FINAL

BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR STREAMS IN THE MIDDLE CIMARRON RIVER STUDY AREA, OKLAHOMA

Prepared By:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

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OKWBID

Cimarron River	OK620920030010_00
Buffalo Creek	OK620920050010_00
Sand Creek	OK620920050050_00
Cimarron River	OK620920020010_00
Long Creek	OK620920020080_00
Cimarron River	OK620920010010_00
Main Creek	OK620920010180_00
Griever Creek	OK620920010130_00
Eagle Chief Creek	OK620920040010_00
Cottonwood Creek	OK620920010080_00
Cimarron River	OK620910020010_10
Cimarron River	OK620910020010_00

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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
ASAE	American Society of Agricultural Engineers
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
IQR	interquartile range
LA	Load allocation
LDC	Load duration curve
LOC	line of organic correlation
mg	Million gallons
mgd	Million gallons per day
mg/L	milligram per liter
mL	Milliliter
MOS	Margin of safety
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NTU	nephelometric turbidity unit
OLS	ordinary least square regression
O.S.	Oklahoma statutes
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
DEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWRB	Oklahoma Water Resources Board
PBCR	Primary body contact recreation
PRG	Percent reduction goal
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)*, Enterococci] and turbidity for certain waterbodies in the Middle Cimarron River watershed. Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic communities. Data assessment and total maximum daily load (TMDL) calculations are conducted in accordance with requirements of Section 303(d) of the Clean Water Act (CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), U.S. Environmental Protection Agency (USEPA) guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ 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 and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) 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 lack of knowledge associated with natural process in aquatic systems, model assumptions, and data limitations.

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

E.1 Problem Identification and Water Quality Target

This TMDL report focuses on waterbodies in the Middle Cimarron River Study Area, identified in Table ES-1, that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC).

Elevated levels of bacteria or turbidity 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 pollutant loading controls needed to restore the primary body contact recreation or fish and wildlife propagation use designated for each waterbody.

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

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
Cimarron River near Buffalo	OK620920030010_00	24	2014	3	X	*X*	X	N		
Buffalo Creek near Lovedale	OK620920050010_00	50	2010	1	X	*X*		N		
Sand Creek	OK620920050050_00	26	2014	3	X	*X*		N		
Cimarron River at Freedom	OK620920020010_00	33	2014	3		*X*		N		
Long Creek	OK620920020080_00	22	2019	4	X			N		
Cimarron River below Waynoka	OK620920010010_00	43	2014	3	X	*X*		N	X	N
Main Creek	OK620920010180_00	19	2019	4	X	*X*		N	X	N
Griever Creek	OK620920010130_00	20	2014	3	X	*X*		N		
Eagle Chief Creek	OK620920040010_00	74	2014	3	X			N		
Cottonwood Creek	OK620920010080_00	22	2014	3	X	*X*	X	N	X	N
Cimarron River near Ames	OK620910020010_10	42	2014	3	X	*X*		N		
Cimarron River near Dover	OK620910020010_00	18	2014	3	X	*X*		N		

ENT = enterococci; FC = fecal coliform; N = Not attaining; X = Criterion Exceeded, TMDL Required Source: 2008 Integrated Report, DEQ 2008.

Table ES-2 summarizes water quality data collected during primary contact recreation season from the water quality monitoring (WQM) stations between 1998 and 2008 for each bacterial indicator. The data summary in Table ES-2 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data collected during the primary contact recreation season includes the data used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2008 303(d) list (ODEQ 2008). It also includes the new date collected after the data cutoff date for the 2008 303(d) list.

Table ES-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 1998-2008

Waterbody ID	Waterbody Name	Indicator Bacteria	Geo-Mean Concentration (count/100ml)	Number of Samples	Number of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	2008 303(d) Listing	Notes
OK620920030010_00	Cimarron River near Buffalo	FC	351	21	8	38%	X	TMDL required
		ENT	220	21	13	62%	X	TMDL required
		EC	1951	21	16	76%	X	TMDL required
OK620920050010_00	Buffalo Creek near Lovedale	ENT	128	42	25	60%	X	TMDL required
		EC	130	42	8	19%	X	TMDL required
OK620920050050_00	Sand Creek	ENT	415	17	15	88%	X	TMDL required
		EC	392	17	10	59%	X	TMDL required
OK620920020010_00	Cimarron River at Freedom	EC	951	14	11	79%	X	TMDL required
OK620920020080_00	Long Creek	ENT	176	18	12	67%	X	TMDL required
		EC	149	18	3	17%		List: TMDL required
OK620920010010_00	Cimarron River below Waynoka	FC	246	14	4	29%		List: TMDL required
		ENT	207	14	9	64%	X	TMDL required
		EC	164	14	4	29%	X	TMDL required
OK620920010180_00	Main Creek	ENT	219	18	13	72%	X	TMDL required
		EC	193	18	1	6%	X	TMDL required
OK620920010130_00	Griever Creek	ENT	209	24	15	63%	X	TMDL required
		EC	92	24	4	17%	X	Delist: Meets standards
OK620920040010_00	Eagle Chief Creek	ENT	175	36	20	56%	X	TMDL required
		EC	165	36	11	31%	X	TMDL required
OK620920010080_00	Cottonwood Creek	FC	247	8	4	50%	X	TMDL required
		ENT	140	5	3	60%	X	Delist: Not enough data
		EC	56	5	1	20%	X	Delist: Not enough data
OK620910020010_10	Cimarron River near Ames	ENT	40	23	8	35%	X	TMDL required
		EC	327	23	13	57%	X	TMDL required
OK620910020010_00	Cimarron River near Dover	FC	343	24	7	29%		List: TMDL required
		ENT	162	24	12	50%	X	TMDL required
		EC	438	24	11	46%	X	TMDL required

Fecal coliform (FC) water quality criterion = Geometric Mean of 400 counts/100 mL *E. coli* (EC) water quality criterion = Geometric Mean of 126 counts/100 mL Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

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

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

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

To implement Oklahoma's WQS for PBCR, the Oklahoma Water Resources Board (OWRB) promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The abbreviated excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

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

(b) Screening levels:

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

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

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

(c) Fecal coliform:

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

(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.

(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.

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 2008). Waterbodies placed on the 303(d) list for not supporting the PBCR are the result of individual samples exceeding the instantaneous criteria or the long-term geometric mean of individual samples exceeding the geometric mean criteria for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1st to September 30th) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no 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.

Turbidity is a measure of water clarity and is caused by suspended particles in the water column. Because turbidity cannot be expressed as a mass load, total suspended solids (TSS) are used as a surrogate for the TMDLs in this report. Therefore, both turbidity and TSS data are presented.

Table ES-3 summarizes a subset of water quality data collected from the WQM stations between 1998 and 2009 for turbidity under base flow conditions, which DEQ considers to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75 percent of flows) Water quality samples collected under flow conditions greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. Table ES-4 presents a subset of data for TSS samples collected during base flow conditions.

Table ES-3 Summary of Turbidity Samples Collected During Base Flow Conditions, 1998-2009

WQM Station	Waterbody Name	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK620920010010_00	Cimarron River below Waynoka	39	9	23%	51
OK620920010180_00	Main Creek	34	6	18%	42
OK620920040010_00	Eagle Chief Creek	78	12	15%	45
OK620920010080_00	Cottonwood Creek	18	9	50%	82
OK620910020010_00	Cimarron River near Dover	74	9	12%	61

Table ES-4 Summary of TSS Samples During Base Flow Conditions, 1998-2009

WQM Station	Waterbody Name	Number of TSS Samples	Average TSS (mg/L)
OK620920010010_00	Cimarron River below Waynoka	9	68
OK620920010180_00	Main Creek	32	45
OK620920040010_00	Eagle Chief Creek	74	59
OK620920010080_00	Cottonwood Creek	17	74
OK620910020010_00	Cimarron River near Dover	14	38

The beneficial use of WWAC is one of several subcategories of the Fish and Wildlife Propagation use established to manage the variety of communities of fish and shellfish throughout the state (OWRB 2008). The numeric criteria for turbidity to maintain and protect the use of "Fish and Wildlife Propagation" from Title 785:45-5-12 (f) (7) is as follows:

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

1. *Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;*
2. *Lakes: 25 NTU; and*
3. *Other surface waters: 50 NTUs.*

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

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

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

The abbreviated excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

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

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

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

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

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

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 nephelometric turbidity units (NTU). However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate in this TMDL. Since there is no numeric criterion in the Oklahoma WQS for TSS, a regression method to convert the turbidity criterion to TSS based on a relationship between turbidity and TSS was used to establish TSS targets as surrogates. Table ES-5 provides the results of the waterbody specific regression analysis.

Table ES-5 Regression Statistics and TSS Targets

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Target (mg/L)
OK620920010010_00	Cimarron River below Waynoka	0.899	7.2%	88
OK620920010180_00	Main Creek	0.891	8.3%	64
OK620920040010_00	Eagle Chief Creek	0.846	11.0%	56
OK620920010080_00	Cottonwood Creek	0.769	10.6%	47
OK620910020010_00	Cimarron River near Dover	0.913	8.3%	86

After re-evaluating bacteria and turbidity/TSS data for the streams listed in Table ES-1, the following stream segments and their corresponding pollutants are recommended for delisting: Griever Creek (*E. coli*) and Cottonwood Creek (Enterococci and *E. coli*). The following stream segments and their corresponding pollutants are recommended for listing after re-evaluation: Eagle Chief Creek (Turbidity) and Cimarron River near Dover (Turbidity). Table ES-6 shows the bacteria and turbidity TMDLs that will be developed in this report:

Table ES-6 Stream Segments and Pollutants for TMDL Development

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Turbidity
OK620920030010_00	Cimarron River near Buffalo	24	2014	3	X	X	X	
OK620920050010_00	Buffalo Creek near Lovedale	50	2010	1	X	X		
OK620920050050_00	Sand Creek	26	2014	3	X	X		
OK620920020010_00	Cimarron River at Freedom	33	2014	3		X		
OK620920020080_00	Long Creek	22	2019	4	X	X		
OK620920010010_00	Cimarron River below Waynoka	43	2014	3	X	X	X	X
OK620920010180_00	Main Creek	19	2019	4	X	X		X
OK620920010130_00	Griever Creek	20	2014	3	X			
OK620920040010_00	Eagle Chief Creek	74	2014	3	X	X		X
OK620920010080_00	Cottonwood Creek	22	2014	3			X	X
OK620910020010_10	Cimarron River near Ames	42	2014	3	X	X		
OK620910020010_00	Cimarron River near Dover	18	2014	3	X	X	X	X

E.2 Pollutant Source Assessment

A pollutant source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Bacteria originate from warm-blooded animals; some plant life and sources may be point or nonpoint in nature. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the 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) and TSS in accordance with their permits. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria or TSS 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. Sediment loading of streams can originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. There is insufficient data available to quantify contributions of TSS from these natural processes. TSS or sediment loading can also occur under non-runoff conditions as a result of anthropogenic activities in riparian corridors which cause erosive conditions. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources whether it is from natural or anthropogenic processes is not feasible in this TMDL development. Table ES-7 summarizes the point and nonpoint sources that contribute bacteria or TSS to each respective waterbody.

Table ES-7 Summary of Potential Pollutant Sources by Category

Waterbody Name	Waterbody ID	Municipal NPDES Facility	Industrial NPDES Facility	MS4	NPDES No Discharge Facility	CAFO	Mines & Quarries	Construction Stormwater Permit	Nonpoint Source
Cimarron River near Buffalo	OK620920030010_00					Bacteria			Bacteria
Buffalo Creek near Lovedale	OK620920050010_00				Bacteria	Bacteria			Bacteria
Sand Creek	OK620920050050_00								Bacteria
Cimarron River at Freedom	OK620920020010_00				Bacteria				Bacteria
Long Creek	OK620920020080_00								Bacteria
Cimarron River below Waynoka	OK620920010010_00	Bacteria			Bacteria				Bacteria, TSS
Main Creek	OK620920010180_00					Bacteria			Bacteria, TSS
Griever Creek	OK620920010130_00								Bacteria
Eagle Chief Creek	OK620920040010_00	Bacteria			Bacteria	Bacteria	TSS		Bacteria, TSS
Cottonwood Creek	OK620920010080_00								Bacteria, TSS
Cimarron River near Ames	OK620910020010_10					Bacteria			Bacteria
Cimarron River near Dover	OK620910020010_00								Bacteria, TSS

No facility present in watershed.

Facility present in watershed, but not recognized as pollutant source.

E.3 Using Load Duration Curves to Develop TMDLs

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

- Preparing flow duration curves for gaged and ungaged WQM stations;
- Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and
- Using LDCs to identify the critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when wastewater treatment plant (WWTP) effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. Violations have been noted under low flow conditions in some watersheds that contain no point sources.

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

The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the U.S. Geological Survey (USGS);
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- matching the water quality observations with the flow data from the same date;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{target} for TSS;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equation in Figure 4-1 and Figure 4-2); or multiplying the flow by the bacteria indicator concentration to calculate daily loads; then

- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

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

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

Where: WQS = 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

For turbidity (TSS) TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (lb/day) = WQ_{target} **** flow (cfs) * unit conversion factor***

where: WQ_{target} ***= waterbody specific TSS concentration derived from regression analysis results presented in Table 4-1***

unit conversion factor = 5.39377 L*s*lb /(ft^3 ****day*mg)***

Historical observations of bacteria, TSS and/or turbidity concentrations are paired with flow data and are plotted as separate LDCs. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform concentration (colonies/100 mL) by the instantaneous flow (cubic feet per second) at the same site and time, with appropriate volumetric and time unit conversions. Fecal coliform/*E. coli*/Enterococci loads representing exceedance of water quality criteria fall above the water quality criterion line. Likewise, the TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line.

E.4 TMDL Calculations

A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for the lack of knowledge concerning the relationship between 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. The difference between existing loading and the water quality target is used to calculate the loading reductions required. PRG are calculated for each waterbody and bacterial indicator species as the reductions in load required so none of the existing instantaneous water quality observations would exceed the water quality target for *E. coli* and Enterococci and no more than 25 percent of the samples exceed the water quality target for fecal coliform.

Table ES-8 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area. Selection of the appropriate PRG for each waterbody in Table ES-8 is denoted by 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 WQSs 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 PRGs range from 13 to 99.99 percent.

Table ES-8 TMDL Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate				
		FC	EC		ENT	
		Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
OK620920030010_00	Cimarron River near Buffalo	**69%**	99%	**94%**	99.99%	**86%**
OK620920050010_00	Buffalo Creek near Lovedale		91%	**13%**	98%	**77%**
OK620920050050_00	Sand Creek		82%	**71%**	96%	**93%**
OK620920020010_00	Cimarron River at Freedom		97%	**88%**		
OK620920020080_00	Long Creek		82%	**24%**	99.99%	**83%**
OK620920010010_00	Cimarron River below Waynoka	**28%**	73%	**31%**	99.99%	**86%**
OK620920010180_00	Main Creek		91%	**41%**	97%	**86%**
OK620920010130_00	Griever Creek				97%	**86%**
OK620920040010_00	Eagle Chief Creek		96%	**31%**	98%	**83%**
OK620920010080_00	Cottonwood Creek	**49%**				
OK620910020010_10	Cimarron River near Ames		89%	**65%**	91%	**26%**
OK620910020010_00	Cimarron River near Dover	**85%**	97%	**74%**	99.99%	**82%**

Similarly, percent reduction goals for TSS are calculated as the required overall reduction so that no more than 10 percent of the samples exceed the water quality target for TSS. The PRGs for the fourteen waterbodies included in this TMDL report are summarized in Table ES-9 and range from 62 to 86 percent.

Table ES-9 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK620920010010_00	Cimarron River below Waynoka	**86%**
OK620920010180_00	Main Creek	**64%**
OK620920040010_00	Eagle Chief Creek	**76%**
OK620920010080_00	Cottonwood Creek	**82%**
OK620910020010_00	Cimarron River near Dover	**62%**

The TMDL, WLA, LA, and MOS vary with flow condition, and are calculated at every 5^{th} flow interval percentile. The WLA component of each TMDL is the sum of all WLAs within each contributing watershed. The sum of the WLAs can be represented as a single line below the LDC. The LDC and the simple equation of:

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

can provide an individual value for the LA in counts per day, which represents the area under the TMDL target line and above the WLA line.

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

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

For turbidity, the TMDLs are calculated for TSS instead of turbidity. Thus, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confidence there is in the TMDL targets. As a result, it leads to a smaller margin of safety. The selection of MOS is based on the normalized root mean square error (NRMSE) for each waterbody. The explicit MOS of 10 or 15 percent was used for waterbodies in this report.

The bacteria TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS which limits the PBCR use to the period of May 1st through September 30th. Similarly, the TSS TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

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. The reduction rates called for in this TMDL report are as high as 86 percent. The ODEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation.

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 bacteria and turbidity TMDLs for certain waterbodies in the Middle Cimarron River study area. The 2008 Integrated Water Quality Assessment Report (Oklahoma Department of Environmental Quality [DEQ] 2008) identified these 14 streams as impaired for either bacteria and/or turbidity. 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 (DEQ) guidance and procedures. DEQ 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 and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and in-stream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the uncertainty associated with natural process in aquatic systems, model assumptions, and data limitations.

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria and /or turbidity 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 waterbodies listed below that DEQ placed in Category 5 of the 2008 Integrated Report [303(d) list] for nonsupport of primary body contact recreation (PBCR) or beneficial use category Fish and Wildlife Propagation:

Cimarron River	OK620920030010_00
Buffalo Creek	OK620920050010_00
Sand Creek	OK620920050050_00
Cimarron River	OK620920020010_00
Traders Creek	OK620920020170_00
Long Creek	OK620920020080_00
Cimarron River	OK620920010010_00
Main Creek	OK620920010180_00
Griever Creek	OK620920010130_00
East Griever Creek	OK620920010140_00
Eagle Chief Creek	OK620920040010_00
Cottonwood Creek	OK620920010080_00
Cimarron River	OK620910020010_10
Cimarron River	OK620910020010_00

Figure 1-1 is a location map showing the impaired segments of these 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's 303(d) list. These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

The TMDLs established in this report are a necessary step in the process to develop the bacteria and turbidity loading controls needed to restore the contact recreation and the Fish and Wildlife Propagation 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 2008 303(d) Listing Decision

Waterbody Name	Waterbody ID	WQM Station	Legal Description
Cimarron River near Buffalo	OK620920030010_00	OK620920030010-001AT	Section 02 - T27N - R20WI
Buffalo Creek near Lovedale	OK620920050010_00	OK620920-05-0010T OK620920-05-0010G OK620920-05-0010P	NE¼ NE¼ NE¼ Section 8-27N-23W NW¼ SW¼ SW¼ Section 33-27N-20W SE¼ SE¼ SW¼ Section 22-27N-21W
Sand Creek	OK620920050050_00	OK620920-05-0050G OK620920-05-0050J	NW¼ NW¼ SW¼ Section 20-26N-21W SW¼ SW¼ SW¼ Section 19-26N-21W
Cimarron River at Freedom	OK620920020010_00	OK620920020010-001RS	Section 35 - T24N - R16WI
Traders Creek	OK620920020170_00	OK620920-02-0170G	SE¼ SE¼ SW¼ Section 22-26N-19W
Long Creek	OK620920020080_00	OK620920-02-0080D OK620920-02-0080T	NW¼ NE¼ NE¼ Section 27-26N-18W SW¼ NE¼ SW¼ Section 12-24N-19W
Cimarron River below Waynoka	OK620920010010_00	OK620920010010-001AT	Section 23 - T22N - R12WI
Main Creek	OK620920010180_00	OK620920-01-0180F	NE¼ NE¼ NE¼ Section 10-23N-16W
Griever Creek	OK620920010130_00	OK620920-01-0130K OK620920-01-0130G	NE¼ NW¼ SE¼ Section 36-22N-16W SE¼ SE¼ SE¼ Section 9-22N-15W
Griever Creek, East	OK620920010140_00	None	No Monitoring Station Available
Eagle Chief Creek	OK620920040010_00	OK620920-04-0010C OK620920-04-0010G	SW¼ SE¼ SE¼ Section 2-22N-12W NW¼ NW¼ NW¼ Section 24-25N-13W
Cottonwood Creek	OK620920010080_00	OK620920-01-0080G	E.B. SE¼ Section 21-22N-12W
Cimarron River near Ames	OK620910020010_10	OK620910020010-004RS	Section 19 - T21N - R10WI
Cimarron River near Dover	OK620910020010_00	OK620910020010-001AT	Section 14 - T17N - R07WI

1.2 Watershed Description

General. The drainage area for the Middle Cimarron River Study Area waterbodies included in this report begins with the upper part of the Cimarron River as it enters Oklahoma from Kansas. This is between Woods and Harper Counties with two of the studied waterbodies draining eastern Harper County. A majority of the waterbodies are in and around the Cimarron River in Woodward and Major Counties. The lower drainage area in this report is in northwestern Kingfisher County. Small areas of northeastern Blaine County and southwestern Alfalfa County also fall within the study area.

Table 1-2, derived from the 2000 U.S. Census, demonstrates that the counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2000).

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Area (square miles)	Population Density (per square mile)
Alfalfa	6,105	881	7
Blaine	11,976	939	13
Harper	3,562	1,041	3
Kingfisher	13,926	906	15
Major	7,545	958	8
Woods	9,089	1,290	7
Woodward	18,486	1,246	15

Climate. Table 1-3 summarizes the average annual precipitation for each stream segment. Average annual precipitation values among the stream segments in this portion of Oklahoma range between 25.3 and 32.8 inches (Oklahoma Climatological Survey 2005).

Table 1-3 Average Annual Precipitation by Stream Segment

Waterbody Name	Waterbody ID	Average Annual (Inches)
Cimarron River near Buffalo	OK620920030010_00	25.5
Buffalo Creek near Lovedale	OK620920050010_00	25.3
Sand Creek	OK620920050050_00	25.3
Cimarron River at Freedom	OK620920020010_00	26.9
Traders Creek	OK620920020170_00	26.1
Long Creek	OK620920020080_00	26.4
Cimarron River below Waynoka	OK620920010010_00	29.8
Main Creek	OK620920010180_00	27.7
Griever Creek	OK620920010130_00	28.2
Griever Creek, East	OK620920010140_00	28.3
Eagle Chief Creek	OK620920040010_00	28.9
Cottonwood Creek	OK620920010080_00	29.2
Cimarron River near Ames	OK620910020010_10	31.5
Cimarron River near Dover	OK620910020010_00	32.8

Land Use. Tables 1-4 and 1-5 summarizes the acreages and the corresponding percentages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2001 National Land Cover Dataset (USGS 2007). The land use categories are displayed in Figure 1-2.

The dominant land use throughout all of the Study Area is Grasslands/Herbaceous and the second most prevalent land use in all sub-watersheds is Row Crops/Cultivated land.

Table 1-4 Land Use Summaries by Watershed

Land Use Category	Stream Segments						
	Cimarron River near Buffalo	Buffalo Creek	Sand Creek	Cimarron River at Freedom	Traders Creek	Long Creek	Cimarron River below Waynoka
Waterbody ID	OK620920030010_00	OK620920050010_00	OK620920050050_00	OK620920020010_00	OK620920020170_00	OK620920020080_00	OK620920010010_00
Barren	2,263	267	5	1,492	0	24	1,781
Cultivated	77,906	59,084	12,741	73,038	4,749	9,376	253,152
Deciduous Forest	365	238	147	2,274	3	0	8,016
Developed High Intensity	56	56	0	29	0	0	132
Developed Low Intensity	0	0	0	0	0	0	0
Developed Medium Intensity	570	482	62	1,088	35	69	3,914
Developed Open Space	14,821	9,939	1,894	13,318	911	1,277	26,846
Evergreen Forest	3,552	3,552	828	29,782	3,718	3,485	22,222
Grassland	375,893	235,637	61,163	331,524	36,122	24,062	352,429
Herbaceous Wetland	2,084	614	2	2,919	0	4	765
Mixed Forest	0	0	0	0	0	0	2,054
Pasture Hay	514	514	239	518	0	0	1,710
Shrub	1,498	1,415	745	3,909	721	444	505
Woody Wetland	865	542	220	3,455	20	30	2,151
Water	8,410	2,831	360	5,045	34	117	4,806
Total (Acres)	**488,796**	**315,171**	**78,407**	**468,391**	**46,312**	**38,888**	**680,483**
Barren	0.46%	0.08%	0.01%	0.32%	0.00%	0.06%	0.26%
Cultivated	15.94%	18.75%	16.25%	15.59%	10.25%	24.11%	37.20%
Deciduous Forest	0.07%	0.08%	0.19%	0.49%	0.01%	0.00%	1.18%
Developed High Intensity	0.01%	0.02%	0.00%	0.01%	0.00%	0.00%	0.02%
Developed Low Intensity	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Developed Medium Intensity	0.12%	0.15%	0.08%	0.23%	0.08%	0.18%	0.58%
Developed Open Space	3.03%	3.15%	2.42%	2.84%	1.97%	3.28%	3.95%
Evergreen Forest	0.73%	1.13%	1.06%	6.36%	8.03%	8.96%	3.27%
Grassland	76.90%	74.76%	78.01%	70.78%	78.00%	61.88%	51.79%
Herbaceous Wetland	0.43%	0.19%	0.00%	0.62%	0.00%	0.01%	0.11%
Mixed Forest	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.30%
Pasture Hay	0.11%	0.16%	0.30%	0.11%	0.00%	0.00%	0.25%
Shrub	0.31%	0.45%	0.95%	0.83%	1.56%	1.14%	0.07%
Woody Wetland	0.18%	0.17%	0.28%	0.74%	0.04%	0.08%	0.32%
Water	1.72%	0.90%	0.46%	1.08%	0.07%	0.30%	0.71%
Total Percentage:	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 1-5 Land Use Summaries by Watershed

Land Use Category	Stream Segments					
	Main Creek	Griever Creek	Eagle Chief Creek	Cottonwood Creek	Cimarron River near Ames	Cimarron River near Dover
Waterbody ID	OK620920010180_00	OK620920010130_00	OK620920040010_00	OK620920010080_00	OK620910020010_10	OK620910020010_00
Barren	189	155	85	12	1,088	22
Cultivated	5,918	5,486	168,297	10,764	183,799	33,486
Deciduous Forest	5	530	2,385	147	10,341	1062
Developed High Intensity	0	2	28	1	72	25
Developed Low Intensity	0	0	0	0	0	0
Developed Medium Intensity	262	391	1,043	314	2,078	373
Developed Open Space	2,213	3,040	12,830	1,396	16,858	2,451
Evergreen Forest	11,532	18,203	492	1,527	11,566	275
Grassland	38,739	53,881	123,580	20,335	143,043	16,210
Herbaceous Wetland	175	0	250	0	308	0
Mixed Forest	0	1,607	0	115	104	0
Pasture Hay	0	0	310	37	466	75
Shrub	936	195	1	0	14	0
Woody Wetland	138	0	743	0	0	0
Water	110	111	1,324	209	5,476	381
Total (Acres)	**60,217**	**83,601**	**311,366**	**34,859**	**375,214**	**54,360**
Barren	0.31%	0.19%	0.03%	0.04%	0.29%	0.04%
Cultivated	9.83%	6.56%	54.05%	30.88%	48.99%	61.60%
Deciduous Forest	0.01%	0.63%	0.77%	0.42%	2.76%	1.95%
Developed High Intensity	0.00%	0.00%	0.01%	0.00%	0.02%	0.05%
Developed Low Intensity	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Developed Medium Intensity	0.43%	0.47%	0.33%	0.90%	0.55%	0.69%
Developed Open Space	3.68%	3.64%	4.12%	4.00%	4.49%	4.51%
Evergreen Forest	19.15%	21.77%	0.16%	4.38%	3.08%	0.50%
Grassland	64.33%	64.45%	39.69%	58.34%	38.12%	29.82%
Herbaceous Wetland	0.29%	0.00%	0.08%	0.00%	0.08%	0.00%
Mixed Forest	0.00%	1.92%	0.00%	0.33%	0.03%	0.00%
Pasture Hay	0.00%	0.00%	0.10%	0.11%	0.12%	0.14%
Shrub	1.55%	0.23%	0.00%	0.00%	0.00%	0.00%
Woody Wetland	0.23%	0.00%	0.24%	0.00%	0.00%	0.00%
Water	0.18%	0.13%	0.43%	0.60%	1.46%	0.70%
Total Percentage:	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Figure 1-1 Middle Cimarron River Study Areas Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation

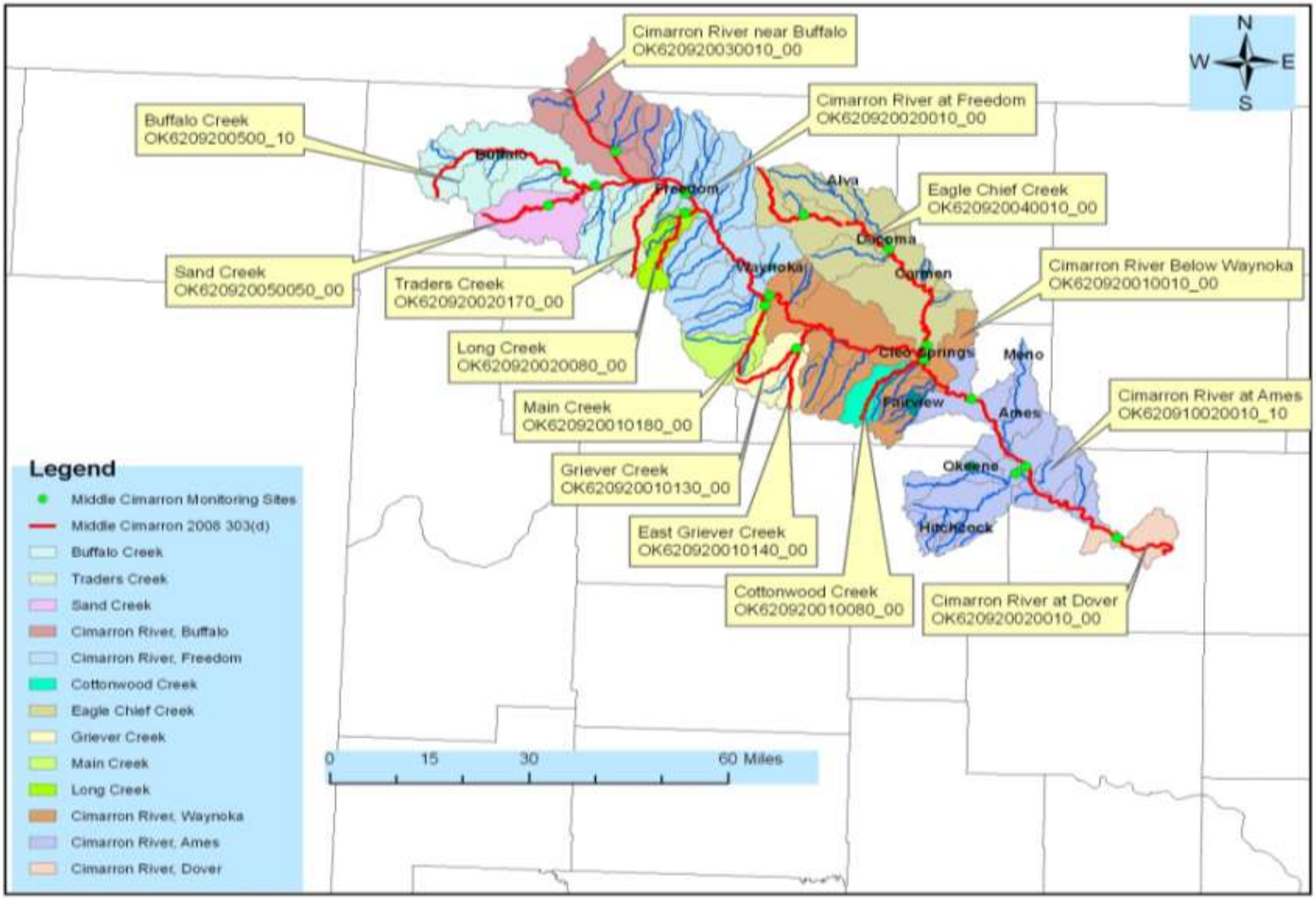
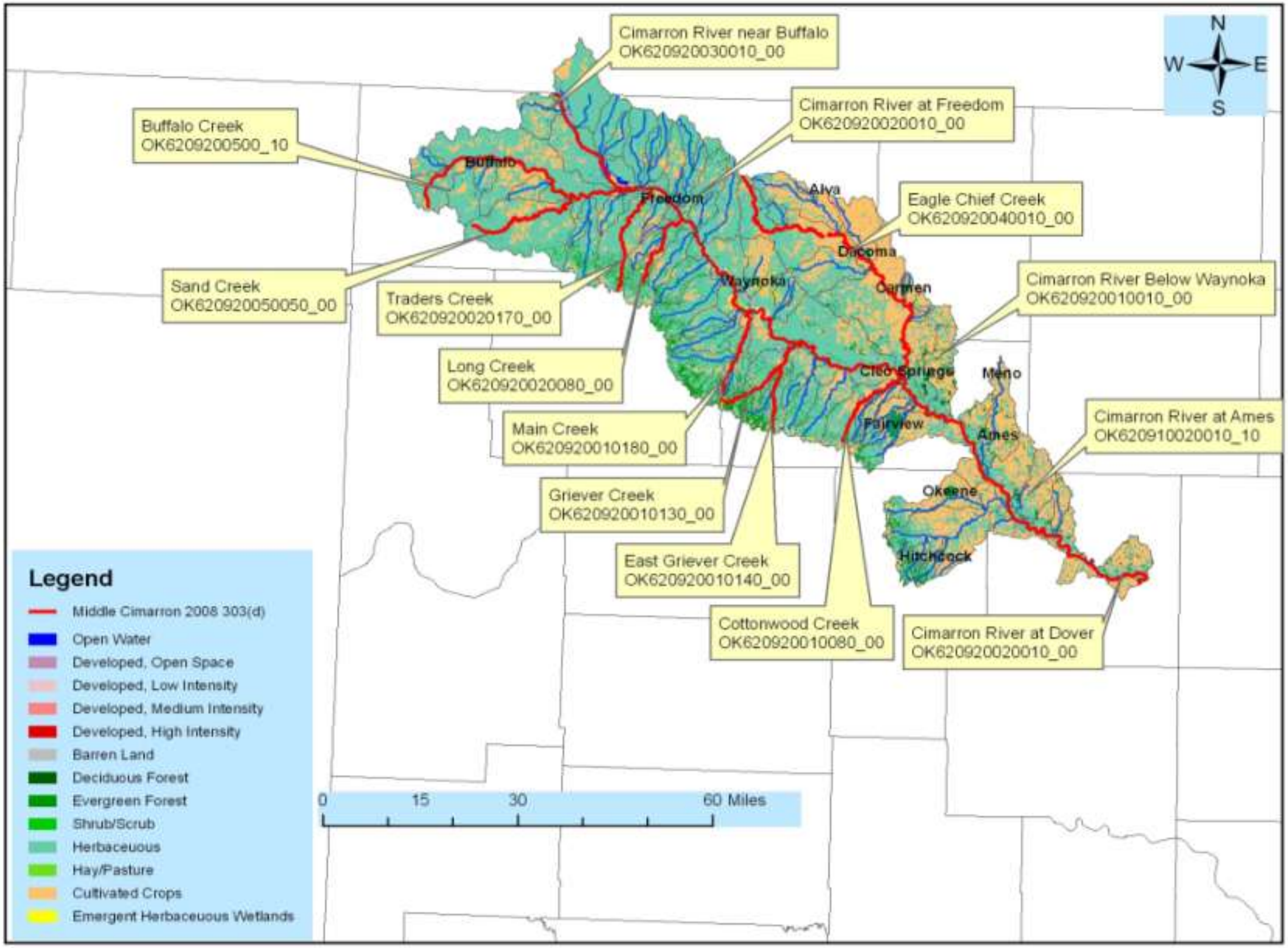


Figure 1-2 Middle Cimarron River Study Area Land Use Map


Cimarron River near Buffalo
OK620920030010_00
Cimarron River at Freedom
OK620920020010_00
Buffalo Creek
OK6209200500_10
Eagle Chief Creek
OK620920040010_00
Sand Creek
OK620920050050_00
Traders Creek
OK620920020170_00
Cimarron River Below Waynoka
OK620920010010_00
Long Creek
OK620920020080_00
Main Creek
OK620920010180_00
Cimarron River at Ames
OK620910020010_10
Griever Creek
OK620920010130_00
East Griever Creek
OK620920010140_00
Cottonwood Creek
OK620920010080_00
Cimarron River at Dover
OK620920020010_00
Buffalo
Freedom
Alva
Dacoma
Carmen
Waynoka
Cleo Springs
Meno
Fairview
Ames
Okeene
Hitchcock
N
W
E
S
Legend
Middle Cimarron 2008 303(d)
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Shrub/Scrub
Herbaceuous
Hay/Pasture
Cultivated Crops
Emergent Herbaceuous Wetlands
0
15
30
60 Miles

1.3 Stream Flow Conditions

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

SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code contains Oklahoma's water quality standards and implementation procedures (OWRB 2008). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state water quality standards, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.* [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2008). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegredation Policy is provided in Appendix D. Table 2-2, an excerpt from the 2008 Integrated Report (DEQ 2008), lists beneficial uses designated for each bacteria and/or turbidity impaired stream segment in the Study Area. The beneficial uses include:

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

Table 2-1 summarizes the PBCR and WWAC use attainment status and bacteria & turbidity impairment status for streams in the Study Area. The TMDL priority shown in Table 2-1 is directly related to the TMDL target date. The TMDLs established in this report, which are a necessary step in the process of restoring water quality, only address bacteria and/or turbidity impairments that affect the PBCR and WWAC-beneficial uses.

The definition of PBCR is summarized by the following excerpt from the Oklahoma Water Quality Standards (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.

Table 2-1 Excerpt from the 2008 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
Cimarron River near Buffalo	OK620920030010_00	24	2014	3	X	X	X	N		
Buffalo Creek near Lovedale	OK620920050010_00	50	2010	1	X	X		N		
Sand Creek	OK620920050050_00	26	2014	3	X	X		N		
Cimarron River at Freedom	OK620920020010_00	33	2014	3		X		N		
Traders Creek	OK620920020170_00	22	2010	1	X			N		
Long Creek	OK620920020080_00	22	2019	4	X			N		
Cimarron River below Waynoka	OK620920010010_00	43	2014	3	X	X		N	X	N
Main Creek	OK620920010180_00	19	2019	4	X	X		N	X	N
Griever Creek	OK620920010130_00	20	2014	3	X	X		N		
Griever Creek, East	OK620920010140_00	13	2014	3	X	X		N		
Eagle Chief Creek	OK620920040010_00	74	2014	3	X			N		
Cottonwood Creek	OK620920010080_00	22	2014	3	X	X	X	N	X	N
Cimarron River near Ames	OK620910020010_10	42	2014	3	X	X		N		
Cimarron River near Dover	OK620910020010_00	18	2014	3	X	X		N		

ENT = enterococci; FC = fecal coliform N = Not attaining; X = Criterion Exceeded, TMDL Required Source: 2008 Integrated Report, DEQ 2008.

Table 2-2 Designated Beneficial Uses for Each Impaired Waterbody in the Study Area

Waterbody Name	Waterbody ID	AES	AG	WWAC	*FISH*	PBCR	PPWS	Limitation
Cimarron River near Buffalo	OK620920030010_00	I	N	I	I	N		EWS
Buffalo Creek near Lovedale	OK620920050010_00	F	F	F	X	N	I	
Sand Creek	OK620920050050_00	I	F	F	X	N	I	
Cimarron River at Freedom	OK620920020010_00	F	N	N	I	N		EWS
Traders Creek	OK620920020170_00	F	F	I	X	N	F	
Long Creek	OK620920020080_00	F	F	F	X	N	I	
Cimarron River below Waynoka	OK620920010180_00	F	F	N	X	N	I	
Main Creek	OK620920010010_00	I	F	N	I	N		EWS
Griever Creek	OK620920010130_00	F	F	I	X	N	I	
East Griever Creek	OK620920010140_00	F	F	F	X	N	I	
Eagle Chief Creek	OK620920040010_00	F	F	F	X	N	I	
Cottonwood Creek	OK620920010080_00	F	F	N	X	N	I	
Cimarron River near Ames	OK620910020010_10	I	N	F	N	N		EWS
Cimarron River near Dover	OK620910020010_00	I	N	F	F	N		EWS

F – Fully supporting; N – Not supporting; I – Insufficient information; X – Not assessed

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

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

(b) Screening levels.

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

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

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

(c) Fecal coliform:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400

colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

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

Compliance with the Oklahoma WQS is based on meeting requirements for all three bacterial indicators. Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2008).

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

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.

The beneficial use of WWAC is one of several subcategories of the Fish and Wildlife Propagation use established to manage the variety of communities of fish and shellfish throughout the state (OWRB 2008). The numeric criteria for turbidity to maintain and protect the use of "Fish and Wildlife Propagation" from Title 785:45-5-12 (f) (7) is as follows:

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

1. *Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;*
2. *Lakes: 25 NTU; and*
3. *Other surface waters: 50 NTUs.*

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

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

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

To implement Oklahoma's WQS for Fish and Wildlife Propagation, promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

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

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

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

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

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

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

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

2.2 Problem Identification

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

2.2.1 Bacteria Data Summary

Table 2-2 summarizes water quality data collected during primary contact recreation season from the WQM stations between 1998 and 2008 for each indicator bacteria. The data summary in Table 2-2 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data collected during the primary contact recreation season was used to support the decision to place specific waterbodies within the Study Area on the DEQ 2008 303(d) list (DEQ 2008). Water quality data from the primary contact recreation seasons are provided in Appendix A. For the data collected between 1998 and 2008, evidence of nonsupport of the PBCR use based on fecal coliform, Enterococci and *E. coli* concentrations was observed in three waterbodies: Cimarron River near Buffalo (OK620920030010_00), Cimarron River below Waynoka (OK620920010010_00) and Cimarron River near Dover (OK620910020010_00). Evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci exceedances was observed in six waterbodies: Buffalo Creek (OK620920050010_00), Sand Creek (OK620920050050_00), Long Creek (OK620920020080_00), Main Creek (OK620920010010_00), Eagle Chief Creek (OK620920040010_00) and Cimarron River near Ames (OK620910020010_10). Evidence of nonsupport of the PBCR use based on *E. coli* exceedances was observed in Cimarron River at Freedom (OK620920020010_00) and fecal coliform exceedances was observed in Cottonwood Creek (OK620920010080_00). Evidence of nonsupport of the PBCR use based on Enterococci exceedances was observed in Griever Creek (OK620920010130_00). There was not enough evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci exceedances observed in Cottonwood Creek (OK620920010080_00). There was also no Evidence of nonsupport of the PBCR use based on Enterococci exceedances in Traders Creek (OK620920020170_00). There was no data available in East Griever Creek (OK620920010140_00).

2.2.2 Turbidity Data Summary

Turbidity is a measure of water clarity and is caused by suspended particles in the water column. Because turbidity cannot be expressed as a mass load, total suspended solids (TSS) are used as a surrogate in this TMDL. Therefore, both turbidity and TSS data are presented in this subsection.

Table 2-3 summarizes water quality data collected from the WQM stations between 1998 and 2009 for turbidity. However, as stipulated in Title *785:45-5-12 (f) (7) (C),* numeric criteria for turbidity only apply under base flow conditions. While the base flow condition is not specifically defined in the Oklahoma Water Quality Standards, DEQ considers base flow conditions to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75 percent of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2007a). Therefore, Table 2-4 was prepared to represent the subset of these data for samples collected during base flow conditions. Water quality samples collected under flow conditions greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. The data in Table 2-4 were used to support the decision to place three of the waterbodies listed in Table 2-1 (Cimarron River below Waynoka, Main Creek and Cottonwood Creek) on the DEQ 2008 303(d) list (DEQ 2008) for nonsupport of the WWAC use based on turbidity levels observed in the waterbody. Evidence for nonsupport of the WWAC use based on turbidity levels was also observed in Eagle Chief Creek and Cimarron River near Dover after water quality samples had been evaluated. In using TSS as a surrogate to support TMDL development at least 10 TSS samples are required to conduct the regression analysis between turbidity and TSS. Water quality data for turbidity and TSS are provided in Appendix A.

Table 2-3 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 1998-2008

Waterbody ID	Waterbody Name	Indicator Bacteria	Geo-Mean Concentration (count/100ml)	Number of Samples	Number of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	2008 303(d) Listing	Notes
OK620920030010_00	Cimarron River near Buffalo	FC	351	21	8	38%	X	TMDL required
		ENT	220	21	13	62%	X	TMDL required
		EC	1951	21	16	76%	X	TMDL required
OK620920050010_00	Buffalo Creek near Lovedale	ENT	128	42	25	60%	X	TMDL required
		EC	130	42	8	19%	X	TMDL required
OK620920050050_00	Sand Creek	ENT	415	17	15	88%	X	TMDL required
		EC	392	17	10	59%	X	TMDL required
OK620920020010_00	Cimarron River at Freedom	EC	951	14	11	79%	X	TMDL required
OK620920020170_00	Traders Creek	ENT	131	6	2	33%	X	Delist: Not enough data
OK620920020080_00	Long Creek	ENT	176	18	12	67%	X	TMDL required
		EC	149	18	3	17%		Impaired: TMDL required
OK620920010010_00	Cimarron River below Waynoka	FC	246	14	4	29%		Impaired: TMDL required
		ENT	207	14	9	64%	X	TMDL required
		EC	164	14	4	29%	X	TMDL required
OK620920010180_00	Main Creek	ENT	219	18	13	72%	X	TMDL required
		EC	193	18	1	6%	X	TMDL required
OK620920010140_00	Griever Creek, East	ENT					X	Delist: No data available
		EC					X	Delist: No data available
OK620920010130_00	Griever Creek	ENT	209	24	15	63%	X	TMDL required
		EC	92	24	4	17%	X	Delist: Meets standards
OK620920040010_00	Eagle Chief Creek	ENT	175	36	20	56%	X	TMDL required
		EC	165	36	11	31%	X	TMDL required
OK620920010080_00	Cottonwood Creek	FC	247	8	4	50%	X	TMDL required
		ENT	140	5	3	60%	X	Delist: Not enough data
		EC	56	5	1	20%	X	Delist: Not enough data
OK620910020010_10	Cimarron River near Ames	ENT	40	23	8	35%	X	TMDL required
		EC	327	23	13	57%	X	TMDL required
OK620910020010_00	Cimarron River near Dover	FC	343	24	7	29%		Impaired: TMDL required
		ENT	162	24	12	50%	X	TMDL required
		EC	438	24	11	46%	X	TMDL required

Fecal coliform (FC) water quality criterion = Geometric Mean of 400 counts/100 mL *E. coli* (EC) water quality criterion = Geometric Mean of 126 counts/100 mL Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

Table 2-4 Summaries of All Turbidity Samples 1998 - 2009

Waterbody ID	Waterbody Name	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK620920010010_00	Cimarron River below Waynoka	60	19	32%	81
OK620920010180_00	Main Creek	41	8	20%	64
OK620920040010_00	Eagle Chief Creek	81	13	16%	48
OK620920010080_00	Cottonwood Creek	20	11	55%	133
OK620910020010_00	Cimarron River near Dover	100	32	32%	138

Table 2-5 Summary of Turbidity Samples Collected During Base Flow Conditions 1998-2009

Waterbody ID	Waterbody Name	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)	2008 303(d)	Comments
OK620920010010_00	Cimarron River below Waynoka	39	9	23%	51	X	TMDL Required
OK620920010180_00	Main Creek	34	6	18%	42	X	TMDL Required
OK620920040010_00	Eagle Chief Creek	78	12	15%	45		Impaired, TMDL Required
OK620920010080_00	Cottonwood Creek	18	9	50%	82	X	TMDL Required
OK620910020010_00	Cimarron River near Dover	74	9	12%	61		Impaired, TMDL Required

After re-evaluating both bacteria and turbidity data following Oklahoma's assessment protocol, TMDLs will be developed only for the streams and pollutants listed in Table 2-6. A total of 29 bacteria/turbidity TMDLs will be developed in this report.

