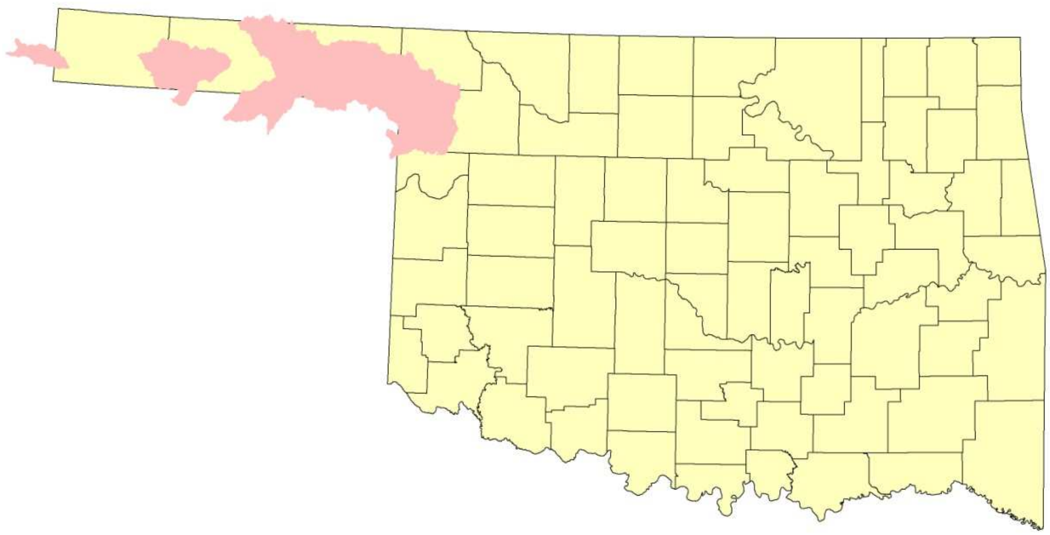
FINAL

BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR STREAMS IN THE BEAVER RIVER WATERSHED, OKLAHOMA



Prepared By:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

SEPTEMBER 2010

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BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR STREAMS IN THE BEAVER RIVER WATERSHED, OKLAHOMA

OKWBID

Beaver River	OK720510000190_00
Beaver River	OK720500020450_00
Beaver River	OK720500020290_00
Beaver River	OK720500020140_00
Beaver River	OK720500020010_00
Clear Creek	OK720500020300_00
Clear Creek	OK720500020070_00
Corrumpa Creek	OK720510000275_00
Duck Pond Creek	OK720500020250_00
Kiowa Creek	OK720500020130_00
Otter Creek	OK720500020050_00
Palo Duro Creek	OK720500020500_10
Palo Duro Creek	OK720500020500_00
Spring Creek	OK720500020100_00
Lower Wolf Creek	OK720500020030_00
Upper Wolf Creek	OK720500030010_00

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ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
ASAE	American Society of Agricultural Engineers
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
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
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWRB	Oklahoma Water Resources Board
PBCR	Primary body contact recreation
PRG	Percent reduction goal
SSO	Sanitary sewer overflow
TMDL	Total maximum daily load
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 Beaver 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 (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria 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 Beaver River watershed, identified in Table ES-1, that ODEQ 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
Beaver River at SH 95, near Guymon	OK720510000190_00	42.54	2016	4	X	X	X	N		
Beaver River at US 83, near Boyd	OK720500020450_00	28.20	2019	4	X	X	X	N		
Beaver River at US 270, Beaver	OK720500020290_00	31.37	2019	4	X	X	X	N		
Beaver River at US 64, near Rosston	OK720500020140_00	38.96	2019	4	X		X	N		
Beaver River at US 283, Laverne	OK720500020010_00	40.07	2016	3	X		X	N		
Buzzard Creek	OK720500030080_00	10.10	2019	4		X		N		
Clear Creek	OK720500020300_00	23.48	2019	4	X			N		
Clear Creek	OK720500020070_00	29.74	2019	4	X	X	X	N		
Corrumpa Creek	OK720510000275_00	12.94	2013	2	X	X	X	N		
Duck Pond Creek	OK720500020250_00	40.62	2016	3	X	X		N		
Kiowa Creek	OK720500020130_00	34.54	2019	4	X		X	N		
Otter Creek	OK720500020050_00	13.55	2016	3	X	X		N		
Palo Duro Creek	OK720500020500_10	4.40	2019	4	X		X	N		
Palo Duro Creek	OK720500020500_00	15.84	2019	4	X	X	X	N	X	N
Spring Creek	OK720500020100_00	6.67	2019	4	X	X		N		
Upper Wolf Creek	OK720500030010_00	43.05	2019	4	X	X		N		
Lower Wolf Creek	OK720500020030_00	5.57	2016	3					X	N

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

Table ES-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 1999-2008

Waterbody ID	Waterbody Name	Indicator Bacteria	Geo-Mean Concentration (count/100ml)	# of Samples	# of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	2008 303(d) Listing	Notes
OK720510000190_00	Beaver River near SH 95, Guymon	FC	469	22	12	54.5%	X	TMDL required
		ENT	383	22	21	95.5%	X	TMDL required
		EC	299	22	20	90.9%	X	TMDL required
OK720500020450_00	Beaver River at US 83, near Boyd	FC	472	19	10	52.6%	X	TMDL required
		ENT	282	19	13	68.4%	X	TMDL required
		EC	262	19	13	68.4%	X	TMDL required
OK720500020290_00	Beaver River at US 270, Beaver	FC	403	23	12	52.2%	X	TMDL required
		ENT	347	23	21	91.3%	X	TMDL required
		EC	322	23	14	60.9%	X	TMDL required
OK720500020140_00	Beaver River at US 64, near Rosston	FC	327	12	5	41.7%	X	TMDL required
		ENT	165	12	10	83.3%	X	TMDL required
		EC						
OK720500020010_00	Beaver River at US 283, Laverne	FC	106	25	8	32.0%	X	TMDL required
		ENT	58	25	16	64.0%	X	TMDL required
		EC						
OK720500030080_00	Buzzard Creek	FC		6	2			Delist: Low sample count
		ENT						
		EC		6			X	Delist: Low sample count
OK720500020300_00	Clear Creek	FC						
		ENT	54	24	15	62.5%	X	TMDL required
		EC						
OK720500020070_00	Clear Creek	FC	326	8	3	37.5%	X	TMDL required
		ENT	184	24	22	91.7%	X	TMDL required
		EC	146	24	12	50.0%	X	TMDL required
OK720510000275_00	Corrumpa Creek	FC	554	8	4	50.0%	X	TMDL required
		ENT		6			X	Delist: Low sample count
		EC		6			X	Delist: Low sample count
OK720500020250_00	Duck Pond Creek	FC						
		ENT	164	18	16	88.9%	X	TMDL required
		EC	131	18	9	50.0%	X	TMDL required

Waterbody ID	Waterbody Name	Indicator Bacteria	Geo-Mean Concentration (count/100ml)	# of Samples	# of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	2008 303(d) Listing	Notes
OK720500020130_00	Kiowa Creek	FC	311	15	6	40.0%	X	List: Does not meet standards
		ENT	162	47	41	87.2%	X	TMDL required
		EC	130	48	27	56.3%	X	TMDL required
OK720500020050_00	Otter Creek	FC						
		ENT	550	14	14	100%	X	TMDL required
		EC	495	14	12	85.7%	X	TMDL required
OK720500020500_10	Palo Duro Creek	FC	440	8	4	50.0%	X	TMDL required
		ENT	191	23	22	95.7%	X	TMDL required
		EC	193	24	13	54.2%		List: Does not meet standards
OK720500020500_00	Palo Duro Creek	FC	571	6	3	50.0%	X	TMDL required
		ENT		6			X	Delist: Low sample count
		EC		6			X	Delist: Low sample count
OK720500020100_00	Spring Creek	FC						
		ENT	512	17	17	100.0%	X	TMDL required
		EC	311	17	12	70.6%	X	TMDL required
OK720500030010_00	Upper Wolf Creek	FC	272	7	3	42.9%		List: Does not meet standards
		ENT	95	25	17	68.0%	X	TMDL required
		EC	113	26	10	38.5%	X	Delist: Geomean < 126
OK720500020030_00	Lower Wolf Creek	FC						
		ENT	52	17	12	70.6%		List: Does not meet standards
		EC						

EC = E. coli ; ENT = enterococci ; FC = fecal coliform Highlighted bacteria indicators require TMDL

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 1^{st} to September 30^{th}) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no 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 1999 and 2009 for turbidity under base flow conditions, which ODEQ considers to be all flows less than the 25^{th} flow exceedance percentile (i.e., the lower 75 percent of flows) Water quality samples collected under flow conditions greater than the 25^{th} 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 Exceeding 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK720500020500-001AT	Palo Duro Creek	7	4	57.1%	58.3
OK720500-02-0030M	Lower Wolf Creek	23	6	26.1%	32.8

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)
OK720500020500-001AT	Palo Duro Creek	7	108.9
OK720500-02-0030M	Lower Wolf Creek	30	28.4

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)
OK720500020500_00	Palo Duro Creek	0.86	13.6%	102
OK720500020030_00	Lower Wolf Creek	0.78	9.1%	39

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: Buzzard Creek (*E. coli*), Corrumpa Creek (Enterococci Enterococci and *E. coli*) and Palo Duro Creek segment OK720500020500_00 (Enterococci and *E. coli*). The following stream segments and their corresponding pollutants are recommended for listing after re-evaluation: Kiowa Creek (*E. coli*), Palo Duro Creek segment OK720500020500_10 (*E. coli*) and Lower Wolf Creek (Fecal Coliform). 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	ENT	*E. coli*	FC	Turbidity
Beaver River at SH 95, near Guymon	OK720510000190_00	X	X	X	
Beaver River at US 83, near Boyd	OK720500020450_00	X	X	X	
Beaver River at US 270, Beaver	OK720500020290_00	X	X	X	
Beaver River at US 64, near Rosston	OK720500020140_00	X		X	
Beaver River at US 283, Laverne	OK720500020010_00	X		X	
Clear Creek	OK720500020300_00	X			
Clear Creek	OK720500020070_00	X	X	X	
Corrumpa Creek	OK720510000275_00	X			
Duck Pond Creek	OK720500020250_00	X	X		
Kiowa Creek	OK720500020130_00	X	X	X	
Otter Creek	OK720500020050_00	X	X		
Palo Duro Creek	OK720500020500_10	X	X	X	
Palo Duro Creek	OK720500020500_00	X			X
Spring Creek	OK720500020100_00	X	X		
Upper Wolf Creek	OK720500030010_00	X	X		
Lower Wolf Creek	OK720500020030_00			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-6 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 ID	Waterbody Name	Municipal NPDES Facility	Industrial NPDES Facility	MS4	NPDES No Discharge Facility	CAFO	Mines	Construction Stormwater Permit	Nonpoint Source
OK720510000190_00	Beaver River at SH 95, near Guymon				Bacteria	Bacteria			Bacteria
OK720500020450_00	Beaver River at US 83, near Boyd				Bacteria	Bacteria			Bacteria
OK720500020290_00	Beaver River at US 270, Beaver					Bacteria			Bacteria
OK720500020140_00	Beaver River at US 64, near Rosston								Bacteria
OK720500020010_00	Beaver River at US 283, Laverne								Bacteria
OK720500020300_00	Clear Creek					Bacteria			Bacteria
OK720500020070_00	Clear Creek					Bacteria			Bacteria
OK720510000275_00	Corrumpa Creek								Bacteria
OK720500020250_00	Duck Pond Creek								Bacteria
OK720500020130_00	Kiowa Creek					Bacteria			Bacteria
OK720500020050_00	Otter Creek								Bacteria
OK720500020500_10	Palo Duro Creek								Bacteria
OK720500020500_00	Palo Duro Creek					Bacteria			Bacteria TSS
OK720500020100_00	Spring Creek					Bacteria			Bacteria
OK720500030010_00	Upper Wolf Creek				Bacteria	Bacteria			Bacteria
OK720500020030_00	Lower Wolf Creek								Bacteria TSS

No facility present in watershed.

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-7 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-7 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 19 to 88 percent. The appropriate PRG for each bacteria indicator for each waterbody in Table ES-8 is denoted by the bold text.

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
OK720510000190_00	Beaver River at SH 95, near Guymon	**71%**	99%	**62%**	99.8%	**92%**
OK720500020450_00	Beaver River at US 83, near Boyd	**83%**	95%	**57%**	100%	**89%**
OK720500020290_00	Beaver River at US 270, Beaver	**64%**	94%	**65%**	99.0%	**91%**
OK720500020140_00	Beaver River at US 64, near Rosston	**64%**			97%	**82%**
OK720500020010_00	Beaver River at US 283, Laverne	**22%**			87%	**49%**
OK720500020300_00	Clear Creek				89%	**45%**
OK720500020070_00	Clear Creek	**28%**	79%	**22%**	99%	**84%**
OK720510000275_00	Corrumpa Creek	**56%**				
OK720500020250_00	Duck Pond Creek		53%	**13%**	90%	**82%**
OK720500020130_00	Kiowa Creek	**28%**	81%	**13%**	99%	**82%**
OK720500020050_00	Otter Creek		96%	**77%**	99.9%	**95%**
OK720500020500_10	Palo Duro Creek	**65%**	79%	**41%**	90%	**84%**
OK720500020500_00	Palo Duro Creek	**64%**				
OK720500020100_00	Spring Creek		96%	**64%**	99%	**94%**
OK720500030010_00	Upper Wolf Creek	**28%**			98%	**69%**
OK720500020030_00	Lower Wolf Creek				56%	**43%**

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-8 and range from 31 to 76 percent.

