310800030010_00	Caddo Creek	3,341	1,642	47	5,030	6.26

The average of number of people per household was calculated to be 2.18 for counties in the Study Area (U.S. Census Bureau 2010). 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 publications (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 was summarized below in Table 3-9.

Table 3-9 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)
OK310830030210_00	Barnitz Creek, East	75,808	101	8	47
OK310830030230_00	Barnitz Creek, West	84,622	172	14	80
OK310830030100_00	Boggy Creek	78,241	230	18	107
OK310830060050_00	Cobb Creek	54,816	453	36	211
OK310830060080_00	Fivemile Creek	27,375	111	9	52
OK310830040010_00	Spring Creek	52,212	276	22	129
OK310820020010_00	Little Washita River	154,573	1,641	131	765
OK310810020020_00	Finn Creek	42,419	349	28	163
OK310810030080_00	Salt Creek	51,144	288	23	134
OK310810030010_00	Wildhorse Creek	117,780	863	69	402
OK310800030010_00	Caddo Creek	167,996	1,642	131	766

3.2.4 Domestic Pets

Fecal matter from dogs and cats, which is transported to streams by runoff from urban and suburban areas can be a potential source of bacteria loading. On average 37.2% of the nation's households own dogs and 32.4% own cats and in these households the average number of dogs is 1.7 and 2.2 cats per household (American Veterinary Medical Association 2007). Using the U.S. Census data at the block level (U.S. Census Bureau 2010), dog and cat populations can be estimated for each watershed. Table 3-10 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-10 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK310830030210_00	Barnitz Creek, East	30	34
OK310830030230_00	Barnitz Creek, West	50	56
OK310830030100_00	Boggy Creek	184	208
OK310830060050_00	Cobb Creek	139	156
OK310830060080_00	Fivemile Creek	38	43
OK310830040010_00	Spring Creek	110	124
OK310820020010_00	Little Washita River	1,682	1,898
OK310810020020_00	Finn Creek	310	350
OK310810030080_00	Salt Creek	182	206
OK310810030010_00	Wildhorse Creek	663	748
OK310800030010_00	Caddo Creek	3,097	3,493

Table 3-11 provides an estimate of the fecal coliform production 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 3-11 Estimated Fecal Coliform Daily Production by Pets ($x10^9$ counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK310830030210_00	Barnitz Creek, East	99	18	117
OK310830030230_00	Barnitz Creek, West	165	31	196
OK310830030100_00	Boggy Creek	608	112	720
OK310830060050_00	Cobb Creek	458	85	542
OK310830060080_00	Fivemile Creek	124	23	147
OK310830040010_00	Spring Creek	362	67	429
OK310820020010_00	Little Washita River	5,551	1,025	6,575
OK310810020020_00	Finn Creek	1,024	189	1,213
OK310810030080_00	Salt Creek	602	111	713
OK310810030010_00	Wildhorse Creek	2,188	404	2,592
OK310800030010_00	Caddo Creek	10,218	1,886	12,105

3.3 Summary of Bacteria Sources

There are no continuous, permitted point sources of bacteria in the East Barnitz Creek, West Barnitz Creek, Boggy Creek, Cobb Creek, Fivemile Creek, Spring Creek, Finn Creek, Salt Creek, and Wildhorse Creek watersheds which require bacteria TMDLs; therefore, the conclusion is that nonsupport of PBCR use in these watersheds is caused by nonpoint sources of bacteria. The Little Washita River and Caddo Creek each have one continuous point source discharge which do contribute bacteria, but the available data suggests that the proportion of bacteria from point sources is minor. The various nonpoint sources are considered to be the major source of bacteria loading in each watershed that requires a TMDL.

Table 3-12 below provides a summary of the estimated fecal coliform loads in cfu/day for the four major nonpoint source categories (commercially raised farm animals, pets, deer, and septic tanks) that contribute to the elevated bacteria concentrations in each watershed. Because of their numbers and animal unit production of bacteria, livestock are estimated to be the largest contributors 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 around the nation demonstrate that wild birds and mammals may represent a major source of the fecal bacteria found in streams.

Table 3-12 Summary of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces (x10^9 counts/day)

Waterbody ID	Waterbody Name	All Livestock	Pets	Deer	Estimated Loads from Septic Tanks
OK310830030210_00	Barnitz Creek, East	969,776	117	252	47
OK310830030230_00	Barnitz Creek, West	1,050,394	196	290	80
OK310830030100_00	Boggy Creek	1,357,589	720	156	107
OK310830060050_00	Cobb Creek	985,958	542	188	211
OK310830060080_00	Fivemile Creek	500,569	147	126	52
OK310830040010_00	Spring Creek	980,325	429	283	129
OK310820020010_00	Little Washita River	2,700,160	6,575	595	765
OK310810020020_00	Finn Creek	715,302	1,213	144	163
OK310810030080_00	Salt Creek	835,883	713	196	134
OK310810030010_00	Wildhorse Creek	1,624,341	2,592	519	402
OK310800030010_00	Caddo Creek	1,768,704	12,105	874	766

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 and a number of other environmental conditions. Also, the structural properties of some manure, such as cow patties, may limit their washoff into streams by runoff. In contrast, malfunctioning septic tank effluent may be present in standing water on the surface, or in shallow groundwater, which may enhance its conveyance to streams.

SECTION 4
TECHNICAL APPROACH AND METHODS

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

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

The WLA is the portion 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.

For *E. coli*, or Enterococci bacteria, TMDLs are expressed as colony-forming units per day and represent the maximum one-day load the stream can assimilate while still attaining the WQS. Percent reduction goals are also calculated to aid in characterizing the possible magnitude of the effort to restore the segment to meeting water quality standards.

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 can help identify whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the three following steps that are described in Subsections 4.2 through 4.4 below:

- Preparing flow duration curves for gaged and ungaged WQM stations;
- Estimating existing bacteria loading in the waterbody using ambient bacteria water quality data; and
- Using LDCs to identify if there is a critical condition.

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. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. It is not used in this report to quantify point source or nonpoint source contributions. Violations that occur during low flows may not be caused exclusively by point sources. Violations during low flows have been noted in some watersheds that contain no point sources.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by a 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. Only four of the eleven waterbodies in the Study Area for which TMDLs are being established have long-term measured flow data from USGS gage stations. The default approach used to develop flow frequencies necessary to establish flow duration curves considers watershed differences in rainfall, land use, and the hydrologic properties of soil that govern runoff and retention. A detailed explanation of the methods for estimating flow for ungaged streams is provided in Appendix B. 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.

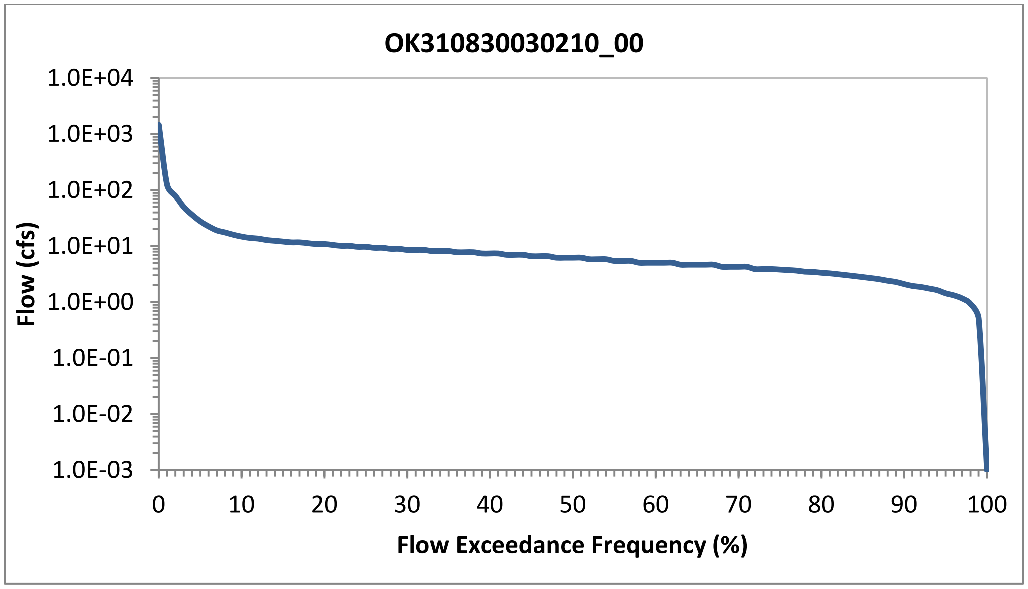
Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations 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 (x-axis), which is numbered from 0% to 100%, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100% indicating that flow has equaled or exceeded this value 100% of the time, while the highest measured flow is found at an exceedance frequency of 0%. The median flow occurs at a flow exceedance frequency of 50%. The flow exceedance percentiles for each waterbody addressed in this report are provided in Appendix B.

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 one 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 2009) to support the Oklahoma TMDL Toolbox.

The USGS National Water Information System serves as the primary source of flow measurements for the Oklahoma TMDL Toolbox. 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 Oklahoma TMDL Toolbox to generate flow duration curves for gaged and ungaged waterbodies. The application includes a data update module that automatically downloads the most recent USGS data and appends it to the existing flow database.

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0% and downward at a frequency near 100%, 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%. 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 quantization. An example of a typical flow duration curve was shown in Figure 4-1.

Figure 4-1 Flow Duration Curve for Barnitz Creek, East (OK310830030210_00)



Flow duration curve for each stream segment in this study will be developed in Section 5.1.

4.3 Estimating Existing Loading

The existing instream load can be estimated as follows:

- calculating the geometric mean of all water quality observations from the period of record selected for the waterbody;
- converting the geometric mean concentration value to loads by multiplying the flow duration curve by the geometric mean of ambient water quality data for each bacteria indicator.

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 pollutant loads must be reduced to meet WQSs in the impaired watershed).

Step 1: Generate LDCs. LDCs are similar in appearance to flow duration curves; however, for bacteria the ordinate is expressed in terms of a bacteria load in cfu/day. The curve represents the geometric mean of all water quality observations from the period of record selected for the waterbody expressed in terms of a load through multiplication by the continuum of flows historically observed at the site. Bacteria TMDLs are not easily expressed in mass per day, the equation below calculates a load in the units of cfu per day. The cfu is a total for the day at a specific flow for bacteria, which is the best equivalent to a mass per day of a pollutant such as sulfate. Expressing bacteria TMDLs as cfu per day is consistent with EPA's Protocol for Developing Pathogen TMDLs (EPA 2001).

The basic steps to generating an LDC involve:

- obtaining daily flow data (measured or projected) for the site of interest from the USGS;
- sorting the flow data and calculating flow exceedance percentiles;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30);
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS numerical criterion (geometric mean) for each respective bacteria indicator; and,
- displaying another curve derived by plotting the geometric mean of all existing bacteria samples continuously along the full spectrum of flow exceedance percentiles which represents load duration curve (See Section 5).

For bacteria TMDLs 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 = 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

unit conversion factor = 24,465,525

The corresponding flow at every percent increment of flow exceedance frequency (x value at the LDC plot) is used in the above formula to calculate the LDC for the TMDL. When the geometric mean of all samples is used in place of WQS in the above formula, the resulting LDC provides a representation of the existing load in the stream. It is inappropriate to compare single sample bacteria observations to a geometric mean water quality criterion in the LDC. Therefore individual bacteria samples are not plotted on the LDCs.

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 (e.g., lake release to provide water downstream) and runoff influence may be observed with low or moderate flows (e.g., persistent high turbidity due to previous storm).

Step 2: Define MOS. The MOS may be defined explicitly or implicitly. A typical explicit approach would reserve some specific fraction of the TMDL as the MOS. In an implicit approach, conservative assumptions used in developing the TMDL are relied upon to provide a MOS to assure that WQSs are attained. For bacteria TMDLs in this report, an explicit MOS of 10% was selected. The 10% MOS has been used in other approved bacteria TMDLs.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for point sources is defined by the WLA. For bacteria TMDLs 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 EPA 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. WLAs can be expressed in terms of a single load, or as different loads allowable under different flows.. WLAs may be set to zero in cases of watersheds with no existing or planned continuous permitted point sources.

WLA for WWTP. For watersheds with permitted point sources discharging the pollutant of concern, NPDES permit limits are used to derive WLAs for evaluation as appropriate for use in the TMDL. The permitted flow rate used for each point source discharge and the water quality concentration defined in a permit are used to estimate the WLA for each wastewater facility. In cases where a permitted flow rate is not available for a WWTP, then the maximum monthly average flow rate derived from DMRs can be used. WLA values for each NPDES wastewater discharger are then summed to represent the total WLA for a given segment. Using this information, bacteria WLAs can be calculated using theapproach as shown in the equation below.

WLA for bacteria:

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

Where:

WQS =126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

flow (mgd) = permitted flow unit conversion factor = 37,854,120

Step 4: Calculate LA and WLA for MS4s.

Given the lack of data and the variability of storm events and discharges from storm sewer system discharges, it is difficult to establish numeric limits on stormwater discharges that accurately address projected loadings. As a result, EPA regulations and guidance recommend expressing NPDES permit limits for MS4s as BMPs.

LAs can be calculated under different flow conditions. The LA at any particular flow exceedance is calculated as shown in the equation below.

LA = TMDL - WLA_WWTP - WLA_MS4 – MOS

WLA for MS4s. For bacteria TMDLs, if there are no permitted MS4s in the study area, WLA_MS4 is set to zero. When there are permitted MS4s in a watershed, first calculate the sum of LA + WLA_MS4 using the above formula, then separate WLA for MS4s from the sum based on the percentage of a watershed that is under a MS4 jurisdiction. This WLA for MS4s may not be the total load allocated for permitted MS4s unless the whole MS4 area is located within the study watershed boundary. However, in most case the study watershed intersects only a portion of the permitted MS4 coverage areas.

Step 5: Estimate Percent Load Reduction. Percent load reductions are not required items and are provided for informational purposes when making inferences about individual TMDLs or between TMDLs usually in regard to implementation of the TMDL.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on stream flow and that the maximum allowable loading varies with flow condition. Existing loading and load reductions required to meet the TMDL can also be calculated under different flow conditions. The difference between existing loading and the TMDL is used to calculate the loading reductions required. Percent reduction goals are calculated through an iterative process of taking a series of percent reduction values applying each value uniformly to the measured concentrations of samples and verifying if the geometric mean of the reduced values of all samples is less than the geomean standards.

WLA Load Reduction: The WLA load reduction for bacteria 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. Currently, bacteria limits are not required for lagoon systems. Lagoon systems located within a sub-watershed of bacteria impaired stream segment will be required to meet E coli standards at the discharge when the permits are renewed.

MS4s are classified as point sources, but they are non-point sources in nature. Therefore, the percent reduction goal calculated for LA will also apply to the MS4 area within the bacteria impaired sub-watershed. If there are no MS4s located within the Study Area requiring a TMDL then there is no need to establish a PRG for permitted stormwater.

LA Load Reduction: After existing loading estimates are computed for each pollutant, nonpoint load reduction estimates for each segment are calculated by using the difference between estimated existing loading and the TMDL with 10% MOS. This difference is expressed as the overall PRG for the impaired waterbody. For *E. coli* and Enterococci, because WQSs are considered to be met if the geometric mean of all future data is maintained below the geometric mean criteria, the TMDL PRG serves as a guide for the amount of pollutant reduction necessary to meet the geometric mean WQS.

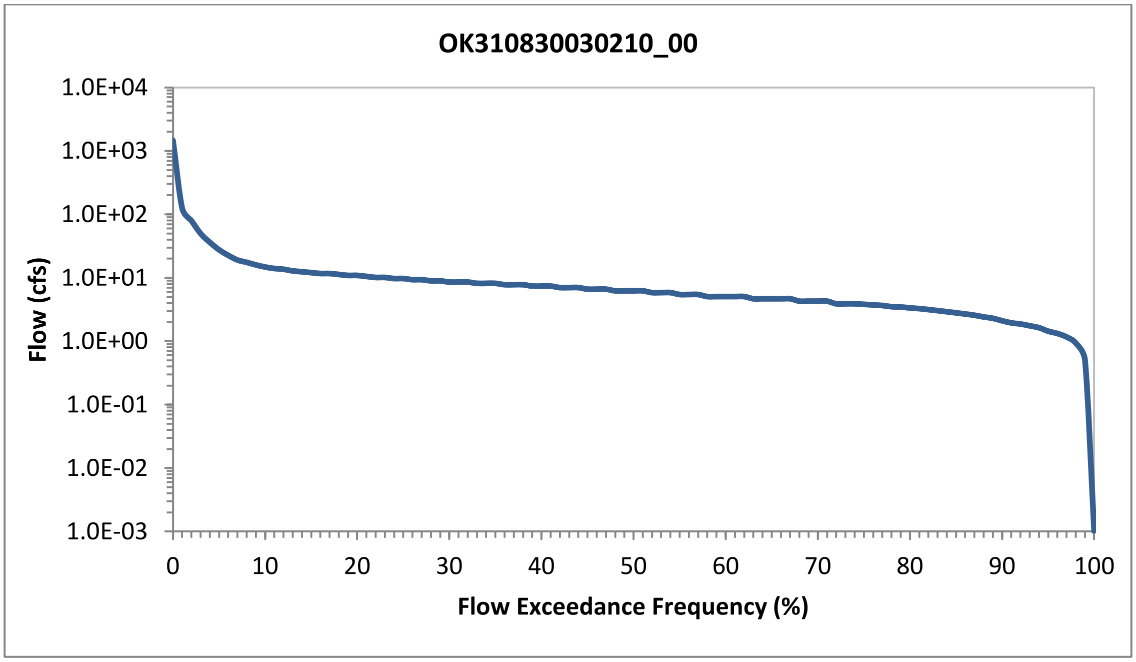
SECTION 5
TMDL CALCULATIONS

5.1 Flow Duration Curve

Following the same procedures described in Section 4.3, a flow duration curve for each stream segment in this study was developed. These are shown in Figure 5-1 through Figure 5-11.

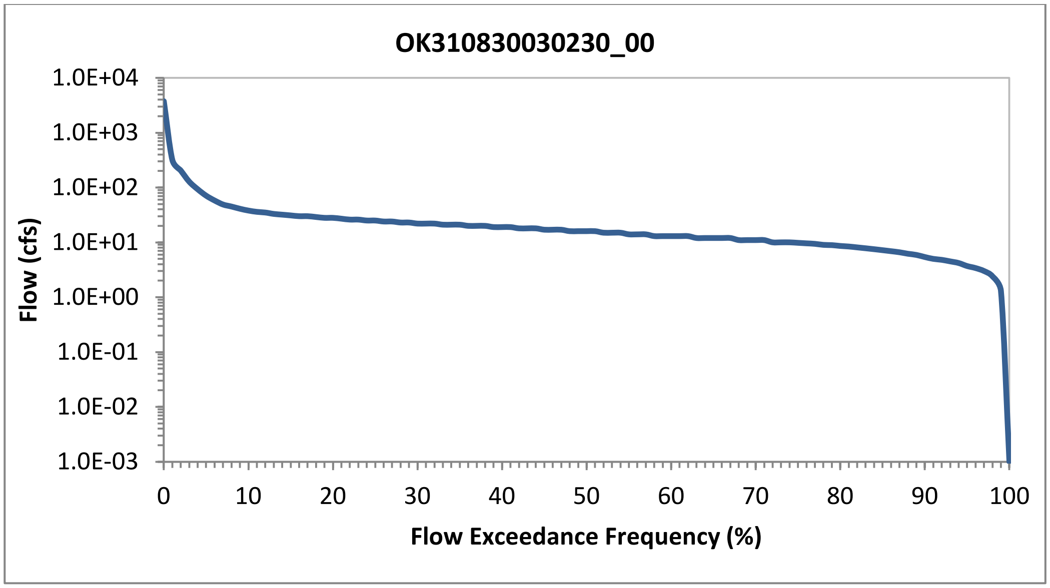
No flow gage exists on East Barnitz Creek, segment OK310830030210_00. Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07325800 located in an adjacent watershed (Cobb Creek near Eakly, OK). The flow duration curve was based on measured flows from 1968 to 2010.