Table 2-6 Stream Segments and Pollutants for TMDL Development

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Turbidity
OK620920030010_00	Cimarron River near Buffalo	24	2014	3	X	X	X	
OK620920050010_00	Buffalo Creek near Lovedale	50	2010	1	X	X		
OK620920050050_00	Sand Creek	26	2014	3	X	X		
OK620920020010_00	Cimarron River at Freedom	33	2014	3		X		
OK620920020080_00	Long Creek	22	2019	4	X	X		
OK620920010010_00	Cimarron River below Waynoka	43	2014	3	X	X	X	X
OK620920010180_00	Main Creek	19	2019	4	X	X		X
OK620920010130_00	Griever Creek	20	2014	3	X			
OK620920040010_00	Eagle Chief Creek	74	2014	3	X	X		X
OK620920010080_00	Cottonwood Creek	22	2014	3			X	X
OK620910020010_10	Cimarron River near Ames	42	2014	3	X	X		
OK620910020010_00	Cimarron River near Dover	18	2014	3	X	X	X	X

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 bacteria TMDLs in this report, defining the water quality target is somewhat complicated by the use of three different bacterial indicators each with different numeric criterion for determining attainment of PBCR use as defined in the Oklahoma WQSs. An individual water quality target is established for each bacterial indicator since each indicator group must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008). 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 both the instantaneous and a long-term geometric mean for each bacterial indicator.

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 long-term geometric mean criterion, whichever is less.

If fecal coliform is utilized to establish the TMDL, then the water quality target is the instantaneous water quality criteria (400/100 mL). If *E. coli* is utilized to establish the TMDL, then the water quality target is the instantaneous water quality criterion value (406/100 mL), and the geometric mean water quality target is the geometric mean criterion value (126/100 mL). If Enterococci is utilized to establish the TMDL, then the water quality target is the instantaneous water quality criterion value (108/100 mL) and the geometric mean water quality target is the geometric mean criterion value (33/100 mL).

The TMDL for bacteria will incorporate an explicit 10 percent margin of safety. The allowable bacteria load is derived by using the actual or estimated flow record multiplied by the water quality target. 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.

An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008). According to the Oklahoma WQS [785:45-5-12(f) (7)], the turbidity criterion for streams with WWAC beneficial use is 50 NTUs (OWRB 2008). The turbidity of 50 NTUs applies only to seasonal base flow conditions. Turbidity levels are expected to be elevated during, and for several days after, a storm event.

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 NTU. However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate for TMDL development. Since there is no numeric criterion in the Oklahoma WQS for TSS, a specific method must be developed to convert the turbidity criterion to TSS based on a relationship between turbidity and TSS. The method for deriving the relationship between turbidity and TSS and for calculating a water body specific water quality target using TSS is summarized in Section 4 of this report.

The MOS for the TSS TMDLs varies by waterbody and is related to the goodness-of-fit metrics of the turbidity-TSS regressions. The method for defining MOS percentages is described in Section 5 of this report.

SECTION 3
POLLUTANT SOURCE ASSESSMENT

A pollutant source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Bacteria originate from warm-blooded animals; some plant life and sources may be point or nonpoint in nature. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the 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) and TSS in accordance with their permits. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria or TSS 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 2008 Integrated Water Quality Assessment Report (DEQ 2008) listed potential sources of turbidity as clean sediment, grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, petroleum/natural gas activities, rangeland grazing, as well as other unknown 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 or TSS loading includes:

- NPDES municipal wastewater treatment plant (WWTP);
- NPDES Industrial WWTP Discharges;
- NPDES municipal no-discharge WWTP;
- NPDES Concentrated Animal Feeding Operation (CAFO);
- NPDES municipal separate storm sewer discharge (MS4);
- NPDES multi-sector general permits; and
- NPDES construction stormwater discharges.

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. It is possible that continuous point source discharges from municipal and industrial WWTPs, could result in discharge of elevated concentrations of TSS if a facility is not properly maintained, is of poor design, or flow rates exceed capacity. However, in most cases suspended solids discharged by WWTPs consist primarily of organic solids rather than inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). Discharges of organic suspended solids from WWTPs are addressed by DEQ through its permitting of point sources to maintain WQS for dissolved oxygen and are not considered a potential source of turbidity in this TMDL. Discharges of TSS will be considered to be organic suspended solids if the discharge permit includes a limit for BOD or CBOD. Only WWTP discharges of inorganic suspended solids will be considered and will receive wasteload allocations.

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. CAFOs 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.

Stormwater runoff from MS4 areas, which is now regulated under the USEPA NPDES Program, can also contain high fecal coliform bacteria concentrations. Stormwater runoff from MS4 areas, facilities under multi-sector general permits, and NPDES construction stormwater discharges, which are regulated under the USEPA NPDES Program, can contain TSS concentrations. 40 C.F.R. § 130.2(h) requires that NPDES-regulated stormwater discharges must be addressed by the wasteload allocation component of a TMDL. However, any stormwater discharge by definition occurs during or immediately following periods of rainfall and elevated flow conditions when where Oklahoma Water Quality Standard for turbidity does not apply. Oklahoma Water Quality Standards specify that the criteria for turbidity "apply only to seasonal base flow conditions" and go on to say "Elevated turbidity levels may be expected during, and for several days after, a runoff event" [OAC 785:45-5-12(f)(7)]. In other words, the turbidity impairment status is limited to base flow conditions and stormwater discharges from MS4 areas or construction sites do not contribute to the violation of Oklahoma's turbidity standard. Therefore, WLAs for NPDES-regulated stormwater discharges is essentially considered unnecessary in this TMDL report and will not be included in the TMDL calculations.

There are no NPDES-permitted facilities in the contributing watersheds of Sand Creek (OK620920050050_00), Traders Creek (OK620920020170_00), Long Creek (OK620920020080_00), Griever Creek (OK620920010130_00), Cottonwood Creek (OK620920010080_00) and Cimarron River near Dover (OK620910020010_00). The remaining seven watersheds in the Study Area have at least one NPDES-permitted facility. Section 5.4 will discuss the permits that have the pollutants of concern.

There are no areas designated as MS4s within this Study Area.

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 Figures 3-1. There are five active continuous point source discharging facilities within the Study Area but they are not all sources of concern for bacteria or TSS loading. None of these facilities are discharging to a waterbody that requires a TMDL for TSS although all of the facilities in Table 3-1 discharge TSS and have specific permit limits for TSS which is provided in Table 3-1. The municipal WWTPs designated with a Standard Industrial Code number 4952 or 4959 in Table 3-1 discharge organic TSS and therefore are not considered a potential source of turbidity within their respective watershed. There are three active NPDES-permitted industrial facilities operating in the Study Area which are shown in Figures 3-1 and facility information is listed in Table 3-1. These industrial facilities do not contribute to the impairment of their respective receiving streams since the streams are impaired for bacteria and not TSS.

Table 3-1 Point Source Discharges in the Study Area

OPDES Permit No.	Name	Receiving Water: Waterbody Name & (Waterbody ID)	Facility Type	SIC Code	County	Design Flow (mgd)	Max. FC cfu/100mL	Max./Avg. TSS mg/L	Expiration Date	Status
OK0040240	Cargill Inc., Salt Division	Cimarron River near Buffalo OK620920030010_00	Chemical Preparations	2899	Woods	0.2307	NA	45	7/31/14	Active
OK0040241	Cargill Inc., Salt Division		Chemical Preparations	2899	Woods	0.5134	NA	45	7/31/14	Active
OK0020079	Fairview WWTP	Cimarron River below Waynoka OK620920010010_00	Sewerage Systems	4952	Major	0.3370	NA	135/90	9/30/12	Active
OKG580045	Town of Aline	Eagle Chief Creek OK620920040010_00	Sewerage Systems	4952	Alfalfa	0.0310	NA	135/90	6/30/11	Active
OK0038806	US Gypsum Company	Cimarron River near Ames OK620910020010_00	Gypsum Products	3275	Blaine	0.2500	NA	45/30	9/30/14	Active
OKG580030	City of Okeene		Sewerage Systems	4952	Blaine	NA	NA	NA	NA	Inactive
OK0025801	Hitchcock Development, Inc.		Sewerage Systems	4952	Blaine	0.020	NA	NA	NA	Inactive
OK0043419	Laverne Remediation Project	Buffalo Creek OK620920050010_00	Sewerage Systems	4959	Harper	NA	NA	NA	NA	Inactive

NA = not available.

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

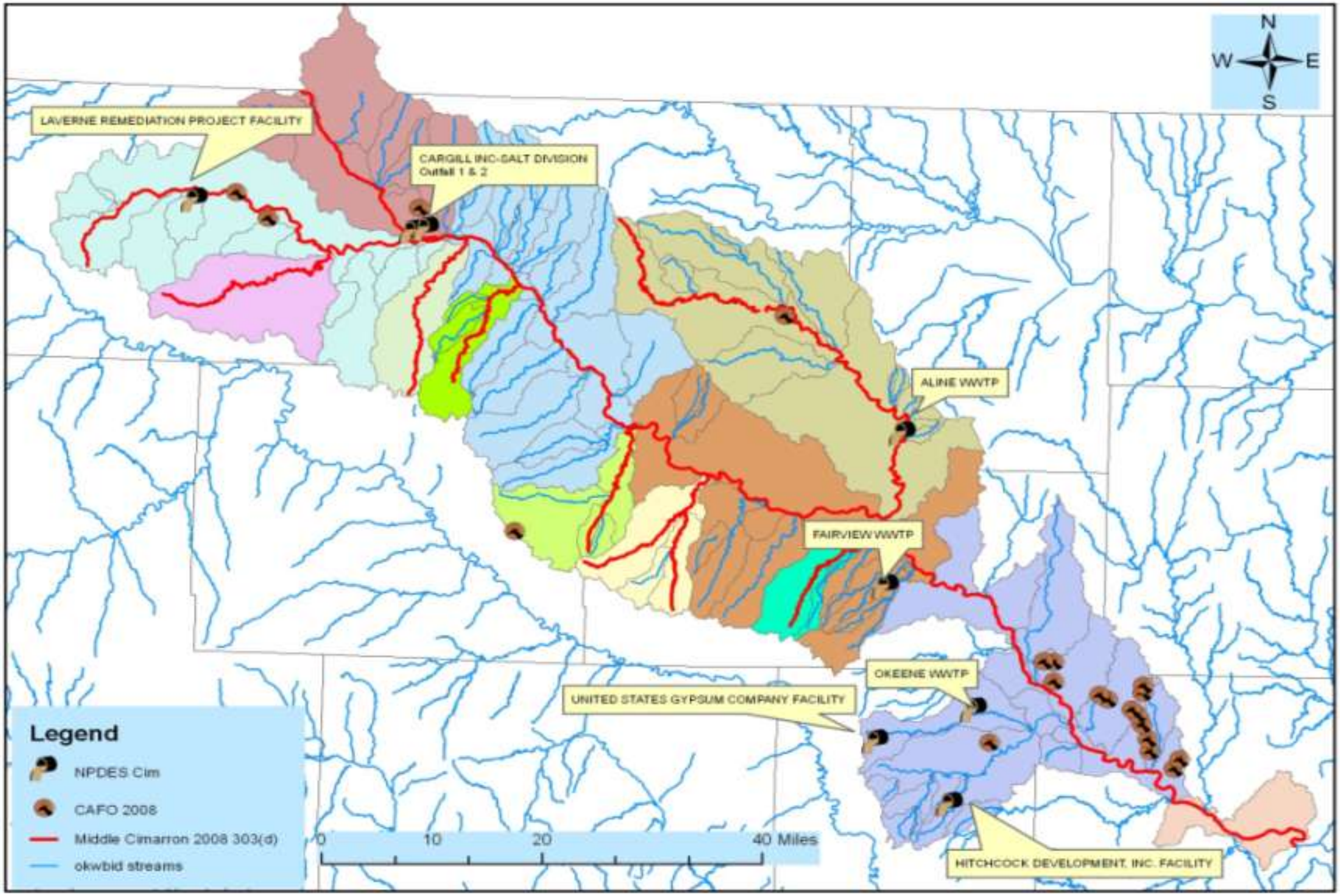
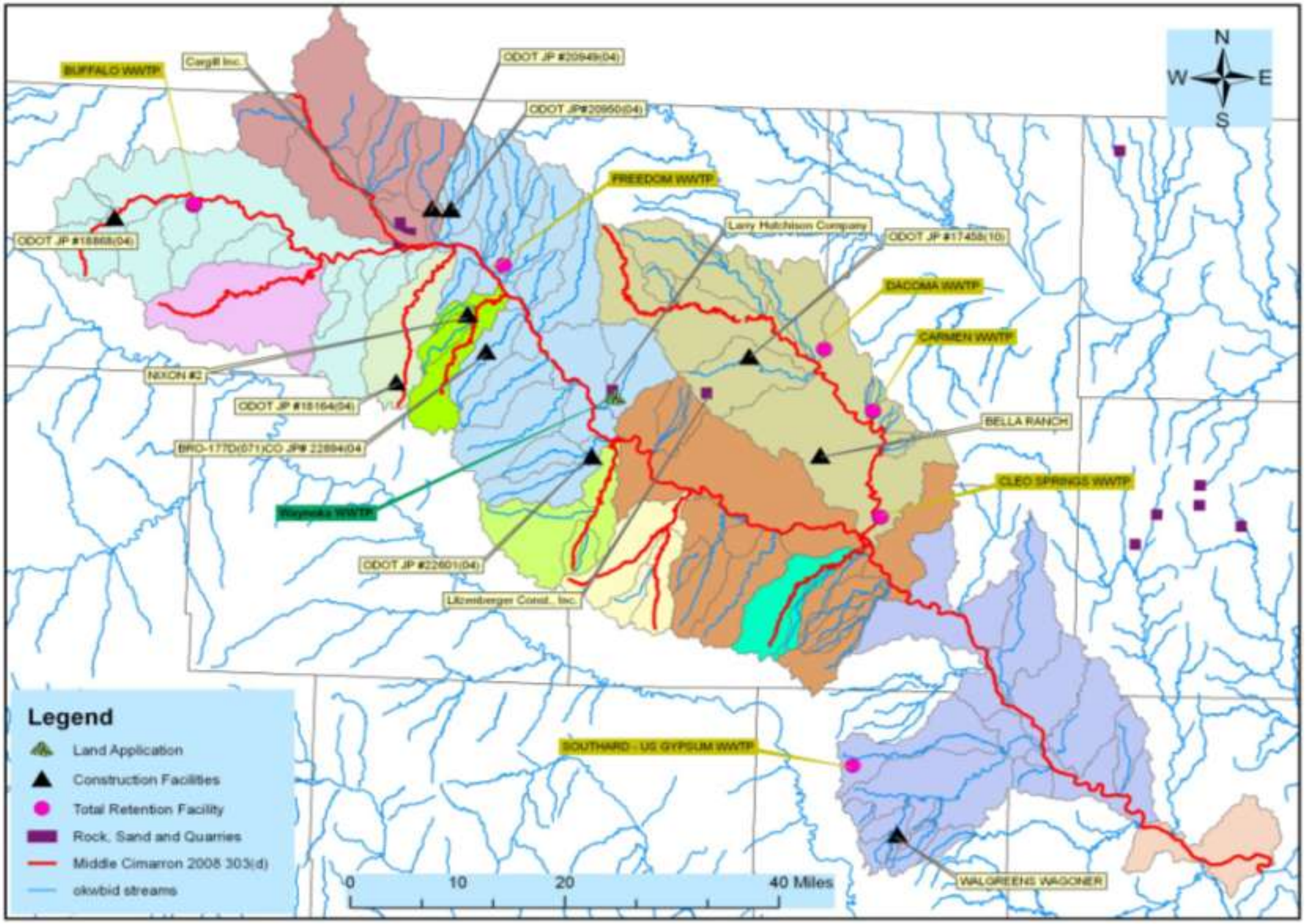


Figure 3-2 Locations of NPDES-Permitted Facilities in the Study Area



3.1.2 NPDES No-Discharge Facilities and Sanitary Sewer Overflows

For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute bacteria or TSS loading. However, it is possible the wastewater collection systems associated with these no-discharge facilities could be a source of bacteria loading, or that discharges from the wastewater plant may occur during large rainfall events that exceed the systems' storage capacities. There are seven recorded municipal and industrial no-discharge facilities in the study area which are listed in Table 3-2.

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

Facility	Facility ID	County	Facility Type	Type	Watershed
Freedom WWT	S20903	Woods	Lagoon (Total Retention)	Municipal	Cimarron River near Freedom OK620920020010_00
Buffalo WWT	S20902	Harper	Lagoon (Total Retention)	Municipal	Buffalo Creek OK620920050010_00
Cleo Springs WWT	S20943	Major	Lagoon (Total Retention)	Municipal	Cimarron River below Waynoka OK620920010010_00
Waynoka WWT	S20904	Woods	Land Application	Municipal	
Carmen WWT	S20906	Alfalfa	Lagoon (Total Retention)	Municipal	Eagle Chief Creek OK620920040010_00
Dacoma WWT	S20905	Woods	Lagoon (Total Retention)	Municipal	
Southard - US Gypsum WWT	S20971	Blaine	Lagoon (Total Retention)	Industrial	Cimarron River near Ames OK620910020010_10

While not all sewer overflows are reported, DEQ has some data on SSOs available. There were 24 combined SSO occurrences in the Middle Cimarron River study area on record which goes back to as early as 1990. The first occurrence was in March 1990 and the last in April 2009. A summary of the reported SSOs are provided in Table 3-3. Additional data on each individual SSO event and the facility are provided in Appendix D.

Table 3-3 Sanitary Sewer Overflow Summary

Facility Name	Facility ID	Receiving Water	Number of Occurrences	Date Range	
				From	To
Freedom WWT	S20903	Cimarron River near Freedom	7	3/5/1990	4/26/2009
Buffalo WWT	S20902	Buffalo Creek	4	6/29/1999	10/21/2008
Waynoka WWT	S20904	Cimarron River below Waynoka	12	3/23/1990	5/15/2007
Dacoma WWT	S20905	Eagle Chief Creek	1	2/23/1997	2/23/1997

Sanitary sewer overflows (SSO) from wastewater collection systems, although infrequent, can be a major source of fecal coliform loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. The reporting of SSOs has been strongly encouraged by USEPA, primarily through enforcement and fines. While not all sewer overflows are reported, DEQ has some data on SSOs available.

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.

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 roadway runoff management, municipal-owned operations, and hazardous waste treatment. There are no Phase I MS4 permits in the Study Area.

Phase II MS4

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

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

The small MS4 General Permit for communities in Oklahoma became effective on February 8, 2005. ODEQ provides information on the current status of the MS4 program on its website, which can be found at:

http://www.deq.state.ok.us/WQDnew/stormwater/ms4/.

There is no permitted MS4s in the study area.

3.1.4 Concentrated Animal Feeding Operations

The Agricultural Environmental Management Services (AEMS) of the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) was created to help develop, coordinate, and oversee environmental policies and programs aimed at protecting the Oklahoma environment from pollutants associated with agricultural animals and their waste. Through regulations established by the Oklahoma Concentrated Animal Feeding Operation (CAFO) Act and Swine Feeding Operation (SFO) Act, AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the state. A CAFO is an animal feeding operation that confines and feeds at least 1,000 animal units for 45 days or more in a 12-month period (ODAFF 2009). The CAFO Act and SFO Act are designed to protect water quality through the use of best management practices (BMP) such as dikes, berms, terraces, ditches, or other similar structures used to isolate animal waste from outside surface drainage, except for a 25-year, 24–hour rainfall event (ODAFF 2009). CAFOs are considered no-discharge facilities.

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

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

Table 3-4 NPDES-Permitted CAFOs in Study Area

ODAFF Owner ID Number	EPA Facility Number	ODAFF ID	ODAFF License Number	Maximum # of Permitted Animals at Facility		Total # of Animal Units at Facility	County	Watershed
				Slaughter Feeder Cattle	Swine			
WQ0000031	OKG010003	31	1347	3,000		3,000	Harper	Buffalo Creek OK620920050010_00
AGN032914	OKG010300	81	15	35,000		35,000	Harper	
WQ0000337	OKU000242	207	12621		4,000	1,600	Kingfisher	Cimarron River near Ames OK620910020010_10
WQ0000334	OKU000254	208	12622		12,000	1,200	Kingfisher	
WQ0000335	OKU000251	209	12623		24,000	9,600	Kingfisher	
WQ0000323	OKU000356	212	1491		11,086	4,434	Kingfisher	
WQ0000341	OKU000243	213	12611		5,460	2,184	Kingfisher	
WQ0000344	OKU000395	214	12612		12,000	1,200	Kingfisher	
WQ0000348	OKU000255	215	12613		6,000	2,400	Kingfisher	
WQ0000346	OKU000247	216	12614		6,000	2,400	Kingfisher	
WQ0000347	OKU000240	217	12615		6,000	2,400	Kingfisher	
WQ0000345	OKU000249	218	12616		6,000	2,400	Kingfisher	
WQ0000342	OKU000244	430	1225		18,264	7,306	Kingfisher	
WQ0000320	OKU000387	211	1490		14,081	5,632	Major	
WQ0000324	OKU000215	223	1311		23,832	7,613	Major	
WQ0000051	OKU000358	128	980004		6,000	2,400	Blaine	
AGN007231	OKG010072	235	86	10,001		10,001	Woods	Cimarron River at Buffalo OK620920030010_00
AGN021005	OKG010209	269	1114	1,500		1,500	Woods	Eagle Chief Creek OK620920040010_00
WQ0000319	OKU000401	210	1489		180,800	50,720	Woodward	Main Creek OK620920010180_00

3.1.5 Stormwater Permits Construction Activities

A general stormwater permit (OKR10) is required by the ODEQ for any stormwater discharges associated with construction activities that result in land disturbance of equal to or greater than one (1) acre, or less than one (1) acre if they are part of a larger common plan of development or sale that totals at least one (1) acre. The permit also authorizes any stormwater discharges from support activities (e.g. concrete or asphalt batch plants, equipment staging yards, material storage areas, excavated material disposal areas, and borrow areas) that are directly related to a construction site that is required to have permit coverage, and is not a commercial operation serving unrelated different sites (ODEQ 2007). Stormwater discharges occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply and are not considered potential contributors to turbidity impairment. The construction permits in the study area are summarized in Table 3-5 and shown in Figure 3-2.

3.1.6 Rock, Sand, and Gravel Quarries

Operators of rock, sand and gravel quarries in Oklahoma are regulated with a general permit (OKG950000) issued by the ODEQ. The general permit does not allow discharge of wastewater to waterbodies included in Oklahoma's 303(d) List of impaired water bodies listed for turbidity for which a TMDL has not been performed or the result of the TMDL indicates that discharge limits more stringent than 45 mg/l for TSS are required (ODEQ 2009). If the TMDL shows that a TSS limit more stringent than 45 mg/L is required, an individual discharge permit with the TMDL required TSS limit will be issued to the facility. Table 3-6 summarizes data from the Oklahoma Department of Mines and provides the permitted mining acres for each of the quarries located within the Study Area. The locations of these quarries are shown in Figures 3-2. However, three of the four facilities are not located in a turbidity impaired sub-watershed. Litzenberger Construction Incorporated, which is located in the sub-watershed of Eagle Chief Creek, does not have a discharge permit because they do not discharge.

3.1.7 Section 404 Permits

Section 404 of the Clean Water Act (CWA) establishes programs to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports) and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt from Section 404 regulation (e.g. certain farming and forestry activities).

Section 404 permits are administrated by the U.S. Army Corps of Engineers. EPA reviews and provides comments on each permit application to make sure it adequately protects water quality and complies with applicable guidelines. Both USACE and EPA can take enforcement actions for violations of Section 404.

Discharge of dredged or fill material in waters can be a significant source of turbidity/TSS. The federal Clean Water Act requires that a permit be issued for activities which discharge dredged or fill materials into the waters of the United States, including wetlands. The state will use its Section 401 certification authority to ensure Section 404 permits protect Oklahoma water quality standards.

Table 3-5 Construction Permits Summary

<table>
<tr><th>Company Name</th><th>County</th><th>Permit ID</th><th>Date Issued</th><th>Waterbody ID</th><th>Receiving Water (Permit)</th><th>Estimated Acres</th></tr>
<tr><td>ODOT JP #18868(04)</td><td>Harper</td><td>7497</td><td>1/11/2008</td><td>OK620920050010_00</td><td>Buffalo Creek</td><td>12.6</td></tr>
<tr><td>ODOT JP #20949(04)</td><td>Woods</td><td>8750</td><td>3/24/2008</td><td>OK620920030010_00</td><td>Cimarron River near Buffalo</td><td>30</td></tr>
<tr><td>NIXON #2</td><td>Woodward</td><td>7276</td><td></td><td>OK620920020080_00</td><td>Long Creek</td><td>1230.26</td></tr>
<tr><td>ODOT JP #18164(04)</td><td>Woodward</td><td>7550</td><td>12/18/2007</td><td>OK620920020170_00</td><td>Traders Creek</td><td>6.25</td></tr>
<tr><td>ODOT JP #22601(04)</td><td>Major</td><td>8550</td><td>12/17/2007</td><td rowspan="3">OK620920020010_00</td><td rowspan="3">Cimarron River near Freedom</td><td>2.37</td></tr>
<tr><td>ODOT JP#20950(04)</td><td>Woods</td><td>9135</td><td>6/11/2008</td><td>30.4</td></tr>
<tr><td>BRO-177D(071)CO JP# 22894(04</td><td>Woodward</td><td>9216</td><td></td><td>3</td></tr>
<tr><td>ODOT JP #17458(10)</td><td>Woods</td><td>7793</td><td>1/10/2008</td><td rowspan="2">OK620920040010_00</td><td rowspan="2">Eagle Chief Creek</td><td>230</td></tr>
<tr><td>BELLA RANCH</td><td>Woods</td><td>7807</td><td></td><td>142</td></tr>
<tr><td>Walgreens Wagoner</td><td>Blaine</td><td>8252</td><td>10/8/2007</td><td>OK620910020010_10</td><td>Cimarron River near Ames</td><td>1</td></tr>
</table>

Table 3-6 Rock, Sand and Gravel Quarries

Company Name	County	Permit ID	Product	Permitted Acres	Permit Issue Date	Permit Renewal Date	Mining Expiration Date	Waterbody ID
U.S. Gypsum Company (Southard-Plant #227)	Blaine	L.E.-1530-D	Gypsum	6205.7	2/1/1997	1/31/2009	1-31-2047	Cimarron River near Ames OK620910020010_00
Larry Hutchison	Woods	X08-1222	Sand	3	1/1/2008	NA	12-31-08	Cimarron River near Freedom OK620920020010_00
Litzenberger Const., Inc.	Woods	X08-1148	Red Shale	3	8/17/2007	NA	8-16-08	Eagle Chief Creek OK620920040010_00
Cargill Inc.	Woods	L.E.-1602	Salt	500	11/1/1997	10/31/2008	10-31-2047	Cimarron River near Buffalo OK620920030010_00

3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the waterbody at a specific location. The relatively homogeneous land use/land cover categories throughout the Study Area associated with rural agricultural, forest and range management activities has an influence on the origin and pathways of pollutant sources to surface water. Bacteria originate from warm-blooded animals in rural, suburban, and urban areas. These sources include wildlife, various agricultural activities, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems and domestic pets. Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's 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). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal coliform bacteria. Water quality data collected from streams draining many of the non-permitted communities show existing loads of fecal coliform bacteria at levels greater than the State's instantaneous standards.

Various potential nonpoint sources of TSS as indicated in the 2008 Integrated Report include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff, non-irrigated crop production, rangeland grazing and other sources of sediment loading (DEQ 2008). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances. The following section provides general information on nonpoint sources contributing bacteria or TSS loading within the Study Area.

3.2.1 Wildlife

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

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

According to a study conducted by ASAE (the American Society of Agricultural Engineers), deer release approximately 5×10^8 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 3-7 in cfu/day provides a relative magnitude of loading in each watershed.

Table 3-7 Estimated Population and Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 10^9 cfu/day) of Deer Population
OK620920030010_00	Cimarron River near Buffalo	488,796	2,657	0.0054	1,329
OK620920050010_00	Buffalo Creek near Lovedale	315,171	1,158	0.0037	579
OK620920050050_00	Sand Creek	78,407	408	0.0052	204
OK620920020010_00	Cimarron River at Freedom	468,391	1,938	0.0041	969
OK620920020170_00	Traders Creek	46,312	37	0.0008	19
OK620920020080_00	Long Creek	38,888	1	0.0000	0
OK620920010180_00	Main Creek	60,217	275	0.0046	138
OK620920010010_00	Cimarron River below Waynoka	680,483	6,722	0.0099	3,361
OK620920010130_00	Griever Creek	83,601	935	0.0112	467
OK620920040010_00	Eagle Chief Creek	311,366	2,841	0.0091	1,421
OK620920010080_00	Cottonwood Creek	34,859	395	0.0113	198
OK620910020010_10	Cimarron River near Ames	375,214	1,831	0.0049	915
OK620910020010_00	Cimarron River near Dover	54,361	375	0.0069	187

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 (Draco and Hubs 2002). The following are examples of commercially raised farm animal activities that can contribute to bacteria sources:

- Processed commercially raised farm animal manure is often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff.
- Animals grazing in pastures deposit manure containing fecal bacteria onto land surfaces. These bacteria may be washed into waterbodies by runoff.
- Animals often have direct access to waterbodies and can provide a concentrated source of fecal bacteria loading directly into streams.

Table 3-7 provides estimated numbers of commercially 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 commercially raised farm animals are not evenly distributed across counties or constant with time, these are rough estimates only. Cattle are clearly the most abundant species of commercially raised farm animals in the Study Area and often have direct access to the impaired waterbodies or their tributaries.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application of manure from commercially raised farm animal. Nor is sufficient information available to describe or quantify the contributions of sediment loading caused by commercially raised farm animal responsible for destabilizing stream banks or erosion in pasture fields. The estimated acreage by watershed where manure was applied in 2002 is shown in Table 3-8. These estimates are also based on the county level reports from the 2002 USDA county agricultural census, and thus, represent approximations of the commercially raised farm animal populations in each watershed. Despite the lack of specific data, for the purpose of these TMDLs, land application of commercially raised farm animal manure is considered a potential source of bacteria loading to the watersheds in the Study Area.

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

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

Using the estimated animal populations and the fecal coliform production rates from ASAE, an estimate of fecal coliform production from each group of commercially raised farm animals was calculated in each watershed of the study area in Table 3-9. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into streams by runoff or by direct deposition from wading animals. Cattle again appear to represent the most likely commercially raised farm animal source of fecal bacteria.

Table 3-8 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	Chicken & Turkeys	Acres of Manure Application
OK620920030010_00	Cimarron River near Buffalo	51,746	195	596	1	408	45	28	267	1,410
OK620920050010_00	Buffalo Creek near Lovedale	24,928	54	246	0	201	0	10	104	456
OK620920050050_00	Sand Creek	8,358	18	78	0	55	0	3	31	114
OK620920020010_00	Cimarron River at Freedom	44,286	104	658	0	935	69	23	374	678
OK620920020170_00	Traders Creek	4,083	5	75	0	130	0	4	45	67
OK620920020080_00	Long Creek	3,298	3	67	0	124	0	4	41	56
OK620920010180_00	Main Creek	6,115	29	96	0	170	0	4	92	221
OK620920010010_00	Cimarron River below Waynoka	80,438	458	789	0	1,003	634	10	754	1,963
OK620920010130_00	Griever Creek	12,517	108	118	0	196	0	3	188	248
OK620920040010_00	Eagle Chief Creek	35,931	132	308	0	310	574	1	112	754
OK620920010080_00	Cottonwood Creek	4,416	38	49	0	81	0	1	79	128
OK620910020010_10	Cimarron River near Ames	42,508	407	386	0	595	89	12	12	1,227
OK620910020010_00	Cimarron River near Dover	9,573	103	115	0	206	172	5	88	178

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

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Total
OK620920030010_00	Cimarron River near Buffalo	5,381,584	19,695	250	12	4,896	486	720	31	5,407,673
OK620920050010_00	Buffalo Creek near Lovedale	2,592,512	5,454	103	0	2,412	0	257	12	2,600,750
OK620920050050_00	Sand Creek	869,232	1,818	33	0	660	0	77	4	871,823
OK620920020010_00	Cimarron River at Freedom	4,605,744	10,504	276	0	11,220	745	591	43	4,629,123
OK620920020170_00	Traders Creek	424,632	505	32	0	1,560	0	103	5	426,836
OK620920020080_00	Long Creek	342,992	303	28	0	1,488	0	103	5	344,919
OK620920010180_00	Main Creek	635,960	2,929	40	0	2,040	0	103	11	641,083
OK620920010010_00	Cimarron River below Waynoka	8,365,552	46,258	331	0	12,036	6,847	257	86	8,431,368
OK620920010130_00	Griever Creek	1,301,772	10,859	49	0	2,347	0	7	17	1,315,051
OK620920040010_00	Eagle Chief Creek	3,736,824	13,332	129	0	3,720	6,199	26	13	3,760,243
OK620920010080_00	Cottonwood Creek	459,264	3,838	21	0	972	0	26	9	464,129
OK620910020010_10	Cimarron River near Ames	4,420,832	41,107	162	0	7,140	961	308	1	4,470,512
OK620910020010_00	Cimarron River near Dover	995,592	10,403	48	0	2,472	1,858	129	10	1,010,511

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

DEQ is responsible for implementing the regulations of Title 252, Chapter 641 of the Oklahoma Administrative Code, which define design standards for individual and small public onsite sewage disposal systems (DEQ 2008a). OSWD systems and illicit discharges can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSWD systems can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater discharges to creeks through springs and seeps.

To estimate the potential magnitude of OSWDs fecal bacteria loading, the number of OSWD systems was estimated for each watershed. The estimate of OSWD systems was derived by using data from the 1990 U.S. Census because this data was not available in the 2000 U.S. Census. The estimate was then prorated based on the population data from both the 1990 and 2000 U.S. Census. The density of OSWD systems within each watershed was estimated by dividing the number of OSWD systems in each census block by the number of acres in each census block. This density was then applied to the number of acres of each census block within a waterbody watershed. Census blocks crossing a watershed boundary required additional calculation to estimate the number of OSWD systems based on the proportion of the census tracking falling within each watershed. This step involved adding all OSWD systems for each whole or partial census block.

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

Table 3-10 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK720510000190_00	Cimarron River near Buffalo	753	429	20	1,202	63%
OK720500020290_00	Buffalo Creek near Lovedale	427	226	11	664	64%
OK720500020450_00	Sand Creek	135	66	4	205	66%
OK720500020140_00	Cimarron River at Freedom	668	562	11	1,241	54%
OK720500020010_00	Traders Creek	80	54	1	135	59%
OK720500030080_00	Long Creek	68	45	1	114	60%
OK720500020300_00	Main Creek	62	94	5	161	39%
OK720500020070_00	Cimarron River below Waynoka	3,644	1,404	90	5,138	71%
OK720510000275_00	Griever Creek	1	176	13	190	1%
OK720500020130_00	Eagle Chief Creek	2,153	531	40	2,724	79%
OK720500020050_00	Cottonwood Creek	0	74	6	80	0%
OK720500020500_00	Cimarron River near Ames	944	773	22	1,740	54%
OK720500020500_10	Cimarron River near Dover	371	268	4	643	58%

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

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

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

The average of number of people per household was calculated to be 2.48 for counties in the Study Area (U.S. Census Bureau 2000). Approximately 70 gallons of wastewater was 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 was summarized below in Table 3-11.

Table 3-11 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)
OK620920030010_00	Cimarron River near Buffalo	488,796	429	34	226
OK620920050010_00	Buffalo Creek near Lovedale	315,171	226	18	119
OK620920050050_00	Sand Creek	78,407	66	5	35
OK620920020010_00	Cimarron River at Freedom	468,391	562	45	296
OK620920020170_00	Traders Creek	46,312	54	4	28
OK620920020080_00	Long Creek	38,888	45	4	24
OK620920010180_00	Main Creek	60,217	94	8	49
OK620920010010_00	Cimarron River below Waynoka	680,483	1,404	112	738
OK620920010130_00	Griever Creek	83,601	176	14	92
OK620920040010_00	Eagle Chief Creek	311,366	531	4	27
OK620920010080_00	Cottonwood Creek	34,859	74	42	279
OK620910020010_10	Cimarron River near Ames	375,214	773	6	39
OK620910020010_00	Cimarron River near Dover	54,361	268	62	407

3.2.4 Domestic Pets

Fecal matter from dogs and cats, which is transported to streams by runoff from urban and suburban areas, can be a potential source of bacteria loading. On average 37.2 percent of the nation's households own dogs and 32.4 percent own cats and in these households the average number of dogs is 1.7 and 2.2 cats per household (American Veterinary Medical Association 2007). Using the U.S. census data at the block level (U.S. Census Bureau 2000), dog and cat populations can be estimated for each watershed. Table 3-12 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-12 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Housing Units	Dogs	Cats
OK620920030010_00	Cimarron River near Buffalo	1,202	2,043	2,644
OK620920050010_00	Buffalo Creek near Lovedale	664	1,129	1,461
OK620920050050_00	Sand Creek	205	349	451
OK620920020010_00	Cimarron River at Freedom	1,241	2,110	2,730
OK620920020170_00	Traders Creek	135	230	297
OK620920020080_00	Long Creek	114	194	251
OK620920010180_00	Main Creek	161	274	354
OK620920010010_00	Cimarron River below Waynoka	5,138	8,735	11,304
OK620920010130_00	Griever Creek	190	323	418
OK620920040010_00	Eagle Chief Creek	2,724	4,631	5,993
OK620920010080_00	Cottonwood Creek	80	136	176
OK620910020010_10	Cimarron River near Ames	1,740	2,957	3,827
OK620910020010_00	Cimarron River near Dover	643	1,093	1,415

Table 3-13 provides an estimate of the fecal coliform load from pets. These estimates are based on estimated fecal coliform production rates of 5.4×10^8 per day for cats and 3.3×10^9 per day for dogs (Schueler 2000).

Table 3-13 Estimated Fecal Coliform Daily Production by Pets (x 10^9)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK620920030010_00	Cimarron River near Buffalo	6,743	1,428	8,171
OK620920050010_00	Buffalo Creek near Lovedale	3,725	789	4,514
OK620920050050_00	Sand Creek	1,150	244	1,394
OK620920020010_00	Cimarron River at Freedom	6,962	1,474	8,436
OK620920020170_00	Traders Creek	757	160	918
OK620920020080_00	Long Creek	640	135	775
OK620920010180_00	Main Creek	903	191	1,094
OK620920010010_00	Cimarron River below Waynoka	28,824	6,104	34,928
OK620920010130_00	Griever Creek	1,066	226	1,292
OK620920040010_00	Eagle Chief Creek	15,282	3,236	18,518
OK620920010080_00	Cottonwood Creek	449	95	544
OK620910020010_10	Cimarron River near Ames	9,759	2,067	11,825
OK620910020010_00	Cimarron River near Dover	3,607	764	4,371

3.3 Summary of Bacteria Sources

NPDES-permitted facilities operate in a few of the watersheds in the Study Area but most of the point sources are relatively minor and for the most part tend to meet instream water quality criteria in their effluent. Thus, nonpoint sources are considered to be the major source of bacteria loading in each watershed. Table 3-14 summarizes the suspected sources of bacteria loading in each impaired watershed.

Table 3-14 Estimated Major Source of Bacteria Loading by Watershed

Waterbody ID	Waterbody Name	Point Sources	Nonpoint Sources	Major Source
OK620920030010_00	Cimarron River near Buffalo	No	Yes	Nonpoint
OK620920050010_00	Buffalo Creek near Lovedale	No	Yes	Nonpoint
OK620920050050_00	Sand Creek	No	Yes	Nonpoint
OK620920020010_00	Cimarron River at Freedom	No	Yes	Nonpoint
OK620920020170_00	Traders Creek	No	Yes	Nonpoint
OK620920020080_00	Long Creek	No	Yes	Nonpoint
OK620920010180_00	Main Creek	No	Yes	Nonpoint
OK620920010010_00	Cimarron River below Waynoka	Yes	Yes	Nonpoint
OK620920010130_00	Griever Creek	No	Yes	Nonpoint
OK620920040010_00	Eagle Chief Creek	Yes	Yes	Nonpoint
OK620920010080_00	Cottonwood Creek	No	Yes	Nonpoint
OK620910020010_10	Cimarron River near Ames	No	Yes	Nonpoint
OK620910020010_00	Cimarron River near Dover	No	Yes	Nonpoint

Table 3-15 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 primary contributors of fecal coliform loading to land surfaces. It must be noted that while no data are available to estimate populations and fecal loading of wildlife other than deer, a number of bacteria source tracking studies demonstrate 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 quantify 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. Also, the structural properties of some manure, such as cow patties, may limit their washoff into streams by runoff. 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. 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 3-15 Summaries of Daily Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces (% of Total Watershed Load)

Waterbody ID	Waterbody Name	Commercially Raised Farm Animals	Pets	Deer	Septic Tanks
OK620920030010_00	Cimarron River near Buffalo	99.82%	0.15%	0.02%	0.00%
OK620920050010_00	Buffalo Creek near Lovedale	99.80%	0.17%	0.02%	0.00%
OK620920050050_00	Sand Creek	99.81%	0.16%	0.02%	0.00%
OK620920020010_00	Cimarron River at Freedom	99.79%	0.18%	0.02%	0.01%
OK620920020170_00	Traders Creek	99.77%	0.21%	0.00%	0.01%
OK620920020080_00	Long Creek	99.77%	0.22%	0.00%	0.01%
OK620920010180_00	Main Creek	99.80%	0.17%	0.02%	0.01%
OK620920010010_00	Cimarron River below Waynoka	99.54%	0.41%	0.04%	0.01%
OK620920010130_00	Griever Creek	99.81%	0.14%	0.04%	0.01%
OK620920040010_00	Eagle Chief Creek	99.47%	0.49%	0.04%	0.01%
OK620920010080_00	Cottonwood Creek	99.83%	0.12%	0.04%	0.01%
OK620910020010_10	Cimarron River near Ames	99.67%	0.29%	0.03%	0.01%
OK620910020010_00	Cimarron River near Dover	99.45%	0.51%	0.02%	0.02%

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

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

4.1 Determining a Surrogate Target for Turbidity

Turbidity is a commonly measured indicator of the suspended solids load in streams. However, turbidity is an optical property of water, which measures scattering of light by suspended solids and colloidal matter. To develop TMDLs, a gravimetric (mass-based) measure of solids loading is required to express loads. There is often a strong relationship between the total suspended solids concentration and turbidity. Therefore, the TSS load, which is expressed as mass per time, is used as a surrogate for turbidity.

To determine the relationship between turbidity and TSS, a linear regression between TSS and turbidity was developed using data collected from 1999 to 2009 at stations within the Study Area. Prior to developing the regression the following steps were taken to refine the dataset:

- Replace TSS samples of "<10" with 9.99;
- Remove data collected under high flow conditions exceeding the base-flow criterion. This means that measurements corresponding to flow exceedance percentiles lower than 25th were not used in the regression;
- Check rainfall data on the day when samples were collected and on the previous two days. If there was a significant rainfall event (>= 1.0 inch) in any of these days, the sample will be excluded from regression analysis with one exception. If the significant rainfall happened on the sampling day and the turbidity reading was less than 25 NTUs (half of turbidity standard for streams), the sample will not be excluded from analysis because most likely the rainfall occurred after the sample was taken, and
- Log-transform both turbidity and TSS data to minimize effects of their non-linear data distributions.

When ordinary least squares regression (OLS) is applied to ascertain the best relationship between two variables (i.e., X and Y), one variable (Y) is considered "dependent" on the other variable (X), but X must be considered "independent" of the other, and known without measurement error. OLS minimizes the differences, or residuals, between measured Y values and Y values predicted based on the X variable.

For current purposes, a relationship is necessary to predict TSS concentrations from measured turbidity values, but also to translate the TSS-based TMDL back to instream turbidity values. For this purpose, an alternate regression fitting procedure known as the line of organic correlation (LOC) was applied. The LOC has three advantages over OLS (Helsel and Hirsch 2002):

- LOC minimizes fitted residuals in both the X and Y directions;
- It provides a unique best-fit line regardless of which parameter is used as the independent variable; and
- Regression-fitted values have the same variance as the original data.