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK720500020500_00	Palo Duro Creek	**86%**
OK720500020030_00	Lower Wolf Creek	**44%**

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

Average LA = average TMDL – MOS - ∑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, thus, allowable loads were calculated using targets that are 10 percent lower than the water quality criterion for each pathogen, which equates to 360 cfu/100 mL, 365.4 cfu/100 mL, and 97.2/100 mL for fecal coliform, *E. coli*, and Enterococci, respectively. This conservative approach to establishing the MOS will ensure that both the 30-day geometric mean and instantaneous bacteria standards can be achieved and maintained.

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 were 10 and 15 percent. Table 5-5 shows the MOS for each waterbody.

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 95 percent for bacteria and 86 percent for turbidity. 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 Beaver River Area. The 2008 Integrated Water Quality Assessment Report (Oklahoma Department of Environmental Quality [ODEQ] 2008) identified these 17 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 (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria 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 ODEQ 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:

Beaver River at SH 95, near Guymon	(OK720510000190_00)
Beaver River at US 83, near Boyd	(OK720500020450_00)
Beaver River at US 270, Beaver	(OK720500020290_00)
Beaver River at US 64, near Rosston	(OK720500020140_00)
Beaver River at US 283, Laverne	(OK720500020010_00)
Clear Creek	(OK720500020300_00)
Clear Creek	(OK720500020070_00)
Corrumpa Creek	(OK720510000275_00)
Duck Pond Creek	(OK720500020250_00)
Kiowa Creek	(OK720500020130_00)
Otter Creek	(OK720500020050_00)
Palo Duro Creek	(OK720500020500_10)
Palo Duro Creek	(OK720500020500_00)
Spring Creek	(OK720500020100_00)
Wolf Creek	(OK720500030010_00)
Wolf Creek	(OK720500020030_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	WQM Station Locations Descriptions
Beaver River at SH 95, near Guymon	OK720510000190_00	OK720510000190-001AT	S22-T03N-R13E Lat:36.70 Long:-101.63
Beaver River at US 83, near Boyd	OK720500020450_00	OK720500020450-001AT	S06-T03N-R21E Lat:36.75 Long:-100.84
Beaver River at US 270, Beaver	OK720500020290_00	OK720500020290-001AT	S07-T04N-R24E Lat:36.82 Long:-100.51
Beaver River at US 64, near Rosston	OK720500020140_00	OK720500020140-001AT	S28-T04N-R28E Lat:36.79 Long:-100.06
Beaver River at US 283, Laverne	OK720500020010_00	OK720500020010-001AT	S10-T26N-R25W Lat: 36.75 Long:-99.89
Buzzard Creek	OK720500030080_00	OK720500-03-0080G	SW¼ SE¼ SW¼ Section 1-21N-24W
Clear Creek	OK720500020300_00	OK720500-02-0300F OK720500-02-0300G	NE¼ NE¼ NE¼ Section 15-3N-24E NE¼ SE¼ NE¼ Section 8-2N-24E
Clear Creek	OK720500020070_00	OK720500-02-0070G	SE¼ SW¼ SW¼ Section 24-25N-25W
Corrumpa Creek	OK720510000275_00	OK720510-00-0275K	SW¼ SW¼ SW¼ Section 8-2N-1E
Duck Pond Creek	OK720500020250_00	OK720500-02-0250F	NW¼ NW¼ NE¼ Section 36-3N-25E
Kiowa Creek	OK720500020130_00	OK720500-02-0130M OK720500-02-0130K OK720500-02-0130C	NW¼ NW¼ NW¼ Section 12-1N-26E SE¼ SE¼ SE¼ Section 20-2N-27E NW¼ NW¼ NW¼ Section 14-26N-26W
Otter Creek	OK720500020050_00	OK720500-02-0050B	NE¼ SW¼ NW¼ Section 26-25N-24W
Palo Duro Creek	OK720500020500_10	OK720500-02-0500G	SE¼ SE¼ SE¼ Section 14-1N-18E
Palo Duro Creek	OK720500020500_00	OK720500020500-001AT	S28-T02N-R19E Lat:36.62 Long:-101.02
Spring Creek	OK720500020100_00	OK720500-02-0100D	NW¼ NW¼ NW¼ Section 15-25N-25W
Upper Wolf Creek	OK720500030010_00	OK720500-03-0010G OK720500-03-0010T OK720500-03-0010M	NE¼ NE¼ NE¼ Section 30-23N-22W SW¼ NW¼ NE¼ Section 16-21N-25W SW¼ SE¼ NW¼ Section 3-21N-24W
Lower Wolf Creek	OK720500020030_00	OK720500-02-0030M	NE¼ SE¼ SE¼ Section 9-24N-22W

1.2 Watershed Description

General. The watersheds in the Beaver River Study Area in this TMDL are located in either in or near the Panhandle in northwestern Oklahoma. The vast majority of the drainage area for the waterbodies included in this report is located in County. Small portions of the drainage areas are located northwestern corner of Woodward County.

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) with the exception of Texas and Counties which are densely populated.

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Area (square miles)	Population Density (per square mile)
Beaver	5,857	1,818	3
Cimarron	3,148	1,841	2
Ellis	4,075	1,232	3
Harper	3,562	1,041	3
Texas	20,107	2,049	10
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 16.6 and 24.9 inches (Oklahoma Climatological Survey 2005).

Table 1-3 Average Annual Precipitation by Stream Segment

Waterbody Name	Waterbody ID	Average Annual (Inches)
Beaver River at SH 95, near Guymon	OK720510000190_00	17.56
Beaver River at US 83, near Boyd	OK720500020450_00	19.14
Beaver River at US 270, Beaver	OK720500020290_00	19.87
Beaver River at US 64, near Rosston	OK720500020140_00	22.61
Beaver River at US 283, Laverne	OK720500020010_00	23.76
Buzzard Creek	OK720500030080_00	24.38
Clear Creek	OK720500020300_00	21.30
Clear Creek	OK720500020070_00	23.45
Corrumpa Creek	OK720510000275_00	16.63
Duck Pond Creek	OK720500020250_00	21.93
Kiowa Creek	OK720500020130_00	22.88
Otter Creek	OK720500020050_00	23.97
Palo Duro Creek	OK720500020500_10	20.01
Palo Duro Creek	OK720500020500_00	19.61
Spring Creek	OK720500020100_00	22.98
Upper Wolf Creek	OK720500030010_00	24.02
Lower Wolf Creek	OK720500020030_00	24.94

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

The dominant land use throughout 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								
	Beaver River at SH 95, near Guymon	Beaver River at US 83, near Boyd	Beaver River at US 270, Beaver	Beaver River at US 64, Rosston	Beaver River at US 283, Laverne	Buzzard Creek	Clear Creek	Clear Creek	Corrumpa Creek
Waterbody ID	OK720510000190_00	OK720500020450_00	OK720500020290_00	OK720500020140_00	OK720500020010_00	OK720500030080_00	OK720500020300_00	OK720500020070_00	OK720510000275_00
Barren	0.01%	0.05%	0.07%	0.17%	0.48%	0.10%	0.06%	0.40%	0.06%
Cultivated	24.52%	36.73%	38.17%	13.06%	14.83%	17.99%	31.45%	10.41%	1.25%
Deciduous Forest	0.00%	0.01%	0.06%	0.03%	0.02%	0.00%	0.02%	0.01%	0.00%
Developed High Intensity	0.01%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%
Developed Low Intensity	0.38%	0.19%	0.13%	0.06%	0.44%	0.59%	0.09%	0.10%	0.00%
Developed Medium Intensity	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Developed Open Space	2.31%	2.53%	2.89%	2.35%	2.67%	2.78%	2.69%	2.29%	0.37%
Evergreen Forest	0.00%	0.00%	0.00%	0.00%	0.03%	0.02%	0.00%	0.00%	0.19%
Grassland	69.74%	52.95%	51.86%	77.58%	70.13%	64.26%	58.18%	81.56%	91.95%
Herbaceous Wetland	0.01%	0.03%	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%	0.63%
Mixed Forest	0.00%	0.00%	0.00%	0.00%	0.14%	0.08%	0.00%	0.00%	0.00%
Pasture Hay	0.00%	0.00%	0.00%	0.21%	0.02%	0.00%	0.00%	0.00%	0.00%
Shrub	3.00%	7.35%	6.50%	5.53%	10.25%	13.85%	7.38%	4.52%	5.41%
Woody Wetland	0.00%	0.08%	0.25%	0.47%	0.27%	0.03%	0.13%	0.48%	0.14%
Water	0.02%	0.08%	0.03%	0.53%	0.70%	0.29%	0.01%	0.23%	0.01%
Total Percentage:	100%	100%	100%	100%	100%	100%	100%	100%	100%
Units in Acres									
Barren	60	326	354	704	3,668	30	82	296	75
Cultivated	120,829	226,976	198,253	55,692	112,947	5,300	42,188	7,687	1,641
Deciduous Forest	4	55	315	122	159	1	30	4	0
Developed High Intensity	41	19	8	3	104	2	0	0	0
Developed Low Intensity	1,882	1,153	669	235	3,383	173	127	73	2
Developed Medium Intensity	0	0	0	0	0	0	0	0	0
Developed Open Space	11,375	15,613	14,994	10,026	20,305	819	3,615	1,690	488
Evergreen Forest	0	0	6	1	246	6	0	0	253
Grassland	343,715	327,198	269,344	330,805	534,284	18,931	78,010	60,206	120,322
Herbaceous Wetland	45	189	116	39	111	0	1	1	819
Mixed Forest	0	0	1	2	1,053	24	0	1	0
Pasture Hay	0	0	0	909	153	0	0	0	0
Shrub	14,762	45,431	33,772	23,600	78,059	4,081	9,904	3,338	7,074
Woody Wetland	7	498	1,298	2,006	2,068	8	180	353	181
Water	109	500	198	2,275	5,297	85	12	170	10

Total (Acres)	492,828	617,958	519,328	426,420	761,837	29,461	134,150	73,819	130,866

Table 1-5 Land Use Summaries by Watershed

Land Use Category	**Stream Segments**							
	Duck Pond Creek	Kiowa Creek	Otter Creek	Palo Duro Creek	Palo Duro Creek	Spring Creek	Wolf Creek	Wolf Creek
Waterbody ID	OK720500020250_00	OK720500020130_00	OK720500020050_00	OK720500020500_00	OK720500020500_10	OK720500020100_00	OK720500030010_00	OK720500020030_00
Barren	0.12%	0.23%	0.08%	0.03%	0.12%	0.18%	0.65%	0.64%
Cultivated	32.26%	11.69%	20.65%	31.86%	45.90%	17.39%	15.08%	14.91%
Deciduous Forest	0.02%	0.02%	0.00%	0.00%	0.02%	0.00%	0.03%	0.03%
Developed High Intensity	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%
Developed Low Intensity	0.07%	0.05%	0.19%	0.10%	0.03%	0.24%	0.46%	0.48%
Developed Medium Intensity	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Developed Open Space	1.96%	2.26%	3.02%	1.86%	2.29%	4.27%	2.28%	2.32%
Evergreen Forest	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.05%
Grassland	56.20%	79.17%	74.49%	59.58%	47.15%	75.40%	65.81%	66.15%
Herbaceous Wetland	0.01%	0.00%	0.01%	0.03%	0.01%	0.00%	0.00%	0.00%
Mixed Forest	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.21%
Pasture Hay	0.00%	0.00%	0.20%	0.00%	0.00%	0.00%	0.01%	0.01%
Shrub	9.04%	6.06%	0.09%	6.41%	4.24%	1.39%	14.81%	14.60%
Woody Wetland	0.25%	0.49%	0.90%	0.10%	0.03%	0.70%	0.10%	0.10%
Water	0.06%	0.07%	0.37%	0.03%	0.23%	0.42%	0.49%	0.49%
Total Percentage:	100%	100%	100%	100%	100%	100%	100%	100%
Units in Acres								
Barren	79	416	24	194	121	48	3,200	3,200
Cultivated	21,631	21,253	5,817	123,572	45,298	4,643	73,941	74,299
Deciduous Forest	15	29	1	26	15	0	129	129
Developed High Intensity	0	3	0	0	0	2	54	65
Developed Low Intensity	47	83	54	269	29	65	2,250	2,389
Developed Medium Intensity	0	0	0	0	0	0	0	0
Developed Open Space	1,313	4,112	850	6,833	2,255	1,139	11,163	11,538
Evergreen Forest	0	0	0	0	0	0	225	246
Grassland	37,680	144,214	20,983	192,922	46,530	20,134	322,629	329,520
Herbaceous Wetland	9	1	2	88	8	0	7	7
Mixed Forest	1	1	0	0	0	0	1,046	1,049
Pasture Hay	0	0	55	0	0	0	27	27
Shrub	6,063	11,029	26	19,931	4,181	370	72,614	72,723
Woody Wetland	168	896	253	276	28	188	508	509

Water	37	119	104	274	224	113	2,415	2,457
Total (Acres)	67,044	182,156	28,169	344,386	98,689	26,703	490,210	498,158

Figure 1-1 Beaver River Watersheds Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation

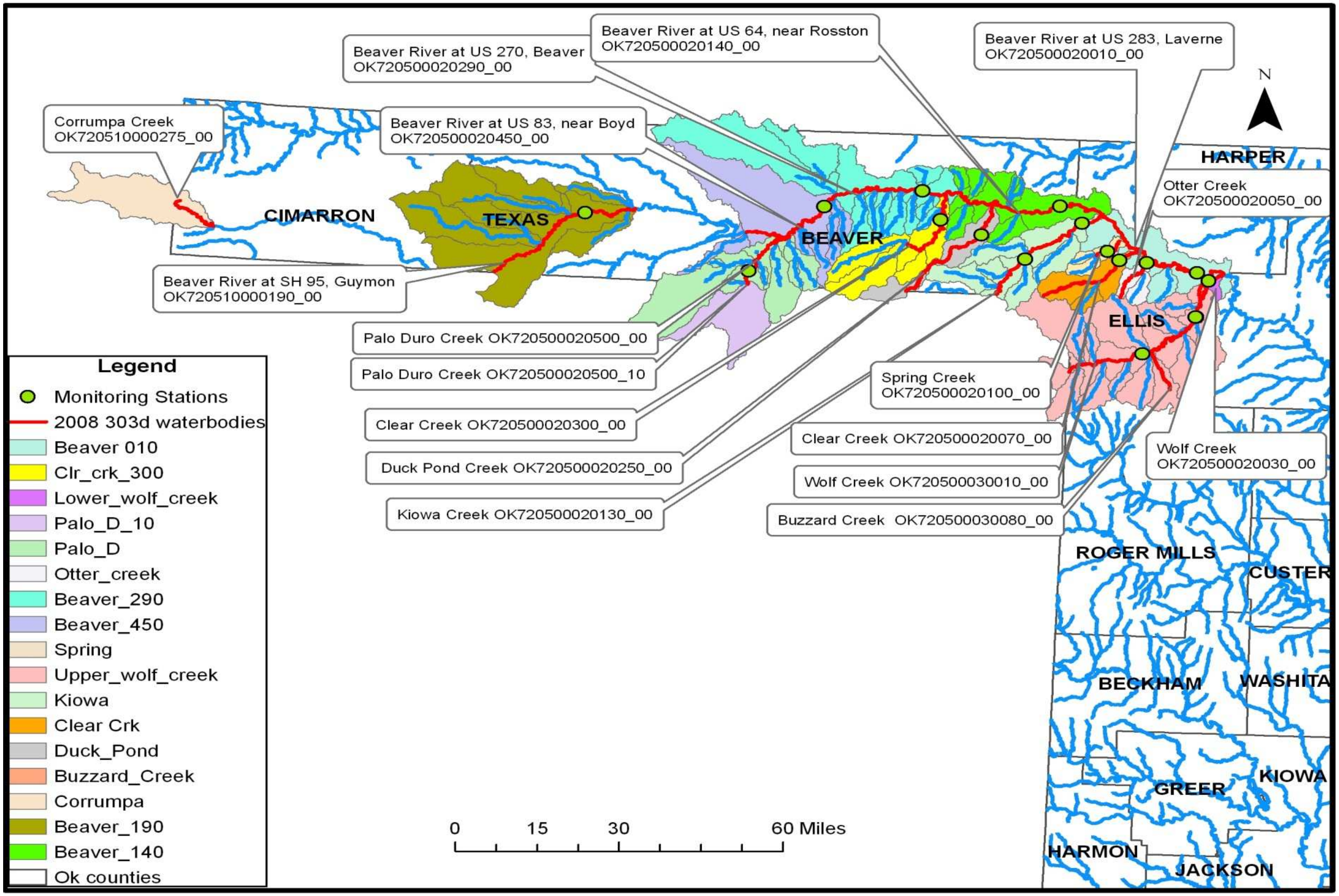
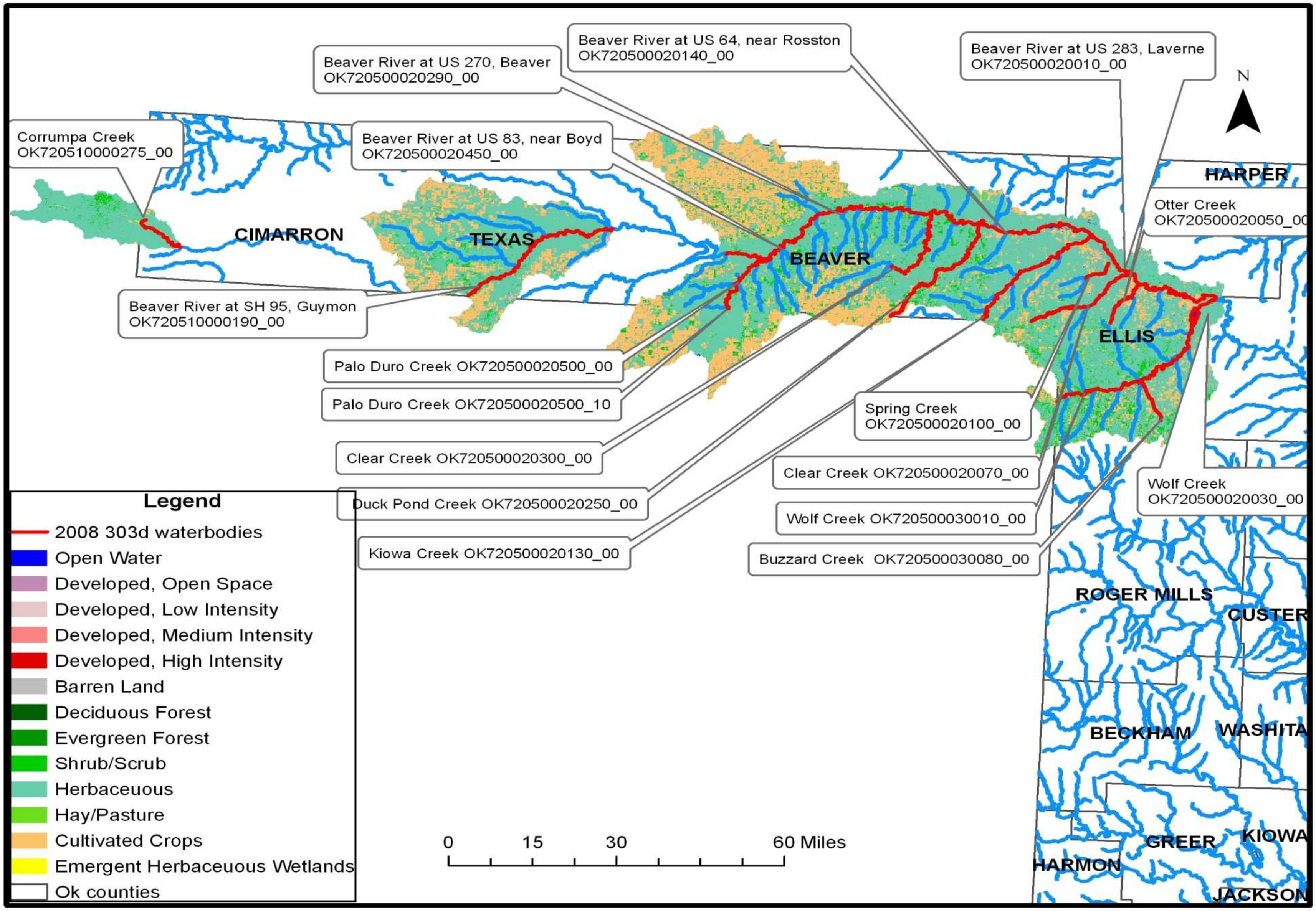


Figure 1-2 Beaver River Watersheds Land Use Map



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 2-1a, an excerpt from the 2008 Integrated Report (ODEQ 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
- HLAC – Habitat Limited Aquatic Community
- WWAC – Warm Water Aquatic Community
- FISH – Fish Consumption
- PBCR – Primary Body Contact Recreation
- SBCR – Secondary Body Contact Recreation
- PPWS – Public & Private Water Supply
- EWS – Emergency Water Supply
- SWS – Sensitive 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 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.

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
Beaver River at SH 95, near Guymon	OK720510000190_00	42.54	2016	4	X	X	X	N		
Beaver River at US 83, near Boyd	OK720500020450_00	28.20	2019	4	X	X	X	N		
Beaver River at US 270, Beaver	OK720500020290_00	31.37	2019	4	X	X	X	N		
Beaver River at US 64, near Rosston	OK720500020140_00	38.96	2019	4	X		X	N		
Beaver River at US 283, Laverne	OK720500020010_00	40.07	2016	3	X		X	N		
Buzzard Creek	OK720500030080_00	10.10	2019	4		X		N		
Clear Creek	OK720500020300_00	23.48	2019	4	X			N		
Clear Creek	OK720500020070_00	29.74	2019	4	X	X	X	N		
Corrumpa Creek	OK720510000275_00	12.94	2013	2	X	X	X	N		
Duck Pond Creek	OK720500020250_00	40.62	2016	3	X	X		N		
Kiowa Creek	OK720500020130_00	34.54	2019	4	X		X	N		
Otter Creek	OK720500020050_00	13.55	2016	3	X	X		N		
Palo Duro Creek	OK720500020500_10	4.40	2019	4	X		X	N		
Palo Duro Creek	OK720500020500_00	15.84	2019	4	X	X	X	N	X	N
Spring Creek	OK720500020100_00	6.67	2019	4	X	X		N		
Upper Wolf Creek	OK720500030010_00	43.05	2019	4	X	X		N		
Lower Wolf Creek	OK720500020030_00	5.57	2016	3					X	N

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

Table 2-1a Designated Beneficial Uses for Each Impaired Waterbody in the Study Area

Waterbody ID	Waterbody Name	AES	AG	WWAC	*FISH*	PBCR	PPWS	Limitation
OK720510000190_00	Beaver River at SH 95, near Guymon	I	F	F	I	N	I	
OK720500020450_00	Beaver River at US 83, near Boyd	I	N	F	I	N		
OK720500020290_00	Beaver River at US 270, Beaver	I	N	F	I	N		
OK720500020140_00	Beaver River at US 64, near Rosston	I	N	I	I	N		
OK720500020010_00	Beaver River at US 283, Laverne	I	F	I	I	N		
OK720500030080_00	Buzzard Creek	F	F	I	X	N	I	SWS
OK720500020300_00	Clear Creek	I	F	N	X	N	I	
OK720500020070_00	Clear Creek	I	F	I	I	N	I	
OK720510000275_00	Corrumpa Creek	F	F	N	X	N	X	HQW
OK720500020250_00	Duck Pond Creek	I	F	N	X	N	I	
OK720500020130_00	Kiowa Creek	I	F	I	I	N	I	
OK720500020050_00	Otter Creek	F	F	N	X	N	I	
OK720500020500_10	Palo Duro Creek	I	F	N	X	N	I	
OK720500020500_00	Palo Duro Creek	I	N	N	I	N	I	
OK720500020100_00	Spring Creek	I	F	I	X	N		
OK720500030010_00	Upper Wolf Creek	I	F	F	I	N	I	SWS
OK720500020030_00	Lower Wolf Creek	F	F	N	X	I		

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 1999 and 2009 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 ODEQ 2008 303(d) list (ODEQ 2008). Water quality data from the primary contact recreation seasons are provided in Appendix A. For the data collected between 1999 and 2008, evidence of nonsupport of the PBCR use based on fecal coliform, Enterococci and *E. coli* concentrations was observed in six waterbodies; Beaver River at SH 95, near Guymon (OK720510000190_00), Beaver River at US 83, near Boyd (OK720510000450_00), Beaver River at US 270, Beaver (OK720510000290_00.), Clear Creek (OK720500020070_00), Kiowa Creek (OK720500020130_00) and Palo Duro Creek (OK720500020500_10). Evidence of nonsupport of the PBCR use based on fecal coliform and Enterococci exceedances was observed in three waterbodies: Beaver River at US 64, near Rosston (OK720500020140_00), Beaver River at US 283, Laverne (OK720500020010_00), and Upper Wolf Creek (OK720500030010_00). Evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci exceedances was observed in three waterbodies: Duck Pond Creek (OK720500020250_00), Otter Creek (OK720500020050_00), and Spring Creek (OK720500020100_00). Evidence of nonsupport of the PBCR use based on fecal coliform exceedances only was observed in two waterbodies: Corrumpa Creek (OK720510000275_00) and Palo Duro Creek (OK720500020500_00). Evidence of nonsupport of the PBCR use based on Enterococci exceedances only was observed in two waterbodies, Clear Creek (OK720500020300_00) and Lower Wolf Creek (OK7205000200030_00). No Evidence of nonsupport of the PBCR use based on *E. coli* exceedances was observed in Buzzard Creek (OK720500030080_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 1999 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, ODEQ considers base flow conditions to be all flows less than the 25^{th} 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 25^{th} 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 two of the waterbodies listed in Table 2-1 (Palo Duro Creek OK720500020500_00 and Lower Wolf Creek OK7205000200030_00) on the ODEQ 2008 303(d) list (ODEQ 2008) for nonsupport of the WWAC use based on turbidity levels observed in the waterbody. Table 2-5 summarizes water quality data collected from the WQM stations between 1999 and 2009 for TSS. Table 2-6 presents a subset of these data for samples collected during base flow conditions. 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 2-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 1999-2008