Figure 5-1 Flow Duration Curve for Barnitz Creek, East (OK310830030210_00)



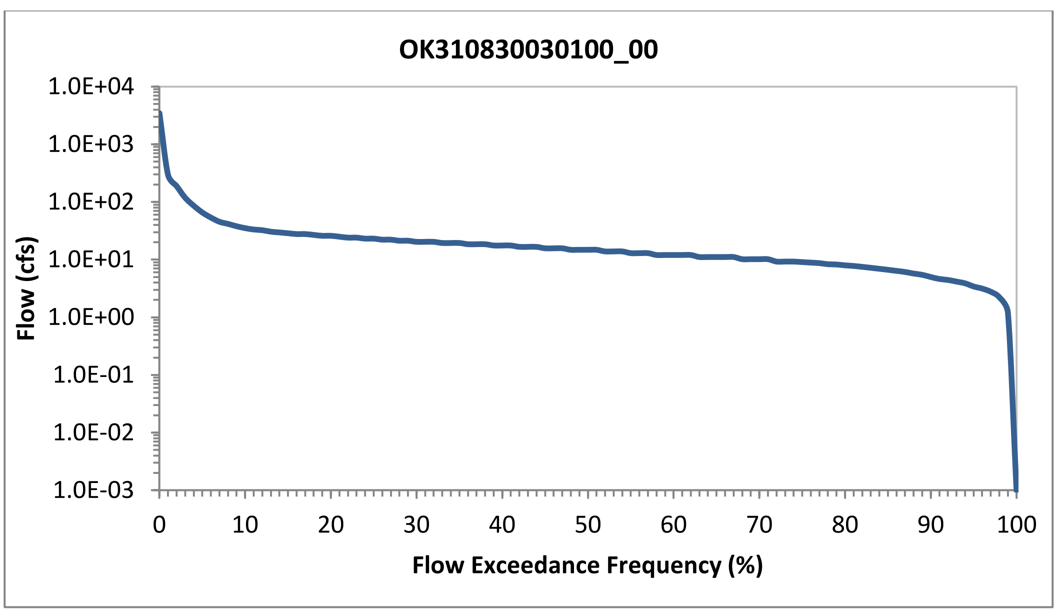
No flow gage exists on West Barnitz Creek, segment OK310830030230_00. Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07325800 located in an adjacent watershed (Cobb Creek near Eakly, OK). The flow duration curve was based on measured flows from 1968 to 2010.

Figure 5-2 Flow Duration Curve for Barnitz Creek, West (OK310830030230_00)



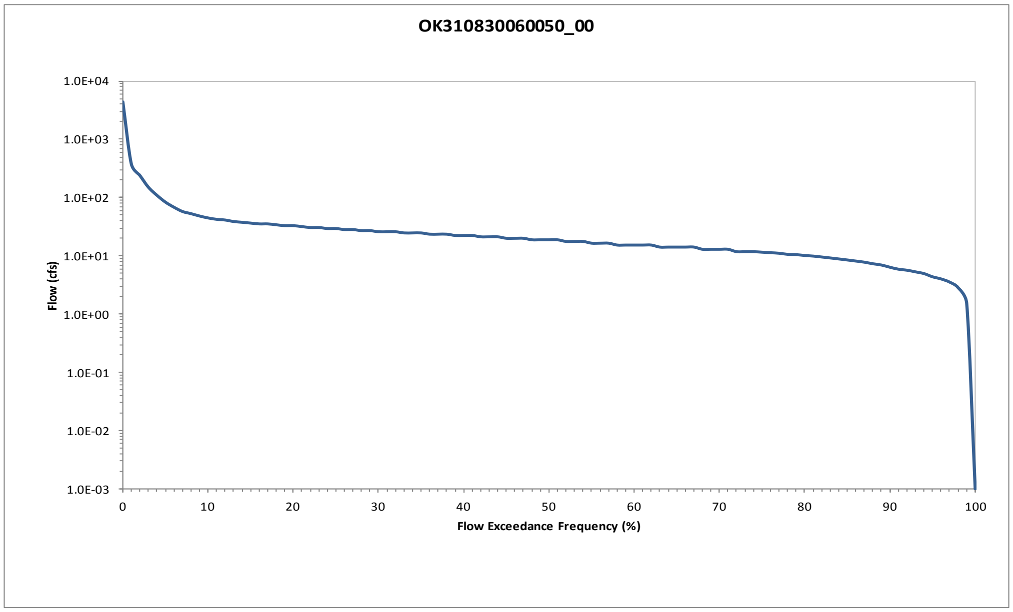
No flow gage exists on Boggy Creek, segment OK310830030100_00. Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07325800 located in an adjacent watershed (Cobb Creek near Eakly, OK). The flow duration curve was based on measured flows from 1968 to 2010.

Figure 5-3 Flow Duration Curve for Boggy Creek (OK310830030100_00)



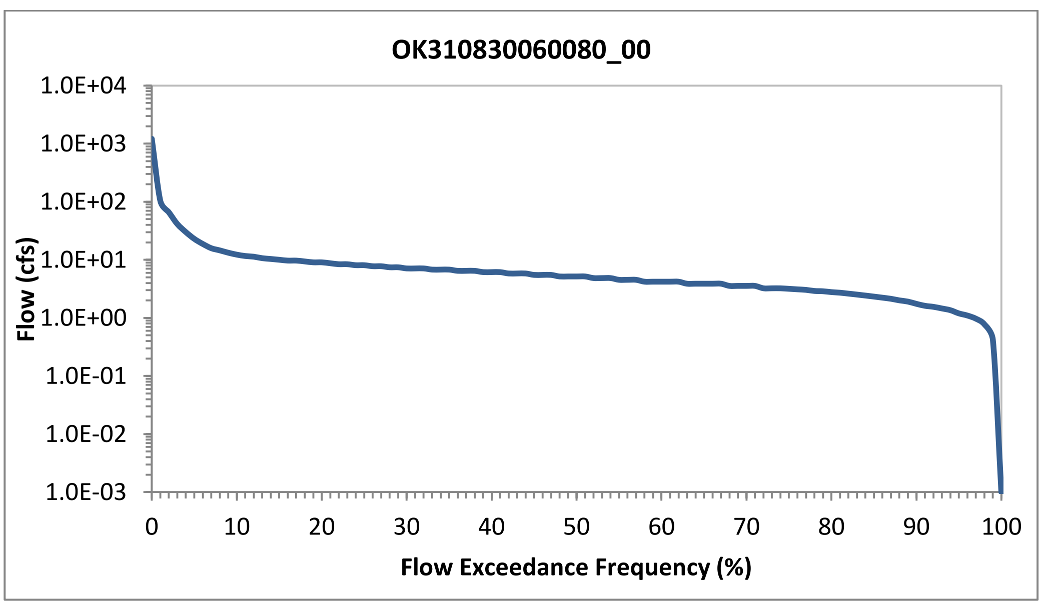
The flow duration curve for Cobb Creek, segment OK310830060050_00 was based on measured flows at USGS gage station 07325800 (Cobb Creek near Eakly, OK). The flow duration curve was based on measured flows from 1968 to 2010.

Figure 5-4 Flow Duration Curve for Cobb Creek (OK310830060050_00)



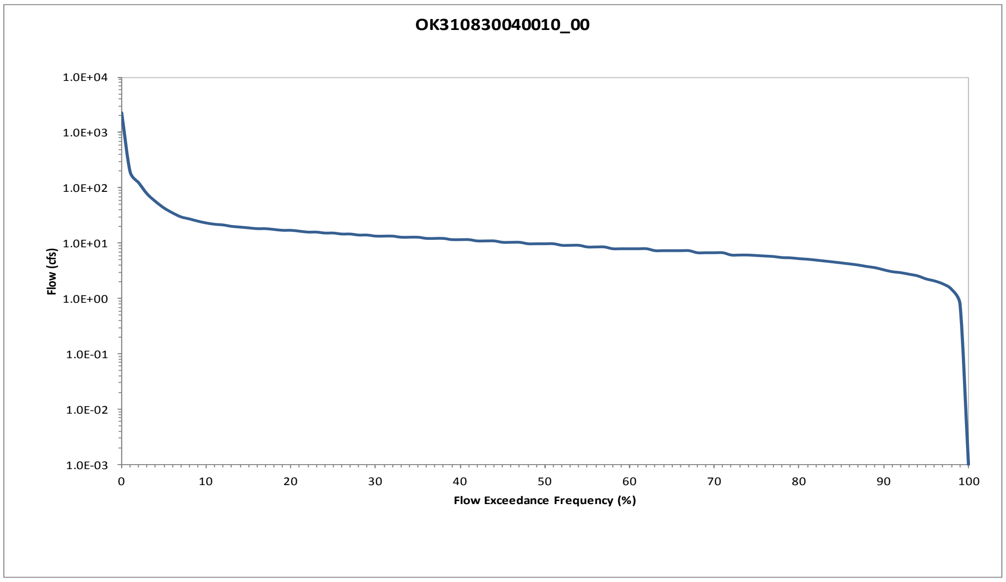
No flow gage exists on Fivemile Creek, segment OK310830060080_00. Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07325800 (Cobb Creek near Eakly, OK). The flow duration curve was based on measured flows from 1968 to 2010.

Figure 5-5 Flow Duration Curve for Fivemile Creek (OK310830060080_00)



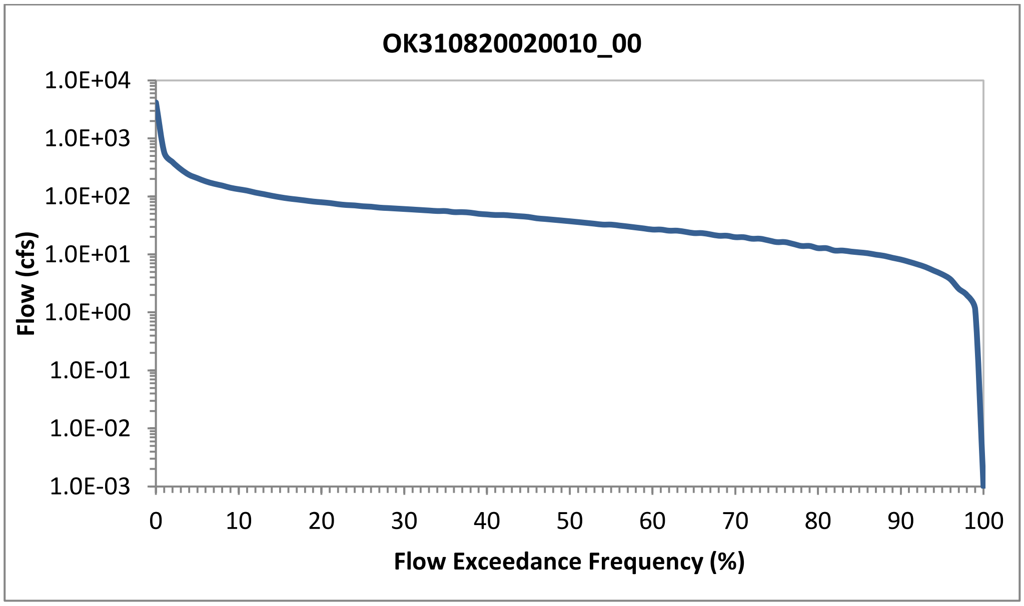
USGS gage station 07327050 is located on Spring Creek, segment OK310830040010_00, however, the period of record for that gage is only 4 years (1991 to 1994). Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07325800 (Cobb Creek near Eakly, OK). The flow duration curve was based on measured flows from 1968 to 2010.

Figure 5-6 Flow Duration Curve for Spring Creek (OK310830040010_00)



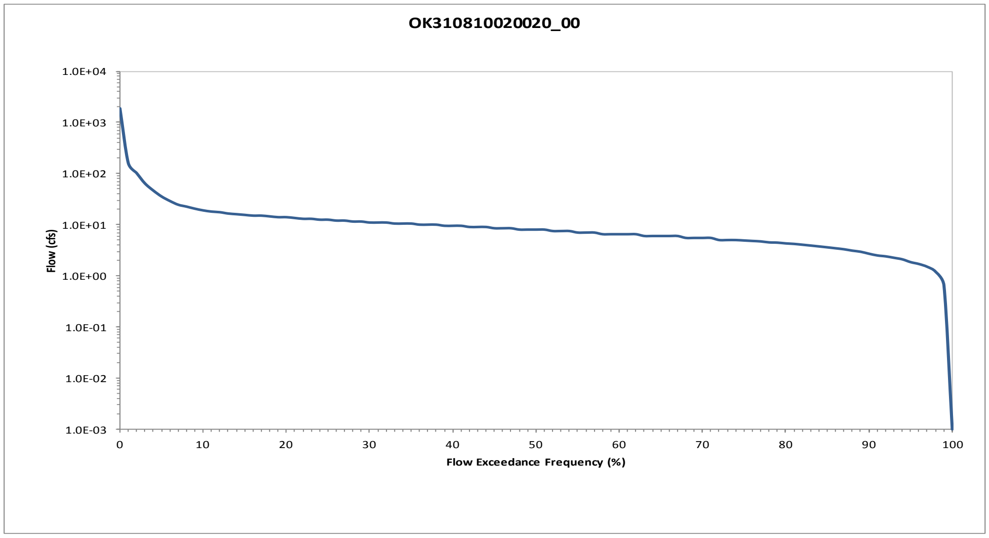
The flow duration curve for Little Washita River, segment OK310820020010_00 was based on measured flows at USGS gage station 07327550. The flow duration curve was based on measured flows from 1992 to 2010.

Figure 5-7 Flow Duration Curve for Little Washita River (OK310820020010_00)



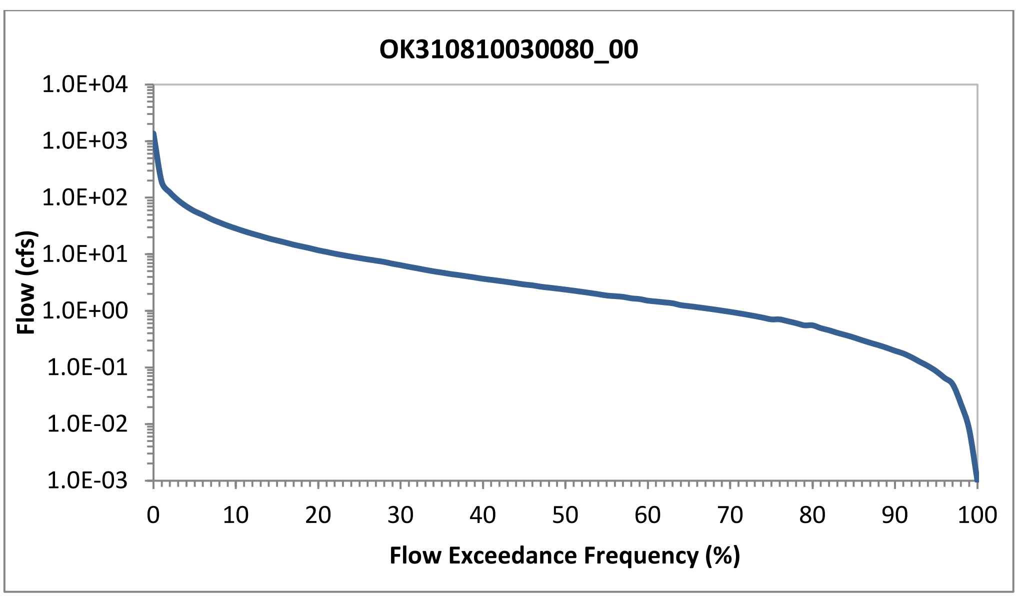
No flow gage exists on Finn Creek, segment OK310810020020_00. Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07325800 located in an adjacent watershed (Cobb Creek near Eakly, OK). The flow duration curve was based on measured flows from 1968 to 2010.

Figure 5-8 Flow Duration Curve for Finn Creek (OK310810020020_00)



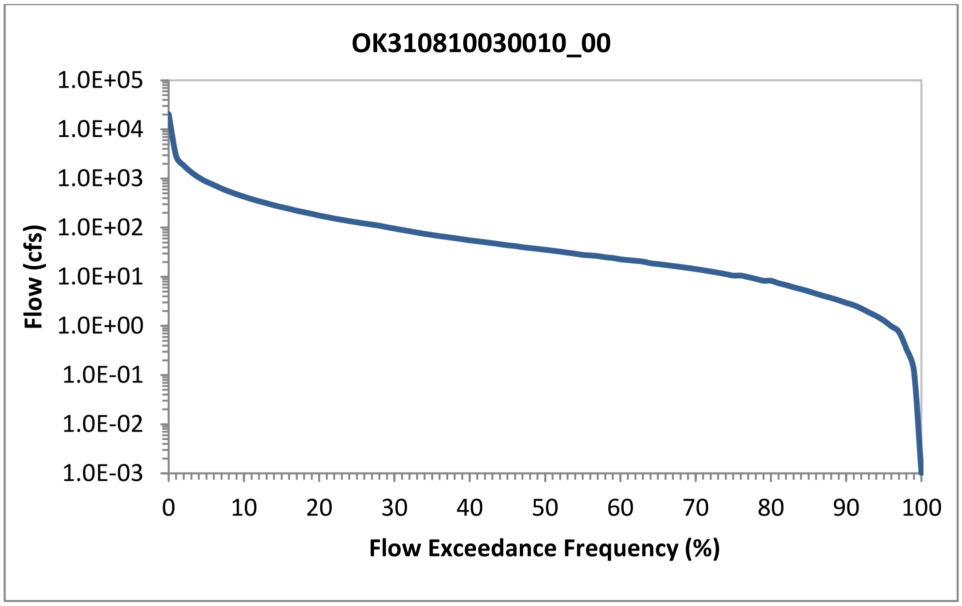
No flow gage exists on Salt Creek, segment OK310810030080_00. Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07329700 (Wildhorse Creek near Hoover, OK). The flow duration curve was based on measured flows from 1969 to 2002.

Figure 5-9 Flow Duration Curve for Salt Creek (OK310810030080_00)



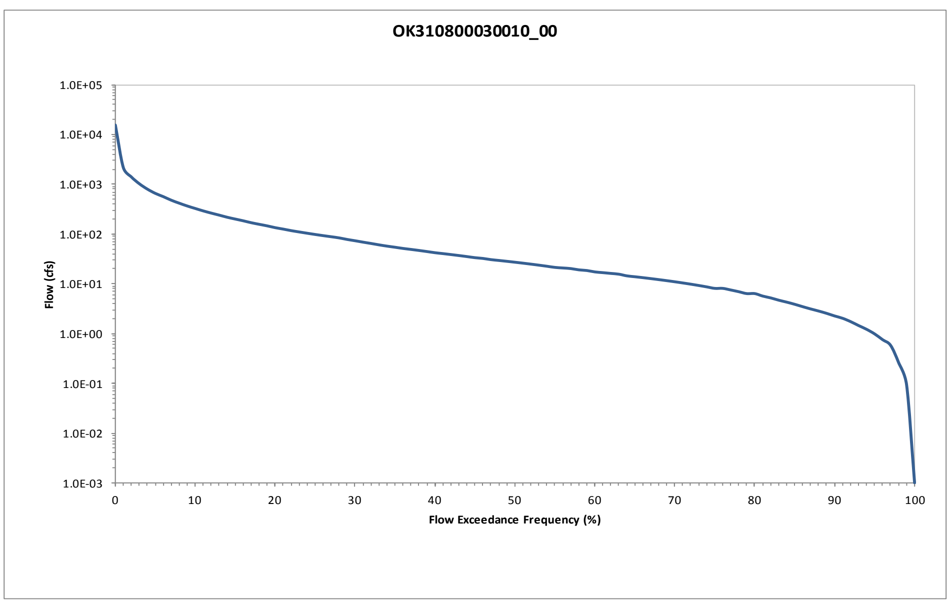
The flow duration curve for Wildhorse Creek, segment OK310810030010_00 was based on measured flows at USGS gage station 07329700 (Wildhorse Creek near Hoover, OK). The flow duration curve was based on measured flows from 1969 to 2002.

