FINAL

BACTERIA TOTAL MAXIMUM DAILY LOADS

for Arkansas River Segments OK120420010010_00, OK120410010080_00 & Haikey Creek Segment OK120410010210_00

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ACRONYMS AND ABBREVIATIONS

ASAE	American Society of Agricultural Engineers
BMP	best management practice
BOD5	Biochemical Oxygen Demand, 5-day
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
LA	Load allocation
LDC	Load duration curve
mg	Million gallons
mgd	Million gallons per day
mL	Milliliter
MOS	Margin of safety
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
OAC	Oklahoma Administrative Code
OCC	Oklahoma Conservation Commission
O.S.	Oklahoma statutes
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWRB	Oklahoma Water Resources Board
PBCR	Primary body contact recreation
POTW	Publicly Owned Treatment Works
PRG	Percent reduction goal
SBCR	Secondary Body Contact Recreation

ACRONYMS AND ABBREVIATIONS (Cont'd)

SSO	Sanitary sewer overflow
TMDL	Total maximum daily load
TSS	Total suspended solids
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater treatment plant

Executive Summary

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

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

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

E.1 Problem Identification and Water Quality Target

A decision was made to place specific waterbodies in this Study Area, listed in Table ES-1, on the ODEQ 2006 303(d) list because evidence of nonsupport of designated recreation uses had apparently occurred. Elevated levels of bacteria above the WQS for one or more of the bacterial indicators result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the bacteria loading controls needed to restore PBCR/SBCR use designated for each waterbody.

Table ES-1 Excerpt from the 2006 Integrated Report – Comprehensive Waterbody Assessment Category List

OKWBID	Waterbody Name	Stream Miles	Category	TMDL Date	Primary/Secondary Body Contact Recreation	Impairment
OK120420010010_00	Arkansas River	19	5	2007	Not supporting (1)	Fecal Coliform, Enterococcus
OK120410010210_00	Haikey Creek	11	5	2009	Not supporting (2)	*E. coli*

Source: 2006 Integrated Report, ODEQ 2007.
(1) Secondary body contact recreation but primary body contact recreation criteria apply
(2) Primary body contact recreation.

An earlier version of this report was completed based on the 2004 Oklahoma Integrated Water Quality Assessment Report. The 2004 Report listed Arkansas River segment OK120410010080_00 for Enterococcus. As a result, a TMDL for Enterococcus was being developed for the segment. However, on December 6, 2007 the 2006 version of the Oklahoma Integrated Water Quality Assessment Report was approved by EPA. This report is based on the 2006 version. In the 2006 Report, Arkansas River segment OK120410010080_00 was de-listed for Enterococcus. Consequently, a TMDL was no longer needed. However, during the time of finalizing this report, the draft 2008 Oklahoma Integrated Water Quality Assessment Report finished its public comment period and is pending for approval from EPA. The 2008 Report re-listed OK120410010080_00 for Enterococcus based on newly available data. This report presents all the information necessary for developing an Enterococcus TMDL for OK120410010080_00. Because the 2008 303(d) list has not been approved, the actual TMDL and load reduction requirements included in this report are not final and are subject to change.

The Haikey Creek data report received from the Oklahoma Conservation Commission (OCC) had a prominent note concerning data quality: "Holding times were frequently violated and may have been as long as 48 hours. All samples were kept between 4 ^{o}C and 10 ^{o}C between collection and delivery to the laboratory." Since neither the OWRB, City of Tulsa nor ODEQ had monitoring data for Haikey Creek, it is presumed that the 2004 impairment listing was based upon the OCC data containing the data quality problem. If the ODEQ evaluates the data used to list this segment on the 2004 and 2006 Category 5 list and finds that the listing should be deferred pending collection of additional data, then the TMDL in this report for Haikey Creek should be reassessed with respect to a possible future delisting.

The OWRB monitoring site at Highway 64 bridge in Bixby (120420010010-001AT) is approximately 100 meters downstream of the Bixby North lagoon's un-disinfected discharge. It is possible that this effluent could have contributed to the high bacteria concentrations measured at this site and for which this segment has been listed as impaired for bacteria. An evaluation of this monitoring site and the bacteria data and consequent impairment decision should be assessed. The Bixby North lagoon is scheduled for disinfection in the near future. If it is determined that a new monitoring location is needed or that additional data should be collected to reassess impairment status, then this TMDL should be revised according to the new findings.

For the data collected between 2002 and 2006 from the City of Tulsa, the OWRB and the OCC, evidence of exceeding the PBCR criteria for fecal coliform concentrations was observed in one waterbody: the Arkansas River (OK120420010010_00). Evidence of nonsupport of the PBCR criteria for Enterococcus concentrations was observed in one waterbody: the Arkansas River (OK120420010010_00). It should be noted here that Arkansas River segment OK120420010010_00 has a designated use of SBCR but the bacterial numerical criteria for PBCR are applicable to this particular water body (Appendix A, Chapter 45 of Title 785 of the Oklahoma Administrative Code). Evidence of nonsupport of the PBCR use based on *E. coli* was observed in one waterbody: Haikey Creek (OK120410010210_00). Table ES-2 summarizes the waterbodies requiring TMDLs for not supporting PBCR.

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

WQM Station	Waterbody ID	Waterbody Name	Indicator Bacteria		
			FC	ENT	*E. coli*
120420010010-001AT	OK120420010010_00	Arkansas River, Hwy 64	X	X	
120410010080-001AT	OK120410010080_00	Arkansas River, Haskell		(1)	
OK120410-01-0210G	OK120410010210_00	Haikey Creek			X

ENT = enterococcus; FC = fecal coliform

(1) 2008 draft Integrated Report recommends listing.

The definition of PBCR is summarized by the following excerpt from Chapter 45 of Title 785 of the Oklahoma Administrative Code (OAC), the Oklahoma’s WQS (785:45-5-16).

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

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

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

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

(b) Screening levels.

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

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in

all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 [INCOG Note: 406 is a typo, should be 108]*colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.*

(c) Fecal coliform:

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

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

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) Escherichia coli (E. coli):

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

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

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

(e) Enterococci:

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

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

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

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

As stipulated in the WQS, utilization of the geometric mean to determine compliance for any of the three indicator bacteria depends on the collection of five samples within a 30-day period. For most WQM stations in Oklahoma there are insufficient data available to calculate the 30-day geometric mean since most water quality samples are collected once a month. Therefore, based on OAC 785:46, waterbodies are placed on the 303(d) list for not supporting the PBCR as the result of individual samples exceeding the instantaneous criterion or the long-term geometric mean of individual samples exceeding the geometric mean criterion for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1 to September 30) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for E. coli and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

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

E.2 Pollutant Source Assessment

There are 25 OPDES permitted non-stormwater discharge facilities within the contributing watersheds of the two Arkansas River segments, and no OPDES dischargers within the Haikey Creek watershed. Since most of the municipal OPDES permitted non-stormwater facilities are relatively minor contributors of flow and bacteria, and the largest municipal dischargers are already practicing disinfection and meet instream water quality criteria in their effluent, nonpoint sources are considered to be the major source of bacteria loading in each watershed. However, it is possible the wastewater collection systems associated with WWTPs could be a source of bacteria loading. While not all sewer overflows are reported, ODEQ has some data on sanitary sewer overflows (SSO) available. There were 2,664 SSO occurrences, ranging from 1 gallon to 11.9 million gallons, reported in the Study Area between January 1990 and August 2007. The City of Tulsa is a Phase I stormwater permitted city, and there are six Phase II cities and three Phase II counties also having at least part of their permitted storm sewer systems within the three watersheds (see Table 3.1 for the percent of each watershed having municipal separate storm sewer system [MS4] areas). There are no NPDES-permitted concentrated animal feeding operations within the Study Area.

Nonpoint source bacteria loadings to the receiving streams of each waterbody emanate from a number of different sources including wildlife, various agricultural activities, domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems, and domestic pets. The data analysis and the load duration curves (LDC) demonstrate that exceedances at the WQM stations are the result of a variety of nonpoint source loading occurring during a range of flow conditions. Low flow exceedances are likely due to a combination of non-point sources and uncontrolled point sources.

E.3 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from Load Duration Curves (LDCs). LDCs facilitate rapid development of TMDLs and, because monitoring data are tied to stream flows over all flow conditions, LDCs can be effective in identifying whether impairments are associated with point or nonpoint sources.

Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when treatment plant effluents would dominate the base flow of the impaired water. However, violations that occur during low flows may not be caused exclusively by point sources. Violations have been noted in some watersheds that contain no point sources. Research has show that bacteria loading in streams during low flow conditions may be due to direct deposit of cattle manure into streams and/or faulty septic tank/lateral field systems.

The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the USGS or estimating flow if no USGS data are available;
- sorting the flow data and calculating flow exceedence percentiles for the time period and season of interest;
- displaying a curve on a plot that represents the allowable load by multiplying the actual or estimated flow by the WQS for each respective indicator (the loading curve);
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30);
- matching the water quality observations with the flow data from the same date;
- multiplying the flow by the water quality observations to calculate daily load observations; then
- Adding the daily load observations in the load duration plot.

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

E.4 TMDL Calculations

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

This definition can be expressed by the following equation:

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

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

Table ES-3 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area. Attainment of WQS in response to TMDL implementation will be based on results measured at each of these WQM stations. Selection of the appropriate PRG for each waterbody in Table ES-3 is denoted by the bold text. The TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria for *E. coli* and Enterococci because WQ standards are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no samples exceed the instantaneous criteria. The PRG for the Arkansas River Hwy 64 segment will be based upon Enterococcus, and the PRG for Haikey Creek will be based on *E. coli*. All of the PRGs are significant, ranging from 72.6% to 81.0%.

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

WQM Station	Percent Reduction Goal Required				
	FC	ENT		E. coli	
	Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
Arkansas River (OK120420010010)					
120420010010-001AT at Hwy 64	63.8 %	97.6 %	**81.0 %**	-	-
Arkansas River (OK120410010080)					
120410010080-001AT at Haskell	--	93.1 %	**13.0 % ***	--	--
Haikey Creek (OK120410010210) at 121st					
OK120410-01-0210G	--	--	--	84.9 %	**72.6 %**

* Projected reduction goal pending the approval of the 2008 303(d) list.

The TMDL, WLAs, LA, and MOS vary with flow condition, and are calculated at every 5th flow interval percentile. For illustrative purposes, the TMDL, WLAs, LA, and MOS are calculated for the median flow at each site in Table ES-4. The WLA for waste water treatment plants (WWTPs) of each TMDL is the sum of all WLAs within the contributing watershed of each WQM station. The sum of the WLAs can be represented as a single horizontal line below the LDC. The WLA for MS4s is estimated according to the percentage of watershed which falls under the MS4 coverage. The LDC and the simple equation of:

Σ LA + Σ WLA_MS4= TMDL – MOS – Σ WLA_WWTP

(where, *Σ* LA: load allocation;
Σ WLA_MS4: waste load allocation for MS4s (= LA × α/(1-α), where α is percentage of watershed in MS4 jurisdictions);
MOS: margin of safety; and
Σ WLA_WWTP: waste load allocation for waste water treatment plants.)

can provide an individual values for the LA and WLA_MS4 in counts per day which represent the area under the TMDL target line (that includes the MOS) and above the WLA_WWTP line. For MS4s the load reduction will be the same as the PRG established for the overall watershed (nonpoint sources). Where there are no point sources or MS4s, the WLA_WWTP or WLA_MS4 is zero, respectively.

Table ES-4 TMDL Summary Examples†

WQM Segment	Indicator Bacteria Species	TMDL (cfu/day)	WLA_WWTP (cfu/day)	WLA_MS4 (cfu/day)	LA (cfu/day)	MOS (cfu/day)
Arkansas River (OK120420010010_00)	Enterococci	1.60E+13	8.78E+10	3.51E+12	1.08E+13	1.60E+12
Arkansas River (OK120420010010_00)	Fecal Coliform	5.91E+13	5.32E+11	1.30E+13	3.97E+13	5.91E+12
Arkansas River †† (OK120410010080_00)	Enterococci	1.94E+13	1.19E+10	9.75E+11	1.64E+13	1.94E+12
Haikey Creek (OK120420010210_00)	*E. coli*	1.49E+10	0.00E+00	1.26E+10	8.18E+08	1.49E+09

† Derived for illustrative purposes at the median flow value
†† Projected TMDL allocations, pending the approval of the 2008 303(d) list by EPA.

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

For the explicit MOS the water quality target was set at 10 percent lower than the water quality criterion for each pathogen which equates to 360 cfu/100 mL, 365.4 cfu/100 mL, and 97.2/100 mL for fecal coliform, *E. coli*, and Enterococci, respectively. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each waterbody is slightly reduced. The MOS at any given percent flow exceedance, therefore, can be defined as the difference in loading between the TMDL and the TMDL with MOS. The use of instream bacteria concentrations to estimate existing loading is another conservative element utilized in these TMDLs that can be recognized as an implicit MOS. This conservative approach to establishing the MOS will ensure that both the 30-day geometric mean and instantaneous bacteria standards can be achieved and maintained.

E.5 Reasonable Assurance

As authorized by Section 402 of the CWA, ODEQ has delegation of the NPDES in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by the Oklahoma Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act, and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES program. Implementation of WLAs for point sources is done through permits issued under the OPDES program. Each point source in the contributing watersheds will be issued an OPDES permit that sets fecal coliform limits in its effluent. Disinfection of the effluent will be required if these limits are not met.

SECTION 1 : INTRODUCTION

1.1 TMDL Program Background

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

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

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

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

This TMDL report focuses on three waterbodies that ODEQ placed in Category 5 of the 2004 Integrated Report [303(d) list] for nonsupport of primary and secondary body contact recreation (PBCR and SBCR; see discussion in Executive Summary concerning potential delisting and re-listing):

Arkansas River (OK120420010010_00)
Arkansas River (OK120410010080_00)
Haikey Creek (OK120410010210_00)

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

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

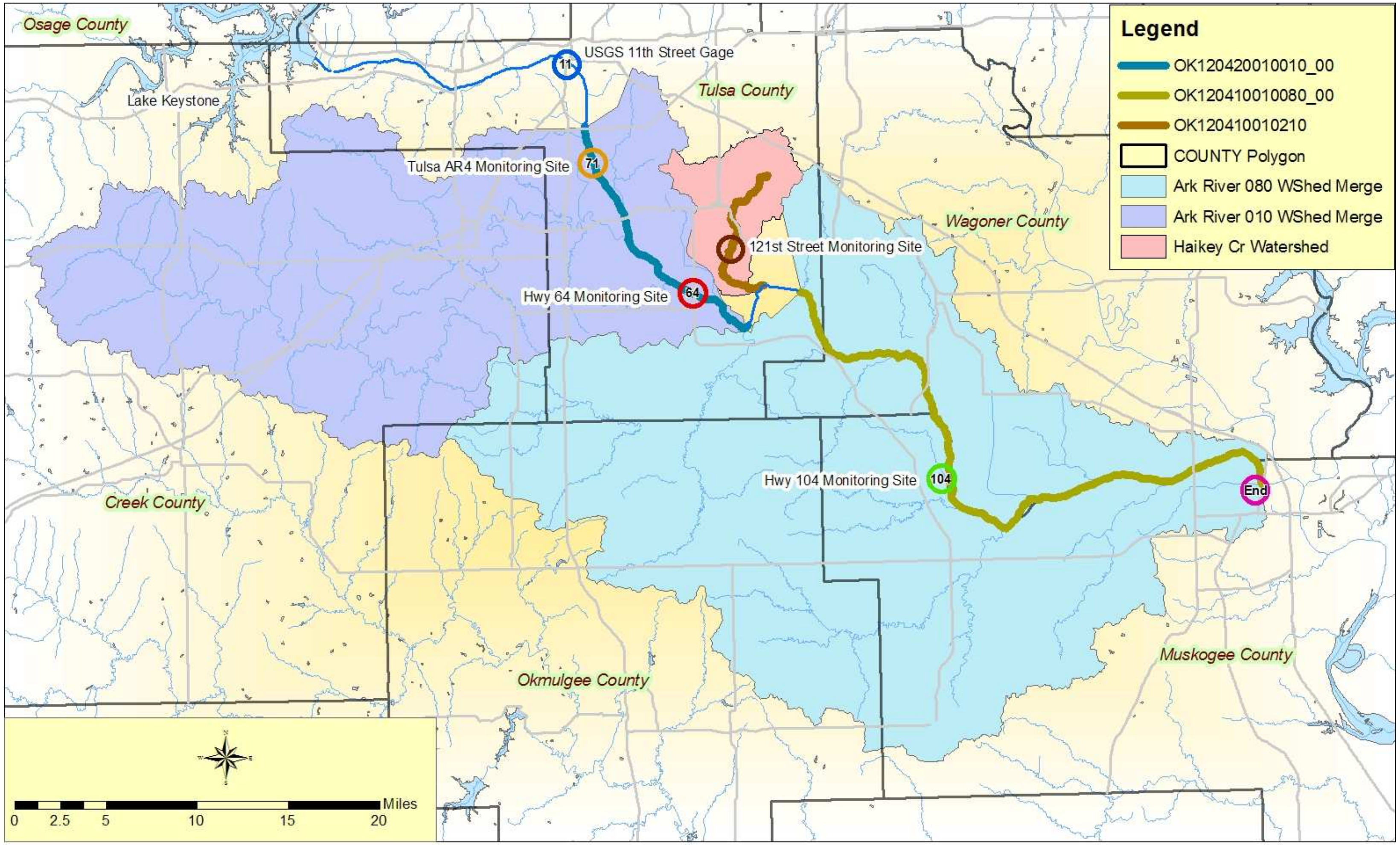
Table 1-1 Water Quality Monitoring Stations used for 2004 303(d) Listing Decision

Waterbody Name	Waterbody ID	WQM Station	WQM Station Locations Descriptions
Arkansas River	OK120420010010_00	120420010010-001AT	Hwy 64 (Memorial Dr.), Bixby, OK
Arkansas River	OK120410010080_00	120410010080-001AT	Hwy 104 Bridge, Haskell, OK
Haikey Creek	OK120410010210_00	OK120410-01-0210G	121st Street Bridge, Tulsa, OK

1.2 Watershed Description

General. The Arkansas River Basin in the Study Area is located in the northeastern portion of Oklahoma. The three waterbodies addressed in this report are located in Tulsa, Creek, Wagoner, Okmulgee and Muskogee Counties. These counties are part of the Central Irregular Plains ecoregion generally to the northeast, and the Cross Timbers ecoregion generally to the southwest. Table 1-2, derived from the 2000 U.S. Census, demonstrates that, with the exception of Tulsa County, all other counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2000).

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



TMDL Watersheds In the Study Area

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Population Density (per square mile)
Tulsa	563,299	988
Wagoner	57,491	102
Creek	67,367	70
Okmulgee	39,685	57
Muskogee	69,451	85

Climate. Table 1-3 summarizes the average annual precipitation for each County. Average annual precipitation values among the Counties in this portion of Oklahoma range between 40.56 and 45.61 inches (Oklahoma Mesonet 2007).

Table 1-3 Average Annual Precipitation by County

County	Average Annual (Inches)
Tulsa	41.91
Wagoner	44.77
Creek	40.56
Okmulgee	43.29
Muskogee	45.61

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

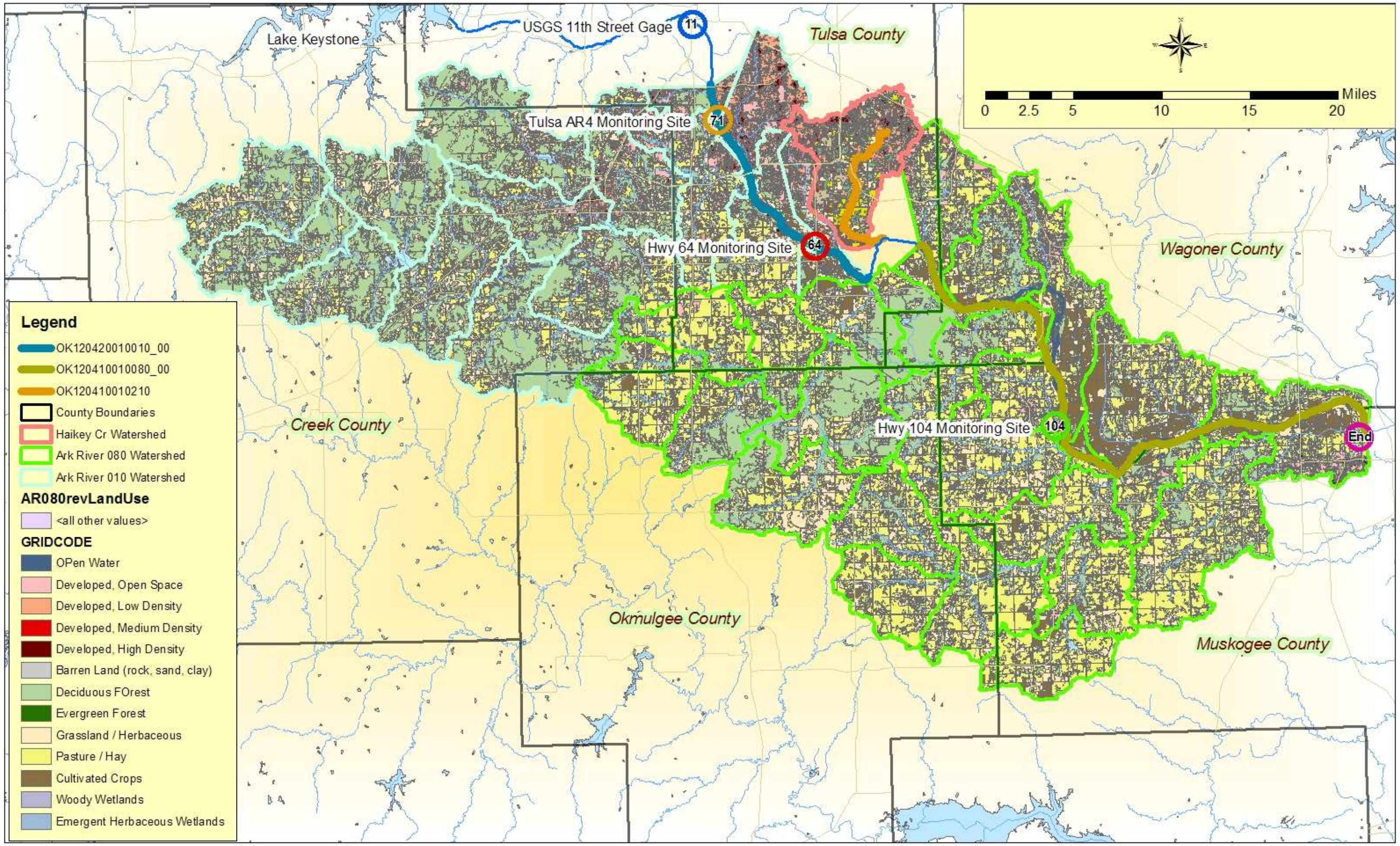
The upper Arkansas River segment (OK120420010010_00) area is primarily deciduous forest (42.8%) and grassland/herbaceous (20.8%). Developed low, medium and high density combined is only 9.4% in this watershed. The lower Arkansas River segment (OK120410010080_00) area is primary pasture / hay (38.0%) and deciduous forest (23.5%). The combined developed low, medium and high density is only 1.3% of the total watershed area. The Haikey Creek watershed (OK120410010210_00) is primarily urbanized development, with a combined open, low, medium and high development of 62.5%. Grassland/herbaceous make up 14.1% of the Haikey Creek watershed, while 10% is deciduous forest and 9.3% is pasture/hay.