Waterbody ID	Waterbody Name	Indicator Bacteria	Geo-Mean Concentration (count/100ml)	# of Samples	# of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	2008 303(d) Listing	Notes
OK720510000190_00	Beaver River at SH 95, near Guymon	FC	469	22	12	54.5%	X	TMDL required
		ENT	383	22	21	95.5%	X	TMDL required
		EC	299	22	20	90.9%	X	TMDL required
OK720500020450_00	Beaver River at US 83, near Boyd	FC	472	19	10	52.6%	X	TMDL required
		ENT	282	19	13	68.4%	X	TMDL required
		EC	262	19	13	68.4%	X	TMDL required
OK720500020290_00	Beaver River at US 270, Beaver	FC	403	23	12	52.2%	X	TMDL required
		ENT	347	23	21	91.3%	X	TMDL required
		EC	322	23	14	60.9%	X	TMDL required
OK720500020140_00	Beaver River at US 64, near Rosston	FC	327	12	5	41.7%	X	TMDL required
		ENT	165	12	10	83.3%	X	TMDL required
		EC						
OK720500020010_00	Beaver River at US 283, Laverne	FC	106	25	8	32.0%	X	TMDL required
		ENT	58	25	16	64.0%	X	TMDL required
		EC						
OK720500030080_00	Buzzard Creek	FC		6	2			Delist: Low sample count
		ENT						
		EC		6			X	Delist: Low sample count
OK720500020300_00	Clear Creek	FC						
		ENT	54	24	15	62.5%	X	TMDL required
		EC						
OK720500020070_00	Clear Creek	FC	326	8	3	37.5%	X	TMDL required
		ENT	184	24	22	91.7%	X	TMDL required
		EC	146	24	12	50.0%	X	TMDL required
OK720510000275_00	Corrumpa Creek	FC	554	8	4	50.0%	X	TMDL required
		ENT		6			X	Delist: Low sample count
		EC		6			X	Delist: Low sample count
OK720500020250_00	Duck Pond Creek	FC						
		ENT	164	18	16	88.9%	X	TMDL required
		EC	131	18	9	50.0%	X	TMDL required

Waterbody ID	Waterbody Name	Indicator Bacteria	Geo-Mean Concentration (count/100ml)	# of Sample s	# of Samples Exceeding Single Sample Criterion	% of Samples Exceeding Single Sample Criterion	2008 303(d) Listing	Notes
OK720500020130_00	Kiowa Creek	FC	311	15	6	40.0%	X	List: Does not meet standards
		ENT	162	47	41	87.2%	X	TMDL required
		EC	130	48	27	56.3%	X	TMDL required
OK720500020050_00	Otter Creek	FC						
		ENT	550	14	14	100%	X	TMDL required
		EC	495	14	12	85.7%	X	TMDL required
OK720500020500_10	Palo Duro Creek	FC	440	8	4	50.0%	X	TMDL required
		ENT	191	23	22	95.7%	X	TMDL required
		EC	193	24	13	54.2%		List: Does not meet standards
OK720500020500_00	Palo Duro Creek	FC	571	6	3	50.0%	X	TMDL required
		ENT		6			X	Delist: Low sample count
		EC		6			X	Delist: Low sample count
OK720500020100_00	Spring Creek	FC						
		ENT	512	17	17	100.0%	X	TMDL required
		EC	311	17	12	70.6%	X	TMDL required
OK720500030010_00	Upper Wolf Creek	FC	272	7	3	42.9%		List: Does not meet standards
		ENT	95	25	17	68.0%	X	TMDL required
		EC	113	26	10	38.5%	X	Delist: Geomean < 126
OK720500020030_00	Lower Wolf Creek	FC						
		ENT	52	17	12	70.6%		List: Does not meet standards
		EC						

EC = E. coli ; ENT = enterococci ; FC = fecal coliform   Highlighted bacteria indicators require TMDL

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

WQM Station	Waterbody ID	Waterbody Name	Indicator Bacteria		
			FC	ENT	*E. coli*
OK720510000190-001AT	OK720510000190_00	Beaver River at SH 95, near Guymon	X	X	X
OK720500020450-001AT	OK720500020450_00	Beaver River at US 83, near Boyd	X	X	X
OK7205000204290-001AT	OK720500020290_00	Beaver River at US 270, Beaver	X	X	X
OK720500020140-001AT	OK720500020140_00	Beaver River at US 64, near Rosston	X	X	
OK720500020010-001AT	OK720500020010_00	Beaver River at US 283, Laverne	X	X	
OK720500-02-0300F OK720500-02-0300G	OK720500020300_00	Clear Creek		X	
OK720500-02-0070G	OK720500020070_00	Clear Creek	X	X	X
OK720510-00-0275K	OK720510000275_00	Corrumpa Creek	X		
OK720500-02-0250F	OK720500020250_00	Duck Pond Creek		X	X
OK720500-02-0130M OK720500-02-0130K OK720500-02-0130C	OK720500020130_00	Kiowa Creek	X	X	X
OK720500-02-0050B	OK720500020050_00	Otter Creek		X	X
OK720500-02-0500G	OK720500020500_10	Palo Duro Creek	X	X	X
OK720500020500-001AT	OK720500020500_00	Palo Duro Creek	X		
OK720500-02-0100D	OK720500020100_00	Spring Creek		X	X
OK720500-03-0010G OK720500-03-0010T OK720500-03-0010M	OK720500030010_00	Upper Wolf Creek	X	X	
OK720500-02-0030M	OK720500020030_00	Lower Wolf Creek		X	

ENT = enterococci; FC = fecal Coliform

Table 2-4 Summary of All Turbidity Samples 1999 - 2009

WQM Station	Waterbody Name	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK720500020500-001AT	Palo Duro Creek	10	4	40.0%	42.6
OK720500-02-0030M	Lower Wolf Creek	32	7	21.9%	32.6

Table 2-5 Summary of Turbidity Samples Collected During Base Flow Conditions 1999 - 2009

WQM Station	Waterbody Name	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK720500020500-001AT	Palo Duro Creek	7	4	57.1%	58.3
OK720500-02-0030M	Lower Wolf Creek	23	6	26.1%	32.8

Table 2-6 summarizes water quality data collected from the WQM stations between 1999 and 2009 for TSS. Table 2-7 presents a subset of these data for samples collected during base flow conditions. Water quality data for turbidity and TSS are provided in Appendix A.

Table 2-6 Summary of All TSS Samples 1999 - 2009

WQM Station	Waterbody Name	Number of TSS Samples	Average TSS (mg/L)
OK720500020500-001AT	Palo Duro Creek	10	82.8
OK720500-02-0030M	Lower Wolf Creek	30	28.4

Table 2-7 Summary of TSS Samples Excluding High Flow Samples

WQM Station	Waterbody Name	Number of TSS Samples	Average TSS (mg/L)
OK720500020500-001AT	Palo Duro Creek	7	108.9
OK720500-02-0030M	Lower Wolf Creek	30	28.4

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.

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

(126/100 mL). For Enterococci the instantaneous water quality target is 97/100 mL, which is 10 percent lower than the criterion value (108/100 mL) and the geometric mean water quality target is 30 organisms/100 mL, which is 10 percent lower than the criterion value (33/100 mL).

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 (ODEQ 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 include:

- 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 ODEQ 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.

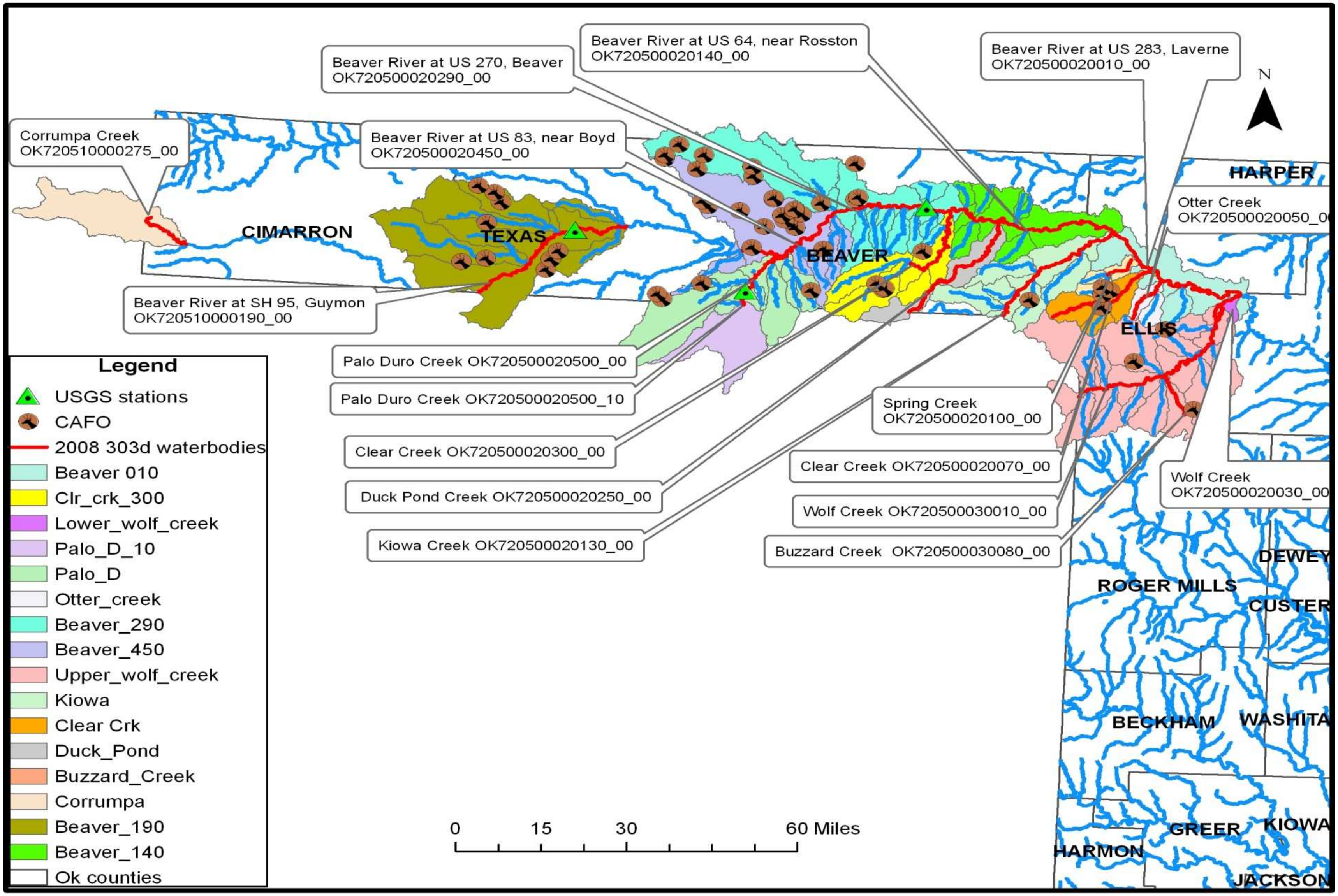
There are no NPDES-permitted facilities of any type in the contributing watersheds of Beaver River at US 64, near Rosston (OK720500020140_00), Corrumpa Creek (OK720510000275_00), Duck Pond Creek (OK720500020250_00), Kiowa Creek (OK720500020130_00), Palo Duro Creek (OK720500020500_10), Palo Duro Creek (OK720500020500_00), Spring Creek (OK720500020100_00) and Lower Wolf Creek (OK720500020030_00).

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

3.1.1 Continuous Point Source Discharges

There are no NPDES permitted facilities within the Study Area.

Figure 3-1 Location of NPDES-permitted Facilities in the Beaver River Watershed



3.1.2 NPDES No-Discharge Facilities and Sanitary Sewer Overflows

There are 17 recorded no-discharge facilities in the Study Area. 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.

Table 3-1 NPDES No-Discharge Facilities in the Study Area

Facility	Facility ID	County	Facility Type	Type	Watershed
Behne Construction Co., Inc.	OKG11T026	Texas	Total Retention	Industrial	Beaver River at SH 95, near Guymon OK720510000190_00
Hitch Pork producers Inc	OKGC3T028	Texas	Total Retention	Industrial	Beaver River at SH 95, near Guymon OK720510000190_00
J-A-G Construction Co.	OKG11T023	Texas	Total Retention	Industrial	Beaver River at SH 95, near Guymon OK720510000190_00
Texhoma WWT	S20503	Texas	Lagoon (Total Retention)	Municipal	Beaver River at SH 95, near Guymon OK720510000190_00
Vall Inc Truck Wash Facility	WD97-017	Texas	Total Retention	Industrial	Beaver River at SH 95, near Guymon OK720510000190_00
Hooker WWT	S20507	Texas	Lagoon (Total Retention)	Municipal	Beaver River at US 83, near Boyd OK720500020450_00
Texas Co. RSD #1 (Adams) WWT	S20509	Texas	Lagoon (Total Retention)	Municipal	Beaver River at US 83, near Boyd OK720500020450_00
Beaver Co. RSD # 1 WWT	S20511	Beaver	Lagoon (Total Retention)	Municipal	Beaver River at US 270, Beaver OK720500020290_00
Forgan WWT	S20513	Beaver	Lagoon (Total Retention)	Municipal	Beaver River at US 270, Beaver OK720500020290_00
Fargo WWT	S20519	Ellis	Lagoon (Total Retention)	Municipal	Beaver River at US 283, Laverne OK720500020010_00
Gage WWT	S20518	Ellis	Lagoon (Total Retention)	Municipal	Beaver River at US 83, near Boyd OK720500020450_00
Shattuck WWT	S20517	Ellis	Lagoon (Total Retention)	Municipal	Beaver River at US 83, near Boyd OK720500020450_00
Fort Supply WWT	S20515	Woodward	Lagoon (Total Retention)	Municipal	Beaver River at US 83, near Boyd OK720500020450_00
Key Correctional Facility	S20516	Woodward	Land Application	Municipal	Beaver River at US 83, near Boyd OK720500020450_00
Laverne WWT	S20514	Harper	Land Application	Municipal	Beaver River at US 83, near Boyd OK720500020450_00
Morris Welding Washout	WD90-034	Harper	Total Retention	Industrial	Clear Creek OK720500020070_00
Balko school	S20593	Beaver	Lagoon (Total Retention)	Municipal	Clear Creek OK720500020300_00

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, ODEQ 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.