Figure 5-10 Flow Duration Curve for Wildhorse Creek (OK310810030010_00)



USGS gage station 07330700 is located on Caddo Creek, segment OK310800030010_00, however, the period of record for that gage is only 3 years (1996 to 1998). Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07329700 (Wildhorse Creek near Hoover, OK). The flow duration curve was based on measured flows from 1969 to 2002.

Figure 5-11 Flow Duration Curve for Caddo Creek (OK310800030010_00)



5.2 Estimated Loading and Critical Conditions

EPA 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.

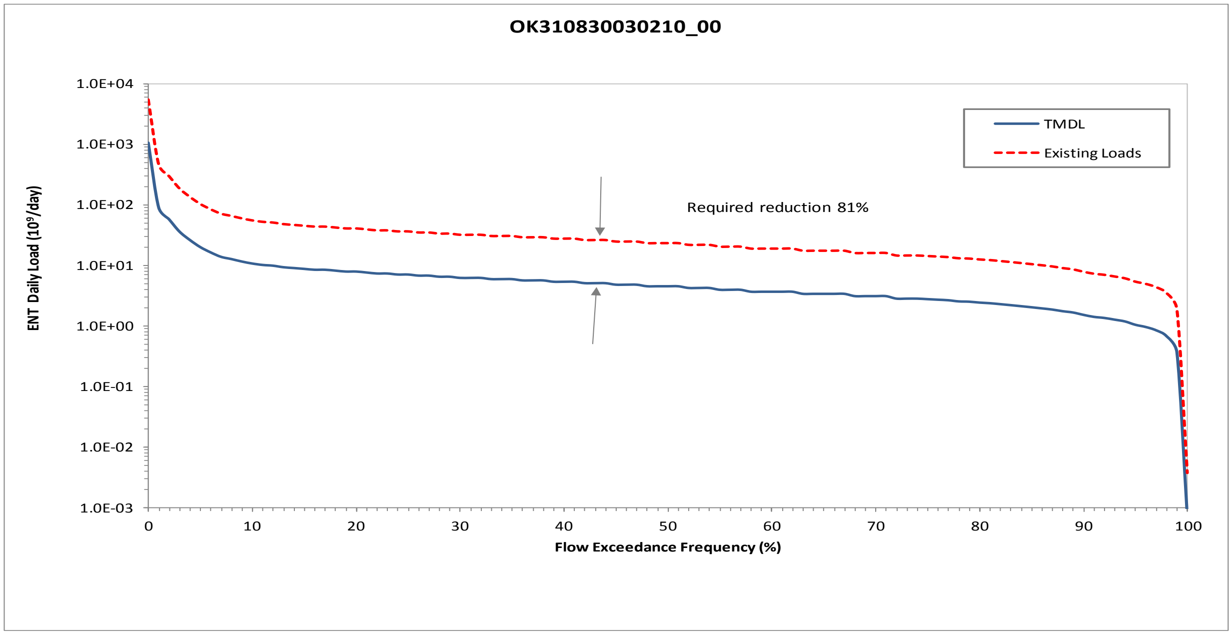
Bacteria LDC: To calculate the allowable bacteria load, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*24,465,525*) and the geometric mean water quality criterion for each bacterial indicator. This calculation produces the maximum allowable bacteria load in the stream over the range of flow conditions. The allowable bacteria (*E. coli* or Enterococci) load at the WQS numerical criterion establishes the TMDL and is 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, the geometric mean of all bacteria observations (concentrations) for the primary contact recreation season (May 1st through September 30th) from 2000 to 2009 are paired with the flows measured or estimated in that waterbody. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor of *24,465,756*.

The bacteria LDCs developed for each impaired waterbody (representing the primary contact recreation season using data from 2000 through 2009) are shown in Figures 5-12 through 5-27. Each waterbody has an LDC for either *E. coli*, Enterococci or both. This is because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

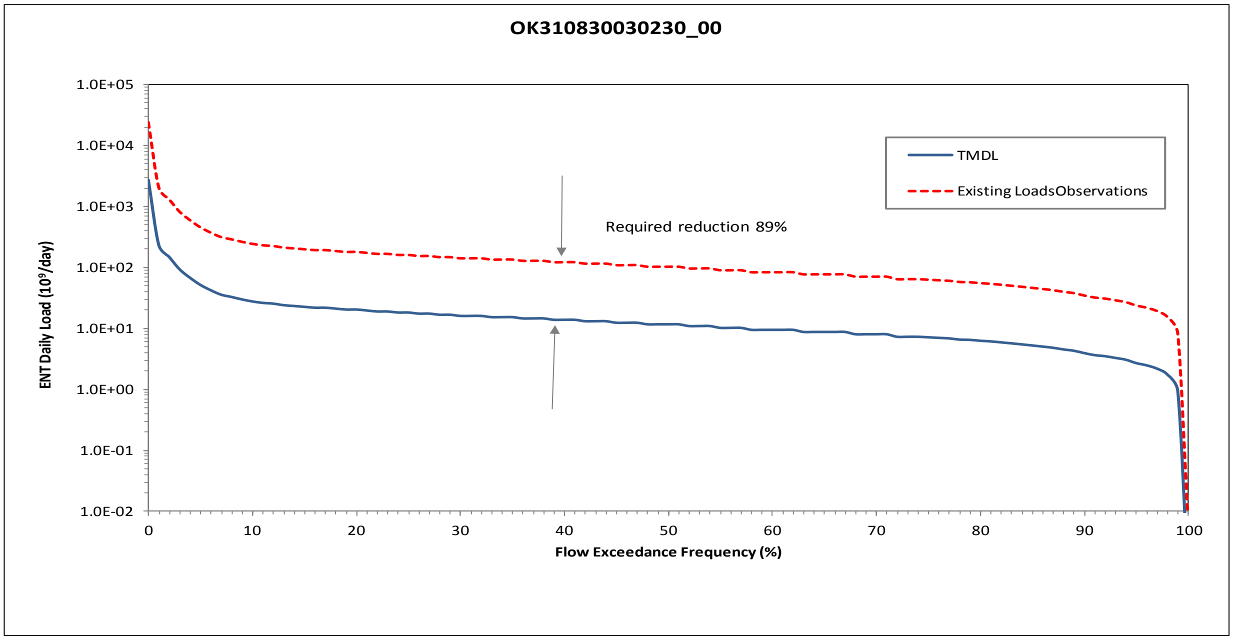
The LDC for East Barnitz Creek, off E0980 Rd. is shown in Figure 5-12 for Enterococcus. It is based on bacteria measurements during primary contact recreation season at WQM station OK310830-03-0210C.

Figure 5-12 Load Duration Curve for Enterococci in Barnitz Creek, East (OK310830030210_00)



The LDC for West Barnitz Creek (Figures 5-13) is based on Enterococcus measurements during primary contact recreation season at WQM stations OK310830-03-0230C and OKR09730-106.

Figure 5-13 Load Duration Curve for Enterococci in Barnitz Creek, West (OK310830030230_00)



Figures 5-14 and 5-15 show the *E. coli* and Enterococcus LDCs for Boggy Creek, off E1180 Rd. and are based on measurements during primary contact recreation season at WQM station OK310830-03-0100C.

Figure 5-14 Load Duration Curve for *E. Coli* in Boggy Creek (OK310830030100_00)

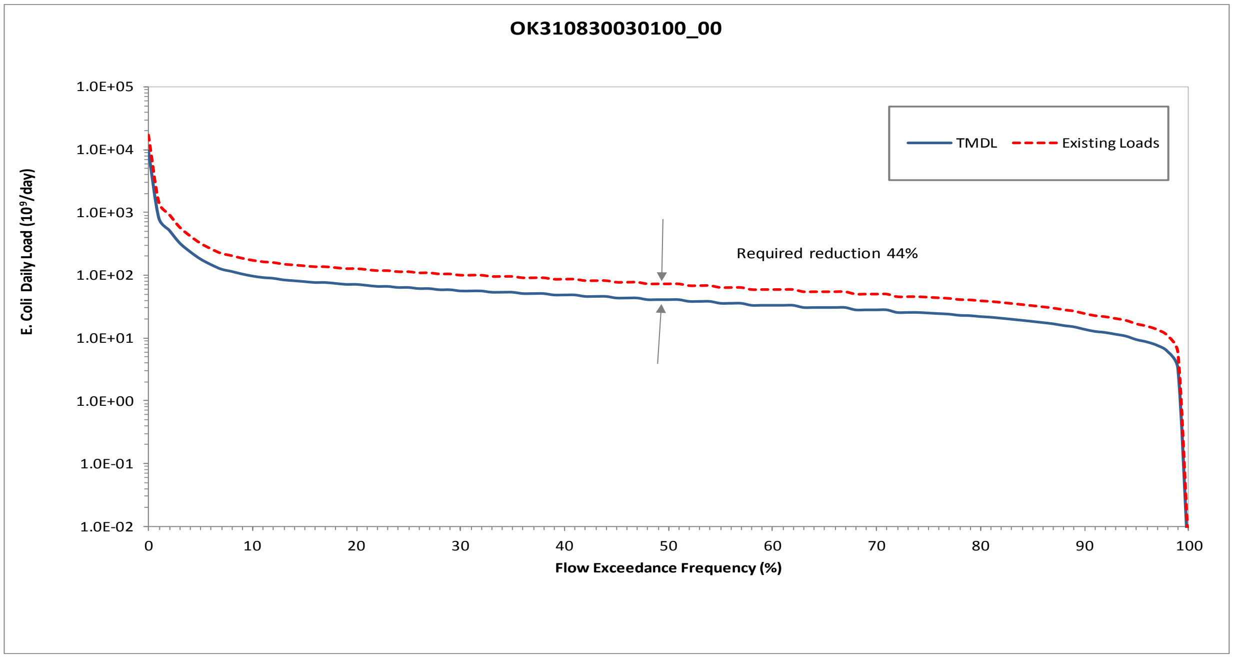
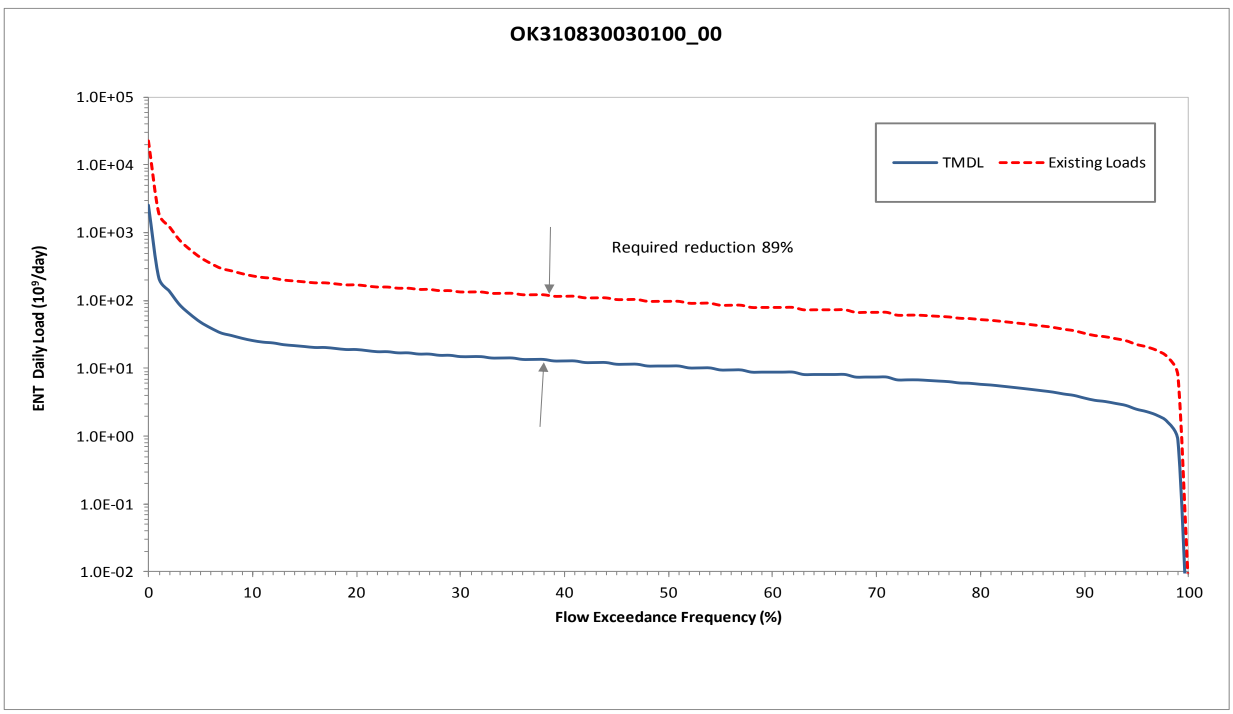


Figure 5-15 Load Duration Curve for Enterococci in Boggy Creek (OK310830030100_00)



The LDCs for Cobb Creek off N2460 Rd. (Figures 5-16 and 5-17 are based on *E. coli* and Enterococcus measurements during primary contact recreation season at WQM station 310830-06-0050M.

Figure 5-16 Load Duration Curve for *E. Coli* in Cobb Creek (OK310830060050_00)

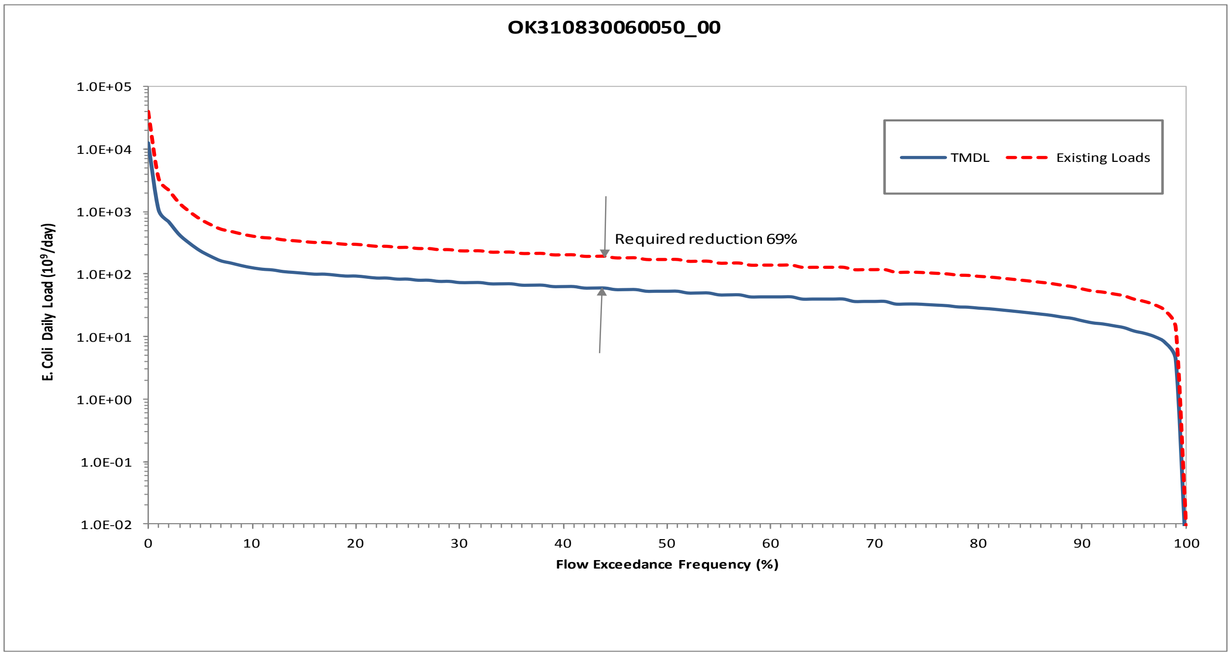
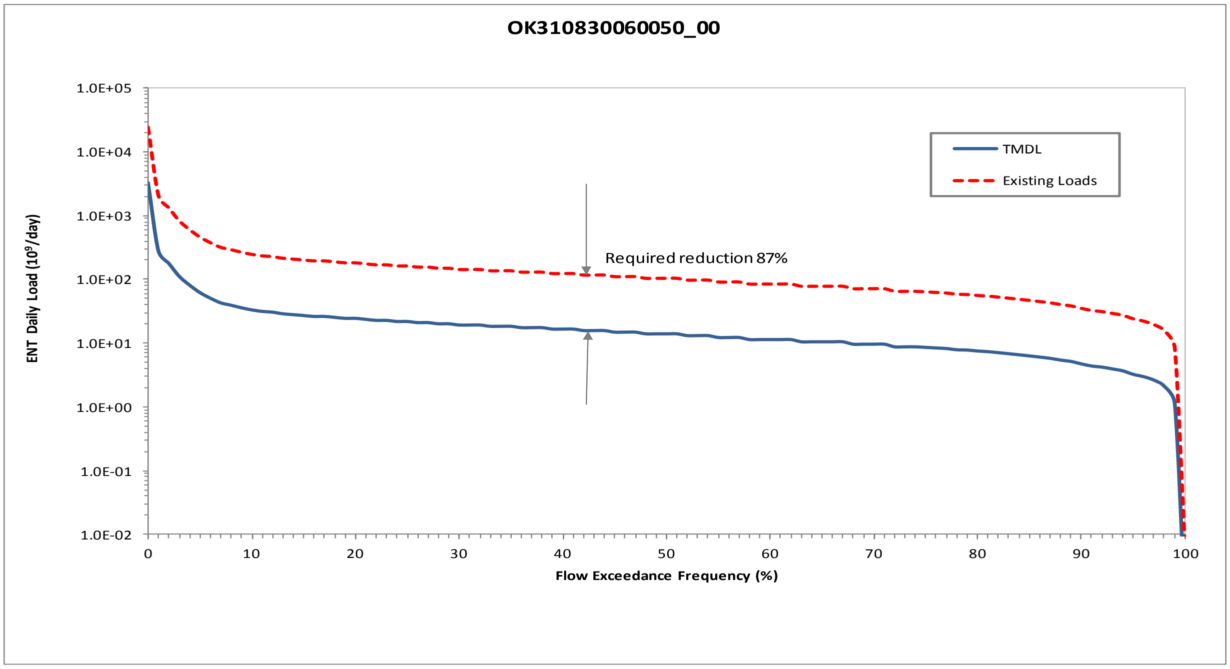


Figure 5-17 Load Duration Curve for Enterococci in Cobb Creek (OK310830060050_00)



The LDCs for Fivemile Creek, off E1180 Rd. (Figures 5-18 and 5-19) are based on *E. coli* and Enterococcus bacteria measurements collected during primary contact recreation season at WQM station OK310830-06-0080D.