Table 1-4 Land Use Summaries by Watershed

Land use Category	Watershed					
	Arkansas River OK120420010010_00		Arkansas River OK120410010080_00		Haikey Creek OK120410010210_00	
Land Use Code and Description	**Square Miles**	**Percent**	**Square Miles**	**Percent**	**Square Miles**	**Percent**
11 Open Water	7.3	1.6%	15.8	2.3%	0.1	0.3%
21 Developed, Open Space	53.7	12.0%	43.4	6.2%	6.7	18.2%
22 Developed, Low Intensity	26.7	6.0%	5.6	0.8%	9.8	26.5%
23 Developed, Medium Intensity	10.3	2.3%	2.3	0.3%	4.6	12.4%
24 Developed, High Intensity	4.9	1.1%	1.3	0.2%	2.0	5.4%
31 Barren Land (Rock/Sand/Clay)	0.0	0.0%	0.7	0.1%	0.004	0.01%
41 Deciduous Forest	190.9	42.8%	163.9	23.5%	3.7	10.0%
42 Evergreen Forest	0.0	0.0%	0.3	0.03%	0	0.0%
71 Grassland/Herbaceous	92.8	20.8%	153.9	22.1%	5.2	14.1%
81 Pasture/Hay	55.4	12.4%	265.0	38.0%	3.4	9.3%
82 Cultivated Crops	4.2	0.9%	44.2	6.3%	1.4	3.7%
90 Woody Wetlands	0	0	0.0	0.0%	0	0.0%
95 Emergent Herbaceous Wetlands	0.02	0	0.3	0.04%	0.01	0.03%

Numbers are land use codes from USGS 2001 National Land Cover Dataset.

Figure 1-2 Land Use Map by Watershed



Land Uses Within Each TMDL Watershed In the Study Area

SECTION 2 : PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code authorizes the Oklahoma Water Resources Board (OWRB) to promulgate Oklahoma's water quality standards and implementation procedures (OWRB 2006). The OWRB has statutory authority and responsibility concerning establishment of state water quality standards, as provided for under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters. [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement (Appendix E), narrative water quality criteria, and numerical criteria (OWRB 2006). The beneficial uses designated for the Arkansas River (OK120420010010_00 and OK120410010080_00), include secondary body contact recreation (SBCR) (but PBCR criteria apply), emergency raw water supply, warm water aquatic community, industrial and municipal process and cooling water, hydropower generation, agricultural water supply, navigation, fish consumption and aesthetics. Haikey Creek (OK120410010210_00) is not specifically listed in the standards, it has the following default beneficial uses: agriculture, industrial and municipal process and cooling water, aesthetics, warm water aquatic community, and primary body contact recreation. The TMDLs in this report only address the PBCR-designated use. Table 2-1, an excerpt from Appendix C of the 2006 Integrated Report (ODEQ 2004), summarizes the PBCR use attainment status for the waterbodies of the Study Area. The priority for targeting TMDL development and implementation is derived from the chronological order of the dates listed in the TMDL Date column of Table 2-1. The TMDLs established in this report are a necessary step in the process to restore the PBCR use designation for each waterbody.

Table 2-1 Excerpt from the 2006 Integrated Report – Comprehensive Waterbody Assessment Category List

OKWBID	Waterbody Name	Stream Miles	Category	TMDL Date	Primary/Secondary Body Contact Recreation	Impairment
OK120420010010_00	Arkansas River	19	5	2007	Not supporting (1)	Fecal Coliform, Enterococcus
OK120410010210_00	Haikey Creek	11	5	2009	Not supporting (2)	*E. coli*

Source: 2006 Integrated Report, ODEQ 2007.

(1) Secondary body contact recreation but primary body contact recreation criteria apply.

(2) Primary Body Contact Recreation.

The definition of PBCR is summarized by the following excerpt from the Oklahoma WQS (Chapter 45, Title 785 of the OAC).

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

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

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

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

(b) Screening levels.

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

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

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 [INCOG Note: 406 is a typo, should be 108] *colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.*

(c) Fecal coliform:

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

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

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per

100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

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

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

(e) Enterococci:

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

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

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

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

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

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

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

2.2 Problem Identification

Using the assessment methodology described in the previous section, all of the 2006 303(d) stream segments in Table 1-1 were re-evaluated with all available data for the bacteria impairment status. There have been additional monitoring data available since the 2006 303(d) list was compiled and those data were used to determine the draft 2008 303(d) list. As a result, stream segments and/or bacteria indicators may be added or removed from the 303(d) list. For example, Arkansas River segment OK120410010080_00 was proposed for re-listing for Enterococci in the draft 2008 Integrated Report.

Table 2-2 summarizes instances where waterbodies or bacterial indicators are recommended for removal from or addition to the 303(d) list based on further data analysis associated with more recent data. TMDLs will be calculated for the bacteria indicators for the stream segments where 303(d) listings are still supported by recent data.

Table 2-2 summarizes water quality data collected during primary contact recreation season from the WQM stations between 2002 and 2006 for each indicator bacteria. The subset of this data collected was used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2004 303(d) list (ODEQ 2004). Water quality data from the primary and secondary contact recreation seasons are provided in Appendix A. For the data collected between 2002 and 2006 and for the stream segments not to be delisted, evidence of nonsupport of the PBCR use based on fecal coliform concentrations was observed in one of the three waterbodies: Arkansas River (OK120420010010_00). Evidence of nonsupport of the PBCR use based on Enterococci concentrations was observed in one of three waterbodies: Arkansas River (OK120420010010_00). Evidence of nonsupport of the PBCR use based on *E. coli* concentrations was observed in one waterbody: Haikey Creek (OK120410010210_00). Table 2-3 summarizes the waterbodies requiring TMDLs for not supporting PBCR and states which waterbodies are to be delisted in the near future.

2.3 Water Quality Target

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." For the WQM stations requiring TMDLs in this report, defining the

Table 2-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 2002-2006

Waterbody ID	Waterbody Name	Indicator Bacteria	Single Sample Water Quality Criterion (#/100ml)	Geometric Mean Concentration (count/100ml)	Number of Samples	Number of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	Listing & TMDL Status
OK120420010010_00	Arkansas River	**FC**	400	105	16	8	50%	TMDL in this report
		EC	406	43	16	2	12.5%	Not listed
		ENT	108	64	16	10	62.5%	TMDL in this report
OK120410010080_00	Arkansas River	FC	400	182	18	3	16.7%	Not listed
		EC	406	75	16	0	0%	Not listed
		ENT	108	39	23	4	17.4%	TMDL in this report* (list proposed to EPA)
OK120410010210_00	Haikey Creek	FC	400	246	8	1	13%	Not listed
		EC	406	123	10	5	50%	TMDL in this report
		ENT	108	162	0	0	0%	Not listed

EC = E. coli; ENT = enterococci; FC = fecal coliform. Highlighted bacterial indicators require load reduction to meet water quality standards
** Listed in the draft 2008 303(d) list; TMDL calculations performed in this report but load reduction goals and allocations not effective until 303(d) list approval by EPA.*

water quality target is somewhat complicated by the use of three different bacterial indicators with three different numeric criterion for determining attainment of PBCR use as defined in the Oklahoma WQS. An individual water quality target is established for each bacterial indicator since each indicator group must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2006). As previously stated, because available bacteria data were collected on an approximate monthly basis (see Appendix A) instead of at least five samples over a 30–day period, data for these TMDLs are analyzed and presented in relation to the instantaneous criteria for fecal coliform and both the instantaneous and a long-term geometric mean for both *E. coli* and Enterococci.

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

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

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

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

WQM Station	Waterbody ID	Waterbody Name	Indicator Bacteria		
			FC	ENT	*E. coli*
120420010010-001AT	OK120420010010_00	Arkansas River, Hwy 64	X	X	
120410010080-001AT	OK120410010080_00	Arkansas River, Haskell		(1)	
OK120410-01-0210G	OK120410010210_00	Haikey Creek			X

ENT = Enterococcus; FC = fecal coliform

(1) 2008 draft Integrated Report recommends listing.

SECTION 3 : POLLUTANT SOURCE ASSESSMENT

A source assessment characterizes known and suspected sources of pollutant loadings 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 some sources may be point or nonpoint in nature.

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

3.1 NPDES-Permitted Facilities

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

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

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

There are no NPDES permitted waste water treatment plants (WWTPs) of any type in the contributing watershed of Haikey Creek. The two Arkansas River watersheds in the Study Area have continuous WWTP point source discharges as identified in Table 3-1 below. There is one Phase I MS4 stormwater permittee, six Phase II MS4 permitted cities and three MS4 permitted counties in the three study watersheds (see Table 3-1).

3.1.1 Continuous Point Source Discharges

The locations of the NPDES permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed in Figure 3-1. For the purposes of the TMDLs calculated in Chapter 5 only facility types identified in Table 3-1 as WWTPs are assumed to contribute bacteria loads within the watersheds of the impaired waterbodies. Data for Table 3-1 is taken from a 2002 Access database provided by ODEQ.

Table 3-1 Point Source Discharges in the Study Area

DISCHARGER: Direct to Arkansas River	PERMIT NO.	TYPE	DESIGN (mgd)	WWTP Receiving Stream	Disinfect Effluent?	Watershed ID
Tulsa Southside POTW	OK0026239	M	42 (31 avg)	Arkansas River	Yes	-010010
Anchor Stone - Jenks	OK0044547	S				-010010
Green Country Cogentrix – Jenks	OK0043869	I				-010010
PSO – Riverside	OK0002429	I				-010010
Anchor Stone Sand & Gravel - Delaware	OK0042404	S				-010010
Jenks POTW	OK0037401	M	2 (0.55 avg)	Arkansas River	Yes	-010010
Glenpool POTW	OK0027138	M	1.44 (0.7 avg)	Arkansas River	No	-010010
Kimberly Clark	OK0040827	I				-010010
Bixby North POTW	OK0036153	M	0.853 (0.339 avg)	Arkansas River	No	-010010
Bixby 4-Star Sand & Gravel	OK0041564	S				-010010
Holiday Sand & Gravel	OK0035319	S				-010010
Bixby South POTW	OK0026913	M	0.684 (0.427 avg)	Arkansas River	No	-010010
RMUA Haikey Creek POTW	OK0034363	M	16 (8 avg)	Arkansas River	Yes	-010010
J & J Sand & Gravel	OK0043893	S				-010010
Broken Arrow POTW	OK0040053	M	8 (2.7 avg)	Arkansas River	Yes	-010010

TYPE: I = Industrial, M = Municipal, S = Sand and Gravel mining

Table 3-1 Point Source Discharges in the Study Area (Cont'd)

DISCHARGER: Direct to Arkansas River	PERMIT NO.	TYPE	DESIGN (mgd)	WWTP Receiving Stream	Disinfect Effluent?	Watershed ID
Coweta POTW	OK0020281	M	0.76 (0.5 avg)	Arkansas River	No	-010080
Coweta Sand & Gravel	OK0043923	S				-010080
Haskell POTW	OK0032271	M	0.39 (0.195 avg)	Arkansas River	No	-010080
Arkhola Sand & Gravel	OK0000400	S				-010080
Muskogee Sand Company	OK0043273	S				-010080
Kellyville POTW	OK0034541	M	0.192 (0.123 avg)	Little Polecat Creek	No	-010010
Sapulpa POTW	OK0025992	M	7.0 (2.67 avg)	Polecat Creek	Yes	-010010
Mounds POTW	OK0022888	M	0.31 (0.05 avg)	Duck Creek	No	-010080
Kiefer POTW	OK0028771	M	0.12 (0.065 avg)	Childres Creek	No	-010010
Boynton POTW	OK0034347	M	0.065 (0.052 avg)	Unnamed trib to Cloud Creek	No	-010080

TYPE: I = Industrial, M = Municipal, S = Sand and Gravel mining

3.1.2 NPDES No-Discharge Facilities and Sanitary Sewer Overflows

There are eight municipal and/or private total retention sewage treatment facilities within segment OK120420010010_00 and one within segment OK120410010080_00 of the Arkansas River (see Figure 3.1 and Table 3-2). There are 30 sewage biosolids land application sites within segment OK120420010010_00 and 39 within OK120410010080_00 (see Table 3-2). Haikey Creek watershed has no total retention facilities or land application sites.

Sanitary sewer overflows (SSOs) or bypasses from wastewater collection systems, although infrequent, can be a major source of fecal coliform loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. The reporting of SSOs over the last 6 years has been strongly encouraged by USEPA, primarily through enforcement and fines. While not all sewer overflows are reported, ODEQ has some data on SSOs available. There were 2,664 occurrences of SSOs, ranging from 1 gal to more than 11 million gallons, reported for certain watersheds within the Study Area between January 1990 and August 2007 which are summarized in Table 3-3. Given the significant number of occurrences and the size of overflows reported, bacteria from SSOs have been a significant source of bacteria loading in the past in both of the Arkansas River segments, particularly segment OK1204200-10010. Because there are many POTW discharge facilities and thousands of SSOs within the three TMDL segments, it is not practical to include detailed SSO data in this report. Such data may be obtained from ODEQ upon request for any POTW within the Study Area.

Table 3-2 Total Retention Facilities and Land Applications Sites

TOTAL RETENTION FACILITY	City	County	Type	Latitude	Longitude	Basin
MOBILE MANOR SOUTH	SAPULPA	CREEK	MUNICIPAL	35.92	-96.12	10010_00
LEON BARNHART	KIEFER	CREEK	MUNICIPAL	35.95	-96.04	10010_00
COUNTRY AIRE MHP	SAPULPA	CREEK	MUNICIPAL	35.97	-96.12	10010_00
JOHN CHRISTNER TRUCKING,	SAPULPA	CREEK	MUNICIPAL	35.99	-96.2	10010_00
BRIAN CUMMING, OWNER	CATOOSA	CREEK	MUNICIPAL	35.99	-96.06	10010_00
WINDMILL TP	TULSA	CREEK	MUNICIPAL	36.04	-96.09	10010_00
RONDIA (RON SCOTT JONES)	n/a	CREEK	MUNICIPAL	36.04	-96.07	10010_00
TOWER ESTATES HOA	TULSA	TULSA	MUNICIPAL	36.08	-96.27	10010_00
TIMBER BROOK	MOUNDS	TULSA	MUNICIPAL	35.86	-95.92	10080_00
LAND APPLICATION FACILITY	**Site Name**	**County**	**Facility ID**	**Latitude**	**Longitude**	**Basin**
TULSA S.	CRMC2	TULSA	S20402	35.91	-96.06	10010_00
TULSA S.	CRMC3	TULSA	S20402	35.91	-96.06	10010_00
TULSA S.	CRMC1	TULSA	S20402	35.91	-96.06	10010_00
TULSA S.	CRMC1&ND2	TULSA	S20402	35.91	-96.06	10010_00
TULSA S.	CRTR5	TULSA	S20402	35.92	-96.04	10010_00
TULSA S.	CRTR4	TULSA	S20402	35.92	-96.04	10010_00
TULSA S.	CRTR3	TULSA	S20402	35.92	-96.03	10010_00
TULSA S.	CRTR2	TULSA	S20402	35.92	-96.03	10010_00
TULSA S.	CRTR1	TULSA	S20402	35.92	-96.03	10010_00
TULSA S.	CRWR3	TULSA	S20402	35.93	-96.27	10010_00
TULSA S.	CRWR3	TULSA	S20402	35.93	-96.26	10010_00
TULSA S.	CRRE	TULSA	S20402	35.93	-96.11	10010_00
TULSA LNDAPP	TUT26	TULSA	S20402	35.93	-96.00	10010_00
TULSA LNDAPP	TUT23	TULSA	S20402	35.93	-95.99	10010_00
TULSA LNDAPP	TUT24	TULSA	S20402	35.93	-95.98	10010_00
TULSA N.	TURW4	TULSA	S21309	35.93	-95.96	10010_00
TULSA S.	CRWR1	TULSA	S20402	35.94	-96.26	10010_00
TULSA S.	CRRR1	TULSA	S20402	35.94	-96.26	10010_00
TULSA S.	CRRR2&3	TULSA	S20402	35.94	-96.26	10010_00
TULSA S.	CRRR2	TULSA	S20402	35.94	-96.26	10010_00
TULSA LNDAPP	TUT21	TULSA	S20402	35.94	-95.99	10010_00
TULSA LNDAPP	TUT22	TULSA	S20402	35.94	-95.99	10010_00
TULSA LNDAPP	TUT21	TULSA	S20402	35.94	-95.99	10010_00
TULSA S.	CRRR3	TULSA	S20402	35.95	-96.26	10010_00
TULSA S.	CRDE1	TULSA	S20402	35.95	-96.12	10010_00
TULSA HAIKEY CK	TURV1	TULSA	S20434	35.96	-95.88	10010_00
JENKS		TULSA	S20403	35.98	-95.94	10010_00
JENKS		TULSA	S20403	35.98	-95.93	10010_00
TULSA S.	CREM	TULSA	S20402	36.00	-96.20	10010_00
TULSA S.	CRJM	TULSA	S20402	36.01	-96.19	10010_00
TULSA S.	OKCW1-6	TULSA	S20402	35.85	-96.06	10080_00

Table 3-2 Total Retention Facilities and Land Applications Sites (Cont'd)

LAND APPLICATION FACILITY	Site Name	County	Facility ID	Latitude	Longitude	Basin
TULSA HAIKEY CK	TUMO1-3	TULSA	S20434	35.85	-95.89	10080_00
TULSA HAIKEY CK	OKRJ1	TULSA	S20434	35.85	-95.89	10080_00
TULSA HAIKEY CK	TUMO4&5	TULSA	S20434	35.85	-95.89	10080_00
TULSA HAIKEY CK	TUMO6&7	TULSA	S20434	35.86	-95.89	10080_00
TULSA S.	TURM4	TULSA	S20402	35.87	-95.99	10080_00
BROKEN ARROW		TULSA	S20409	35.87	-95.68	10080_00
TULSA S.	TUGS3&4	TULSA	S20402	35.88	-96.02	10080_00
TULSA S.	TUGSS 5&6	TULSA	S20402	35.88	-96.02	10080_00
TULSA S.	TUGS1&2	TULSA	S20402	35.88	-96.01	10080_00
TULSA LNDAPP	TUGW2	TULSA	S20402	35.88	-96.01	10080_00
TULSA S.	TURM1	TULSA	S20402	35.88	-96.00	10080_00
TULSA LNDAPP	TUGW3	TULSA	S20402	35.88	-96.00	10080_00
TULSA S.	TURM3	TULSA	S20402	35.88	-95.99	10080_00
TULSA S.	TUDL1	TULSA	S20402	35.88	-95.97	10080_00
TULSA S.	TURM2	TULSA	S20402	35.89	-95.99	10080_00
TULSA S.	CRBT2	TULSA	S20402	35.90	-96.04	10080_00
TULSA S.	CRGL1-4	TULSA	S20402	35.90	-96.03	10080_00
TULSA LNDAPP	TUGW1	TULSA	S20402	35.90	-96.00	10080_00
TULSA S.	TUWR	TULSA	S20402	35.90	-95.97	10080_00
BROKEN ARROW		TULSA	S20409	35.90	-95.64	10080_00
TULSA S.	CRBT1	TULSA	S20402	35.91	-96.04	10080_00
BROKEN ARROW		TULSA	S20409	35.91	-95.66	10080_00
TULSA LNDAPP	TUT25	TULSA	S20402	35.92	-95.98	10080_00
TULSA HAIKEY CK	TURV6	TULSA	S20434	35.93	-95.78	10080_00
TULSA HAIKEY CK	TURV5	TULSA	S20434	35.93	-95.77	10080_00
TULSA HAIKEY CK	TUMO4&5	TULSA	S20434	35.93	-95.77	10080_00
TULSA HAIKEY CK	TUMO6&7	TULSA	S20434	35.93	-95.77	10080_00
TULSA HAIKEY CK	TUMO1-3	TULSA	S20434	35.93	-95.77	10080_00
TULSA HAIKEY CK	TURV4	TULSA	S20434	35.94	-95.78	10080_00
TULSA HAIKEY CK	WADCA1	TULSA	S20434	35.94	-95.76	10080_00
TULSA HAIKEY CK	WABC	TULSA	S20434	35.94	-95.75	10080_00
TULSA HAIKEY CK	TULB4	TULSA	S20434	35.95	-95.79	10080_00
BROKEN ARROW		TULSA	S20409	35.96	-95.78	10080_00
TULSA S.	WACC2	TULSA	S20402	35.98	-95.72	10080_00
TULSA HAIKEY CK	WASW	TULSA	S20434	36.00	-95.72	10080_00
TULSA HAIKEY CK	TUMR3	TULSA	S20434	36.01	-95.76	10080_00
TULSA HAIKEY CK	TUMR1	TULSA	S20434	36.01	-95.76	10080_00
TULSA HAIKEY CK	TUMR2	TULSA	S20434	36.01	-95.76	10080_00

Table 3-3 Sanitary Sewer Overflow Summary

Facility Name	NPDES Permit No.	Receiving Water	Facility Id	Number of Occurrence	Date Range		Amount (gallons)	
					From	To	Max	Min*
Coweta POTW	OK0020281	Arkansas River (OK120410010080)	S20410	187	3/15/1990	8/6/2007	75,000	2
Mounds POTW	OK0022888	Duck Creek (OK120410010080)	S20431	3	5/17/2002	6/2/2007	8,000	2,000
Sapulpa POTW	OK0025992	Polecat Creek (OK120420010010)	S20406	148	3/11/1990	6/30/2004	3.4 m	2
Tulsa South POTW	OK0026239	Arkansas River (OK120420010010)	S20402	1,747	1/12/1990	6/30/2007	11.9 m	1
Bixby POTW (South)	OK0026913	Arkansas River (OK120420010010)	S20407	17	3/14/1990	6/23/2007	4 m	10
Glenpool POTW	OK0027138	Arkansas River (OK120420010010)	S20430	59	1/31/1991	6/1/2007	5,000	15
Kiefer POTW	OK0028771	Childress Creek (OK120420010010)	S20404	9	2/21/1998	2/22/2007	324,000	60
Haskell POWA	OK0032271	Arkansas River (OK120410010080)	S20411	10	4/8/1993	4/10/2000	100,000	300
Boynton, Town Of	OK0034347	Unnamed Trib. To Cloud Crk (OK120410010080)	S20412	15	1/24/1990	5/19/2005	75,000	50
RMUA-Haikey Creek	OK0034363	Arkansas River (OK120420010010)	S20434	91	3/15/1990	5/7/2007	6 m	1
Kellyville POTW	OK0034541	Little Polecat (OK120420010010)	S20451	48	4/20/1992	6/17/2005	92	2
Bixby POTW (North)	OK0036153	Arkansas River (OK120420010010)	S20438	20	2/16/1990	7/21/2007	1,000	1
Jenks POTW	OK0037401	Arkansas River (OK120420010010)	S20403	20	1/29/1990	12/12/2006	100,000	50
Broken Arrow POTW	OK0040053	Arkansas River (OK120420010010)	S20409	290	1/10/1990	8/17/2007	1 m	1

*Not including reported values that are either “0” or “unknown”.

SSOs are a common result of the aging wastewater infrastructure around the state. DEQ has been ahead of other states and, in some cases, EPA itself in its handling of SSOs. Due to the widespread nature of the SSO problem, DEQ has focused its limited resources to first target SSOs that result in definitive environmental harm, such as fish kills, or lead to citizen complaints. All SSOs falling in these two categories are addressed through DEQ’s formal enforcement process. A Notice of Violation (NOV) is first issued to the owner of the collection system and a Consent Order (CO) is negotiated between the owner and DEQ to establish a schedule for necessary collection system upgrades to eliminate future SSOs.

Another target area for DEQ is chronic SSOs from OPDES major facilities, those with a total design flow in excess of 1 MGD. DEQ periodically reviews the bypass reports submitted by these major facilities and identifies problem areas and chronic SSOs. When these problems are attributable to wet weather, DEQ endeavors to enter into a CO with the owner of the collection system to establish a schedule for necessary repairs. When the problems seem to be dry weather-related, DEQ will encourage the owner of the collection system to implement the proposed Capacity, Management, Operation, and Maintenance (CMOM) guidelines aimed at minimizing or eliminating dry weather SSOs. This is often accomplished through entering into a Consent Order to establish a schedule for implementation and annual auditing of the CMOM program.

All SSOs are considered unpermitted discharges under State statute and DEQ regulations. The smaller towns have a smaller reserve, are more likely to use utility revenue for general purposes, and/or tend to budget less for ongoing and/or preventive maintenance. If and when DEQ becomes aware of chronic SSOs (more than one from a single location in a year) or receives a complaint about an SSO in a smaller community, DEQ will pursue enforcement action. Enforcement almost always begins with the issuance of an NOV and, if the problem is not corrected by a long-term solution, DEQ will enter into a CO with the facility for a long-term solution. Long-term solutions usually begin with sanitary sewer evaluation surveys (SSESs). Based on the result of the SSES, the facilities can prioritize and take corrective action.