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

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

3.1.3 NPDES Municipal Separate Storm Sewer Discharge

Bacteria

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. There are no permitted MS4s within the study area.

Turbidity

There are no urbanized areas designated as MS4s within this Study Area. A general stormwater permit is required for construction activities. Permittees are authorized to discharge pollutants in stormwater runoff associated with construction activities for construction sites. 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. ODEQ provides information on the current status of its MS4 program on its website, found at:

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

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 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 is designed to protect water quality through the use of best management practices (BMP) such as dikes, berms, terraces, ditches, or other similar structures used to isolate animal waste from outside surface drainage, except for a 25-year, 24–hour rainfall event (ODAFF 2009). CAFOs are considered no-discharge facilities.

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.

Regulated CAFOs within the watershed operate under NPDES and State permits issued and overseen by EPA and ODAFF. 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. The locations of the CAFOs were shown in Figures 3-1 and listed in Table 3-2.

3.1.5 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 of Oklahoma will use its Section 401 certification authority to ensure Section 404 permits protect Oklahoma water quality standards.

Table 3-2 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	Horses			
WQ0000162		335	980026		5349		2014	Ellis	Upper Wolf Creek OK720500030010_00
AGN026104	OKG010078	279	1231	12600			12600	Ellis	Upper Wolf Creek OK720500030010_00
WQ0000317	OKG010235	333	1360	10000			10000	Ellis	Upper Wolf Creek OK720500030010_00
200719	OKU000238	181	980006		15000		6000	Ellis	Clear Creek OK720500020070_00
WQ0000215		441	200201		3840		1536	Beaver	Kiowa Creek OK720500020130_00
WQ0000049	OKG010340	124	970009		11060		4424	Texas	Palo Duro Creek OK720500020500_00
WQ0000157	OKU000499	353	980012		14945		5978	Ellis	Spring Creek OK720500020100_00
WQ0000120	OKU000490	280	980020		7560		3024	Beaver	Palo Duro Creek OK720500020500_00
200720	OKU000402	180	980011		30976		11670	Ellis	Clear Creek OK720500020070_00
WQ0000248	OKU000498	396	200001		10000		1600	Beaver	Clear Creek OK720500020300_00
WQ200204	OKU000430	459	200204		5740		2296	Beaver	Clear Creek OK720500020300_00
WQ0000157	OKU000499	179	980012		14945		5978	Harper	Spring Creek OK720500020100_00
WQ0000121	OKG010321	285	1359		2950		1180	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000135	OKG010329	295	1379		8640		864	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000248	OKU000498	395	200001		16000		1600	Beaver	Clear Creek OK720500020300_00
WQ0000099	OKU000257	241	970032		21600		8640	Texas	Palo Duro Creek OK720500020500_00

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	Horses			
WQ0000304		381	990008	4500			4500	Beaver	Beaver River at US 83, near Boyd OK720500020450_00
AGN031433	OKG010171	331	1337		1672		669	Beaver	Clear Creek OK720500020300_00
AGN007220	OKG010046	225	74	75000			75000	Texas	Beaver River at US 83, near Boyd OK720500020450_00
AGN031789	OKG010047	80	1376		3344		1338	Beaver	Beaver River at US 83, near Boyd OK720500020450_00
WQ0000110	OKU000375	251	970027		8640		3456	Texas	Beaver River at US 83, near Boyd OK720500020450_00
AGN031951	OKG010206	22	1412		7200		2880	Texas	Beaver River at US 83, near Boyd OK720500020450_00
AGN031950	OKG010205	20	1410		8067		2135	Texas	Beaver River at US 83, near Boyd OK720500020450_00
AGN022163	OKG010225	15	1157		5363		1482	Beaver	Beaver River at US 83, near Boyd OK720500020450_00
AGN032024	OKG010082	310	1430	1000			1000	Texas	Beaver River at US 83, near Boyd OK720500020450_00
AGN031946	OKG010203	384	1406		16134		4270	Beaver	Beaver River at US 83, near Boyd OK720500020450_00
WQ0000095	OKU000453	237	970013		8640		3456	Texas	Beaver River at US 83, near Boyd OK720500020450_00
AGN007238	OKG010009	281	93	30000			30000	Beaver	Beaver River at US 270, Beaver OK720500020290_00
WQ0000116	OKU000451	257	970021		8640		3456	Texas	Beaver River at US 83, near Boyd OK720500020450_00
AGN031953	OKG010207	23	1413		8067		2135	Texas	Beaver River at US 83, near Boyd OK720500020450_00
WQ0000267	OKU000245	443	990011		26250		10500	Beaver	Beaver River at US 270, Beaver OK720500020290_00
WQ0000111	OKU000260	252	970028		39960		15984	Texas	Beaver River at US 270, Beaver OK720500020290_00
200223	OKU000293	482	200223		9074		3630	Texas	Beaver River at US 83, near Boyd OK720500020450_00

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	Horses			
WQ0000107	OKU000259	248	970026		17280		6912	Texas	Beaver River at US 270, Beaver OK720500020290_00
WQ0000279	OKU000399	455	200203		28350		11340	Beaver	Beaver River at US 270, Beaver OK720500020290_00
WQ0000253	OKU000494	383	990010		7560		3024	Texas	Beaver River at US 83, near Boyd OK720500020450_00
WQ0000114	OKU000293	255	980001		5400		2160	Texas	Beaver River at US 270, Beaver OK720500020290_00
WQ0000252		382	990009		7560		3024	Texas	Beaver River at US 270, Beaver OK720500020290_00
WQ0000108	OKU000290	249	980009		5400		2160	Texas	Beaver River at US 270, Beaver OK720500020290_00
WQ0000129	OKG010327	290	980015		2950		1180	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000137	OKG010332	298	980018		8640		864	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000281	OKG010333	362	990007		8640		864	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000328	OKU000292	402	200006		2835		1134	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
200205	OKG010325	460	200205		2950		1180	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000143	OKG010328	302	980016		2950		1180	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000258	OKU000288	360	990005		2835		1134	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000150	OKU000284	322	980024		8640		3456	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000105	OKU000286	246	970015		2835		1134	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
AGN031633	OKG010022	69	1365	1000		8	1016	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000125	OKG010323	287	1488		2950		1180	Texas	Beaver River at SH 95, near Guymon OK720510000190_00

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	Horses			
WQ0000124	OKG010322	286	1471		2950		1180	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000138	OKG010330	332	1476		8640		864	Cimarron	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000126	OKG010324	288	970041		2950		1180	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000139	OKG010331	299	1496		8640		864	Texas	Beaver River at SH 95, near Guymon OK720510000190_00
WQ0000112	OKU000400	253	970017		424		170	Texas	Beaver River at SH 95, near Guymon OK720510000190_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 and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems and domestic pets. Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's 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 nonpermitted 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 (ODEQ 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. Table 3-3 provides the estimated number of deer for each watershed.

Table 3-3 Estimated Deer Populations

Waterbody ID	Waterbody Name	Deer	Acre
OK720510000190_00	Beaver River at SH 95, near Guymon	557	492,828
OK720500020450_00	Beaver River at US 83, near Boyd	476	617,958
OK720500020450_00	Beaver River at US 270, Beaver	845	519,328
OK720500020140_00	Beaver River at US 64, near Rosston	934	426,420
OK720500020010_00	Beaver River at US 283, Laverne	3,182	761,837
OK720500020300_00	Clear Creek	262	134,150
OK720500020070_00	Clear Creek	325	73,819
OK720510000275_00	Corrumpa Creek	11	130,866
OK720500020250_00	Duck Pond Creek	119	67,044
OK720500020130_00	Kiowa Creek	393	182,156
OK720500020050_00	Otter Creek	154	28,169
OK720500020500_00	Palo Duro Creek	145	344,386
OK720500020500_10	Palo Duro Creek	2	98,689
OK720500020100_00	Spring Creek	134	26,703
OK720500030010_00	Upper Wolf Creek	1,916	490,210
OK720500020030_00	Lower Wolf Creek	1,916	498,158

According to a study conducted by ASAE (the American Society of Agricultural Engineers), deer release approximately $5x10^8$ fecal coliform units per animal per day (ASAE 1999). Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production for deer provided in Table 3-4 in cfu/day provides a relative magnitude of loading in each watershed.

Table 3-4 Estimated Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 10^9 cfu/day) of Deer Population
OK720510000190_00	Beaver River at SH 95, near Guymon	492,828	557	0.0011	279
OK720500020450_00	Beaver River at US 83, near Boyd	617,958	476	0.0008	238
OK720500020290_00	Beaver River at US 270, Beaver	519,328	845	0.0016	423
OK720500020140_00	Beaver River at US 64, near Rosston	426,420	934	0.0022	467
OK720500020010_00	Beaver River at US 283, Laverne	761,837	3182	0.0042	1,591
OK720500020300_00	Clear Creek	134,150	262	0.0020	131
OK720500020070_00	Clear Creek	73,819	325	0.0044	163
OK720510000275_00	Corrumpa Creek	130,866	11	0.0001	5
OK720500020250_00	Duck Pond Creek	67,044	119	0.0018	60
OK720500020130_00	Kiowa Creek	182,156	393	0.0022	197
OK720500020050_00	Otter Creek	28,169	154	0.0055	77
OK720500020500_00	Palo Duro Creek	344,386	145	0.0004	73
OK720500020500_10	Palo Duro Creek	98,689	2	0.0000	1
OK720500020100_00	Spring Creek	26,703	134	0.0050	67
OK720500030010_00	Upper Wolf Creek	490,210	1916	0.0039	958
OK720500020030_00	Lower Wolf Creek	498,158	1916	0.0038	958

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 3-5 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 3-5 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 generate the largest amount of fecal coliform and often have direct access to the impaired waterbodies.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application of manure. The estimated acreage by watershed where manure was applied in 2002 is shown in Table 3-5. These estimates are also based on the county level reports from the 2002 USDA county agricultural census, and thus represent approximations of the land application area in each watershed. Because of the lack of specific data, for the purpose of these TMDLs, land application of animal manure is not quantified in Table 3-6 but is considered a potential source of bacteria loading to the waterbodies in the Study Area. Most poultry feeding operations are regulated by ODAFF, and are required to land apply chicken waste in accordance with their Animal Waste Management Plans or Comprehensive Nutrient Management Plans. While these plans are not designed to control bacteria loading, best management practices and conservation measures, if properly implemented, could greatly reduce the contribution of bacteria from this group of animals to the watershed.

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 3-6. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into streams by runoff or by direct deposition from wading animals. Cattle appear to represent the largest source of fecal bacteria.

According to data provided by Oklahoma Department of Agriculture, Food, and Forestry (ODAFF), there are fifty five (55) CAFOs or poultry operations in the study area (Figure 3-1).

Table 3-5 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
OK720510000190_00	Beaver River at SH 95, near Guymon	166,758	80	764	0	97	310,964	4	337	3,175
OK720500020450_00	Beaver River at US 83, near Boyd	130,983	88	423	0	65	237,018	6	326	2,377
OK720500020290_00	Beaver River at US 270, Beaver	53,534	113	402	0	84	138,605	10	143	3,898
OK720500020140_00	Beaver River at US 64, near Rosston	35,593	100	314	0	87	49,507	10	92	3,272
OK720500020010_00	Beaver River at US 283, Laverne	68,655	312	748	0	604	9,960	16	310	2,568
OK720500020300_00	Clear Creek	10,838	31	96	0	22	16,927	3	28	1,029
OK720500020070_00	Clear Creek	6,296	32	67	0	33	3,270	1	22	336
OK720510000275_00	Corrumpa Creek	9,358	1	23	0	12	2	0	16	339
OK720500020250_00	Duck Pond Creek	6,155	14	45	0	10	7,696	1	19	514
OK720500020130_00	Kiowa Creek	14,730	43	134	0	36	21,445	4	36	1,359
OK720500020050_00	Otter Creek	2,367	16	28	0	15	382	0	10	55
OK720500020500_00	Palo Duro Creek	93,243	29	163	0	22	85,572	2	2	971
OK720500020500_10	Palo Duro Creek	32,679	1	16	0	1	1,997	0	73	66
OK720500020100_00	Spring Creek	3,105	9	26	0	17	295	1	10	144
OK720500030010_00	Upper Wolf Creek	40,768	210	471	0	396	5,545	8	200	602
OK720500020030_00	Lower Wolf Creek	41,567	211	485	0	421	5,545	9	209	605

Table 3-6 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
OK720510000190_00	Beaver River at SH 95, near Guymon	166,758	80	764	0	97	310,964	4	337	479,004
OK720500020450_00	Beaver River at US 83, near Boyd	130,983	88	423	0	65	237,018	6	326	368,910
OK720500020290_00	Beaver River at US 270, Beaver	53,534	113	402	0	84	138,605	10	143	192,892
OK720500020140_00	Beaver River at US 64, near Rosston	35,593	100	314	0	87	49,507	10	92	85,703
OK720500020010_00	Beaver River at US 283, Laverne	68,655	312	748	0	604	9,960	16	310	80,605
OK720500020300_00	Clear Creek	10,838	31	96	0	22	16,927	3	28	27,946
OK720500020070_00	Clear Creek	6,296	32	67	0	33	3,270	1	22	9,721
OK720510000275_00	Corrumpa Creek	9,358	1	23	0	12	2	0	16	9,413
OK720500020250_00	Duck Pond Creek	6,155	14	45	0	10	7,696	1	19	13,940
OK720500020130_00	Kiowa Creek	14,730	43	134	0	36	21,445	4	36	36,428
OK720500020050_00	Otter Creek	2,367	16	28	0	15	382	0	10	2,818
OK720500020500_00	Palo Duro Creek	93,243	29	163	0	22	85,572	2	2	179,033
OK720500020500_10	Palo Duro Creek	32,679	1	16	0	1	1,997	0	73	34,766
OK720500020100_00	Spring Creek	3,105	9	26	0	17	295	1	10	3,463
OK720500030010_00	Upper Wolf Creek	40,768	210	471	0	396	5,545	8	200	47,597
OK720500020030_00	Lower Wolf Creek	41,567	211	485	0	421	5,545	9	209	48,445

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

ODEQ is responsible for implementing the regulations of Title 252, Chapter 641 of the Oklahoma Administrative Code, which define design standards for individual and small public onsite sewage disposal systems (ODEQ 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 3-7 summarizes estimates of sewered and unsewered households for each watershed in the study area.