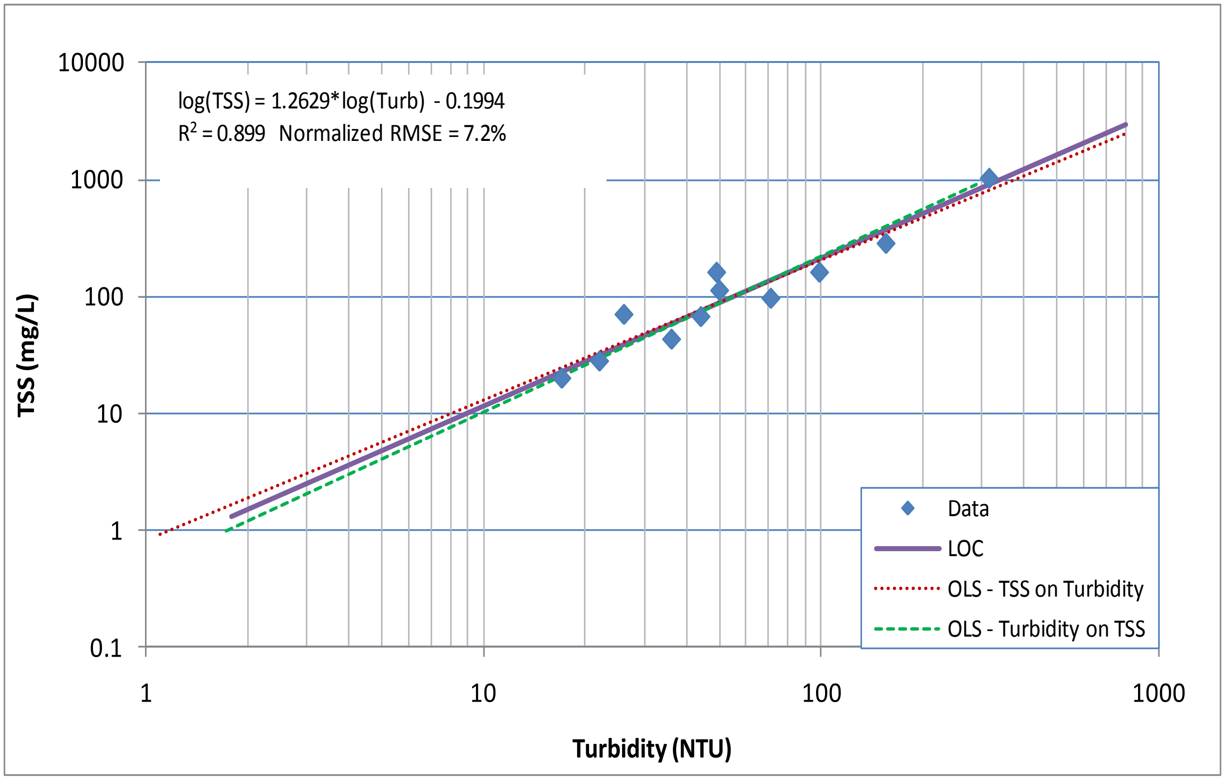
The LOC minimizes the areas of the right triangles formed by horizontal and vertical lines drawn from observations to the fitted line. The slope of the LOC line equals the geometric mean of the Y on X (TSS on turbidity) and X on Y (turbidity on TSS) OLS slopes, and is calculated as:

$$m1 = \sqrt{m \cdot m'} = sign[r] \cdot \frac{s_y}{s_x}$$

where *m*1 is the slope of the LOC line, *m* is the TSS on turbidity OLS slope, *m'* is the turbidity on TSS OLS slope, *r* is the TSS-turbidity correlation coefficient, s_y is the standard deviation of the TSS measurements, and s_x is the standard deviation of the turbidity measurements.

The intercept of the LOC (*b*1) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). Figure 4-1 shows an example of the correlation between TSS and turbidity, along with the LOC and the OLS lines.

Figure 4-1 Linear Regression for TSS-Turbidity for Cimarron River below Waynoka (OK620920010010_00)



The NRMSE and R-square (r^2) were used as the primary measures of goodness-of-fit. As shown in Figure 4-1, the LOC yields a NRMSE value of 7.2 which means the root mean square error (RMSE) is 7.2% of the average of the measured TSS values. The R-square (r^2) value indicates the fraction of the total variance in TSS or turbidity observations that is explained by the LOC. The regression equation can be used to convert turbidity standard of 50 NTUs to TSS goals.

It was noted that there may be a few outliers that exerted undue influence on the regression relationship. These outliers were identified by applying the Tukey's Boxplot method (Tukey 1977) to the dataset of the distances from observed points to the regression line. The Tukey Method is based on the interquartile range (IQR), the difference between the 75th and 25th percentiles of distances between observed points and the LOC. Using the Tukey method, any point with an error greater than the 75th percentile + 1.5 times the IQR or smaller than the 25th percentile - 1.5 times the IQR was identified as an outlier and removed from the regression dataset. The above regressions were recalculated using the dataset with outliers removed.

It is worth to note that the Tukey Method is equivalent to using three times standard deviation to identify outliers if the residuals (observed - predicted) follow a normal distribution. The probability of three times standard deviation is 99.73% while the probability for the Tukey Method is 99.65%. If we use three times standard deviation to identify outliers, we have to first confirm that the residuals are indeed normally distributed. This is difficult to do because most of the time we don't have a large turbidity & TSS dataset. The Tukey's method, however, does not have the assumption of distribution. Therefore, it can be used regardless of the shape of distribution.

Outliers were removed from the dataset only for calculating the turbidity-TSS relationship, not from the dataset used to develop the TMDL.

The regression between TSS and turbidity and its statistics for each turbidity impaired stream segments will be shown in Section 5.1.

4.2 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool are effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the following steps that are described in Subsections 4.3 through 4.5 below:

- Preparing flow duration curves for gaged and ungaged WQM stations;
- Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and
- Using LDCs to identify the critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure adequate water quality across a range of flow conditions. Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when WWTP effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. It is not used in this report to quantify point source or nonpoint source contributions. Violations that occur during low flows may not be caused exclusively by point sources. Violations have been noted in some watersheds that contain no point sources.

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

4.3 Development of Flow Duration Curves

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

Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the ordinate (y-axis), which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the abscissa, 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 waterbody addressed in this report are provided in Appendix B.

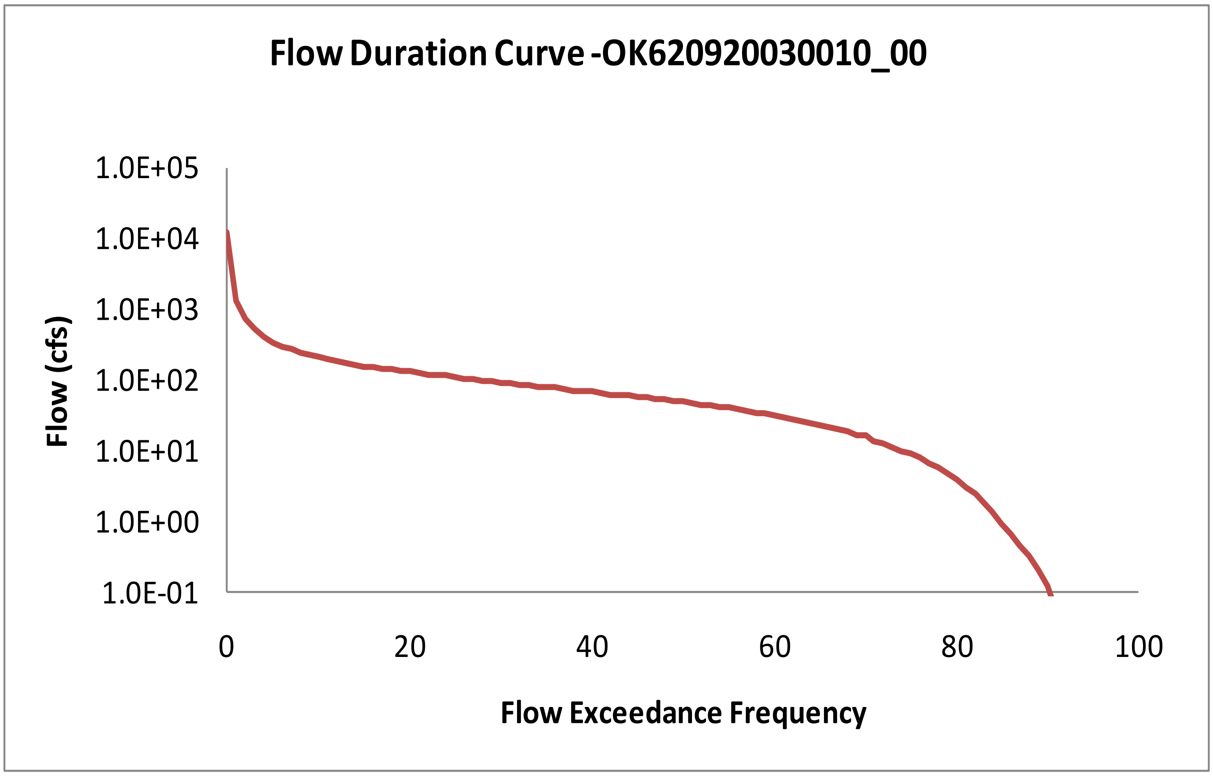
While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 1 year of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the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

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

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

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100 percent. As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a "stair step" effect due to the USGS flow data rounding conventions near the limits of quantitation. An example of a typical flow duration curve was shown in Figure 4-2. Flow duration curve for each stream segment in this study will be developed in Section 5.2.

Figure 4-2 Flow Duration Curve for Cimarron River, near Buffalo (OK620920030010_00)



4.4 Estimating Current Point and Nonpoint Loading for Bacteria

A key step in the use of LDCs for TMDL development is the estimation of existing instream loads. This is accomplished by:

- matching the water quality observations with the flow data from the same date;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equations described); or multiplying the flow by the bacteria indicator concentration to calculate daily loads.

4.5 Development of TMDLs Using Load Duration Curves

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

Step 1: Generate LDCs. LDCs are similar in appearance to flow duration curves; however, for bacteria the ordinate is expressed in terms of a bacteria load in cfu/day, and for TSS the ordinate is expressed in terms of a load in lbs/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 the site. For turbidity, the curve represents the water quality target for TSS from Table 4-1 expressed in terms of a load obtained through multiplication of the TSS target by the continuum of flows historically observed at the site. The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the USGS;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS;
- matching the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile;
- plotting the flow exceedance percentiles and daily load observations in a load duration plot (See Section 5).

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

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

Where: WQS = 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

For turbidity (TSS) TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (lb/day) = WQ target * flow (cfs) * unit conversion factor

where: WQ target = waterbody specific TSS concentration derived from regression analysis results presented in Table 5-1

unit conversion factor = 5.39377 L*s*lb /(ft^3****day*mg)***

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, TSS and/or turbidity concentrations are paired with flow data and are plotted as separate LDCs. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform concentration (colonies/100 mL) by the instantaneous flow (cubic feet per second) at the same site and time, with appropriate volumetric and time unit conversions. Fecal coliform/*E. coli*/Enterococci loads representing exceedance of water quality criteria fall above the water quality criterion line. Likewise, the TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line. Regarding bacteria data, it is noted that only those flows and water quality samples observed in the months comprising the primary contact recreation season are used to generate the LDCs. It is inappropriate to compare single sample bacteria observations and instantaneous or daily flow durations to a 30-day geometric mean water quality criterion in the LDC.

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

Step 2: Define MOS. The MOS may be defined explicitly or implicitly. A typical explicit approach would reserve some specific fraction of the TMDL as the MOS. In an implicit approach, conservative assumptions used in developing the TMDL are relied upon to provide an MOS to assure that WQSs are attained. For bacteria TMDLs in this report, an explicit MOS of 10 percent was selected. The 10% MOS has been used in other approved bacteria TMDLs. For turbidity (TSS) TMDLs an explicit MOS is derived from the NRMSE established by the turbidity/TSS regression analysis conducted for each waterbody. This approach for setting an explicit MOS has been used in other approved turbidity TMDLs.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for point sources is defined by the WLA. For bacteria TMDLs a point source can be either a wastewater (continuous) or stormwater (MS4) discharge. Stormwater point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes NPDES-permitted stormwater discharges as point source discharges and, therefore, part of the WLA. For TMDL development purposes when addressing turbidity or TSS, a WLA will be established for wastewater (continuous) discharges in impaired watersheds that do not have a BOD or CBOD permit limit but do have a TSS limit. These point source discharges of inorganic suspended solids will be assigned a TSS WLA as part of turbidity TMDLs to ensure WQS can be maintained. As discussed in Section 3.1 a WLA for TSS is not necessary for MS4s.

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. For bacteria TMDLs a 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). For turbidity (TSS) TMDLs a load-based approach also meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs “in terms of mass per time, toxicity, or other appropriate measures.”

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, NPDES permit limits are used to derive WLAs. The permitted flow rate used for each point source discharge and the water quality concentration defined in a permit are used to estimate the WLA for each wastewater facility. In cases where a permitted flow rate is not available for a WWTP, then the maximum monthly average flow rate derived from DMRs can be used. WLA values for each NPDES wastewater discharger are then summed to represent the total WLA for a given watershed. Using this information bacteria and TSS WLAs can be calculated using a mass balance approach as shown in the equations below.

WLA for bacteria:

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

Where:

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

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

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

WLA for TSS:

WLA = WQ target * flow * unit conversion factor (lb/day)

Where:

WQ target is provided in Table 5-1;

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

unit conversion factor = 8.3445 L*lb/(gal*mg)

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. For bacteria TMDLs, if there are no permitted MS4s in the study area, WLA_MS4 is set to zero. When there are permitted MS4s in 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 a MS4 jurisdiction. This WLA for MS4s may not be the total load allocated for permitted MS4s unless the whole MS4 area is located within the study watershed boundary. However, in most case the study watershed intersects only a portion of the permitted MS4 coverage areas.

For turbidity TMDLs, WLAs for permitted stormwater such as MS4s, construction, and multi-sector general permits are not calculated since these discharges occur under high flow conditions when the turbidity criteria do not apply.

Step 5: Estimate WLA Load Reduction. The WLA load reduction for bacteria was not calculated as it was assumed that continuous dischargers (NPDES-permitted WWTPs) are adequately regulated under existing permits to achieve water quality standards at the end-of-pipe and, therefore, no WLA reduction would be required. If there are no MS4s located within the Study Area requiring a TMDL then there is no need to establish a PRG for permitted stormwater.

The WLA load reduction for TSS for dischargers without BOD/CBOD limits can be determined as follows:

If permitted TSS limit is less than TSS goal for the receiving stream, there will be no reductions;

If permitted TSS limit is greater than TSS goal for the receiving stream, the permit limit will be set at the TSS goal.

Step 6: Estimate LA Load Reduction. After existing loading estimates are computed for each pollutant, 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 which ensures that no more than 25 percent of the samples exceed the TMDL based on the instantaneous criteria allocates the loads in manner that is also protective of the geometric mean criterion. For *E. coli* and Enterococci, because WQSs are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no sample exceeds the instantaneous criteria, the TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria. For turbidity, the PRG is the load reduction that ensures that no more than 10 percent of the samples under flow-base conditions exceed the TMDL.

SECTION 5
TMDL CALCULATIONS

5.1 Surrogate TMDL Target for Turbidity

Using the LOC method described in Section 4.1, the correlation between TSS and turbidity were developed for all turbidity impaired streams (Figures 5-1 through 5-5). The statistics of the regressions and the resultant TSS goals were shown in Table 5-1.

Figure 5-1 Linear Regression for TSS-Turbidity for Cimarron River below Waynoka (OK620920010010_00)

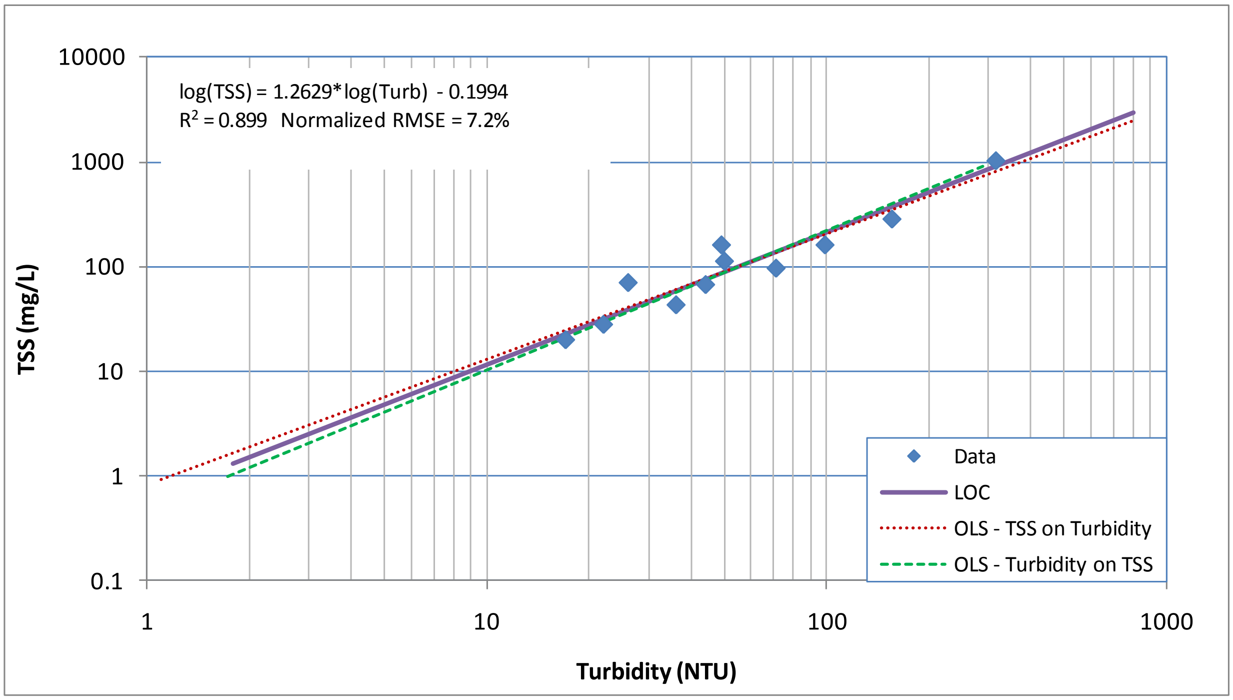


Figure 5-2 Linear Regression for TSS-Turbidity for Main Creek (OK620920010180_00)

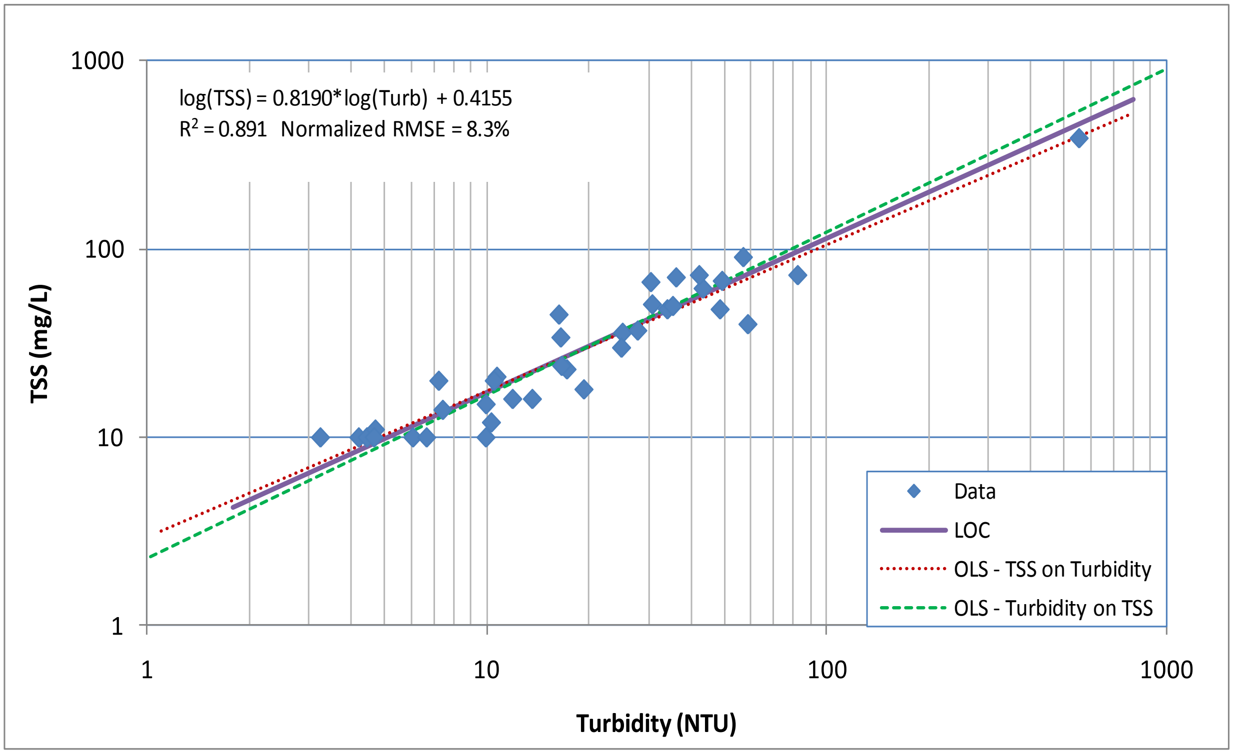


Figure 5-3 Linear Regression for TSS-Turbidity for Eagle Chief Creek (OK620920040010_00)

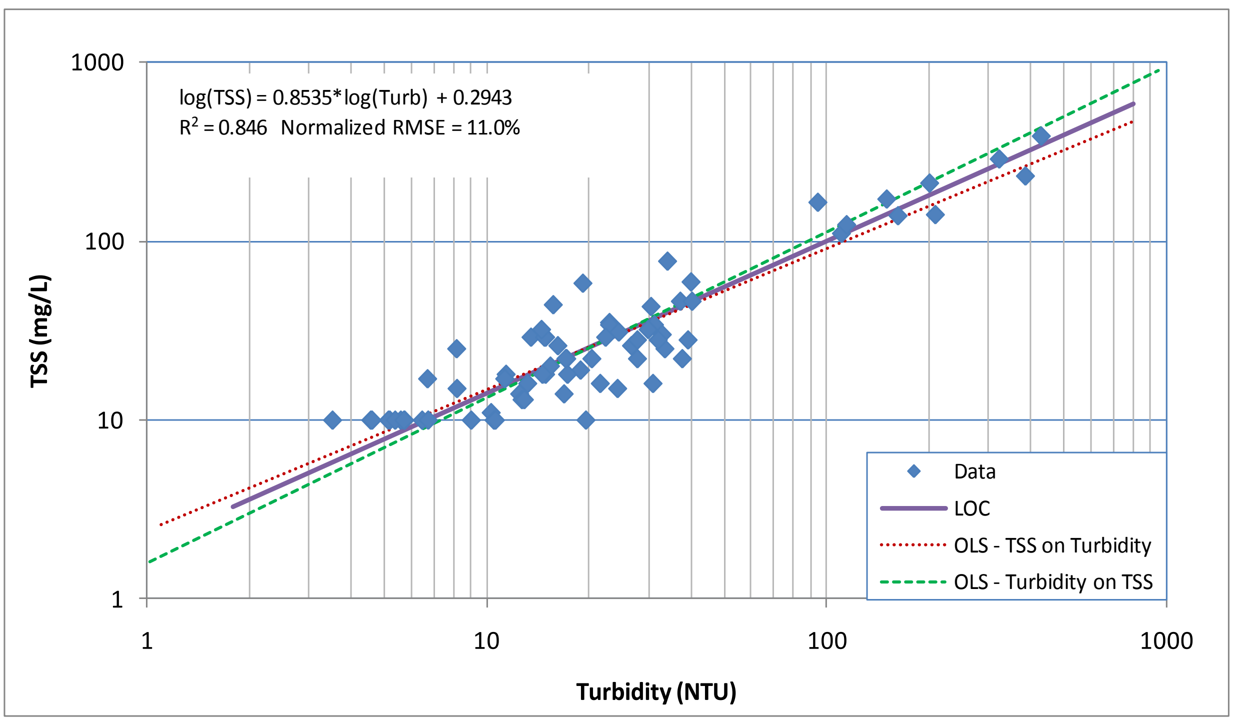


Figure 5-4 Linear Regression for TSS-Turbidity for Cottonwood Creek (OK620920010080_00)

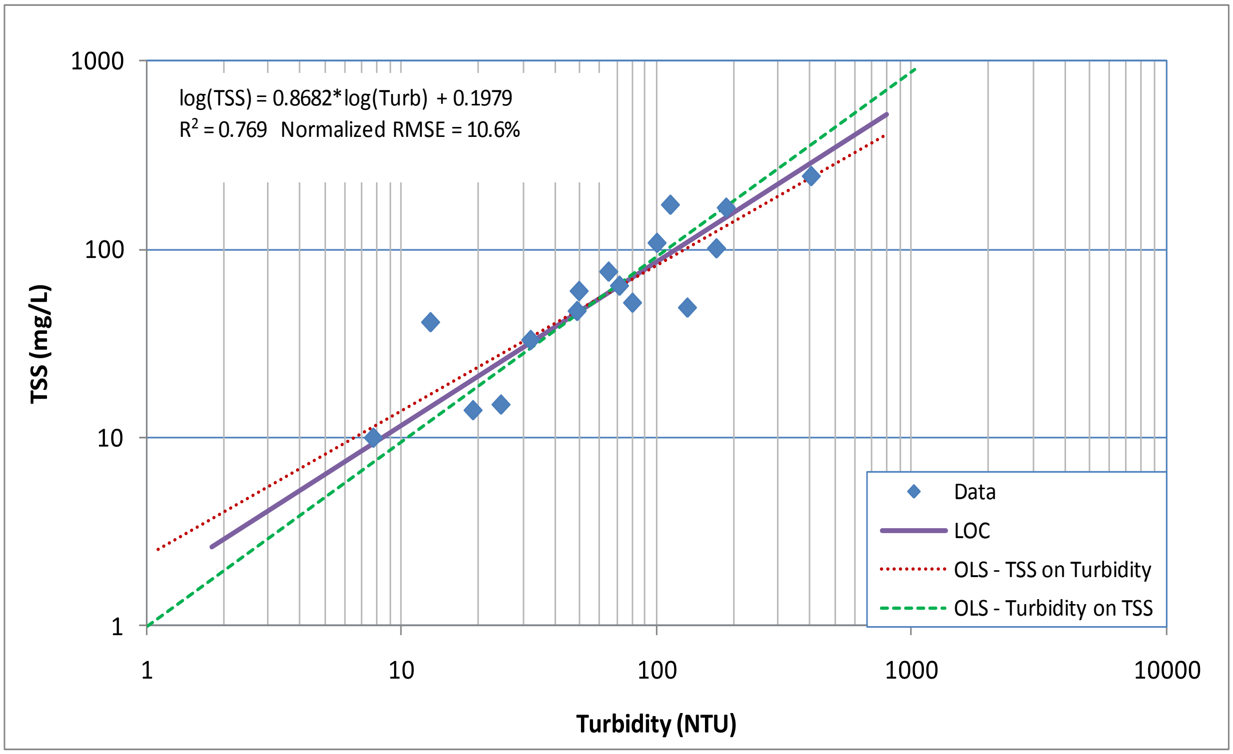


Figure 5-5 Linear Regression for TSS-Turbidity for Cimarron River near Dover (OK620910020010_00)

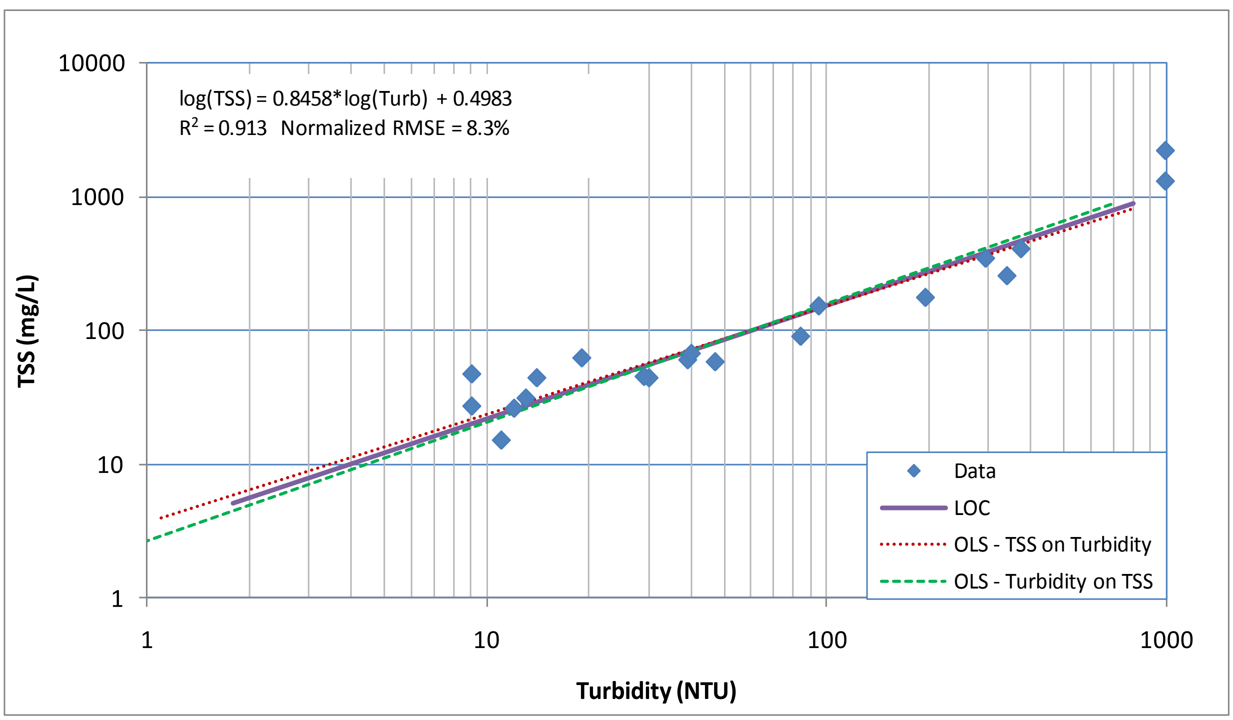


Table 5-1 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R- square	NRMSE	MOS[b]	TSS Goal (mg/L)[a]
OK620920010010_00	Cimarron River below Waynoka	0.899	7.2%	10%	88
OK620920010180_00	Main Creek	0.891	8.3%	10%	64
OK620920040010_00	Eagle Chief Creek	0.846	11.0%	15%	56
OK620920010080_00	Cottonwood Creek	0.769	10.6%	15%	47
OK620910020010_00	Cimarron River near Dover	0.913	8.3%	10%	86

[a] Calculated using the regression equation and the turbidity standard (50 NTU)
[b] Based on the goodness-of-fit of the turbidity-TSS regression (NRMSE)
[c] WQ goal minus MOS

5.2 Flow Duration Curves

Following the same procedures described in Section 4.3, flow duration curve for each stream segment in this study was developed and shown in Figure 5-6 through Figure 5-18.

Figure 5-6 Flow Duration Curve for Cimarron River near Buffalo (OK620920030010_00)

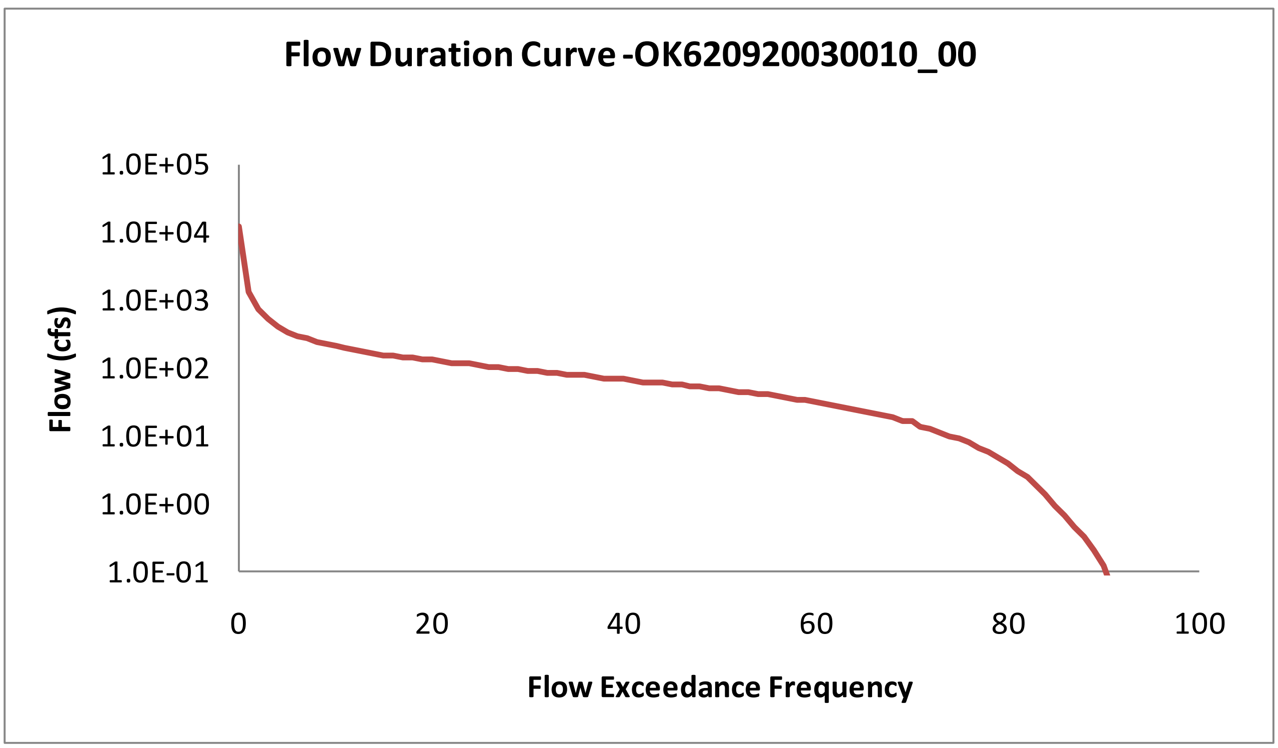


Figure 5-7 Flow Duration Curve for Buffalo Creek near Lovedale (OK620920050010_00)

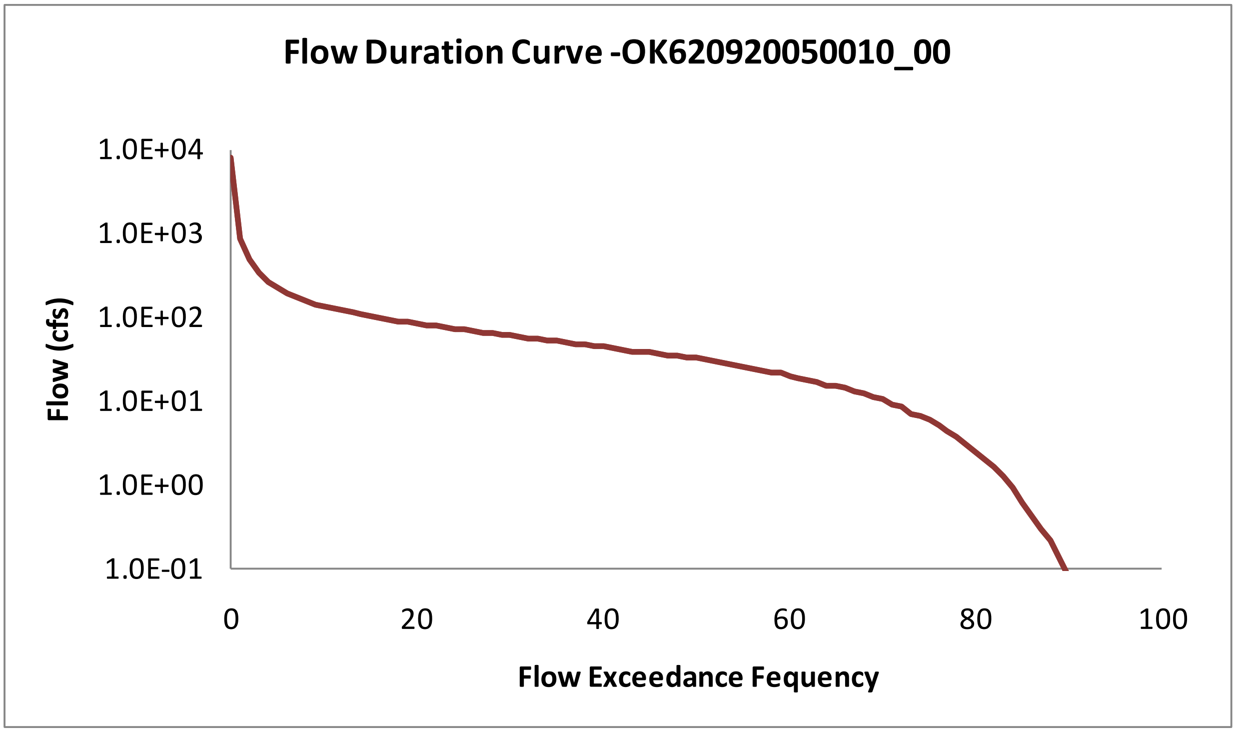


Figure 5-8 Flow Duration Curve for Sand Creek (OK620920050050_00)

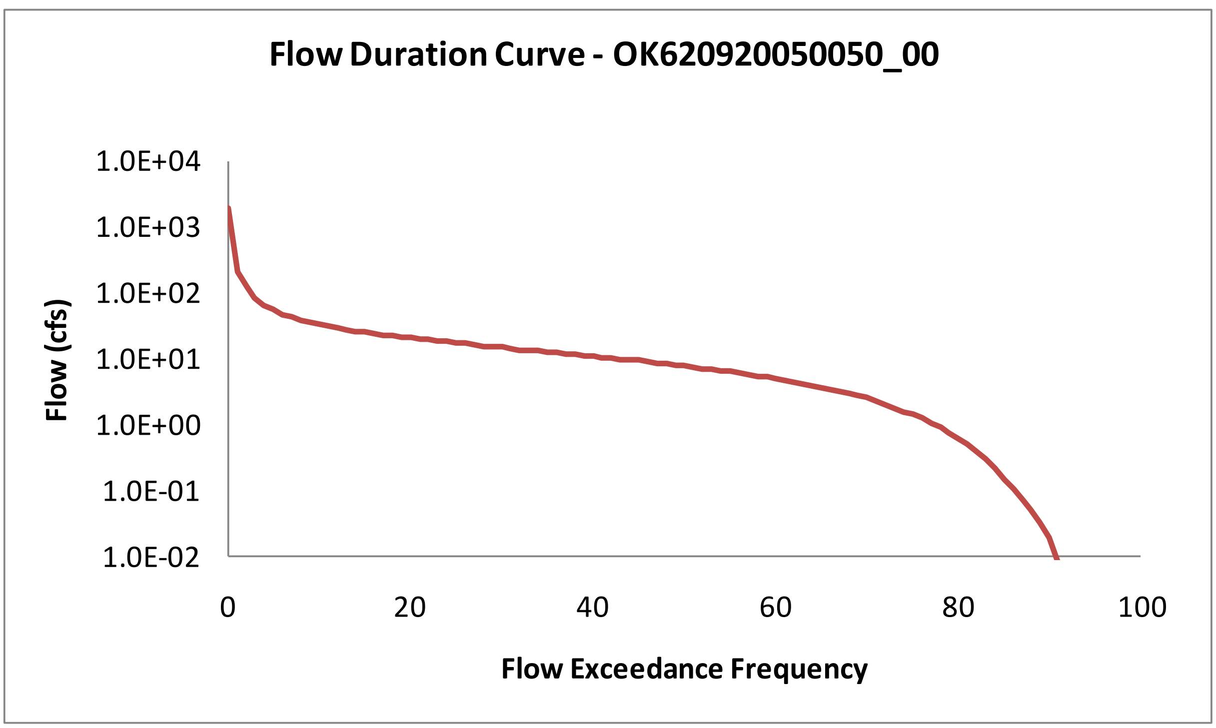


Figure 5-9 Flow Duration Curve for Cimarron River at Freedom (OK620920020010_00)

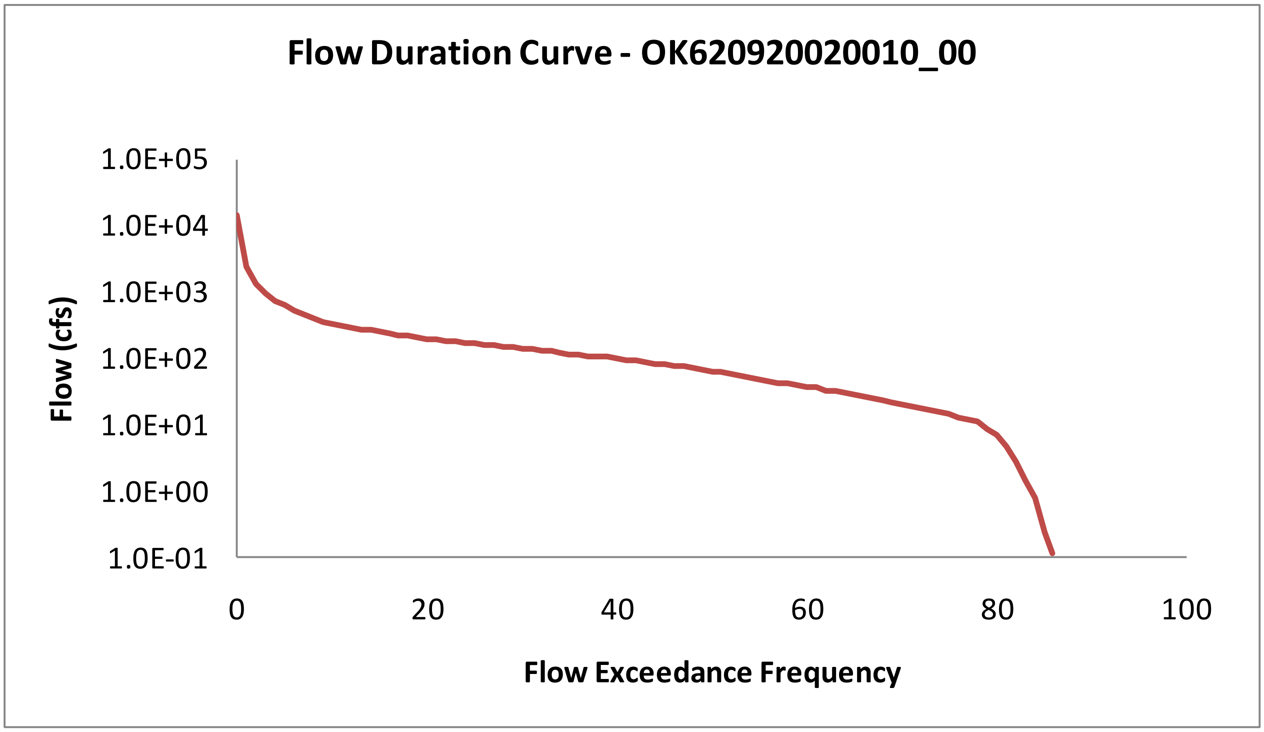


Figure 5-10 Flow Duration Curve for Traders Creek (OK620920020170_00)

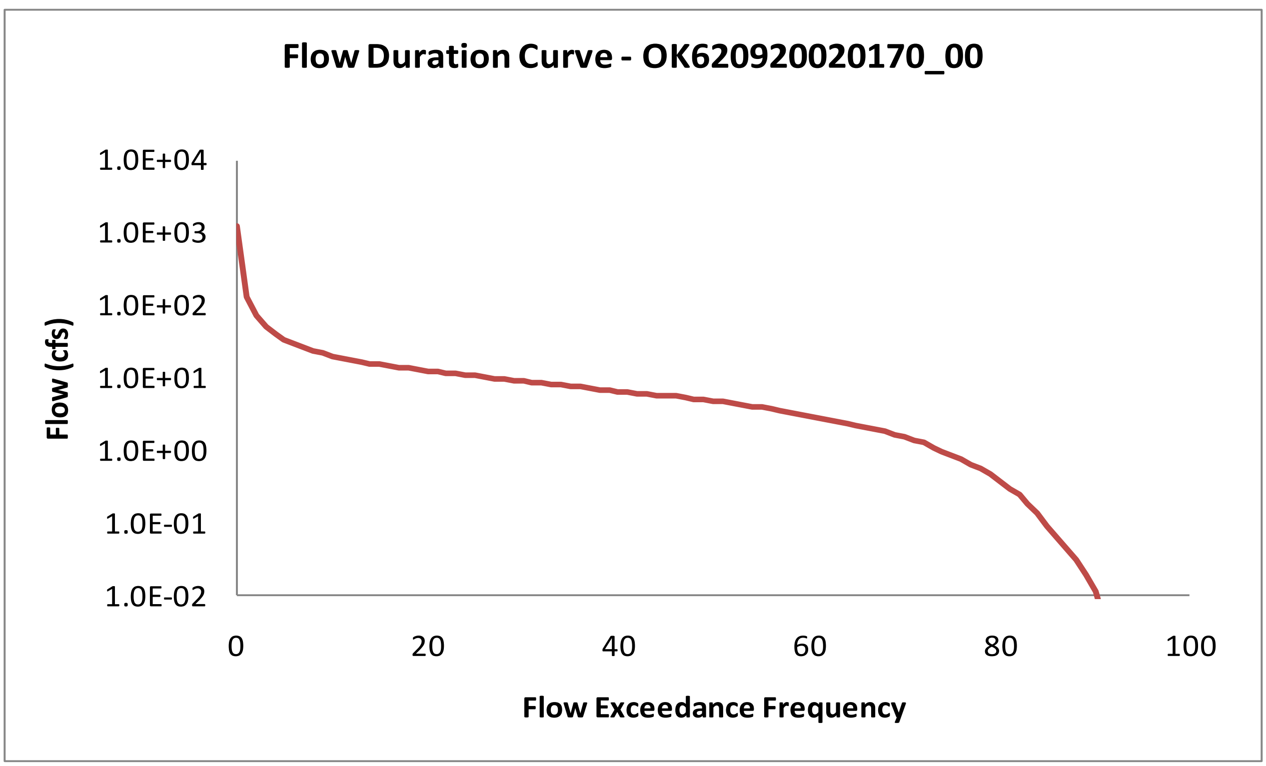


Figure 5-11 Flow Duration Curve for Long Creek (OK620920020080_00)