3.1.3 NPDES Municipal Separate Storm Sewer Discharge

Phase I MS4

In 1990 the USEPA 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 (USEPA 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 management of runoff from residential, industrial and commercial sites, municipal-owned operations and facilities, and construction activities. There is one Phase I MS4 permit, City of Tulsa (which also covers transportation infrastructures managed by Oklahoma Department of Transportation and Oklahoma Turnpike Authority), in the Study Area (see Table 3-4).

Phase II MS4

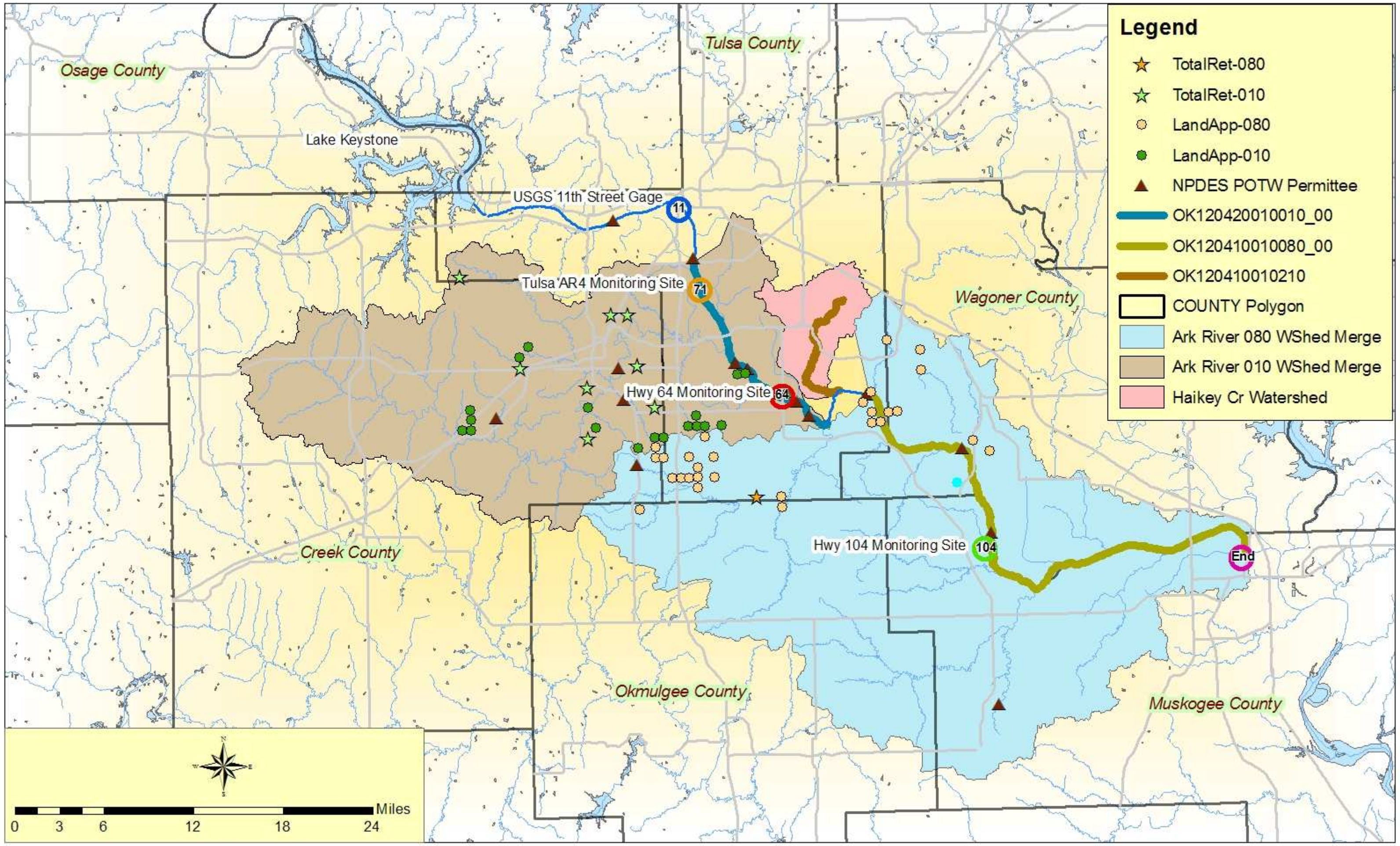
Phase II of the rule extends coverage of the NPDES Stormwater Program to certain small MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Stormwater Program and having Urbanized Area as defined by the US Bureau of Census or otherwise designated Phase II by ODEQ. Phase II requires operators of regulated small MS4s to obtain NPDES permits and develop a stormwater management program for their Urbanized Areas. 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. The specific requirements for bacteria control in both Phase I and II MS4 permits can be found in Appendix F. Appendix F also includes information on a list of BMPs and its effectiveness. BMPs such as buffer strips and proper disposal of domestic animal waste reduce bacteria loading to waterbodies.

Table 3-4 Permitted MS4's in the Study Areas

DISCHARGER: OPDES Storm Water Permits in Watershed	PERMIT NO.	TYPE	Percent of Watershed Having MS4 Area		
			120420010010	120410010080	120410010210
City of Tulsa	OKS000201	Phase 1	10.6 %		24.0 %
City of Jenks	OKR040024	Phase 2	3.9 %		
City of Bixby	OKR040042	Phase 2	3.2 %	1.0 %	13.6 %
City of Coweta	OKR040009	Phase 2		1.2 %	
City of Broken Arrow	OKR040001	Phase 2		1.9 %	53.7 %
City of Sapulpa	OKR040018	Phase 2	5.2 %		
City of Muskogee	OKR040013	Phase 2		1.1 %	
Tulsa County	OKR040019	Phase 2	0.2 %	0.2 %	2.6 %
Wagoner County	OKR040020	Phase 2		0.2 %	
Creek County	OKR040026	Phase 2	1.6 %		
Oklahoma Dept. of Transportation	OKS000201	Phase 1	*	*	*
Oklahoma Turnpike Authority	OKS000201	Phase 1	*	*	*
Oklahoma Turnpike Authority	OKR040045	Phase 2	*	*	*
Total			24.6%	5.6%	93.9%

* Jurisdiction areas of Oklahoma Dept. of Transportation and Oklahoma Turnpike Authority fall completely within other MS4s in the study area.

Figure 3-1 Locations of NPDES-Permitted, Total Retention and Land Application Facilities in the Study Area



OPDES Permittees, Total Retention and Land Application Sites

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. Table 3-4 lists all cities and counties having a portion of their permitted MS4 within each watershed; the table also lists the percent of each watershed that has the MS4 area. The two Arkansas River watersheds had only small portions of the total watershed area under permitted MS4 (OK120420010010_00 was 24.6% and OK120410010080_00 was 5.6%). The Haikey Creek watershed (OK120410010210_00) had 93.9% of its area within permitted MS4s. The bacterial loads from the Haikey Creek permitted MS4 areas are likely the greatest source of bacteria within the watershed, whereas most of the watershed areas of the two Arkansas River segments are outside of permitted MS4 areas.

ODEQ provides information about the current status of the MS4 program on its website, found at: http://www.deq.state.ok.us/WQDnew/stormwater/ms4/ .

3.1.4 Concentrated Animal Feeding Operations

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

3.2 Nonpoint Sources

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

Nonpoint sources include wildlife, various agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems and domestic pets. As previously stated, all large and most small municipal wastewater NPDES permitted facilities within the contributing watersheds of the Arkansas River already disinfect (see Table 3-1); therefore, nonsupport of PBCR use is caused mainly by nonpoint sources of bacteria. There are no NPDES permitted facilities within the Haikey Creek watershed, so all sources of bacteria are nonpoint sources. Within all three segments of the Study Area there are OPDES permitted stormwater discharge cities and counties (see Table 3-4), so portions of the nonpoint sources are addressed in these stormwater discharge permits.

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

Animal census data referenced in Section 3.2 was considered for use from the ODEQ Pathogen Toolbox which was developed by Parsons Engineering, Austin, TX, under a FY07 Section 106 Grant CA# I-006400-05) from ODEQ. The data sources cited by Parsons include the 2002 Census of Agriculture Oklahoma, released June 3, 2004, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, U.S. Department of Agriculture. The Toolbox also cites the American Veterinarian Association's 2000 census of household pets to determine the number of cats and dogs within each watershed. The 1990 federal US Bureau of Census data were used in the Toolbox to calculate the occurrence of sewage disposal methods (sanitary sewer, septic tank, or other) in each watershed. The Toolbox also used the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) for locations and descriptions of CAFOs, dairy and non-dairy cattle and poultry. Data for deer harvests was used in the Toolbox from the Oklahoma Department of Wildlife Conservation (ODWC). Due to the limitations of the Toolbox in watershed coverage and data updating, in most cases animal data was complied from other similar but more updated sources cited in this report. The Toolbox data for sewered and unsewered areas was used in the report.

3.2.1 Wildlife

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

However, 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 per county for 2005 was combined with an estimated annual harvest rate of 20 percent to predict deer population by county. Using the estimated deer population by county and the percentage of the watershed area within each county, a wild deer population can be calculated for each watershed. Table 3-5 provides the estimated number of deer for each watershed.

Table 3-5 Estimated Deer Populations

WATERSHED	DEER / WATERSHED BY HARVEST DATA					TOTAL
	TULSA	WAGONER	CREEK	OKMULGEE	MUSKOGEE	
DEER HARVEST/COUNTY	446	1,162	1,957	1,003	1,731	6,299
Deer / County assuming 20% percent harvested:	2,230	5,810	9,785	5,015	8,655	31,495
OK120420010010_00	456	0	3245	33	0	3,734
OK120410010080_00	289	1643	127	1474	2421	5,954
OK120410010210_00	140	0	0	0	0	140

According to a livestock study conducted by the American Society of Agricultural Engineers (ASAE), deer release approximately $5x10^8$ fecal coliform units per animal per day (ASAE 1999). Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production for deer provided in Table 3-6 in colony-forming units per day (cfu/day) provides a relative magnitude of loading in each watershed.

Table 3-6 Estimated Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Wild Deer Population	Watershed Area (acres)	Estimated Wild Deer per acre	Fecal Production ($\times 10^8$ cfu/day) of Deer Population
OK120420010010_00	Arkansas River	3,734	285,591	0.013	18,668
OK120410010080_00	Arkansas River	5,954	445,964	0.013	29,769
OK120410010210_00	Haikey Creek	140	23,651.4	0.006	702

3.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

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

- Processed manure from commercial raised farm animal operations such as poultry facilities is often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff.

- 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 by livestock can provide a concentrated source of fecal bacteria loading directly into streams.

Table 3-7 provides estimated numbers of commercial raised farm animals by watershed based on the 2002 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2002). The estimated animal populations in Table 3-7 were derived by using the percentage of the watershed within each county. Because the watersheds are generally much smaller than the counties, and commercial raised farm animals are not evenly distributed across counties or constant with time, these are rough estimates only. Beef cattle are the most abundant type of livestock in the Study Area. Since cattle often have direct access to tributaries within the Study Area they may in fact contribute the greatest load of fecal coliform to the stream as suggested in Table 3-7.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application of manure. The estimated acreage by watershed where manure was applied in 2002 is shown in Table 3-7. These estimates of land application acreage are also based on the county level reports from the 2002 USDA county agricultural census, and thus represent approximations of the land application area in each watershed. Because of the lack of specific data, land application of animal manure is not quantified in Table 3-8 but is considered a potential source of bacteria loading to these watersheds. Most poultry feeding operations are regulated by ODAFF, and are required to land apply chicken waste in accordance with their Animal Waste Management Plans or Comprehensive Nutrient Management Plans. Considering the similar origin and transport pathways of bacteria in animal manure to those of nutrients (especially phosphorus), best management practices (e.g., stream buffers) and conservation measures, if properly implemented, could greatly reduce the contribution of bacteria from this group of animals to the watershed.

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

Beef cattle release approximately 1.04×10^{11} fecal coliform counts per animal per day;
Dairy cattle release approximately 1.01×10^{11} per animal per day
Swine release approximately 1.08×10^{10} per animal per day
Chickens release approximately 1.36×10^{8} per animal per day
Sheep release approximately 1.20×10^{10} per animal per day
Horses release approximately 4.20×10^{8} per animal per day;
Turkey release approximately 9.30×10^{7} per animal per day
Ducks release approximately 2.43×10^{9} per animal per day
Geese release approximately 4.90×10^{10} per animal per day

Using the estimated animal populations and the fecal coliform production rates from ASAE, Table 3-8 gives an estimate of fecal coliform production from each group of commercially raised farm animals calculated in each watershed of the Study Area. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into

Table 3-7 Commercially Raised Farm Animals and Manure Application Area Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Acres of Manure Application
OK120420010010_00	Arkansas River	18,666	135	2,026	72	493	469	34	12,208	1,305
OK120410010080_00	Arkansas River	48,060	828	3,027	158	970	534	35	17,956	4,758
OK120410010210_00	Haikey Creek	1,364	6	197	10	40	8	3	93	55

Table 3-8 Fecal Coliform Production Estimates for Selected Commercially Raised Farm Animals ($\times 10^9$ number/day)

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Total
OK120420010010_00	Arkansas River	1,941,304	13,654	851	864	5,920	5,064	879	1,398	1,969,933
OK120410010080_00	Arkansas River	4,998,285	83,665	1,271	1,899	11,639	5,770	904	2,056	5,105,490
OK120410010210_00	Haikey Creek	141,805	560	83	114	484	88	73	11	143,217

streams by runoff or by direct deposition from wading animals. Cattle appear to represent the largest source of fecal bacteria.

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

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

To estimate the potential magnitude of OSWDs fecal bacteria loading, the number of OSWD systems was estimated for each watershed. The estimate of OSWD systems was obtained from the ODEQ Pathogen Toolbox for each watershed. The Toolbox derived the data by using data from the 1990 U.S. Census (U.S. Census Bureau 2000). Data from the site just upstream of the OK120420010010 watershed (11th Street site) was subtracted from the Hwy 64 site representing OK120420010010 to estimate households within this watershed that were sewered, using OSWD or other means and the percent sewered. Data from the Hwy 64 site were subtracted from the Haskell site to give values representing OK120410010080. Data for Haikey Creek from the Toolbox were used without edits.

Over time, most OSWD systems operating at full capacity will fail. OSWD system failures are proportional to the adequacy of a state's minimum design criteria (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSWD systems experience malfunctions during the year (U.S. Census Bureau 1995). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSWD systems in northeast Texas 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 3-9 summarizes estimates of sewered and unsewered households for each watershed in the Study Area.

Table 3-9 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK120420010010_00	Arkansas River	83,878	11,162	116	95,156	79%
OK120410010080_00	Arkansas River	34,348	7,262	89	41,699	79%
OK120410010210_00	Haikey Creek	17,678	517	9	18,205	97%

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

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

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

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

Table 3-10 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)
OK120420010010_00	Arkansas River	285,591	11,162	1,339	9,114
OK120410010080_00	Arkansas River	445,964	7,262	871	5,930
OK120410010210_00	Haikey Creek	23,651.4	517	62	422

3.2.4 Domestic Pets

Fecal matter from dogs and cats transported to streams by runoff from urban and suburban areas can be a potential source of bacteria loading. On average nationally, there are 0.58 dogs per household and 0.66 cats per household (American Veterinary Medical Association 2004). Using the U.S. census data at the block level (U.S. Census Bureau 2000), dog and cat populations can be estimated for each watershed. Table 3-11 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-11 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK120420010010_00	Arkansas River	55,190	62,803
OK120410010080_00	Arkansas River	24,185	27,521
OK120410010210_00	Haikey Creek	10,559	12,015

Table 3-12 provides an estimate of the fecal coliform load from pets. These estimates are based on estimated fecal coliform production rates of 5.4×10^8 counts per day for cats and 3.3×10^9 per day for dogs (Schueler 2000).

Table 3-12 Estimated Fecal Coliform Daily Production by Pets (× 10^9 counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK120420010010_00	Arkansas River	182,129	33,914	216,042
OK120410010080_00	Arkansas River	79,812	14,862	94,673
OK120410010210_00	Haikey Creek	34,844	6,488	41,333

3.3 Summary of Bacteria Sources

All large NPDES-permitted POTW facilities in the watersheds have disinfected effluents, and most of the other POTWs are relatively minor and, for the most part, tend to meet instream water quality criteria in their effluent. Thus, nonpoint sources are considered to be the major origin of bacteria loading in each watershed. Table 3-13 summarizes the suspected sources of bacteria loading in each impaired watershed.

Table 3-13 Estimated Major Source of Bacteria Loading by Watershed

Waterbody ID	Waterbody Name	Have Point Sources	Nonpoint Sources	Major Source
OK120420010010_00	Arkansas River	Yes	Yes	Nonpoint
OK120410010080_00	Arkansas River	Yes	Yes	Nonpoint
OK120410010210_00	Haikey Creek	No	Yes	Nonpoint

Table 3-14 below provides a summary of the estimated fecal coliform loads in percentage for the four major nonpoint source categories (commercially raised farm animals, pets, deer and septic tanks) that are contributing to the elevated bacteria concentrations in each watershed. Commercially raised farm animals are estimated to be the largest contributor of fecal coliform loading to land surfaces. It must be noted that while no data are available to estimate populations and fecal loading of wildlife other than deer, a number of bacteria source tracking studies have demonstrated that wild birds and mammals represent a major source of the fecal bacteria found in streams.

The magnitude of loading to a stream may not reflect the magnitude of loading to land surfaces. While no studies have quantified these effects, bacteria may die off or survive at different rates depending on the manure characteristics and a number of other environmental conditions. Manure handling practices, use of BMPs, and relative location to streams can also affect stream loading. For example, because litter is applied in a pulverized form, it could be a larger source during storm runoff events. The Shoal Creek report showed that poultry litter was about 71% of the high flow load and cow pats contributed only about 28% of it (Missouri Department of Natural Resources, 2003). The Shoal Creek report also showed that poultry litter was insignificant under low flow conditions up to 50% frequency. Also, the structural properties of some manures, such as cow patties, may limit their washoff into streams by runoff. In contrast, malfunctioning septic tank effluent may be present in pools on the surface, or in shallow groundwater, which may enhance its conveyance to streams.

Table 3-14 Summary of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces.

Waterbody ID	Waterbody Name	Commercially Raised Farm Animals	Pets	Deer	Estimated Loads from Septic Tanks
OK120420010010_00	Arkansas River	89.7%	9.8%	0.1%	0.4%
OK120410010080_00	Arkansas River	98.0%	1.8%	0.1%	0.1%
OK120410010210_00	Haikey Creek	77.4%	22.3%	0.0%	0.2%

SECTION 4 : TECHNICAL APPROACH AND METHODS

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

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

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

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

4.1 Using Load Duration Curves to Develop TMDLs

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

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

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (e.g., 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure adequate water quality across a range of flow conditions where nonpoint sources were a significant portion of loads. 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, violations that occur during low flows may not be caused exclusively by point sources. Violations have been noted in some watersheds that contain no point sources. Research has show that bacteria loading in streams during low flow conditions may be due to direct deposit of cattle manure into streams and faulty septic tank/lateral field systems. For the two Arkansas River segments in this report, high flows are usually controlled not by rainfall, with its resultant nonpoint source runoff potential, but instead by artificial releases from upstream at Keystone Dam for hydropower generation and lake pool maintenance by the US Army Corps of Engineers. Throughout the year, releases are intermittent and very frequent, and it is not uncommon to have a diurnal cycle of high releases (around 6,000 to 12,000 cfs) to occur in late afternoon and dissipate before dawn the next morning back to a base flow of around 1,000 cfs. This does not mean that nonpoint source loadings do not occur during rainfall events, only that the high flow datasets from the two Arkansas River monitoring stations are more likely to reflect artificial flows from dam releases, not rainfall events. Since there are no artificial flows in Haikey Creek, the dataset from the 121st Street monitoring station used in this report reflects a more natural, rainfall-driven high flow regime with consequent nonpoint source loads.

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

4.2 Development of Flow Duration Curves

Flow duration curves serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream gages to forecast future recurrence frequencies. Flow duration curves (FDCs) were generated using a USEPA application provided by Bruce Cleland, EPA Region 10. This consisted of Excel spreadsheets and a PowerPoint template to display a graph of the spreadsheet calculations. Drafts of the FDC spreadsheets and PowerPoint templates were submitted to Curry Jones, USEPA Region 6 and to Andrew Fang of ODEQ for review. Modifications were made based upon their comments, and EPA provided a written guide for creating FDCs using these tools. There are several ways to prepare a flow duration curve; a step-by-step procedure on how to generate a flow duration curve and flow exceedance percentiles is provided in Appendix C.

The USGS National Water Information System serves as the primary source of flow measurements for the application. All daily average flow values for all the three gages and for the periods of record as discussed above were retrieved for use in the application via Internet link.

Many WQM stations throughout Oklahoma do not have long term flow data and therefore, flow frequencies must be estimated. The most basic method to estimate flows at an ungaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the ungaged sites and the flow gage; and 3) calculating daily flows at the ungaged site by using the flow at the gaged site multiplied by the drainage area ratio. The more complex approach also considers watershed differences in rainfall, land use, and the hydrologic properties of soil that govern runoff and retention. More than one upstream flow gage may also be considered. For this TMDL, USGS gage data were available for use at all three segments.

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

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

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

The flow duration curve for Arkansas River segment OK120420010010_00 (Figure 4-1) was based on measured flows at USGS gage station 07164500 (Arkansas River at 11th Street Bridge in Tulsa, OK). This USGS gage is located about 15 river miles upstream of WQM station 120410010080-001AT operated by the OWRB.

The flow duration curve for Arkansas River segment OK120410010080_00 (Figure 4-2) was based on measured flows at USGS gage station 07165570 (Arkansas River at U.S. Highway 104 near Haskell, OK). This gage is co-located with WQM station 120410010080-001AT, also operated by the OWRB.

Because the impoundment of the Arkansas River in 1969 significantly altered the flow regime, measured flows from 1969 through 2006 for both of these segments were used to develop the flow duration curve.

The flow duration curve for Haikey Creek segment OK120410010210_00 (Figure 4-3) was based on measured flows at USGS gage station 07165562 (Haikey Creek at 101st Street bridge in Broken Arrow, OK). This gage is located about two river miles upstream of WQM station OK120410-01-0210G operated by the OCC. Measured flows from 1988 through 2006 were used to develop the flow duration curve.