Figure 5-18 Load Duration Curve for *E. Coli* in Fivemile Creek (OK310830060080_00)

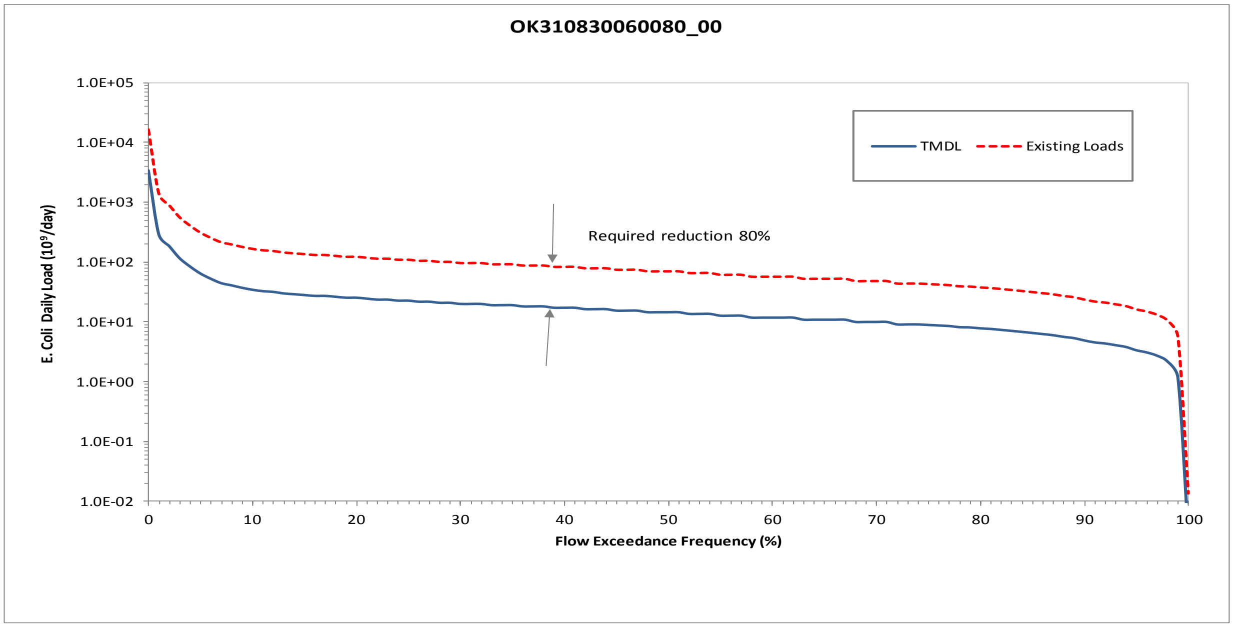
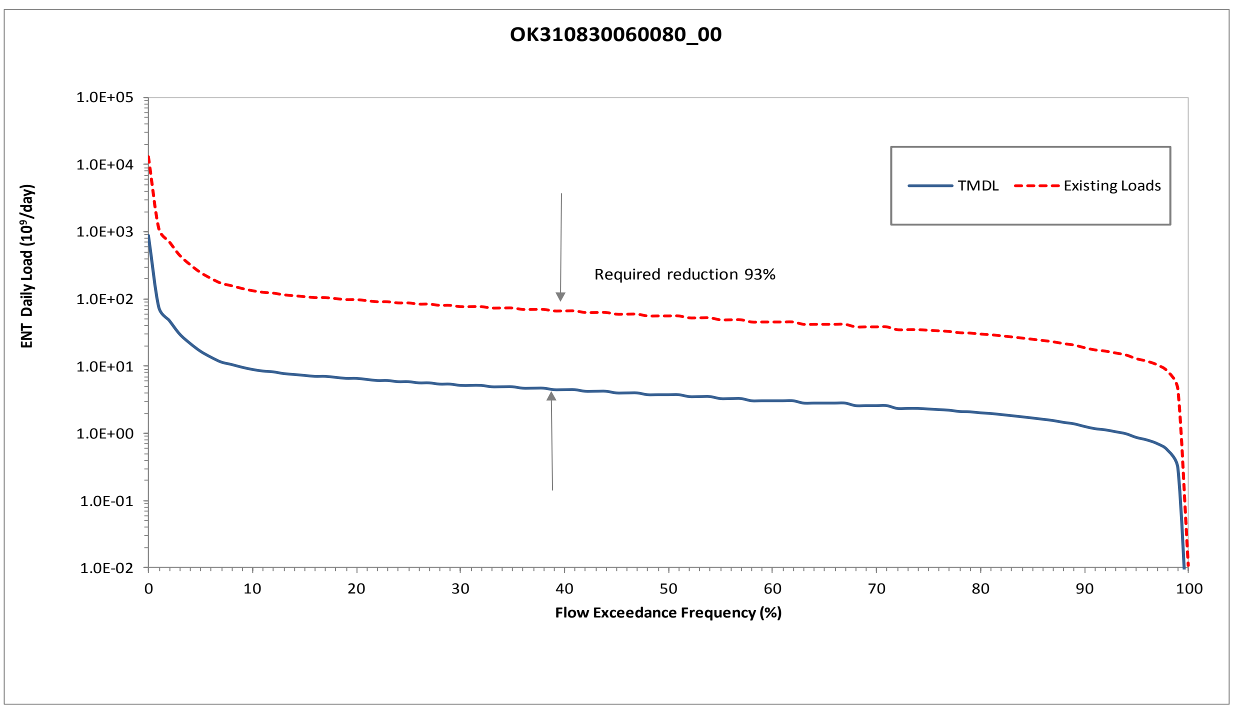


Figure 5-19 Load Duration Curve for Enterococci in Fivemile Creek (OK310830060080_00)



The LDCs for Spring Creek, off E1260 Rd. are shown in Figures 5-20 and 5-21 for *E. coli* and Enterococcus. It is based on bacteria measurements during primary contact recreation season at WQM station OK310830-04-0010G.

Figure 5-20 Load Duration Curve for *E. Coli* in Spring Creek (OK310830040010_00)

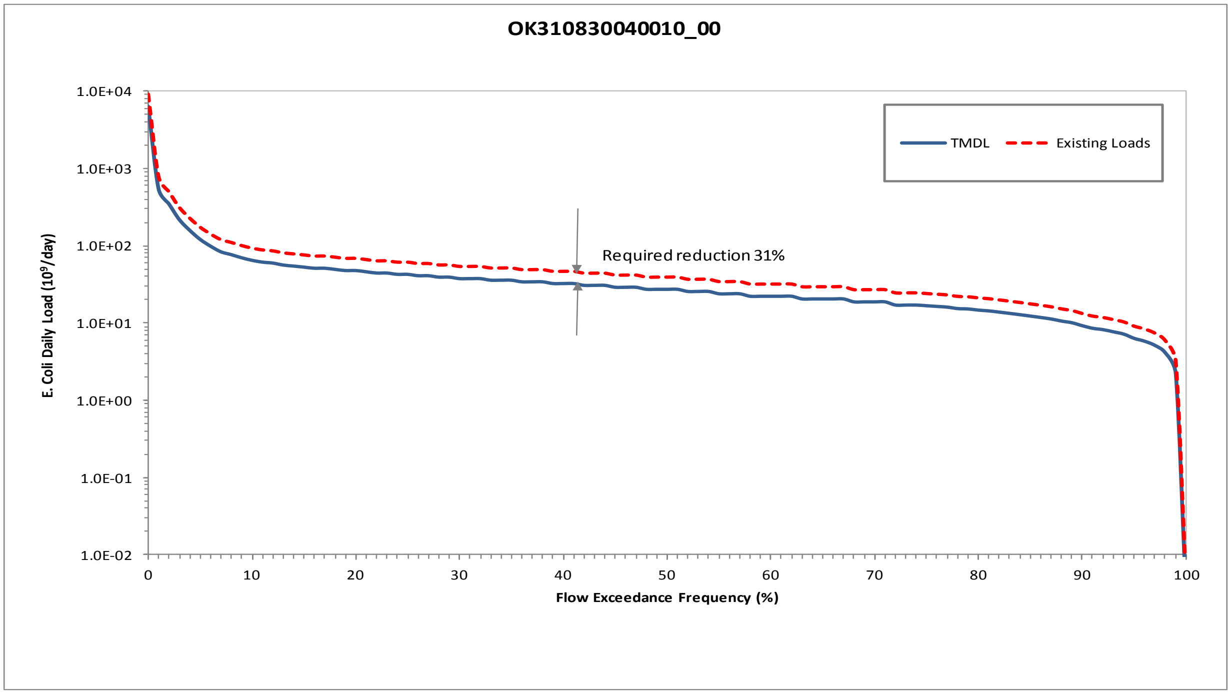
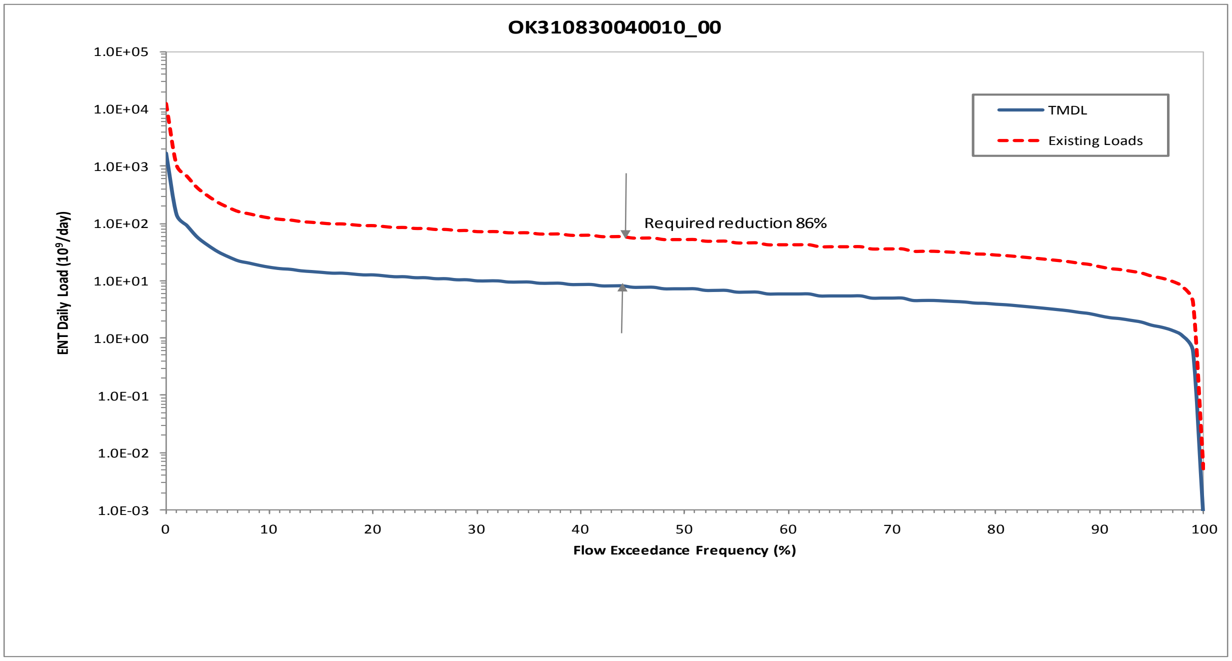
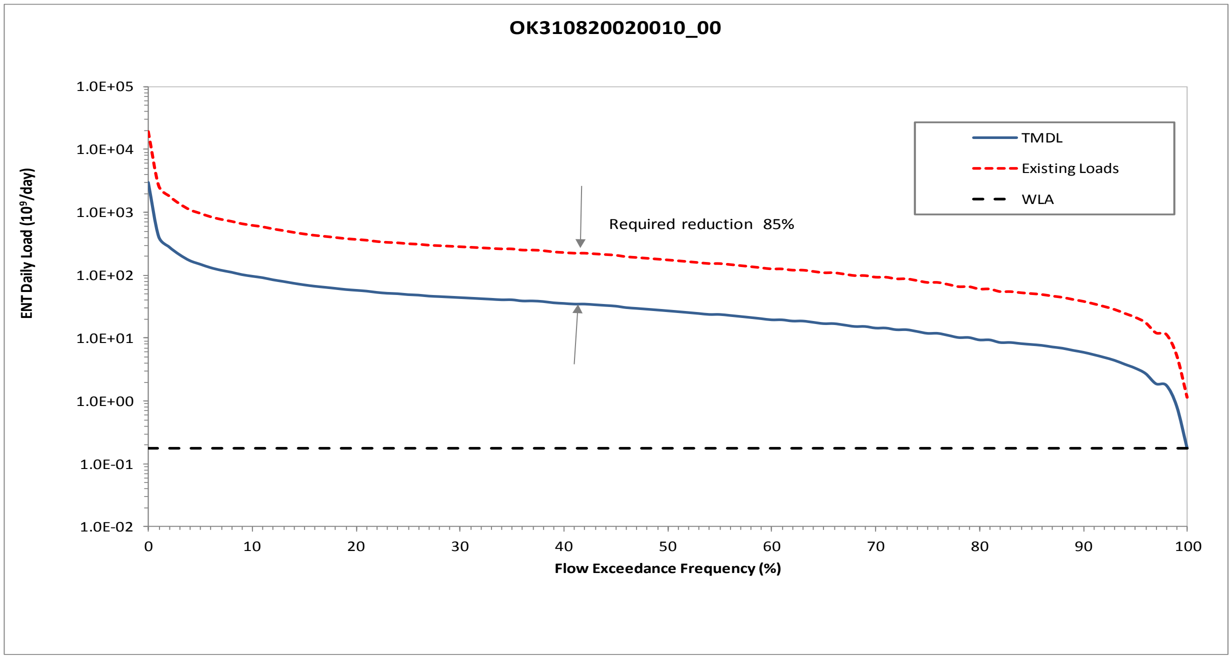


Figure 5-21 Load Duration Curve for Enterococci in Spring Creek (OK310830040010_00)



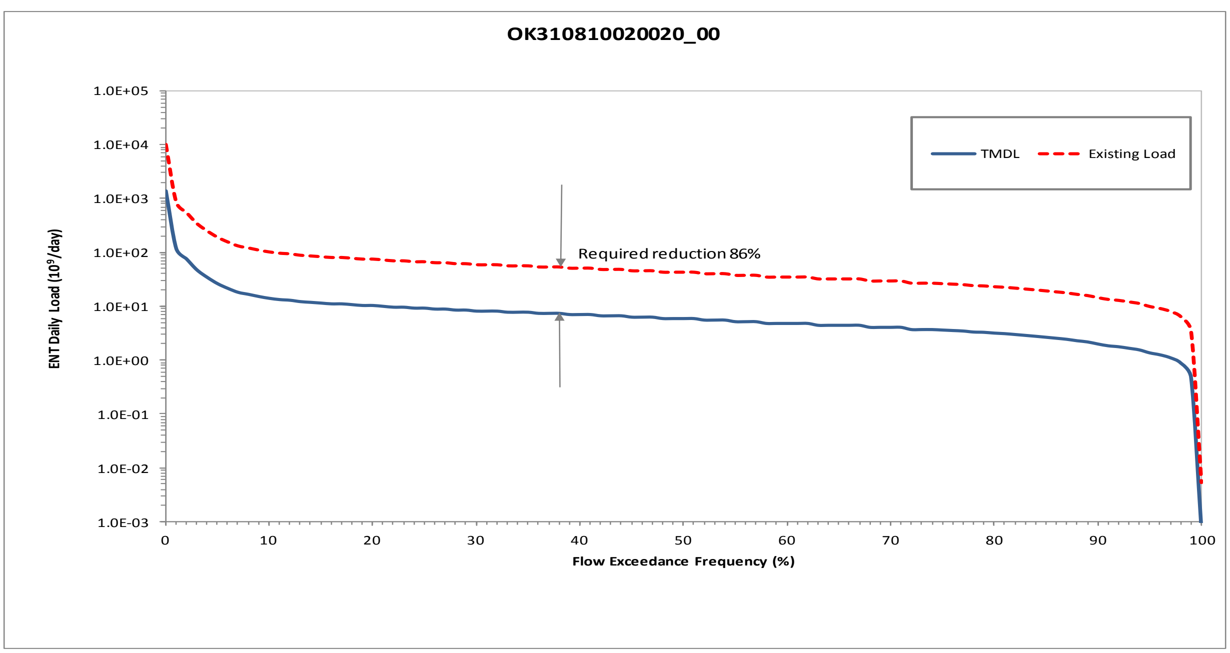
The LDC for Little Washita Creek is shown in Figure 5-22 for Enterococcus. It is based on bacteria measurements during primary contact recreation season at WQM stations OK310820-02-0010B and OK310820-02-0010F.

Figure 5-22 Load Duration Curve for Enterococci in Little Washita Creek (OK310820020010_00)



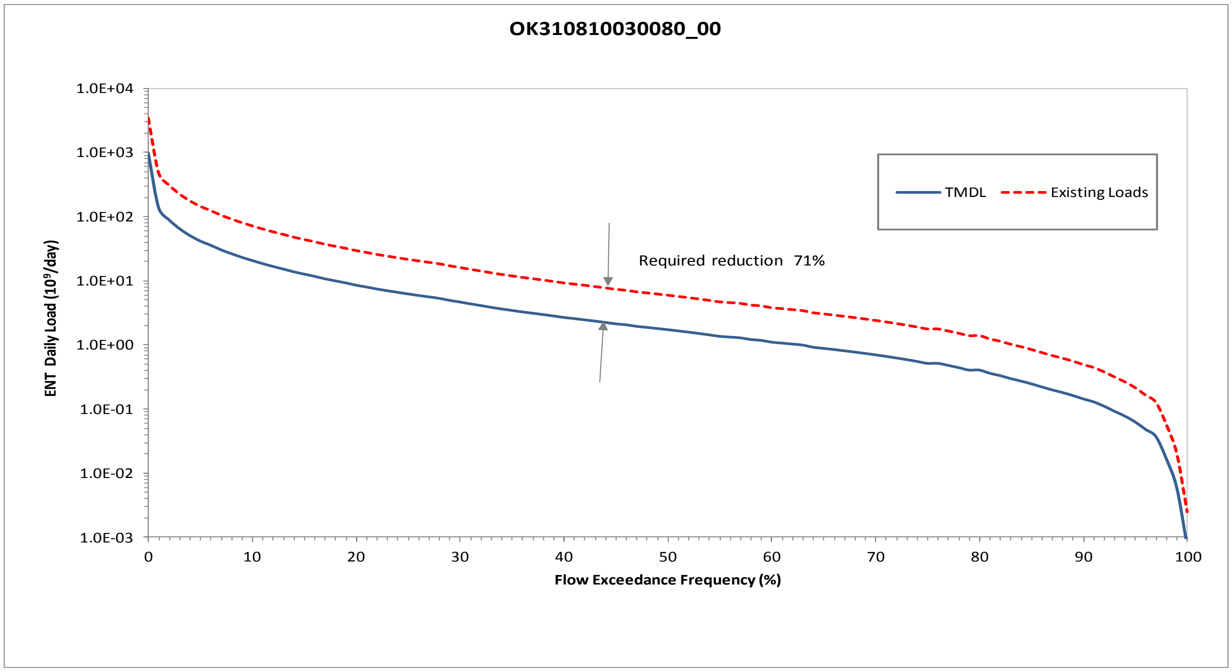
The LDC for Finn Creek, off SH24 is shown in Figure 5-23 for Enterococcus. It is based on bacteria measurements during primary contact recreation season at WQM station OK310810-02-0020D.