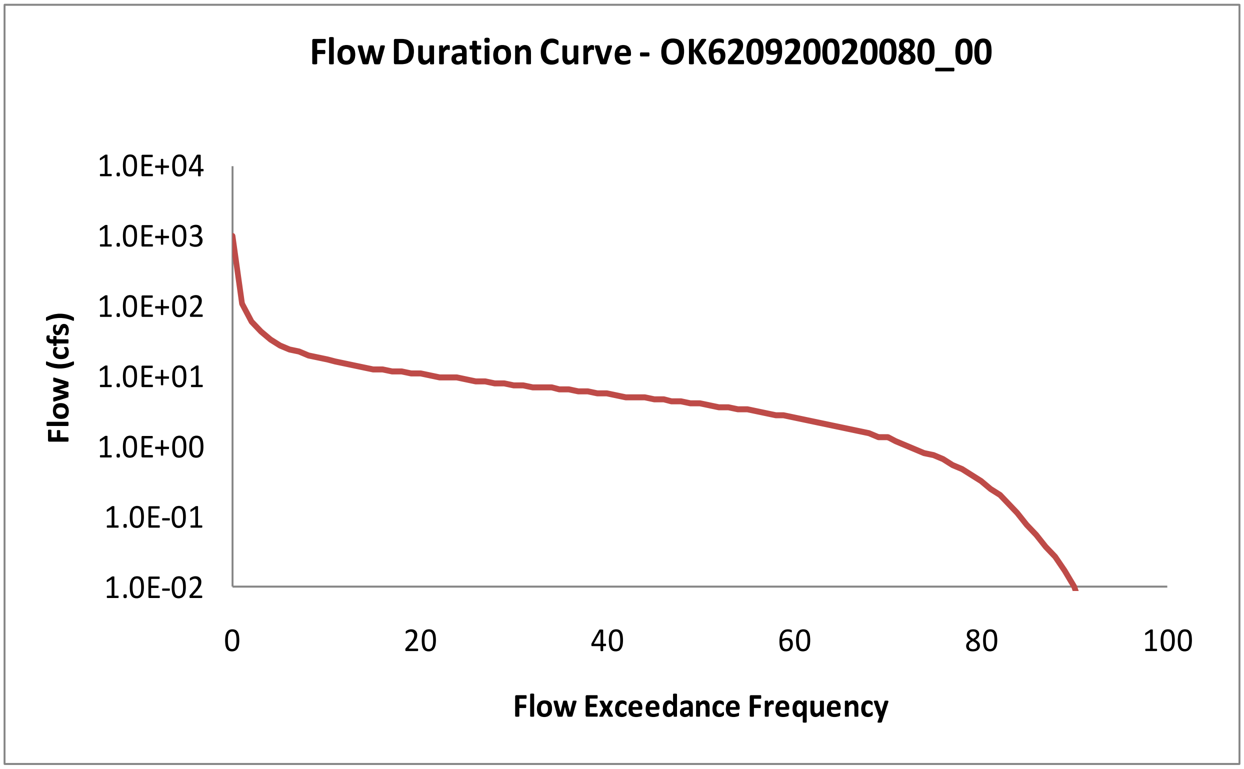


Figure 5-12 Flow Duration Curve for Cimarron River below Waynoka (OK620920010010_00)

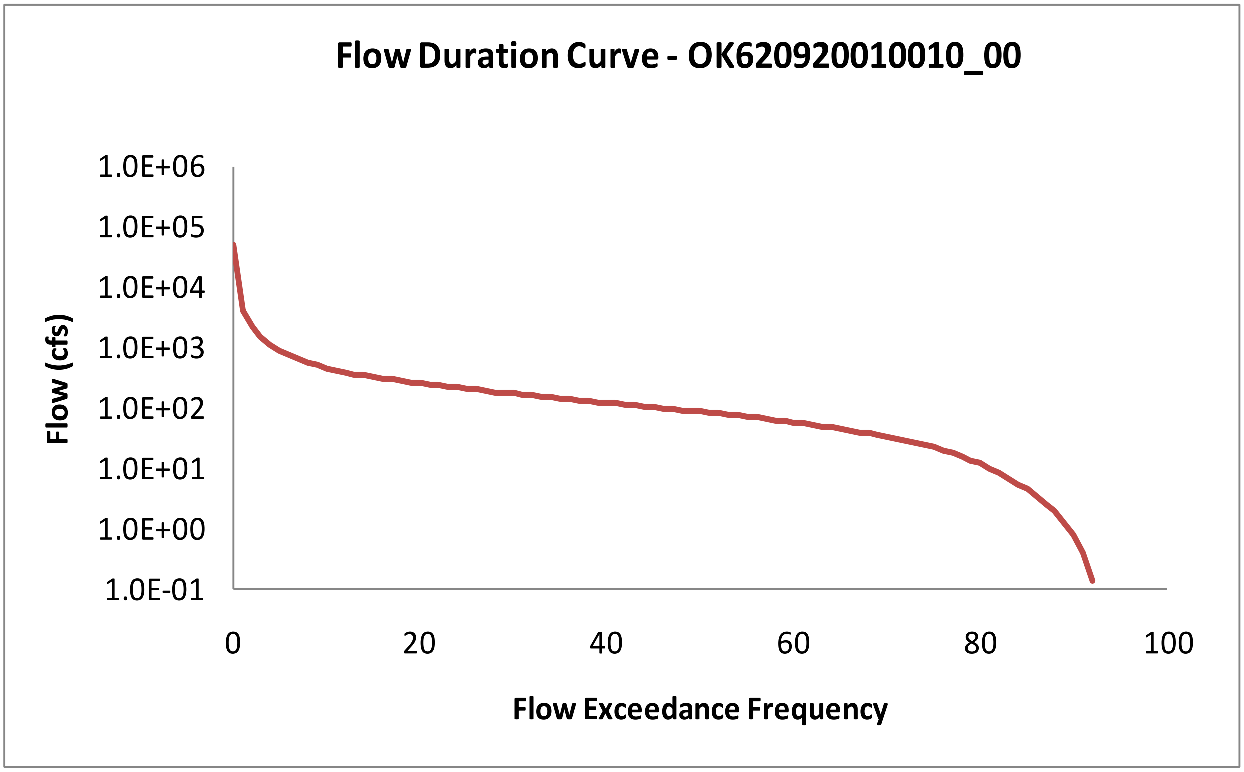


Figure 5-13 Flow Duration Curve for Main Creek (OK620920010180_00)

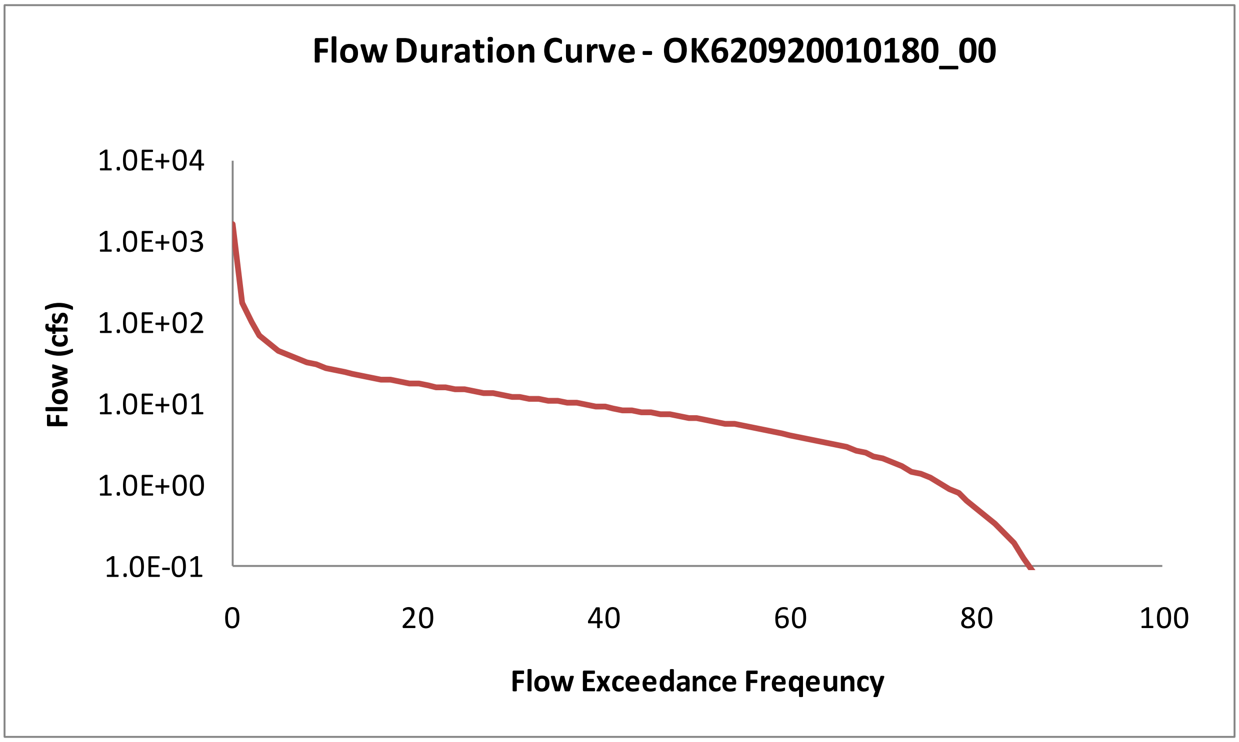


Figure 5-14 Flow Duration Curve for Griever Creek (OK620920010130_00)

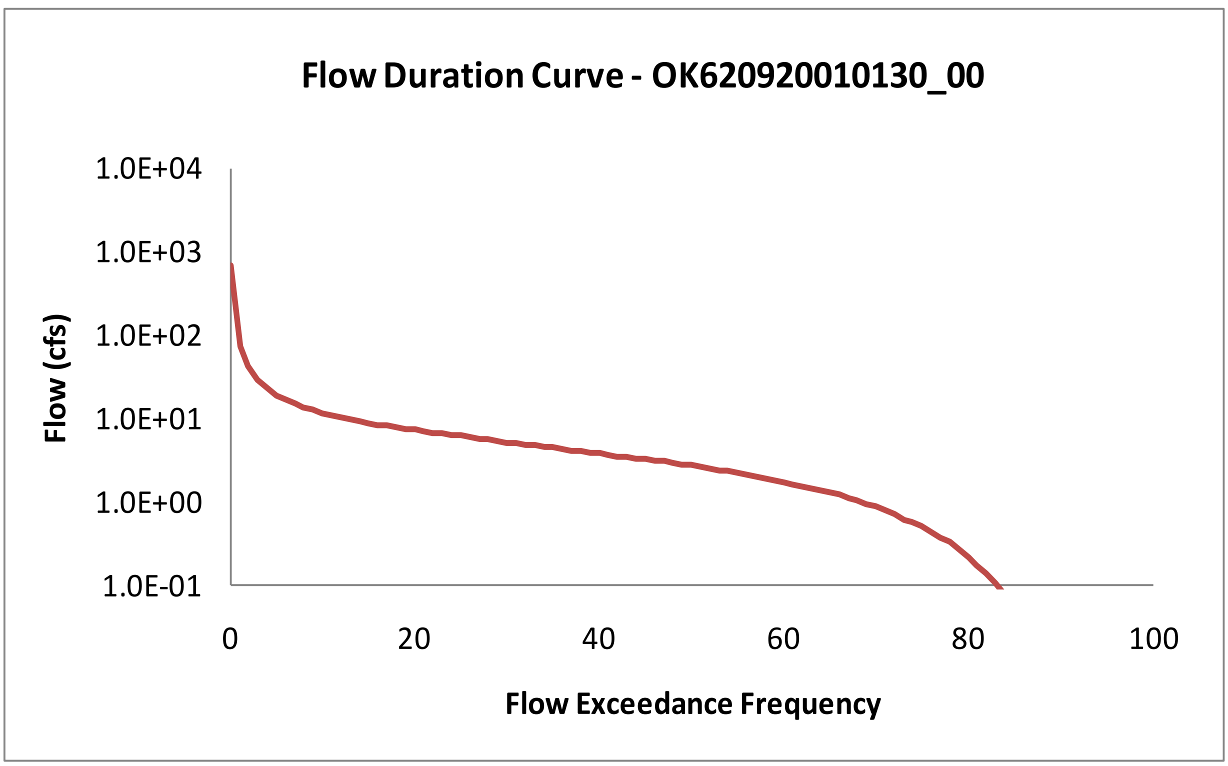


Figure 5-15 Flow Duration Curve for Eagle Chief Creek (OK620920040010_00)

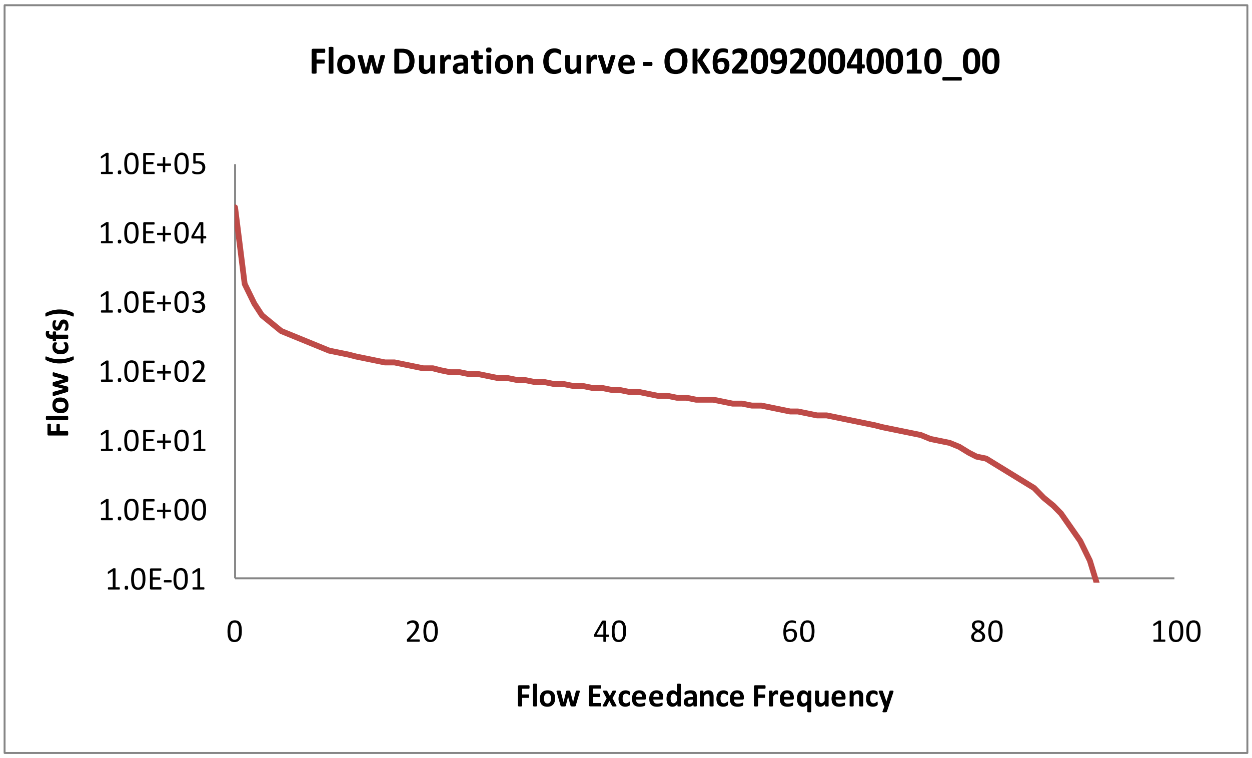


Figure 5-16 Flow Duration Curve for Cottonwood Creek (OK620920010080_00)

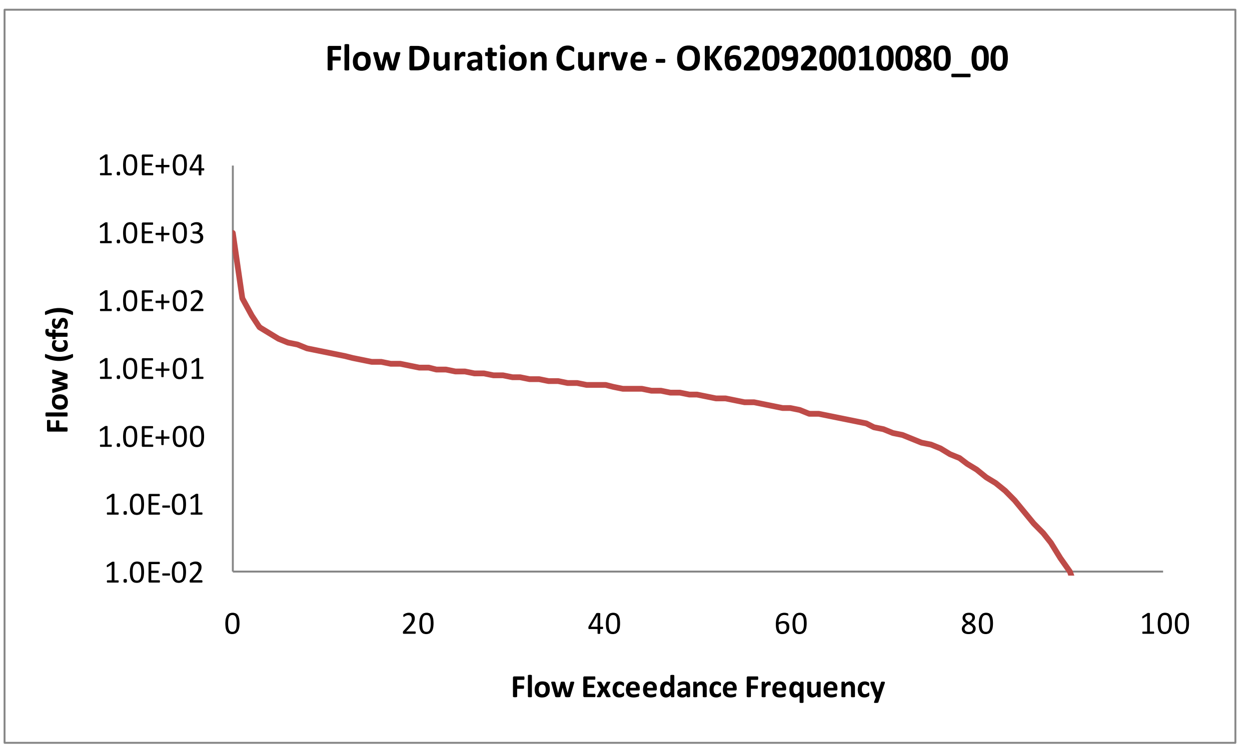


Figure 5-17 Flow Duration Curve for Cimarron River near Ames (OK620910020010_10)

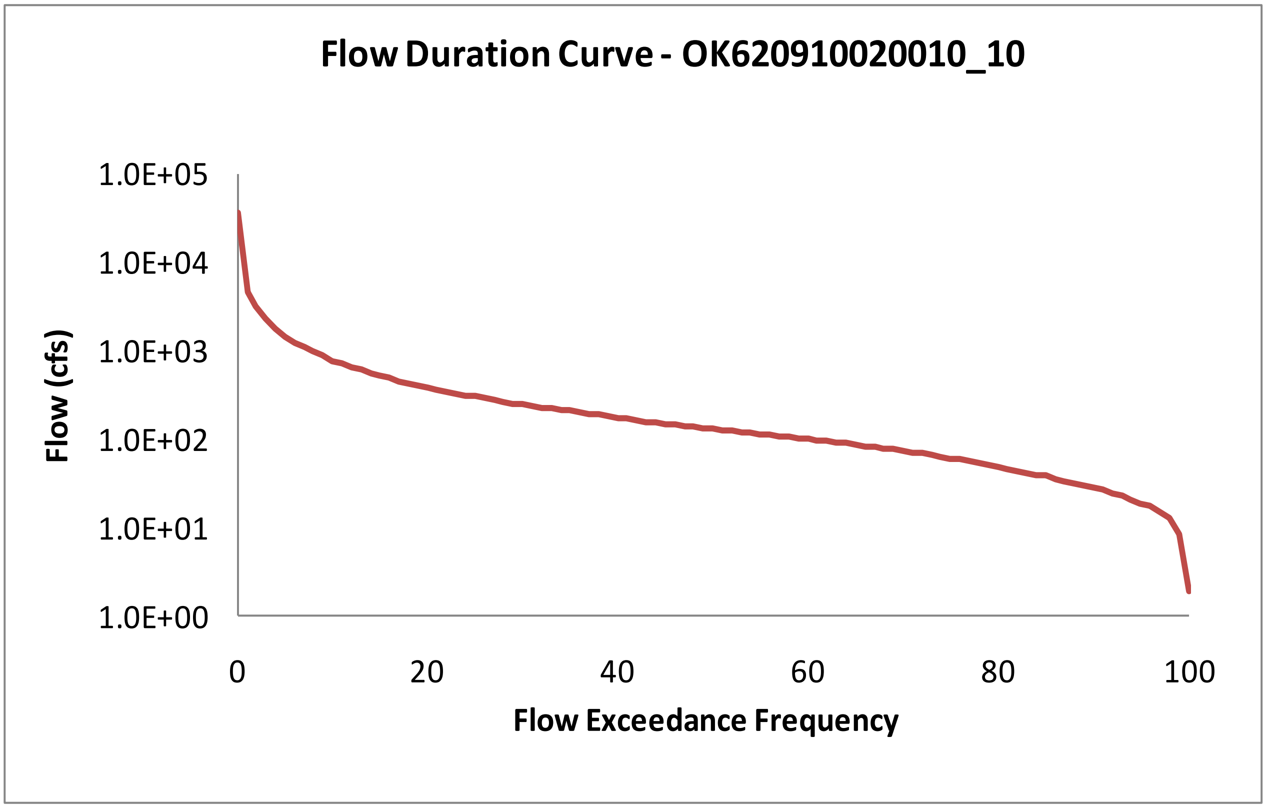
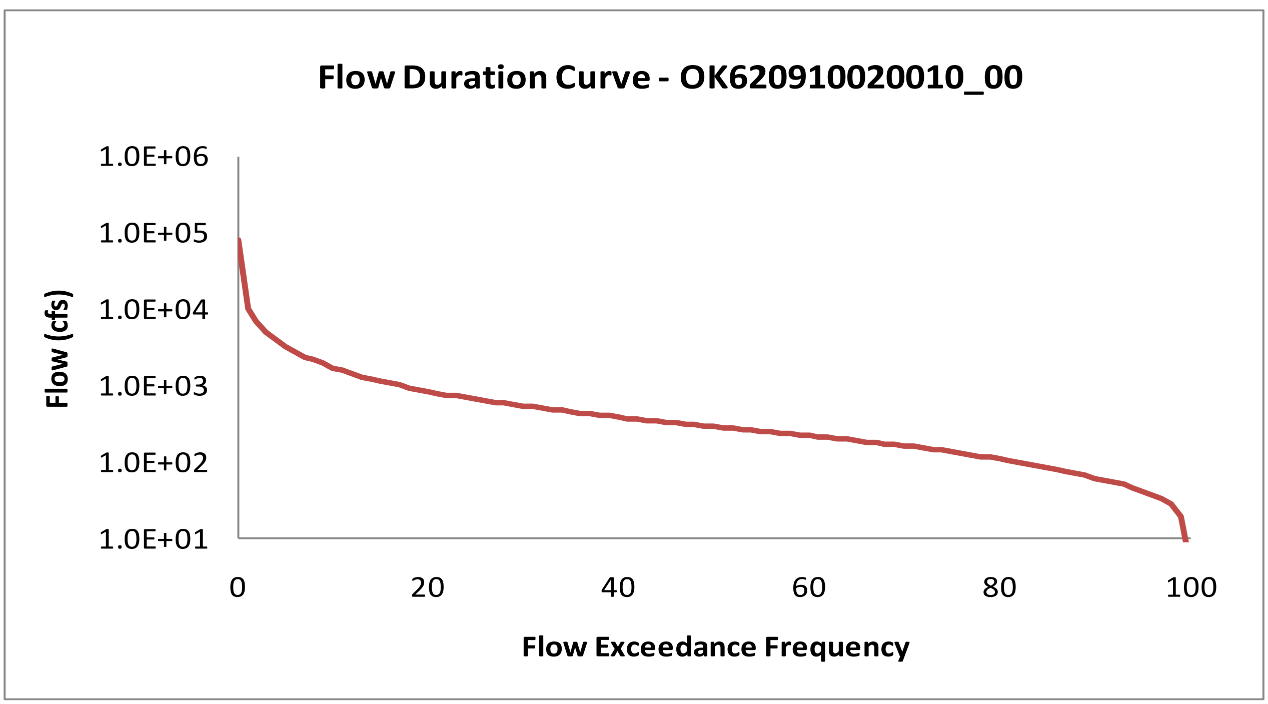


Figure 5-18 Flow Duration Curve for Cimarron River near Dover (OK620910020010_00)



5.3 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.

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

To estimate existing loading, bacteria observations for the primary contact recreation season (May 1st through September 30th) from 1999 to 2008 are paired with the flows measured or estimated in that waterbody on the same date. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor of *24,465,756 mLs / ft^3 day*. The associated flow exceedance percentile is then matched with the measured flow from the tables provided in Appendix C. The observed bacteria loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of bacteria. Points above the LDC indicate the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the WQS.

The bacteria LDCs developed for each impaired waterbody (representing the primary contact recreation season from 1999 through 2008) and for each bacteria indicator are shown in Figures 5-19 through 5-42.

The LDCs for Cimarron River, near Buffalo, segment OK620920030010_00 are shown in Figures 5-19 through 5-21 for E. coli, Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM station OK620920030010-001AT. The LDCs indicate that all three indicator levels exceed the instantaneous water quality criteria under moderate to low flow conditions. The exceedance under low flow may be caused by point sources, but also could be caused by failing onsite systems, or direct deposition of animal manure.

Figure 5-19 Load Duration Curve for *E. coli* in Cimarron River near Buffalo

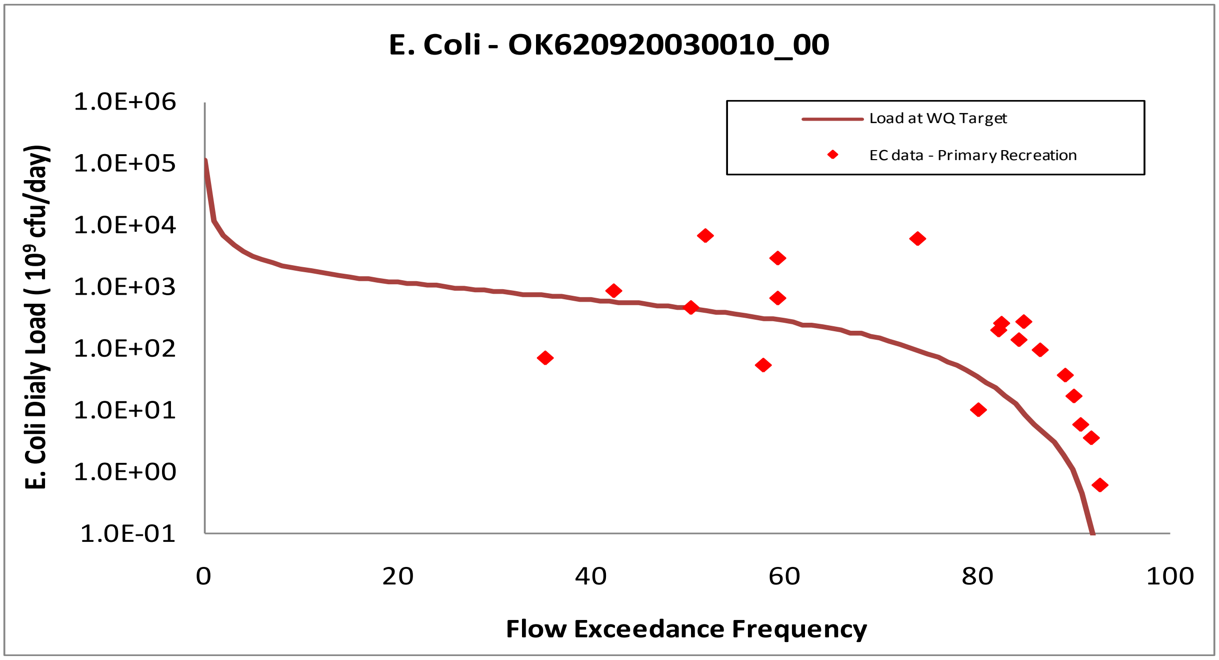


Figure 5-20 Load Duration Curve for Enterococci in Cimarron River near Buffalo

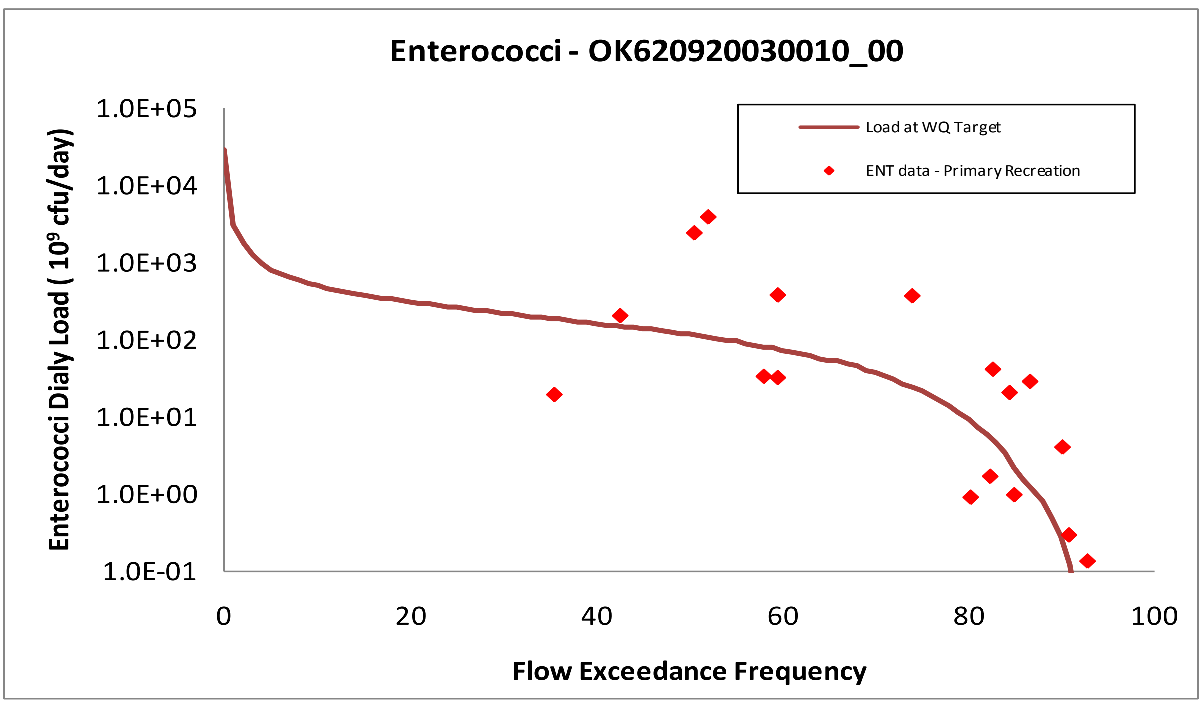
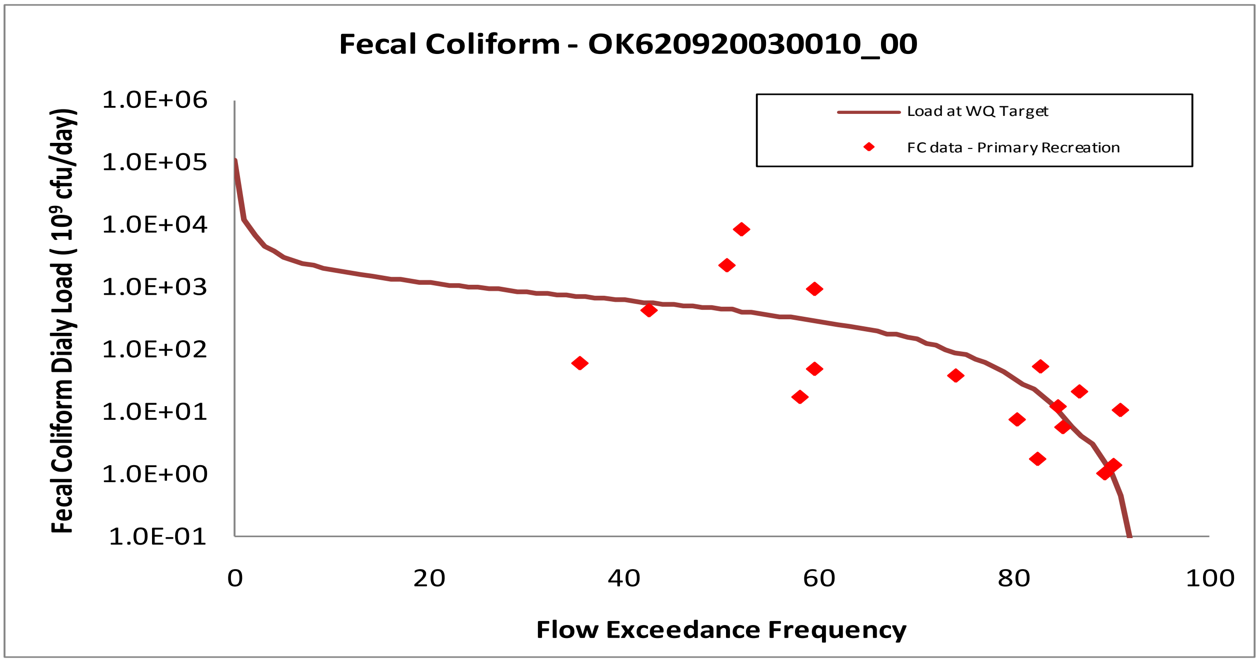


Figure 5-21 Load Duration Curve for Fecal Coliform in Cimarron River near Buffalo



The LDCs for Buffalo Creek, segment OK620920050010_00 are shown in Figures 5-22 and 5-23 for E. coli and Enterococci. They are based on bacteria measurements at WQM stations OK620920-05-0010T, OK620920-05-0010G and OK620920-05-0010P. The LDCs indicate that all two indicator levels exceed the instantaneous water quality criteria under various flow conditions for E. coli and Enterococci.

Figure 5-22 Load Duration Curve for *E. coli* in Buffalo Creek

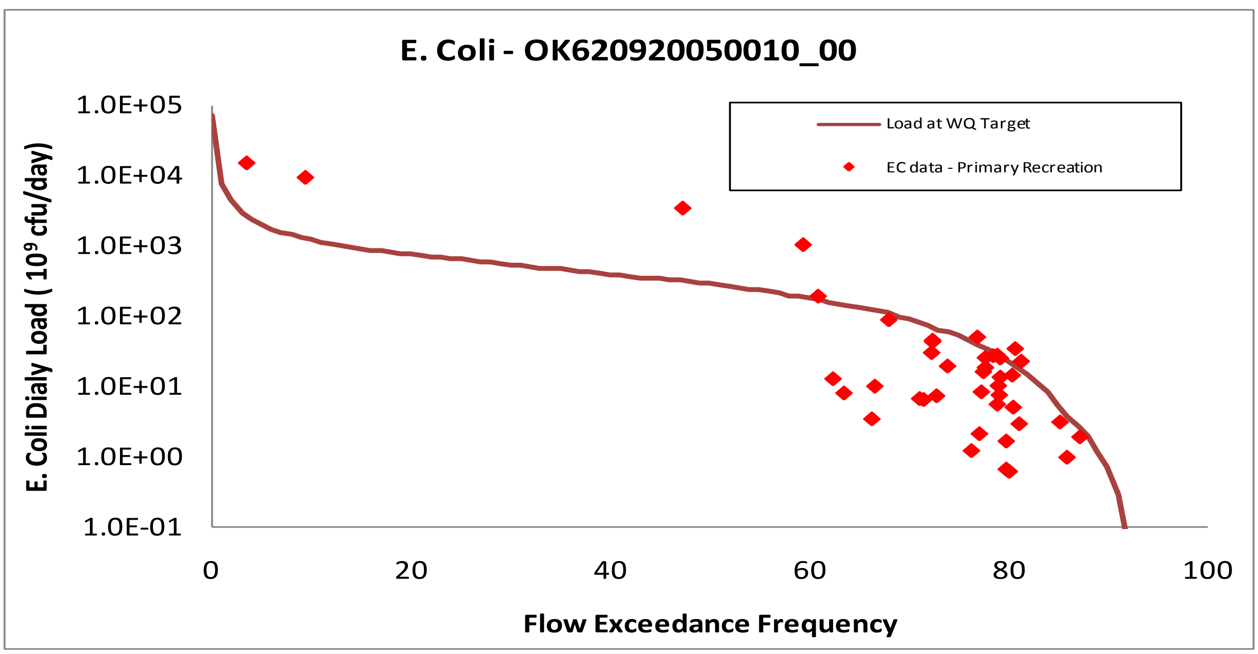
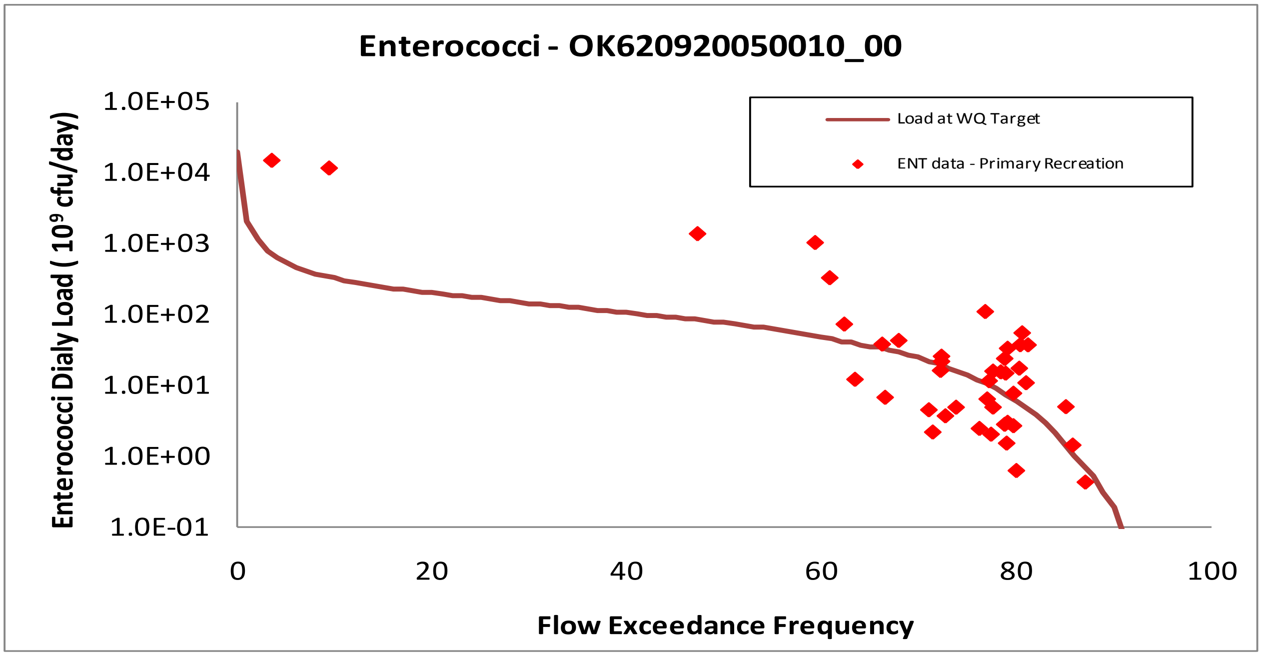


Figure 5-23 Load Duration Curve for Enterococci in Buffalo Creek



The LDCs for Sand Creek, segment OK620920050050_00 are shown in Figures 5-24 and 5-25 for E. coli and Enterococci. They are based on bacteria measurements at WQM station OK620920-05-0050G and OK620920-05-0050J. The LDCs indicate that all two indicator levels exceed the instantaneous water quality criteria under moderate to low flow conditions.

Figure 5-24 Load Duration Curve for *E. coli* in Sand Creek

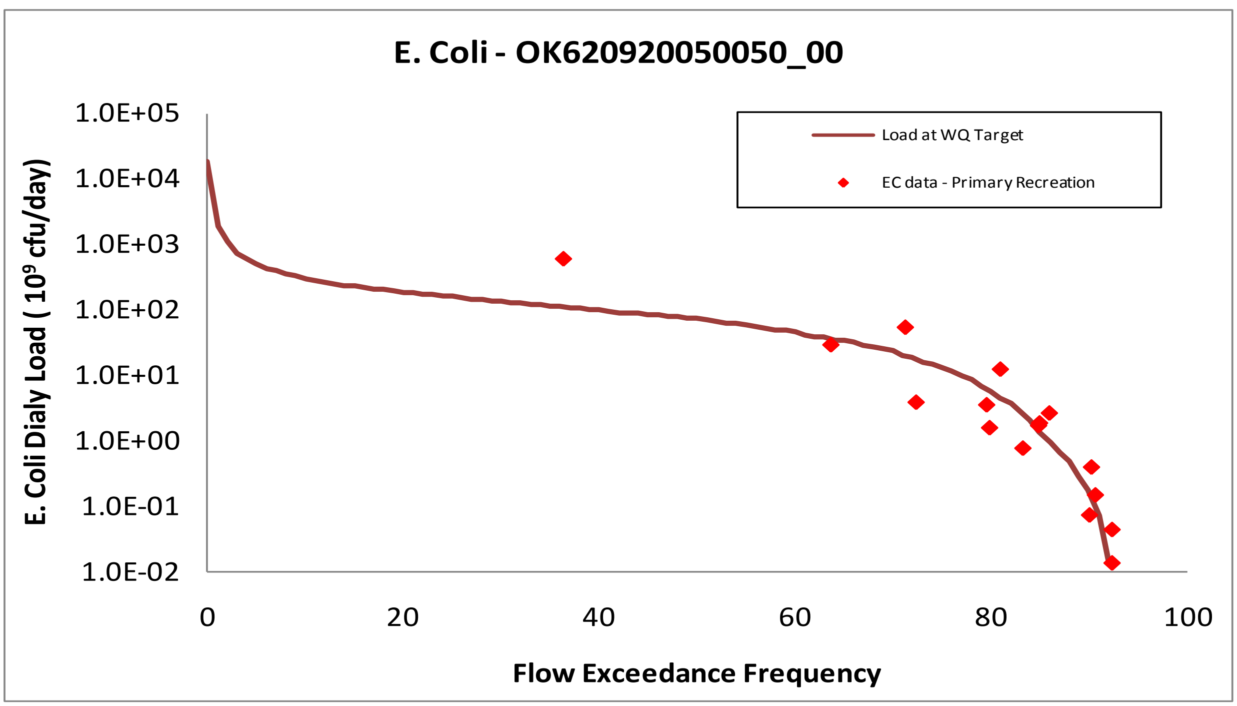
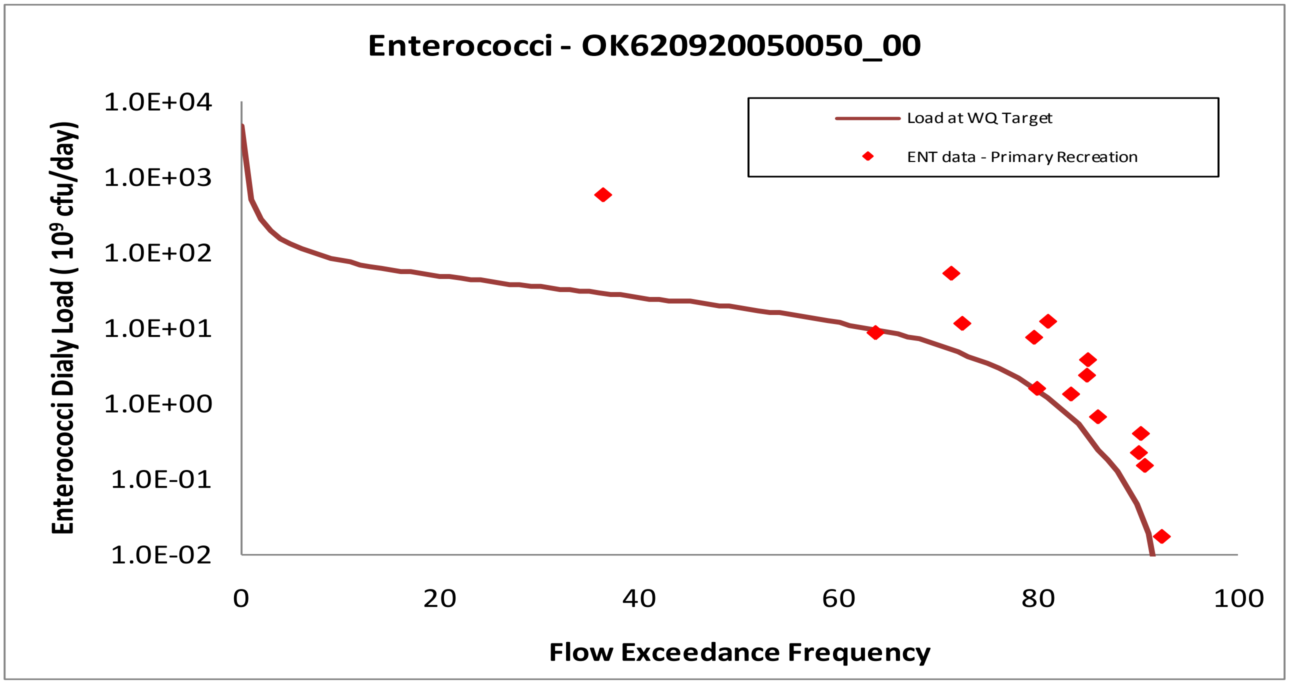
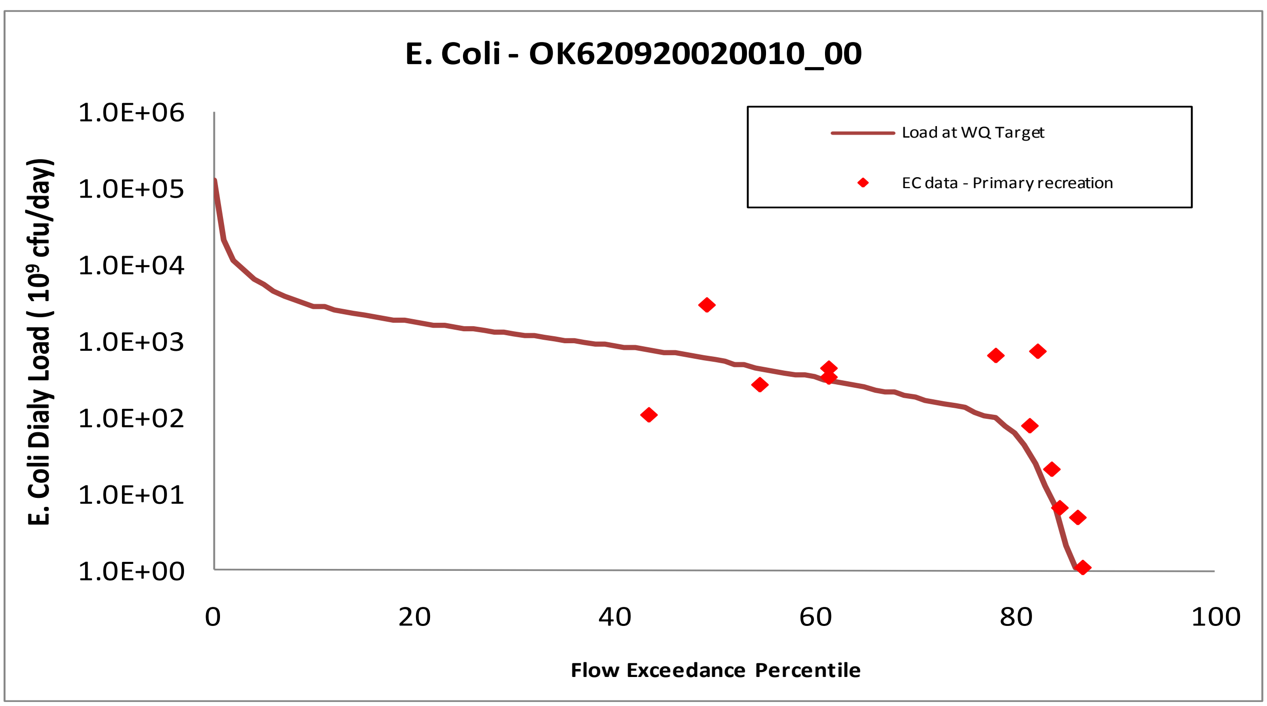


Figure 5-25 Load Duration Curve for Enterococci in Sand Creek



The LDC for Cimarron River at Freedom, segment OK620920020010_00 is shown in Figure 5-26 for E. coli. They are based on bacteria measurements at WQM station OK620920020010-001RS. The LDC indicates that E. coli levels exceed the instantaneous water quality criteria under moderate to low flow conditions.