Figure 4-1 Flow Duration Curve for Arkansas River (OK120420010010_00)

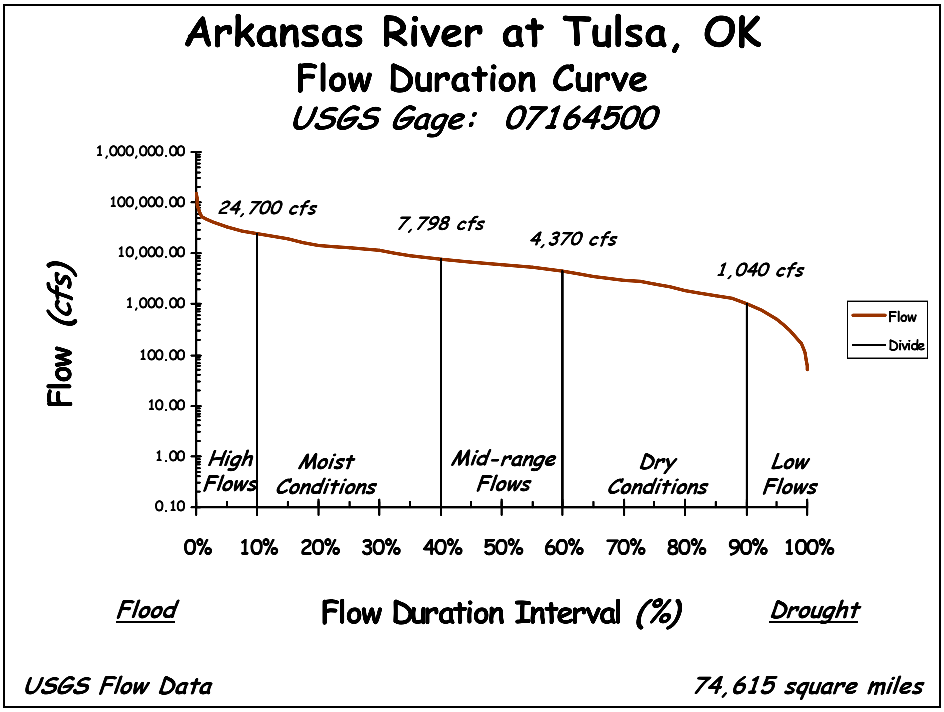


Figure 4-2 Flow Duration Curve for Arkansas River (OK120410010080_00)

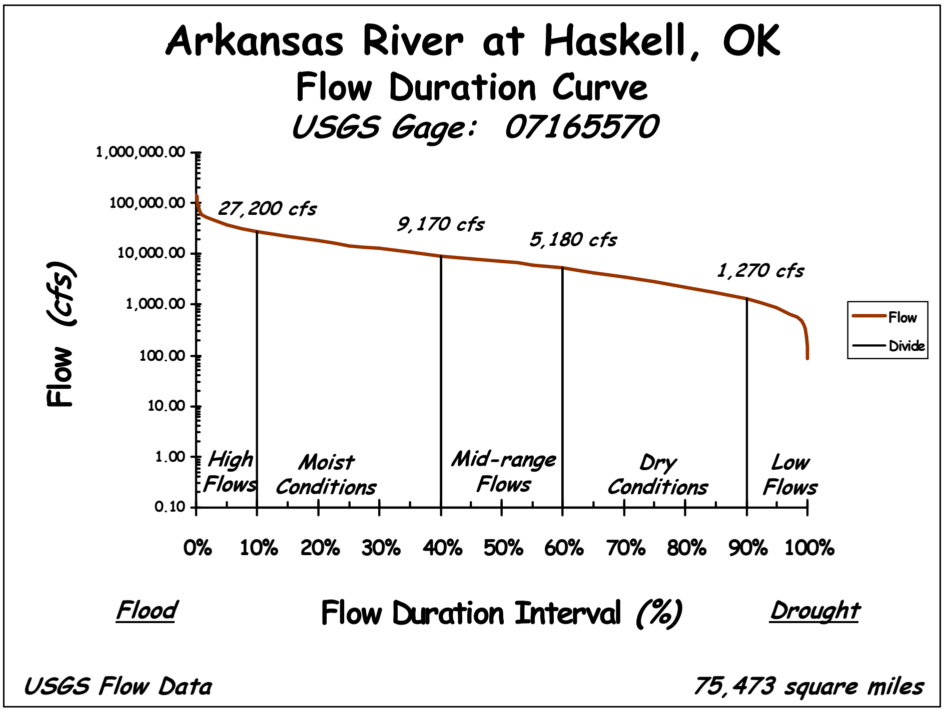
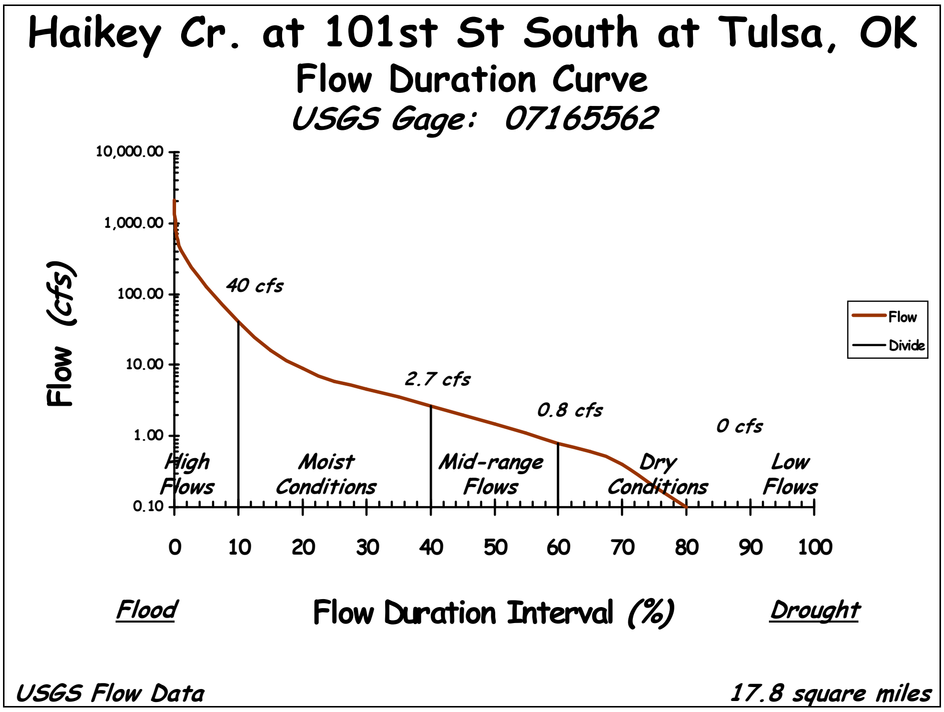


Figure 4-3 Flow Duration Curve for Haikey Creek (OK120410010210_00)



Flow duration curves can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of flow and LDCs (Table 4-1). The hydrologic classification scheme utilized in this application is similar to that described by Cleland (2003):

Table 4-1 Hydrologic Classification Scheme

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

4.3 Estimating Current Point and Nonpoint Loading

Another key step in the use of LDCs for TMDL development is the estimation of existing bacteria loading from point and nonpoint sources and the display of this loading in relation to the TMDL. In Oklahoma, WWTPs that discharge treated sanitary wastewater must meet the state

WQS for bacteria at the point of discharge. However, for TMDL analysis it is necessary to understand the relative contribution of WWTPs to the overall pollutant loading and its general compliance with required effluent limits. The monthly bacteria load for continuous point source dischargers is estimated by multiplying the monthly average design flow rates by the monthly WQS geometric mean using a conversion factor. The current pollutant loading from each permitted point source discharge is calculated using the equation below.

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

Where:

unit conversion factor = 37,854,120 *(100-mL/mg; converts flow in MGD and standards cfu/100mL to cfu/day)*

It is difficult to estimate current nonpoint loading due to lack of specific water quality and flow information that would assist in estimating the relative proportion of non-specific sources within the watershed. Therefore, existing instream loads minus the point source loads were used as an estimate for nonpoint loading.

There were five WWTP dischargers that had actual monitoring data for fecal coliform and associated average daily flows. These data were used to calculate an actual average 5-year seasonal period load and then compared to the permitted monthly load based upon design flow and permit monthly limit for fecal coliform (200 cfu/100 mL). Only data from the recreational period (May – September) and for the past five years (2002 – 2006) were used. Results are presented in Table 4.2 below. One discharger Bixby North, had only two reported data points, far too few for a meaningful result. Therefore, loading was not calculated for Bixby North. The two data points from Bixby North are higher than the monthly limit. The Bixby North lagoons are being required to disinfect, so effluent bacteria loads will decrease. For other WWTPs, the actual average 5-year seasonal period load was lower than the permitted monthly load.

Table 4-2 Comparison of Actual and Permit Based Fecal Coliform Wasteloads

	Bixby South WLA	Broken Arrow WLA	RMUA Haikey WLA	Tulsa S-Side WLA
Avg. Actual WLA	4.04E+09	3.36E+09	3.11E+09	8.00E+09
WLA@permit limit	5.18E+09	6.06E+10	1.21E+11	3.18E+11
Difference	1.14E+09	5.72E+10	1.18E+11	3.10E+11

Values are fecal coliform loads (cfu/day): MGD x 200 col/100mL x 37,854,120 conversion factor.

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 percent reduction goal (PRG) which is one method of presenting how much bacteria loading must be reduced to meet WQS in the impaired watershed.

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

- obtaining daily flow data for the site of interest from the USGS or estimating flow if no USGS data are available;
- sorting the flow data and calculating flow exceedence percentiles for the time period and season of interest;
- displaying a curve on a plot that represents the allowable load by multiplying the actual or estimated flow by the WQS for each respective indicator (the loading curve);
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30);
- matching the water quality observations with the flow data from the same date;
- multiplying the flow by the water quality observations to calculate daily load observations; then
- Adding the daily load observations in the load duration plot.

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

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

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

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

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

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

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. Yet flows do not always correspond directly to local runoff; high flows may occur in dry weather and runoff influence may be observed with low or moderate flows, especially in streams having flows regulated by dam releases such as the Arkansas River.

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

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

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

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

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

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

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

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

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

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

LA = TMDL - WLA_WWTP - WLA_MS4 - MOS

WLA for MS4s. If there are no permitted MS4s in the study area, WLA_MS4 is set to zero. When there are permitted MS4s in the watershed, we can 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 MS4 jurisdictions. This WLA for MS4s may not be the total load allocated for individual 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 area. As a result, one MS4 may have multiple WLAs (and PRGs) depending on how many TMDL watersheds it covers.

Step 5: Estimate WLA Load Reduction. The WLA load reduction was not calculated as it was assumed that continuous dischargers (NPDES permitted WWTPs) are adequately regulated under existing permits to achieve water quality standards at the end-of-pipe and, therefore, no WLA reduction would be required. All SSOs are considered unpermitted discharges under State statute and DEQ regulations. For any MS4s that are located within a watershed requiring a TMDL the load reduction will be equal to the PRG established for LA in the overall watershed.

Step 6: Estimate LA Load Reduction. After existing loading estimates are computed for each non-compliance bacterial indicator, nonpoint load reduction estimates for each WQM station are calculated by using the difference between estimated existing loading and the allowable load expressed by the LDC (TMDL-MOS). This difference is expressed as the overall PRG for the impaired waterbody. For fecal coliform the PRG ensures that no more than 25 percent of the samples exceed the TMDL based on the instantaneous criteria and allocates the loads in manner that is also protective of the geometric mean criterion. For *E. coli* and Enterococci, because WQ standards are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no samples exceed the instantaneous criteria, the TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria.

SECTION 5 : TMDL CALCULATIONS

5.1 Estimated Loading and Critical Conditions

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

To calculate the bacteria load at the WQS, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (24,465,525 ml·s / ft3·day) and the criterion specific to each bacterial indicator. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions. The allowable bacteria (fecal coliform, E. coli, or Enterococci) loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a bacteria load.

To estimate existing loading, bacteria observations for the primary contact recreation season (May 1st through September 30th) from 2002 to 2006 are paired with the flows measured or estimated in that segment on the same date. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor. The associated flow exceedance percentile is then matched with the flow from the tables provided in Appendix D. The observed bacteria loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of bacteria. Points above the LDC indicate the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the WQS.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading, and load reductions required to meet the TMDL water quality target, can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. Percent reduction goals are calculated for each WQM site and bacterial indicator species as the reductions in load required in order that no more than 25 percent of the existing instantaneous fecal coliform observations and none of the existing instantaneous *E. coli* or Enterococci observations would exceed the water quality target. This is because for the contact recreation use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

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

(OK120420010010) will be based on Enterococci and the PRG for Haikey Creek will be based on E. coli. At 72.6% and 81.0%, both of the PRGs are significant.

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

WQM Station	Percent Reduction Goal Required				
	FC	ENT		E. coli	
	Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
Arkansas River (OK120420010010)					
120420010010-001AT at Hwy 64	63.8 %	97.6 %	**81.0 %**	-	-
Arkansas River (OK120410010080)					
120410010080-001AT at Haskell	--	93.1 %	**13.0 % ***	--	--
Haikey Creek (OK120410010210) at 121st					
OK120410-01-0210G	--	--	--	84.9 %	**72.6 %**

* Projected reduction goal pending the approval of the 2008 303(d) list.

LDCs for the appropriate bacterial indicator species that will ensure all criteria for PBCR in each impaired waterbody should be attained are shown in Figures 5-1 through 5-4.

The LDCs for Arkansas River segment OK120420010010_00 (Figures 5-1 and 5-2) are based on fecal coliform and Enterococci bacteria measurements during primary contact recreation season at WQM station OK120420010010-001AT (Arkansas River at US Highway 64 in Bixby, OK). No LDC was developed for *E. Coli* for this river segment because monitoring data indicated water quality standards for *E. Coli* had been met in this segment. The LDCs indicate that levels of both indicator bacteria exceed the instantaneous water quality criteria over a wide range of flow conditions, indicative of both point and nonpoint sources. The exceedances found during dry weather conditions indicate some level of pollution may be due to point sources, failing onsite systems, or direct deposition of animal manure.

The LDC for Haikey Creek segment OK120410010210_00 (Figure 5-3) is based on *E. coli* bacteria measurements during primary contact recreation season at WQM station OK120410-01-0210G (Haikey Creek at 101st Street in Broken Arrow, OK). The LDC indicates that *E. coli* levels exceed the instantaneous water quality criteria over a wide range of flow conditions. Since there are no point sources in the watershed, all loading must be from nonpoint sources. The exceedances found during dry weather conditions indicate some level of pollution may be due to failing onsite systems, direct deposition of animal manure, or other urban sources.

The LDC for Arkansas River segment OK120410010080_00 is based on Enterococcus bacteria measurements during primary contact recreation season at WQM station OK120410010080-001AT. The LDC indicates that Enterococcus levels exceed the instantaneous water quality criteria over dry and mid-range flow conditions, indicative of both point and nonpoint sources. The exceedances found during dry weather conditions indicate some level of pollution may be due to point sources, failing onsite systems, or direct deposition of animal manure.

Figure 5-1 Load Duration Curve for Enterococci in Arkansas River Segment (OK120420010010_00)

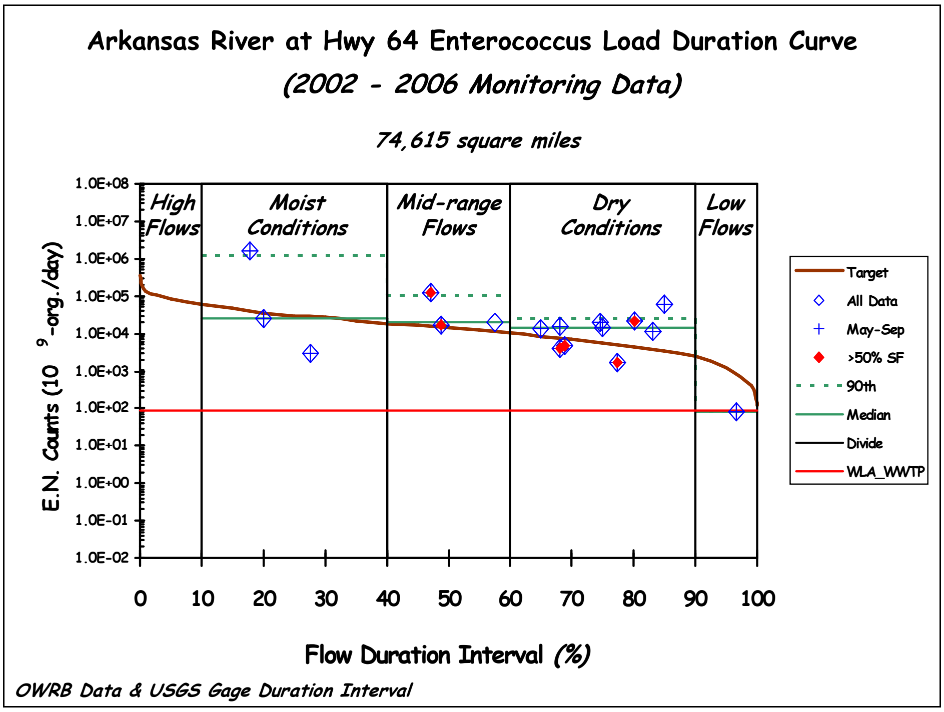


Figure 5-2 Load Duration Curve for Fecal Coliform in Arkansas River Segment(OK120410010080_00)

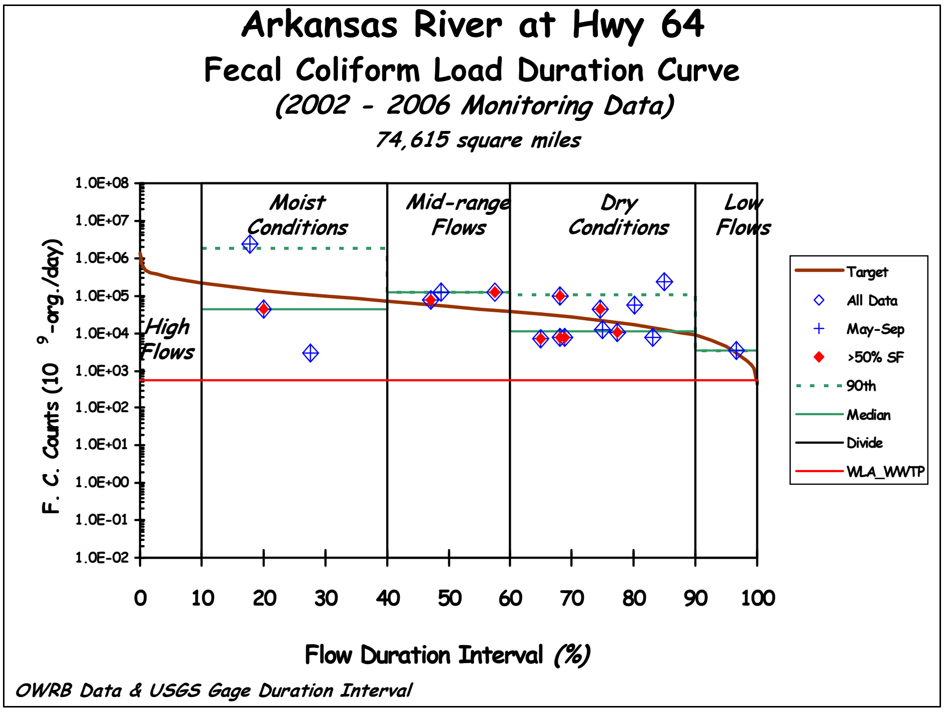


Figure 5-3 Load Duration Curve for *E. coli* in Haikey Creek Segment(OK120410010210_00)

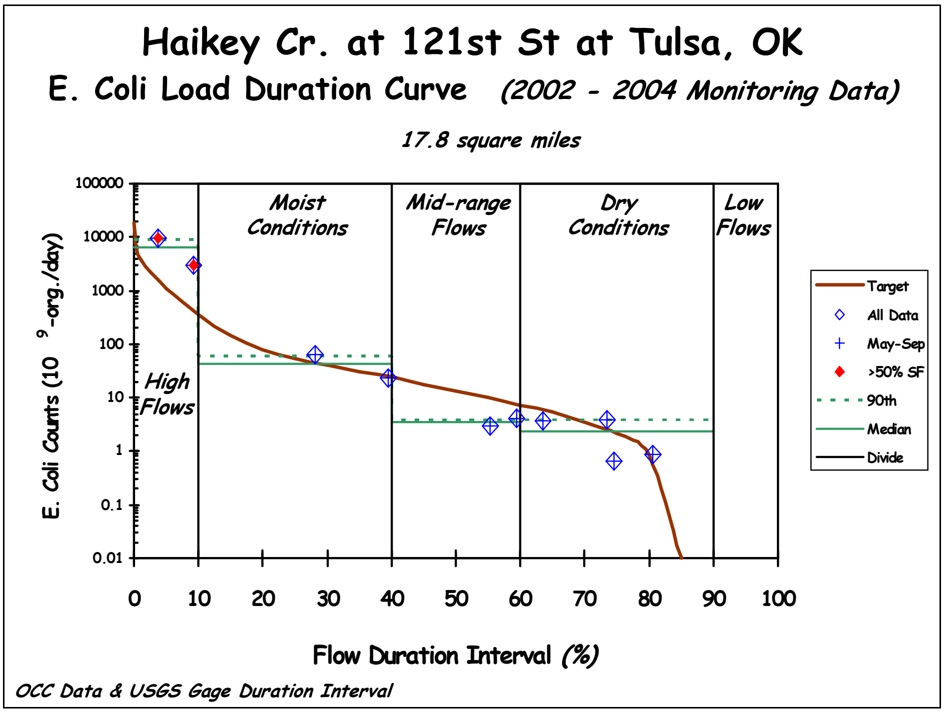
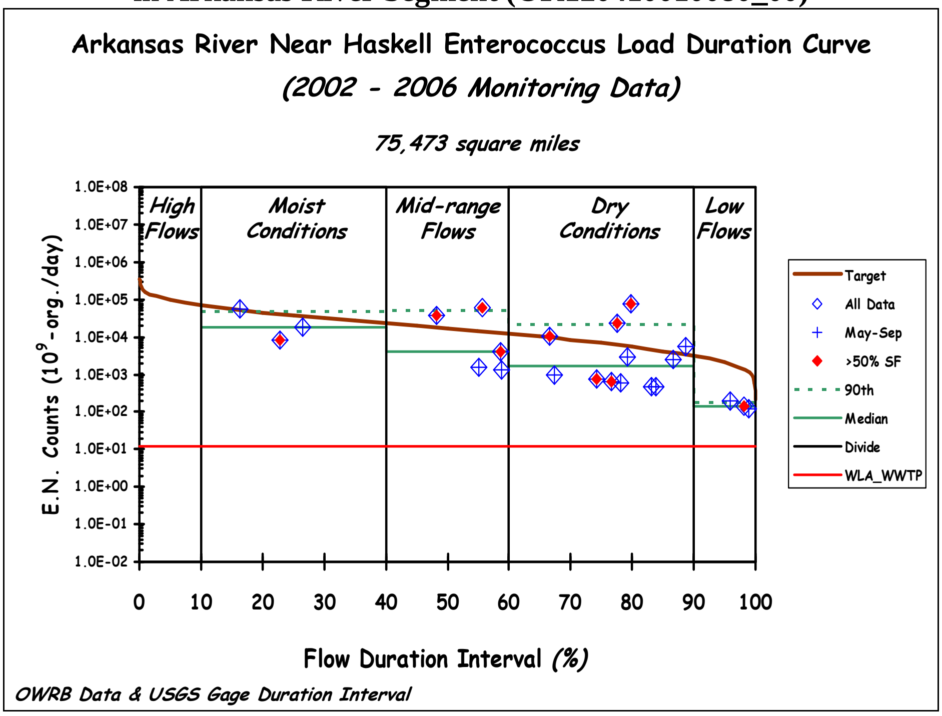


Figure 5-4 Load Duration Curve for Enterococcus in Arkansas River Segment (OK120410010080_00)



Recent research has pointed out the possibility of pathogen indicator bacteria surviving and even reproducing in the environment. ODEQ will continue monitoring the progress of related research and consider its potential impact on bacteria TMDLs in the future.

5.2 Wasteload Allocation

NPDES-permitted facilities are allocated a daily wasteload calculated as their allocated maximum discharge flow rate multiplied by a monthly average permit limit which is equal to the appropriate geometric mean water quality criterion. In other words, it is assumed that the facilities are now or will be required to meet instream criteria in their discharge. Table 5-2 summarizes the WLA of the NPDES-permitted POTW facilities within the Study Area. The WLA for each facility is derived from the following equation:

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

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

flow (10^6 gal/day) = permitted flow

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

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES facilities discharging into the contributing watershed of a WQM station, then the WLA is zero. Compliance with the WLA will be achieved by issuing NPDES permits to all point sources in contributing watersheds that set fecal coliform limits in their effluent. Disinfection of the effluent will be required if these limits are not met. Table 3-1 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.

Permitted stormwater discharges are considered point sources. The WLA calculations for MS4s must be expressed as different maximum loads allowable under different flow conditions. Therefore the percentage of a watershed that is under a MS4 jurisdiction is used to estimate the MS4 contribution. Table 3-4 lists the Phase I and Phase II MS4 permitted cities and counties in the two Arkansas River and the Haikey Creek watersheds and the percentage of each watershed having each MS4 area.