Figure 5-23 Load Duration Curve for Enterococci in Finn Creek (OK310810020020_00)



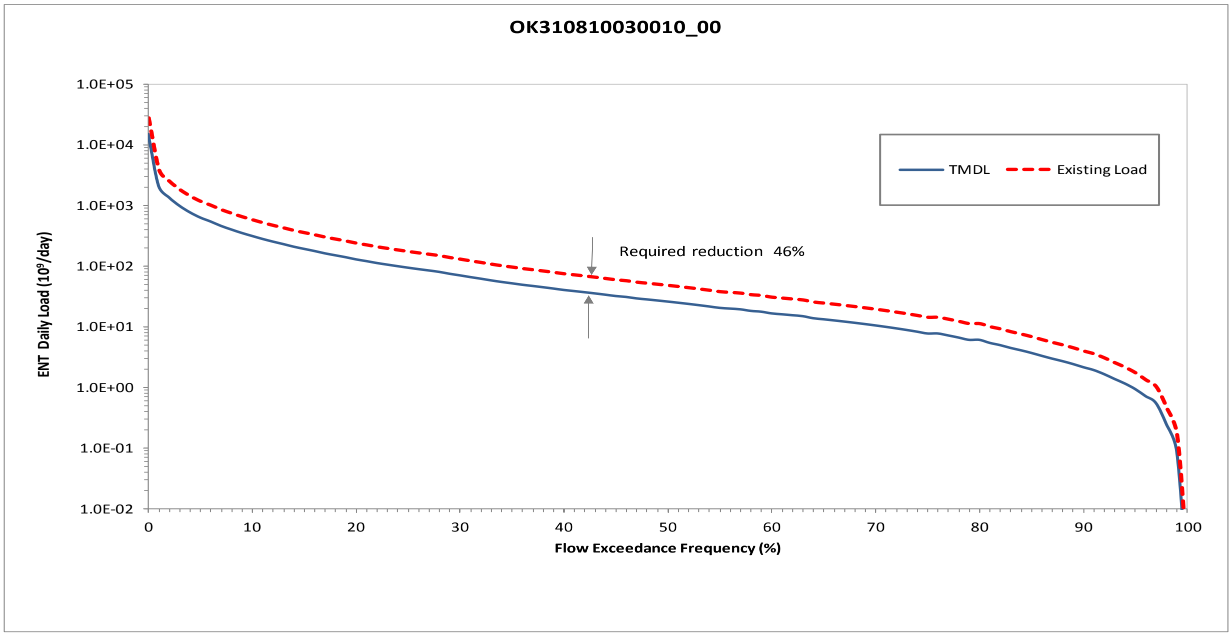
The LDC for Salt Creek, off SH 74 is shown in Figure 5-24 for Enterococcus. It is based on bacteria measurements during primary contact recreation season at WQM station OK310810-03-0080G.

Figure 5-24 Load Duration Curve for Enterococci in Salt Creek (OK310810030080_00)



The LDC for Wildhorse Creek, off Cemetery Rd. is shown in Figure 5-25 for Enterococcus. It is based on bacteria measurements during primary contact recreation season at WQM station OK310810-03-0010R.

Figure 5-25 Load Duration Curve for Enterococci in Wildhorse Creek (OK310810030010_00)



The LDCs for Caddo Creek, off Gene Autry Rd. (Figures 5-26 and 5-27) are based on *E. coli* and Enterococcus bacteria measurements collected during primary contact recreation season at WQM station OK310800-03-0010F.

Figure 5-26 Load Duration Curve for *E. Coli* in Caddo Creek (OK310800030010_00)

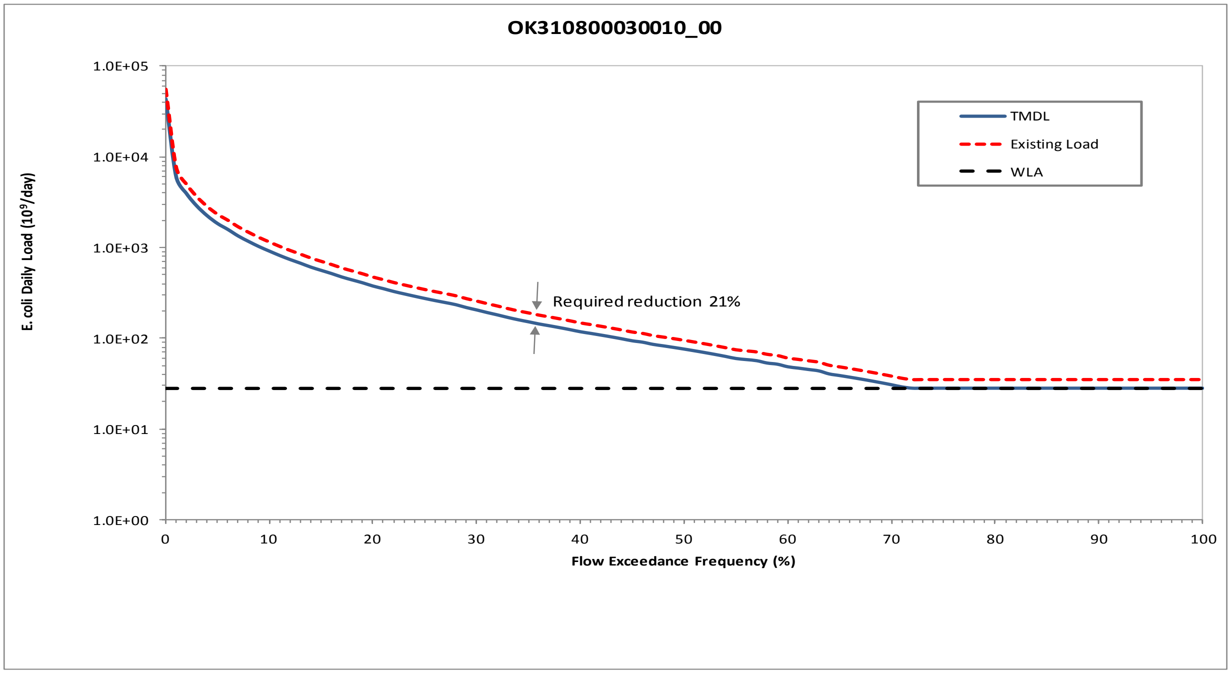
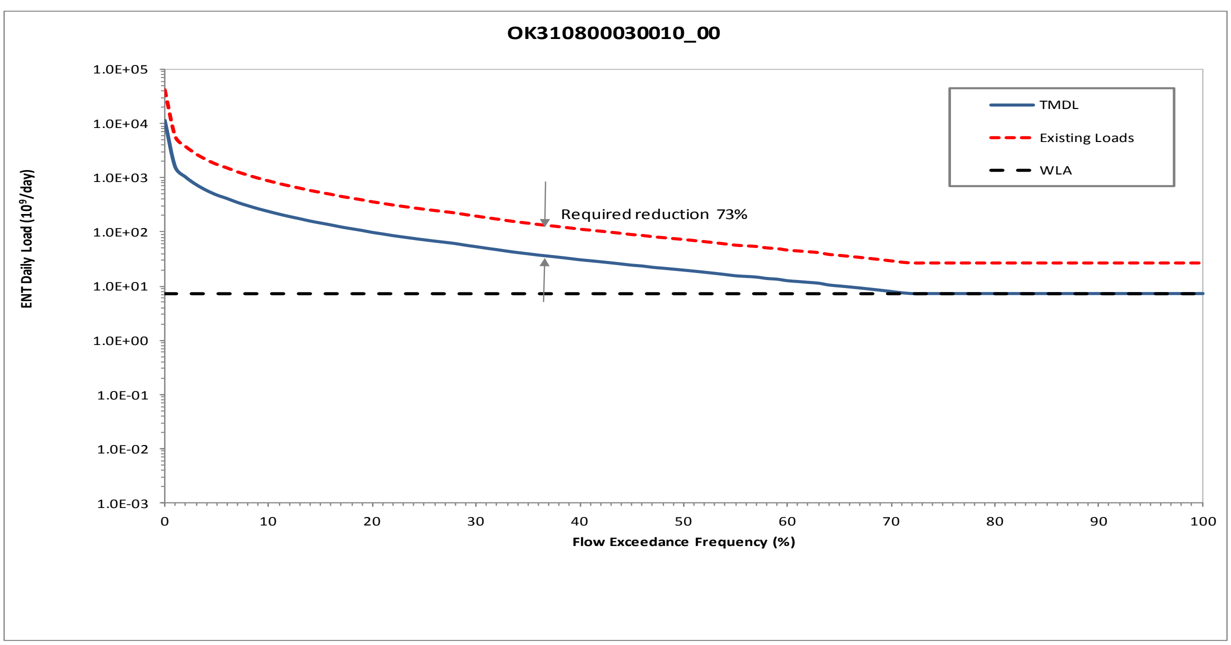


Figure 5-27 Load Duration Curve for Enterococci in Caddo Creek (OK310800030010_00)



Establishing Percent Reduction Goals: The LDC approach recognizes that the assimilative capacity of a waterbody depends on stream flow and that the maximum allowable loading varies with flow condition. Existing loading and load reductions required to meet the TMDL can also be calculated under different flow conditions. The difference between existing loading and the TMDL is used to calculate the loading reductions required. Percent reduction goals are calculated through an iterative process of taking a series of percent reduction values applying each value uniformly to the concentrations of samples and verifying if the geometric mean of the reduced values of all samples is less than the geomean standards. Table 5-1 presents the percent reductions necessary for each bacterial indicator in each of the impaired waterbodies in the Study Area. The PRGs range from 21% to 93%.

Table 5-1 TMDL Percent Reductions Required to Meet Geometric Mean Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate	
		EC	ENT
OK310830030210_00	Barnitz Creek, East	-----	81%
OK310830030230_00	Barnitz Creek, West	-----	89%
OK310830030100_00	Boggy Creek	44%	89%
OK310830060050_00	Cobb Creek	69%	87%
OK310830060080_00	Fivemile Creek	80%	93%
OK310830040010_00	Spring Creek	31%	86%
OK310820020010_00	Little Washita River	-----	85%
OK310810020020_00	Finn Creek	-----	86%
OK310810030080_00	Salt Creek	-----	71%
OK310810030010_00	Wildhorse Creek	-----	46%
OK310800030010_00	Caddo Creek	21%	73%

5.3 Wasteload Allocation

5.3.1 Indicator Bacteria

For bacteria TMDLs, NPDES-permitted facilities are allocated a daily wasteload calculated as their permitted flow rate multiplied by the instream geometric mean water quality criterion. In other words, the facilities are required to meet instream criteria in their discharge. Table 5-3 summarizes the WLA for the NPDES-permitted facilities within the Washita River Study Area. The WLA for each facility discharging to a bacteria-impaired reach is derived from the following equation:

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

Where:

WQS = 33 and 126 cfu/100 mL for Enterococci and E. coli respectively

flow (mgd) = permitted flow unit conversion factor = 37,854,120

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 stream segment, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform or E coli limits and disinfection requirements of NPDES permits. Currently, facilities that discharge treated wastewater are currently required to monitor for fecal coliform. These discharges or any other discharges with a bacteria WLA will be required to monitor for E coli as their permits are renewed.

Table 5-2 indicates which point source dischargers within the study area currently have a disinfection requirement in their permit. Certain facilities that utilize lagoons for treatment have not been required to provide disinfection since storage time and exposure to ultraviolet radiation from sunlight should reduce bacteria levels. In the future, all point source dischargers which are assigned a wasteload allocation but do not currently have a bacteria limit in their permit will receive a permit limit consistent with the wasteload allocation as their permits are reissued. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacteria load from existing discharges will be considered consistent with the TMDL provided that the NPDES permit requires instream criteria to be met.

Table 5-2 Bacteria Wasteload Allocations for NPDES-Permitted Facilities

Waterbody ID	NPDES Permit No.	Name	Dis-infection?	Design Flow (mgd)	Wasteload Allocation (cfu/day)	
					E. Coli	Enterococci
OK310820020010_00	OK0041467	Town of Cyril	No	0.14	-	1.58×10^{8}
OK310800030010_00	OK0038440	City of Ardmore	Yes	5.9	2.53×10^{10}	6.63×10^{9}

Permitted stormwater discharges are considered point sources. However, because there are no MS4 permitted areas within the watersheds in this Study Area, allocations for permitted stormwater are not necessary in this TMDL report.

5.4 Load Allocation

As discussed in Section 3, nonpoint source bacteria loading to 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 waterbody are calculated as the difference between the TMDL, MOS, and WLA, as follows:

$$\mathbf{LA = TMDL - \sum WLA - MOS}$$

5.5 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The bacteria 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 five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.6 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained. EPA guidance allows for use of implicit or explicit expressions of the MOS, or both. For bacteria TMDLs, an explicit MOS was set at 10%.

5.7 TMDL Calculations

The TMDLs for the 303(d)-listed waterbodies 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 the lack of knowledge concerning the relationship between pollutant loading and water quality.

This definition can be expressed by the following equation:

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

The TMDL represents a continuum of desired load over all flow conditions, rather than fixed at a single value, because loading capacity varies as a function of the flow present in the stream. The higher the flow is, the more wasteload the stream can handle without violating water quality standards. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges or increased load from existing discharges will be considered consistent with the TMDL provided the NPDES permit requires instream criteria to be met.

The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5th flow interval percentile. Tables 5-3 through 5-18 summarize the allocations for indicator bacteria. The TMDLs calculated in these tables apply to the recreation season (May 1 through September 30) only.

Table 5-3 Enterococci TMDL Calculations for Barnitz Creek, East (OK310830030210_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,459	1.18E+12	0	0	1.06E+12	1.18E+11
5	28	2.23E+10	0	0	2.01E+10	2.23E+09
10	15	1.19E+10	0	0	1.07E+10	1.19E+09
15	12	9.74E+09	0	0	8.76E+09	9.74E+08
20	11	8.79E+09	0	0	7.91E+09	8.79E+08
25	10	7.85E+09	0	0	7.07E+09	7.85E+08
30	8.6	6.91E+09	0	0	6.22E+09	6.91E+08
35	8.2	6.60E+09	0	0	5.94E+09	6.60E+08
40	7.4	5.97E+09	0	0	5.37E+09	5.97E+08
45	6.6	5.34E+09	0	0	4.81E+09	5.34E+08
50	6.2	5.02E+09	0	0	4.52E+09	5.02E+08
55	5.4	4.40E+09	0	0	3.96E+09	4.40E+08
60	5.1	4.08E+09	0	0	3.67E+09	4.08E+08
65	4.7	3.77E+09	0	0	3.39E+09	3.77E+08
70	4.3	3.45E+09	0	0	3.11E+09	3.45E+08
75	3.8	3.08E+09	0	0	2.77E+09	3.08E+08
80	3.3	2.70E+09	0	0	2.43E+09	2.70E+08
85	2.8	2.26E+09	0	0	2.04E+09	2.26E+08
90	2.1	1.70E+09	0	0	1.53E+09	1.70E+08
95	1.4	1.16E+09	0	0	1.05E+09	1.16E+08
100	0	0	0	0	0	0

Table 5-4 Enterococci TMDL Calculations for Barnitz Creek, West (OK310830030230_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	3,750	3.03E+12	0	0	2.72E+12	3.03E+11
5	71	5.73E+10	0	0	5.16E+10	5.73E+09
10	38	3.07E+10	0	0	2.76E+10	3.07E+09
15	31	2.50E+10	0	0	2.25E+10	2.50E+09
20	28	2.26E+10	0	0	2.03E+10	2.26E+09
25	25	2.02E+10	0	0	1.82E+10	2.02E+09
30	22	1.78E+10	0	0	1.60E+10	1.78E+09
35	21	1.70E+10	0	0	1.53E+10	1.70E+09
40	19	1.53E+10	0	0	1.38E+10	1.53E+09
45	17	1.37E+10	0	0	1.24E+10	1.37E+09
50	16	1.29E+10	0	0	1.16E+10	1.29E+09
55	14	1.13E+10	0	0	1.02E+10	1.13E+09
60	13	1.05E+10	0	0	9.45E+09	1.05E+09
65	12	9.69E+09	0	0	8.72E+09	9.69E+08
70	11	8.88E+09	0	0	7.99E+09	8.88E+08
75	10	7.91E+09	0	0	7.12E+09	7.91E+08
80	9	6.94E+09	0	0	6.25E+09	6.94E+08
85	7	5.81E+09	0	0	5.23E+09	5.81E+08
90	5	4.36E+09	0	0	3.92E+09	4.36E+08
95	4	2.99E+09	0	0	2.69E+09	2.99E+08
100	0	0	0	0	0	0

Table 5-5 *E.coli* TMDL Calculations for Boggy Creek (OK310830030100_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	3,470	1.07E+13	0	0	9.63E+12	1.07E+12
5	66	2.03E+11	0	0	1.82E+11	2.03E+10
10	35	1.08E+11	0	0	9.75E+10	1.08E+10
15	29	8.84E+10	0	0	7.96E+10	8.84E+09
20	26	7.99E+10	0	0	7.19E+10	7.99E+09
25	23	7.13E+10	0	0	6.42E+10	7.13E+09
30	20	6.28E+10	0	0	5.65E+10	6.28E+09
35	19	5.99E+10	0	0	5.39E+10	5.99E+09
40	18	5.42E+10	0	0	4.88E+10	5.42E+09
45	16	4.85E+10	0	0	4.36E+10	4.85E+09
50	15	4.56E+10	0	0	4.11E+10	4.56E+09
55	13	3.99E+10	0	0	3.59E+10	3.99E+09
60	12	3.71E+10	0	0	3.34E+10	3.71E+09
65	11	3.42E+10	0	0	3.08E+10	3.42E+09
70	10	3.14E+10	0	0	2.82E+10	3.14E+09
75	9	2.80E+10	0	0	2.52E+10	2.80E+09
80	8	2.45E+10	0	0	2.21E+10	2.45E+09
85	7	2.05E+10	0	0	1.85E+10	2.05E+09
90	5	1.54E+10	0	0	1.39E+10	1.54E+09
95	3	1.06E+10	0	0	9.50E+09	1.06E+09
100	0	0	0	0	0	0

Table 5-6 Enterococci TMDL Calculations for Boggy Creek (OK31030030100_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	3,470	2.80E+12	0	0	2.52E+12	2.80E+11
5	66	5.30E+10	0	0	4.77E+10	5.30E+09
10	35	2.84E+10	0	0	2.55E+10	2.84E+09
15	29	2.32E+10	0	0	2.08E+10	2.32E+09
20	26	2.09E+10	0	0	1.88E+10	2.09E+09
25	23	1.87E+10	0	0	1.68E+10	1.87E+09
30	20	1.64E+10	0	0	1.48E+10	1.64E+09
35	19	1.57E+10	0	0	1.41E+10	1.57E+09
40	18	1.42E+10	0	0	1.28E+10	1.42E+09
45	16	1.27E+10	0	0	1.14E+10	1.27E+09
50	15	1.20E+10	0	0	1.08E+10	1.20E+09
55	13	1.05E+10	0	0	9.41E+09	1.05E+09
60	12	9.71E+09	0	0	8.74E+09	9.71E+08
65	11	8.96E+09	0	0	8.07E+09	8.96E+08
70	10	8.22E+09	0	0	7.40E+09	8.22E+08
75	9	7.32E+09	0	0	6.59E+09	7.32E+08
80	8	6.42E+09	0	0	5.78E+09	6.42E+08
85	7	5.38E+09	0	0	4.84E+09	5.38E+08
90	5	4.03E+09	0	0	3.63E+09	4.03E+08
95	3	2.76E+09	0	0	2.49E+09	2.76E+08
100	0	0	0	0	0	0

Table 5-7 *E. Coli* TMDL Calculations for Cobb Creek (OK310830060050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	4,468	1.38E+13	0	0	1.24E+13	1.38E+12
5	85	2.61E+11	0	0	2.35E+11	2.61E+10
10	45	1.40E+11	0	0	1.26E+11	1.40E+10
15	37	1.14E+11	0	0	1.02E+11	1.14E+10
20	33	1.03E+11	0	0	9.26E+10	1.03E+10
25	30	9.18E+10	0	0	8.26E+10	9.18E+09
30	26	8.08E+10	0	0	7.27E+10	8.08E+09
35	25	7.71E+10	0	0	6.94E+10	7.71E+09
40	23	6.98E+10	0	0	6.28E+10	6.98E+09
45	20	6.24E+10	0	0	5.62E+10	6.24E+09
50	19	5.88E+10	0	0	5.29E+10	5.88E+09
55	17	5.14E+10	0	0	4.63E+10	5.14E+09
60	15	4.78E+10	0	0	4.30E+10	4.78E+09
65	14	4.41E+10	0	0	3.97E+10	4.41E+09
70	13	4.04E+10	0	0	3.64E+10	4.04E+09
75	12	3.60E+10	0	0	3.24E+10	3.60E+09
80	10	3.16E+10	0	0	2.84E+10	3.16E+09
85	9	2.64E+10	0	0	2.38E+10	2.64E+09
90	6	1.98E+10	0	0	1.79E+10	1.98E+09
95	4	1.36E+10	0	0	1.22E+10	1.36E+09
100	0	0	0	0	0	0