Figure 5-26 Load Duration Curve for *E. coli* in Cimarron River at Freedom



The LDCs for Long Creek, segment OK620920020080_00 are shown in Figures 5-27 and 5-28 for E. coli and Enterococci respectively. They are based on bacteria measurements at WQM station OK620920-02-0080D and OK620920-02-0080T. The LDCs indicate that both indicator levels exceed the instantaneous water quality criteria under all flow conditions.

Figure 5-27 Load Duration Curve for *E. coli* in Long Creek

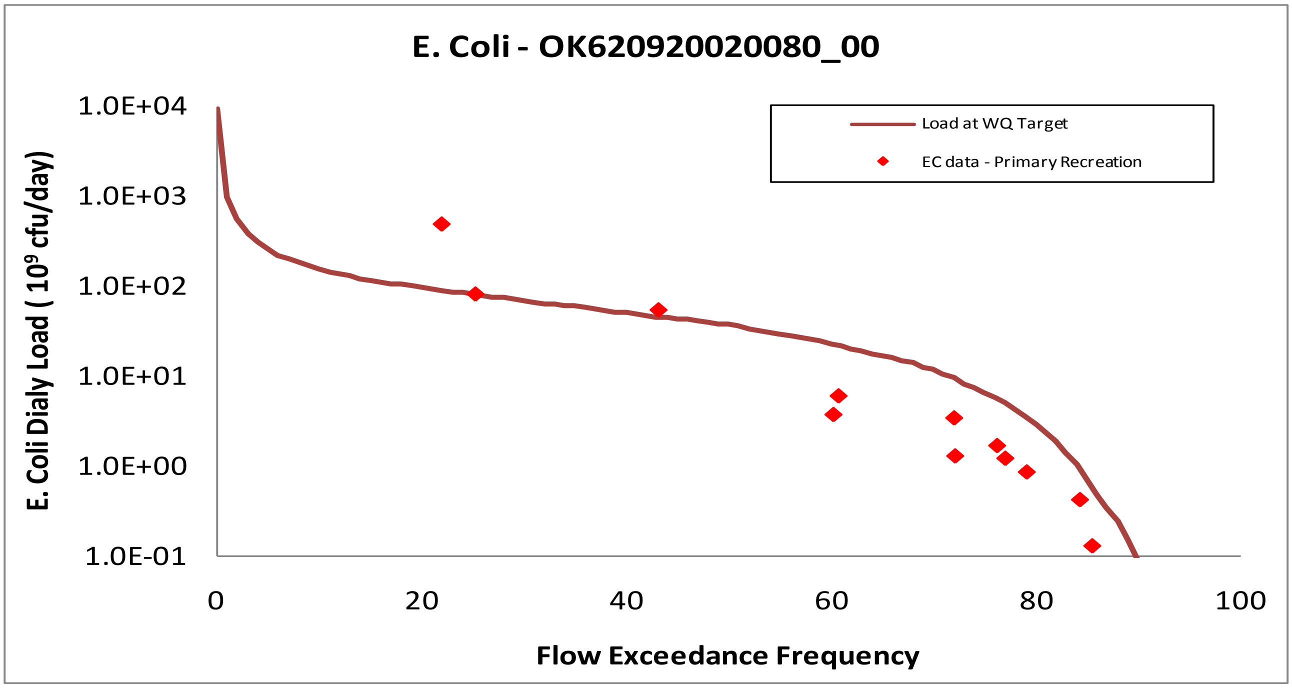
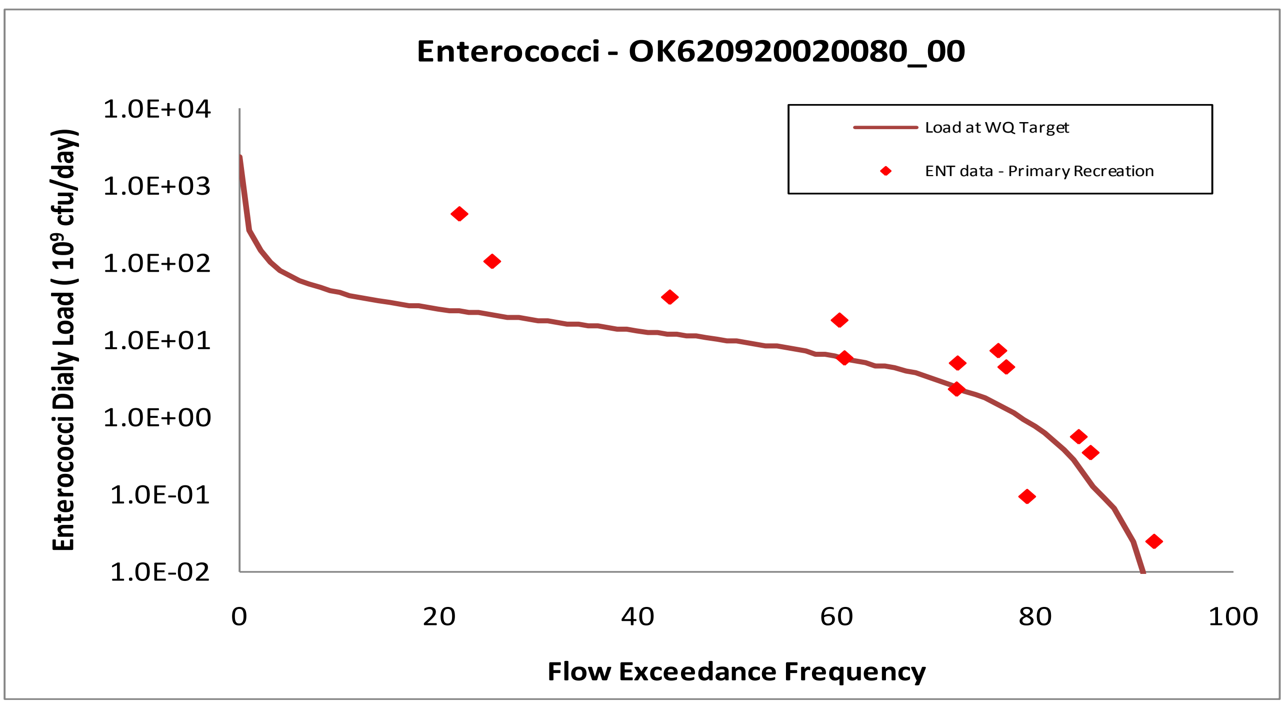


Figure 5-28 Load Duration Curve for Enterococci in Long Creek



The LDC for Cimarron River below Waynoka, segment OK620920010010_00 is shown in Figures 5-29 through 5-31for E. coli, Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM stations OK620920010010-001AT. The LDCs for E. coli, Enterococci indicate that levels exceed the instantaneous water quality criteria under various flow conditions while the LDC for Fecal Coliform indicate that levels exceed the instantaneous water quality criteria under low flow conditions. The exceedance under low flow may be caused by point sources, but also could be caused by failing onsite systems, or direct deposition of animal manure.

Figure 5-29 Load Duration Curve for *E. coli* in Cimarron River below Waynoka

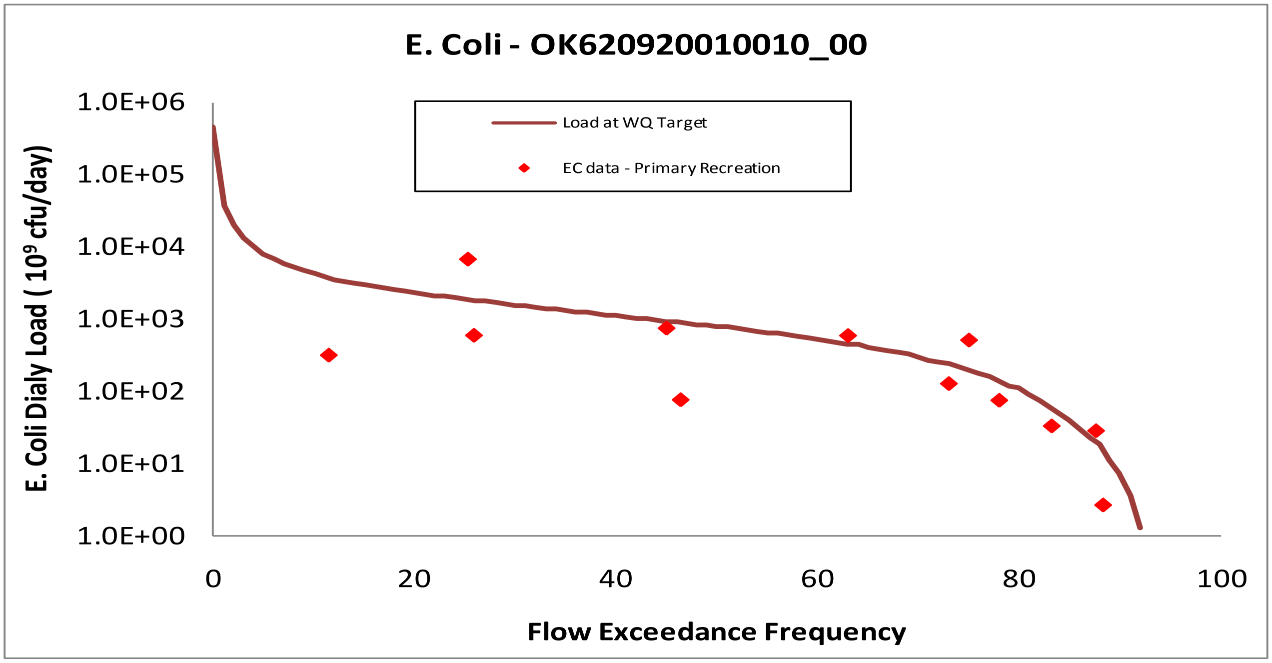


Figure 5-30 Load Duration Curve for Enterococci in Cimarron River below Waynoka

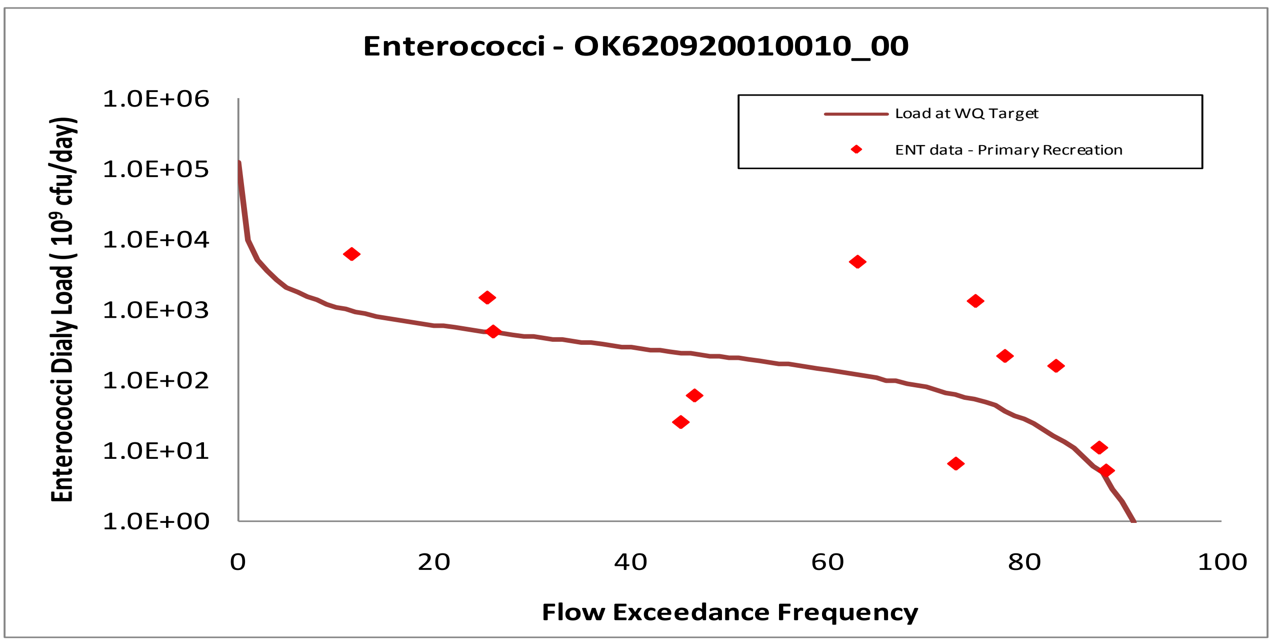
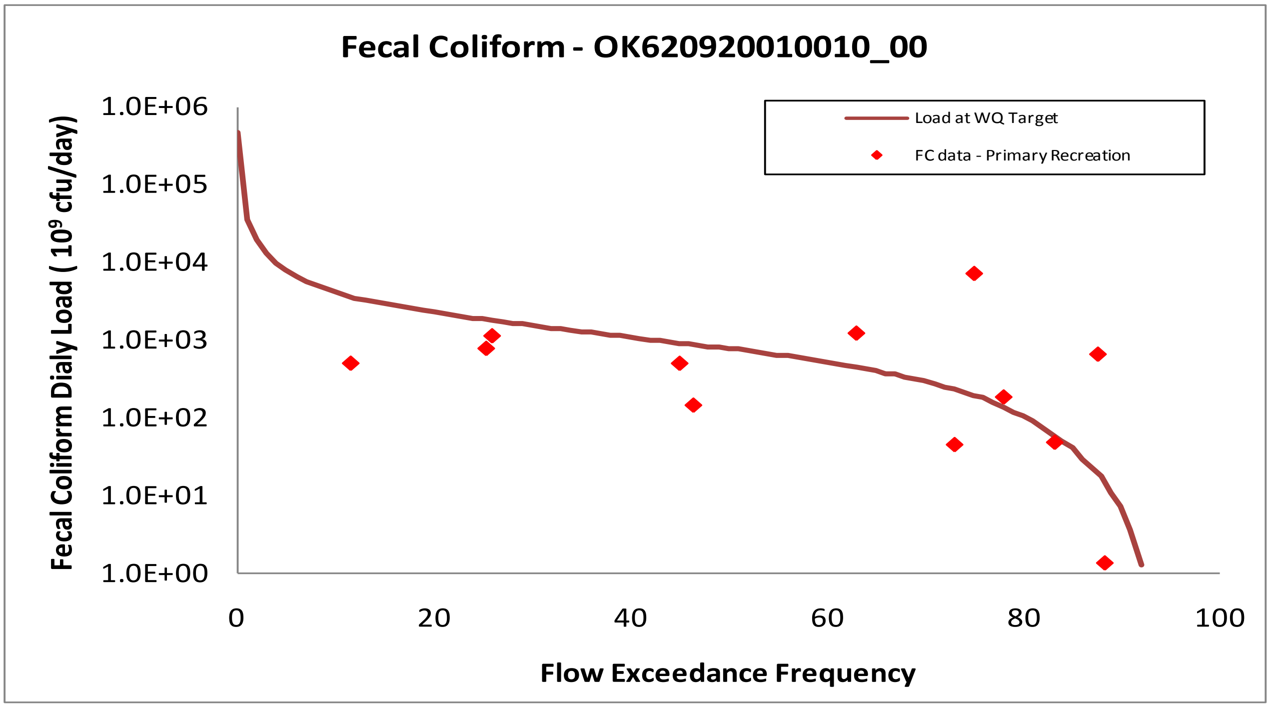


Figure 5-31 Load Duration Curve for Fecal Coliform in Cimarron River below Waynoka



The LDCs for Main Creek, segment OK620920010180_00 are shown in Figures 5-32 and 5-33 for E. coli and Enterococci. They are based on bacteria measurements at WQM station OK620920-01-0180F. The LDC indicates that both E. coli levels exceed the instantaneous water quality criteria under moderate flow conditions. Enterococci LDC indicates that levels exceed the instantaneous water quality criteria under all flow conditions.

Figure 5-32 Load Duration Curve for E. *coli* in Main Creek

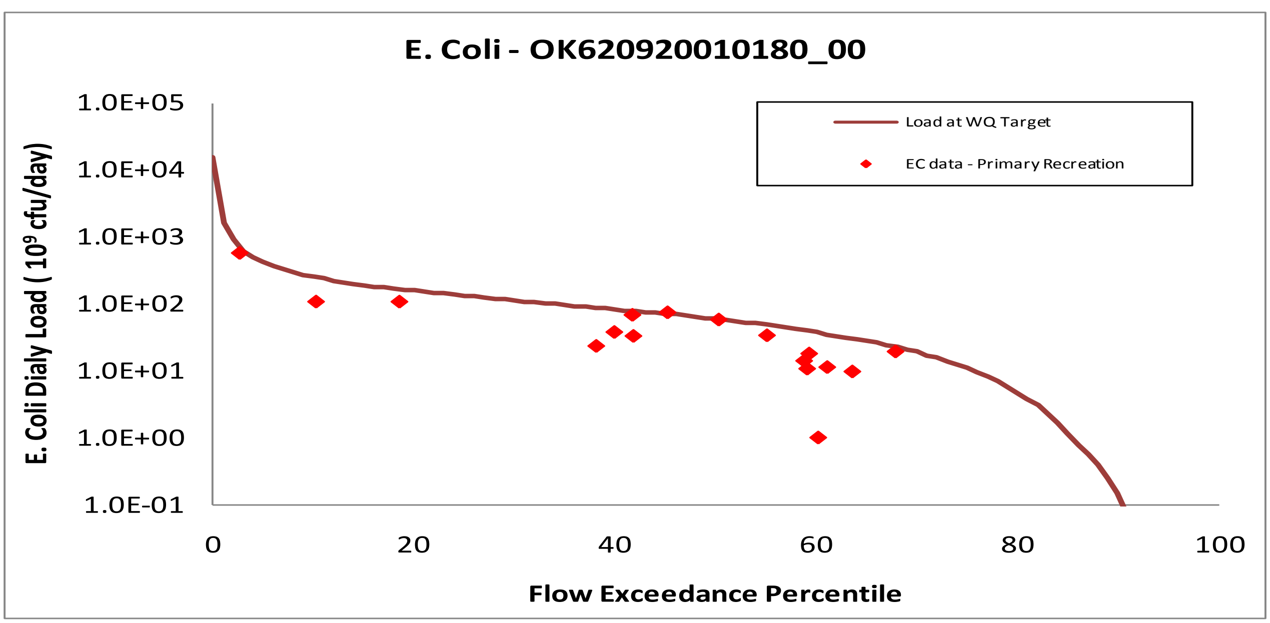
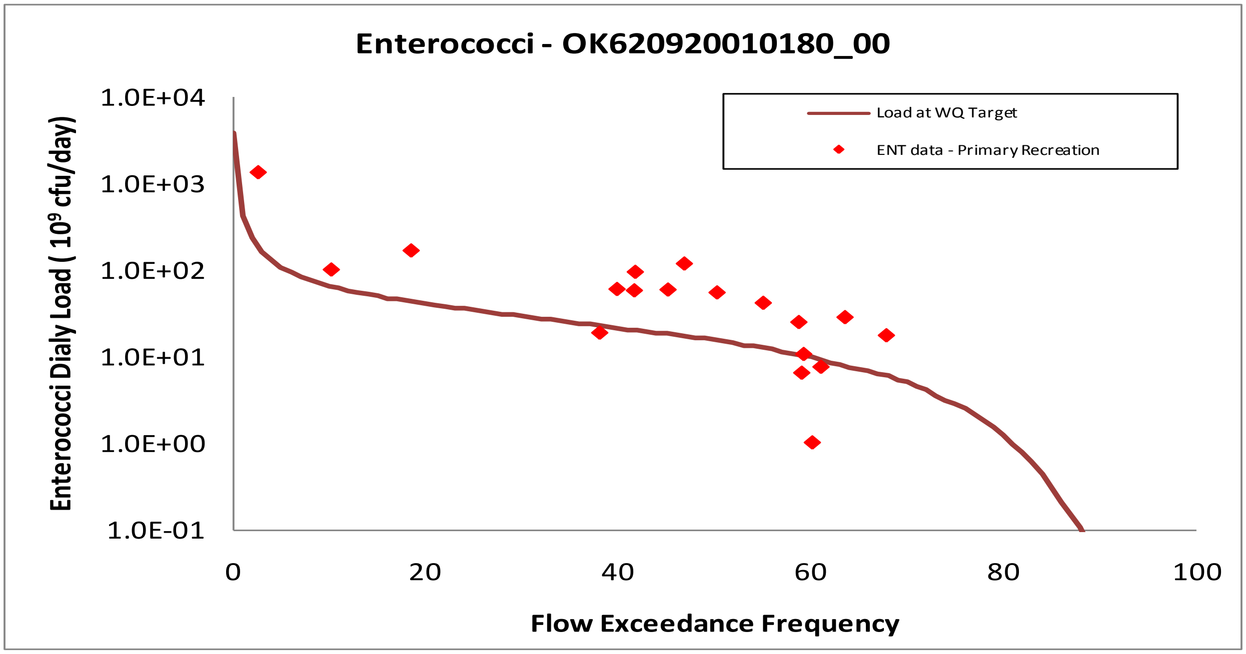
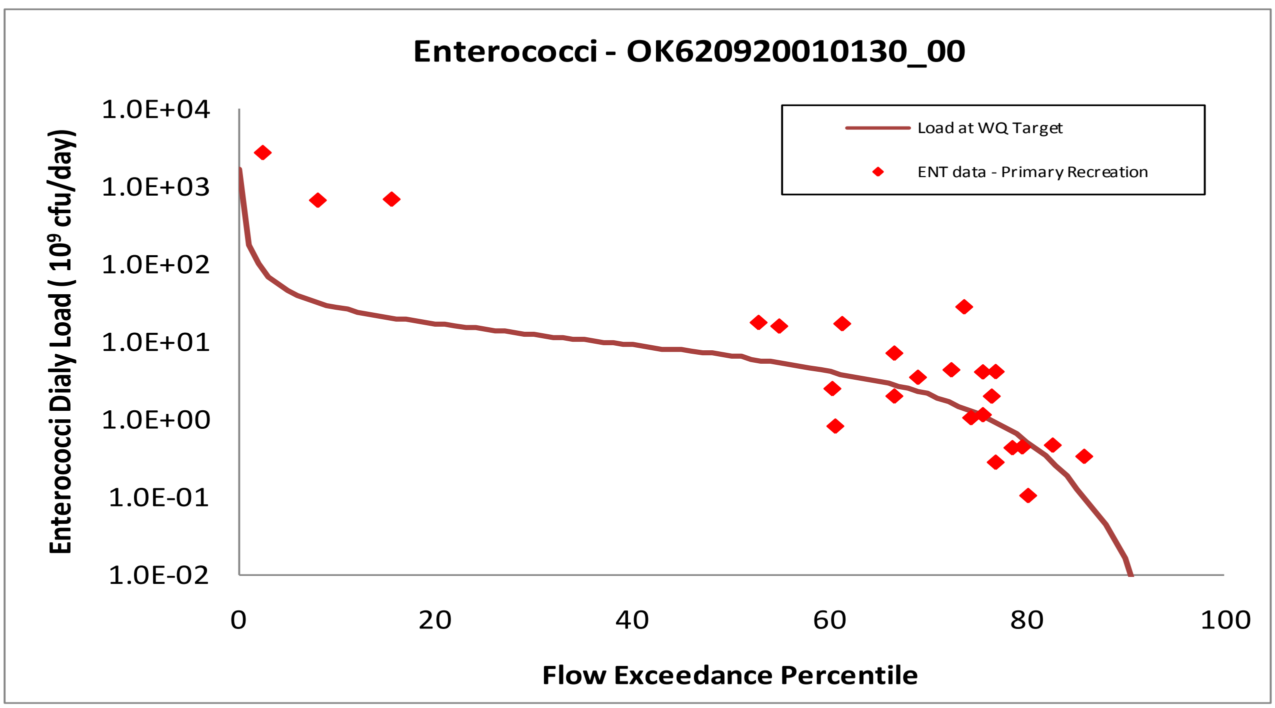


Figure 5-33 Load Duration Curve for Enterococci in Main Creek



The LDC for Griever Creek, segment OK620920010130_00 is shown in Figure 5-34 for Enterococci. They are based on bacteria measurements at WQM stations OK620920-01-0130K. The LDC indicates that Enterococci levels exceed water quality targets at both high and low flow conditions. The exceedance under low flow may be caused by point sources, but also could be caused by failing onsite systems, or direct deposition of animal manure.

Figure 5-34 Load Duration Curve for Enterococci in Griever Creek



The LDC for Eagle Chief Creek, segment OK620920040010_00 is shown in Figures 5-35 and 5-36 shows E. coli and Enterococci measurements at WQM station OK720500-02-0250F. The LDCs indicate that levels exceed the instantaneous water quality criteria under all flow conditions, which is indicative of loading from both point and nonpoint sources.

Figure 5-35 Load Duration Curve for *E. coli* in Eagle Chief Creek

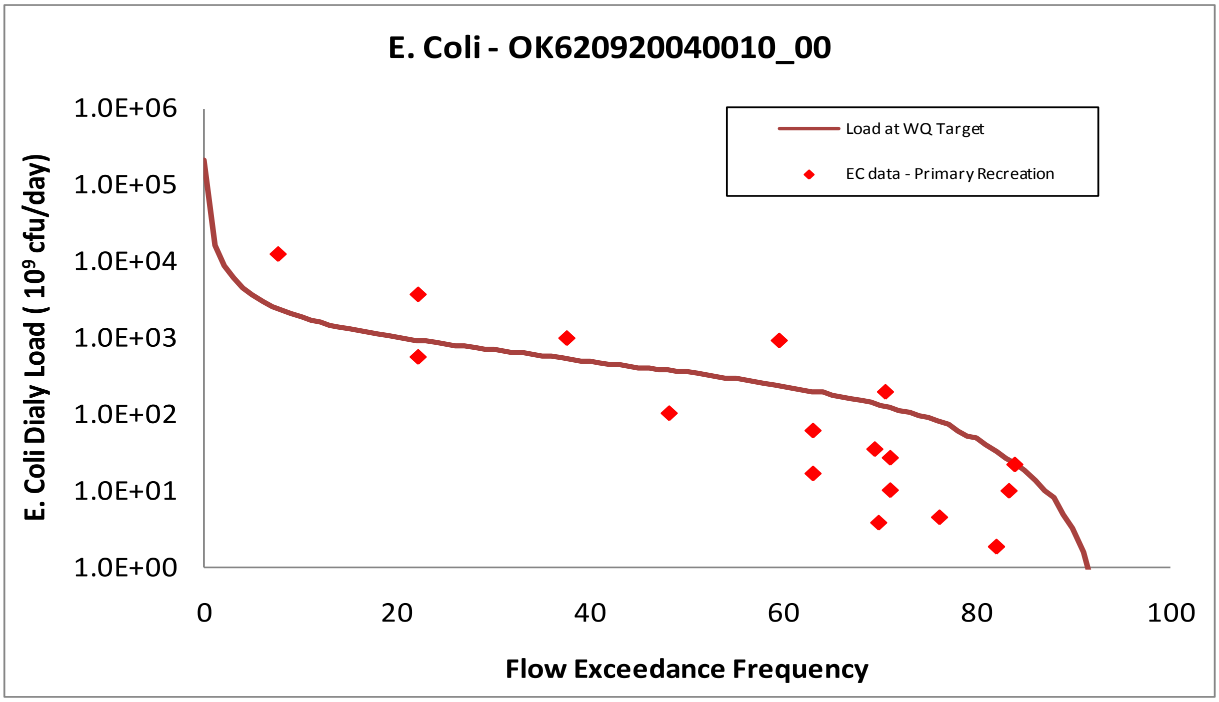
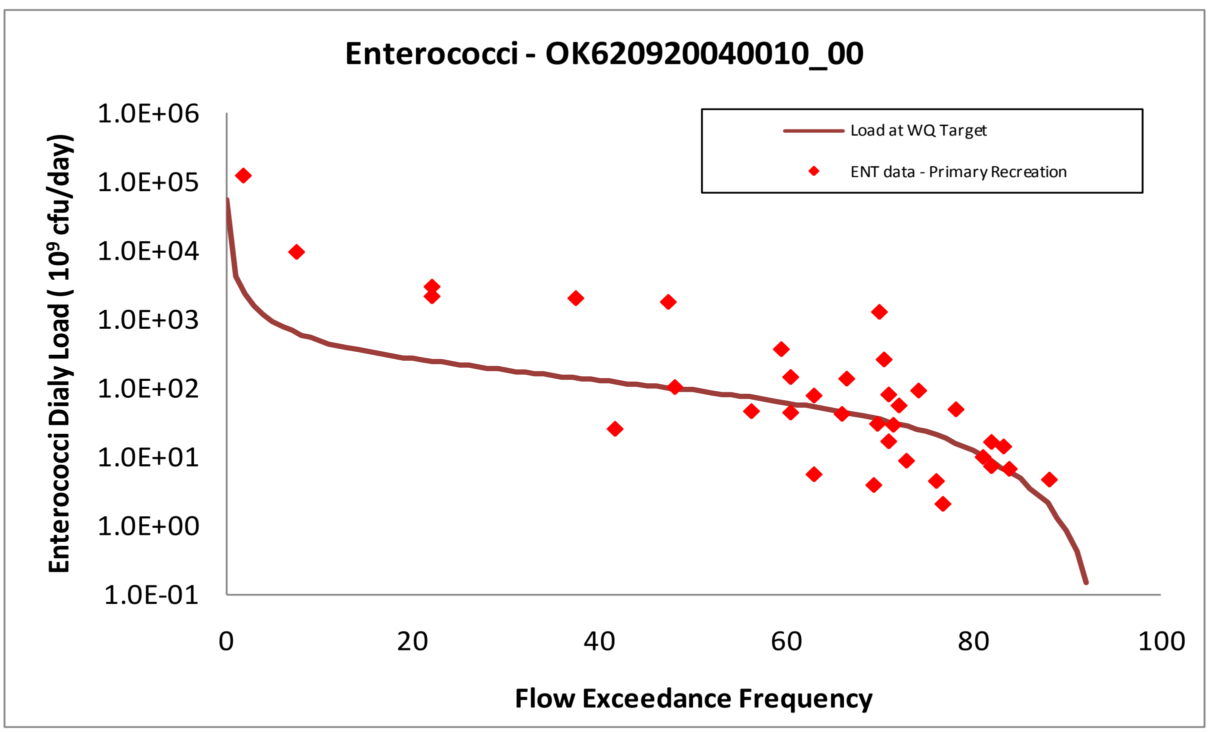
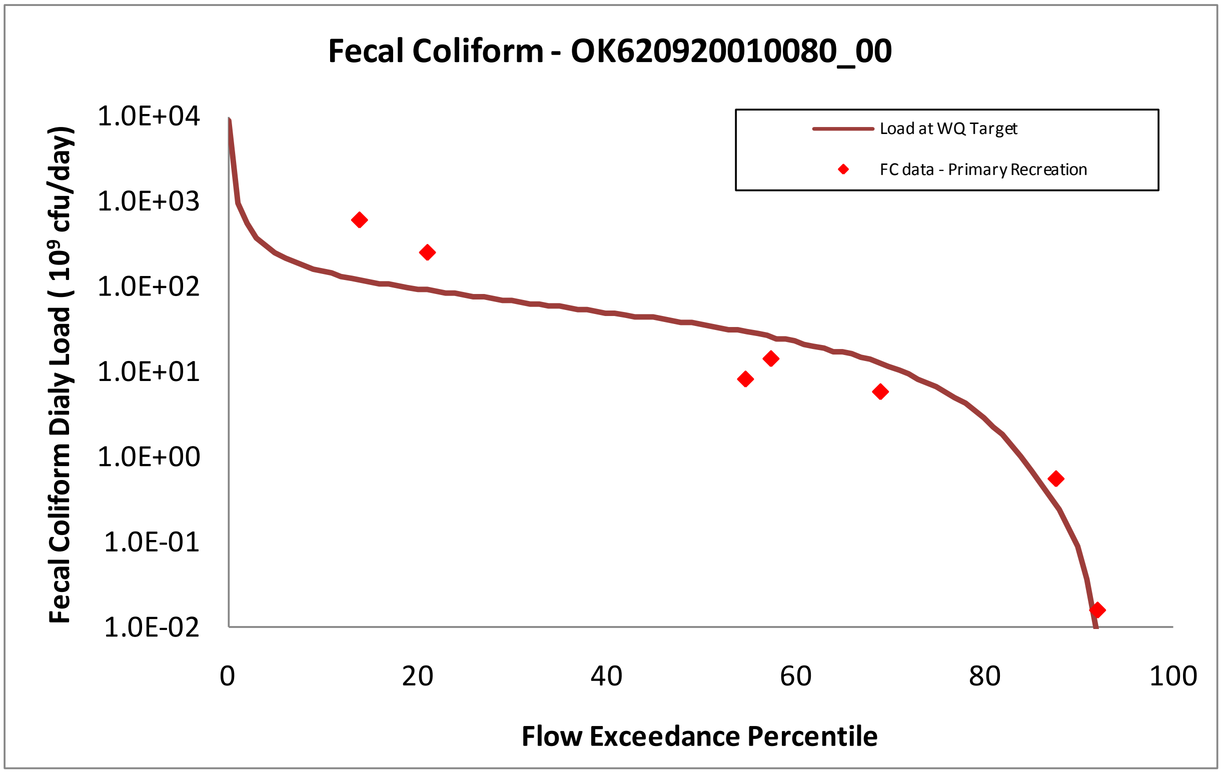


Figure 5-36 Load Duration Curve for Enterococci in Eagle Chief Creek



The LDC for Cottonwood Creek, segment OK620920-010080_00 (Figure 5-37) Fecal Coliform measurements at WQM stations OK620920-01-0080G. The LDC for Fecal Coliform indicates that bacteria levels exceed the instantaneous water quality criteria under both high and low flow conditions. The exceedance under low flow may be caused by point sources, but also could be caused by failing onsite systems, or direct deposition of animal manure.

Figure 5-37 Load Duration Curve for Fecal Coliform in Cottonwood Creek



The LDC for Cimarron River near Ames, segment OK620910020010_10 (Figures 5-38 and 5-39) shows bacteria measurements at WQM stations OK620910020010-004RS. The LDCs indicate that E. coli and Enterococci levels exceed the instantaneous water quality criteria under high and low flow conditions, which is indicative of loading from both point and nonpoint sources.

Figure 5-38 Load Duration Curve for *E. coli* in Cimarron River near Ames

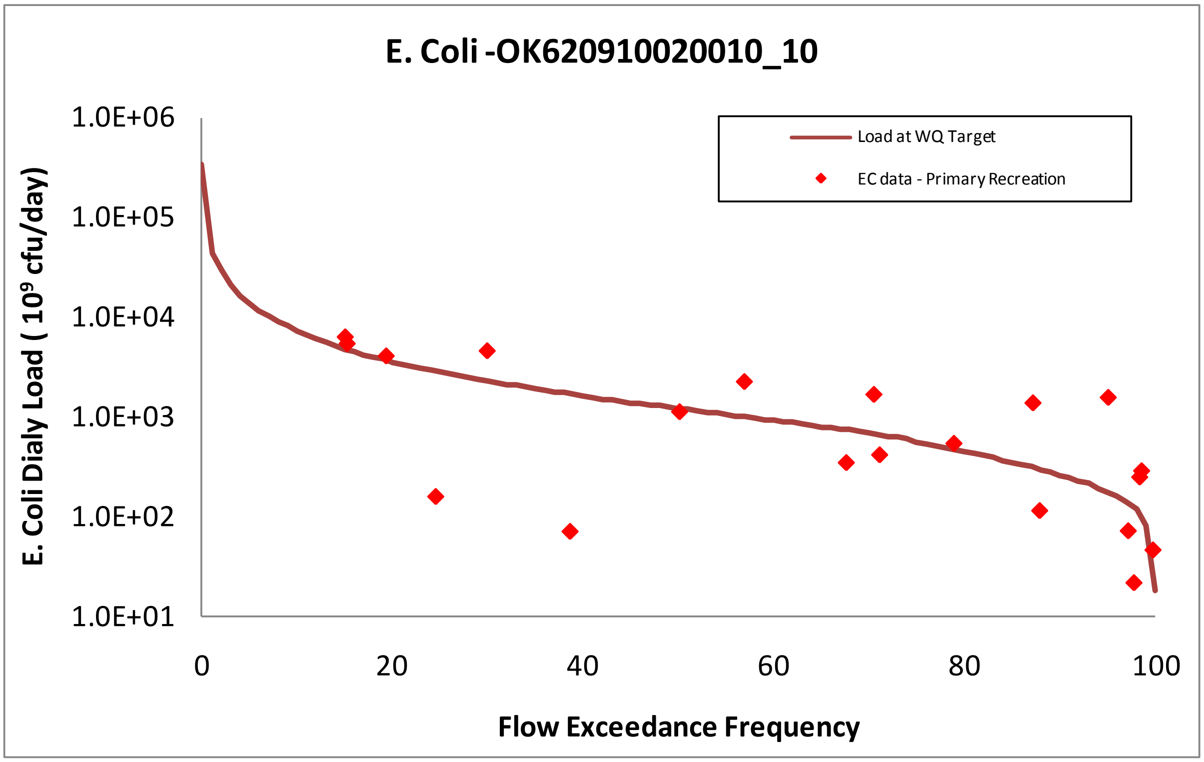
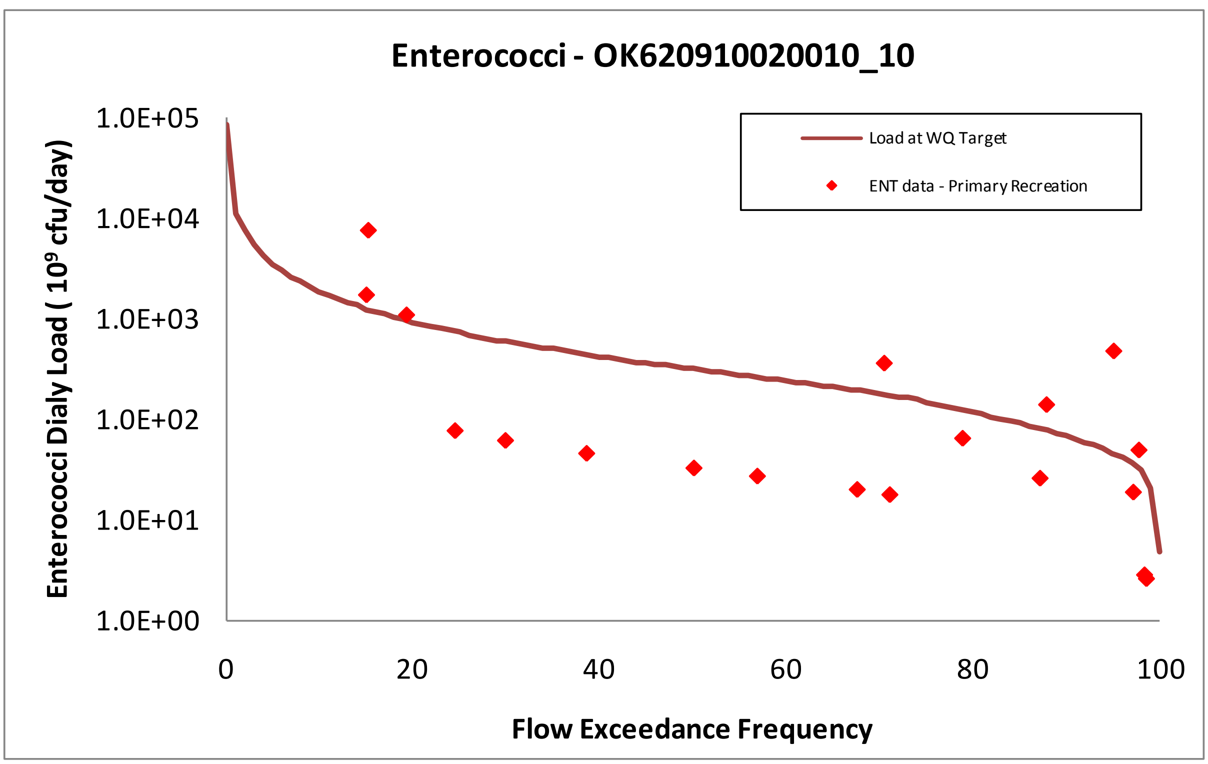


Figure 5-39 Load Duration Curve for Enterococci in Cimarron River near Ames



The LDC for Cimarron River near Dover, segment OK620910020010_00 (Figure 5-40 through 5-42) shows bacteria measurements at WQM station OK620910020010-001AT. The LDCs indicate that all three indicator levels exceed the instantaneous water quality criteria under all flow conditions. The exceedance under low flow may be caused by point sources, but also could be caused by failing onsite systems, or direct deposition of animal manure.