Table 5-2 Wasteload Allocations for NPDES Permitted Facilities

Waterbody ID	Waterbody Name	NPDES Permit Number	Facility Name	Flow (mgd)	Wasteload Allocation (cfu/day)	
					Enterococci	Fecal Coliform
OK120420010010_00	Arkansas River	OK0026239	Tulsa Southside	42.000	5.25E+10	3.18E+11
		OK0037401	Jenks	2.000	2.50E+09	1.51E+10
		OK0027138	Glenpool	1.440	1.80E+09	1.09E+10
		OK0036153	Bixby North	0.853	1.07E+09	6.46E+09
		OK0026913	Bixby South	0.684	8.54E+08	5.18E+09
		OK0034363	RMUA Haikey Creek	16.000	2.00E+10	1.21E+11
		OK0025992	Sapulpa	7.000	8.74E+09	5.30E+10
		OK0034541	Kellyville	0.192	2.40E+08	1.45E+09
		OK0028771	Kiefer	0.120	1.50E+08	9.08E+08
OK120410010080_00	Arkansas River †	OK0040053	Broken Arrow	8.000	9.99E+09	N/A
		OK0020281	Coweta	0.760	9.49E+08	
		OK0032271	Haskell	0.390	4.87E+08	
		OK0022888	Mounds	0.310	3.87E+08	
		OK0034347	Boynton	0.065	8.12E+07	
OK120410010210_00	Haikey Creek	no POTWs				

† **TMDL allocations for Arkansas River (OK120410010080_00) are pending approval of the 2008 303(d) list by EPA.**

5.3 Load Allocation

As discussed in Section 3, nonpoint source bacteria loading to the receiving streams emanate from a number of different sources. The data analysis and the LDCs demonstrate that exceedances at the WQM stations are the result of a variety of nonpoint source loading. The LAs for each stream segment are calculated as the difference between the TMDL, MOS, and WLA for WWTP and MS4s as follows:

LA = TMDL – WLA_WWTP – WLA_MS4 - MOS

5.4 Seasonal Variability

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

5.5 Margin of Safety

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

For the explicit MOS the water quality target was set at 10 percent lower than the water quality criterion for each pathogen which equates to 360 cfu/100 ml, 365.4 cfu/100 ml, and 97.2/100 ml for fecal coliform, *E. coli*, and Enterococci, respectively. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each waterbody is slightly reduced. These TMDLs incorporate an explicit MOS by using a curve representing 90 percent of the TMDL as the average MOS. The MOS at any given percent flow exceedance, therefore, can be defined as the difference in loading between the TMDL and the TMDL with MOS. The use of instream bacteria concentrations to estimate existing loading is another conservative element utilized in these TMDLs that can be recognized as an implicit MOS. This conservative approach to establishing the MOS will ensure that both the 30-day geometric mean and instantaneous bacteria standards can be achieved and maintained.

5.6 TMDL Calculations

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

This definition can be expressed by the following equation:

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

Where the Σ WLA component can be further divided into WLA for WWTPs and WLA for MS4s:

$$\Sigma\ WLA = \Sigma\ WLA\_WWTP + \Sigma\ WLA\_MS4$$

For each stream segment the TMDLs presented in this report are expressed as a percent reduction across the full range of flow conditions. The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5^{th} flow interval percentile (Tables 5-4 through 5-6). For illustrative purposes, the TMDL, WLA, LA, and MOS are calculated for the median flow at each site in Table 5-3. The WLA component of each TMDL is the sum of all WLAs within the contributing watershed of each WQM station. The sum of the WLAs can be represented as a single line below the LDC. The LDC and the simple equation of:

$$\Sigma\ LA + \Sigma\ WLA\_MS4 = TMDL - MOS - \Sigma\ WLA\_WWTP$$

(where, **Σ** *WLA_MS4*: waste load allocation for MS4s (= LA × α/(1-α), where α is percentage of watershed in MS4 jurisdictions; and **Σ** *WLA_WWTP*: waste load allocation for waste water treatment plants.)

can provide an individual value for the LA in counts per day which represents the area under the TMDL target line and above the WLA line. For MS4s the load reduction will be the same as the PRG established for the overall watershed. Where there are no point sources the WLA is zero.

Table 5-3 TMDL Summary Examples†

WQM Segment	Indicator Bacteria Species	TMDL† (cfu/day)	WLA_WWTP † (cfu/day)	WLA_MS4 † (cfu/day)	LA† (cfu/day)	MOS† (cfu/day)
Arkansas River (OK120420010010_00)	Enterococci	1.60E+13	8.78E+10	3.51E+12	1.08E+13	1.60E+12
Arkansas River (OK120420010010_00)	Fecal Coliform	5.91E+13	5.32E+11	1.30E+13	3.97E+13	5.91E+12
Haikey Creek (OK120420010210_00)	*E. coli*	1.49E+10	0.00E+00	1.26E+10	8.18E+08	1.49E+09

† Derived for illustrative purposes at the median flow value. See Appendix D Tables D-2 and D-3 for TMDL calculations for *E. coli* for Arkansas River (OK120420010010_00) and Enterococcus for Arkansas River (OK120410010080_00), where load reductions are not required as part of this TMDL development.

Table 5-4 Enterococci TMDL Calculations for Arkansas River (OK120420010010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_WWTP (cfu/day)	WLA_MS4s (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	148,000	3.91E+14	8.78E+10	8.65E+13	2.65E+14	3.91E+13
5	33,700	8.90E+13	8.78E+10	1.97E+13	6.04E+13	8.90E+12
10	24,700	6.53E+13	8.78E+10	1.44E+13	4.42E+13	6.53E+12
15	19,605	5.18E+13	8.78E+10	1.14E+13	3.51E+13	5.18E+12
20	14,900	3.94E+13	8.78E+10	8.69E+12	2.66E+13	3.94E+12
25	12,800	3.38E+13	8.78E+10	7.47E+12	2.29E+13	3.38E+12
30	11,200	2.96E+13	8.78E+10	6.53E+12	2.00E+13	2.96E+12
35	9,235	2.44E+13	8.78E+10	5.38E+12	1.65E+13	2.44E+12
40	7,798	2.06E+13	8.78E+10	4.54E+12	1.39E+13	2.06E+12
45	6,840	1.81E+13	8.78E+10	3.98E+12	1.22E+13	1.81E+12
50	6,040	1.60E+13	8.78E+10	3.51E+12	1.08E+13	1.60E+12
55	5,180	1.37E+13	8.78E+10	3.01E+12	9.22E+12	1.37E+12
60	4,370	1.15E+13	8.78E+10	2.53E+12	7.77E+12	1.15E+12
65	3,606	9.53E+12	8.78E+10	2.09E+12	6.40E+12	9.53E+11
70	2,979	7.87E+12	8.78E+10	1.72E+12	5.27E+12	7.87E+11
75	2,420	6.39E+12	8.78E+10	1.39E+12	4.27E+12	6.39E+11
80	1,880	4.97E+12	8.78E+10	1.08E+12	3.30E+12	4.97E+11
85	1,420	3.75E+12	8.78E+10	8.09E+11	2.48E+12	3.75E+11
90	1,040	2.75E+12	8.78E+10	5.87E+11	1.80E+12	2.75E+11
95	507	1.34E+12	8.78E+10	2.75E+11	8.42E+11	1.34E+11
100	50	1.32E+11	8.78E+10	7.65E+09	2.34E+10	1.32E+10

Table 5-5 Fecal Coliform TMDL Calculations for Arkansas River (OK120420010010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_WWTP (cfu/day)	WLA_MS4s (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	148,000	1.45E+15	5.32E+11	3.20E+14	9.82E+14	1.45E+14
5	33,700	3.30E+14	5.32E+11	7.29E+13	2.23E+14	3.30E+13
10	24,700	2.42E+14	5.32E+11	5.34E+13	1.64E+14	2.42E+13
15	19,605	1.92E+14	5.32E+11	4.23E+13	1.30E+14	1.92E+13
20	14,900	1.46E+14	5.32E+11	3.21E+13	9.85E+13	1.46E+13
25	12,800	1.25E+14	5.32E+11	2.76E+13	8.46E+13	1.25E+13
30	11,200	1.10E+14	5.32E+11	2.41E+13	7.40E+13	1.10E+13
35	9,235	9.04E+13	5.32E+11	1.99E+13	6.09E+13	9.04E+12
40	7,798	7.63E+13	5.32E+11	1.68E+13	5.14E+13	7.63E+12
45	6,840	6.69E+13	5.32E+11	1.47E+13	4.50E+13	6.69E+12
50	6,040	5.91E+13	5.32E+11	1.30E+13	3.97E+13	5.91E+12
55	5,180	5.07E+13	5.32E+11	1.11E+13	3.40E+13	5.07E+12
60	4,370	4.28E+13	5.32E+11	9.34E+12	2.86E+13	4.28E+12
65	3,606	3.53E+13	5.32E+11	7.68E+12	2.35E+13	3.53E+12
70	2,979	2.91E+13	5.32E+11	6.32E+12	1.94E+13	2.91E+12
75	2,420	2.37E+13	5.32E+11	5.11E+12	1.57E+13	2.37E+12
80	1,880	1.84E+13	5.32E+11	3.94E+12	1.21E+13	1.84E+12
85	1,420	1.39E+13	5.32E+11	2.95E+12	9.03E+12	1.39E+12
90	1,040	1.02E+13	5.32E+11	2.12E+12	6.50E+12	1.02E+12
95	507	4.96E+12	5.32E+11	9.67E+11	2.96E+12	4.96E+11
100[†]	109	1.06E+12	5.32E+11	1.05E+11	3.21E+11	1.06E+11

[†] The flow value here is the sum of the design flow of all the WWTPs in the watershed. The actual historic low flow value of 50 cfs (recorded on July 11, 1994) is much smaller. Using this historic value and keeping the same MOS and WLA_WWTP would result in negative values of LA and WLA_MS4. However, even in the worst scenario of an extreme draught condition coupled with all WWTPs running at their full design capacity, the flow in the stream would still at least be at the level of the combined design flow of all WWTPs. As long as the WWTPs meet their discharge limits for fecal coliform, the water quality standard would be met in the river in such a scenario. Therefore, at the 100 percentile, combined design flow of the WWTPs in the watershed (109 cfs) is used here for TMDL calculation.

Table 5-6 *E. coli* TMDL Calculations for Haikey Creek (OK120410010210_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_WWTP (cfu/day)	WLA_MS4s (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,090	2.08E+13	0.00E+00	1.75E+13	1.14E+12	2.08E+12
5	125	1.24E+12	0.00E+00	1.05E+12	6.82E+10	1.24E+11
10	40.0	3.97E+11	0.00E+00	3.36E+11	2.18E+10	3.97E+10
15	16.0	1.59E+11	0.00E+00	1.34E+11	8.72E+09	1.59E+10
20	9.0	8.94E+10	0.00E+00	7.55E+10	4.91E+09	8.94E+09
25	5.9	5.86E+10	0.00E+00	4.95E+10	3.22E+09	5.86E+09
30	4.5	4.47E+10	0.00E+00	3.78E+10	2.45E+09	4.47E+09
35	3.5	3.48E+10	0.00E+00	2.94E+10	1.91E+09	3.48E+09
40	2.7	2.68E+10	0.00E+00	2.27E+10	1.47E+09	2.68E+09
45	2.0	1.99E+10	0.00E+00	1.68E+10	1.09E+09	1.99E+09
50	1.5	1.49E+10	0.00E+00	1.26E+10	8.18E+08	1.49E+09
55	1.1	1.09E+10	0.00E+00	9.23E+09	6.00E+08	1.09E+09
60	0.8	7.85E+09	0.00E+00	6.63E+09	4.31E+08	7.85E+08
65	0.6	5.96E+09	0.00E+00	5.04E+09	3.27E+08	5.96E+08
70	0.4	3.97E+09	0.00E+00	3.36E+09	2.18E+08	3.97E+08
75	0.2	2.28E+09	0.00E+00	1.93E+09	1.25E+08	2.28E+08
80	0.1	8.94E+08	0.00E+00	7.55E+08	4.91E+07	8.94E+07
85	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-7. Enterococci TMDL Calculations for Arkansas River (OK120410010080_00). †

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_WWTP (cfu/day)	WLA_MS4s (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	146,000	3.86E+14	1.19E+10	1.94E+13	3.28E+14	3.86E+13
5	40,920	1.08E+14	1.19E+10	5.45E+12	9.18E+13	1.08E+13
10	29,140	7.70E+13	1.19E+10	3.88E+12	6.54E+13	7.70E+12
15	22,800	6.02E+13	1.19E+10	3.04E+12	5.12E+13	6.02E+12
20	18,900	4.99E+13	1.19E+10	2.52E+12	4.24E+13	4.99E+12
25	15,200	4.02E+13	1.19E+10	2.02E+12	3.41E+13	4.02E+12
30	13,100	3.46E+13	1.19E+10	1.74E+12	2.94E+13	3.46E+12
35	11,100	2.93E+13	1.19E+10	1.48E+12	2.49E+13	2.93E+12
40	9,446	2.50E+13	1.19E+10	1.26E+12	2.12E+13	2.50E+12
45	8,238	2.18E+13	1.19E+10	1.10E+12	1.85E+13	2.18E+12
50	7,330	1.94E+13	1.19E+10	9.75E+11	1.64E+13	1.94E+12
55	6,310	1.67E+13	1.19E+10	8.40E+11	1.42E+13	1.67E+12
60	5,350	1.41E+13	1.19E+10	7.12E+11	1.20E+13	1.41E+12
65	4,410	1.17E+13	1.19E+10	5.87E+11	9.89E+12	1.17E+12
70	3,598	9.51E+12	1.19E+10	4.78E+11	8.06E+12	9.51E+11
75	2,910	7.69E+12	1.19E+10	3.87E+11	6.52E+12	7.69E+11
80	2,290	6.05E+12	1.19E+10	3.04E+11	5.13E+12	6.05E+11
85	1,740	4.60E+12	1.19E+10	2.31E+11	3.89E+12	4.60E+11
90	1,306	3.45E+12	1.19E+10	1.73E+11	2.92E+12	3.45E+11
95	883	2.33E+12	1.19E+10	1.17E+11	1.97E+12	2.33E+11
100	87	2.30E+11	1.19E+10	1.09E+10	1.84E+11	2.30E+10

† **TMDL allocations for Arkansas River (OK120410010080_00) are pending approval of the 2008 303(d) list by EPA.**

Table 5.8 lists the percent of each watershed that contains MS4 area. The table also lists, for each individual MS4 in each watershed, the median bacteria loads in cfu/day. For each watershed, the median (50th percentile) Load Allocation was multiplied by the percent of the watershed having the area from each MS4. In this way, each MS4's wasteload allocation (WLA_MS4) is calculated at the median load value.

Table 5-8 Median Wasteload Allocation for each MS4 In Each Watershed†

			Fecal Coliform	*E. coli*	Enterococcus
MS4s	Area (acres)	Percent of Watershed Having MS4	WLA_MS4	WLA_MS4	WLA_MS4
Arkansas River (OK120420010010_00)					
Tulsa	30,178.2	10.6%	5.58E+12	n/a	1.51E+12
Jenks	11,196.8	3.9%	2.05E+12	n/a	5.57E+11
Sapulpa	14,712.9	5.2%	2.74E+12	n/a	7.42E+11
Bixby	9,001.8	3.2%	1.69E+12	n/a	4.57E+11
Tulsa County	545.4	0.2%	1.05E+11	n/a	2.85E+10
Creek County	4,670.0	1.6%	8.43E+11	n/a	2.28E+11
Total Watershed	285,591	24.6%	1.30E+13	n/a	3.51E+12
Haikey Creek (OK120410010210_00)					
Tulsa	5,681.4	24.0%	n/a	3.22E+09	n/a
Bixby	3,207.9	13.6%	n/a	1.82E+09	n/a
Broken Arrow	12,700.8	53.7%	n/a	7.20E+09	n/a
Tulsa Co.	626.4	2.6%	n/a	3.49E+08	n/a
Total Watershed	23,651.4	93.9%	n/a	1.26E+10	n/a
Arkansas River (OK120410010080_00) §					
Bixby	4,274.00	1.00%	n/a	n/a	1.74E+11
Broken Arrow	8,686.80	1.90%	n/a	n/a	3.31E+11
Coweta	5,328.90	1.20%	n/a	n/a	2.09E+11
Muskogee	5,074.00	1.10%	n/a	n/a	1.92E+11
Tulsa County	779.9	0.20%	n/a	n/a	3.48E+10
Wagoner County	673.3	0.20%	n/a	n/a	3.48E+10
Total Watershed	445,964	5.60%	n/a	n/a	9.75E+11

†Values are loads (cfu/day) based upon the median (50^{th} percentile) Load Allocation for each watershed (See Tables 5-4 and 5-7). This list does not include Oklahoma Department of Transportation and the Oklahoma Turnpike Authority. Their MS4 jurisdiction falls completely within other MS4s and likely accounts for a negligibly small area in the study watersheds.

§ TMDL allocations for Arkansas River (OK120410010080_00) are pending approval of the 2008 303(d) list by EPA.

5.7 Reasonable Assurances

ODEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources provide reasonable assurance that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. ODEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (ODEQ 2002). The CPP can be viewed from ODEQ's website at http://www.deq.state.ok.us/WQDnew/pubs/2002_cpp_final.pdf. Table 5-9 provides a partial list of the state partner agencies ODEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-9 Partial List of Oklahoma Water Quality Management Agencies

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

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

As authorized by Section 402 of the CWA, the ODEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by State Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES Program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES program. Implementation of point source WLAs is done through permits issued under the OPDES program. Each point source in the contributing watersheds will be issued an OPDES permit that sets fecal coliform limits in its effluent. Disinfection of the effluent will be required if these limits are not met.

The reduction rates called for in this TMDL report are as high as 81 percent. The ODEQ recognizes that achieving such high reductions may not be realistic, especially since unregulated nonpoint sources are a major cause of the impairment. The high reduction rates are not uncommon for pathogen impaired waters. Similar reduction rates are often found in other pathogen TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of the receiving stream should be reviewed. For example, Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the USEPA. Additionally, USEPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the near future.

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

Removing the PBCR use: This revision would require documentation in a Use Attainability Analysis that the use is not existing and cannot be attained. Since existing uses cannot be removed, it must be demonstrated that the use, in this case PBCR, does not exist or cannot be expected to exist.

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 bacteria violations occur over all flow ranges indicating significant natural and/or uncontrollable nonpoint sources, this approach has merit and should be considered.

Revising the existing numeric criteria: Oklahoma's current pathogen criteria are based on USEPA guidelines (See Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft; and Ambient Water Quality Criteria for Bacteria – 1986, January 1986). However, those guidelines have received much criticism and USEPA studies that could result in revisions to their recommendations are on-going. The use of the three indicators specified in Oklahoma's standards should be evaluated. The numeric criteria values should also be evaluated using a risk-based method such as that found in USEPA guidance.

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

SECTION 6 : PUBLIC PARTICIPATION

This TMDL report was sent to other related state agencies and local government agencies for peer review and was submitted to the EPA for technical review. The report was technically approved by the EPA on December 20, 2007. A public notice about this TMDL report was sent to local newspapers and through the TMDL mailing list on August 21, 2008. The public was given an opportunity to review the TMDL report and submit comments. The public comment period lasted for 45 days. Comments from three individuals/organizations were received .

All comments were responded and the report was updated accordingly. The response to comments was included in Appendix G of this report.

SECTION 7 : REFERENCES

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

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

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

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

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

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

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

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

Missouri Department of Natural Resources 2003, Total Maximum daily Loads (TMDLs) for Shoal Creek Newton and Barry Counties, Missouri.

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

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

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

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

Oklahoma Mesonet 2007. Viewed October 5, 2007 at http://www.mesonet.ou.edu/

OWRB 2006. Oklahoma Water Resources Board. *Oklahoma's Water Quality Standards*. Available at http://www.owrb.ok.gov/util/rules/pdf_rul/Chap45.pdf

OWRB 2007. Oklahoma Water Resources Board. *Implementation of Oklahoma's Water Quality Standards*. Available at http://www.owrb.ok.gov/util/rules/pdf_rul/Chap46.pdf

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

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

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

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

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

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

Agriculture. http://www.nass.usda.gov/Census/Create_Census_US_CNTY.jsp

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

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

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

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

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

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

APPENDIX A : AMBIENT WATER QUALITY BACTERIA DATA – 2002 TO 2006

WQM Station	Water Body Name	Date	Bacteria Conc. (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	05/08/02	30.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/03/02	100.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/08/02	50.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/03/02	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/30/02	50.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/02/03	100.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/18/03	20.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/07/03	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/29/03	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	08/11/03	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/15/03	200.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	10/01/03	400.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	05/23/06	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/12/06	63.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/26/06	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/05/06	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/24/06	10.0	EN	108
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	05/08/02	52.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/03/02	84.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/08/02	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/03/02	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/30/02	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/02/03	20.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/18/03	31.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/07/03	10.0	EC	406

WQM Station	Water Body Name	Date	Bacteria Conc. (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/29/03	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	08/11/03	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/15/03	231.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	10/01/03	63.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	05/23/06	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/12/06	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/26/06	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/05/06	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/24/06	10.0	EC	406
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	03/13/02	10.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	04/10/02	800.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	05/08/02	70.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/03/02	500.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/08/02	10.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/03/02	10.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/30/02	100.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/02/03	20.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/18/03	40.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/07/03	20.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/29/03	10.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	08/11/03	60.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	09/15/03	1100.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	10/01/03	70.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	05/23/06	40.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/12/06	20.0	FC	400

WQM Station	Water Body Name	Date	Bacteria Conc. (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	06/26/06	10.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/05/06	10.0	FC	400
120410010080-001AT	ARKANSAS RIVER, SH 104, HASKELL	07/24/06	130.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	05/29/02	75000.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/25/02	200.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/06/02	100.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/04/02	10.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/25/02	80.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	05/04/04	100.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/02/04	200.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/06/04	700.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/21/04	10.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/10/04	10.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/25/04	10.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/14/04	10.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/14/06	10.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/18/06	10.0	EN	108
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	05/29/02	4884.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/25/02	10.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/06/02	41.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/04/02	10.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/25/02	31.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	05/04/04	108.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/02/04	52.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/06/04	74.0	EC	406

WQM Station	Water Body Name	Date	Bacteria Conc. (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/21/04	10.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/10/04	20.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/25/04	31.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/14/04	10.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/14/06	20.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/18/06	10.0	EC	406
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	05/29/02	17000.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/25/02	100.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/06/02	100.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/04/02	30.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/25/02	30.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	05/04/04	200.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/02/04	300.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/06/04	500.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/21/04	110.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/10/04	20.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	08/25/04	100.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	09/14/04	10.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	06/14/06	10.0	FC	400
121400010260-001AT	ARKANSAS RIVER, US 62, MUSKOGEE	07/18/06	100.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	05/08/02	150.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/03/02	200.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/08/02	10.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/03/02	50.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/30/02	60.0	EN	108

WQM Station	Water Body Name	Date	Bacteria Conc. (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/02/03	4000.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/18/03	70.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/07/03	110.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/29/03	300.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	08/11/03	1700.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/15/03	800.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	10/01/03	170.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	05/23/06	31.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/12/06	10.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/26/06	471.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/05/06	323.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/24/06	243.0	EN	108
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	05/08/02	30.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/03/02	228.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/08/02	10.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/03/02	31.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/30/02	122.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/02/03	836.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/18/03	20.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/07/03	73.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/29/03	31.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	08/11/03	512.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/15/03	146.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	10/01/03	408.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	05/23/06	107.0	EC	406

WQM Station	Water Body Name	Date	Bacteria Conc. (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/12/06	85.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/26/06	235.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/05/06	41.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/24/06	10.0	EC	406
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	05/08/02	80.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/03/02	1200.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/08/02	10.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/03/02	100.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/30/02	100.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/02/03	6000.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/18/03	120.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/07/03	800.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/29/03	200.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	08/11/03	6700.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	09/15/03	500.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	10/01/03	1100.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	05/23/06	200.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/12/06	410.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	06/26/06	1190.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/05/06	720.0	FC	400
120420010010-001AT	ARKANSAS RIVER, US 64, BIXBY	07/24/06	210.0	FC	400
OK120410-01-0210G	Haikey Creek: 121st Street	5/23/2002	345	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	6/20/2002	517	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	7/18/2002	205	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	8/22/2002	109	EC	406

WQM Station	Water Body Name	Date	Bacteria Conc. (#/100ml)	Bacterial indicator	Single Sample Criteria (#/100ml)
OK120410-01-0210G	Haikey Creek: 121st Street	9/19/2002	>2419	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	6/26/2003	>2400	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	7/24/2003	580	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	8/21/2003	435	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	9/25/2003	229	EC	406
OK120410-01-0210G	Haikey Creek: 121st Street	9/16/2004	110	EC	406