Table 5-8 Enterococci TMDL Calculations for Cobb Creek (OK310830060050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	4,468	3.61E+12	0	0	3.25E+12	3.61E+11
5	85	6.83E+10	0	0	6.15E+10	6.83E+09
10	45	3.66E+10	0	0	3.29E+10	3.66E+09
15	37	2.98E+10	0	0	2.68E+10	2.98E+09
20	33	2.69E+10	0	0	2.42E+10	2.69E+09
25	30	2.41E+10	0	0	2.16E+10	2.41E+09
30	26	2.12E+10	0	0	1.90E+10	2.12E+09
35	25	2.02E+10	0	0	1.82E+10	2.02E+09
40	23	1.83E+10	0	0	1.65E+10	1.83E+09
45	20	1.64E+10	0	0	1.47E+10	1.64E+09
50	19	1.54E+10	0	0	1.39E+10	1.54E+09
55	17	1.35E+10	0	0	1.21E+10	1.35E+09
60	15	1.25E+10	0	0	1.13E+10	1.25E+09
65	14	1.15E+10	0	0	1.04E+10	1.15E+09
70	13	1.06E+10	0	0	9.52E+09	1.06E+09
75	12	9.43E+09	0	0	8.48E+09	9.43E+08
80	10	8.27E+09	0	0	7.45E+09	8.27E+08
85	9	6.93E+09	0	0	6.23E+09	6.93E+08
90	6	5.19E+09	0	0	4.68E+09	5.19E+08
95	4	3.56E+09	0	0	3.20E+09	3.56E+08
100	0	0	0	0	0	0

Table 5-9 *E. Coli* TMDL Calculations for Fivemile Creek (OK310830060080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,213	3.74E+12	0	0	3.36E+12	3.74E+11
5	23	7.08E+10	0	0	6.37E+10	7.08E+09
10	12.3	3.79E+10	0	0	3.41E+10	3.79E+09
15	10.0	3.09E+10	0	0	2.78E+10	3.09E+09
20	9.1	2.79E+10	0	0	2.51E+10	2.79E+09
25	8.1	2.49E+10	0	0	2.24E+10	2.49E+09
30	7.1	2.19E+10	0	0	1.97E+10	2.19E+09
35	6.8	2.09E+10	0	0	1.88E+10	2.09E+09
40	6.1	1.89E+10	0	0	1.70E+10	1.89E+09
45	5.5	1.69E+10	0	0	1.53E+10	1.69E+09
50	5.2	1.60E+10	0	0	1.44E+10	1.60E+09
55	4.5	1.40E+10	0	0	1.26E+10	1.40E+09
60	4.2	1.30E+10	0	0	1.17E+10	1.30E+09
65	3.9	1.20E+10	0	0	1.08E+10	1.20E+09
70	3.6	1.10E+10	0	0	9.87E+09	1.10E+09
75	3.2	9.77E+09	0	0	8.79E+09	9.77E+08
80	2.8	8.57E+09	0	0	7.72E+09	8.57E+08
85	2.3	7.18E+09	0	0	6.46E+09	7.18E+08
90	1.7	5.38E+09	0	0	4.85E+09	5.38E+08
95	1.2	3.69E+09	0	0	3.32E+09	3.69E+08
100	0	0	0	0	0	0

Table 5-10 Enterococci TMDL Calculations for Fivemile Creek (OK310830060080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,213	9.79E+11	0	0	8.81E+11	9.79E+10
5	23	1.85E+10	0	0	1.67E+10	1.85E+09
10	12.3	9.92E+09	0	0	8.93E+09	9.92E+08
15	10.0	8.09E+09	0	0	7.28E+09	8.09E+08
20	9.1	7.31E+09	0	0	6.58E+09	7.31E+08
25	8.1	6.53E+09	0	0	5.87E+09	6.53E+08
30	7.1	5.74E+09	0	0	5.17E+09	5.74E+08
35	6.8	5.48E+09	0	0	4.93E+09	5.48E+08
40	6.1	4.96E+09	0	0	4.46E+09	4.96E+08
45	5.5	4.44E+09	0	0	3.99E+09	4.44E+08
50	5.2	4.18E+09	0	0	3.76E+09	4.18E+08
55	4.5	3.66E+09	0	0	3.29E+09	3.66E+08
60	4.2	3.39E+09	0	0	3.05E+09	3.39E+08
65	3.9	3.13E+09	0	0	2.82E+09	3.13E+08
70	3.6	2.87E+09	0	0	2.58E+09	2.87E+08
75	3.2	2.56E+09	0	0	2.30E+09	2.56E+08
80	2.8	2.25E+09	0	0	2.02E+09	2.25E+08
85	2.3	1.88E+09	0	0	1.69E+09	1.88E+08
90	1.7	1.41E+09	0	0	1.27E+09	1.41E+08
95	1.2	9.66E+08	0	0	8.69E+08	9.66E+07
100	0	0	0	0	0	0

Table 5-11 *E. Coli* TMDL Calculations for Spring Creek (OK310830040010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,311	7.12E+12	0	0	6.41E+12	7.12E+11
5	44	1.35E+11	0	0	1.21E+11	1.35E+10
10	23	7.22E+10	0	0	6.50E+10	7.22E+09
15	19	5.89E+10	0	0	5.30E+10	5.89E+09
20	17	5.32E+10	0	0	4.79E+10	5.32E+09
25	15	4.75E+10	0	0	4.27E+10	4.75E+09
30	14	4.18E+10	0	0	3.76E+10	4.18E+09
35	13	3.99E+10	0	0	3.59E+10	3.99E+09
40	12	3.61E+10	0	0	3.25E+10	3.61E+09
45	10	3.23E+10	0	0	2.91E+10	3.23E+09
50	10	3.04E+10	0	0	2.74E+10	3.04E+09
55	9	2.66E+10	0	0	2.39E+10	2.66E+09
60	8	2.47E+10	0	0	2.22E+10	2.47E+09
65	7	2.28E+10	0	0	2.05E+10	2.28E+09
70	6.8	2.09E+10	0	0	1.88E+10	2.09E+09
75	6.0	1.86E+10	0	0	1.68E+10	1.86E+09
80	5.3	1.63E+10	0	0	1.47E+10	1.63E+09
85	4.4	1.37E+10	0	0	1.23E+10	1.37E+09
90	3.3	1.03E+10	0	0	9.23E+09	1.03E+09
95	2.3	7.03E+09	0	0	6.33E+09	7.03E+08
100	0	0	0	0	0	0

Table 5-12 Enterococci TMDL Calculations for Spring Creek (OK310830040010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,311	1.87E+12	0	0	1.68E+12	1.87E+11
5	44	3.53E+10	0	0	3.18E+10	3.53E+09
10	23	1.89E+10	0	0	1.70E+10	1.89E+09
15	19	1.54E+10	0	0	1.39E+10	1.54E+09
20	17	1.39E+10	0	0	1.25E+10	1.39E+09
25	15	1.24E+10	0	0	1.12E+10	1.24E+09
30	14	1.09E+10	0	0	9.85E+09	1.09E+09
35	13	1.04E+10	0	0	9.40E+09	1.04E+09
40	12	9.45E+09	0	0	8.51E+09	9.45E+08
45	10	8.46E+09	0	0	7.61E+09	8.46E+08
50	10	7.96E+09	0	0	7.16E+09	7.96E+08
55	9	6.96E+09	0	0	6.27E+09	6.96E+08
60	8	6.47E+09	0	0	5.82E+09	6.47E+08
65	7	5.97E+09	0	0	5.37E+09	5.97E+08
70	6.8	5.47E+09	0	0	4.92E+09	5.47E+08
75	6.0	4.88E+09	0	0	4.39E+09	4.88E+08
80	5.3	4.28E+09	0	0	3.85E+09	4.28E+08
85	4.4	3.58E+09	0	0	3.22E+09	3.58E+08
90	3.3	2.69E+09	0	0	2.42E+09	2.69E+08
95	2.3	1.84E+09	0	0	1.66E+09	1.84E+08
100	0	0	0	0	0	0

Table 5-13 Enterococci TMDL Calculations for Little Washita River (OK310820020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	4,161	3.36E+12	1.58E+08	0	3.02E+12	3.36E+11
5	206	1.67E+11	1.58E+08	0	1.50E+11	1.67E+10
10	133	1.07E+11	1.58E+08	0	9.61E+10	1.07E+10
15	97	7.81E+10	1.58E+08	0	7.01E+10	7.81E+09
20	79	6.40E+10	1.58E+08	0	5.74E+10	6.40E+09
25	68	5.46E+10	1.58E+08	0	4.90E+10	5.46E+09
30	61	4.89E+10	1.58E+08	0	4.39E+10	4.89E+09
35	56	4.52E+10	1.58E+08	0	4.05E+10	4.52E+09
40	49	3.95E+10	1.58E+08	0	3.54E+10	3.95E+09
45	44	3.58E+10	1.58E+08	0	3.21E+10	3.58E+09
50	37	3.01E+10	1.58E+08	0	2.69E+10	3.01E+09
55	33	2.64E+10	1.58E+08	0	2.36E+10	2.64E+09
60	27	2.16E+10	1.58E+08	0	1.93E+10	2.16E+09
65	23	1.88E+10	1.58E+08	0	1.68E+10	1.88E+09
70	20	1.60E+10	1.58E+08	0	1.42E+10	1.60E+09
75	16	1.32E+10	1.58E+08	0	1.17E+10	1.32E+09
80	13	1.04E+10	1.58E+08	0	9.20E+09	1.04E+09
85	11	8.75E+09	1.58E+08	0	7.72E+09	8.75E+08
90	8	6.59E+09	1.58E+08	0	5.77E+09	6.59E+08
95	5	3.67E+09	1.58E+08	0	3.15E+09	3.67E+08
100	0.24	1.95E+08	1.58E+08	0	1.80E+07	1.95E+07

Table 5-14 Enterococci TMDL Calculations for Finn Creek (OK310810020020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,874	1.51E+12	0	0	1.36E+12	1.51E+11
5	35	2.86E+10	0	0	2.58E+10	2.86E+09
10	19	1.53E+10	0	0	1.38E+10	1.53E+09
15	15	1.25E+10	0	0	1.13E+10	1.25E+09
20	14	1.13E+10	0	0	1.02E+10	1.13E+09
25	12	1.01E+10	0	0	9.08E+09	1.01E+09
30	11	8.88E+09	0	0	7.99E+09	8.88E+08
35	10	8.47E+09	0	0	7.63E+09	8.47E+08
40	9.5	7.67E+09	0	0	6.90E+09	7.67E+08
45	8.5	6.86E+09	0	0	6.17E+09	6.86E+08
50	8.0	6.46E+09	0	0	5.81E+09	6.46E+08
55	7.0	5.65E+09	0	0	5.08E+09	5.65E+08
60	6.5	5.25E+09	0	0	4.72E+09	5.25E+08
65	6.0	4.84E+09	0	0	4.36E+09	4.84E+08
70	5.5	4.44E+09	0	0	3.99E+09	4.44E+08
75	4.9	3.95E+09	0	0	3.56E+09	3.95E+08
80	4.3	3.47E+09	0	0	3.12E+09	3.47E+08
85	3.6	2.91E+09	0	0	2.61E+09	2.91E+08
90	2.7	2.18E+09	0	0	1.96E+09	2.18E+08
95	1.8	1.49E+09	0	0	1.34E+09	1.49E+08
100	0	0	0	0	0	0

Table 5-15 Enterococci TMDL Calculations for Salt Creek (OK310810030080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,362	1.10E+12	0	0	9.90E+11	1.10E+11
5	58	4.64E+10	0	0	4.18E+10	4.64E+09
10	29	2.31E+10	0	0	2.07E+10	2.31E+09
15	18	1.41E+10	0	0	1.27E+10	1.41E+09
20	12	9.49E+09	0	0	8.54E+09	9.49E+08
25	8.6	6.92E+09	0	0	6.23E+09	6.92E+08
30	6.4	5.17E+09	0	0	4.66E+09	5.17E+08
35	4.7	3.83E+09	0	0	3.45E+09	3.83E+08
40	3.7	2.97E+09	0	0	2.68E+09	2.97E+08
45	2.9	2.36E+09	0	0	2.13E+09	2.36E+08
50	2.4	1.91E+09	0	0	1.72E+09	1.91E+08
55	1.9	1.51E+09	0	0	1.36E+09	1.51E+08
60	1.5	1.22E+09	0	0	1.10E+09	1.22E+08
65	1.2	9.78E+08	0	0	8.80E+08	9.78E+07
70	1.0	7.74E+08	0	0	6.96E+08	7.74E+07
75	0.7	5.70E+08	0	0	5.13E+08	5.70E+07
80	0.6	4.48E+08	0	0	4.03E+08	4.48E+07
85	0.3	2.73E+08	0	0	2.46E+08	2.73E+07
90	0.2	1.59E+08	0	0	1.43E+08	1.59E+07
95	0.1	6.92E+07	0	0	6.23E+07	6.92E+06
100	0	0	0	0	0	0

Table 5-16 Enterococci TMDL Calculations for Wildhorse Creek (OK310810030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	20,431	1.65E+13	0	0	1.48E+13	1.65E+12
5	863	6.96E+11	0	0	6.27E+11	6.96E+10
10	428	3.46E+11	0	0	3.11E+11	3.46E+10
15	263	2.12E+11	0	0	1.91E+11	2.12E+10
20	176	1.42E+11	0	0	1.28E+11	1.42E+10
25	129	1.04E+11	0	0	9.35E+10	1.04E+10
30	96	7.76E+10	0	0	6.98E+10	7.76E+09
35	71	5.74E+10	0	0	5.17E+10	5.74E+09
40	55	4.46E+10	0	0	4.01E+10	4.46E+09
45	44	3.54E+10	0	0	3.19E+10	3.54E+09
50	36	2.87E+10	0	0	2.58E+10	2.87E+09
55	28	2.26E+10	0	0	2.03E+10	2.26E+09
60	23	1.83E+10	0	0	1.65E+10	1.83E+09
65	18	1.47E+10	0	0	1.32E+10	1.47E+09
70	14	1.16E+10	0	0	1.04E+10	1.16E+09
75	11	8.55E+09	0	0	7.70E+09	8.55E+08
80	8	6.72E+09	0	0	6.05E+09	6.72E+08
85	5	4.09E+09	0	0	3.68E+09	4.09E+08
90	3	2.38E+09	0	0	2.14E+09	2.38E+08
95	1	1.04E+09	0	0	9.35E+08	1.04E+08
100	0	0	0	0	0	0

Table 5-17 *E. Coli* TMDL Calculations for Caddo Creek (OK310800030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	15,752	4.86E+13	2.53E+10	0	4.37E+13	4.86E+12
5	665	2.05E+12	2.53E+10	0	1.82E+12	2.05E+11
10	330	1.02E+12	2.53E+10	0	8.93E+11	1.02E+11
15	202	6.24E+11	2.53E+10	0	5.36E+11	6.24E+10
20	136	4.19E+11	2.53E+10	0	3.52E+11	4.19E+10
25	99	3.06E+11	2.53E+10	0	2.50E+11	3.06E+10
30	74	2.28E+11	2.53E+10	0	1.80E+11	2.28E+10
35	55	1.69E+11	2.53E+10	0	1.27E+11	1.69E+10
40	43	1.31E+11	2.53E+10	0	9.26E+10	1.31E+10
45	34	1.04E+11	2.53E+10	0	6.83E+10	1.04E+10
50	27	8.45E+10	2.53E+10	0	5.08E+10	8.45E+09
55	22	6.65E+10	2.53E+10	0	3.46E+10	6.65E+09
60	18	5.40E+10	2.53E+10	0	2.33E+10	5.40E+09
65	14	4.32E+10	2.53E+10	0	1.36E+10	4.32E+09
70	11	3.42E+10	2.53E+10	0	5.49E+09	3.42E+09
75	10	3.13E+10	2.53E+10	0	2.88E+09	3.13E+09
80	10	3.13E+10	2.53E+10	0	2.88E+09	3.13E+09
85	10	3.13E+10	2.53E+10	0	2.88E+09	3.13E+09
90	10	3.13E+10	2.53E+10	0	2.88E+09	3.13E+09
95	10	3.13E+10	2.53E+10	0	2.88E+09	3.13E+09
100	10	3.13E+10	2.53E+10	0	2.88E+09	3.13E+09

Table 5-18 Enterococci TMDL Calculations for Caddo Creek (OK310800030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	15,752	1.27E+13	6.63E+09	0	1.14E+13	1.27E+12
5	665	5.37E+11	6.63E+09	0	4.77E+11	5.37E+10
10	330	2.67E+11	6.63E+09	0	2.34E+11	2.67E+10
15	202	1.63E+11	6.63E+09	0	1.40E+11	1.63E+10
20	136	1.10E+11	6.63E+09	0	9.24E+10	1.10E+10
25	99	8.01E+10	6.63E+09	0	6.55E+10	8.01E+09
30	74	5.98E+10	6.63E+09	0	4.72E+10	5.98E+09
35	55	4.43E+10	6.63E+09	0	3.32E+10	4.43E+09
40	43	3.44E+10	6.63E+09	0	2.43E+10	3.44E+09
45	34	2.73E+10	6.63E+09	0	1.79E+10	2.73E+09
50	27	2.21E+10	6.63E+09	0	1.33E+10	2.21E+09
55	22	1.74E+10	6.63E+09	0	9.03E+09	1.74E+09
60	18	1.41E+10	6.63E+09	0	6.06E+09	1.41E+09
65	14	1.13E+10	6.63E+09	0	3.54E+09	1.13E+09
70	11	8.95E+09	6.63E+09	0	1.42E+09	8.95E+08
75	10	8.19E+09	6.63E+09	0	7.38E+08	8.19E+08
80	10	8.19E+09	6.63E+09	0	7.38E+08	8.19E+08
85	10	8.19E+09	6.63E+09	0	7.38E+08	8.19E+08
90	10	8.19E+09	6.63E+09	0	7.38E+08	8.19E+08
95	10	8.19E+09	6.63E+09	0	7.38E+08	8.19E+08
100	10	8.19E+09	6.63E+09	0	7.38E+08	8.19E+08

5.8 TMDL Implementation

DEQ 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 will be utilized so that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. DEQ'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 (DEQ 2006). The CPP can be viewed from DEQ's website at http://www.deq.state.ok.us/WQDnew/pubs.html Table 5-19 provides a partial list of the state partner agencies DEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-19 Partial List of Oklahoma Water Quality Management Agencies

Agency	Web Link
Oklahoma Conservation Commission	http://www.ok.gov/conservation/Agency_Divisions/Water_Quality_Division
Oklahoma Department of Wildlife Conservation	http://www.wildlifedepartment.com/wildlifemgmt/endangeredspecies.htm
Oklahoma Department of Agriculture, Food, and Forestry	http://www.ok.gov/~okag/aems
Oklahoma Water Resources Board	http://www.owrb.state.ok.us/quality/index.php

5.8.1 Point Sources

As authorized by Section 402 of the CWA, the DEQ 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 EPA 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 DEQ and EPA relating to administration and enforcement of the delegated NPDES Program. Implementation of point source WLAs is done through permits issued under the OPDES program.