Figure 5-40 Load Duration Curve for *E. coli* in Cimarron River near Dover

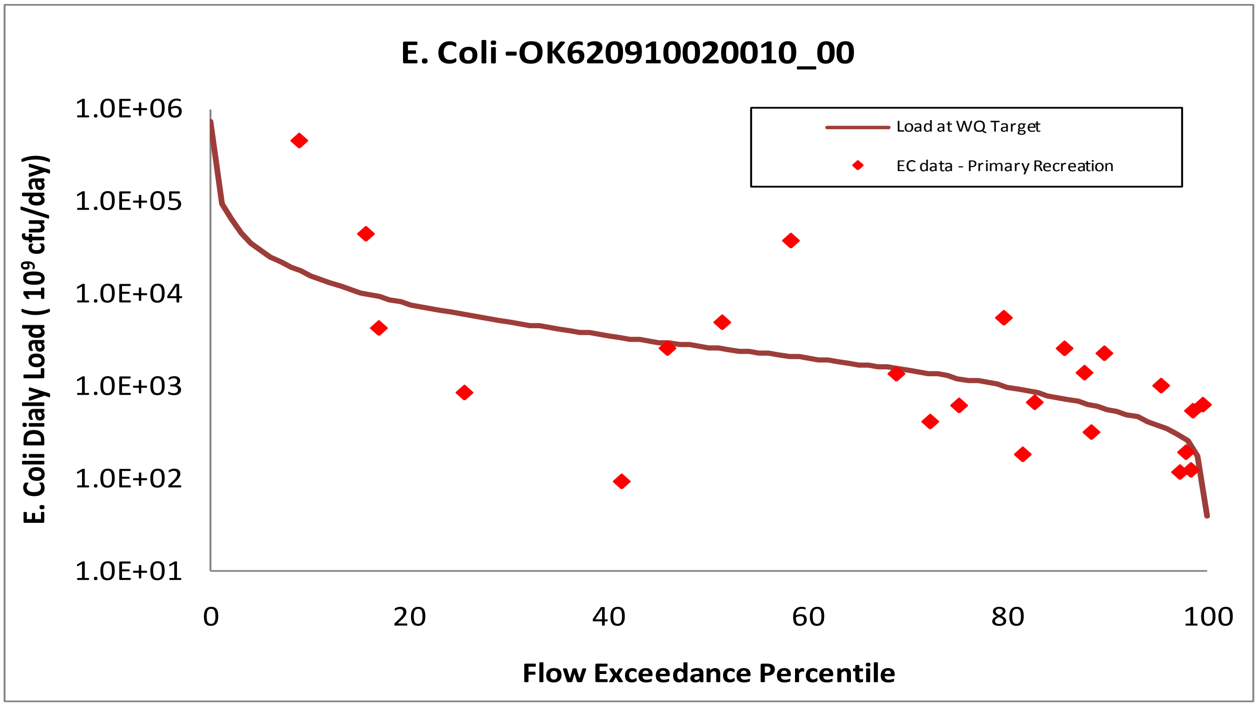


Figure 5-41 Load Duration Curve for Enterococci in Cimarron River near Dover

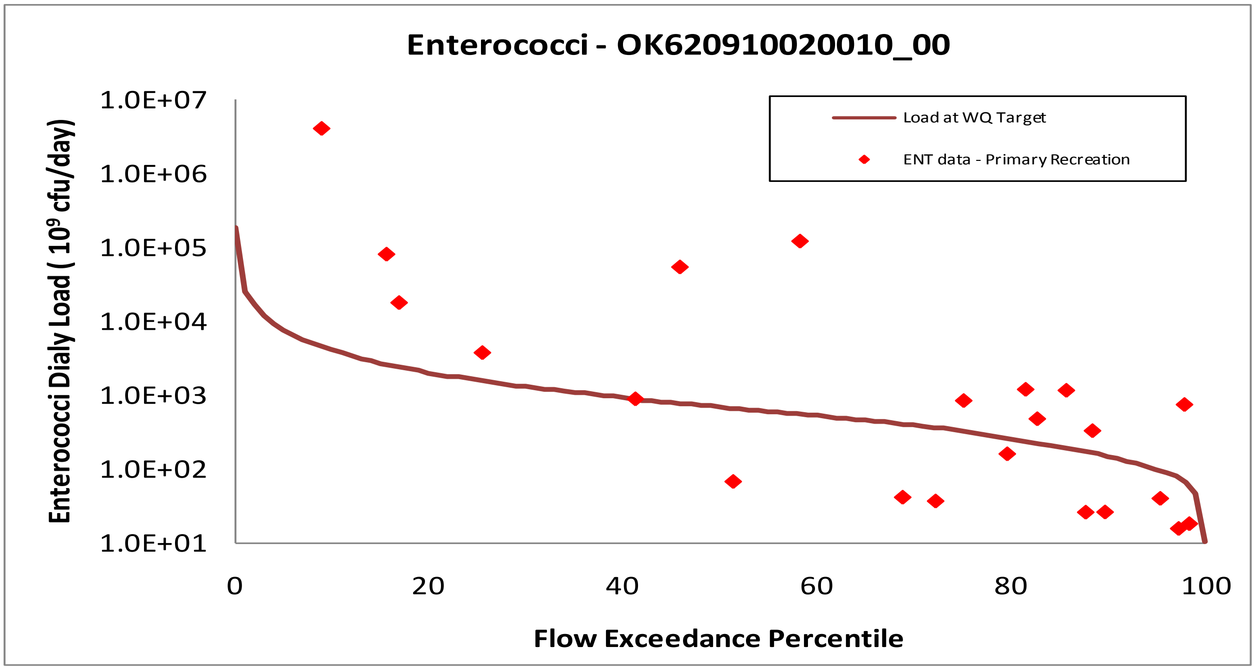
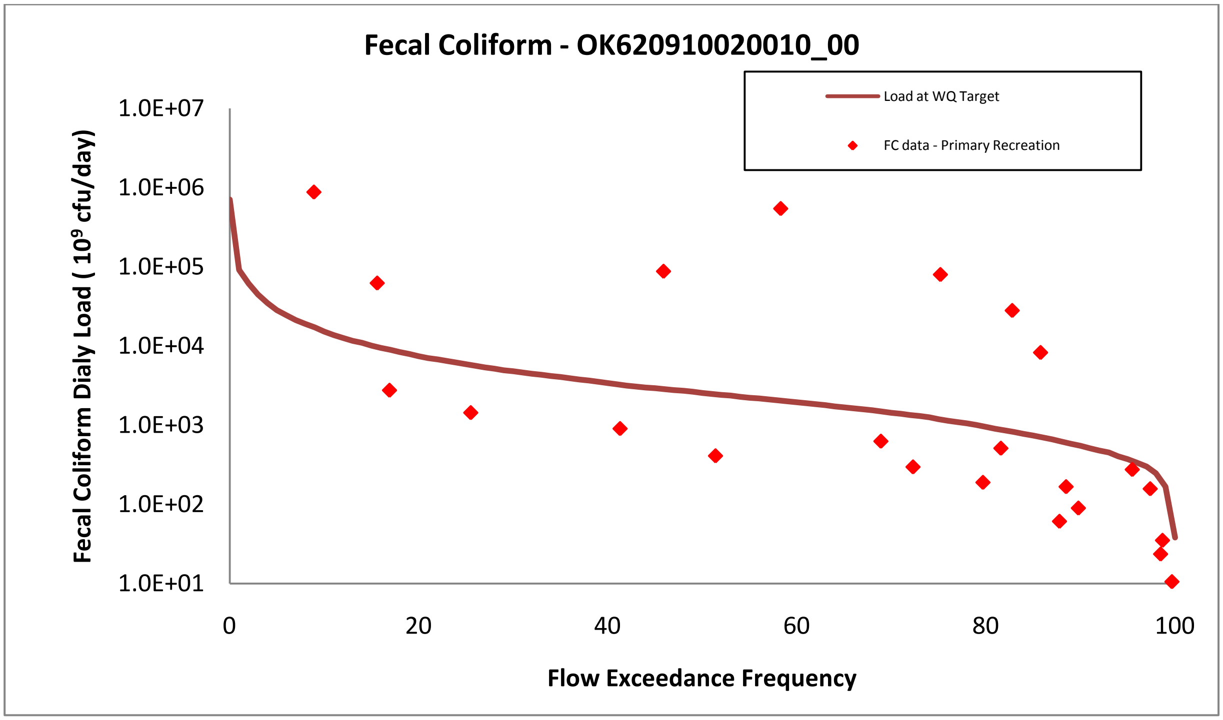


Figure 5-42 Load Duration Curve for Fecal Coliform in Cimarron River near Dover



TSS LDC: To calculate the TSS load at the WQ_{target}, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*5.39377 L*s*lb /ft³/day/mg*) and the TSS goal for each waterbody. This calculation produces the maximum TSS load in the waterbody that will result in attainment of the 50 NTU target for turbidity. The allowable TSS 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 TSS load in pounds per day.

To estimate existing loading, TSS and turbidity observations from 1998 to 2009 are paired with the flows measured on the same date or projected for the waterbody. For sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equation in Figure 4-1 and Figure 4-2. Pollutant loads are then calculated by multiplying the TSS 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 C. The observed TSS or converted turbidity loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of TSS. Points above the LDC indicate the TSS goal was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample did not exceed the TSS goal.

Figures 5-43 through Figure 5-47 show the TSS LDCs developed for Cimarron River below Waynoka, Main Creek, Eagle Chief Creek, Cottonwood Creek and Cimarron River near Dover. Data in the figures indicate that for these waterbodies, TSS levels exceed the water quality target during all flow conditions, indicating water quality impairments due to nonpoint sources or a combination of point and nonpoint sources. It is noted that the LDC plots include data under all flow conditions to show the overall condition of the waterbody. However, the turbidity standard only applies for base-flow conditions. Thus, when interpreting the LDC to derive TMDLs for TSS, only the portion of the graph corresponding to flows above the 25th flow exceedance percentile should be used. WLAs for point sources discharges (continuous) of inorganic TSS are shown on a LDC as a horizontal line which represents the sum of all WLAs for TSS in a given watershed.

Figure 5-43 Load Duration Curve for Total Suspended Solids in Cimarron River below Waynoka

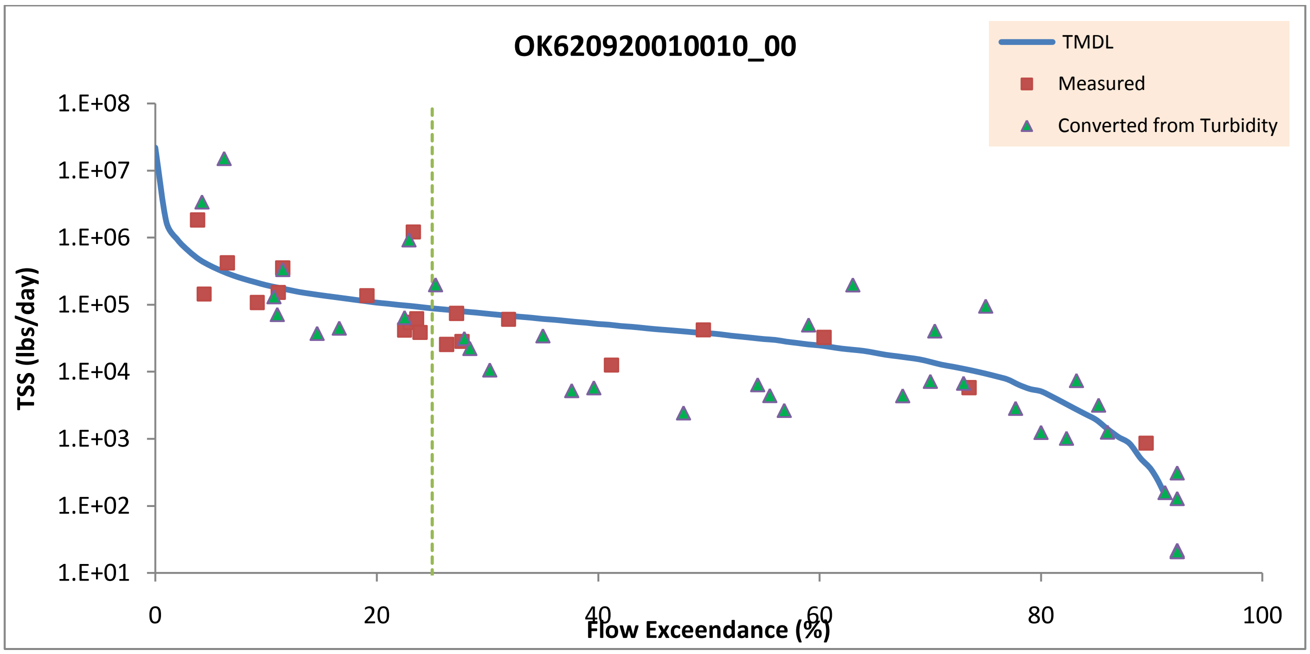


Figure 5-44 Load Duration Curve for Total Suspended Solids in Main Creek

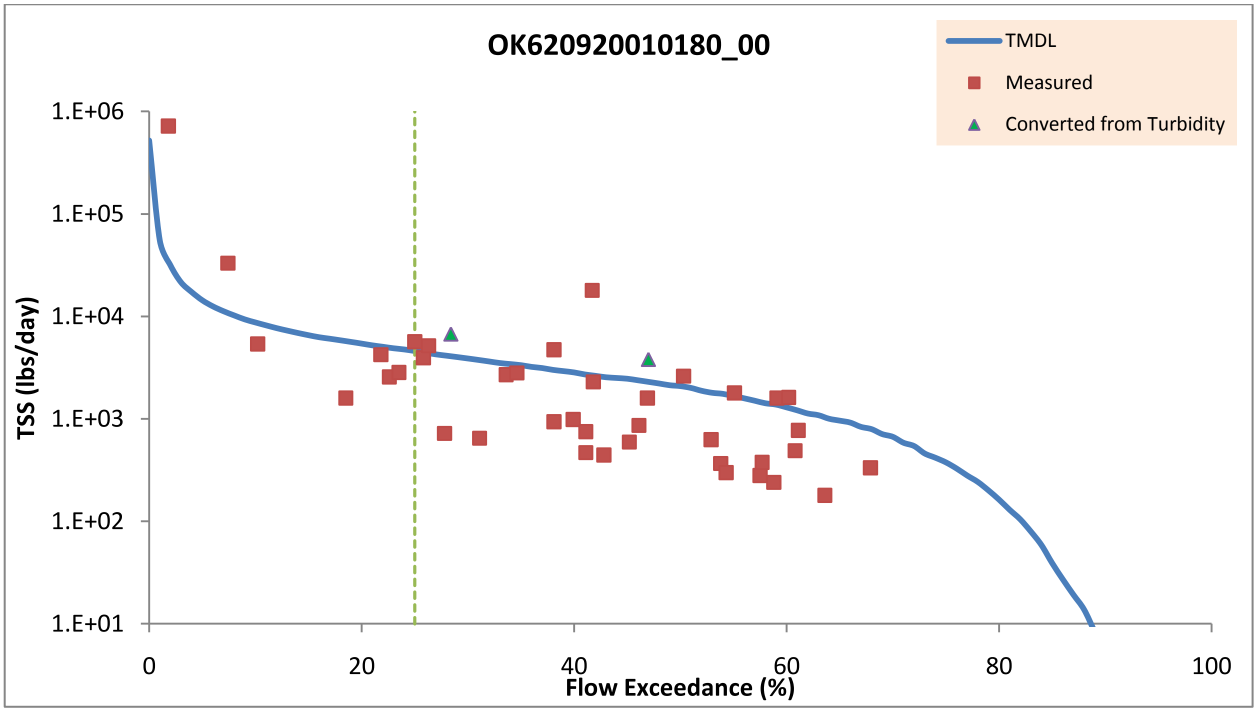


Figure 5-45 Load Duration Curve for Total Suspended Solids in Eagle Chief Creek

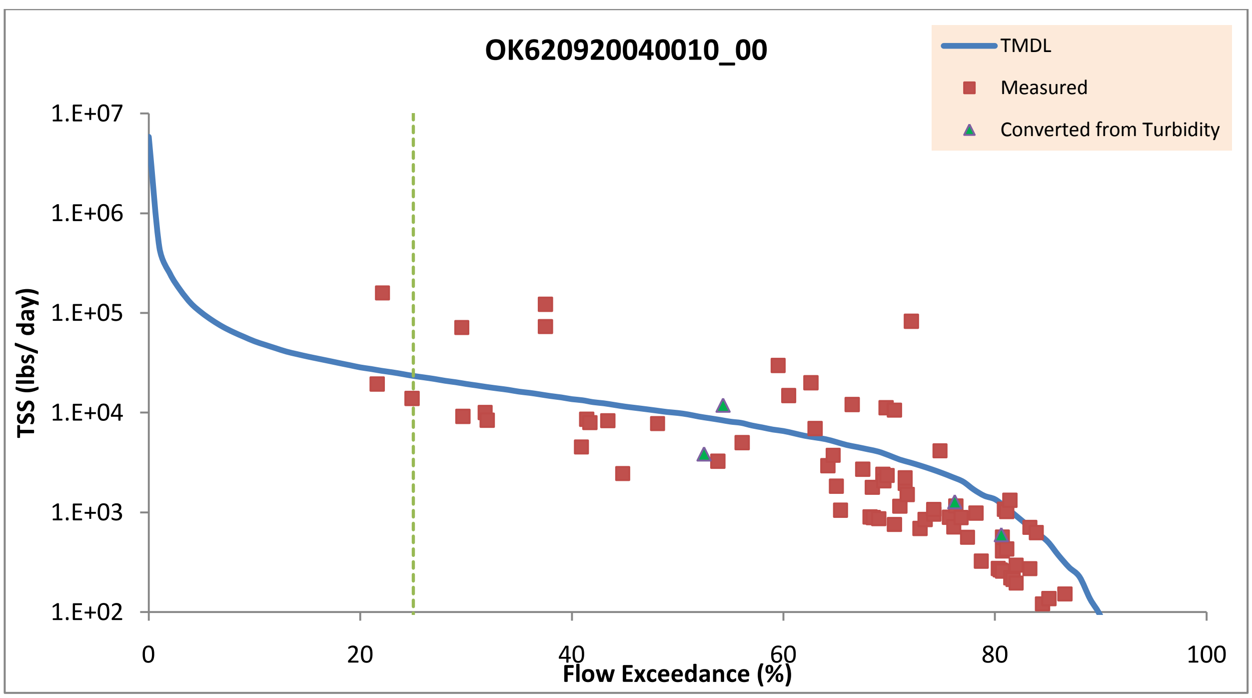


Figure 5-46 Load Duration Curve for Total Suspended Solids in Cottonwood Creek

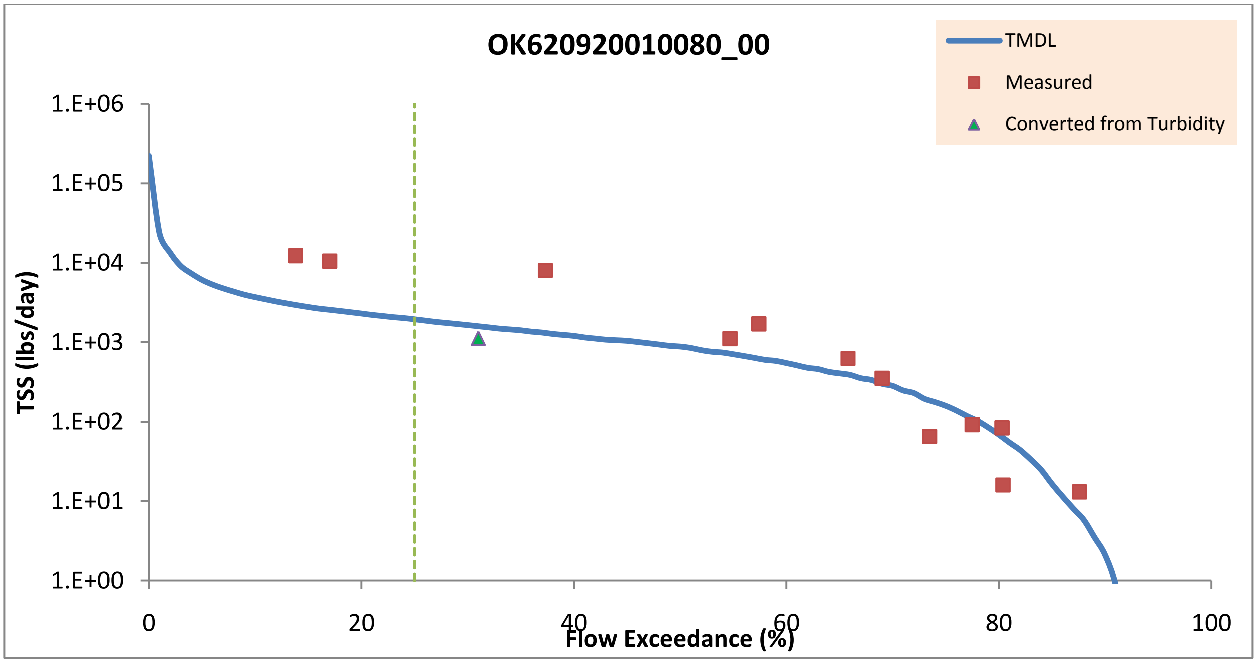
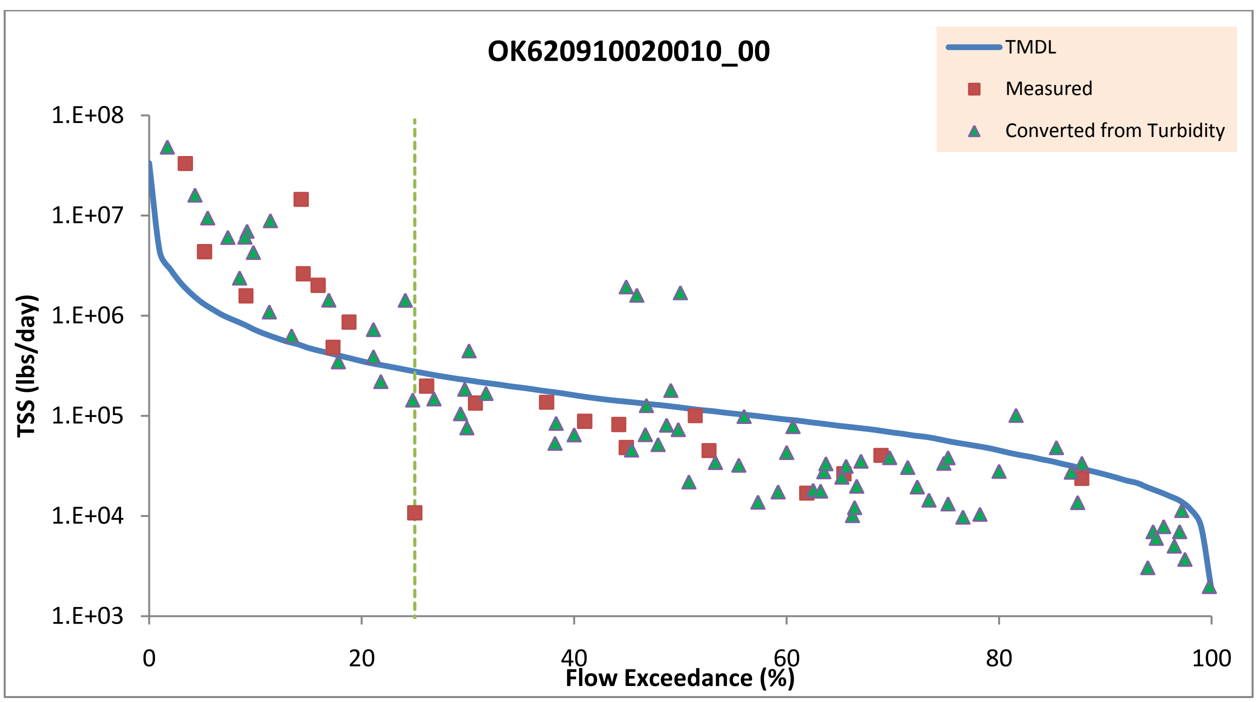


Figure 5-47 Load Duration Curve for Total Suspended Solids in Cimarron River near Dover



Establishing Percent Reduction Goals: 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 through an iterative process of taking a series of percent reduction values applying each value uniformly between the concentrations of samples and verifying that no more than a fixed percent of the samples exceed the water quality target concentration. PRG are calculated for each watershed and bacterial indicator species as the reductions in load required so none of the existing instantaneous water quality observations would exceed the water quality target for *E. coli* and Enterococci and no more than 25 percent of the samples exceed the water quality target for fecal coliform. This is because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody. Table 5-2 presents the percent reductions necessary for each bacterial indicator in each of the impaired waterbodies in the Study Area. The appropriate PRG for each bacteria indicator for each waterbody in Table 5-2 is denoted by the bold text.

Table 5-2 TMDL Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate				
		FC	EC		ENT	
		Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
OK620920030010_00	Cimarron River near Buffalo	**69%**	99%	**94%**	99.99%	**86%**
OK620920050010_00	Buffalo Creek near Lovedale		91%	**13%**	98%	**77%**
OK620920050050_00	Sand Creek		82%	**71%**	96%	**93%**
OK620920020010_00	Cimarron River at Freedom		97%	**88%**		
OK620920020080_00	Long Creek		82%	**24%**	99.99%	**83%**
OK620920010010_00	Cimarron River below Waynoka	**28%**	73%	**31%**	99.99%	**86%**
OK620920010180_00	Main Creek		91%	**41%**	97%	**86%**
OK620920010130_00	Griever Creek				97%	**86%**
OK620920040010_00	Eagle Chief Creek		96%	**31%**	98%	**83%**
OK620920010080_00	Cottonwood Creek	**49%**				
OK620910020010_10	Cimarron River near Ames		89%	**65%**	91%	**26%**
OK620910020010_00	Cimarron River near Dover	**85%**	97%	**74%**	99.99%	**82%**

Similarly, percent reduction goals for TSS are calculated as the required overall reduction so that no more than 10 percent of the samples exceed the water quality target for TSS. The PRGs for the two waterbodies included in this TMDL report are summarized in Table 5-3 and are 62 and 86 percent respectively.

Table 5-3 TMDL Percent Reductions Required to Meet Water Quality Targets for Indicator for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK620920010010_00	Cimarron River below Waynoka	86%
OK620920010180_00	Main Creek	64%
OK620920040010_00	Eagle Chief Creek	76%
OK620920010080_00	Cottonwood Creek	82%
OK620910020010_00	Cimarron River near Dover	62%

5.4 Wasteload Allocation

5.4.1 Indicator Bacteria

For bacteria TMDLs, NPDES-permitted facilities are allocated a daily wasteload calculated as their permitted flow rate multiplied by the instream geometric mean water quality criterion. In other words, the facilities are required to meet instream criteria in their discharge. Table 5-4 summarizes the WLA for the NPDES-permitted facilities within the Middle Cimarron River Study Area. The WLA for each facility is derived from the following equation:

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

Where:

WQS = 33, 200, and 126 cfu/100 mL for Enterococci, fecal coliform, and E. coli respectively

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

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

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES WWTPs discharging into the contributing watershed of a WQM station, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform limits and disinfection requirements of NPDES permits. There are two NPDES WWTPs discharging into the contributing watersheds of stream segments that require bacteria TMDLs. Table 5-4 indicates which point source dischargers within the study area currently have a disinfection requirement in their permit. Certain facilities that utilize lagoons for treatment have not been required to provide disinfection since storage time and exposure to ultraviolet radiation from sunlight should reduce bacteria levels. In the future, all point source dischargers which are assigned a wasteload allocation but do not currently have a bacteria limit in their permit will receive a permit limit consistent with the wasteload allocation as their permits are reissued. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacteria load from existing discharges will be considered consistent with the TMDL provided that the NPDES permit requires instream criteria to be met.

Table 5-4 Permit Information for NPDES-Permitted Facilities

Waterbody ID	NPDES Permit No.	Name	Disinfection	Design Flow (mgd)	Wasteload Allocation (cfu/day)		
					Fecal Coliform	*E. Coli*	Enterococci
OK620920010010_00	OK0020079	Fairview WWTP	No	0.200	3.03E+09	9.54E+08	2.50E+08
OK620920040010_00	OKG580045	Aline WWTP	No	0.031		1.48E+08	3.87E+07

Permitted stormwater discharges are considered point sources; however, there are no areas designated as MS4s within this Study Area, so the WLA for MS4 is zero.

5.4.2 Total Suspended Solids

NPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated by using the maximum self-reported monthly average flow multiplied by the water quality target. In other words, the facilities are required to meet instream criteria in their discharge. If the current monthly TSS limits of a facility are greater than instream TSS criteria, the new limits equal to instream criteria will be applied to the facility as their permit is renewed. There are no NPDES-permitted facilities discharging inorganic TSS within the Study Area, otherwise the WLA for each facility is derived as follows:

WLA_WWTP = WQ goal * flow * unit conversion factor (lb/day)

Where:

WQ goal = waterbody-specific water quality goal as summarized in Table 4-1

flow (10^6 gal/day) = maximum monthly average flow

unit conversion factor = 8.3445L*lb/dal/mg

No wasteload allocations are needed for stormwater dischargers in the Study Area. By definition, any stormwater discharge occurs during periods of rainfall and elevated flow conditions. Oklahoma's Water Quality Standards specify that the criteria for turbidity "apply only to seasonal base flow conditions" and go on to say "Elevated turbidity levels may be expected during, and for several days after, a runoff event" [OAC 785:45-5-12(f)(7)]. To accommodate the potential for future growth in those watersheds with no WLA for TSS, 1% of TSS loading is reserved as part of the WLA.

5.4.3 Section 404 Permits

No TSS wasteload allocations were set aside for Section 404 permits. The state will use its Section 401 certification authority to ensure Section 404 permits protect Oklahoma water quality standards and comply with TSS TMDLs in this report. Section 401 certifications will be conditioned to meet one of the following two conditions to be certified by the state:

- Include TSS limits in the permit and establish a monitoring requirement to ensure compliance with turbidity standard and TSS TMDLs.

or

- Submit to the DEQ a BMP turbidity reduction plan which should include all practicable turbidity control techniques. The turbidity reduction plan must be approved first before a Section 401 certification can be issued.

Compliance with the Section 401 certification condition will be considered compliance with this TMDL.

5.5 Load Allocation

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

LA = TMDL – WLA_WWTP – WLA_growth - MOS

5.6 Seasonal Variability

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

5.7 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained.

For bacteria TMDLs, an explicit MOS of 10 percent was selected.

For turbidity, the TMDLs are calculated for TSS instead of turbidity. Thus, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confidence there is in the TMDL targets. As a result, it leads to a smaller margin of safety. The selection of MOS is based on the NRMSE for each waterbody. The explicit MOS were 10 percent and 15 percent. Table 5-5 shows the MOS for each waterbody.

Table 5-5 Explicit Margin of Safety for Total Suspended Solids TMDLs

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK620920010010_00	Cimarron River below Waynoka	7.2%	10%
OK620920010180_00	Main Creek	8.3%	10%
OK620920040010_00	Eagle Chief Creek	11.0%	15%
OK620920010080_00	Cottonwood Creek	10.6%	15%
OK620910020010_00	Cimarron River near Dover	8.3%	10%

5.8 TMDL Calculations

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

This definition can be expressed by the following equation:

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

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

The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5^{th} flow interval percentile. Tables 5-6 and 5-7 summarize the TMDL, WLA, LA and MOS loadings at the 50% flow percentile. Tables 5-8 through 5-31 summarize the allocations for indicator bacteria and Tables 5-32 and 5-36 present the allocations for total suspended solids.

Table 5-6 Summaries of Bacteria TMDLs

Waterbody ID	Stream Name	Pollutant	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
OK620920030010_00	Cimarron River near Buffalo	E. coli	4.97E+11	0	4.47E+11	4.97E+10
OK620920030010_00	Cimarron River near Buffalo	Enterococci	1.32E+11	0	1.19E+11	1.32E+10
OK620920030010_00	Cimarron River near Buffalo	Fecal Coliform	4.89E+11	0	4.40E+11	4.89E+10
OK620920050010_00	Buffalo Creek near Lovedale	E. coli	3.18E+11	0	2.86E+11	3.18E+10
OK620920050010_00	Buffalo Creek near Lovedale	Enterococci	8.46E+10	0	7.62E+10	8.46E+09
OK620920050050_00	Sand Creek	E. coli	7.91E+10	0	7.12E+10	7.91E+09
OK620920050050_00	Sand Creek	Enterococci	2.10E+10	0	1.89E+10	2.10E+09
OK620920020010_00	Cimarron River at Freedom	E. coli	6.36E+11	0	5.72E+11	6.36E+10
OK620920020080_00	Long Creek	E. coli	4.09E+10	0	3.68E+10	4.09E+09
OK620920020080_00	Long Creek	Enterococci	1.09E+10	0	9.79E+09	1.09E+09
OK620920010010_00	Cimarron River below Waynoka	E. coli	8.74E+11	9.54E+08	7.86E+11	8.74E+10
OK620920010010_00	Cimarron River below Waynoka	Enterococci	2.33E+11	2.50E+08	2.09E+11	2.33E+10
OK620920010010_00	Cimarron River below Waynoka	Fecal Coliform	8.61E+11	3.03E+09	7.72E+11	8.61E+10
OK620920010180_00	Main Creek	E. coli	6.66E+10	0	5.99E+10	6.66E+09
OK620920010180_00	Main Creek	Enterococci	1.77E+10	0	1.59E+10	1.77E+09
OK620920010130_00	Griever Creek	Enterococci	7.40E+09	0	6.66E+09	7.40E+08
OK620920040010_00	Eagle Chief Creek	E. coli	3.88E+11	1.48E+08	3.49E+11	3.88E+10
OK620920040010_00	Eagle Chief Creek	Enterococci	1.03E+11	3.87E+07	9.28E+10	1.03E+10
OK620920010080_00	Cottonwood Creek	Fecal Coliform	4.00E+10	0	3.60E+10	4.00E+09
OK620910020010_10	Cimarron River near Ames	E. coli	1.33E+12	0	1.20E+12	1.33E+11
OK620910020010_10	Cimarron River near Ames	Enterococci	3.54E+11	0	3.18E+11	3.54E+10
OK620910020010_00	Cimarron River near Dover	E. coli	2.88E+12	0	2.59E+12	2.88E+11
OK620910020010_00	Cimarron River near Dover	Enterococci	7.66E+11	0	6.88E+11	7.66E+10
OK620910020010_00	Cimarron River near Dover	Fecal Coliform	2.84E+12	0	2.54E+12	2.84E+11

Table 5-7 Summaries of TSS TMDLs

Waterbody ID	Stream Name	Pollutant	TMDL (lbs/day)	WLA * (lbs/day)	LA (lbs/day)	MOS (lbs/day)
OK620920010010_00	Cimarron River below Waynoka	TSS	4.84E+04	4.84E+02	4.30E+04	4.84E+03
OK620920010180_00	Main Creek	TSS	3.68E+03	3.68E+01	3.28E+03	3.68E+02
OK620920040010_00	Eagle Chief Creek	TSS	2.15E+04	2.15E+02	1.80E+04	3.22E+03
OK620920010080_00	Cottonwood Creek	TSS	2.24E+03	2.24E+01	1.88E+03	3.37E+02
OK620910020010_00	Cimarron River near Dover	TSS	1.59E+05	1.59E+03	1.42E+05	1.59E+04

* WLA reserved for growth

Table 5-8 *E. coli* TMDL Calculations for Cimarron River near Buffalo (OK620920030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	12500.00	1.24E+14	0	1.12E+14	1.24E+13
5	344.15	3.42E+12	0	3.08E+12	3.42E+11
10	209.00	2.08E+12	0	1.87E+12	2.08E+11
15	157.00	1.56E+12	0	1.40E+12	1.56E+11
20	130.00	1.29E+12	0	1.16E+12	1.29E+11
25	110.00	1.09E+12	0	9.83E+11	1.09E+11
30	93.00	9.24E+11	0	8.31E+11	9.24E+10
35	80.00	7.95E+11	0	7.15E+11	7.95E+10
40	68.00	6.75E+11	0	6.08E+11	6.75E+10
45	59.00	5.86E+11	0	5.27E+11	5.86E+10
50	50.00	4.97E+11	0	4.47E+11	4.97E+10
55	40.00	3.97E+11	0	3.58E+11	3.97E+10
60	31.00	3.08E+11	0	2.77E+11	3.08E+10
65	23.00	2.28E+11	0	2.06E+11	2.28E+10
70	16.00	1.59E+11	0	1.43E+11	1.59E+10
75	9.00	8.94E+10	0	8.05E+10	8.94E+09
80	3.90	3.87E+10	0	3.49E+10	3.87E+09
85	0.94	9.29E+09	0	8.36E+09	9.29E+08
90	0.12	1.19E+09	0	1.07E+09	1.19E+08
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-9 Enterococci TMDL Calculations for Cimarron River near Buffalo *E. coli* (OK620920030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	12500.00	3.30E+13	0	2.97E+13	3.30E+12
5	344.15	9.09E+11	0	8.18E+11	9.09E+10
10	209.00	5.52E+11	0	4.97E+11	5.52E+10
15	157.00	4.15E+11	0	3.73E+11	4.15E+10
20	130.00	3.43E+11	0	3.09E+11	3.43E+10
25	110.00	2.91E+11	0	2.62E+11	2.91E+10
30	93.00	2.46E+11	0	2.21E+11	2.46E+10
35	80.00	2.11E+11	0	1.90E+11	2.11E+10
40	68.00	1.80E+11	0	1.62E+11	1.80E+10
45	59.00	1.56E+11	0	1.40E+11	1.56E+10
50	50.00	1.32E+11	0	1.19E+11	1.32E+10
55	40.00	1.06E+11	0	9.51E+10	1.06E+10
60	31.00	8.19E+10	0	7.37E+10	8.19E+09
65	23.00	6.08E+10	0	5.47E+10	6.08E+09
70	16.00	4.23E+10	0	3.80E+10	4.23E+09
75	9.00	2.38E+10	0	2.14E+10	2.38E+09
80	3.90	1.03E+10	0	9.27E+09	1.03E+09
85	0.94	2.47E+09	0	2.22E+09	2.47E+08
90	0.12	3.17E+08	0	2.85E+08	3.17E+07
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-10 Fecal Coliform TMDL Calculations for Cimarron River near Buffalo (OK620920030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	12500.00	1.22E+14	0	1.10E+14	1.22E+13
5	344.15	3.37E+12	0	3.03E+12	3.37E+11
10	209.00	2.05E+12	0	1.84E+12	2.05E+11
15	157.00	1.54E+12	0	1.38E+12	1.54E+11
20	130.00	1.27E+12	0	1.14E+12	1.27E+11
25	110.00	1.08E+12	0	9.69E+11	1.08E+11
30	93.00	9.10E+11	0	8.19E+11	9.10E+10
35	80.00	7.83E+11	0	7.05E+11	7.83E+10
40	68.00	6.65E+11	0	5.99E+11	6.65E+10
45	59.00	5.77E+11	0	5.20E+11	5.77E+10
50	50.00	4.89E+11	0	4.40E+11	4.89E+10
55	40.00	3.91E+11	0	3.52E+11	3.91E+10
60	31.00	3.03E+11	0	2.73E+11	3.03E+10
65	23.00	2.25E+11	0	2.03E+11	2.25E+10
70	16.00	1.57E+11	0	1.41E+11	1.57E+10
75	9.00	8.81E+10	0	7.93E+10	8.81E+09
80	3.90	3.82E+10	0	3.43E+10	3.82E+09
85	0.94	9.16E+09	0	8.24E+09	9.16E+08
90	0.12	1.17E+09	0	1.06E+09	1.17E+08
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-11 E. coli TMDL Calculations for Buffalo Creek near Lovedale (OK620920050010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	8009	7.95E+13	0	7.16E+13	7.95E+12
5	220	2.19E+12	0	1.97E+12	2.19E+11
10	134	1.33E+12	0	1.20E+12	1.33E+11
15	101	9.99E+11	0	8.99E+11	9.99E+10
20	83	8.27E+11	0	7.45E+11	8.27E+10
25	70	7.00E+11	0	6.30E+11	7.00E+10
30	60	5.92E+11	0	5.33E+11	5.92E+10
35	51	5.09E+11	0	4.58E+11	5.09E+10
40	44	4.33E+11	0	3.89E+11	4.33E+10
45	38	3.75E+11	0	3.38E+11	3.75E+10
50	32	3.18E+11	0	2.86E+11	3.18E+10
55	26	2.55E+11	0	2.29E+11	2.55E+10
60	19.9	1.97E+11	0	1.78E+11	1.97E+10
65	14.7	1.46E+11	0	1.32E+11	1.46E+10
70	10.3	1.02E+11	0	9.16E+10	1.02E+10
75	5.8	5.73E+10	0	5.15E+10	5.73E+09
80	2.5	2.48E+10	0	2.23E+10	2.48E+09
85	0.6	5.95E+09	0	5.36E+09	5.95E+08
90	0.1	7.64E+08	0	6.87E+08	7.64E+07
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-12 Enterococci TMDL Calculations for Buffalo Creek near Lovedale (OK620920050010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	8009	2.12E+13	0	1.90E+13	2.12E+12
5	220	5.83E+11	0	5.24E+11	5.83E+10
10	134	3.54E+11	0	3.18E+11	3.54E+10
15	101	2.66E+11	0	2.39E+11	2.66E+10
20	83	2.20E+11	0	1.98E+11	2.20E+10
25	70	1.86E+11	0	1.68E+11	1.86E+10
30	60	1.57E+11	0	1.42E+11	1.57E+10
35	51	1.35E+11	0	1.22E+11	1.35E+10
40	44	1.15E+11	0	1.04E+11	1.15E+10
45	38	9.99E+10	0	8.99E+10	9.99E+09
50	32	8.46E+10	0	7.62E+10	8.46E+09
55	26	6.77E+10	0	6.09E+10	6.77E+09
60	20	5.25E+10	0	4.72E+10	5.25E+09
65	14.7	3.89E+10	0	3.50E+10	3.89E+09
70	10.3	2.71E+10	0	2.44E+10	2.71E+09
75	5.8	1.52E+10	0	1.37E+10	1.52E+09
80	2.5	6.60E+09	0	5.94E+09	6.6E+08
85	0.6	1.58E+09	0	1.43E+09	1.58E+08
90	0.1	2.03E+08	0	1.83E+08	2.03E+07
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-13 E. coli TMDL Calculations for Sand Creek (OK620920050050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1990	1.98E+13	0	1.78E+13	1.98E+12
5	55	5.44E+11	0	4.90E+11	5.44E+10
10	33	3.31E+11	0	2.98E+11	3.31E+10
15	25	2.48E+11	0	2.23E+11	2.48E+10
20	21	2.06E+11	0	1.85E+11	2.06E+10
25	18	1.74E+11	0	1.57E+11	1.74E+10
30	15	1.47E+11	0	1.32E+11	1.47E+10
35	13	1.27E+11	0	1.14E+11	1.27E+10
40	11	1.08E+11	0	9.68E+10	1.08E+10
45	9	9.33E+10	0	8.40E+10	9.33E+09
50	8	7.91E+10	0	7.12E+10	7.91E+09
55	6	6.33E+10	0	5.69E+10	6.33E+09
60	4.9	4.90E+10	0	4.41E+10	4.90E+09
65	3.7	3.64E+10	0	3.27E+10	3.64E+09
70	2.5	2.53E+10	0	2.28E+10	2.53E+09
75	1.4	1.42E+10	0	1.28E+10	1.42E+09
80	0.6	6.17E+09	0	5.55E+09	6.17E+08
85	0.1	1.48E+09	0	1.33E+09	1.48E+08
90	0.0	1.90E+08	0	1.71E+08	1.90E+07
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-14 Enterococci TMDL Calculations for Sand Creek (OK620920050050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1990	5.26E+12	0	4.73E+12	5.26E+11
5	55	1.45E+11	0	1.30E+11	1.45E+10
10	33	8.79E+10	0	7.91E+10	8.79E+09
15	25	6.61E+10	0	5.95E+10	6.61E+09
20	21	5.47E+10	0	4.92E+10	5.47E+09
25	18	4.63E+10	0	4.17E+10	4.63E+09
30	15	3.91E+10	0	3.52E+10	3.91E+09
35	13	3.37E+10	0	3.03E+10	3.37E+09
40	11	2.86E+10	0	2.57E+10	2.86E+09
45	9	2.48E+10	0	2.23E+10	2.48E+09
50	8	2.10E+10	0	1.89E+10	2.10E+09
55	6	1.68E+10	0	1.51E+10	1.68E+09
60	4.9	1.30E+10	0	1.17E+10	1.30E+09
65	3.7	9.68E+09	0	8.71E+09	9.68E+08
70	2.5	6.73E+09	0	6.06E+09	6.73E+08
75	1.4	3.79E+09	0	3.41E+09	3.79E+08
80	0.6	1.64E+09	0	1.48E+09	1.64E+08
85	0.1	3.94E+08	0	3.54E+08	3.94E+07
90	0.0	5.05E+07	0	4.54E+07	5.05E+06
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-15 E. coli TMDL Calculations for Cimarron River at Freedom (OK620920020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	14800.00	1.47E+14	0	1.32E+14	1.47E+13
5	637.00	6.33E+12	0	5.69E+12	6.33E+11
10	330.00	3.28E+12	0	2.95E+12	3.28E+11
15	250.00	2.48E+12	0	2.23E+12	2.48E+11
20	199.00	1.98E+12	0	1.78E+12	1.98E+11
25	168.00	1.67E+12	0	1.50E+12	1.67E+11
30	141.00	1.40E+12	0	1.26E+12	1.40E+11
35	117.00	1.16E+12	0	1.05E+12	1.16E+11
40	99.00	9.83E+11	0	8.85E+11	9.83E+10
45	80.00	7.95E+11	0	7.15E+11	7.95E+10
50	64.00	6.36E+11	0	5.72E+11	6.36E+10
55	48.00	4.77E+11	0	4.29E+11	4.77E+10
60	38.00	3.77E+11	0	3.40E+11	3.77E+10
65	28.60	2.84E+11	0	2.56E+11	2.84E+10
70	20.80	2.07E+11	0	1.86E+11	2.07E+10
75	15.00	1.49E+11	0	1.34E+11	1.49E+10
80	6.92	6.87E+10	0	6.19E+10	6.87E+09
85	0.24	2.36E+09	0	2.13E+09	2.36E+08
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-16 E. coli TMDL Calculations for Long Creek (OK620920020080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1029.07	1.02E+13	0	9.20E+12	1.02E+12
5	28.33	2.81E+11	0	2.53E+11	2.81E+10
10	17.21	1.71E+11	0	1.54E+11	1.71E+10
15	12.93	1.28E+11	0	1.16E+11	1.28E+10
20	10.70	1.06E+11	0	9.57E+10	1.06E+10
25	9.06	9.00E+10	0	8.10E+10	9.00E+09
30	7.66	7.61E+10	0	6.84E+10	7.61E+09
35	6.59	6.54E+10	0	5.89E+10	6.54E+09
40	5.60	5.56E+10	0	5.00E+10	5.56E+09
45	4.86	4.82E+10	0	4.34E+10	4.82E+09
50	4.12	4.09E+10	0	3.68E+10	4.09E+09
55	3.29	3.27E+10	0	2.94E+10	3.27E+09
60	2.55	2.54E+10	0	2.28E+10	2.54E+09
65	1.89	1.88E+10	0	1.69E+10	1.88E+09
70	1.32	1.31E+10	0	1.18E+10	1.31E+09
75	0.74	7.36E+09	0	6.62E+09	7.36E+08
80	0.32	3.19E+09	0	2.87E+09	3.19E+08
85	0.08	7.65E+08	0	6.89E+08	7.65E+07
90	0.01	9.81E+07	0	8.83E+07	9.81E+06
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-17 Enterococci TMDL Calculations for Long Creek (OK620920020080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1029.07	2.72E+12	0	2.45E+12	2.72E+11
5	28.33	7.49E+10	0	6.74E+10	7.49E+09
10	17.21	4.55E+10	0	4.09E+10	4.55E+09
15	12.93	3.42E+10	0	3.07E+10	3.42E+09
20	10.70	2.83E+10	0	2.55E+10	2.83E+09
25	9.06	2.39E+10	0	2.15E+10	2.39E+09
30	7.66	2.02E+10	0	1.82E+10	2.02E+09
35	6.59	1.74E+10	0	1.57E+10	1.74E+09
40	5.60	1.48E+10	0	1.33E+10	1.48E+09
45	4.86	1.28E+10	0	1.16E+10	1.28E+09
50	4.12	1.09E+10	0	9.79E+09	1.09E+09
55	3.29	8.70E+09	0	7.83E+09	8.70E+08
60	2.55	6.74E+09	0	6.07E+09	6.74E+08
65	1.89	5.00E+09	0	4.50E+09	5.00E+08
70	1.32	3.48E+09	0	3.13E+09	3.48E+08
75	0.74	1.96E+09	0	1.76E+09	1.96E+08
80	0.32	8.48E+08	0	7.64E+08	8.48E+07
85	0.08	2.03E+08	0	1.83E+08	2.03E+07
90	0.01	2.61E+07	0	2.35E+07	2.61E+06
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-18 E. coli TMDL Calculations for Cimarron River below Waynoka (OK620920010010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	51600	5.13E+14	9.54E+08	4.61E+14	5.13E+13
5	889	8.83E+12	9.54E+08	7.95E+12	8.83E+11
10	460	4.57E+12	9.54E+08	4.11E+12	4.57E+11
15	324	3.22E+12	9.54E+08	2.89E+12	3.22E+11
20	252	2.50E+12	9.54E+08	2.25E+12	2.50E+11
25	207	2.06E+12	9.54E+08	1.85E+12	2.06E+11
30	172	1.71E+12	9.54E+08	1.54E+12	1.71E+11
35	144	1.43E+12	9.54E+08	1.29E+12	1.43E+11
40	121	1.20E+12	9.54E+08	1.08E+12	1.20E+11
45	102	1.01E+12	9.54E+08	9.10E+11	1.01E+11
50	88	8.74E+11	9.54E+08	7.85E+11	8.74E+10
55	72	7.15E+11	9.54E+08	6.42E+11	7.15E+10
60	58	5.76E+11	9.54E+08	5.17E+11	5.76E+10
65	45	4.47E+11	9.54E+08	4.01E+11	4.47E+10
70	33	3.28E+11	9.54E+08	2.93E+11	3.28E+10
75	22	2.19E+11	9.54E+08	1.95E+11	2.19E+10
80	12	1.19E+11	9.54E+08	1.06E+11	1.19E+10
85	4.5	4.47E+10	9.54E+08	3.86E+10	4.47E+09
90	0.80	7.95E+09	9.54E+08	5.54E+09	7.95E+08
95	0	9.54E+08	9.54E+08	0	0
100	0	9.54E+08	9.54E+08	0	0