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

APPENDIX B : NPDES PERMIT DISCHARGE MONITORING REPORT DATA

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
Bixby North	OK0036153	Fecal Coliform	8/31/2006			#/100mL		230	230
Bixby North	OK0036153	Fecal Coliform	9/30/2006			#/100mL		303	540
Bixby North	OK0036153	Flow (MGD)	1/31/2005	0.64	0.9				
Bixby North	OK0036153	Flow (MGD)	2/28/2005	0.61	0.69				
Bixby North	OK0036153	Flow (MGD)	3/31/2005	0.6	0.69				
Bixby North	OK0036153	Flow (MGD)	4/30/2005	0.61	0.69				
Bixby North	OK0036153	Flow (MGD)	5/31/2005	0.65	0.69				
Bixby North	OK0036153	Flow (MGD)	6/30/2005	0.67	0.84				
Bixby North	OK0036153	Flow (MGD)	7/31/2005	0.62	0.64				
Bixby North	OK0036153	Flow (MGD)	8/31/2005	0.71	0.95				
Bixby North	OK0036153	Flow (MGD)	9/30/2005	0.66	0.76				
Bixby North	OK0036153	Flow (MGD)	10/31/2005	0.65	0.74				
Bixby North	OK0036153	Flow (MGD)	11/30/2005	0.51	0.7				
Bixby North	OK0036153	Flow (MGD)	12/31/2005	0.76	0.83				
Bixby North	OK0036153	Flow (MGD)	1/31/2006	0.75	0.82				
Bixby North	OK0036153	Flow (MGD)	2/28/2006	0.77	0.93				
Bixby North	OK0036153	Flow (MGD)	3/31/2006	0.83	0.91				
Bixby North	OK0036153	Flow (MGD)	4/30/2006	0.52	0.69				
Bixby North	OK0036153	Flow (MGD)	5/31/2006	0.79	1.03				
Bixby North	OK0036153	Flow (MGD)	6/30/2006	0.78	0.97				
Bixby North	OK0036153	Flow (MGD)	7/31/2006	0.83	1.5				
Bixby North	OK0036153	Flow (MGD)	8/31/2006	0.809	1.017				
Bixby North	OK0036153	Flow (MGD)	9/30/2006	0.7977	0.9				
Bixby North	OK0036153	Flow (MGD)	10/31/2006	0.815	1.02				
Bixby North	OK0036153	Flow (MGD)	11/30/2006	0.882	1.021				
Bixby North	OK0036153	Flow (MGD)	12/31/2006	0.952	1.361				
Bixby North	OK0036153	Flow (MGD)	1/31/2007	0.908	1.005				
Bixby North	OK0036153	Flow (MGD)	2/28/2007	0.853	0.95				
Bixby North	OK0036153	Flow (MGD)	3/31/2007	0.685	0.931				
Bixby North	OK0036153	Flow (MGD)	4/30/2007	0.727	0.797				
Bixby South	OK0026913	Fecal Coliform	1/31/2005			#/100mL		5.5	11
Bixby South	OK0026913	Fecal Coliform	2/28/2005			#/100mL		6.2	7.4
Bixby South	OK0026913	Fecal Coliform	3/31/2005			#/100mL		10	13
Bixby South	OK0026913	Fecal Coliform	4/30/2005			#/100mL		14.25	24.5
Bixby South	OK0026913	Fecal Coliform	5/31/2005			#/100mL		5.9	8.2
Bixby South	OK0026913	Fecal Coliform	6/30/2005			#/100mL		3.5	5
Bixby South	OK0026913	Fecal Coliform	7/31/2005			#/100mL		9.7	12.1
Bixby South	OK0026913	Fecal Coliform	8/31/2005			#/100mL		10.5	13
Bixby South	OK0026913	Fecal Coliform	9/30/2005			#/100mL		8	14
Bixby South	OK0026913	Fecal Coliform	10/31/2005			#/100mL		2.7	2.7
Bixby South	OK0026913	Fecal Coliform	11/30/2005			#/100mL		2.95	4.9
Bixby South	OK0026913	Fecal Coliform	12/31/2005			#/100mL		1.8	3.6

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
Bixby South	OK0026913	Fecal Coliform	1/31/2006			#/100mL		2.45	4.9
Bixby South	OK0026913	Fecal Coliform	2/28/2006			#/100mL		0.95	1.9
Bixby South	OK0026913	Fecal Coliform	3/31/2006			#/100mL		3.4	4.9
Bixby South	OK0026913	Fecal Coliform	4/30/2006			#/100mL		7	11
Bixby South	OK0026913	Fecal Coliform	5/31/2006			#/100mL		8.8	11
Bixby South	OK0026913	Fecal Coliform	6/30/2006			#/100mL		1	2
Bixby South	OK0026913	Fecal Coliform	7/31/2006			#/100mL		4.35	6.7
Bixby South	OK0026913	Fecal Coliform	8/31/2006			#/100mL		28	28
Bixby South	OK0026913	Fecal Coliform	9/30/2006			#/100mL		68	68
Bixby South	OK0026913	Fecal Coliform	10/31/2006			#/100mL		51.5	86
Bixby South	OK0026913	Fecal Coliform	11/30/2006			#/100mL		340	620
Bixby South	OK0026913	Fecal Coliform	12/31/2006			#/100mL		903	1456
Bixby South	OK0026913	Fecal Coliform	1/31/2007			#/100mL		2600	2700
Bixby South	OK0026913	Fecal Coliform	2/28/2007			#/100mL		900	1260
Bixby South	OK0026913	Fecal Coliform	3/31/2007			#/100mL		2060	3500
Bixby South	OK0026913	Fecal Coliform	4/30/2007			#/100mL		225	250
Bixby South	OK0026913	Flow (MGD)	1/31/2005	0.37	0.43				
Bixby South	OK0026913	Flow (MGD)	2/28/2005	0.34	0.37				
Bixby South	OK0026913	Flow (MGD)	3/31/2005	0.3	0.34				
Bixby South	OK0026913	Flow (MGD)	4/30/2005	0.3	0.35				
Bixby South	OK0026913	Flow (MGD)	5/31/2005	0.28	0.33				
Bixby South	OK0026913	Flow (MGD)	6/30/2005	0.27	0.36				
Bixby South	OK0026913	Flow (MGD)	7/31/2005	0.25	0.3				
Bixby South	OK0026913	Flow (MGD)	8/31/2005	0.34	0.5				
Bixby South	OK0026913	Flow (MGD)	9/30/2005	0.3	0.34				
Bixby South	OK0026913	Flow (MGD)	10/31/2005	0.29	0.31				
Bixby South	OK0026913	Flow (MGD)	11/30/2005	0.29	0.31				
Bixby South	OK0026913	Flow (MGD)	12/31/2005	0.33	0.38				
Bixby South	OK0026913	Flow (MGD)	1/31/2006	0.29	0.34				
Bixby South	OK0026913	Flow (MGD)	2/28/2006	0.32	0.36				
Bixby South	OK0026913	Flow (MGD)	3/31/2006	0.32	0.4				
Bixby South	OK0026913	Flow (MGD)	4/30/2006	0.29	0.31				
Bixby South	OK0026913	Flow (MGD)	5/31/2006	0.42	0.5				
Bixby South	OK0026913	Flow (MGD)	6/30/2006	0.34	0.44				
Bixby South	OK0026913	Flow (MGD)	7/31/2006	0.36	0.53				
Bixby South	OK0026913	Flow (MGD)	8/31/2006	0.291	0.399				
Bixby South	OK0026913	Flow (MGD)	9/30/2006	0.344	0.365				
Bixby South	OK0026913	Flow (MGD)	10/31/2006	0.32	0.399				
Bixby South	OK0026913	Flow (MGD)	11/30/2006	0.332	0.421				
Bixby South	OK0026913	Flow (MGD)	12/31/2006	0.4105	0.543				
Bixby South	OK0026913	Flow (MGD)	1/31/2007	0.449	0.525				
Bixby South	OK0026913	Flow (MGD)	2/28/2007	0.408	0.465				
Bixby South	OK0026913	Flow (MGD)	3/31/2007	0.388	0.438				
Bixby South	OK0026913	Flow (MGD)	4/30/2007	0.396	0.48				

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
Broken Arrow	OK0040053	Fecal Coliform	5/31/2005			#/100mL		9	43
Broken Arrow	OK0040053	Fecal Coliform	6/30/2005			#/100mL		4.8	13.3
Broken Arrow	OK0040053	Fecal Coliform	7/31/2005			#/100mL		5.5	7.5
Broken Arrow	OK0040053	Fecal Coliform	8/31/2005			#/100mL		26	79
Broken Arrow	OK0040053	Fecal Coliform	9/30/2005			#/100mL		27	29
Broken Arrow	OK0040053	Fecal Coliform	5/31/2006			#/100mL		36	53
Broken Arrow	OK0040053	Fecal Coliform	6/30/2006			#/100mL		50	150
Broken Arrow	OK0040053	Fecal Coliform	7/31/2006			#/100mL		36	56
Broken Arrow	OK0040053	Fecal Coliform	8/31/2006			#/100mL		28	62
Broken Arrow	OK0040053	Fecal Coliform	9/30/2006			#/100mL		71	133
Broken Arrow	OK0040053	Flow (MGD)	1/31/2005	3.686	6.881				
Broken Arrow	OK0040053	Flow (MGD)	2/28/2005	3.651	4.844				
Broken Arrow	OK0040053	Flow (MGD)	3/31/2005	3.447	4.322				
Broken Arrow	OK0040053	Flow (MGD)	4/30/2005	3.509	5.446				
Broken Arrow	OK0040053	Flow (MGD)	5/31/2005	2.893	3.419				
Broken Arrow	OK0040053	Flow (MGD)	6/30/2005	2.842	3.702				
Broken Arrow	OK0040053	Flow (MGD)	7/31/2005	2.684	3.145				
Broken Arrow	OK0040053	Flow (MGD)	8/31/2005	3.261	5.531				
Broken Arrow	OK0040053	Flow (MGD)	9/30/2005	2.992	4.056				
Broken Arrow	OK0040053	Flow (MGD)	10/31/2005	2.801	3.569				
Broken Arrow	OK0040053	Flow (MGD)	11/30/2005	2.694	3.19				
Broken Arrow	OK0040053	Flow (MGD)	12/31/2005	2.678	3.161				
Broken Arrow	OK0040053	Flow (MGD)	1/31/2006	2.762	3.307				
Broken Arrow	OK0040053	Flow (MGD)	2/28/2006	2.776	3.177				
Broken Arrow	OK0040053	Flow (MGD)	3/31/2006	2.964	4.78				
Broken Arrow	OK0040053	Flow (MGD)	4/30/2006	3.117	6.255				
Broken Arrow	OK0040053	Flow (MGD)	5/31/2006	3.674	6.338				
Broken Arrow	OK0040053	Flow (MGD)	6/30/2006	2.745	3.562				
Broken Arrow	OK0040053	Flow (MGD)	7/31/2006	2.778	4.236				
Broken Arrow	OK0040053	Flow (MGD)	8/31/2006	2.944	5.119				
Broken Arrow	OK0040053	Flow (MGD)	9/30/2006	3.019	4.504				
Broken Arrow	OK0040053	Flow (MGD)	10/31/2006	2.999	3.998				
Broken Arrow	OK0040053	Flow (MGD)	11/30/2006	2.933	4.023				
Broken Arrow	OK0040053	Flow (MGD)	12/31/2006	3.8	6.275				
Broken Arrow	OK0040053	Flow (MGD)	1/31/2007	4.032	6.305				
Broken Arrow	OK0040053	Flow (MGD)	2/28/2007	3.602	4.817				
Broken Arrow	OK0040053	Flow (MGD)	3/31/2007	3.5	4.633				
Broken Arrow	OK0040053	Flow (MGD)	4/30/2007	3.882	5.27				
Coweta	OK0020281	Flow (MGD)	1/31/2005	1.07	2.25				
Coweta	OK0020281	Flow (MGD)	2/28/2005	1.06	1.8				
Coweta	OK0020281	Flow (MGD)	3/31/2005	0.806	1.17				
Coweta	OK0020281	Flow (MGD)	4/30/2005	0.789	1.47				
Coweta	OK0020281	Flow (MGD)	5/31/2005	0.677	1.11				
Coweta	OK0020281	Flow (MGD)	6/30/2005	0.59	0.99				

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
Coweta	OK0020281	Flow (MGD)	7/31/2005	0.557	1				
Coweta	OK0020281	Flow (MGD)	8/31/2005	0.718	1.44				
Coweta	OK0020281	Flow (MGD)	9/30/2005	0.578	0.97				
Coweta	OK0020281	Flow (MGD)	10/31/2005	0.528	0.67				
Coweta	OK0020281	Flow (MGD)	11/30/2005	0.49	0.62				
Coweta	OK0020281	Flow (MGD)	12/31/2005	0.499	0.64				
Coweta	OK0020281	Flow (MGD)	1/31/2006	0.499	0.65				
Coweta	OK0020281	Flow (MGD)	2/28/2006	0.498	0.62				
Coweta	OK0020281	Flow (MGD)	3/31/2006	0.548	0.99				
Coweta	OK0020281	Flow (MGD)	4/30/2006	0.586	1.66				
Coweta	OK0020281	Flow (MGD)	5/31/2006	0.783	1.67				
Coweta	OK0020281	Flow (MGD)	6/30/2006	0.486	0.56				
Coweta	OK0020281	Flow (MGD)	7/31/2006	0.54	1.27				
Coweta	OK0020281	Flow (MGD)	8/31/2006	0.52	0.82				
Coweta	OK0020281	Flow (MGD)	9/30/2006	0.53	1.2				
Coweta	OK0020281	Flow (MGD)	10/31/2006	0.5	0.88				
Coweta	OK0020281	Flow (MGD)	11/30/2006	0.544	1.64				
Coweta	OK0020281	Flow (MGD)	12/31/2006	0.789	1.84				
Coweta	OK0020281	Flow (MGD)	1/31/2007	0.986	1.87				
Coweta	OK0020281	Flow (MGD)	2/28/2007	0.79	1.14				
Coweta	OK0020281	Flow (MGD)	3/31/2007	0.716	1.03				
Coweta	OK0020281	Flow (MGD)	4/30/2007	0.769	1.32				
Glenpool	OK0027138	Flow (MGD)	1/31/2005	0.973	1.851				
Glenpool	OK0027138	Flow (MGD)	2/28/2005	1.007	1.373				
Glenpool	OK0027138	Flow (MGD)	3/31/2005	0.753	0.991				
Glenpool	OK0027138	Flow (MGD)	4/30/2005	0.793	1.32				
Glenpool	OK0027138	Flow (MGD)	5/31/2005	0.7385	1.314				
Glenpool	OK0027138	Flow (MGD)	6/30/2005	0.7092	1.591				
Glenpool	OK0027138	Flow (MGD)	7/31/2005	0.545	0.67				
Glenpool	OK0027138	Flow (MGD)	8/31/2005	0.7076	1.396				
Glenpool	OK0027138	Flow (MGD)	9/30/2005	0.535	0.702				
Glenpool	OK0027138	Flow (MGD)	10/31/2005	0.536	0.875				
Glenpool	OK0027138	Flow (MGD)	11/30/2005	0.455	0.615				
Glenpool	OK0027138	Flow (MGD)	12/31/2005	0.532	1.114				
Glenpool	OK0027138	Flow (MGD)	1/31/2006	0.487	0.552				
Glenpool	OK0027138	Flow (MGD)	2/28/2006	0.488	0.569				
Glenpool	OK0027138	Flow (MGD)	3/31/2006	0.548	0.867				
Glenpool	OK0027138	Flow (MGD)	4/30/2006	0.5886	1.287				
Glenpool	OK0027138	Flow (MGD)	5/31/2006	0.851	2.476				
Glenpool	OK0027138	Flow (MGD)	6/30/2006	0.674	1.168				
Glenpool	OK0027138	Flow (MGD)	7/31/2006	0.6088	1.335				
Glenpool	OK0027138	Flow (MGD)	8/31/2006	0.636	1.055				
Glenpool	OK0027138	Flow (MGD)	9/30/2006	0.629	1.143				
Glenpool	OK0027138	Flow (MGD)	10/31/2006	0.616	0.983				

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
Glenpool	OK0027138	Flow (MGD)	11/30/2006	0.6488	1.799				
Glenpool	OK0027138	Flow (MGD)	12/31/2006	0.9366	2.011				
Glenpool	OK0027138	Flow (MGD)	1/31/2007	1.162	1.836				
Glenpool	OK0027138	Flow (MGD)	2/28/2007	0.991	1.635				
Glenpool	OK0027138	Flow (MGD)	3/31/2007	0.9574	2.092				
Glenpool	OK0027138	Flow (MGD)	4/30/2007	1.032					
Haskell	OK0032271	Flow (MGD)	5/31/2005	0.39	0.39				
Jenks	OK0037401	Flow (MGD)	1/31/2005	1.248	1.607				
Jenks	OK0037401	Flow (MGD)	2/28/2005	1.275	1.556				
Jenks	OK0037401	Flow (MGD)	3/31/2005	1.126	1.392				
Jenks	OK0037401	Flow (MGD)	4/30/2005	1.131	1.304				
Jenks	OK0037401	Flow (MGD)	5/31/2005	1.102	1.33				
Jenks	OK0037401	Flow (MGD)	6/30/2005	0.952	1.273				
Jenks	OK0037401	Flow (MGD)	7/31/2005	0.944	1.14				
Jenks	OK0037401	Flow (MGD)	8/31/2005	1.154	1.476				
Jenks	OK0037401	Flow (MGD)	9/30/2005	1.044	1.161				
Jenks	OK0037401	Flow (MGD)	10/31/2005	1.015	1.184				
Jenks	OK0037401	Flow (MGD)	11/30/2005	1.065	1.192				
Jenks	OK0037401	Flow (MGD)	12/31/2005	1.042	1.171				
Jenks	OK0037401	Flow (MGD)	1/31/2006	1.076	1.523				
Jenks	OK0037401	Flow (MGD)	2/28/2006	1.027	1.187				
Jenks	OK0037401	Flow (MGD)	3/31/2006	1.048	1.305				
Jenks	OK0037401	Flow (MGD)	4/30/2006	1.09	1.427				
Jenks	OK0037401	Flow (MGD)	5/31/2006	1.29	1.715				
Jenks	OK0037401	Flow (MGD)	6/30/2006	1.156	1.517				
Jenks	OK0037401	Flow (MGD)	7/31/2006	1.175	1.366				
Jenks	OK0037401	Flow (MGD)	8/31/2006	1.126	1.427				
Jenks	OK0037401	Flow (MGD)	9/30/2006	1.231	1.702				
Jenks	OK0037401	Flow (MGD)	10/31/2006	1.112	1.449				
Jenks	OK0037401	Flow (MGD)	11/30/2006	1.106	1.239				
Jenks	OK0037401	Flow (MGD)	12/31/2006	1.324	2.039				
Jenks	OK0037401	Flow (MGD)	1/31/2007	1.527	2.275				
Jenks	OK0037401	Flow (MGD)	2/28/2007	1.372	1.577				
Jenks	OK0037401	Flow (MGD)	3/31/2007	1.26	1.959				
Jenks	OK0037401	Flow (MGD)	4/30/2007	1.3996	1.744				
RMUA Haikey Creek	OK0034363	Fecal Coliform	5/31/2005			#/100mL		4	24
RMUA Haikey Creek	OK0034363	Fecal Coliform	6/30/2005			#/100mL		8	138
RMUA Haikey Creek	OK0034363	Fecal Coliform	7/31/2005			#/100mL		8	172
RMUA Haikey Creek	OK0034363	Fecal Coliform	8/31/2005			#/100mL		> 5	T
RMUA Haikey Creek	OK0034363	Fecal Coliform	9/30/2005			#/100mL		6	138
RMUA Haikey Creek	OK0034363	Fecal Coliform	5/31/2006			#/100mL		14	

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
RMUA Haikey Creek	OK0034363	Fecal Coliform	6/30/2006			#/100mL		8	
RMUA Haikey Creek	OK0034363	Fecal Coliform	7/31/2006			#/100mL		12	
RMUA Haikey Creek	OK0034363	Fecal Coliform	8/31/2006			#/100mL		11	
RMUA Haikey Creek	OK0034363	Fecal Coliform	9/30/2006			#/100mL		7	
RMUA Haikey Creek	OK0034363	Fecal Coliform	5/31/2006			Percent			0
RMUA Haikey Creek	OK0034363	Fecal Coliform	6/30/2006			Percent			0
RMUA Haikey Creek	OK0034363	Fecal Coliform	7/31/2006			Percent			0
RMUA Haikey Creek	OK0034363	Fecal Coliform	8/31/2006			Percent			0
RMUA Haikey Creek	OK0034363	Fecal Coliform	9/30/2006			Percent			5
RMUA Haikey Creek	OK0034363	Flow (MGD)	1/31/2005	10.61	13.48				
RMUA Haikey Creek	OK0034363	Flow (MGD)	2/28/2005	11	13.79				
RMUA Haikey Creek	OK0034363	Flow (MGD)	3/31/2005	9.93	11.5				
RMUA Haikey Creek	OK0034363	Flow (MGD)	4/30/2005	10.54	13.1				
RMUA Haikey Creek	OK0034363	Flow (MGD)	5/31/2005	10.15	12.45				
RMUA Haikey Creek	OK0034363	Flow (MGD)	6/30/2005	9.63	11.53				
RMUA Haikey Creek	OK0034363	Flow (MGD)	7/31/2005	9.13	10.14				
RMUA Haikey Creek	OK0034363	Flow (MGD)	8/31/2005	10.4	12.97				
RMUA Haikey Creek	OK0034363	Flow (MGD)	9/30/2005	9.78	11.53				
RMUA Haikey Creek	OK0034363	Flow (MGD)	10/31/2005	9.13	10.46				
RMUA Haikey Creek	OK0034363	Flow (MGD)	11/30/2005	8.98	10.82				
RMUA Haikey Creek	OK0034363	Flow (MGD)	12/31/2005	9.93	10.83				
RMUA Haikey Creek	OK0034363	Flow (MGD)	1/31/2006	9.61	11.33				
RMUA Haikey Creek	OK0034363	Flow (MGD)	2/28/2006	9.61	10.3				
RMUA Haikey Creek	OK0034363	Flow (MGD)	3/31/2006	9.03	10.9				
RMUA Haikey Creek	OK0034363	Flow (MGD)	4/30/2006	10.08	13.95				
RMUA Haikey Creek	OK0034363	Flow (MGD)	5/31/2006	11.23	14.02				
RMUA Haikey Creek	OK0034363	Flow (MGD)	6/30/2006	9.89	11.15				
RMUA Haikey Creek	OK0034363	Flow (MGD)	7/31/2006	9.5	12.17				

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
RMUA Haikey Creek	OK0034363	Flow (MGD)	8/31/2006	9.54	12.92				
RMUA Haikey Creek	OK0034363	Flow (MGD)	9/30/2006	9.28	11.14				
RMUA Haikey Creek	OK0034363	Flow (MGD)	10/31/2006	9.24	11				
RMUA Haikey Creek	OK0034363	Flow (MGD)	11/30/2006	9.33	10.56				
RMUA Haikey Creek	OK0034363	Flow (MGD)	12/31/2006	10.55	13.32				
RMUA Haikey Creek	OK0034363	Flow (MGD)	1/31/2007	11.56	14.42				
RMUA Haikey Creek	OK0034363	Flow (MGD)	2/28/2007	10.53	12.92				
RMUA Haikey Creek	OK0034363	Flow (MGD)	3/31/2007	10.35	13.55				
RMUA Haikey Creek	OK0034363	Flow (MGD)	4/30/2007	10.61	13.29				
Tulsa SouthSide	OK0026239	Fecal Coliform	5/31/2005			#/100mL		22	
Tulsa SouthSide	OK0026239	Fecal Coliform	6/30/2005			#/100mL		43	
Tulsa SouthSide	OK0026239	Fecal Coliform	7/31/2005			#/100mL		21	
Tulsa SouthSide	OK0026239	Fecal Coliform	8/31/2005			#/100mL		6	
Tulsa SouthSide	OK0026239	Fecal Coliform	9/30/2005			#/100mL		3	
Tulsa SouthSide	OK0026239	Fecal Coliform	5/31/2006			#/100mL		23	
Tulsa SouthSide	OK0026239	Fecal Coliform	6/30/2006			#/100mL		7	
Tulsa SouthSide	OK0026239	Fecal Coliform	7/31/2006			#/100mL		7	
Tulsa SouthSide	OK0026239	Fecal Coliform	8/31/2006			#/100mL		3	
Tulsa SouthSide	OK0026239	Fecal Coliform	9/30/2006			#/100mL		4	
Tulsa SouthSide	OK0026239	Fecal Coliform	5/31/2005			#/100mL		9	
Tulsa SouthSide	OK0026239	Fecal Coliform	6/30/2005			#/100mL		5	
Tulsa SouthSide	OK0026239	Fecal Coliform	5/31/2005			Percent			3.2
Tulsa SouthSide	OK0026239	Fecal Coliform	6/30/2005			Percent			16.7
Tulsa SouthSide	OK0026239	Fecal Coliform	7/31/2005			Percent			19.4
Tulsa SouthSide	OK0026239	Fecal Coliform	8/31/2005			Percent			0
Tulsa SouthSide	OK0026239	Fecal Coliform	9/30/2005			Percent			0
Tulsa SouthSide	OK0026239	Fecal Coliform	5/31/2006			Percent			3.2
Tulsa SouthSide	OK0026239	Fecal Coliform	6/30/2006			Percent			6.7