5.8.2 Non-Point Sources

Nonpoint source pollution in Oklahoma is managed by the Oklahoma Conservation Commission. The Oklahoma Conservation Commission works with state partners such as ODAFF and federal partners such as the EPA and the National Resources Conservation Service of the U.S. Department of Agriculture, to address water quality problems similar to those seen in the Study Area. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach. Other programs include regulations and permits for CAFOs. The CAFO Act, as administered by the ODAFF, provides CAFO operators the necessary tools and information to deal with the manure and wastewater animals produce so streams, lakes, ponds, and groundwater sources are not polluted.

The reduction rates called for in this TMDL report are as high as 93%. The DEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of a waterbody should be reviewed. For example, the Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the EPA. Additionally, EPA 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 an existing use 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 EPA 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 EPA studies that could result in revisions to their recommendations are ongoing. The numeric criteria values should be evaluated using a risk-based method such as that found in EPA guidance.

Unless or until the WQSs are revised and approved by EPA, 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.

5.9 Reasonable Assurances

Reasonable assurance is required by the EPA guidance for a TMDL to be approvable only when a waterbody is impaired by both point and non-point sources and where a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. In such a case, "reasonable assurance" that the NPS load reductions will actually occur must be demonstrated. In this report, all point source discharges either already have or will be given discharging discharge limitations less than or equal to the water quality standards numerical criteria. This ensures that the impairments to of the waterbodies in this report will not be caused by point sources. Since the point source WLAs in this TMDL report are not dependent on NPS load reduction, reasonable assurance does not apply.

SECTION 6
PUBLIC PARTICIPATION

This report was preliminarily reviewed by EPA prior to public notice. The public notice was then sent to local newspapers, stakeholders in the areas affected by the TMDLs in this Study Area, and to stakeholders who requested copies of all TMDL public notices. The public notice was also posted at the DEQ website: http://www.deq.state.ok.us/wqdnew/index.htm.

The public comment period lasted 45 days. During that time, the public had the opportunity to review the TMDL report and make written comments. Since there were no public comments, a public meeting was not held. These TMDLs have been submitted to EPA for final approval. After EPA's final approval, each TMDL will be adopted into the Water Quality Management Plan (WQMP). The adoption of these TMDLs into the WQMP provides a mechanism to recalculate acceptable loads when information changes in the future. Updates to the WQMP demonstrate compliance with the water quality criteria. The updates to the WQMP are also useful when the water quality criteria change and the loading scenario is reviewed to ensure that the instream criterion is predicted to be met.

SECTION 7
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APPENDIX A

AMBIENT WATER QUALITY DATA

BACTERIA DATA — 2000 TO 2009

Ambient Water Quality Bacteria Data, 2000-2009

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK310830030210_00	OK310830-03-0210C	08/24/04	500	300
OK310830030210_00	OK310830-03-0210C	06/01/05	180	80
OK310830030210_00	OK310830-03-0210C	07/06/05	60	215
OK310830030210_00	OK310830-03-0210C	08/09/05	340	230
OK310830030210_00	OK310830-03-0210C	09/13/05	35	90
OK310830030210_00	OK310830-03-0210C	05/31/06	430	180
OK310830030210_00	OK310830-03-0210C	07/11/06	40	90
OK310830030210_00	OK310830-03-0210C	05/26/09	50	90
OK310830030210_00	OK310830-03-0210C	06/29/09	190	190
OK310830030210_00	OK310830-03-0210C	07/27/09	325	330
OK310830030210_00	OK310830-03-0210C	09/09/09	35	125
OK310830030230_00	OK310830-03-0230C	08/24/04	410	470
OK310830030230_00	OK310830-03-0230C	06/01/05	150	90
OK310830030230_00	OK310830-03-0230C	07/06/05	145	130
OK310830030230_00	OK310830-03-0230C	08/09/05	130	290
OK310830030230_00	OK310830-03-0230C	09/13/05	40	135
OK310830030230_00	OK310830-03-0230C	05/31/06	1000	1000
OK310830030230_00	OK310830-03-0230C	07/11/06	20	80
OK310830030230_00	OK310830-03-0230C	05/26/09	890	3100
OK310830030230_00	OKR09730-106	06/09/09	15	340
OK310830030230_00	OK310830-03-0230C	06/29/09	240	240
OK310830030230_00	OK310830-03-0230C	07/27/09	50	175
OK310830030230_00	OK310830-03-0230C	09/09/09	85	125
OK310830030100_00	OK310830-03-0100C	08/24/04	5	50
OK310830030100_00	OK310830-03-0100C	06/01/05	180	110
OK310830030100_00	OK310830-03-0100C	07/06/05	25	45
OK310830030100_00	OK310830-03-0100C	08/09/05	760	340
OK310830030100_00	OK310830-03-0100C	09/13/05	5	60
OK310830030100_00	OK310830-03-0100C	05/31/06	2000	2000
OK310830030100_00	OK310830-03-0100C	07/11/06	2000	2000
OK310830030100_00	OK310830-03-0100C	05/26/09	5100	2000
OK310830030100_00	OK310830-03-0100C	06/29/09	250	250
OK310830030100_00	OK310830-03-0100C	07/27/09	390	500
OK310830030100_00	OK310830-03-0100C	09/09/09	130	105
OK310830060050_00	OK310830-06-0050M	08/24/04	150	430
OK310830060050_00	OK310830-06-0050M	06/01/05	550	300
OK310830060050_00	OK310830-06-0050M	07/06/05	90	260
OK310830060050_00	OK310830-06-0050M	08/09/05	70	420
OK310830060050_00	OK310830-06-0050M	09/13/05	350	205

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK310830060050_00	OK310830-06-0050M	05/02/06	510	150
OK310830060050_00	OK310830-06-0050M	05/31/06	870	350
OK310830060050_00	OK310830-06-0050M	07/11/06	295	85
OK310830060050_00	OK310830-06-0050M	05/26/09	10000	37
OK310830060050_00	OK310830-06-0050M	06/29/09	670	670
OK310830060050_00	OK310830-06-0050M	07/27/09	280	120
OK310830060050_00	OK310830-06-0050M	09/09/09	140	475
OK310830060080_00	OK310830-06-0080D	08/24/04	500	440
OK310830060080_00	OK310830-06-0080D	06/01/05	650	390
OK310830060080_00	OK310830-06-0080D	07/06/05	435	265
OK310830060080_00	OK310830-06-0080D	08/09/05	240	200
OK310830060080_00	OK310830-06-0080D	09/13/05	500	500
OK310830060080_00	OK310830-06-0080D	05/02/06	480	210
OK310830060080_00	OK310830-06-0080D	05/31/06	490	270
OK310830060080_00	OK310830-06-0080D	07/11/06	1000	330
OK310830060080_00	OK310830-06-0080D	05/26/09	10000	10000
OK310830060080_00	OK310830-06-0080D	06/29/09	510	510
OK310830060080_00	OK310830-06-0080D	07/27/09	340	410
OK310830060080_00	OK310830-06-0080D	09/09/09	135	360
OK310830040010_00	OK310830-04-0010G	08/23/04	295	220
OK310830040010_00	OK310830-04-0010G	05/31/05	290	260
OK310830040010_00	OK310830-04-0010G	07/05/05	250	380
OK310830040010_00	OK310830-04-0010G	08/08/05	1000	575
OK310830040010_00	OK310830-04-0010G	09/12/05	340	245
OK310830040010_00	OK310830-04-0010G	05/30/06	1000	270
OK310830040010_00	OK310830-04-0010G	05/19/09	10	90
OK310830040010_00	OK310830-04-0010G	06/22/09	180	115
OK310830040010_00	OK310830-04-0010G	08/03/09	10	90
OK310830040010_00	OK310830-04-0010G	09/01/09	105	305
OK310820020010_00	OK310820-02-0010F	08/01/00	52	30
OK310820020010_00	OK310820-02-0010B	09/05/00	62	1000
OK310820020010_00	OK310820-02-0010F	09/06/00	41	230
OK310820020010_00	OK310820-02-0010B	05/15/01	74	700
OK310820020010_00	OK310820-02-0010F	05/15/01	209	300
OK310820020010_00	OK310820-02-0010B	06/19/01	41	300
OK310820020010_00	OK310820-02-0010F	06/19/01	74	1000
OK310820020010_00	OK310820-02-0010B	07/24/01	5	65
OK310820020010_00	OK310820-02-0010F	07/24/01	70	85
OK310820020010_00	OK310820-02-0010B	08/28/01	20	80
OK310820020010_00	OK310820-02-0010F	08/28/01	290	70
OK310810020020_00	OK310810-02-0020D	08/25/04	105	350

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK310810020020_00	OK310810-02-0020D	09/28/04	10	210
OK310810020020_00	OK310810-02-0020D	05/31/05	490	220
OK310810020020_00	OK310810-02-0020D	07/05/05	1000	1000
OK310810020020_00	OK310810-02-0020D	08/08/05	230	390
OK310810020020_00	OK310810-02-0020D	09/12/05	25	105
OK310810020020_00	OK310810-02-0020D	05/30/06	15	85
OK310810020020_00	OK310810-02-0020D	06/26/06	25	145
OK310810020020_00	OK310810-02-0020D	05/18/09	290	100
OK310810020020_00	OK310810-02-0020D	06/22/09	50	125
OK310810020020_00	OK310810-02-0020D	07/29/09	50	670
OK310810020020_00	OK310810-02-0020D	08/31/09	15	175
OK310810030080_00	OK310810-03-0080G	08/24/04	40	60
OK310810030080_00	OK310810-03-0080G	09/28/04	20	10
OK310810030080_00	OK310810-03-0080G	06/01/05	260	40
OK310810030080_00	OK310810-03-0080G	07/06/05	860	280
OK310810030080_00	OK310810-03-0080G	08/09/05	330	130
OK310810030080_00	OK310810-03-0080G	09/13/05	80	95
OK310810030080_00	OK310810-03-0080G	05/31/06	500	500
OK310810030080_00	OK310810-03-0080G	06/26/06	15	5
OK310810030080_00	OK310810-03-0080G	05/19/09	60	120
OK310810030080_00	OK310810-03-0080G	06/23/09	270	435
OK310810030080_00	OK310810-03-0080G	07/27/09	265	500
OK310810030080_00	OK310810-03-0080G	09/01/09	50	265
OK310810030010_00	OK310810-03-0010R	08/24/04	5	10
OK310810030010_00	OK310810-03-0010R	09/28/04	15	10
OK310810030010_00	OK310810-03-0010R	06/01/05	60	10
OK310810030010_00	OK310810-03-0010R	07/06/05	1000	1000
OK310810030010_00	OK310810-03-0010R	08/09/05	110	80
OK310810030010_00	OK310810-03-0010R	09/13/05	195	60
OK310810030010_00	OK310810-03-0010R	05/31/06	395	265
OK310810030010_00	OK310810-03-0010R	06/26/06	5	25
OK310810030010_00	OK310810-03-0010R	05/19/09	360	110
OK310810030010_00	OK310810-03-0010R	06/23/09	25	55
OK310810030010_00	OK310810-03-0010R	07/27/09	15	40
OK310810030010_00	OK310810-03-0010R	09/01/09	175	95
OK310800030010_00	OK310800-03-0010F	08/23/04	55	30
OK310800030010_00	OK310800-03-0010F	09/27/04	55	20
OK310800030010_00	OK310800-03-0010F	06/01/05	1000	1000
OK310800030010_00	OK310800-03-0010F	07/06/05	820	170
OK310800030010_00	OK310800-03-0010F	08/09/05	800	245
OK310800030010_00	OK310800-03-0010F	09/13/05	85	115

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK310800030010_00	OK310800-03-0010F	05/31/06	95	80
OK310800030010_00	OK310800-03-0010F	06/27/06	220	140
OK310800030010_00	OK310800-03-0010F	05/19/09	60	70
OK310800030010_00	OK310800-03-0010F	06/23/09	30	100
OK310800030010_00	OK310800-03-0010F	07/27/09	100	110
OK310800030010_00	OK310800-03-0010F	09/01/09	115	110
OK310800010120_00	OK310800-01-0120G	08/23/04	5	40
OK310800010120_00	OK310800-01-0120G	09/27/04	5	10
OK310800010120_00	OK310800-01-0120G	06/01/05	110	40
OK310800010120_00	OK310800-01-0120G	07/06/05	80	40
OK310800010120_00	OK310800-01-0120G	08/09/05	290	40
OK310800010120_00	OK310800-01-0120G	09/13/05	35	25
OK310800010120_00	OK310800-01-0120G	05/31/06	10	20
OK310800010120_00	OK310800-01-0120G	06/27/06	30	55
OK310800010120_00	OK310800-01-0120G	05/19/09	20	230
OK310800010120_00	OK310800-01-0120G	06/23/09	5	5
OK310800010120_00	OKR09730-124	07/14/09	25	25
OK310800010120_00	OK310800-01-0120G	07/27/09	5	5
OK310800010120_00	OK310800-01-0120G	09/01/09	5	25

EC = E. coli (STORET Code: 31609); ENT = enterococci (STORET Code: 31649)
> 1000 reported as 1000.001 in data analysis
[1] Units = counts/100 mL

APPENDIX B

GENERAL METHOD FOR ESTIMATING FLOW FOR UNGAGED STREAMS

AND

ESTIMATED FLOW EXCEEDANCE PERCENTILES

Appendix B
General Method for Estimating Flow for Ungaged Streams

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 gages. All gages within 150 km radius are identified. For each of the identified gage with a minimum of 99 flow measurements on matching dates, four different regressions are calculated including linear, log linear, logarithmic and exponential regressions. The regression with the lowest root mean square error (RMSE) is chosen for each gage. The potential filling gages are ranked by RMSE from lowest to highest. The record is filled from the first gage (lowest RMSE) for those dates that exist in both records. If dates remain unfilled in the desired timespan of the timeseries, the filling process is repeated with the next gage with the next lowest RMSE and proceeds in this fashion until all missing values in the desired timespan are filled.

c. The flow frequency for the flow duration curves will be based on measured flows only. The filled timeseries described above is used to match flows to sampling dates to calculate loads.

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 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 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 February 20, 2004).

Table B-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. The method used to project flow from a gaged location to an ungaged location was adapted by combining aspects of two other flow projection methodologies developed by Furness (Furness 1959) and Wurbs (Wurbs 1999).

Furness Method

The Furness method has been employed in Kansas by both the USGS and Kansas Department of Health and Environment to estimate flow-duration curves. The method typically uses maps, graphs, and computations to identify six unique factors of flow duration for ungaged sites. These factors include:

- the mean streamflow and percentage duration of mean streamflow;
- the ratio of 1-percent-duration streamflow to mean streamflow;
- the ratio of 0.1-percent-duration streamflow to 1-percent-duration streamflow;
- the ratio of 50-percentduration streamflow to mean streamflow;
- the percentage duration of appreciable (0.10 ft /s) streamflow; and
- average slope of the flow-duration curve.

Furness defined appreciable flow as 0.10 ft/s. This value of streamflow was important because, for many years, this was the smallest non-zero streamflow value reported in most Kansas streamflow records. The average slope of the duration curve is a graphical approximation of the variability index, which is the standard deviation of the logarithms of the streamflows (Furness 1959, p. 202-204, figs. 147 and 148). On a duration curve that fits the log-normal distribution exactly, the variability index is equal to the ratio of the streamflow at the 15.87-percent-duration point to the streamflow at the 50-percent-duration point. Because duration curves usually do not exactly fit the log-normal distribution, the average-slope line is drawn through an arbitrary point, and the slope is transferred to a position approximately defined by the previously estimated points.

The method provides a means of both describing shape of the flow duration curve and scaling the magnitude of the curve to another location, basically generating a new flow duration curve with a very similar shape but different magnitude at the ungaged location.

Wurbs Modified NRCS Method

As a part of the Texas water availability modeling (WAM) system developed by Texas Natural Resources Conservation Commission, now known as the Texas Commission on Environmental Quality (TCEQ), and partner agencies, various contractors developed models of all Texas rivers. As a part of developing the model code to be used, Dr. Ralph Wurbs of Texas A&M University researched methods to distribute flows from gaged locations to ungaged locations. (Wurbs 2006) His results included the development of a modified NRCS curve-number (CN) method for distributing flows from gaged locations to ungaged locations.

This modified NRCS method is based on the following relationship between rainfall depth, P in inches, and runoff depth, Q in inches (NRCS 1985; McCuen 2005):

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

where:

Q = runoff depth (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:

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

P and Q in inches must be multiplied by the watershed area to obtain volumes. The potential maximum retention, S in inches, represents an upper limit on the amount of water that can be abstracted by the watershed through surface storage, infiltration, and other hydrologic abstractions. For convenience, S is expressed in terms of a curve number CN, which is a dimensionless watershed parameter ranging from 0 to 100. A CN of 100 represents a limiting condition of a perfectly impervious watershed with zero retention and thus all the rainfall becoming runoff. A CN of zero conceptually represents the other extreme with the watershed abstracting all rainfall with no runoff regardless of the rainfall amount.

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, 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:

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

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.

In a subsequent study (Wurbs 2006), Wurbs evaluated the predictive ability of various flow distribution methods including:

- Distribution of flows in proportion to drainage area;
- Flow distribution equation with ratios for various watershed parameters;
- Modified NRCS curve-number method;
- Regression equations relating flows to watershed characteristics;
- Use of recorded data at gaging stations to develop precipitation-runoff relationships; and
- Use of watershed (precipitation-runoff) computer models such as SWAT.

As a part of the analysis, the methods were used to predict flows at one gaged station to another gage station so that fit statistics could be calculated to evaluate the efficacy of each of the methods. Based upon similar analyses performed for many gaged sites which reinforced the tests performed as part of the study, Wurbs observed that temporal variations in flows are dramatic, ranging from zero flows to major floods. Mean flows are reproduced reasonably well with the all flow distribution methods and the NRCS CN method reproduces the mean closest. Accuracy in predicting mean flows is much better than the accuracy of predicting the flow-frequency relationship. Performance in reproducing flow-frequency relationships is better than for reproducing flows for individual flows.

Wurbs concluded that the NRCS CN method, the drainage area ratio method, and drainage area – CN – mean annual precipitation depth (MP) ratio methods all yield similar levels of accuracy. If the CN and MP are the same for the gaged and ungaged watersheds, the three alternative methods yield identical results. Drainage area is the most important watershed parameter. However, the NRCS method adaptation is preferable in those situations in which differences in CN (land use and soil type) and long-term MP are significantly different between the gaged and ungaged watersheds. The CN and MP are usually similar but not identical.

Generalized Flow Projection Methodology

In the first several versions of the Oklahoma TMDL toolbox, all flows at ungaged sites that required projection from a gaged site were performed with the Modified NRCS CN method. This led a number of problems with flow projections in the early versions. As described previously, the NRCS method, in common with all others, reproduces the mean or central tendency best but the accuracy of the fit degrades towards the extremes of the frequency spectrum. Part of the degradation in accuracy is due to the quite non-linear nature of the NRCS equations. On the low flow end of the frequency spectrum, Equation 2 above constitutes a low flow limit below which the NRCS equations are not applicable at all. Given the flashy nature of most streams in locations for which the toolbox was developed, high and low flows are relatively more common and spurious results from the limits of the equations abounded.

In an effort to increase the flow prediction efficacy and remedy the failure of the NRCS CN method at the extremes of the flow spectrum, a hybrid of the NRCS CN method and the Furness method was developed. Noting the facts that all tested projection methods, and particularly the NRCS CN method, perform best near the central tendency or mean and that none of the methods predict the entire flow frequency spectrum well, an assumption that is implicit in the Furness method is applied. The Furness method implicitly assumes that the shape of the flow frequency curve at an upstream site is related to and similar to the shape of the flow frequency curve at a site downstream. As described previously, the Furness method employs several relationships derived between the mean flows and flows at differing frequencies to replicate the shape of the flow frequency curve at the projected site, while utilizing other regressed relationships to scale the magnitude of the curve. Since, as part of the toolbox calculations, the entire flow frequency curve at a 1% interval is calculated for every USGS gage utilizing very long periods of record, this vector in association with the mean flow was used to project the flow frequency curve.