Table 5-19 Enterococci TMDL Calculations for Cimarron River below Waynoka (OK620920010010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	51600	1.36E+14	2.50E+08	1.23E+14	1.36E+13
5	889	2.35E+12	2.50E+08	2.11E+12	2.35E+11
10	460	1.22E+12	2.50E+08	1.09E+12	1.22E+11
15	324	8.56E+11	2.50E+08	7.70E+11	8.56E+10
20	252	6.66E+11	2.50E+08	5.99E+11	6.66E+10
25	207	5.47E+11	2.50E+08	4.92E+11	5.47E+10
30	172	4.54E+11	2.50E+08	4.09E+11	4.54E+10
35	144	3.80E+11	2.50E+08	3.42E+11	3.80E+10
40	121	3.20E+11	2.50E+08	2.87E+11	3.20E+10
45	102	2.70E+11	2.50E+08	2.42E+11	2.70E+10
50	88	2.33E+11	2.50E+08	2.09E+11	2.33E+10
55	72	1.90E+11	2.50E+08	1.71E+11	1.90E+10
60	58	1.53E+11	2.50E+08	1.38E+11	1.53E+10
65	45	1.19E+11	2.50E+08	1.07E+11	1.19E+10
70	33	8.72E+10	2.50E+08	7.81E+10	8.72E+09
75	22	5.81E+10	2.50E+08	5.19E+10	5.81E+09
80	12	3.17E+10	2.50E+08	2.81E+10	3.17E+09
85	4.5	1.19E+10	2.50E+08	1.03E+10	1.19E+09
90	0.80	2.11E+09	2.50E+08	1.48E+09	2.11E+08
95	0	2.50E+08	2.50E+08	0	0
100	0	2.50E+08	2.50E+08	0	0

Table 5-20 Fecal Coliform TMDL Calculations for Cimarron River below Waynoka (OK620920010010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	51600	5.05E+14	3.03E+09	4.54E+14	5.05E+13
5	889	8.70E+12	3.03E+09	7.83E+12	8.70E+11
10	460	4.50E+12	3.03E+09	4.05E+12	4.50E+11
15	324	3.17E+12	3.03E+09	2.85E+12	3.17E+11
20	252	2.47E+12	3.03E+09	2.22E+12	2.47E+11
25	207	2.03E+12	3.03E+09	1.82E+12	2.03E+11
30	172	1.68E+12	3.03E+09	1.51E+12	1.68E+11
35	144	1.41E+12	3.03E+09	1.27E+12	1.41E+11
40	121	1.18E+12	3.03E+09	1.06E+12	1.18E+11
45	102	9.98E+11	3.03E+09	8.95E+11	9.98E+10
50	88	8.61E+11	3.03E+09	7.72E+11	8.61E+10
55	72	7.05E+11	3.03E+09	6.31E+11	7.05E+10
60	58	5.68E+11	3.03E+09	5.08E+11	5.68E+10
65	45	4.40E+11	3.03E+09	3.93E+11	4.40E+10
70	33	3.23E+11	3.03E+09	2.88E+11	3.23E+10
75	22	2.15E+11	3.03E+09	1.91E+11	2.15E+10
80	12	1.17E+11	3.03E+09	1.03E+11	1.17E+10
85	4.5	4.40E+10	3.03E+09	3.66E+10	4.40E+09
90	0.80	7.83E+09	3.03E+09	4.02E+09	7.83E+08
95	0	3.03E+09	3.03E+09	0	0
100	0	3.03E+09	3.03E+09	0	0

Table 5-21 E. coli TMDL Calculations for Main Creek (OK620920010180_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1676	1.66E+13	0	1.50E+13	1.66E+12
5	46	4.58E+11	0	4.12E+11	4.58E+10
10	28	2.78E+11	0	2.50E+11	2.78E+10
15	21	2.09E+11	0	1.88E+11	2.09E+10
20	17	1.73E+11	0	1.56E+11	1.73E+10
25	15	1.46E+11	0	1.32E+11	1.46E+10
30	12	1.24E+11	0	1.11E+11	1.24E+10
35	11	1.07E+11	0	9.59E+10	1.07E+10
40	9	9.06E+10	0	8.15E+10	9.06E+09
45	8	7.86E+10	0	7.07E+10	7.86E+09
50	7	6.66E+10	0	5.99E+10	6.66E+09
55	5	5.33E+10	0	4.79E+10	5.33E+09
60	4.2	4.13E+10	0	3.72E+10	4.13E+09
65	3.1	3.06E+10	0	2.76E+10	3.06E+09
70	2.1	2.13E+10	0	1.92E+10	2.13E+09
75	1.2	1.20E+10	0	1.08E+10	1.20E+09
80	0.5	5.19E+09	0	4.67E+09	5.19E+08
85	0.13	1.25E+09	0	1.12E+09	1.25E+08
90	0.02	1.60E+08	0	1.44E+08	1.60E+07
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-22 Enterococci TMDL Calculations for Main Creek (OK620920010180_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1676	4.43E+12	0	3.99E+12	4.43E+11
5	46	1.22E+11	0	1.10E+11	1.22E+10
10	28	7.40E+10	0	6.66E+10	7.40E+09
15	21	5.56E+10	0	5.01E+10	5.56E+09
20	17	4.61E+10	0	4.14E+10	4.61E+09
25	15	3.90E+10	0	3.51E+10	3.90E+09
30	12	3.29E+10	0	2.97E+10	3.29E+09
35	11	2.83E+10	0	2.55E+10	2.83E+09
40	9	2.41E+10	0	2.17E+10	2.41E+09
45	8	2.09E+10	0	1.88E+10	2.09E+09
50	7	1.77E+10	0	1.59E+10	1.77E+09
55	5	1.42E+10	0	1.28E+10	1.42E+09
60	4.2	1.10E+10	0	9.88E+09	1.10E+09
65	3.1	8.15E+09	0	7.33E+09	8.15E+08
70	2.1	5.67E+09	0	5.10E+09	5.67E+08
75	1.2	3.19E+09	0	2.87E+09	3.19E+08
80	0.5	1.38E+09	0	1.24E+09	1.38E+08
85	0.13	3.31E+08	0	2.98E+08	3.31E+07
90	0.02	4.25E+07	0	3.83E+07	4.25E+06
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-23 Enterococci TMDL Calculations for Griever Creek (OK620920010130_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	700	1.85E+12	0	1.66E+12	1.85E+11
5	19.26	5.09E+10	0	4.58E+10	5.09E+09
10	11.70	3.09E+10	0	2.78E+10	3.09E+09
15	8.79	2.32E+10	0	2.09E+10	2.32E+09
20	7.28	1.92E+10	0	1.73E+10	1.92E+09
25	6.16	1.63E+10	0	1.46E+10	1.63E+09
30	5.21	1.38E+10	0	1.24E+10	1.38E+09
35	4.48	1.18E+10	0	1.06E+10	1.18E+09
40	3.81	1.01E+10	0	9.05E+09	1.01E+09
45	3.30	8.73E+09	0	7.85E+09	8.73E+08
50	2.80	7.40E+09	0	6.66E+09	7.40E+08
55	2.24	5.92E+09	0	5.32E+09	5.92E+08
60	1.74	4.59E+09	0	4.13E+09	4.59E+08
65	1.29	3.40E+09	0	3.06E+09	3.40E+08
70	0.90	2.37E+09	0	2.13E+09	2.37E+08
75	0.50	1.33E+09	0	1.20E+09	1.33E+08
80	0.22	5.77E+08	0	5.19E+08	5.77E+07
85	0.05	1.38E+08	0	1.25E+08	1.38E+07
90	0.01	1.77E+07	0	1.60E+07	1.77E+06
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-24 E. coli TMDL Calculations for Eagle Chief Creek (OK620920040010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	22891	2.27E+14	1.48E+08	2.05E+14	2.27E+13
5	394	3.92E+12	1.48E+08	3.52E+12	3.92E+11
10	204	2.03E+12	1.48E+08	1.82E+12	2.03E+11
15	144	1.43E+12	1.48E+08	1.28E+12	1.43E+11
20	112	1.11E+12	1.48E+08	9.98E+11	1.11E+11
25	92	9.12E+11	1.48E+08	8.19E+11	9.12E+10
30	76	7.58E+11	1.48E+08	6.81E+11	7.58E+10
35	64	6.35E+11	1.48E+08	5.70E+11	6.35E+10
40	54	5.33E+11	1.48E+08	4.78E+11	5.33E+10
45	45	4.49E+11	1.48E+08	4.03E+11	4.49E+10
50	39	3.88E+11	1.48E+08	3.48E+11	3.88E+10
55	32	3.17E+11	1.48E+08	2.84E+11	3.17E+10
60	25.7	2.56E+11	1.48E+08	2.29E+11	2.56E+10
65	20.0	1.98E+11	1.48E+08	1.77E+11	1.98E+10
70	14.6	1.45E+11	1.48E+08	1.29E+11	1.45E+10
75	9.8	9.69E+10	1.48E+08	8.58E+10	9.69E+09
80	5.32	5.29E+10	1.48E+08	4.61E+10	5.29E+09
85	2.00	1.98E+10	1.48E+08	1.64E+10	1.98E+09
90	0.35	3.53E+09	1.48E+08	1.69E+09	3.53E+08
95	0	1.48E+08	1.48E+08	0	0
100	0	1.48E+08	1.48E+08	0	0

Table 5-25 Enterococci TMDL Calculations for Eagle Chief Creek (OK620920040010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	22891	6.05E+13	3.87E+07	5.44E+13	6.05E+12
5	394	1.04E+12	3.87E+07	9.38E+11	1.04E+11
10	204	5.39E+11	3.87E+07	4.85E+11	5.39E+10
15	144	3.80E+11	3.87E+07	3.41E+11	3.80E+10
20	112	2.95E+11	3.87E+07	2.65E+11	2.95E+10
25	92	2.43E+11	3.87E+07	2.18E+11	2.43E+10
30	76	2.02E+11	3.87E+07	1.81E+11	2.02E+10
35	64	1.69E+11	3.87E+07	1.52E+11	1.69E+10
40	54	1.42E+11	3.87E+07	1.27E+11	1.42E+10
45	45	1.20E+11	3.87E+07	1.07E+11	1.20E+10
50	39	1.03E+11	3.87E+07	9.24E+10	1.03E+10
55	32	8.44E+10	3.87E+07	7.56E+10	8.44E+09
60	25.7	6.80E+10	3.87E+07	6.08E+10	6.80E+09
65	20.0	5.27E+10	3.87E+07	4.71E+10	5.27E+09
70	14.6	3.87E+10	3.87E+07	3.44E+10	3.87E+09
75	9.8	2.58E+10	3.87E+07	2.28E+10	2.58E+09
80	5.32	1.41E+10	3.87E+07	1.23E+10	1.41E+09
85	2.00	5.27E+09	3.87E+07	4.36E+09	5.27E+08
90	0.35	9.38E+08	3.87E+07	4.57E+08	9.38E+07
95	0	3.87E+07	3.87E+07	0	0
100	0	3.87E+07	3.87E+07	0	0

Table 5-26 Fecal Coliform TMDL Calculations for Cottonwood Creek (OK620920010080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1021	9.99E+12	0	8.99E+12	9.99E+11
5	28	2.75E+11	0	2.47E+11	2.75E+10
10	17	1.67E+11	0	1.50E+11	1.67E+10
15	13	1.25E+11	0	1.13E+11	1.25E+10
20	11	1.04E+11	0	9.35E+10	1.04E+10
25	9	8.79E+10	0	7.91E+10	8.79E+09
30	8	7.43E+10	0	6.69E+10	7.43E+09
35	7	6.39E+10	0	5.75E+10	6.39E+09
40	6	5.43E+10	0	4.89E+10	5.43E+09
45	5	4.71E+10	0	4.24E+10	4.71E+09
50	4	4.00E+10	0	3.60E+10	4.00E+09
55	3	3.20E+10	0	2.88E+10	3.20E+09
60	2.53	2.48E+10	0	2.23E+10	2.48E+09
65	1.88	1.84E+10	0	1.65E+10	1.84E+09
70	1.31	1.28E+10	0	1.15E+10	1.28E+09
75	0.73	7.19E+09	0	6.47E+09	7.19E+08
80	0.32	3.12E+09	0	2.80E+09	3.12E+08
85	0.08	7.47E+08	0	6.73E+08	7.47E+07
90	0.01	9.59E+07	0	8.63E+07	9.59E+06
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-27 E. coli TMDL Calculations for Cimarron River near Ames (OK620910020010_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	37041.92	3.68E+14	0	3.31E+14	3.68E+13
5	1487.22	1.48E+13	0	1.33E+13	1.48E+12
10	794.42	7.89E+12	0	7.10E+12	7.89E+11
15	526.53	5.23E+12	0	4.71E+12	5.23E+11
20	389.17	3.87E+12	0	3.48E+12	3.87E+11
25	306.68	3.05E+12	0	2.74E+12	3.05E+11
30	250.75	2.49E+12	0	2.24E+12	2.49E+11
35	211.54	2.10E+12	0	1.89E+12	2.10E+11
40	177.82	1.77E+12	0	1.59E+12	1.77E+11
45	152.81	1.52E+12	0	1.37E+12	1.52E+11
50	133.94	1.33E+12	0	1.20E+12	1.33E+11
55	116.39	1.16E+12	0	1.04E+12	1.16E+11
60	101.61	1.01E+12	0	9.08E+11	1.01E+11
65	87.76	8.72E+11	0	7.84E+11	8.72E+10
70	75.28	7.48E+11	0	6.73E+11	7.48E+10
75	62.35	6.19E+11	0	5.57E+11	6.19E+10
80	49.88	4.95E+11	0	4.46E+11	4.95E+10
85	38.80	3.85E+11	0	3.46E+11	3.85E+10
90	28.64	2.84E+11	0	2.56E+11	2.84E+10
95	19.40	1.93E+11	0	1.73E+11	1.93E+10
100	1.99	1.97E+10	0	1.73E+10	1.97E+09

Table 5-28 Enterococci TMDL Calculations for Cimarron River near Ames (OK620910020010_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	37041.92	9.79E+13	0	8.81E+13	9.79E+12
5	1487.22	3.93E+12	0	3.54E+12	3.93E+11
10	794.42	2.10E+12	0	1.89E+12	2.10E+11
15	526.53	1.39E+12	0	1.25E+12	1.39E+11
20	389.17	1.03E+12	0	9.25E+11	1.03E+11
25	306.68	8.10E+11	0	7.29E+11	8.10E+10
30	250.75	6.63E+11	0	5.96E+11	6.63E+10
35	211.54	5.59E+11	0	5.03E+11	5.59E+10
40	177.82	4.70E+11	0	4.23E+11	4.70E+10
45	152.81	4.04E+11	0	3.63E+11	4.04E+10
50	133.94	3.54E+11	0	3.18E+11	3.54E+10
55	116.39	3.08E+11	0	2.77E+11	3.08E+10
60	101.61	2.68E+11	0	2.42E+11	2.68E+10
65	87.76	2.32E+11	0	2.09E+11	2.32E+10
70	75.28	1.99E+11	0	1.79E+11	1.99E+10
75	62.35	1.65E+11	0	1.48E+11	1.65E+10
80	49.88	1.32E+11	0	1.19E+11	1.32E+10
85	38.80	1.03E+11	0	9.22E+10	1.03E+10
90	28.64	7.57E+10	0	6.80E+10	7.57E+09
95	19.40	5.13E+10	0	4.60E+10	5.13E+09
100	1.99	5.25E+09	0	4.61E+09	5.25E+08

Table 5-29 E. coli TMDL Calculations for Cimarron River near Dover (OK620910020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	80200	7.97E+14	0	7.17E+14	7.97E+13
5	3220	3.20E+13	0	2.88E+13	3.20E+12
10	1720	1.71E+13	0	1.54E+13	1.71E+12
15	1140	1.13E+13	0	1.02E+13	1.13E+12
20	843	8.37E+12	0	7.53E+12	8.37E+11
25	664	6.60E+12	0	5.93E+12	6.60E+11
30	543	5.39E+12	0	4.85E+12	5.39E+11
35	458	4.55E+12	0	4.09E+12	4.55E+11
40	385	3.82E+12	0	3.44E+12	3.82E+11
45	331	3.29E+12	0	2.95E+12	3.29E+11
50	290	2.88E+12	0	2.59E+12	2.88E+11
55	252	2.50E+12	0	2.25E+12	2.50E+11
60	220	2.19E+12	0	1.96E+12	2.19E+11
65	190	1.89E+12	0	1.69E+12	1.89E+11
70	163	1.62E+12	0	1.45E+12	1.62E+11
75	135	1.34E+12	0	1.20E+12	1.34E+11
80	108	1.07E+12	0	9.62E+11	1.07E+11
85	84	8.34E+11	0	7.47E+11	8.34E+10
90	62	6.16E+11	0	5.50E+11	6.16E+10
95	42	4.17E+11	0	3.72E+11	4.17E+10
100	4	4.27E+10	0	3.46E+10	4.27E+09

Table 5-30 Enterococci TMDL Calculations for Cimarron River near Dover (OK620910020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	80200	2.12E+14	0	1.91E+14	2.12E+13
5	3220	8.51E+12	0	7.66E+12	8.51E+11
10	1720	4.54E+12	0	4.09E+12	4.54E+11
15	1140	3.01E+12	0	2.71E+12	3.01E+11
20	843	2.23E+12	0	2.00E+12	2.23E+11
25	664	1.75E+12	0	1.58E+12	1.75E+11
30	543	1.43E+12	0	1.29E+12	1.43E+11
35	458	1.21E+12	0	1.09E+12	1.21E+11
40	385	1.02E+12	0	9.15E+11	1.02E+11
45	331	8.74E+11	0	7.86E+11	8.74E+10
50	290	7.66E+11	0	6.89E+11	7.66E+10
55	252	6.66E+11	0	5.98E+11	6.66E+10
60	220	5.81E+11	0	5.22E+11	5.81E+10
65	190	5.02E+11	0	4.51E+11	5.02E+10
70	163	4.31E+11	0	3.87E+11	4.31E+10
75	135	3.57E+11	0	3.20E+11	3.57E+10
80	108	2.85E+11	0	2.56E+11	2.85E+10
85	84	2.22E+11	0	1.99E+11	2.22E+10
90	62	1.64E+11	0	1.46E+11	1.64E+10
95	42	1.11E+11	0	9.89E+10	1.11E+10
100	4	1.14E+10	0	9.22E+09	1.14E+09

Table 5-31 Fecal Coliform TMDL Calculations for Cimarron River near Dover (OK620910020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	80200	7.85E+14	0	7.06E+14	7.85E+13
5	3220	3.15E+13	0	2.83E+13	3.15E+12
10	1720	1.68E+13	0	1.51E+13	1.68E+12
15	1140	1.12E+13	0	1.00E+13	1.12E+12
20	843	8.25E+12	0	7.40E+12	8.25E+11
25	664	6.50E+12	0	5.83E+12	6.50E+11
30	543	5.31E+12	0	4.76E+12	5.31E+11
35	458	4.48E+12	0	4.02E+12	4.48E+11
40	385	3.77E+12	0	3.37E+12	3.77E+11
45	331	3.24E+12	0	2.90E+12	3.24E+11
50	290	2.84E+12	0	2.54E+12	2.84E+11
55	252	2.47E+12	0	2.20E+12	2.47E+11
60	220	2.15E+12	0	1.92E+12	2.15E+11
65	190	1.86E+12	0	1.66E+12	1.86E+11
70	163	1.60E+12	0	1.42E+12	1.60E+11
75	135	1.32E+12	0	1.17E+12	1.32E+11
80	108	1.06E+12	0	9.33E+11	1.06E+11
85	84	8.22E+11	0	7.22E+11	8.22E+10
90	62	6.07E+11	0	5.28E+11	6.07E+10
95	42	4.11E+11	0	3.52E+11	4.11E+10
100	4	4.21E+10	0	1.96E+10	4.21E+09

Table 5-32 Turbidity TMDL Calculations for Cimarron River below Waynoka (OK620920010010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)			LA (lb/day)	MOS (lb/day)
			WWTP	MS4	Future Growth		
0	51600	N/A	0	0	N/A	N/A	N/A
5	889	N/A	0	0	N/A	N/A	N/A
10	460	N/A	0	0	N/A	N/A	N/A
15	324	N/A	0	0	N/A	N/A	N/A
20	252	N/A	0	0	N/A	N/A	N/A
25	207	1.14E+05	0	0	1.14E+03	1.01E+05	1.14E+04
30	172	9.45E+04	0	0	9.45E+02	8.41E+04	9.45E+03
35	144	7.91E+04	0	0	7.91E+02	7.04E+04	7.91E+03
40	121	6.65E+04	0	0	6.65E+02	5.92E+04	6.65E+03
45	102	5.61E+04	0	0	5.61E+02	4.99E+04	5.61E+03
50	88	4.84E+04	0	0	4.84E+02	4.30E+04	4.84E+03
55	72	3.96E+04	0	0	3.96E+02	3.52E+04	3.96E+03
60	58	3.19E+04	0	0	3.19E+02	2.84E+04	3.19E+03
65	45	2.47E+04	0	0	2.47E+02	2.20E+04	2.47E+03
70	33	1.81E+04	0	0	1.81E+02	1.61E+04	1.81E+03
75	22	1.21E+04	0	0	1.21E+02	1.08E+04	1.21E+03
80	12	6.59E+03	0	0	6.59E+01	5.87E+03	6.59E+02
85	5	2.47E+03	0	0	2.47E+01	2.20E+03	2.47E+02
90	1	4.40E+02	0	0	4.40E+00	3.91E+02	4.40E+01
95	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0

Table 5-33 Turbidity TMDL Calculations for Main Creek (OK620920010180_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)			LA (lb/day)	MOS (lb/day)
			WWTP	MS4	Future Growth		
0	1676	N/A	0	0	N/A	N/A	N/A
5	46	N/A	0	0	N/A	N/A	N/A
10	28	N/A	0	0	N/A	N/A	N/A
15	21	N/A	0	0	N/A	N/A	N/A
20	17	N/A	0	0	N/A	N/A	N/A
25	15	8.10E+03	0	0	8.10E+01	7.21E+03	8.10E+02
30	12	6.85E+03	0	0	6.85E+01	6.10E+03	6.85E+02
35	11	5.89E+03	0	0	5.89E+01	5.25E+03	5.89E+02
40	9	5.01E+03	0	0	5.01E+01	4.46E+03	5.01E+02
45	8	4.35E+03	0	0	4.35E+01	3.87E+03	4.35E+02
50	7	3.68E+03	0	0	3.68E+01	3.28E+03	3.68E+02
55	5	2.95E+03	0	0	2.95E+01	2.62E+03	2.95E+02
60	4	2.28E+03	0	0	2.28E+01	2.03E+03	2.28E+02
65	3	1.69E+03	0	0	1.69E+01	1.51E+03	1.69E+02
70	2	1.18E+03	0	0	1.18E+01	1.05E+03	1.18E+02
75	1.21	6.63E+02	0	0	6.63E+00	5.90E+02	6.63E+01
80	0.52	2.87E+02	0	0	2.87E+00	2.56E+02	2.87E+01
85	0.13	6.89E+01	0	0	6.89E-01	6.13E+01	6.89E+00
90	0.02	8.84E+00	0	0	8.84E-02	7.87E+00	8.84E-01
95	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0

Table 5-34 Turbidity TMDL Calculations for Eagle Chief Creek (OK620920040010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)			LA (lb/day)	MOS (lb/day)
			WWTP	MS4	Future Growth		
0	22891	N/A	0	0	N/A	N/A	N/A
5	394	N/A	0	0	N/A	N/A	N/A
10	204	N/A	0	0	N/A	N/A	N/A
15	144	N/A	0	0	N/A	N/A	N/A
20	112	N/A	0	0	N/A	N/A	N/A
25	92	5.05E+04	0	0	5.05E+02	4.24E+04	7.57E+03
30	76	4.19E+04	0	0	4.19E+02	3.52E+04	6.29E+03
35	64	3.51E+04	0	0	3.51E+02	2.95E+04	5.27E+03
40	54	2.95E+04	0	0	2.95E+02	2.48E+04	4.42E+03
45	45	2.49E+04	0	0	2.49E+02	2.09E+04	3.73E+03
50	39	2.15E+04	0	0	2.15E+02	1.80E+04	3.22E+03
55	32	1.76E+04	0	0	1.76E+02	1.47E+04	2.63E+03
60	26	1.41E+04	0	0	1.41E+02	1.19E+04	2.12E+03
65	20	1.10E+04	0	0	1.10E+02	9.22E+03	1.65E+03
70	15	8.04E+03	0	0	8.04E+01	6.76E+03	1.21E+03
75	10	5.36E+03	0	0	5.36E+01	4.51E+03	8.04E+02
80	5	2.93E+03	0	0	2.93E+01	2.46E+03	4.39E+02
85	2	1.10E+03	0	0	1.10E+01	9.22E+02	1.65E+02
90	0.4	1.95E+02	0	0	1.95E+00	1.64E+02	2.93E+01
95	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0

Table 5-35 Turbidity TMDL Calculations for Cottonwood Creek (OK620920010080_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)			LA (lb/day)	MOS (lb/day)
			WWTP	MS4	Future Growth		
0	1021	N/A	0	0	N/A	N/A	N/A
5	28	N/A	0	0	N/A	N/A	N/A
10	17	N/A	0	0	N/A	N/A	N/A
15	13	N/A	0	0	N/A	N/A	N/A
20	11	N/A	0	0	N/A	N/A	N/A
25	9	4.94E+03	0	0	4.94E+01	4.15E+03	7.40E+02
30	8	4.17E+03	0	0	4.17E+01	3.51E+03	6.26E+02
35	7	3.59E+03	0	0	3.59E+01	3.02E+03	5.38E+02
40	6	3.05E+03	0	0	3.05E+01	2.56E+03	4.58E+02
45	5	2.65E+03	0	0	2.65E+01	2.22E+03	3.97E+02
50	4	2.24E+03	0	0	2.24E+01	1.88E+03	3.37E+02
55	3.27	1.79E+03	0	0	1.79E+01	1.51E+03	2.69E+02
60	2.53	1.39E+03	0	0	1.39E+01	1.17E+03	2.09E+02
65	1.88	1.03E+03	0	0	1.03E+01	8.67E+02	1.55E+02
70	1.31	7.18E+02	0	0	7.18E+00	6.03E+02	1.08E+02
75	0.73	4.04E+02	0	0	4.04E+00	3.39E+02	6.06E+01
80	0.32	1.75E+02	0	0	1.75E+00	1.47E+02	2.62E+01
85	0.08	4.20E+01	0	0	4.20E-01	3.53E+01	6.30E+00
90	0.01	5.38E+00	0	0	5.38E-02	4.52E+00	8.08E-01
95	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0

Table 5-36 Turbidity TMDL Calculations for Cimarron River near Dover (OK620910020010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)			LA (lb/day)	MOS (lb/day)
			WWTP	MS4	Future Growth		
0	80200	N/A	0	0	N/A	N/A	N/A
5	3220	N/A	0	0	N/A	N/A	N/A
10	1720	N/A	0	0	N/A	N/A	N/A
15	1140	N/A	0	0	N/A	N/A	N/A
20	843	N/A	0	0	N/A	N/A	N/A
25	664	3.65E+05	0	0	3.65E+03	3.25E+05	3.65E+04
30	543	2.98E+05	0	0	2.98E+03	2.66E+05	2.98E+04
35	458	2.52E+05	0	0	2.52E+03	2.24E+05	2.52E+04
40	385	2.12E+05	0	0	2.12E+03	1.88E+05	2.12E+04
45	331	1.82E+05	0	0	1.82E+03	1.62E+05	1.82E+04
50	290	1.59E+05	0	0	1.59E+03	1.42E+05	1.59E+04
55	252	1.38E+05	0	0	1.38E+03	1.23E+05	1.38E+04
60	220	1.21E+05	0	0	1.21E+03	1.08E+05	1.21E+04
65	190	1.04E+05	0	0	1.04E+03	9.29E+04	1.04E+04
70	163	8.96E+04	0	0	8.96E+02	7.97E+04	8.96E+03
75	135	7.42E+04	0	0	7.42E+02	6.60E+04	7.42E+03
80	108	5.94E+04	0	0	5.94E+02	5.28E+04	5.94E+03
85	84	4.62E+04	0	0	4.62E+02	4.11E+04	4.62E+03
90	62	3.41E+04	0	0	3.41E+02	3.03E+04	3.41E+03
95	42	2.31E+04	0	0	2.31E+02	2.05E+04	2.31E+03
100	4	2.36E+03	0	0	2.36E+01	2.10E+03	2.36E+02

5.9 Reasonable Assurances

DEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources 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. DEQ's Continuing Planning Process (CPP), required by the CWA §303(e) (3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (DEQ 2007). The CPP can be viewed from DEQ's website at http://www.deq.state.ok.us/WQDnew/pubs.html Table 5-37 provides a partial list of the state partner agencies DEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-37 Partial Lists of Oklahoma Water Quality Management Agencies

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

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

As authorized by Section 402 of the CWA, the DEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by State Department of Agriculture and Oklahoma Corporation Commission, for which the 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 DEQ and USEPA relating to administration and enforcement of the delegated NPDES Program. Implementation of point source WLAs is done through permits issued under the OPDES program.

The reduction rates called for in this TMDL report are as high as 99.99 percent. The DEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of a waterbody should be reviewed. For example, the Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the USEPA. Additionally, USEPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the near future.

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

- Removing the PBCR use: This revision would require documentation in a Use Attainability Analysis that the use is not an existing use and cannot be attained. It is unlikely that this approach would be successful since there is evidence that people do swim in this segment of the river, thus constituting an existing use. Existing uses cannot be removed.
- Modifying application of the existing criteria: This approach would include considerations such as an exemption under certain high flow conditions, an allowance for wildlife or "natural conditions," a sub-category of the use or other special provision for urban areas, or other special provisions for storm flows. Since large bacteria violations occur over all flow ranges, it is likely that large reductions would still be necessary. However, this approach may have merit and should be considered.
- Revising the existing numeric criteria: Oklahoma's current pathogen criteria are based on USEPA guidelines (See Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft; and Ambient Water Quality Criteria for Bacteria-1986, January 1986). However, those guidelines have received much criticism and USEPA studies that could result in revisions to their recommendations are ongoing. The use of the three indicators specified in Oklahoma's standards should be evaluated. The numeric criteria values should also be evaluated using a risk-based method such as that found in USEPA guidance.

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

SECTION 6
PUBLIC PARTICIPATION

This report was submitted to EPA for technical review on May 20, 2011 and was technically accepted on June 27, 2011. A public notice was circulated on July 7, 2011 to local newspapers and/or other publications in the area affected by this TMDL and persons on the DEQ contact list. The public comment period ended on August 22, 2011. No public comments were received.

SECTION 7
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APPENDIX A
AMBIENT WATER QUALITY DATA

FOR BACTERIA AND TURBIDITY– 1998 TO 2009

Appendix A

Ambient Water Quality Bacteria Data – 1998 to 2009

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK620920030010-001AT	Cimarron River	6/5/2001	313.5	5505	3000
OK620920030010-001AT	Cimarron River	7/10/2001	426	50	300
OK620920030010-001AT	Cimarron River	8/7/2001	>24100	300	400
OK620920030010-001AT	Cimarron River	5/14/2002	376	2000	1800
OK620920030010-001AT	Cimarron River	6/11/2002	4611	700	400
OK620920030010-001AT	Cimarron River	7/16/2002	6131	1500	500
OK620920030010-001AT	Cimarron River	8/13/2002	4884	800	1000
OK620920030010-001AT	Cimarron River	9/17/2002	3873	200	7000
OK620920030010-001AT	Cimarron River	5/12/2003	63	40	20
OK620920030010-001AT	Cimarron River	5/9/2006	820	41	60
OK620920030010-001AT	Cimarron River	5/22/2006	3448	30	30
OK620920030010-001AT	Cimarron River	6/26/2006	11199	41	230
OK620920030010-001AT	Cimarron River	7/5/2006	24192	1500	150
OK620920030010-001AT	Cimarron River	7/19/2006	14136	175	130
OK620920030010-001AT	Cimarron River	8/14/2006	556	134	270
OK620920030010-001AT	Cimarron River	8/22/2006	7270	2247	1600
OK620920030010-001AT	Cimarron River	5/12/2008	35.5	10	30
OK620920030010-001AT	Cimarron River	6/2/2008	3654	481	1150
OK620920030010-001AT	Cimarron River	6/23/2008	6019.5	3505.5	7400
OK620920030010-001AT	Cimarron River	7/14/2008	109	10	80
OK620920030010-001AT	Cimarron River	8/4/2008	8183	20.5	225
OK620920-05-0010G	Buffalo Creek: Lower	5/23/2000			400
OK620920-05-0010G	Buffalo Creek: Lower	6/27/2000			100
OK620920-05-0010G	Buffalo Creek: Lower	8/1/2000	30	20	240
OK620920-05-0010G	Buffalo Creek: Lower	9/6/2000	132	190	1000
OK620920-05-0010G	Buffalo Creek: Lower	5/15/2001	408	700	600
OK620920-05-0010G	Buffalo Creek: Lower	6/18/2001	20	30	30
OK620920-05-0010G	Buffalo Creek: Lower	7/23/2001	70	35	130
OK620920-05-0010G	Buffalo Creek: Lower	8/27/2001	10	40	30
OK620920-05-0010G	Buffalo Creek: Lower	7/29/2002	>2667	3334	
OK620920-05-0010P	Buffalo Creek: Upper	7/29/2002	3920	1580	
OK620920-05-0010G	Buffalo Creek: Lower	9/3/2002	20	60	
OK620920-05-0010P	Buffalo Creek: Upper	9/3/2002	60	220	
OK620920-05-0010G	Buffalo Creek: Lower	5/5/2003	40	20	
OK620920-05-0010P	Buffalo Creek: Upper	5/5/2003	160	20	
OK620920-05-0010G	Buffalo Creek: Lower	6/2/2003	120	30	
OK620920-05-0010P	Buffalo Creek: Upper	6/2/2003	320	180	
OK620920-05-0010G	Buffalo Creek: Lower	7/7/2003	150	80	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK620920-05-0010P	Buffalo Creek: Upper	7/7/2003	190	50	
OK620920-05-0010G	Buffalo Creek: Lower	8/11/2003	290	140	
OK620920-05-0010P	Buffalo Creek: Upper	8/11/2003	340	40	
OK620920-05-0010G	Buffalo Creek: Lower	9/15/2003	30	10	
OK620920-05-0010P	Buffalo Creek: Upper	9/15/2003	30	20	
OK620920-05-0010G	Buffalo Creek: Lower	6/1/2004	10	20	
OK620920-05-0010P	Buffalo Creek: Upper	6/1/2004	100	20	
OK620920-05-0010G	Buffalo Creek: Lower	6/5/2007	10	110	
OK620920-05-0010P	Buffalo Creek: Upper	6/5/2007	220	130	
OK620920-05-0010G	Buffalo Creek: Lower	6/18/2007	230	110	
OK620920-05-0010P	Buffalo Creek: Upper	6/18/2007	260	160	
OK620920-05-0010G	Buffalo Creek: Lower	7/10/2007	30	170	
OK620920-05-0010P	Buffalo Creek: Upper	7/10/2007	250	300	
OK620920-05-0010G	Buffalo Creek: Lower	8/7/2007	350	300	
OK620920-05-0010P	Buffalo Creek: Upper	8/7/2007	480	780	
OK620920-05-0010G	Buffalo Creek: Lower	9/18/2007	180	440	
OK620920-05-0010P	Buffalo Creek: Upper	9/18/2007	220	350	
OK620920-05-0010G	Buffalo Creek: Lower	5/20/2008	80	110	
OK620920-05-0010P	Buffalo Creek: Upper	5/20/2008	90	660	
OK620920-05-0010G	Buffalo Creek: Lower	6/23/2008	>2000	>2000	
OK620920-05-0010P	Buffalo Creek: Upper	6/23/2008	>2000	>2000	
OK620920-05-0010G	Buffalo Creek: Lower	7/16/2008	460	>1000	
OK620920-05-0010P	Buffalo Creek: Upper	7/16/2008	630	>1000	
OK620920-05-0010G	Buffalo Creek: Lower	7/28/2008	25	115	
OK620920-05-0010P	Buffalo Creek: Upper	7/28/2008	90	130	
OK620920-05-0010G	Buffalo Creek: Lower	9/2/2008	10	10	
OK620920-05-0010P	Buffalo Creek: Upper	9/2/2008	270	60	
OK620920-05-0050G	Sand Creek	7/29/2002	165	495	
OK620920-05-0050G	Sand Creek	9/3/2002	80	240	
OK620920-05-0050G	Sand Creek	5/5/2003	100	100	
OK620920-05-0050G	Sand Creek	6/2/2003	550	240	
OK620920-05-0050G	Sand Creek	7/7/2003	130	290	
OK620920-05-0050G	Sand Creek	8/11/2003	1780	200	
OK620920-05-0050G	Sand Creek	9/15/2003	190	680	
OK620920-05-0050G	Sand Creek	6/1/2004	>1000	>1000	
OK620920-05-0050J	Sand Creek	6/5/2007	210	450	
OK620920-05-0050J	Sand Creek	6/18/2007	300	90	
OK620920-05-0050J	Sand Creek	7/10/2007	440	610	
OK620920-05-0050J	Sand Creek	8/7/2007	490	>1000	
OK620920-05-0050J	Sand Creek	9/18/2007	>1000	>1000	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK620920-05-0050J	Sand Creek	5/20/2008	>1000	250	
OK620920-05-0050J	Sand Creek	6/23/2008	>2000	>2000	
OK620920-05-0050J	Sand Creek	7/16/2008	>1000	>1000	
OK620920-05-0050J	Sand Creek	7/28/2008	>500	>500	
OK620920-05-0050J	Sand Creek	9/2/2008	110	190	
OK620920020010-001RS	Cimarron River	5/9/2006	404		
OK620920020010-001RS	Cimarron River	5/22/2006	12300		
OK620920020010-001RS	Cimarron River	6/14/2006	1333		
OK620920020010-001RS	Cimarron River	6/26/2006	813		
OK620920020010-001RS	Cimarron River	7/5/2006	2489		
OK620920020010-001RS	Cimarron River	7/24/2006	1333		
OK620920020010-001RS	Cimarron River	8/7/2006	2282		
OK620920020010-001RS	Cimarron River	8/14/2006	1860		
OK620920020010-001RS	Cimarron River	8/22/2006	471		
OK620920020010-001RS	Cimarron River	10/3/2006	2755		
OK620920020010-001RS	Cimarron River	5/12/2008	52		
OK620920020010-001RS	Cimarron River	6/2/2008	529		
OK620920020010-001RS	Cimarron River	6/23/2008	228		
OK620920020010-001RS	Cimarron River	7/14/2008	798		
OK620920-02-0170G	Traders Creek	5/15/2000	146	100	400
OK620920-02-0170G	Traders Creek	5/23/2000			100
OK620920-02-0170G	Traders Creek	6/18/2000	30	100	400
OK620920-02-0170G	Traders Creek	6/27/2000			300
OK620920-02-0170G	Traders Creek	7/23/2000	55	615	130
OK620920-02-0170G	Traders Creek	8/1/2000	96	70	600
OK620920-02-0170G	Traders Creek	8/27/2000	30	60	280
OK620920-02-0170G	Traders Creek	9/6/2000	20	200	130
OK620920-02-0080D	Long Creek	7/29/2002	>2000	1825	
OK620920-02-0080D	Long Creek	9/3/2002	80	220	
OK620920-02-0080D	Long Creek	5/5/2003	100	100	
OK620920-02-0080D	Long Creek	6/2/2003	50	200	
OK620920-02-0080D	Long Creek	7/7/2003	90	340	
OK620920-02-0080D	Long Creek	8/11/2003	100	180	
OK620920-02-0080D	Long Creek	9/15/2003	470	170	
OK620920-02-0080D	Long Creek	6/1/2004	90	10	
OK620920-02-0080D	Long Creek	6/5/2007	130	90	
OK620920-02-0080D	Long Creek	6/18/2007	440	300	
OK620920-02-0080D	Long Creek	7/10/2007	370	490	
OK620920-02-0080D	Long Creek	8/7/2007	60	300	
OK620920-02-0080D	Long Creek	9/18/2007	110	490	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK620920-02-0080D	Long Creek	5/20/2008	220	20	
OK620920-02-0080D	Long Creek	6/23/2008	60	40	
OK620920-02-0080D	Long Creek	7/16/2008	250	>1000	
OK620920-02-0080D	Long Creek	7/28/2008	55	85	
OK620920-02-0080D	Long Creek	9/2/2008	170	230	
620920010010-001AT	Cimarron River	6/5/2001	31	630	50
620920010010-001AT	Cimarron River	6/5/2002	933	2500	13396
620920010010-001AT	Cimarron River	7/10/2002	512	200	12161
620920010010-001AT	Cimarron River	8/27/2002	475	4000	1000
620920010010-001AT	Cimarron River	9/24/2002	51	100	30
620920010010-001AT	Cimarron River	5/6/2003	31	25	60
620920010010-001AT	Cimarron River	5/26/2003	119	100	230
620920010010-001AT	Cimarron River	6/10/2003	1339	300	155
620920010010-001AT	Cimarron River	7/1/2003	295	10	200
620920010010-001AT	Cimarron River	7/8/2003	196	10	70
620920010010-001AT	Cimarron River	8/5/2003	41	400	90
620920010010-001AT	Cimarron River	8/12/2003	58	115	30
620920010010-001AT	Cimarron River	9/9/2003	199	600	500
620920010010-001AT	Cimarron River	9/16/2003	202	1000	300
OK620920-01-0180F	Main Creek	7/29/2002	>4000	3600	
OK620920-01-0180F	Main Creek	9/3/2002	280	660	
OK620920-01-0180F	Main Creek	5/5/2003	100	80	
OK620920-01-0180F	Main Creek	6/2/2003	330	280	
OK620920-01-0180F	Main Creek	7/7/2003	130	230	
OK620920-01-0180F	Main Creek	8/11/2003	260	320	
OK620920-01-0180F	Main Creek	9/15/2003	120	350	
OK620920-01-0180F	Main Creek	6/1/2004	100	60	
OK620920-01-0180F	Main Creek	6/4/2007	360	340	
OK620920-01-0180F	Main Creek	6/18/2007	390	310	
OK620920-01-0180F	Main Creek	7/9/2007	160	150	
OK620920-01-0180F	Main Creek	8/6/2007	170	270	
OK620920-01-0180F	Main Creek	9/17/2007	160	460	
OK620920-01-0180F	Main Creek	5/19/2008	<10	10	
OK620920-01-0180F	Main Creek	6/24/2008	120	80	
OK620920-01-0180F	Main Creek	7/16/2008	170	100	
OK620920-01-0180F	Main Creek	7/28/2008	240	375	
OK620920-01-0180F	Main Creek	9/2/2008	310	280	
OK620920-01-0130G	Griever Creek	5/20/1998			500
OK620920-01-0130G	Griever Creek	6/17/1998			2300
OK620920-01-0130G	Griever Creek	7/23/1998			<200