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
Tulsa SouthSide	OK0026239	Fecal Coliform	7/31/2006			Percent			6.5
Tulsa SouthSide	OK0026239	Fecal Coliform	8/31/2006			Percent			0
Tulsa SouthSide	OK0026239	Fecal Coliform	9/30/2006			Percent			0
Tulsa SouthSide	OK0026239	Fecal Coliform	5/31/2005			Percent			0
Tulsa SouthSide	OK0026239	Fecal Coliform	6/30/2005			Percent			3.4
Tulsa SouthSide	OK0026239	Flow (MGD)	1/31/2005	14.2	32.78				
Tulsa SouthSide	OK0026239	Flow (MGD)	2/28/2005	13.59	16.33				
Tulsa SouthSide	OK0026239	Flow (MGD)	3/31/2005	10.96	12.41				
Tulsa SouthSide	OK0026239	Flow (MGD)	4/30/2005	14.12	20.34				
Tulsa SouthSide	OK0026239	Flow (MGD)	5/31/2005	11.6	14.98				
Tulsa SouthSide	OK0026239	Flow (MGD)	6/30/2005	10.84	16.88				
Tulsa SouthSide	OK0026239	Flow (MGD)	7/31/2005	22.2	31.6				
Tulsa SouthSide	OK0026239	Flow (MGD)	8/31/2005	22.03	30.28				
Tulsa SouthSide	OK0026239	Flow (MGD)	9/30/2005	21.97	33.9				
Tulsa SouthSide	OK0026239	Flow (MGD)	10/31/2005	20.47	28.92				
Tulsa SouthSide	OK0026239	Flow (MGD)	11/30/2005	18.84	22.48				
Tulsa SouthSide	OK0026239	Flow (MGD)	12/31/2005	18.35	21.24				
Tulsa SouthSide	OK0026239	Flow (MGD)	1/31/2006	18.7	20.31				
Tulsa SouthSide	OK0026239	Flow (MGD)	2/28/2006	19.01	21.71				
Tulsa SouthSide	OK0026239	Flow (MGD)	3/31/2006	19.87	28.58				
Tulsa SouthSide	OK0026239	Flow (MGD)	4/30/2006	22.3	48.8				
Tulsa SouthSide	OK0026239	Flow (MGD)	5/31/2006	23.97	42.5				
Tulsa SouthSide	OK0026239	Flow (MGD)	6/30/2006	21.44	31.49				
Tulsa SouthSide	OK0026239	Flow (MGD)	7/31/2006	21.3	33.5				
Tulsa SouthSide	OK0026239	Flow (MGD)	8/31/2006	21.34	27.63				
Tulsa SouthSide	OK0026239	Flow (MGD)	9/30/2006	19.36	22.68				
Tulsa SouthSide	OK0026239	Flow (MGD)	10/31/2006	18.9	24.63				
Tulsa SouthSide	OK0026239	Flow (MGD)	11/30/2006	18.83	24.6				

FACILITY	OPDES	PARAMETER	MONITORING END DATE	QUANTITY (lbs/d)		CONCENTRATION			
				Avg.	Max.	Units	Min.	Avg.	Max.
Tulsa SouthSide	OK0026239	Flow (MGD)	12/31/2006	24.23	47.7				
Tulsa SouthSide	OK0026239	Flow (MGD)	1/31/2007	24.73	36.54				
Tulsa SouthSide	OK0026239	Flow (MGD)	2/28/2007	22.63	31.59				
Tulsa SouthSide	OK0026239	Flow (MGD)	3/31/2007	23.03	35.92				
Tulsa SouthSide	OK0026239	Flow (MGD)	4/30/2007	24.78	32.95				
Tulsa SouthSide	OK0026239	Flow (MGD)	1/31/2005	14.11	29.56				
Tulsa SouthSide	OK0026239	Flow (MGD)	2/28/2005	12.07	14.25				
Tulsa SouthSide	OK0026239	Flow (MGD)	3/31/2005	11.75	12.47				
Tulsa SouthSide	OK0026239	Flow (MGD)	4/30/2005	9.97	18.93				
Tulsa SouthSide	OK0026239	Flow (MGD)	5/31/2005	9.49	14.69				
Tulsa SouthSide	OK0026239	Flow (MGD)	6/30/2005	10.29	19.26				

APPENDIX C: DURATION CURVE DEVELOPMENT

Flow data was obtained from three USGS gage stations, one on each of the three TMDL segments in the Study Area. Flows in the Arkansas River within the Study Area are substantially dependent upon releases from Keystone Dam upstream of the Study Area. These releases frequently fluctuate between around a thousand cfs to over 10,000 cfs on a daily basis, with high flow nighttime releases for a few hours being common. The significant artificial flow regime is due to the US Army Corps of Engineers routine and seasonal management of the Keystone Lake reservoir pool, which includes consideration of downstream requirements for water quality and habitat protection for listed species of Least Terns and Bald Eagles. In addition, the Southwest Power Administration (SWPA) controls frequent daily releases from their allocated water rights for hydropower generation. The SWPA releases provide the greatest daily fluctuations of water flows in the Arkansas River.

Because of these artificial and very significant release requirements, flows in the Arkansas River within the Study Area are essentially independent of rainfall and runoff events. Consequently, it is not possible to employ a watershed runoff model approach to estimate flows in the Arkansas River within the Study Area based upon rainfall amounts and runoff potentials. Fortunately, each of the three TMDL segments has a USGS flow gage with many years of continuous flow monitoring data. These data were used to develop the Flow Duration Curve for each segment.

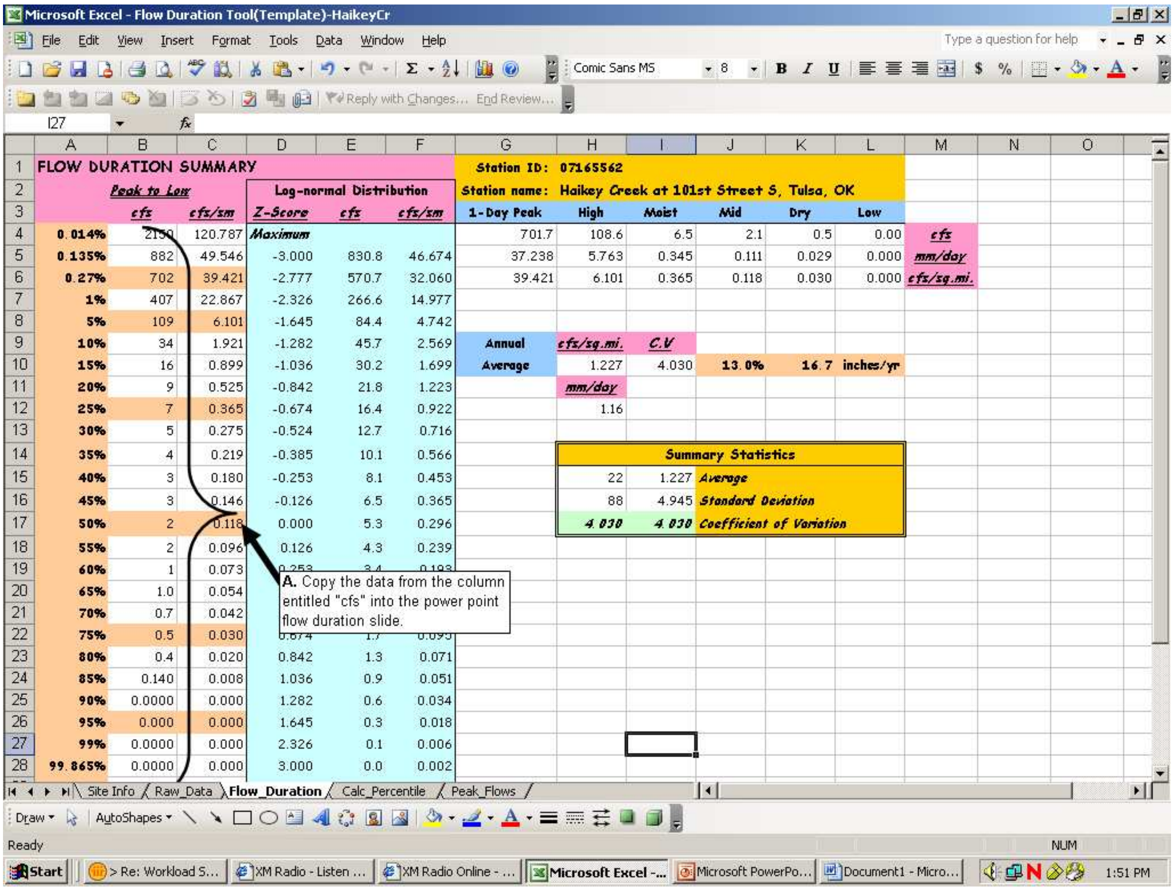
The Flow Duration Curve (FDC) spreadsheet and Flow Analysis PowerPoint file for displaying FDC results graphically were provided by Bruce Cleland of EPA Region 10. Curry Jones of EPA Region 6 prepared the following instructions to help with the Excel and PowerPoint tools developed by Bruce Cleland. Andrew Fang of ODEQ assisted with review of FDC preparations for this TMDL, and modifications to the spreadsheets and calculations were made based upon comments received from these sources. The spreadsheet and PowerPoint files can be obtained from ODEQ upon request. The following FDC instructions were prepared by Curry Jones for these tools.

Flow and Load Duration Curve Development Step-by-Step

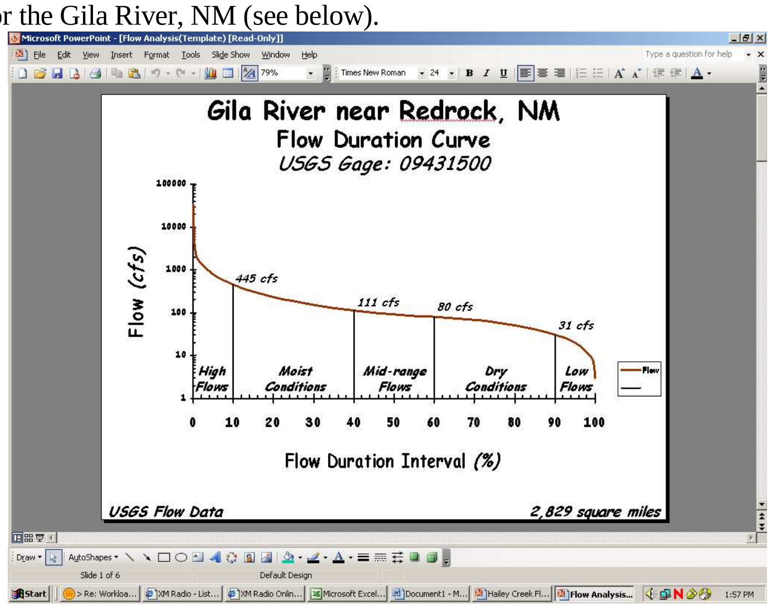
1. Open up the Flow Duration Tool(Template)-Haikey Creek. Once you have pasted your flow data into the Site_Info. tab and into the Raw_Data tab, then go to the Flow_Duration tab. Column B (as shown below) will have your flow duration data processed. The data is ranked from highest flow to lowest flow.

Flow Duration Curve Analysis

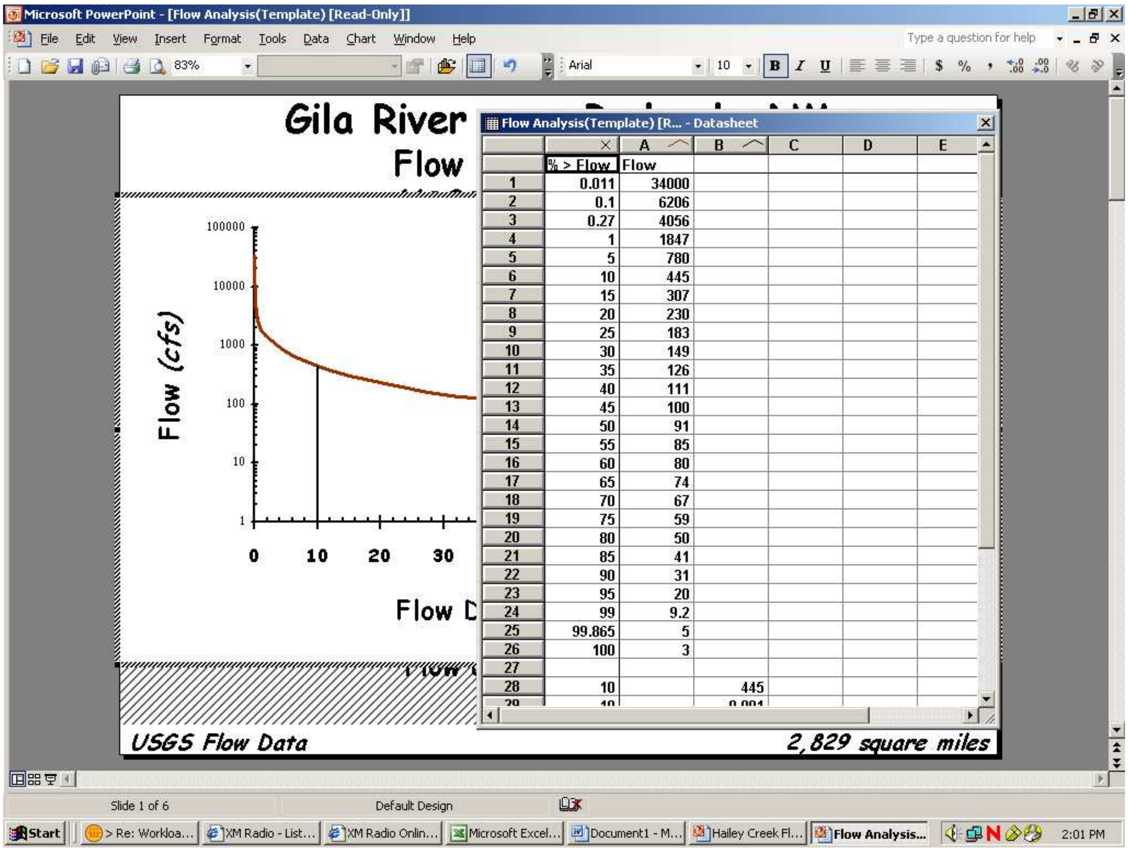
2. To create the flow duration curve in power point, click in column b4 and drag your mouse down to cell b29. Right click and copy this information.



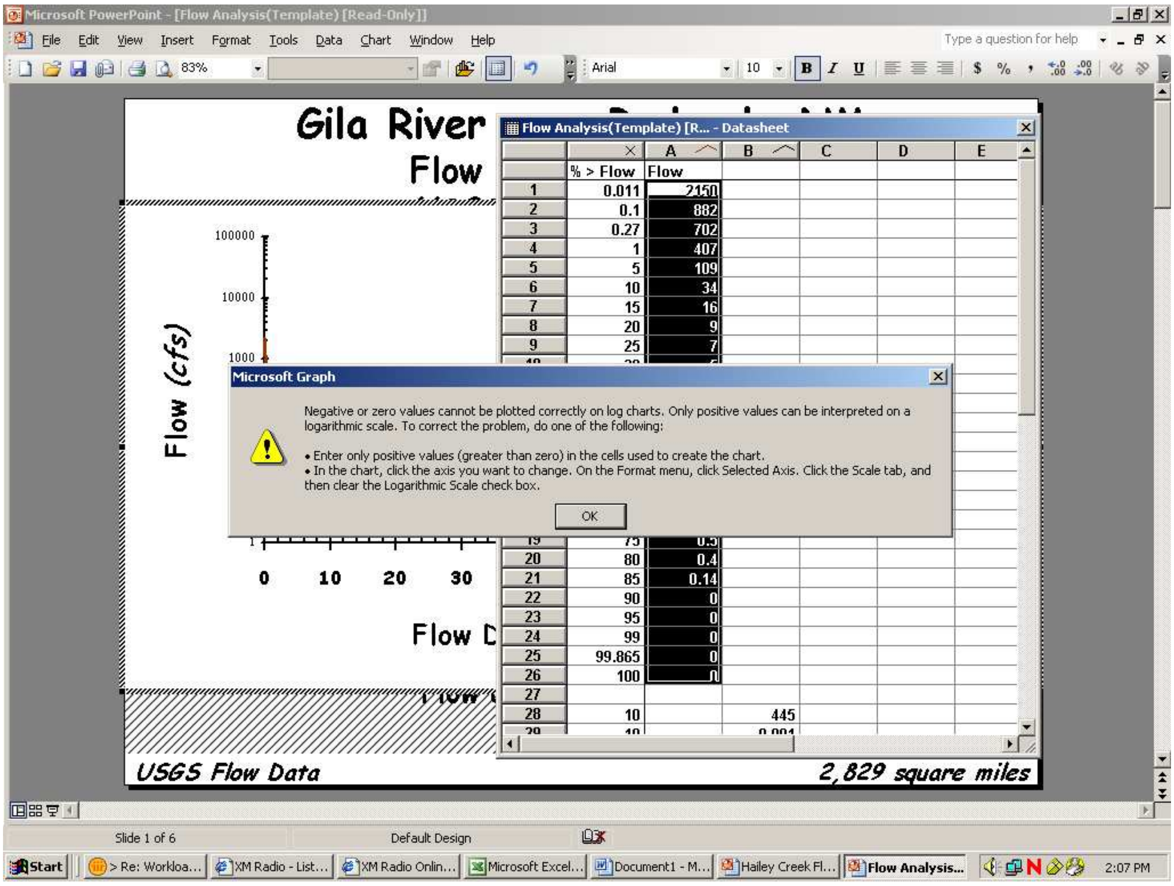
3. Next, open up the Flow_Analysis(Template) file in power point. Once this file is open, you should see a file for the Gila River, NM (see below).



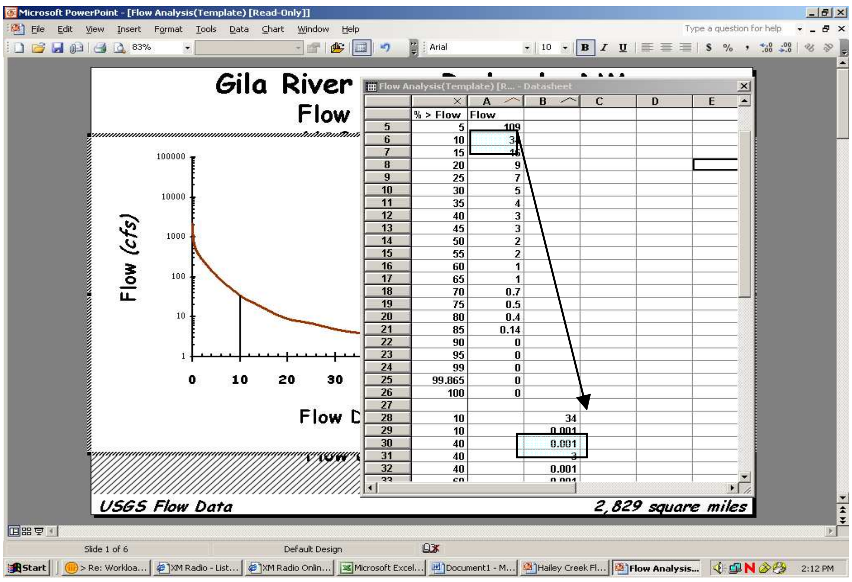
4. In order create your flow duration curve, double click on the flow duration in power point and a table should appear. Once the table appears, expand the table by dragging the bottom right-hand corner.



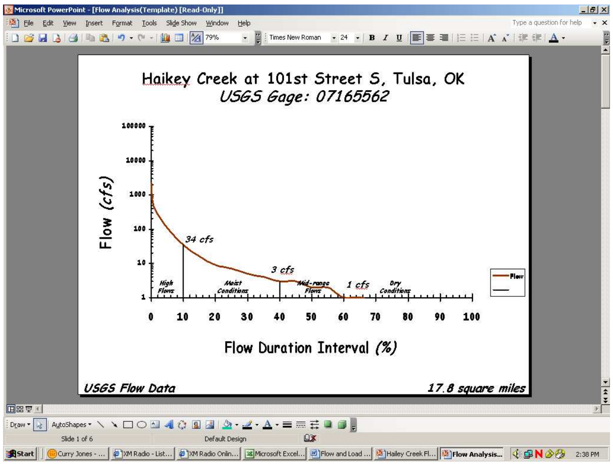
5. Click in column A1 of the table and then right click and scroll down to paste (or just do Ctrl V from column A1) and your flow data for Haikey will appear in column A (should be A1 through A26. Because your flows are less than 0, you will get a Microsoft Graph message letting you know some of you values are below 0. Ignore it by clicking ok (see below).



6. While you are still in the table, scroll down (remember to scroll down the table and not to the next slide) to cells 28 through 37. This is where you will code your information to create your hydrologic flow zones. To create your flow zones, type in the flows for the appropriate zone into the following cells, 10th percentile (b28), 40th percentile (b31), 60th percentile (b34) and 90th percentile (b37).



7. Once the data is entered, click outside the power point area (i.e. the gray area), and you will then have your flow duration curve with the various hydrologic zones. You can then go into the text and change the heading information to reflect your watershed.



APPENDIX D: CALCULATED FLOW EXCEEDANCE PERCENTILES

Table D-1. Calculated Flow Exceedance Percentiles for All Three River Segments Studied.

Percent Exceedance	FLOW (cfs)		
	OK120420-010010_00	OK120410-010080_00	OK120410-010210_00
0.0%	148,000.0	146,000.0	2,090.0
0.135%	123,152.5	132,814.0	900.9
0.27%	99,537.0	120,832.9	700.0
1%	54,357.0	60,477.0	419.0
5%	33,700.0	36,785.0	125.0
10%	24,700.0	27,200.0	40.0
15%	19,605.0	21,900.0	16.0
20%	14,900.0	17,800.0	9.0
25%	12,800.0	14,500.0	5.9
30%	11,200.0	12,600.0	4.5
35%	9,234.5	10,600.0	3.5
40%	7,798.0	9,170.0	2.7
45%	6,840.0	7,990.0	2.0
50%	6,040.0	7,070.0	1.5
55%	5,180.0	6,100.0	1.1
60%	4,370.0	5,180.0	0.8
65%	3,605.5	4,290.0	0.6
70%	2,979.0	3,489.0	0.4
75%	2,420.0	2,820.0	0.2
80%	1,880.0	2,246.0	0.1
85%	1,420.0	1,700.0	0.0
90%	1,040.0	1,270.0	0.0
95%	506.7	861.0	0.0
99%	164.8	480.7	0.0
99.87%	75.0	239.8	0.0
100%	50.0	87.0	0.0

APPENDIX E: 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...within 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 within 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 F

STORM WATER PERMITTING REQUIREMENTS AND PRESUMPTIVE BEST MANAGEMENT PRACTICES (BMPs) APPROACH

BACKGROUND

The National Pollutant Discharge Elimination System (NPDES) permitting program for stormwater discharges was established under the Clean Water Act as the result of a 1987 amendment. The Act specifies the level of control to be incorporated into the NPDES stormwater permitting program depending on the source (industrial versus municipal stormwater). These programs contain specific requirements for the regulated communities/facilities to establish a comprehensive stormwater management program (SWMP) or storm water pollution prevention plan (SWPPP) to implement any requirements of the total maximum daily load (TMDL) allocation. [See 40 CFR §130.]

Storm water discharges are highly variable both in terms of flow and pollutant concentration, and the relationships between discharges and water quality can be complex. For municipal stormwater discharges in particular, the current use of system-wide permits and a variety of jurisdiction-wide BMPs, including educational and programmatic BMPs, does not easily lend itself to the existing methodologies for deriving numeric water quality-based effluent limitations. These methodologies were designed primarily for process wastewater discharges which occur at predictable rates with predictable pollutant loadings under low flow conditions in receiving waters.