Table 3-7 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK720510000190_00	Beaver River at SH 95, near Guymon	2,994	807	34	3,836	78%
OK720500020450_00	Beaver River at US 83, near Boyd	1,088	761	14	1,863	58%
OK720500020290_00	Beaver River at US 270, Beaver	1,559	716	9	2,284	68%
OK720500020140_00	Beaver River at US 64, near Rosston	192	526	8	726	26%
OK720500020010_00	Beaver River at US 283, Laverne	1,790	982	68	2,840	63%
OK720500020300_00	Clear Creek	9	165	3	177	5%
OK720500020070_00	Clear Creek	217	78	9	304	71%
OK720510000275_00	Corrumpa Creek	0	47	1	48	0%
OK720500020250_00	Duck Pond Creek	7	79	1	87	8%
OK720500020130_00	Kiowa Creek	47	222	5	274	17%
OK720500020050_00	Otter Creek	81	36	3	120	68%
OK720500020500_00	Palo Duro Creek	450	362	12	824	55%
OK720500020500_10	Palo Duro Creek	221	104	4	329	67%
OK720500020100_00	Spring Creek	68	33	2	103	66%
OK720500030010_00	Upper Wolf Creek	1,117	627	46	1,790	62%
OK720500020030_00	Lower Wolf Creek	1,123	648	46	1,817	62%

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 8 percent was used. Using this 8 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 3-8.

Table 3-8 Estimated Fecal Coliform Load from OSWD Systems

Waterbody ID	Waterbody Name	Acres	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day)
OK720510000190_00	Beaver River at SH 95, near Guymon	492,828	807	65	424
OK720500020450_00	Beaver River at US 83, near Boyd	617,958	761	57	377
OK720500020290_00	Beaver River at US 270, Beaver	519,328	716	61	400
OK720500020140_00	Beaver River at US 64, near Rosston	426,420	526	42	277
OK720500020010_00	Beaver River at US 283, Laverne	761,837	982	79	516
OK720500020300_00	Clear Creek	134,150	165	13	87
OK720500020070_00	Clear Creek	73,819	78	6	41
OK720510000275_00	Corrumpa Creek	130,866	47	4	25
OK720500020250_00	Duck Pond Creek	67,044	79	6	42
OK720500020130_00	Kiowa Creek	182,156	222	18	117
OK720500020050_00	Otter Creek	28,169	36	3	19
OK720500020500_00	Palo Duro Creek	344,386	362	29	190
OK720500020500_10	Palo Duro Creek	98,689	104	8	55
OK720500020100_00	Spring Creek	26,703	33	3	17
OK720500030010_00	Upper Wolf Creek	490,210	627	50	330
OK720500020030_00	Lower Wolf Creek	498,158	648	52	341

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 3-9 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-9 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Housing Units	Dogs	Cats
OK720510000190_00	Beaver River at SH 95, near Guymon	3,836	6,521	8,439
OK720500020450_00	Beaver River at US 83, near Boyd	1,863	3,167	4,099
OK720500020290_00	Beaver River at US 270, Beaver	2,284	3,883	5,025
OK720500020140_00	Beaver River at US 64, near Rosston	726	1,234	1,597
OK720500020010_00	Beaver River at US 283, Laverne	2,840	4,828	6,248
OK720500020300_00	Clear Creek	177	301	389
OK720500020070_00	Clear Creek	304	517	669
OK720510000275_00	Corrumpa Creek	48	82	106
OK720500020250_00	Duck Pond Creek	87	148	191
OK720500020130_00	Kiowa Creek	274	466	603
OK720500020050_00	Otter Creek	120	204	264
OK720500020500_00	Palo Duro Creek	824	1,401	1,813
OK720500020500_10	Palo Duro Creek	329	559	724
OK720500020100_00	Spring Creek	103	175	227
OK720500030010_00	Upper Wolf Creek	1,790	3,043	3,938
OK720500020030_00	Lower Wolf Creek	1,817	3,089	3,997

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

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

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK720510000190_00	Beaver River at SH 95, near Guymon	21,520	4,557	26,077
OK720500020450_00	Beaver River at US 83, near Boyd	10,451	2,213	12,665
OK720500020290_00	Beaver River at US 270, Beaver	12,813	2,713	15,527
OK720500020140_00	Beaver River at US 64, near Rosston	4,073	862	4,935
OK720500020010_00	Beaver River at US 283, Laverne	15,932	3,374	19,306
OK720500020300_00	Clear Creek	993	210	1,203
OK720500020070_00	Clear Creek	1,705	361	2,067
OK720510000275_00	Corrumpa Creek	269	57	326
OK720500020250_00	Duck Pond Creek	488	103	591
OK720500020130_00	Kiowa Creek	1,537	326	1,863
OK720500020050_00	Otter Creek	673	143	816
OK720500020500_00	Palo Duro Creek	4,623	979	5,602
OK720500020500_10	Palo Duro Creek	1,846	391	2,237
OK720500020100_00	Spring Creek	578	122	700
OK720500030010_00	Upper Wolf Creek	10,042	2,127	12,168
OK720500020030_00	Lower Wolf Creek	10,193	2,159	12,352

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 3-11 summarizes the suspected sources of bacteria loading in each impaired watershed.

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

Waterbody ID	Waterbody Name	Point Sources	Nonpoint Sources	Major Source
OK720510000190_00	Beaver River at SH 95, near Guymon	No	Yes	Nonpoint
OK720500020450_00	Beaver River at US 83, near Boyd	No	Yes	Nonpoint
OK720500020290_00	Beaver River at US 270, Beaver	No	Yes	Nonpoint
OK720500020140_00	Beaver River at US 64, near Rosston	No	Yes	Nonpoint
OK720500020010_00	Beaver River at US 283, Laverne	No	Yes	Nonpoint
OK720500020300_00	Clear Creek	No	Yes	Nonpoint
OK720500020070_00	Clear Creek	No	Yes	Nonpoint
OK720510000275_00	Corrumpa Creek	No	Yes	Nonpoint
OK720500020250_00	Duck Pond Creek	No	Yes	Nonpoint
OK720500020130_00	Kiowa Creek	No	Yes	Nonpoint
OK720500020050_00	Otter Creek	No	Yes	Nonpoint
OK720500020500_00	Palo Duro Creek	No	Yes	Nonpoint
OK720500020500_10	Palo Duro Creek	No	Yes	Nonpoint
OK720500020100_00	Spring Creek	No	Yes	Nonpoint
OK720500030010_00	Upper Wolf Creek	No	Yes	Nonpoint
OK720500020030_00	Lower Wolf Creek	No	Yes	Nonpoint

Table 3-12 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 manures, 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 3-12 Summary of Daily Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces

Waterbody ID	Waterbody Name	Commercially Raised Farm Animals	Pets	Deer	Septic Tanks
OK720510000190_00	Beaver River at SH 95, near Guymon	94.71%	5.16%	0.06%	0.08%
OK720500020450_00	Beaver River at US 83, near Boyd	96.53%	3.31%	0.06%	0.10%
OK720500020290_00	Beaver River at US 270, Beaver	92.19%	7.42%	0.20%	0.19%
OK720500020140_00	Beaver River at US 64, near Rosston	93.79%	5.40%	0.51%	0.30%
OK720500020010_00	Beaver River at US 283, Laverne	79.01%	18.92%	1.56%	0.51%
OK720500020300_00	Clear Creek	95.16%	4.10%	0.45%	0.30%
OK720500020070_00	Clear Creek	81.07%	17.23%	1.36%	0.34%
OK720510000275_00	Corrumpa Creek	96.35%	3.34%	0.05%	0.26%
OK720500020250_00	Duck Pond Creek	95.26%	4.04%	0.41%	0.29%
OK720500020130_00	Kiowa Creek	94.36%	4.82%	0.51%	0.30%
OK720500020050_00	Otter Creek	75.55%	21.87%	2.06%	0.51%
OK720500020500_00	Palo Duro Creek	96.83%	3.03%	0.04%	0.10%
OK720500020500_10	Palo Duro Creek	93.81%	6.04%	0.00%	0.15%
OK720500020100_00	Spring Creek	81.54%	16.49%	1.58%	0.40%
OK720500030010_00	Upper Wolf Creek	77.96%	19.93%	1.57%	0.54%
OK720500020030_00	Lower Wolf Creek	78.02%	19.89%	1.54%	0.55%

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 25^{th} 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 $m1$ 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 ($b1$) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). The correlation between TSS and turbidity, along with the LOC and the OLS lines are shown in Figures 4-1 and 4-2.

Figure 4-1 Linear Regression for TSS-Turbidity for Palo Duro Creek (OK720500020500_00)

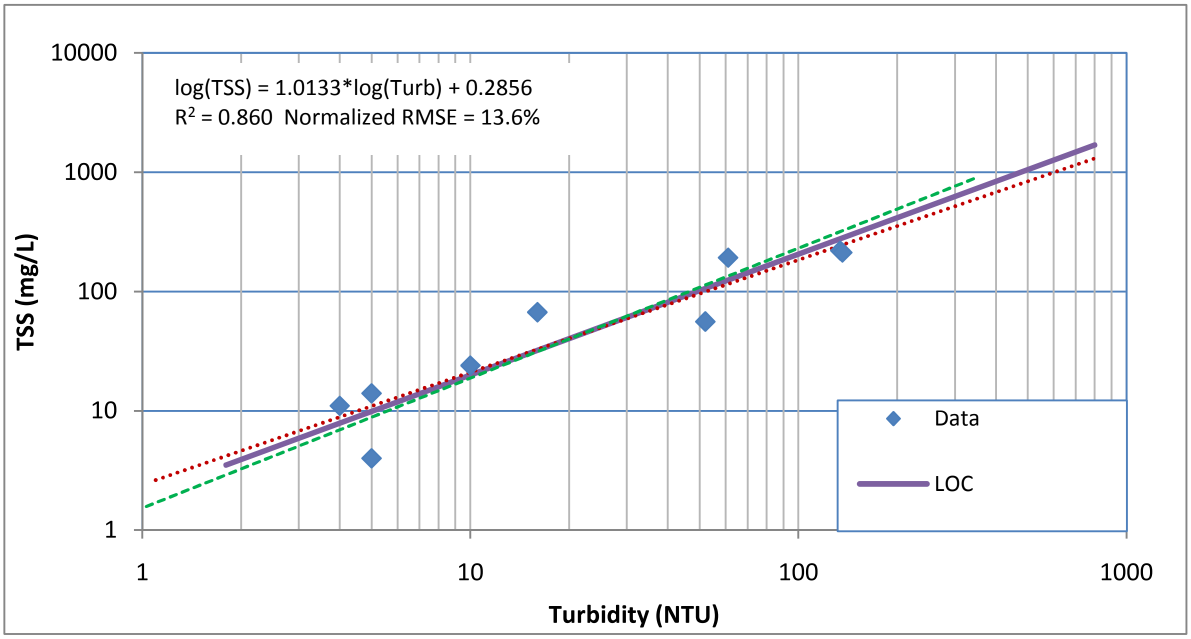
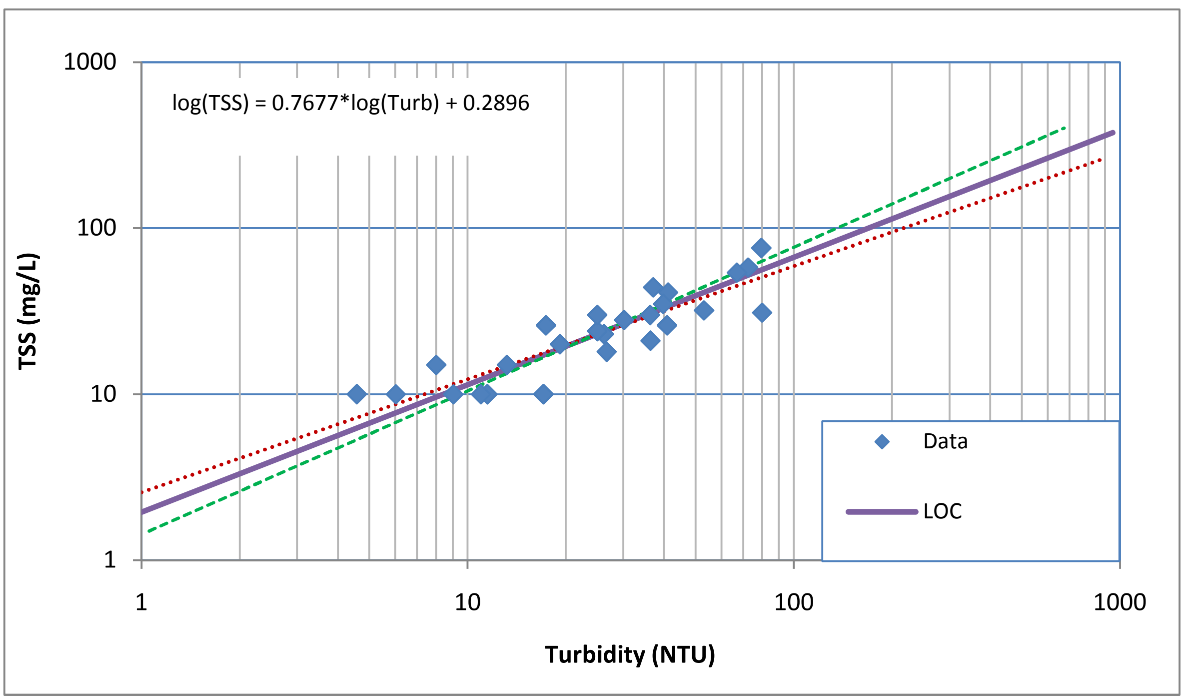


Figure 4-2 Linear Regression for TSS-Turbidity for Lower Wolf Creek (OK720500020030_00)



The NRMSE and R-square (r^2) were used as the primary measures of goodness-of-fit. For example, as shown in Figure 4-1, the LOC yields a NRMSE value of 13.6 which means the root mean square error (RMSE) is 13.6% of the average of the measured TSS values. The R-square (r2) value indicates the fraction of the total variance in TSS or turbidity observations that is explained by the LOC. Table 4-1 shows the statistics of the regressions and the resultant TSS targets.