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK620920-01-0130G	Griever Creek	8/17/1998			200
OK620920-01-0130G	Griever Creek	9/21/1998			1100
OK620920-01-0130K	Griever Creek	5/23/2000			<100
OK620920-01-0130K	Griever Creek	6/27/2000			<100
OK620920-01-0130K	Griever Creek	7/31/2000	20	70	80
OK620920-01-0130K	Griever Creek	9/6/2000	52	360	170
OK620920-01-0130K	Griever Creek	5/15/2001	<10	300	40
OK620920-01-0130K	Griever Creek	6/18/2001	86	2000	50
OK620920-01-0130K	Griever Creek	7/23/2001	9	75	60
OK620920-01-0130K	Griever Creek	8/27/2001	150	100	310
OK620920-01-0130G	Griever Creek	7/29/2002	>2667	3300	
OK620920-01-0130G	Griever Creek	9/3/2002	>20	440	
OK620920-01-0130G	Griever Creek	5/5/2003	400	20	
OK620920-01-0130G	Griever Creek	6/2/2003	>3000	>3000	
OK620920-01-0130G	Griever Creek	7/7/2003	40	150	
OK620920-01-0130G	Griever Creek	8/11/2003	80	200	
OK620920-01-0130G	Griever Creek	9/15/2003	20	160	
OK620920-01-0130G	Griever Creek	6/1/2004	50	80	
OK620920-01-0130G	Griever Creek	6/4/2007	360	440	
OK620920-01-0130G	Griever Creek	6/18/2007	520	260	
OK620920-01-0130G	Griever Creek	7/9/2007	>2000	>2000	
OK620920-01-0130G	Griever Creek	8/6/2007	10	250	
OK620920-01-0130G	Griever Creek	9/17/2007	110	290	
OK620920-01-0130G	Griever Creek	5/19/2008	80	60	
OK620920-01-0130G	Griever Creek	6/24/2008	160	<20	
OK620920-01-0130G	Griever Creek	7/16/2008	10	30	
OK620920-01-0130G	Griever Creek	7/28/2008	65	350	
OK620920-01-0130G	Griever Creek	9/2/2008	140	60	
OK620920-01-0080G	Cottonwood Creek: Major Co.	5/15/2000			200
OK620920-01-0080G	Cottonwood Creek: Major Co.	6/19/2000			100
OK620920-01-0080G	Cottonwood Creek: Major Co.	7/24/2000			1000
OK620920-01-0080G	Cottonwood Creek: Major Co.	8/28/2000	41	80	700
OK620920-01-0080G	Cottonwood Creek: Major Co.	5/8/2001	139	5000	1800
OK620920-01-0080G	Cottonwood Creek: Major Co.	6/12/2001	41	180	170
OK620920-01-0080G	Cottonwood Creek: Major Co.	7/24/2001	5	5	5
OK620920-01-0080G	Cottonwood Creek: Major Co.	9/25/2001	480	150	640
OK620920-04-0010C	Eagle Chief Creek: Lower	7/23/2002	>8000	4400	
OK620920-04-0010G	Eagle Chief Creek: Upper	7/30/2002	1910	1434	
OK620920-04-0010G	Eagle Chief Creek: Upper	9/4/2002	<20	180	
OK620920-04-0010G	Eagle Chief Creek: Upper	9/4/2002	<20	80	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK620920-04-0010C	Eagle Chief Creek: Lower	5/5/2003	100	100	
OK620920-04-0010G	Eagle Chief Creek: Upper	5/6/2003	20	20	
OK620920-04-0010C	Eagle Chief Creek: Lower	6/9/2003	1460	1160	
OK620920-04-0010G	Eagle Chief Creek: Upper	6/9/2003	220	840	
OK620920-04-0010C	Eagle Chief Creek: Lower	7/14/2003	30	10	
OK620920-04-0010G	Eagle Chief Creek: Upper	7/14/2003	110	140	
OK620920-04-0010C	Eagle Chief Creek: Lower	8/18/2003	30	50	
OK620920-04-0010G	Eagle Chief Creek: Upper	8/18/2003	80	240	
OK620920-04-0010G	Eagle Chief Creek: Upper	9/22/2003	140	200	
OK620920-04-0010C	Eagle Chief Creek: Lower	9/23/2003	10	80	
OK620920-04-0010C	Eagle Chief Creek: Lower	6/7/2004	90	10	
OK620920-04-0010G	Eagle Chief Creek: Upper	6/8/2004	345	105	
OK620920-04-0010C	Eagle Chief Creek: Lower	5/30/2007	1420	560	
OK620920-04-0010G	Eagle Chief Creek: Upper	6/4/2007	560	740	
OK620920-04-0010C	Eagle Chief Creek: Lower	6/25/2007	680	1380	
OK620920-04-0010G	Eagle Chief Creek: Upper	7/10/2007	2400	3500	
OK620920-04-0010C	Eagle Chief Creek: Lower	7/23/2007	100	60	
OK620920-04-0010G	Eagle Chief Creek: Upper	7/23/2007	120	90	
OK620920-04-0010C	Eagle Chief Creek: Lower	7/30/2007	80	20	
OK620920-04-0010G	Eagle Chief Creek: Upper	8/7/2007	50	350	
OK620920-04-0010C	Eagle Chief Creek: Lower	9/17/2007	>1000	70	
OK620920-04-0010G	Eagle Chief Creek: Upper	9/17/2007	210	230	
OK620920-04-0010C	Eagle Chief Creek: Lower	5/12/2008	820	180	
OK620920-04-0010G	Eagle Chief Creek: Upper	5/19/2008	90	90	
OK620920-04-0010C	Eagle Chief Creek: Lower	6/16/2008	600	300	
OK620920-04-0010G	Eagle Chief Creek: Upper	6/24/2008	360	300	
OK620920-04-0010C	Eagle Chief Creek: Lower	7/21/2008	30	30	
OK620920-04-0010G	Eagle Chief Creek: Upper	7/28/2008	40	630	
OK620920-04-0010C	Eagle Chief Creek: Lower	8/25/2008	310	10	
OK620920-04-0010G	Eagle Chief Creek: Upper	9/2/2008	70	220	
OK620920-04-0010C	Eagle Chief Creek: Lower	9/16/2008	1000	1700	
OK620920-04-0010C	Eagle Chief Creek: Lower	9/29/2008	10	90	
620910020010-004RS	Cimarron River	5/6/2003	15	10	
620910020010-004RS	Cimarron River	5/26/2003	402	110	
620910020010-004RS	Cimarron River	6/10/2003	420	600	
620910020010-004RS	Cimarron River	7/1/2003	336	10	
620910020010-004RS	Cimarron River	7/8/2003	169	10	
620910020010-004RS	Cimarron River	8/5/2003	185	50	
620910020010-004RS	Cimarron River	8/12/2003	63.5	150	
620910020010-004RS	Cimarron River	9/9/2003	408	50	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
620910020010-004RS	Cimarron River	9/16/2003	139	175	
620910020010-004RS	Cimarron River	10/1/2003	906	200	
620910020010-004RS	Cimarron River	5/9/2006	228	10	
620910020010-004RS	Cimarron River	6/14/2006	3255	1017	
620910020010-004RS	Cimarron River	6/26/2006	481	134	
620910020010-004RS	Cimarron River	7/5/2006	813	10	
620910020010-004RS	Cimarron River	7/24/2006	857	10	
620910020010-004RS	Cimarron River	8/7/2006	1081	10	
620910020010-004RS	Cimarron River	8/22/2006	1616	31	
620910020010-004RS	Cimarron River	10/3/2006	481	10	
620910020010-004RS	Cimarron River	5/12/2008	20	10	
620910020010-004RS	Cimarron River	6/2/2008	733	10	
620910020010-004RS	Cimarron River	6/23/2008	512	20	
620910020010-004RS	Cimarron River	7/14/2008	537	211	
620910020010-104RS	Cimarron River	8/4/2008	95	52	
620910020010-001AT	Cimarron River	6/5/2001	166	730	110
620910020010-001AT	Cimarron River	6/5/2002	183	260	>24192
620910020010-001AT	Cimarron River	7/10/2002	282	210	12131
620910020010-001AT	Cimarron River	8/27/2002	316	7000	11000
620910020010-001AT	Cimarron River	9/24/2002	73	500	210
620910020010-001AT	Cimarron River	5/7/2003	10	100	100
620910020010-001AT	Cimarron River	5/28/2003	52	240	90
620910020010-001AT	Cimarron River	6/11/2003	9208	87000	18000
620910020010-001AT	Cimarron River	7/1/2003	703	10	60
620910020010-001AT	Cimarron River	7/8/2003	318	10	150
620910020010-001AT	Cimarron River	8/5/2003	145	20	200
620910020010-001AT	Cimarron River	8/12/2003	272	1100	10
620910020010-001AT	Cimarron River	9/9/2003	1989	60	70
620910020010-001AT	Cimarron River	9/16/2003	185	200	100
620910020010-001AT	Cimarron River	9/30/2003	1274	600	4200
620910020010-001AT	Cimarron River	5/9/2006	108.5	10	80
620910020010-001AT	Cimarron River	5/22/2006	1431	17	58
620910020010-001AT	Cimarron River	6/14/2006	1005	41	280
620910020010-001AT	Cimarron River	6/26/2006	1617	3078	2300
620910020010-001AT	Cimarron River	7/5/2006	6499	22028	95500
620910020010-001AT	Cimarron River	7/24/2006	204	31	40
620910020010-001AT	Cimarron River	8/7/2006	975	10	65
620910020010-001AT	Cimarron River	8/14/2006	2498	10	43
620910020010-001AT	Cimarron River	8/22/2006	781.5	15	35

[1] Units = counts/100 mL

Appendix A

Ambient Water Quality Turbidity and TSS Data – 1998 to 2009

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620920010010-001AT	Cimarron	12/2/1998	38	33	High
OK620920010010-001AT	Cimarron	1/19/1999	8	45	High
OK620920010010-001AT	Cimarron	3/7/1999	14	52	High
OK620920010010-001AT	Cimarron	4/5/1999	233	26	High
OK620920010010-001AT	Cimarron	5/5/1999	156	282	High
OK620920010010-001AT	Cimarron	6/7/1999	99	160	High
OK620920010010-001AT	Cimarron	7/6/1999	50	112	High
OK620920010010-001AT	Cimarron	8/2/1999	31	106	Low
OK620920010010-001AT	Cimarron	9/7/1999	36	43	Low
OK620920010010-001AT	Cimarron	10/18/1999	8	88	Low
OK620920010010-001AT	Cimarron	11/15/1999	17	20	Low
OK620920010010-001AT	Cimarron	12/13/1999	22	28	Low
OK620920010010-001AT	Cimarron	1/31/2000	4	34	High
OK620920010010-001AT	Cimarron	2/22/2000	9	24	Low
OK620920010010-001AT	Cimarron	3/21/2000	163	40	High
OK620920010010-001AT	Cimarron	4/17/2000	44	67	High
OK620920010010-001AT	Cimarron	5/15/2000	18	72	Low
OK620920010010-001AT	Cimarron	6/20/2000	71	96	High
OK620920010010-001AT	Cimarron	7/24/2000	316	1012	High
OK620920010010-001AT	Cimarron	8/21/2000	49	160	Low
OK620920010010-001AT	Cimarron	9/19/2000	46		Low
OK620920010010-001AT	Cimarron	10/16/2000		136	High
OK620920010010-001AT	Cimarron	11/13/2000	26	70	Low
OK620920010010-001AT	Cimarron	2/6/2001	16		High
OK620920010010-001AT	Cimarron	3/6/2001	35		High
OK620920010010-001AT	Cimarron	4/3/2001	22		High
OK620920010010-001AT	Cimarron	5/8/2001	226		High
OK620920010010-001AT	Cimarron	6/5/2001	77		High
OK620920010010-001AT	Cimarron	7/10/2001	109		Low
OK620920010010-001AT	Cimarron	8/7/2001	221		Low
OK620920010010-001AT	Cimarron	9/11/2001	110		Low
OK620920010010-001AT	Cimarron	10/2/2001	71		Low
OK620920010010-001AT	Cimarron	2/5/2002	10		Low
OK620920010010-001AT	Cimarron	3/12/2002	10		Low
OK620920010010-001AT	Cimarron	4/9/2002	13		Low
OK620920010010-001AT	Cimarron	5/14/2002	23		Low

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620920010010-001AT	Cimarron	6/5/2002	288		Low
OK620920010010-001AT	Cimarron	7/9/2002	42		Low
OK620920010010-001AT	Cimarron	8/27/2002	268		Low
OK620920010010-001AT	Cimarron	9/24/2002	26		Low
OK620920010010-001AT	Cimarron	10/29/2002	1000		High
OK620920010010-001AT	Cimarron	12/3/2002	7		Low
OK620920010010-001AT	Cimarron	1/21/2003	8		Low
OK620920010010-001AT	Cimarron	3/5/2003	276		High
OK620920010010-001AT	Cimarron	3/31/2003	17		Low
OK620920010010-001AT	Cimarron	6/10/2003	88		Low
OK620920010010-001AT	Cimarron	7/8/2003	31		Low
OK620920010010-001AT	Cimarron	8/11/2003	27		Low
OK620920010010-001AT	Cimarron	9/16/2003	100		Low
OK620920010010-001AT	Cimarron	10/21/2003	15		Low
OK620920010010-001AT	Cimarron	11/18/2003	16		Low
OK620920010010-001AT	Cimarron	12/16/2003	7		Low
OK620920010010-001AT	Cimarron	1/14/2004	5		Low
OK620920010010-001AT	Cimarron	3/2/2004	22		Low
OK620920010010-001AT	Cimarron	5/3/2004	29		Low
OK620920010010-001AT	Cimarron	6/14/2004	26		Low
OK620920010010-001AT	Cimarron	7/20/2004	27		Low
OK620920010010-001AT	Cimarron	8/24/2004	78		Low
OK620920010010-001AT	Cimarron	9/28/2004	18		Low
OK620920010010-001AT	Cimarron	12/8/2004	33		High
OK620920010010-001AT	Cimarron	2/22/2005	20		High
OK620920-01-0180F	Main Creek	6/21/2002	81.2		Low
OK620920-01-0180F	Main Creek	9/3/2002	58.7	40	Low
OK620920-01-0180F	Main Creek	10/7/2002	180	176	High
OK620920-01-0180F	Main Creek	11/12/2002	34	48	High
OK620920-01-0180F	Main Creek	12/9/2002	16.5	34	High
OK620920-01-0180F	Main Creek	1/21/2003	16.3	45	Low
OK620920-01-0180F	Main Creek	3/10/2003	30.7	51	Low
OK620920-01-0180F	Main Creek	3/24/2003	36.1	71	Low
OK620920-01-0180F	Main Creek	5/5/2003	19.3	18	Low
OK620920-01-0180F	Main Creek	6/2/2003	555	391	Low
OK620920-01-0180F	Main Creek	7/7/2003	4.65	10	Low
OK620920-01-0180F	Main Creek	8/11/2003	43.3	62	Low
OK620920-01-0180F	Main Creek	9/15/2003	9.93	9.99	Low

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620920-01-0180F	Main Creek	10/20/2003	17.2	23	Low
OK620920-01-0180F	Main Creek	12/1/2003	10.3	12	Low
OK620920-01-0180F	Main Creek	1/5/2004	9.94	15	Low
OK620920-01-0180F	Main Creek	2/9/2004	48.6	48	Low
OK620920-01-0180F	Main Creek	3/15/2004	49.3	68	Low
OK620920-01-0180F	Main Creek	4/26/2004	56.9	91	Low
OK620920-01-0180F	Main Creek	6/1/2004	30.4	67	Low
OK620920-01-0180F	Main Creek	6/4/2007	82.3	73	Low
OK620920-01-0180F	Main Creek	6/12/2007	80.9		Low
OK620920-01-0180F	Main Creek	7/9/2007	25.1	36	High
OK620920-01-0180F	Main Creek	8/6/2007	7.21	20	Low
OK620920-01-0180F	Main Creek	9/17/2007	35.3	50	Low
OK620920-01-0180F	Main Creek	10/23/2007	10.7	21	Low
OK620920-01-0180F	Main Creek	11/26/2007	4.69	11	Low
OK620920-01-0180F	Main Creek	1/8/2008	7.41	14	Low
OK620920-01-0180F	Main Creek	2/5/2008	10.5	20	Low
OK620920-01-0180F	Main Creek	3/11/2008	3.23	9.99	Low
OK620920-01-0180F	Main Creek	4/15/2008	6.05	9.99	Low
OK620920-01-0180F	Main Creek	5/19/2008	42.2	73	Low
OK620920-01-0180F	Main Creek	6/24/2008	27.8	37	Low
OK620920-01-0180F	Main Creek	7/28/2008	11.9	16	High
OK620920-01-0180F	Main Creek	9/2/2008	16.6	24	Low
OK620920-01-0180F	Main Creek	10/6/2008	1000.99	1114	High
OK620920-01-0180F	Main Creek	11/17/2008	6.64	9.99	Low
OK620920-01-0180F	Main Creek	12/15/2008	4.43	9.99	Low
OK620920-01-0180F	Main Creek	2/9/2009	13.6	16	Low
OK620920-01-0180F	Main Creek	3/2/2009	4.19	9.99	Low
OK620920-01-0180F	Main Creek	4/13/2009	24.9	30	High
OK620920-04-0010C	Eagle Chief Creek:	6/27/2002	62.4		Low
OK620920-04-0010G	Eagle Chief Creek:	8/8/2002	17.7		Low
OK620920-04-0010G	Eagle Chief Creek:	9/4/2002	10.6	9.99	Low
OK620920-04-0010G	Eagle Chief Creek:	9/4/2002	21.7	9.99	Low
OK620920-04-0010G	Eagle Chief Creek:	10/8/2002	94.6	164	Low
OK620920-04-0010G	Eagle Chief Creek:	10/8/2002	140	20	Low
OK620920-04-0010C	Eagle Chief Creek:	11/13/2002	31.2	34	High
OK620920-04-0010G	Eagle Chief Creek:	11/13/2002	14.9	18	Low
OK620920-04-0010C	Eagle Chief Creek:	12/9/2002	16.2	26	Low
OK620920-04-0010G	Eagle Chief Creek:	12/10/2002	18.9	19	Low

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620920-04-0010C	Eagle Chief Creek: Lower	1/21/2003	6.45	9.99	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	1/22/2003	6.72	10	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	3/3/2003	27.8	22	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	3/12/2003	33.5	25	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	3/31/2003	29.9	32	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	3/31/2003	14.5	32	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	5/5/2003	23	35	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	5/6/2003	8.17	15	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	6/9/2003	324	286	High
OK620920-04-0010G	Eagle Chief Creek: Upper	6/9/2003	163	138	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	7/14/2003	19.2	58	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	7/14/2003	19.6	10	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	8/18/2003	13.2	16	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	8/18/2003	20.4	22	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	9/22/2003	14.6	18	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	9/23/2003	14.8	29	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	10/27/200	5.7	9.99	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	10/28/200	5.58	9.99	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	12/8/2003	37.2	46	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	12/9/2003	4.55	9.99	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	1/12/2004	12.7	13	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	1/13/2004	8.15	25	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	2/17/2004	24.3	15	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	2/18/2004	26.7	26	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	3/23/2004	11.4	18	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	3/23/2004	9	9.99	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	4/20/2004	17.2	22	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	4/27/2004	151	171	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	6/7/2004	14.9	29	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	6/8/2004	40.3	46	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	5/30/2007	202	210	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	6/4/2007	210	140	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	6/25/2007	387	230	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	7/30/2007	13.5	29	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	8/7/2007	6.69	17	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	8/10/2007	15.4		Low
OK620920-04-0010G	Eagle Chief Creek: Upper	8/10/2007	21.7		Low
OK620920-04-0010C	Eagle Chief Creek: Lower	9/17/2007	111	110	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	9/17/2007	15.7	44	Low

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620920-04-0010C	Eagle Chief Creek: Lower	10/15/2007	22.4	29	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	10/22/2007	5.37	9.99	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	11/13/2007	16.9	14	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	11/26/2007	5.73	9.99	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	12/18/2007	11.3	17	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	1/8/2008	17.1	22	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	1/22/2008	34.1	77	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	2/4/2008	40	59	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	3/3/2008	23	34	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	3/11/2008	24.5	31	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	4/7/2008	32.9	30	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	4/15/2008	21.6	16	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	5/12/2008	241	1235	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	5/19/2008	30.5	43	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	6/16/2008	115	123	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	6/24/2008	32	28	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	7/21/2008	10.3	11	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	7/28/2008	11.3	17	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	8/25/2008	15.4	20	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	9/2/2008	12.9	13	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	9/29/2008	27.8	28	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	10/20/2008	37.7	22	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	11/3/2008	30.9	16	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	11/18/2008	4.59	9.99	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	12/15/2008	5.13	9.99	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	12/29/2008	10.5	9.99	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	2/2/2009	5.18	9.99	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	2/9/2009	17.3	18	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	3/2/2009	3.51	9.99	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	3/10/2009	12.5	14	Low
OK620920-04-0010C	Eagle Chief Creek: Lower	4/6/2009	39.2	28	Low
OK620920-04-0010G	Eagle Chief Creek: Upper	4/14/2009	431	384	Low
OK620920-01-0080G	Cottonwood Creek: Major	5/15/2000	59.1	109	Low
OK620920-01-0080G	Cottonwood Creek: Major	6/19/2000	43.4	62	Low
OK620920-01-0080G	Cottonwood Creek: Major	7/24/2000	114	172	Low
OK620920-01-0080G	Cottonwood Creek: Major	8/28/2000	65.2	76	Low
OK620920-01-0080G	Cottonwood Creek: Major	10/2/2000	133	49	Low
OK620920-01-0080G	Cottonwood Creek: Major	11/6/2000	408	244	Low
OK620920-01-0080G	Cottonwood Creek: Major	12/12/2000	7.75	10	Low

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620920-01-0080G	Cottonwood Creek: Major	1/23/2001	19.1	14	Low
OK620920-01-0080G	Cottonwood Creek: Major	2/26/2001	1000.99	164	High
OK620920-01-0080G	Cottonwood Creek: Major	4/2/2001	71.9	64	Low
OK620920-01-0080G	Cottonwood Creek: Major	5/8/2001	189	166	High
OK620920-01-0080G	Cottonwood Creek: Major	6/12/2001	49	47	Low
OK620920-01-0080G	Cottonwood Creek: Major	6/21/2001	27.8		Low
OK620920-01-0080G	Cottonwood Creek: Major	7/24/2001	13	41	Low
OK620920-01-0080G	Cottonwood Creek: Major	9/25/2001	173	101	Low
OK620920-01-0080G	Cottonwood Creek: Major	10/29/2001	32.2	33	Low
OK620920-01-0080G	Cottonwood Creek: Major	12/11/2001	24.6	15	Low
OK620920-01-0080G	Cottonwood Creek: Major	1/15/2002	49.9	60	Low
OK620920-01-0080G	Cottonwood Creek: Major	2/20/2002	101	108	Low
OK620920-01-0080G	Cottonwood Creek: Major	3/26/2002	80.9	52	Low
OK620910020010-001AT	Cimarron	12/2/1998	76	3	Low
OK620910020010-001AT	Cimarron	1/19/1999	9	47	Low
OK620910020010-001AT	Cimarron	2/8/1999	84	90	High
OK620910020010-001AT	Cimarron	3/7/1999	29	45	Low
OK620910020010-001AT	Cimarron	4/5/1999	1000	1310	High
OK620910020010-001AT	Cimarron	5/5/1999	341	256	High
OK620910020010-001AT	Cimarron	6/7/1999		424	High
OK620910020010-001AT	Cimarron	7/6/1999	95	152	High
OK620910020010-001AT	Cimarron	8/2/1999	30	44	Low
OK620910020010-001AT	Cimarron	9/7/1999	14	44	Low
OK620910020010-001AT	Cimarron	10/18/1999	12	26	Low
OK620910020010-001AT	Cimarron	11/15/1999	11	15	Low
OK620910020010-001AT	Cimarron	12/13/1999	196	176	High
OK620910020010-001AT	Cimarron	1/31/2000	9	27	Low
OK620910020010-001AT	Cimarron	2/22/2000	13	31	Low
OK620910020010-001AT	Cimarron	3/21/2000	350		High
OK620910020010-001AT	Cimarron	4/17/2000	295	346	High
OK620910020010-001AT	Cimarron	5/15/2000	40	67	Low
OK620910020010-001AT	Cimarron	6/20/2000	375	408	High
OK620910020010-001AT	Cimarron	7/24/2000	1000	2220	High
OK620910020010-001AT	Cimarron	8/21/2000	19	62	Low
OK620910020010-001AT	Cimarron	9/19/2000	10	0	Low
OK620910020010-001AT	Cimarron	10/16/2000	39	60	Low
OK620910020010-001AT	Cimarron	11/13/2000	47	58	Low
OK620910020010-001AT	Cimarron	2/6/2001	28		High
OK620910020010-001AT	Cimarron	3/6/2001	83		High

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620910020010-001AT	Cimarron	4/3/2001	37		High
OK620910020010-001AT	Cimarron	5/8/2001	692		High
OK620910020010-001AT	Cimarron	6/5/2001	185		High
OK620910020010-001AT	Cimarron	7/10/2001	22		Low
OK620910020010-001AT	Cimarron	8/7/2001	19		Low
OK620910020010-001AT	Cimarron	9/11/2001	35		Low
OK620910020010-001AT	Cimarron	10/2/2001	37		Low
OK620910020010-001AT	Cimarron	2/5/2002	18		Low
OK620910020010-001AT	Cimarron	3/12/2002	11		Low
OK620910020010-001AT	Cimarron	4/9/2002	18		Low
OK620910020010-001AT	Cimarron	5/14/2002	17		Low
OK620910020010-001AT	Cimarron	6/5/2002	28		Low
OK620910020010-001AT	Cimarron	7/9/2002	25		Low
OK620910020010-001AT	Cimarron	8/27/2002	820		Low
OK620910020010-001AT	Cimarron	9/24/2002	127		Low
OK620910020010-001AT	Cimarron	10/29/2002	1000		High
OK620910020010-001AT	Cimarron	12/3/2002	11		Low
OK620910020010-001AT	Cimarron	1/21/2003	12		Low
OK620910020010-001AT	Cimarron	3/5/2003	34		Low
OK620910020010-001AT	Cimarron	3/31/2003	12		Low
OK620910020010-001AT	Cimarron	6/9/2003	1000		High
OK620910020010-001AT	Cimarron	7/7/2003	15		Low
OK620910020010-001AT	Cimarron	8/11/2003	12		Low
OK620910020010-001AT	Cimarron	9/15/2003	66		Low
OK620910020010-001AT	Cimarron	10/20/2003	8		Low
OK620910020010-001AT	Cimarron	11/17/2003	7		Low
OK620910020010-001AT	Cimarron	12/15/2003	9		Low
OK620910020010-001AT	Cimarron	1/12/2004	6		Low
OK620910020010-001AT	Cimarron	3/1/2004	15		Low
OK620910020010-001AT	Cimarron	5/3/2004	33		Low
OK620910020010-001AT	Cimarron	6/15/2004	14		Low
OK620910020010-001AT	Cimarron	7/19/2004	18		Low
OK620910020010-001AT	Cimarron	8/23/2004	1000		Low
OK620910020010-001AT	Cimarron	9/28/2004	12		Low
OK620910020010-001AT	Cimarron	12/7/2004	53		High
OK620910020010-001AT	Cimarron	2/1/2005	53		High
OK620910020010-001AT	Cimarron	5/3/2005	11		Low
OK620910020010-001AT	Cimarron	6/21/2005	385		High
OK620910020010-001AT	Cimarron	7/18/2005	19		Low

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK620910020010-001AT	Cimarron	8/15/2005	1000		Low
OK620910020010-001AT	Cimarron	9/20/2005	37		Low
OK620910020010-001AT	Cimarron	10/26/2005	11		Low
OK620910020010-001AT	Cimarron	12/6/2005	4		Low
OK620910020010-001AT	Cimarron	2/1/2006	12		Low
OK620910020010-001AT	Cimarron	2/28/2006	7		Low
OK620910020010-001AT	Cimarron	4/5/2006	5		Low
OK620910020010-001AT	Cimarron	5/9/2006	11		Low
OK620910020010-001AT	Cimarron	6/14/2006	18		Low
OK620910020010-001AT	Cimarron	8/22/2006	51		Low
OK620910020010-001AT	Cimarron	10/3/2006	24		Low
OK620910020010-001AT	Cimarron	12/13/2006	5		Low
OK620910020010-001AT	Cimarron	1/31/2007	7		Low
OK620910020010-001AT	Cimarron	3/7/2007	8		Low
OK620910020010-001AT	Cimarron	4/4/2007	573		High
OK620910020010-001AT	Cimarron	5/23/2007	23		Low
OK620910020010-001AT	Cimarron	6/6/2007	111		High
OK620910020010-001AT	Cimarron	7/18/2007	146		High
OK620910020010-001AT	Cimarron	8/15/2007	24		Low
OK620910020010-001AT	Cimarron	9/25/2007	26		Low
OK620910020010-001AT	Cimarron	10/24/2007	42		Low
OK620910020010-001AT	Cimarron	11/26/2007	6		Low
OK620910020010-001AT	Cimarron	1/29/2008	15		Low
OK620910020010-001AT	Cimarron	3/5/2008	290		High
OK620910020010-001AT	Cimarron	4/18/2008	20		High
OK620910020010-001AT	Cimarron	5/28/2008	479		High
OK620910020010-001AT	Cimarron	7/22/2008	42		Low
OK620910020010-001AT	Cimarron	9/16/2008	477		High
OK620910020010-001AT	Cimarron	11/11/2008	15		Low
OK620910020010-001AT	Cimarron	1/21/2009	6		Low
OK620910020010-001AT	Cimarron	3/17/2009	4.25		Low
OK620910020010-001AT	Cimarron	4/14/2009	17.25		Low
OK620910020010-001AT	Cimarron	5/27/2009	19		Low
OK620910020010-001AT	Cimarron	7/7/2009	23.5		Low
OK620910020010-001AT	Cimarron	8/25/2009	68		Low
OK620910020010-001AT	Cimarron	11/3/2009	98.3		Low

APPENDIX B
ESTIMATED FLOW EXCEEDANCE FREQUENCIES

Appendix B

Estimated Flow Exceedance Frequencies

	Cimarron River near Buffalo	Buffalo Creek near Lovedale	Sand Creek	Cimarron River at Freedom	Traders Creek	Long Creek	Main Creek	Cimarron River below Waynoka	Griever Creek	Eagle Chief Creek	Cottonwood Creek	Cimarron River near Ames	Cimarron River near Dover
WBID Segment	OK620920030010_00	OK620920050010_00	OK620920050050_00	OK620920020010_00	OK620920020170_00	OK620920020080_00	OK620920010180_00	OK620920010010_00	OK620920010130_00	OK620920040010_00	OK620920010080_00	OK620910020010_10	OK620910020010_00
USGS Gage Reference	07157950	07157960	07157960	07157980	07157960	07157960	07157960	07158000	07157960	07158000	07157960	07159100	07159100
Drainage Area (sq. mile)	763.74	492.45	122.51	731.86	72.36	60.76	94.09	1063.25	92.10	486.51	54.47	895.15	1858.15
NRCS Curve Number	65.09	65.56	65.78	68.05	68.20	69.11	67.03	71.64	66.98	72.24	72.88	69.80	74.12
Average Annual Rainfall (inch)	25.48	25.31	25.29	26.86	26.10	26.36	27.73	29.83	28.17	28.92	29.17	31.47	32.82
Exceedance Frequency	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
0	12500	8009	1990	14800	1213	1029	1676	51600	1667	22891	1021	37042	80200
1	1322	847	211	2400	128	109	177	4010	176	1779	108	4803	10400
2	755	484	120	1309	73	62	101	2190	101	972	62	3210	6949
3	515	330	82	964	50	42	69	1490	69	661	42	2329	5042
4	414	265	66	746	40	34	56	1100	55	488	34	1819	3938
5	344	220	55	637	33	28	46	889	46	394	28	1487	3220
6	300	192	48	520	29	25	40	746	40	331	24	1275	2760
7	269	172	43	448	26	22	36	643	36	285	22	1108	2400
8	245	157	39	400	24	20	33	568	33	252	20	997	2158
9	224	144	36	360	22	18	30	510	30	226	18	896	1940
10	209	134	33	330	20	17	28	460	28	204	17	794	1720
11	196	126	31	316	19	16	26	424	26	188	16	721	1560
12	184	118	29	290	18	15	25	392	25	174	15	660	1430
13	174	111	28	274	17	14	23	363	23	161	14	610	1320
14	165	106	26	264	16	14	22	342	22	152	13	573	1240
15	157	101	25	250	15	13	21	324	21	144	13	527	1140
16	150	96	24	234	15	12	20	308	20	137	12	494	1070
17	145	93	23	228	14	12	19	293	19	130	12	466	1010
18	140	90	22	218	14	12	19	278	19	123	11	439	950
19	135	86	21	210	13	11	18	265	18	118	11	413	895
20	130	83	21	199	13	11	17	252	17	112	11	389	843
21	125	80	20	192	12	10	17	243	17	108	10	369	798
22	121	78	19	186	12	10	16	233	16	103	10	353	764

	Cimarron River near Buffalo	Buffalo Creek near Lovedale	Sand Creek	Cimarron River at Freedom	Traders Creek	Long Creek	Main Creek	Cimarron River below Waynoka	Griever Creek	Eagle Chief Creek	Cottonwood Creek	Cimarron River near Ames	Cimarron River near Dover
WBID Segment	OK620920030010_00	OK620920050010_00	OK620920050050_00	OK620920020010_00	OK620920020170_00	OK620920020080_00	OK620920010180_00	OK620920010010_00	OK620920010130_00	OK620920040010_00	OK620920010080_00	OK620910020010_10	OK620910020010_00
USGS Gage Reference	07157950	07157960	07157960	07157980	07157960	07157960	07157960	07158000	07157960	07158000	07157960	07159100	07159100
Drainage Area (sq. mile)	763.74	492.45	122.51	731.86	72.36	60.76	94.09	1063.25	92.10	486.51	54.47	895.15	1858.15
NRCS Curve Number	65.09	65.56	65.78	68.05	68.20	69.11	67.03	71.64	66.98	72.24	72.88	69.80	74.12
Average Annual Rainfall (inch)	25.48	25.31	25.29	26.86	26.10	26.36	27.73	29.83	28.17	28.92	29.17	31.47	32.82
Exceedance Frequency	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
23	117	75	19	180	11	10	16	225	16	100	10	337	730
24	114	73	18	174	11	9	15	216	15	96	9	321	696
25	110	70	18	168	11	9	15	207	15	92	9	307	664
26	106	68	17	163	10	9	14	200	14	89	9	293	635
27	102	65	16	156	10	8	14	193	14	86	8	280	607
28	99	63	16	150	10	8	13	185	13	82	8	269	583
29	96	62	15	150	9	8	13	179	13	79	8	259	561
30	93	60	15	141	9	8	12	172	12	76	8	251	543
31	90	58	14	137	9	7	12	166	12	74	7	241	523
32	87	56	14	132	8	7	12	160	12	71	7	234	506
33	84	54	13	128	8	7	11	155	11	69	7	226	490
34	82	53	13	123	8	7	11	150	11	67	7	218	472
35	80	51	13	117	8	7	11	144	11	64	7	212	458
36	77	49	12	114	7	6	10	140	10	62	6	205	443
37	75	48	12	110	7	6	10	135	10	60	6	197	427
38	72	46	11	105	7	6	10	130	10	58	6	191	414
39	70	45	11	104	7	6	9	126	9	56	6	185	400
40	68	44	11	99	7	6	9	121	9	54	6	178	385
41	65	42	10	95	6	5	9	118	9	52	5	171	371
42	63	40	10	91	6	5	8	113	8	50	5	166	359
43	61	39	10	88	6	5	8	110	8	49	5	161	348
44	60	38	10	83	6	5	8	106	8	47	5	157	339
45	59	38	9	80	6	5	8	102	8	45	5	153	331
46	57	37	9	78	6	5	8	99	8	44	5	149	323
47	55	35	9	75	5	5	7	96	7	43	4	145	314
48	53	34	8	71	5	4	7	93	7	41	4	142	307

	Cimarron River near Buffalo	Buffalo Creek near Lovedale	Sand Creek	Cimarron River at Freedom	Traders Creek	Long Creek	Main Creek	Cimarron River below Waynoka	Griever Creek	Eagle Chief Creek	Cottonwood Creek	Cimarron River near Ames	Cimarron River near Dover
WBID Segment	OK620920030010_00	OK620920050010_00	OK620920050050_00	OK620920020010_00	OK620920020170_00	OK620920020080_00	OK620920010180_00	OK620920010010_00	OK620920010130_00	OK620920040010_00	OK620920010080_00	OK620910020010_10	OK620910020010_00
USGS Gage Reference	07157950	07157960	07157960	07157980	07157960	07157960	07157960	07158000	07157960	07158000	07157960	07159100	07159100
Drainage Area (sq. mile)	763.74	492.45	122.51	731.86	72.36	60.76	94.09	1063.25	92.10	486.51	54.47	895.15	1858.15
NRCS Curve Number	65.09	65.56	65.78	68.05	68.20	69.11	67.03	71.64	66.98	72.24	72.88	69.80	74.12
Average Annual Rainfall (inch)	25.48	25.31	25.29	26.86	26.10	26.36	27.73	29.83	28.17	28.92	29.17	31.47	32.82
Exceedance Frequency	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
49	51	33	8	68	5	4	7	90	7	40	4	138	299
50	50	32	8	64	5	4	7	88	7	39	4	134	290
51	48	31	8	62	5	4	6	85	6	38	4	130	281
52	45.0	28.8	7.2	57.0	4.4	3.7	6.0	81.0	6.0	35.9	3.7	126.1	273.0
53	43.0	27.5	6.8	55.0	4.2	3.5	5.8	78.0	5.7	34.6	3.5	123.3	267.0
54	42.0	26.9	6.7	50.0	4.1	3.5	5.6	75.0	5.6	33.3	3.4	119.6	259.0
55	40.0	25.6	6.4	48.0	3.9	3.3	5.4	72.0	5.3	31.9	3.3	116.4	252.0
56	38.0	24.3	6.1	46.0	3.7	3.1	5.1	70.0	5.1	31.1	3.1	113.6	246.0
57	36.0	23.1	5.7	43.0	3.5	3.0	4.8	66.0	4.8	29.3	2.9	110.8	240.0
58	34.0	21.8	5.4	42.0	3.3	2.8	4.6	63.0	4.5	27.9	2.8	107.6	233.0
59	33.0	21.1	5.3	40.0	3.2	2.7	4.4	60.0	4.4	26.6	2.7	104.4	226.0
60	31.0	19.9	4.9	38.0	3.0	2.6	4.2	58.0	4.1	25.7	2.5	101.6	220.0
61	29.0	18.6	4.6	35.8	2.8	2.4	3.9	55.0	3.9	24.4	2.4	99.3	215.0
62	27.0	17.3	4.3	33.0	2.6	2.2	3.6	52.0	3.6	23.1	2.2	96.1	208.0
63	26.0	16.7	4.1	32.0	2.5	2.1	3.5	50.0	3.5	22.2	2.1	93.3	202.0
64	24.0	15.4	3.8	30.0	2.3	2.0	3.2	48.0	3.2	21.3	2.0	90.5	196.0
65	23.0	14.7	3.7	28.6	2.2	1.9	3.1	45.0	3.1	20.0	1.9	87.8	190.0
66	22.0	14.1	3.5	26.0	2.1	1.8	2.9	42.0	2.9	18.6	1.8	85.4	185.0
67	20.0	12.8	3.2	25.0	1.9	1.6	2.7	40.0	2.7	17.7	1.6	83.1	180.0
68	19.0	12.2	3.0	24.0	1.8	1.6	2.5	38.0	2.5	16.9	1.6	80.8	175.0
69	17.0	10.9	2.7	22.0	1.7	1.4	2.3	36.0	2.3	16.0	1.4	78.1	169.0
70	16.0	10.3	2.5	20.8	1.6	1.3	2.1	33.0	2.1	14.6	1.3	75.3	163.0
71	14.0	9.0	2.2	19.0	1.4	1.2	1.9	30.0	1.9	13.3	1.1	73.0	158.0
72	13.0	8.3	2.1	18.0	1.3	1.1	1.7	28.0	1.7	12.4	1.1	70.2	152.0
73	11.0	7.0	1.8	17.1	1.1	0.9	1.5	26.0	1.5	11.5	0.9	68.4	148.0
74	10.0	6.4	1.6	16.0	1.0	0.8	1.3	24.0	1.3	10.6	0.8	65.6	142.0

	Cimarron River near Buffalo	Buffalo Creek near Lovedale	Sand Creek	Cimarron River at Freedom	Traders Creek	Long Creek	Main Creek	Cimarron River below Waynoka	Griever Creek	Eagle Chief Creek	Cottonwood Creek	Cimarron River near Ames	Cimarron River near Dover
WBID Segment	OK620920030010_00	OK620920050010_00	OK620920050050_00	OK620920020010_00	OK620920020170_00	OK620920020080_00	OK620920010180_00	OK620920010010_00	OK620920010130_00	OK620920040010_00	OK620920010080_00	OK620910020010_10	OK620910020010_00
USGS Gage Reference	07157950	07157960	07157960	07157980	07157960	07157960	07157960	07158000	07157960	07158000	07157960	07159100	07159100
Drainage Area (sq. mile)	763.74	492.45	122.51	731.86	72.36	60.76	94.09	1063.25	92.10	486.51	54.47	895.15	1858.15
NRCS Curve Number	65.09	65.56	65.78	68.05	68.20	69.11	67.03	71.64	66.98	72.24	72.88	69.80	74.12
Average Annual Rainfall (inch)	25.48	25.31	25.29	26.86	26.10	26.36	27.73	29.83	28.17	28.92	29.17	31.47	32.82
Exceedance Frequency	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
75	9.0	5.8	1.4	15.0	0.9	0.7	1.2	22.0	1.2	9.8	0.7	62.4	135.0
76	7.8	5.0	1.2	13.0	0.8	0.6	1.1	20.0	1.0	8.9	0.6	59.6	129.0
77	6.7	4.3	1.1	12.0	0.7	0.6	0.9	18.0	0.9	8.0	0.5	57.3	124.0
78	5.8	3.7	0.9	11.0	0.6	0.5	0.8	15.0	0.8	6.7	0.5	55.0	119.0
79	4.8	3.1	0.8	8.6	0.5	0.4	0.6	13.0	0.6	5.8	0.4	52.7	114.0
80	3.9	2.5	0.6	6.9	0.4	0.3	0.5	12.0	0.5	5.3	0.3	49.9	108.0
81	3.1	2.0	0.5	4.9	0.3	0.3	0.4	10.0	0.4	4.4	0.3	47.1	102.0
82	2.5	1.6	0.4	2.8	0.2	0.2	0.3	8.2	0.3	3.6	0.2	44.8	97.0
83	1.9	1.2	0.3	1.5	0.2	0.2	0.3	6.7	0.3	3.0	0.2	43.0	93.0
84	1.40	0.90	0.22	0.82	0.14	0.12	0.19	5.50	0.19	2.44	0.11	40.64	88.00
85	0.94	0.60	0.15	0.24	0.09	0.08	0.13	4.50	0.12	2.00	0.08	38.80	84.00
86	0.65	0.42	0.10	0.12	0.06	0.05	0.09	3.30	0.09	1.46	0.05	36.49	79.00
87	0.46	0.29	0.07	0.00	0.04	0.04	0.06	2.50	0.06	1.11	0.04	34.64	75.00
88	0.33	0.21	0.05	0.00	0.03	0.03	0.04	2.00	0.04	0.89	0.03	32.33	70.00
89	0.20	0.13	0.03	0.00	0.02	0.02	0.03	1.20	0.03	0.53	0.02	30.48	66.00
90	0.12	0.08	0.02	0.00	0.01	0.01	0.02	0.80	0.02	0.35	0.01	28.64	62.00
91	0.05	0.03	0.01	0.00	0.00	0.00	0.01	0.40	0.01	0.18	0.00	26.79	58.00
92	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.06	0.00	24.94	54.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.56	51.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.25	46.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.40	42.00
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.55	38.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.70	34.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.93	28.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.78	19.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.99	4.30

Appendix B
General Methodology for Estimating Stream Flow

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

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

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

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

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

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

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

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

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

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

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

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

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

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

where:

Q = runoff (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

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

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

Thus, the runoff curve number equation can be rewritten:

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

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

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

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

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

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

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

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

APPENDIX C
STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix C
State of Oklahoma Antidegradation Policy

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

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

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

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

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

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

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

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

785:46-13-1. Applicability and scope

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

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

(1) Tier 1. Attainment or maintenance of an existing or designated beneficial use.

(2) Tier 2. Maintenance or protection of High Quality Waters and Sensitive Public and Private Water Supply waters.

(3) Tier 3. No degradation of water quality allowed in Outstanding Resource Water©(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 designate "ORW" and/or "Scenic River" may be permitted by the permitting authority. Regardless of 785:46-13-5(a), discharges of stormwater to waterbodies and watersheds designated "ORW" and/or "Scenic River" from point sources existing as of June 25, 1992, whether or not such stormwater discharges were permitted as point sources prior to June 25, 1992, may be permitted by the permitting authority; provided, however, increased load of any pollutant from such stormwater discharge shall be prohibited.

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

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

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

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

APPENDIX D

NPDES DISCHARGE MONITORING REPORT DATA
AND
SANITARY SEWER OVERFLOW DATA

Appendix D

Summary of Discharge Monitoring Report Data for facilities in the Study

NPDES	Name of Facility	Date	Daily Max Flow (mgd)	Ave Flow (mgd)	Permitted TSS (mg/L)	Reported TSS (mg/L)
OK0020079	City of Fairview	01/31/2009	No Discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	02/28/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	03/31/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	04/30/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	05/31/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	06/30/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	07/31/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	08/31/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	09/30/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	10/31/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	11/30/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	12/31/2009	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	01/31/2010	0.2	0.2	90	13
OK0020079	City of Fairview	02/28/2010	0.2	0.2	90	83
OK0020079	City of Fairview	03/31/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	04/30/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	05/31/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	06/30/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	07/31/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	08/31/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	09/30/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	10/31/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	11/30/2010	No discharge	No discharge	No discharge	No discharge
OK0020079	City of Fairview	12/31/2010	Not received	Not received	Not received	Not received
OKG580045	Town of Aline	01/31/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	02/28/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	03/31/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	04/30/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	05/31/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	06/30/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	07/31/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	08/31/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	09/30/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	10/31/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	11/30/2009	No discharge	No discharge	No discharge	No discharge

NPDES	Name of Facility	Date	Daily Max Flow (mgd)	Ave Flow (mgd)	Permitted TSS (mg/L)	Ave TSS (mg/L)
OKG580045	Town of Aline	12/31/2009	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	01/31/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	02/28/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	03/31/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	04/30/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	05/31/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	06/30/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	07/31/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	08/31/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	09/30/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	10/31/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	11/30/2010	No discharge	No discharge	No discharge	No discharge
OKG580045	Town of Aline	12/31/2010	No discharge	No discharge	No discharge	No discharge

ODEQ Summary of Available Reports of Sanitary Sewer Overflows

Facility Name	Date	Facility ID	Location	Amount (gal)	Cause	Type of Source
Freedom WWTP	3/5/1990	S20903	East cell north side		Over full	
Freedom WWTP	1/10/1992	S20903	SE of Town approximately 3/4 of a mile		Too much groundwater	
Freedom WWTP	1/10/1992	S20903	Lagoon overflowing by siphon		Lagoon too small for flow in rainy weather	
Freedom WWTP	2/14/1992	S20903	Lagoon		Excessive rainfall and I/I	
Freedom WWTP	2/21/1992	S20903	Lagoons	80,000	Lowering lagoons due to overfilling	
Freedom WWTP	6/6/2001	S20903	Lagoons		Rains	Lagoon/basin
Freedom WWTP	4/26/2009	S20903	Lift station		Blown fuses	Manhole
Buffalo WWTP	6/29/1999	S20902	East of town		Rain	
Buffalo WWTP	3/13/2002	S20902	Plant	50,000	Lower drying beds	Drying beds
Buffalo WWTP	3/19/2002	S20902	Sewer plant	50,000	Lower pond	Lagoon/basin
Buffalo WWTP	10/21/2008	S20902	N.E. side of lagoons cell #6	100,000	Breach in dam	Lagoon/basin
Waynoka WWTP	3/23/1990	S20904	Lift station #1	4,000	Check valve not holding	
Waynoka WWTP	3/23/1990	S20904		4,000	Valve failure	
Waynoka WWTP	6/22/1990	S20904	Ash street lift station	15,000	Electrical storm	
Waynoka WWTP	12/21/1990	S20904	Lift station	5,000	Power out	
Waynoka WWTP	5/3/1993	S20904	Main lift station		Heavy rains	
Waynoka WWTP	5/8/1993	S20904	Everywhere		Excessive rain/flooding	
Waynoka WWTP	5/8/1993	S20904	Lift station	50,000	Hydraulic overload from i/i and flooding	
Waynoka WWTP	5/18/1993	S20904	WWTP		Lift station and surrounding area flooded	
Waynoka WWTP	2/19/1997	S20904	South of Waynoka	10	Break in line	
Waynoka WWTP	4/13/1999	S20904	Cedar Street Bridge and various manholes		Floodwater & destroyed water line	
Waynoka WWTP	6/16/2005	S20904	Santa Fe & Flynn, Santa Fe & Missouri, & Broadway	5,000	Flooding	Manhole
Waynoka WWTP	5/15/2007	S20904			Rain	Manhole
Dacoma WWTP	2/23/1997	S20905	Manhole into a uninhabited pasture	1,500	Mechanical failure in lift station	

APPENDIX E

RESPONSE TO COMMENTS