EPA has recognized these problems and developed permitting guidance for stormwater permits. [See "Interim Permitting Approach for Water Quality-Based Effluent Limitations in Stormwater Permits" (EPA-833-D-96-00, Date published: 09/01/1996)] Due to the nature of storm water discharges, and the typical lack of information on which to base numeric water quality-based effluent limitations (expressed as concentration and mass), EPA recommends an interim permitting approach for NPDES storm water permits which is based on BMPs. "The interim permitting approach uses best management practices (BMPs) in first-round storm water permits, and expanded or better-tailored BMPs in subsequent permits, where necessary, to provide for the attainment of water quality standards." (*ibid.*)

A monitoring component is also included in the recommended BMP approach. "Each storm water permit should include a coordinated and cost-effective monitoring program to gather necessary information to determine the extent to which the permit provides for attainment of applicable water quality standards and to determine the appropriate conditions or limitations for subsequent permits." (*ibid.*)

This approach was further elaborated in a guidance memo issued in 2002. [See Memorandum from Robert Wayland, Director of OWOW and James Hanlon, Director of OWM to Regional Water Division Directors: "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit requirements Based on Those WLAs " (Date published: 11/22/2002)] "The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address storm water discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. …… If it is determined that a BMP approach (including an iterative BMP approach) is appropriate to meet the storm water component of the TMDL, EPA recommends that the TMDL reflect this."

This TMDL adopts the EPA recommended approach and relies on appropriate BMPs for implementation. No numeric effluent limitations are required or anticipated for municipal stormwater discharge permits.

SPECIFIC SWMP/SWPPP REQUIREMENTS

As noted in Section 3 of this report, Oklahoma Pollutant Discharge Elimination System (OPDES)-permitted facilities and non-point sources (e.g., wildlife, agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal system, and domestic pets) could contribute to exceedances of the water quality criteria. In particular, stormwater runoff from the Phase 1 and 2 municipal separate storm sewer systems (MS4s) is likely to contain elevated bacteria concentrations. Permits for these discharges must comply with the provisions of this TMDL. Table 3-4 provides a list of Phase 1 and 2 MS4s that are affected by the TMDL for the Arkansas River and Haikey Creek Basins.

Agricultural activities and other nonpoint sources of bacteria are unregulated. Voluntary measures and incentives should be used and encouraged wherever possible, and such sources should strive to attain the reduction goals established in this TMDL. The Oklahoma Conservation Commission may be developing watershed plans for the Arkansas River and Haikey Creek segments of the TMDL that should facilitate these actions. Table F-1 below replicates some of the information shown in Table 3-4 along with the issuing dates of the permits.

The provisions of this appendix apply only to OPDES/NPDES regulated stormwater discharges. There are no regulated CAFOs within the study area watersheds, therefore there is no need to review CAFO permits in the watershed or their associated management plans.

To ensure compliance with the TMDL requirements under the permit, stormwater permittees must develop strategies designed to achieve progress toward meeting the reduction goals established in the TMDL. Relying primarily upon a Best Management Practices (BMP) approach, permittees should take advantage of existing information on BMP performance and select a suite of BMPs appropriate to the local community that are expected to result in progress toward meeting the reduction goals established in the TMDL. The permittee should provide guidance on BMP installation and maintenance, as well as a monitoring and/or inspection schedule.

Table F–2 provides a summary description of some BMPs with reported effectiveness in reducing bacteria. Permittees may choose different BMPs to meet the permit requirements, as long as the permittees demonstrate that these practices will result in progress toward attaining water quality standards.

Table F-1. MS4 Permits that are affected by the bacteria TMDL for the Arkansas River and Haikey Creek Basins

OPDES Storm Water Permits in Study Area	PERMIT NO.	TYPE	DATE ISSUED
City of Tulsa	OKS000201	Phase 1	01/13/2003
City of Jenks	OKR040024	Phase 2	12/08/2005
City of Bixby	OKR040042	Phase 2	12/08/2005
City of Coweta	OKR040009	Phase 2	03/03/2006
City of Broken Arrow	OKR040001	Phase 2	11/21/2005
City of Sapulpa	OKR040018	Phase 2	10/27/2006
City of Muskogee	OKR040013	Phase 2	11/15/2005
Tulsa County	OKR040019	Phase 2	12/16/2005
Wagoner County	OKR040020	Phase 2	10/31/2005
Creek County	OKR040026	Phase 2	10/27/2006
Oklahoma Department of Transportation	OKS000201 OKR040044	Phase 1 Phase 2	01/13/2003 DEQ review
Oklahoma Turnpike Authority	OKS000201 OKR040045	Phase 1 Phase 2	01/13/2003 05/23/2006

As noted above, when a BMP approach is selected a coordinated monitoring program is necessary to establish the effectiveness of the selected BMPs and demonstrate progress toward attaining water quality standards. The monitoring results should be used to refine bacteria controls in the future. With ten permitted entities in the two watersheds, it is likely that a cooperative monitoring program would be more cost-effective than ten individual programs. The Indian Nations Council of Governments (INCOG) has expressed interest in facilitating a coordinated monitoring program to address this requirement. Individual permittees are not required to participate in a coordinated program and are free to develop their own program if desired.

After EPA approval of the final TMDL, existing small MS4 permittees will be notified of the TMDL provisions and schedule. The “Phase 1” permit for the City of Tulsa expires in January 2008. The re-issued permit will contain general provisions addressing this TMDL. Industrial stormwater permittees are not expected to be a significant source of bacteria but if any are identified, similar actions will be required. Compliance with the following provisions will constitute compliance with the requirements of this TMDL.

1. Develop a Bacteria Reduction Plan

Permittees shall submit an approvable Bacteria Reduction Plan to the DEQ within 12 months of notification. Unless disapproved by the Director within 60 days of submission, the plan shall be approved then implemented by the permittee. This plan shall, at a minimum, include the following:

a. Consideration of ordinances or other regulatory mechanisms to require bacteria pollution control, as well enforcement procedures for noncompliance;
b. Evaluation of the existing SWMP in relation to TMDL reduction goals;
c. Educational programs directed at reducing bacterial pollution;
d. Investigation and implementation of BMPs that prevent additional storm water bacteria pollution associated with new development and re-development;
e. Implementation of BMPs applicable to bacteria. Table F-2 below presents summary information on some BMPs that should be considered. Permittees are not limited to BMPs on this list and should select BMPs appropriate to the local community that are expected to meet all or part of the reduction goals established in the TMDL.
f. Modifications to the dry weather field screening and illicit discharge detection and elimination provisions of the SWMP to consider storm water sampling and other measures intended to specifically identify bacterial pollution sources and high priority areas for bacteria reductions.
g. Periodic evaluation of the effectiveness of the bacteria reduction plan to ensure progress toward attainment of water quality standards.
h. An implementation schedule leading to modification of the SWMP and full implementation of the plan within 3 years of notification.

2. Develop or Participate in a Bacteria Monitoring Program

Permittees may participate in a coordinated regional bacteria monitoring program or develop their own individual program. The monitoring program should be designed to establish the effectiveness of the selected BMPs and demonstrate progress toward the reduction goals of the TMDL and eventual attainment of water quality standards.

Within 18 months of notification, the permittee shall prepare and submit to the DEQ either a TMDL monitoring schedule or a commitment to participate in a coordinated regional monitoring program. The schedule or program shall include:

a. A detailed description of the goals, monitoring, and sampling and analytical methods;
b. A list and map of the selected TMDL monitoring sites;
c. The frequency of data collection to occur at each station or site;
d. The parameters to be measured, as appropriate for and relevant to the TMDL;
e. A Quality Assurance Project Plan that complies with EPA requirements [EPA Requirements for QA Project Plans (QA/R-5)]

The monitoring program shall be fully implemented within 3 years of notification.

3. Annual Reporting

The permittee shall include a TMDL implementation report as part of their annual report. The TMDL report shall include the status and actions taken by the permittee to implement the TMDL. The TMDL report shall document relevant actions taken by the permittee that affect MS4 storm water discharges to the waterbody segment that is the subject of the TMDL. This TMDL report also shall identify the status of any applicable TMDL implementation schedule milestones.

Table F-2. Some BMPs Applicable to Bacteria

BEST MANAGEMENT PRACTICE	IMPAIRMENT SOURCE		REPORTED EFFICIENCY	NOTE
	AGRICULTURE	URBAN		
Animal waste management: A planned system designed to manage liquid and solid waste from livestock and poultry. It improves water quality by storing and spreading waste at the proper time, rate and location.	X		75 %[1]	
Artificial wetland/rock reed microbial filter: Long shallow hydroponic plant/rock filter system that treats polluted waste and wastewater. It combines horizontal and vertical flow of water through the filter (filled with aquatic and semi-aquatic plants and microorganisms) and provides a high surface area of support media, such as rocks or crushed stone.	X	X	99%[7]	
Compost facility: Treating organic agricultural wastes in order to reduce the pollution potential to surface and ground water. The composting facility must be constructed, operated and maintained without polluting air and/or water resources.	X	X		DEQ permit needed
Conservation landscaping: The placement of vegetation in and around stormwater management BMPs. Its purpose is to help stabilize disturbed areas, enhance the pollutant removal capabilities of storm water BMP, and improve the overall aesthetics of a storm water BMP.		X		
Detention pond/basin: Detention ponds/basins maintain a permanent pool of water in addition to temporarily detaining storm water. The permanent pool of water enhances the removal of many pollutants. These ponds fill with stormwater and release most of it over a period of a few days, slowly returning to its normal depth of water.	X	X	25 %[1], 40%[2], 51%[3], and 90%[4]	90% with filter
Diversions/earthen embankments: 1). Diversions -Establishing a channel with a supporting ridge on the lower side constructed along the general land slope which improves water quality by directing nutrient and sediment laden water to sites where it can be used or disposed of safely. 2). Earthen embankment- A raised impounding structure made from compacted soil. It is appropriate for use with infiltration, detention, extended-detention or retention facilities.	X	X		
Drain Inlet Inserts: A proprietary BMP that is generally easily installed in a drain inlet or catch basin to treat storm water runoff. Three basic types of inlet insert are available, the tray type, bag type and basket type. The tray type allows flow to pass through filter media residing in a tray located		X	5%[2]	

BEST MANAGEMENT PRACTICE	IMPAIRMENT SOURCE AGRICULTURE	IMPAIRMENT SOURCE URBAN	REPORTED EFFICIENCY	NOTE
around the perimeter of the inlet.				
Drip irrigation: An irrigation method that supplies a slow, even application of low-pressure water through polyethylene tubing running from supply line directly to a plant's base. Water soaks into the soil gradually, reducing runoff and evaporation (i.e., salinity). Transmission of nutrients and pathogens spread by splashing water and wet foliage created by overhead sprinkler irrigation is greatly reduced. Weed growth is minimized, thereby reducing herbicide applications. Vegetable farming and virtually every type of landscape situation can benefit from the use of drip irrigation.	X	X		
Fencing: A constructed barrier to livestock, wildlife or people. Standard or conventional (barbed or smooth wire), suspension, woven wire, or electric fences shall consist of acceptable fencing designs to control the animal(s) or people of concern and meet the intended life of the practice.	X		75 %[1]	
Filtration (e.g., sand filters): Intermittent sand filters capture, pre-treat to remove sediments, store while awaiting treatment, and treat to remove pollutants (by percolation through sand media) the most polluted stormwater from a site. Intermittent sand filter BMPs may be constructed in underground vaults, in paved trenches within or at the perimeter of impervious surfaces, or in either earthen or concrete open basins.	X	X	30 %[1], 55%[2], 51%[3]	
Infiltration Basin: A vegetated open impoundment where incoming stormwater runoff is stored until it gradually infiltrates into the soil strata. While flooding and channel erosion control may be achieved within an infiltration basin, they are primarily used for water quality enhancement.		X	50 %[1]	
Infiltration Trench: A shallow, excavated trench backfilled with a coarse stone aggregate to create an underground reservoir. Stormwater runoff diverted into the trench gradually infiltrates into the surrounding soils from the bottom and sides of the trench. The trench can be either an open surface trench or an underground facility.		X	50 %[1]	
Irrigation water management: The process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner. An irrigation system adapted for site conditions (soil, slope, crop grown, climate, water quantity and quality, etc.) must be available and capable of applying water to meet the intended purpose(s).	X	X		
Lagoon pump out: A waste treatment impoundment made by constructing an embankment and/or excavating a pit or dugout in order to biologically treat waste (such as manure	X	X		

BEST MANAGEMENT PRACTICE	IMPAIRMENT SOURCE AGRICULTURE	IMPAIRMENT SOURCE URBAN	REPORTED EFFICIENCY	NOTE
and wastewater) and thereby reduce pollution potential by serving as a treatment component of a waste management system.				
Land-use conversion: BMPs that involve a change in land use in order to retire land contributing detrimentally to the environment. Some examples of BMPs with associated land use changes are: Conservation Reserve Program (CRP) - cropland to pasture; Forest conservation - pervious urban to forest; Forest/grass buffers - cropland to forest/pasture; Tree planting - cropland/pasture to forest; and Conservation tillage – conventional tillage to conservation tillage.	X	X		
Limit livestock access: Excluding livestock from areas where grazing or trampling will cause erosion of stream banks and lowering of water quality by livestock activity in or adjacent to the water. Limitation is generally accomplished by permanent or temporary fencing. In addition, installation of an alternative water source away from the stream has been shown to reduce livestock access.	X			
Litter control: Litter includes larger items and articulates deposited on street surfaces, such as paper, vegetation residues, animal feces, bottles and broken glass, plastics and fallen leaves. Litter-control programs can reduce the amount of deposition of pollutants by as much as 50%, and may be an effective measure of controlling pollution by storm runoff.		X		
Livestock water crossing facility: Providing a controlled crossing for livestock and/or farm machinery in order to prevent streambed erosion and reduce sediment.	X		100 %[1]	
Manufactured BMP systems: Structural measures which are specifically designed and sized by the manufacturer to intercept storm water runoff and prevent the transfer of pollutants downstream. They are used solely for water quality enhancement in urban and ultra-urban areas where surface BMPs are not feasible.	X	X		
Onsite treatment system installation: Conventional onsite wastewater treatment and disposal system (onsite system) consists of three major components: a septic tank, a distribution box, and a subsurface soil absorption field (consisting of individual trenches). This system relies on gravity to carry household waste to the septic tank, move effluent from the septic tank to the distribution box, and distribute effluent from the distribution box throughout the subsurface soil absorption field. All of these components are essential for a conventional onsite system to function in an acceptable manner.		X		
Porous pavement: An alternative to conventional		X	50 %[1]	

BEST MANAGEMENT PRACTICE	IMPAIRMENT SOURCE AGRICULTURE	IMPAIRMENT SOURCE URBAN	REPORTED EFFICIENCY	NOTE
pavement, it is made from asphalt (in which fine filler fractions are missing) or modular or poured-in concrete pavements. Its use allows rainfall to percolate through it to the sub-base, providing storage and enhancing soil infiltration that can be used to reduce runoff and combined sewer overflows. The water stored in the sub-base then gradually infiltrates the subsoil.				
Proper site selection for animal feeding facility: Establishing or relocating confined feeding facilities away from environmentally vulnerable areas such as sinkholes, streams, and rivers in order to reduce or eliminate the amount of pollutant runoff reaching these areas.	X			
Rain garden /bio-retention basin: Rain gardens are landscaped gardens of trees, shrubs, and plants located in commercial or residential areas in order to treat storm water runoff through temporary collection of the water before infiltration. They are slightly depressed areas into which storm water runoff is channeled by pipes, curb openings, or gravity.		X	40 %[1]	
Range and pasture management: Systems of practices to protect the vegetative cover on improved pasture and native rangelands. It includes practices such as seeding or reseeding, brush management (mechanical, chemical, physical, or biological), proper stocking rates and proper grazing use, and deferred rotational systems.	X		50 %[1]	
Retention ponds/basins Retention basin: A storm water facility that includes a permanent pool of water and, therefore, is normally wet even during non-rainfall periods. Inflows from storm water runoff may be temporarily stored above this permanent pool.	X	X	32 %[1] and 96%~99%[5]	
Riparian Buffer Zone: A protection method used along streams to reduce erosion, sedimentation, and the pollution of water from agricultural non-point sources.	X	X	43 – 57 %[1]	Forested buffer w/o incentive payment
Septic system pump-out: A typical septic system consists of a tank that receives waste from a residence or business, and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.		X	5 %[1]	
Sewer line maintenance/sewer flushing: Sewer flushing during dry weather is designed to periodically remove solids that have deposited on the bottom of the sewer and the biological slime that grows on the walls of combined sewers during periods of low-flow. Flushing is especially		X		

BEST MANAGEMENT PRACTICE	IMPAIRMENT SOURCE AGRICULTURE	IMPAIRMENT SOURCE URBAN	REPORTED EFFICIENCY	NOTE
necessary in sewer systems that have low grades which has resulted in velocities during low-flow periods that fall below those needed for self-cleaning.				
Stream bank protection and stabilization (e.g., riprap, gabions): Stabilizing shoreline areas that are being eroded by landscaping, constructing bulkheads, riprap revetments, gabion systems, or establishing vegetation.	X	X	40 - 75 %[1]	40 % w/o fencing; 75 % w/ fencing
Terrace: An earth embankment, or a combination ridge and channel, constructed across the field slope. Terraces can be used when there is a need to conserve water, excessive runoff is a problem, and the soils and topography are such that terraces can be constructed and farmed with reasonable effort.	X	X		
Vegetated filter strip: A densely vegetated strip of land engineered to accept runoff from upstream development as overland sheet flow. It may adopt any naturally vegetated form, from grassy meadow to small forest. The purpose of a vegetated filter strip is to enhance the quality of stormwater runoff through filtration, sediment deposition, infiltration and absorption.	X	X	13% for E. Coli, 54% for Fecal Coliform and 28% for total Coliform[6]	
Waste system/storage (e.g., lagoons, litter shed): Waste treatment lagoons biologically treat liquid waste to reduce the nutrient and BOD content. Lagoons must be emptied and their contents disposed of properly.	X	X	80 – 100 %[1]	
Water treatment (e.g., disinfection, flocculation, carbon filter system) Water treatment: Physical, chemical and/or biological processes used to treat concentrated discharges. Physical-chemical processes that have been demonstrated to effectively treat discharge include sedimentation, vortex separation, screening (e.g., fine-mesh screening), and sand-peat filters. Chemical additives used to enhance separation of particles from liquid include chemical coagulants such as lime, alum, ferric chloride, and various polyelectrolytes. Biological processes that have been demonstrated to effectively treat discharges include contact stabilization, biodiscs, oxidation ponds, aerated lagoons, and facultative lagoons.	X	X		
Wetland development/enhancement: The construction of a wetland for the treatment of animal waste runoff or storm water runoff. Wetlands improve water quality by removing nutrients from animal waste or sediments and nutrients from storm water runoff.	X	X	30 %[1]	Including creation & restoration

[1] Sources: BMP Efficiencies Chesapeake Bay Watershed Model (Phase IV) August 1999; Draft FC and Nitrate TMDL IP for Dry River (2001); EPA (1998); EPA (1999b); Novotny (1994); Storm Water Best

Management Practice Categories and Pollutant Removal Efficiencies (2003); USDA (2003); DCR (1999); DEQ/DCR (2001).

[2] Barrett, M.E., Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices, Texas Natural Resource Conservation Commission Report RG-348, June, (1999).

[3] Watershed Protection Techniques. *Vol 3. No. 1*, 1999
[4.] International Strom Water Best Management Practices Database at
http:// www.bmpdatabase.org/

[5.] Rifai H., Study on the effectiveness of BMPs to control Bacteria Loads, Final Report, August 2006
[6.] Goel, P.K, R.P. Rudra, B Gharabagh, S. Das, N. Gupta (2004). Pollutants Removal by Vegetative Strips Planted with Different Grasses. 2004 ASAE/CSAE Annual International Meeting, Ottawa, Ontario, Canada
[7.] G. Vacca et al., Water Reseach 39, 2005, Effect of Plants and Filter Materials on Bacteria Removal in Pilot-Scale Constructed Wet Lands.

APPENDIX G

RESPONSE TO COMMENTS

A: Comments from Quang Pham, P.E., Agricultural. Environmental Management Services Division, OK Dept. of Agriculture Food and Forestry

A1. Table 3.1: Point Source Discharges in the Study Area (page 3-2): Glenpool, Bixby North and Bixby South POTWs discharging to Arkansas River are listed as **Effluent not disinfected.** The Executive Summary (page ix) indicated that Bixby North Facility is scheduled for disinfection in the near future. Will the Glenpool and Bixby South facilities be disinfected also?

- *Response to A1: 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. Disinfection will be required if they do not meet the limits. See pages xvi, 5-5 and 5-14. No change was made as a result of this comment.*

A2. Section 5.2: Waste Load Allocation (page 5-5) and Table 5-2 Waste Load Allocation for NPDES Permitted Facilities (page 5-6): Waste Load Allocations (WLAs) for all POTWs discharging to Arkansas River, waterbodies (WB) ID # OK 120420010010_00 and OK 120420010080_00, are listed on Table 5-2 in term of Enterococci. Since percentage of reduction goal (PRG) is also required for fecal Coliform in WBID 120420010010_00, would another WLAs in term of Fecal Coliform be developed for POTWs discharging to this stream segment?

- *Response to A2: WLAs were developed for fecal coliform for POTWs in this segment but were inadvertently omitted from Table 5-2. The table has been updated to reflect the addition of fecal coliform WLAs for POTWs in river segment 120420010010_00 .*

B: Comments from Greg Kloxin, Oklahoma Conservation Commission

B1. Line 1, Para. 1, Page 2-4, I believe this (sample quantity exception) applies to all the indicators and not just FC.

- *Response to B1: The sample quantity exception applies only to fecal coliform because the Implementation of Oklahoma Water Quality Standards (OAC 785:46-15-6(c)(1))specifies that "The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level* (400 colonies per 100 ml) *prescribed in (b) of this Section." The 25% quantity rule doesn't apply to the other two indicators. No change was made as a result of this comment.*

B2. Line 1, Para. 1, Page 3-15, OCC would prefer the following amendment:"Due to the numbers, cattle appear to constitute the largest potential production of fecal coliform of this group".

Response to B2: Similar language has been proposed by OCC and adopted by ODEQ for bacterial TMDLs developed for other streams in the state. The current language is the result of those previous revisions. As a result, no change was made based on this comment.

B3. Lines 4 and 7, Para. 1, Page 3-18, typographic changes requested for capitalization and a delete a comma in the two lines, respectively.

Response to B3: Changes were made accordingly.

B4. Line 1, Para. 1, Page 5-14, The OCC requests this statement be modified. Outside of provisions for CAFOs administered by ODAFF, the state's NPS program is non-regulatory. OCC is the state's technical lead for the NPS program. Suggested amendment: "Oklahoma's Nonpoint Source Management Program is largely non-regulatory and is lead in technical capacity by the Oklahoma Conservation Commission."

Response to B2: Based on this comment and similar language proposed by OCC and adopted by ODEQ for bacterial TMDLs developed for other streams in the state, the word "regulated" was changed to "managed" in the sentence.

C: Comments from Kody N. Moore, Fisheries Biologist – OK Dept. of Wildlife Conservation

C1. "… If the high bacteria load of the area pose a threat to the health of humans consuming the fish in these systems, has a fish consumption advisory been issued for the area to keep the fishermen from harvesting and consuming them?..."

- *Response to C1: High bacteria load poses threats to human health directly, not via fish consumption. Elevated bacteria levels are not a basis for issuing fish consumption advisories. No change was made as a result of this comment.*

C2. "… Does contact with the water pose a risk to human health as well? ..."

- *Response to C2: Yes and that's why TMDLs were developed in this report to protect the public from this risk. The waters of concern in this TMDL report have use designation of either primary or secondary body contact recreation. Because they do not meet the bacteria standards for these use designations, TMDLs were developed and illustrated in this report. When the wasteload and load allocations in the TMDLs are met after the implementation of the TMDLs, we expect these waters will no longer pose a risk to human health if they are used as designated. No change was made as a result of this comment.*

C3. "…Do these high bacterial loads pose a threat to the health of the fish populations located there? ..."

- *Response to C3: Bacteria of concern in this TMDL report are not known to pose a threat to the fish populations in these waters. No change was made as a result of this comment.*