Table 4-1 Regression Statistics and TSS Targets

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]	TSS Target (mg/L)[c]
OK720500020500_00	Palo Duro Creek	0.86	13.6%	120	15%	102
OK720500020030_00	Lower Wolf Creek	0.78	9.1%	44	10%	39

[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

It was noted that there were 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.

It is also worth to note that outliers were removed only from the turbidity-TSS relationship, not from the dataset used to develop the TMDL.

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. Figures 4-3 through 4-19 are flow duration curves for each impaired waterbody.

Figure 4-3 Flow Duration Curve for Beaver River at SH 95, near Guymon

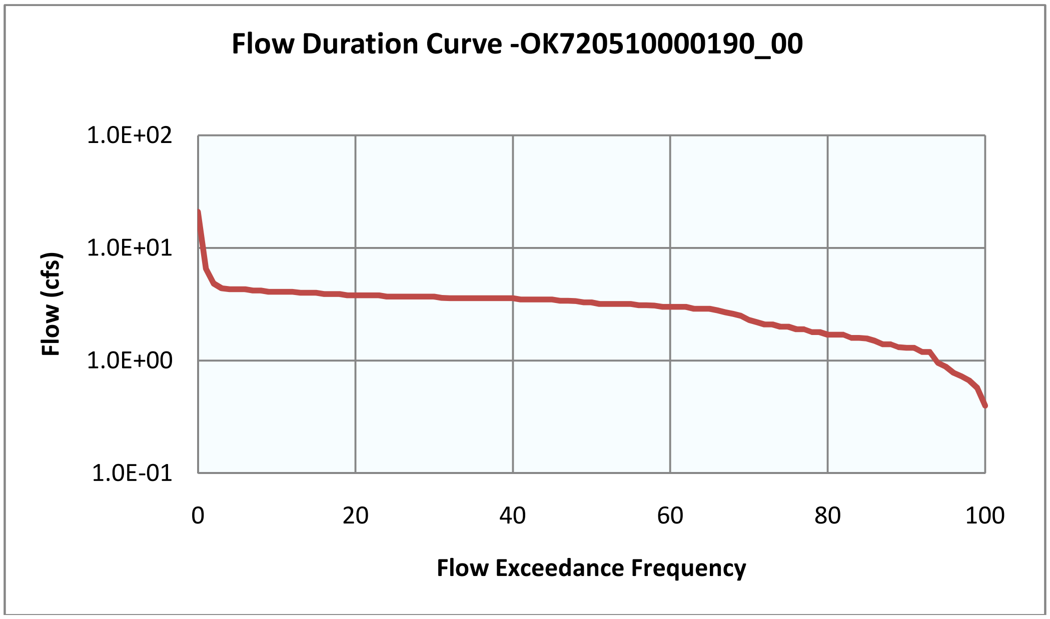


Figure 4-4 Flow Duration Curve for Beaver River at US 83, near Boyd

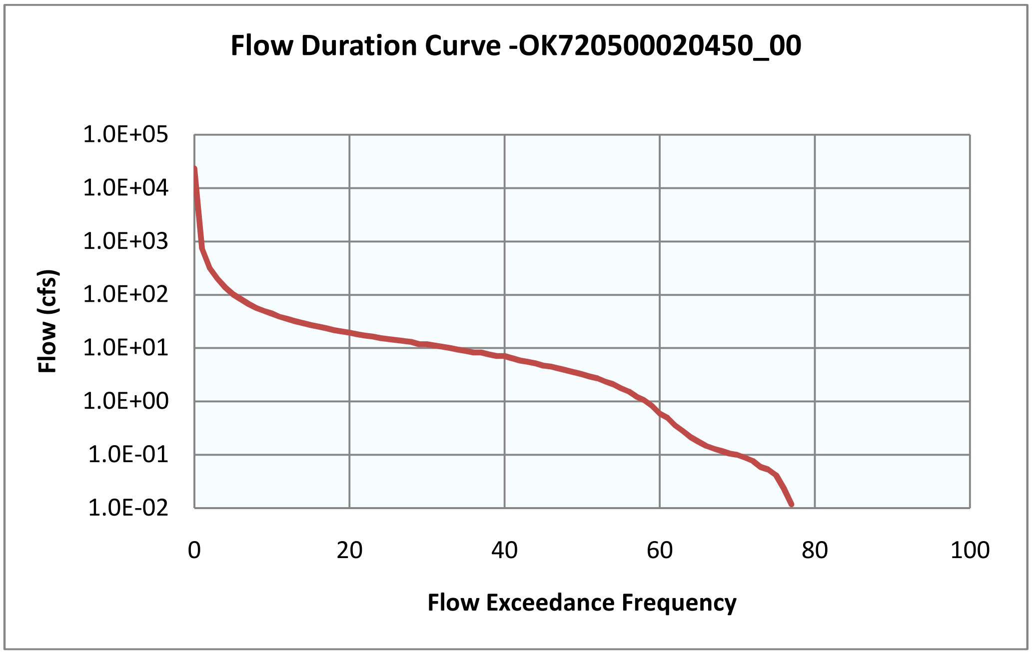