In the ideal situation flows are projected from an ungaged location from a downstream gaged location. The toolbox also has the capability to project flows from and upstream gaged location if there is no useable downstream gage.

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

References

Furness, L.W., 1959, *Kansas Streamflow Characteristics- Part 1, Flow Duration*: Kansas Water Resources Board Technical Report No. 1.

Wurbs, R.A., and E.D. Sisson, *Evaluation of Methods for Distributing Naturalized Streamflows from Gaged Watersheds to Ungaged Subwatersheds*, Technical Report 179, Texas Water Resources Institute and Texas Natural Resource Conservation Commission, August 1999.

Wurbs, R.A . 2006. *Methods for Developing Naturalized Monthly Flows at Gaged and Ungaged Sites*. Journal of Hydrologic Engineering, January/February 2006, ASCE

Estimated Flow Exceedance Percentiles

WBID	OK310830030210_00	OK310830030230_00	OK310830030100_00	OK310830060050_00	OK310830060080_00	OK310830040010_00	OK310820020010_00	OK310810020020_00	OK310810030080_00	OK310810030010_00	OK310800030010_00
USGS Gage Reference	07325800 (adjacent)	07325800 (adjacent)	07325800 (adjacent)	07325800 (upstream)	07325800 (adjacent)	07325800 (adjacent)	07327550 (upstream)	07325800 (adjacent)	07329700 (adjacent)	07329700 (downstream)	07329700 (adjacent)
Projected Gage	2575	2575	2575	2575	2575	2575	2873	2575	2861	2861	2861
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
0	1458.7	3750.0	3469.8	4,468.2	1212.8	2310.6	4161.3	1874.1	1362.1	20,431.0	15,751.9
1	124.5	320.0	296.1	381.3	103.5	197.2	570.0	159.9	189.7	2,845.2	2,193.6
2	79.4	204.0	188.8	243.1	66.0	125.7	390.5	101.9	123.1	1,846.4	1,423.5
3	49.8	128.0	118.4	152.5	41.4	78.9	293.7	64.0	89.8	1,346.9	1,038.5
4	36.2	93.0	86.1	110.8	30.1	57.3	235.5	46.5	70.1	1,051.8	810.9
5	27.6	71.0	65.7	84.6	23.0	43.7	206.3	35.5	57.5	862.6	665.1
6	22.6	58.0	53.7	69.1	18.8	35.7	181.8	29.0	49.4	741.6	571.7
7	19.1	49.0	45.3	58.4	15.8	30.2	165.5	24.5	41.9	628.1	484.2
8	17.5	45.0	41.6	53.6	14.6	27.7	153.9	22.5	36.5	547.1	421.8
9	15.9	41.0	37.9	48.9	13.3	25.3	141.0	20.5	32.0	480.5	370.5
10	14.8	38.0	35.2	45.3	12.3	23.4	132.9	19.0	28.6	428.3	330.2
11	14.0	36.0	33.3	42.9	11.6	22.2	125.9	18.0	25.5	382.9	295.2
12	13.6	35.0	32.4	41.7	11.3	21.6	116.6	17.5	23.1	345.8	266.6
13	12.8	33.0	30.5	39.3	10.7	20.3	109.6	16.5	21.0	314.8	242.7
14	12.4	32.0	29.6	38.1	10.3	19.7	102.6	16.0	19.0	285.3	219.9
15	12.1	31.0	28.7	36.9	10.0	19.1	96.7	15.5	17.5	262.6	202.4
16	11.7	30.0	27.8	35.7	9.7	18.5	92.1	15.0	16.1	242.1	186.7
17	11.7	30.0	27.8	35.7	9.7	18.5	88.6	15.0	14.8	221.7	170.9
18	11.3	29.0	26.8	34.6	9.4	17.9	85.1	14.5	13.7	205.8	158.7
19	10.9	28.0	25.9	33.4	9.1	17.3	81.6	14.0	12.8	191.4	147.6
20	10.9	28.0	25.9	33.4	9.1	17.3	79.3	14.0	11.8	176.3	135.9
21	10.5	27.0	25.0	32.2	8.7	16.6	76.9	13.5	11.0	165.0	127.2
22	10.1	26.0	24.1	31.0	8.4	16.0	73.4	13.0	10.2	153.6	118.4
23	10.1	26.0	24.1	31.0	8.4	16.0	71.1	13.0	9.6	144.5	111.4
24	9.7	25.0	23.1	29.8	8.1	15.4	69.9	12.5	9.1	136.2	105.0
25	9.7	25.0	23.1	29.8	8.1	15.4	67.6	12.5	8.6	128.6	99.2
26	9.3	24.0	22.2	28.6	7.8	14.8	66.4	12.0	8.1	121.8	93.9
27	9.3	24.0	22.2	28.6	7.8	14.8	64.1	12.0	7.7	115.8	89.3
28	8.9	23.0	21.3	27.4	7.4	14.2	62.9	11.5	7.3	109.7	84.6

WBID	OK310830030210_00	OK310830030230_00	OK310830030100_00	OK310830060050_00	OK310830060080_00	OK310830040010_00	OK310820020010_00	OK310810020020_00	OK310810030080_00	OK310810030010_00	OK310800030010_00
USGS Gage Reference	07325800 (adjacent)	07325800 (adjacent)	07325800 (adjacent)	07325800 (upstream)	07325800 (adjacent)	07325800 (adjacent)	07327550 (upstream)	07325800 (adjacent)	07329700 (adjacent)	07329700 (downstream)	07329700 (adjacent)
Projected Gage	2575	2575	2575	2575	2575	2575	2873	2575	2861	2861	2861
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
29	8.9	23.0	21.3	27.4	7.4	14.2	61.8	11.5	6.8	102.2	78.8
30	8.6	22.0	20.4	26.2	7.1	13.6	60.6	11.0	6.4	96.1	74.1
31	8.6	22.0	20.4	26.2	7.1	13.6	59.4	11.0	6.0	90.0	69.4
32	8.6	22.0	20.4	26.2	7.1	13.6	58.3	11.0	5.7	84.8	65.3
33	8.2	21.0	19.4	25.0	6.8	12.9	57.1	10.5	5.3	79.5	61.3
34	8.2	21.0	19.4	25.0	6.8	12.9	56.0	10.5	5.0	74.9	57.8
35	8.2	21.0	19.4	25.0	6.8	12.9	56.0	10.5	4.7	71.1	54.8
36	7.8	20.0	18.5	23.8	6.5	12.3	53.6	10.0	4.5	67.3	51.9
37	7.8	20.0	18.5	23.8	6.5	12.3	53.6	10.0	4.3	64.3	49.6
38	7.8	20.0	18.5	23.8	6.5	12.3	52.5	10.0	4.1	61.3	47.3
39	7.4	19.0	17.6	22.6	6.1	11.7	50.1	9.5	3.9	58.3	44.9
40	7.4	19.0	17.6	22.6	6.1	11.7	49.0	9.5	3.7	55.2	42.6
41	7.4	19.0	17.6	22.6	6.1	11.7	47.8	9.5	3.5	53.0	40.8
42	7.0	18.0	16.7	21.4	5.8	11.1	47.8	9.0	3.4	50.7	39.1
43	7.0	18.0	16.7	21.4	5.8	11.1	46.6	9.0	3.2	48.4	37.3
44	7.0	18.0	16.7	21.4	5.8	11.1	45.5	9.0	3.1	46.2	35.6
45	6.6	17.0	15.7	20.3	5.5	10.5	44.3	8.5	2.9	43.9	33.8
46	6.6	17.0	15.7	20.3	5.5	10.5	42.0	8.5	2.8	42.4	32.7
47	6.6	17.0	15.7	20.3	5.5	10.5	40.8	8.5	2.7	40.1	30.9
48	6.2	16.0	14.8	19.1	5.2	9.9	39.6	8.0	2.6	38.6	29.8
49	6.2	16.0	14.8	19.1	5.2	9.9	38.5	8.0	2.5	37.1	28.6
50	6.2	16.0	14.8	19.1	5.2	9.9	37.3	8.0	2.4	35.6	27.4
51	6.2	16.0	14.8	19.1	5.2	9.9	36.1	8.0	2.3	34.1	26.3
52	5.8	15.0	13.9	17.9	4.9	9.2	35.0	7.5	2.2	32.5	25.1
53	5.8	15.0	13.9	17.9	4.9	9.2	33.8	7.5	2.1	31.0	23.9
54	5.8	15.0	13.9	17.9	4.9	9.2	32.6	7.5	2.0	29.5	22.8
55	5.4	14.0	13.0	16.7	4.5	8.6	32.6	7.0	1.9	28.0	21.6
56	5.4	14.0	13.0	16.7	4.5	8.6	31.5	7.0	1.8	27.2	21.0
57	5.4	14.0	13.0	16.7	4.5	8.6	30.3	7.0	1.8	26.5	20.4
58	5.1	13.0	12.0	15.5	4.2	8.0	29.1	6.5	1.7	25.0	19.3

WBID	OK310830030210_00	OK310830030230_00	OK310830030100_00	OK310830060050_00	OK310830060080_00	OK310830040010_00	OK310820020010_00	OK310810020020_00	OK310810030080_00	OK310810030010_00	OK310800030010_00
USGS Gage Reference	07325800 (adjacent)	07325800 (adjacent)	07325800 (adjacent)	07325800 (upstream)	07325800 (adjacent)	07325800 (adjacent)	07327550 (upstream)	07325800 (adjacent)	07329700 (adjacent)	07329700 (downstream)	07329700 (adjacent)
Projected Gage	2575	2575	2575	2575	2575	2575	2873	2575	2861	2861	2861
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
59	5.1	13.0	12.0	15.5	4.2	8.0	28.0	6.5	1.6	24.2	18.7
60	5.1	13.0	12.0	15.5	4.2	8.0	26.8	6.5	1.5	22.7	17.5
61	5.1	13.0	12.0	15.5	4.2	8.0	26.8	6.5	1.5	21.9	16.9
62	5.1	13.0	12.0	15.5	4.2	8.0	25.6	6.5	1.4	21.2	16.3
63	4.7	12.0	11.1	14.3	3.9	7.4	25.6	6.0	1.4	20.4	15.8
64	4.7	12.0	11.1	14.3	3.9	7.4	24.5	6.0	1.3	18.9	14.6
65	4.7	12.0	11.1	14.3	3.9	7.4	23.3	6.0	1.2	18.2	14.0
66	4.7	12.0	11.1	14.3	3.9	7.4	23.3	6.0	1.2	17.4	13.4
67	4.7	12.0	11.1	14.3	3.9	7.4	22.1	6.0	1.1	16.6	12.8
68	4.3	11.0	10.2	13.1	3.6	6.8	21.0	5.5	1.1	15.9	12.3
69	4.3	11.0	10.2	13.1	3.6	6.8	21.0	5.5	1.0	15.1	11.7
70	4.3	11.0	10.2	13.1	3.6	6.8	19.8	5.5	1.0	14.4	11.1
71	4.3	11.0	10.2	13.1	3.6	6.8	19.8	5.5	0.9	13.6	10.5
72	3.9	10.0	9.3	11.9	3.2	6.2	18.7	5.0	0.9	12.9	10.2
73	3.9	10.0	9.3	11.9	3.2	6.2	18.7	5.0	0.8	12.1	10.2
74	3.9	10.0	9.3	11.9	3.2	6.2	17.5	5.0	0.8	11.4	10.2
75	3.8	9.8	9.1	11.7	3.2	6.0	16.3	4.9	0.7	10.6	10.2
76	3.7	9.6	8.9	11.4	3.1	5.9	16.3	4.8	0.7	10.6	10.2
77	3.7	9.4	8.7	11.2	3.0	5.8	15.2	4.7	0.7	9.8	10.2
78	3.5	9.0	8.3	10.7	2.9	5.5	14.0	4.5	0.6	9.1	10.2
79	3.5	8.9	8.2	10.6	2.9	5.5	14.0	4.4	0.6	8.3	10.2
80	3.3	8.6	8.0	10.2	2.8	5.3	12.8	4.3	0.6	8.3	10.2
81	3.3	8.4	7.8	10.0	2.7	5.2	12.8	4.2	0.5	7.4	10.2
82	3.2	8.1	7.5	9.7	2.6	5.0	11.7	4.0	0.5	6.8	10.2
83	3.0	7.8	7.2	9.3	2.5	4.8	11.7	3.9	0.4	6.1	10.2
84	2.9	7.5	6.9	8.9	2.4	4.6	11.2	3.7	0.4	5.6	10.2
85	2.8	7.2	6.7	8.6	2.3	4.4	10.8	3.6	0.3	5.1	10.2
86	2.7	6.9	6.4	8.2	2.2	4.3	10.5	3.4	0.3	4.5	10.2
87	2.6	6.6	6.1	7.9	2.1	4.1	9.9	3.3	0.3	4.1	10.2
88	2.4	6.2	5.7	7.4	2.0	3.8	9.4	3.1	0.2	3.7	10.2

WBID	OK310830030210_00	OK310830030230_00	OK310830030100_00	OK310830060050_00	OK310830060080_00	OK310830040010_00	OK310820020010_00	OK310810020020_00	OK310810030080_00	OK310810030010_00	OK310800030010_00
USGS Gage Reference	07325800 (adjacent)	07325800 (adjacent)	07325800 (adjacent)	07325800 (upstream)	07325800 (adjacent)	07325800 (adjacent)	07327550 (upstream)	07325800 (adjacent)	07329700 (adjacent)	07329700 (downstream)	07329700 (adjacent)
Projected Gage	2575	2575	2575	2575	2575	2575	2873	2575	2861	2861	2861
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
89	2.3	5.9	5.5	7.0	1.9	3.6	8.7	2.9	0.2	3.3	10.2
90	2.1	5.4	5.0	6.4	1.7	3.3	8.2	2.7	0.2	3.0	10.2
91	1.9	5.0	4.6	6.0	1.6	3.1	7.5	2.5	0.2	2.6	10.2
92	1.9	4.8	4.4	5.7	1.6	3.0	6.8	2.4	0.2	2.3	10.2
93	1.8	4.5	4.2	5.4	1.5	2.8	6.1	2.2	0.1	1.9	10.2
94	1.6	4.2	3.9	5.0	1.4	2.6	5.2	2.1	0.1	1.6	10.2
95	1.4	3.7	3.4	4.4	1.2	2.3	4.5	1.8	0.1	1.3	10.2
96	1.3	3.4	3.1	4.1	1.1	2.1	3.7	1.7	0.1	1.0	10.2
97	1.2	3.0	2.8	3.6	1.0	1.8	2.6	1.5	0.1	0.8	10.2
98	0.9	2.4	2.2	2.9	0.8	1.5	2.0	1.2	0.0	0.3	10.2
99	0.5	1.3	1.2	1.5	0.4	0.8	1.1	0.6	0.0	0.1	10.2
100	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	10.2

APPENDIX C

STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix C
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.

APPENDIX D

NPDES DISCHARGE MONITORING REPORT DATA

NPDES Discharge Monitoring Data Report

NPDES No.	Outfall	Monitoring Date	Max FC Concentration (cfu/100ml)	Average FC Concentration (cfu/100ml)	Max Flow (MGD)	Average Flow (MGD)
OK0041467	001	6/30/2007			0.216	0.216
OK0041467	001	7/31/2007			0.216	0.216
OK0041467	001	8/31/2007			0.216	0.216
OK0041467	001	3/31/2008			0.38	0.35
OK0041467	001	4/30/2008			0.38	0.35
OK0041467	001	5/31/2008			0.38	0.35
OK0041467	001	2/28/2010			0.135	0.135
OK0041467	001	3/31/2010			0.125	0.0975
OK0041467	001	4/30/2010			0.1124	0.1124
OK0041467	001	5/31/2010			10.11	0.09
OK0038440	001	7/31/2006	40	6.5	4.774	2.839
OK0038440	001	8/31/2006	71	17.8	3.325	2.814
OK0038440	001	9/30/2006	375	118.8	4.275	2.869
OK0038440	001	10/31/2006			4.751	2.992
OK0038440	001	11/30/2006			4.163	2.79
OK0038440	001	12/31/2006			4.298	3.334
OK0038440	001	1/31/2006			5.466	3.854
OK0038440	001	2/28/2007			5.816	3.046
OK0038440	001	3/31/2007			6.398	3.368
OK0038440	001	4/30/2007			6.42	3.741
OK0038440	001	5/31/2007	317	26.2	5.11	4.09
OK0038440	001	6/30/2007	251	44.05	5.478	4.706
OK0038440	001	7/31/2007	25	8.24	5.353	4.577
OK0038440	001	8/31/2007	30	11.86	4.049	3.342
OK0038440	001	9/30/2007	260	14.24	3.441	3.022
OK0038440	001	10/31/2007			6.553	3.184
OK0038440	001	11/30/2007			3.606	2.775
OK0038440	001	12/31/2007			4.124	2.774
OK0038440	001	1/31/2008			3.386	2.692
OK0038440	001	2/29/2008			3.998	2.915
OK0038440	001	3/31/2008			4.766	3.752
OK0038440	001	4/30/2008			4.358	3.661
OK0038440	001	5/31/2008	**760***	33.2	4.26	3.483
OK0038440	001	6/30/2008	30	1.88	3.72	3.12
OK0038440	001	7/31/2008	266	3.6	3.433	2.781
OK0038440	001	8/31/2008	41	4.3	3.908	3.135
OK0038440	001	9/30/2008	87	4.99	4.175	2.791
OK0038440	001	10/31/2008			2.908	2.349

* Red highlights show permit limit exceedances for FC. Facility permit limits are shown in Table 3-1.

NPDES No.	Outfall	Monitoring Date	Max FC Concentration (cfu/100ml)	Average FC Concentration (cfu/100ml)	Max Flow (MGD)	Average Flow (MGD)
OK0038440	001	11/30/2008			3.129	2.341
OK0038440	001	12/31/2008			2.695	2.303
OK0038440	001	1/31/2009			3.001	2.338
OK0038440	001	2/28/3009			3.246	2.55
OK0038440	001	3/31/2009			3.043	2.455
OK0038440	001	4/30/2009			3.135	2.657
OK0038440	001	5/31/2009	110	4.6	5.442	4.16
OK0038440	001	6/30/2009	73	20.4	3.575	3.183
OK0038440	001	7/31/2009	32.5	4.6	3.74	3.176
OK0038440	001	8/31/2009	151	30.5	3.815	3.206
OK0038440	001	9/30/2009	14.75	10.8	4.645	3.277
OK0038440	001	10/31/2009			5.148	3.539
OK0038440	001	11/30/2009			4.912	2.946
OK0038440	001	12/31/2009			4.019	3.269
OK0038440	001	1/31/2010			4.358	3.369
OK0038440	001	2/28/2010			4.231	3.793
OK0038440	001	3/31/2010			3.764	3.437
OK0038440	001	4/30/2010			3.899	3.464
OK0038440	001	5/31/2010	152	4.9	4.037	3.444
OK0038440	001	6/30/2010	260	5	3.904	3.316
OK0038440	001	7/31/2010	37	6.6	3.994	3.575
OK0038440	001	8/31/2010	32	9.2	3.827	3.257
OK0038440	001	9/30/2010	120	8	4.674	3.523
OK0038440	001	10/31/2010			3.447	2.839
OK0038440	001	11/30/2010			3.332	2.84
OK0038440	001	12/31/2010			3.576	2.786
OK0038440	001	1/31/2011			3.166	2.798
OK0038440	001	2/28/2011			3.441	3.081
OK0038440	001	3/31/2011			3.15	2.803
OK0038440	001	4/30/2011			3.262	2.978
OK0038440	001	5/31/2011	11	2	4.155	3.33
OK0038440	001	6/30/2011	21	9	3.472	3.091