Figure 4-5 Flow Duration Curve for Beaver River at US 270, Beaver

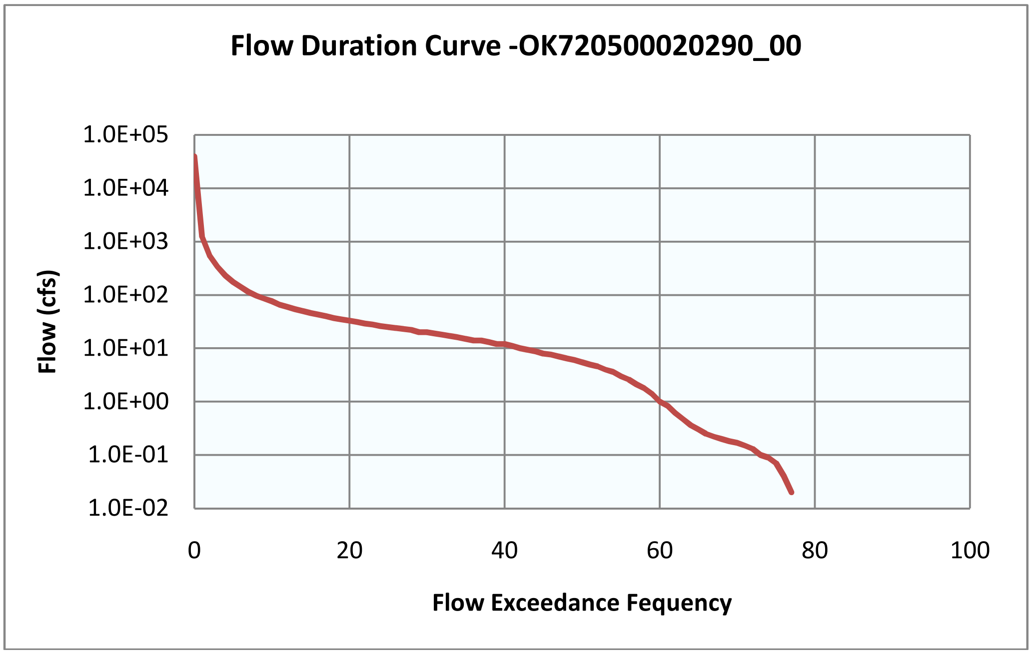


Figure 4-6 Flow Duration Curve for Beaver River at US 64, near Rosston

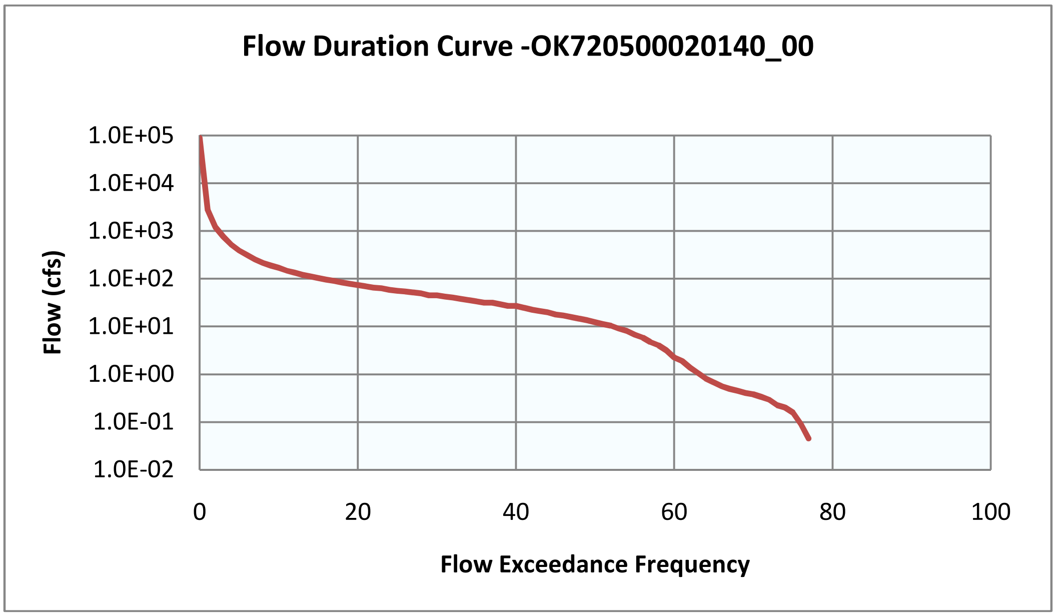


Figure 4-7 Flow Duration Curve for Beaver River at US 283, Laverne

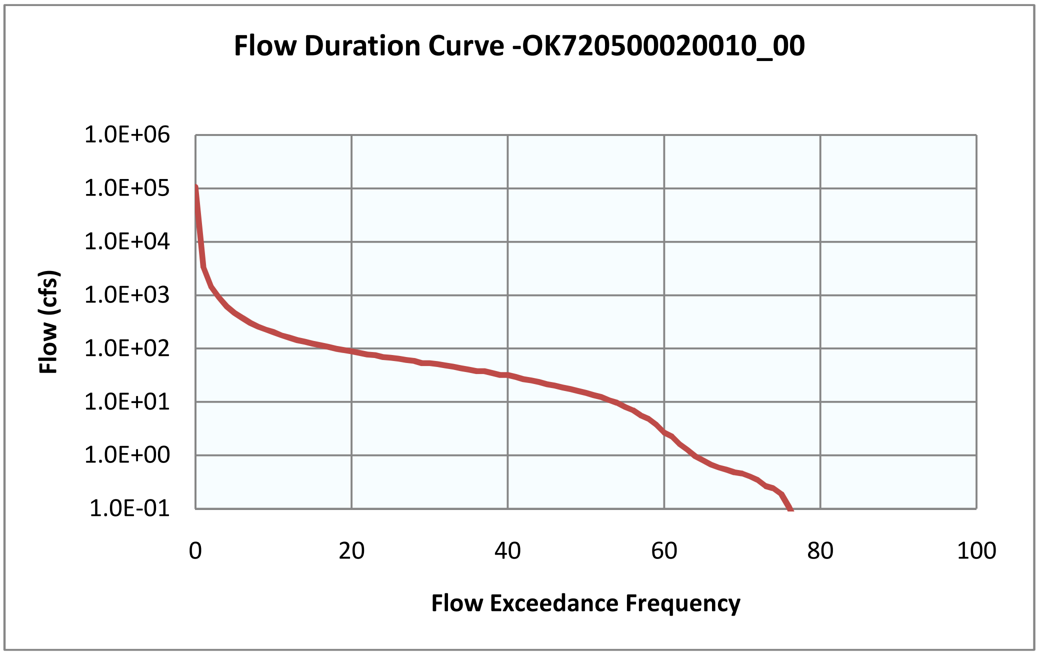


Figure 4-8 Flow Duration Curve for Buzzard Creek

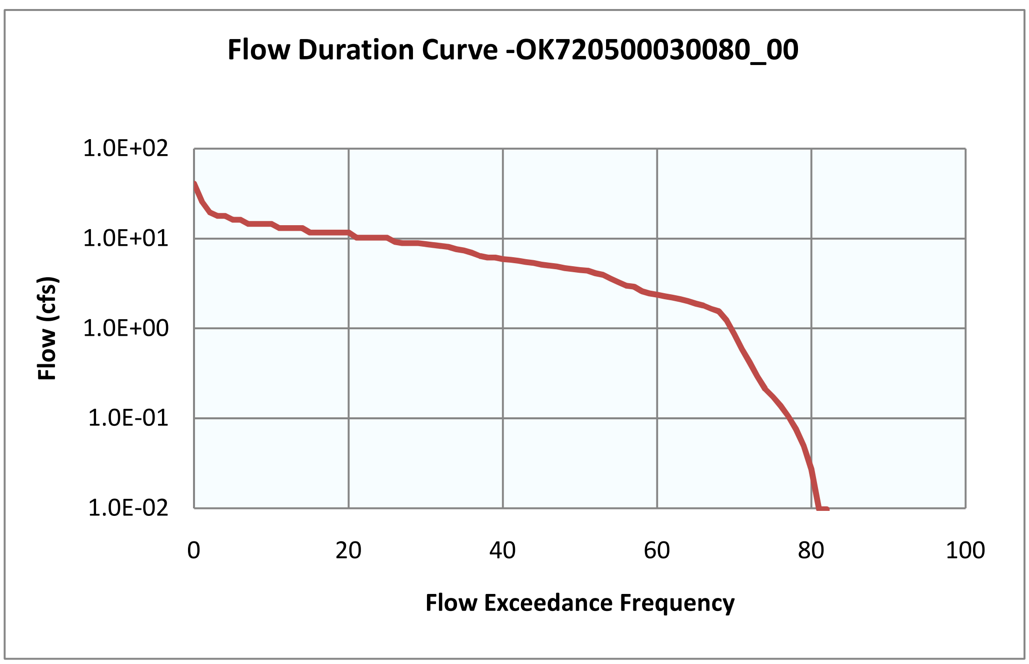


Figure 4-9 Flow Duration Curve for Clear Creek

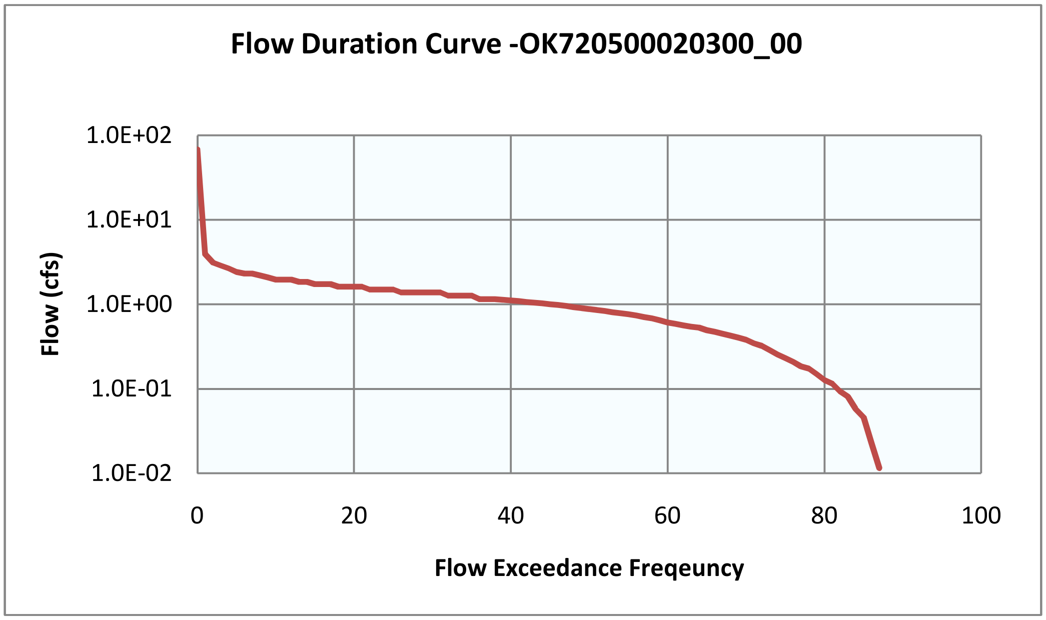


Figure 4-10 Flow Duration Curve for Clear Creek

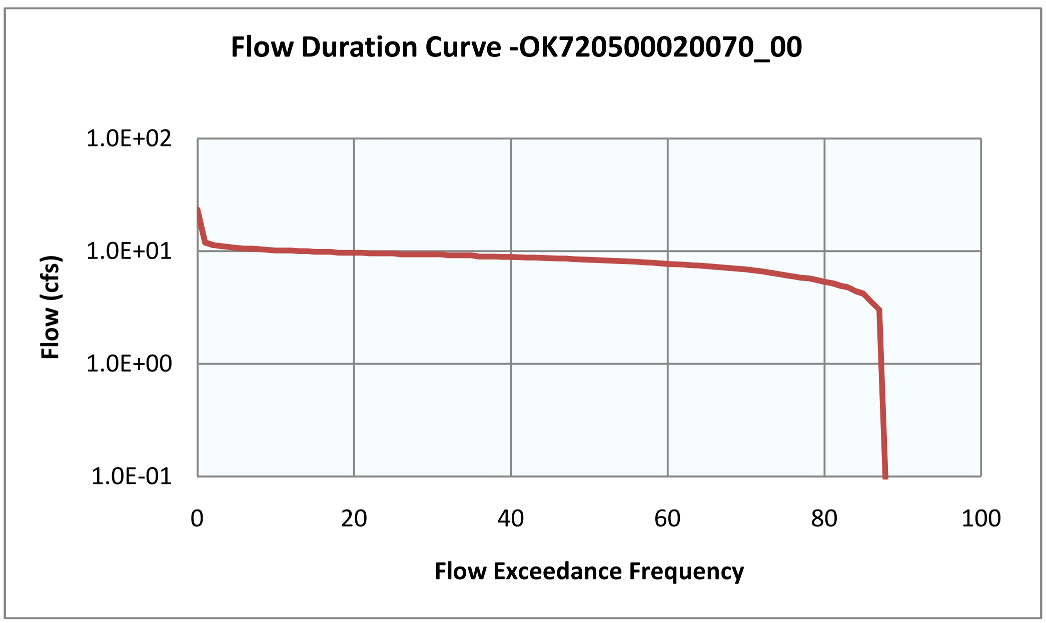


Figure 4-11 Flow Duration Curve for Corrumpa Creek

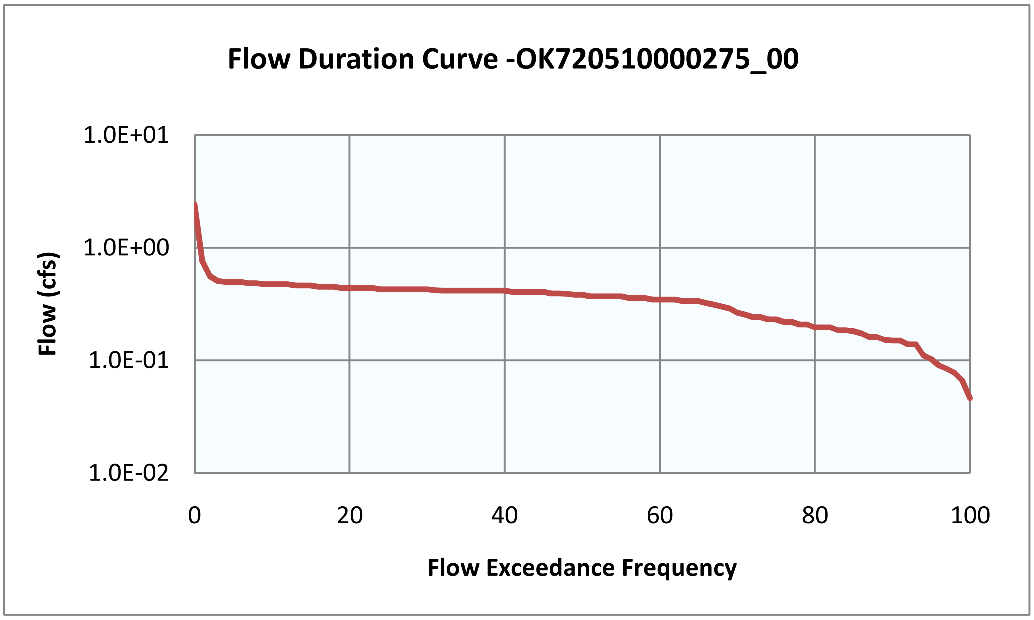


Figure 4-12 Flow Duration Curve for Duck Pond Creek

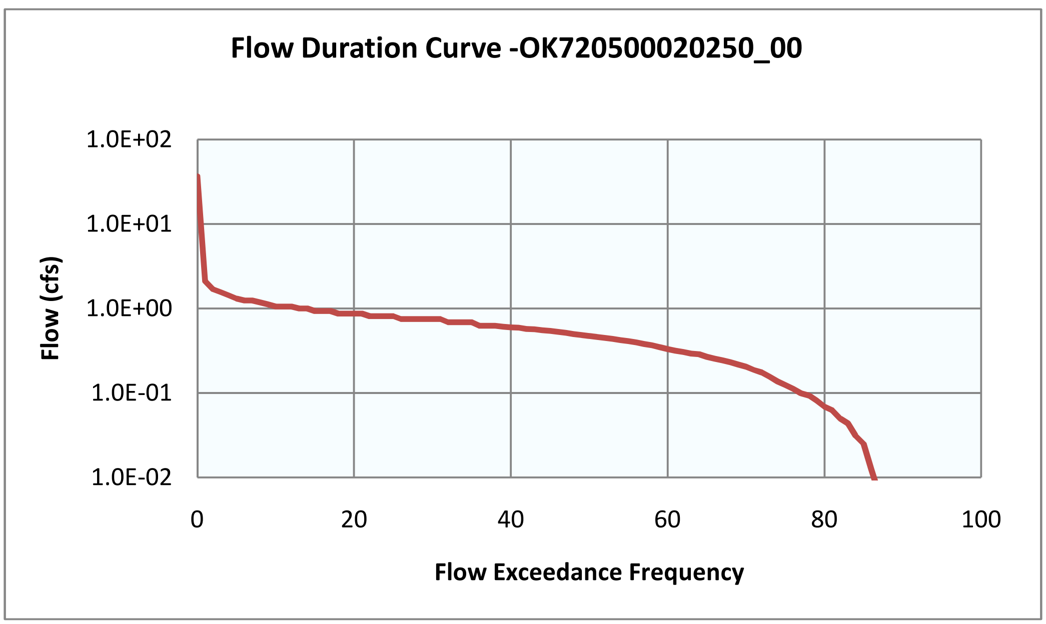


Figure 4-13 Flow Duration Curve for Kiowa Creek

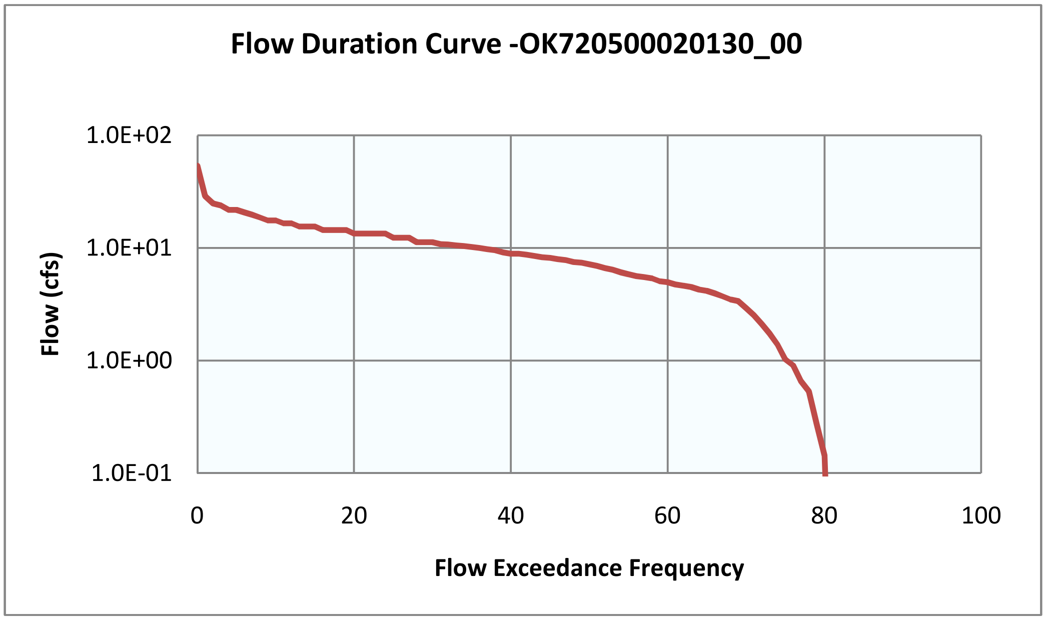


Figure 4-14 Flow Duration Curve for Otter Creek

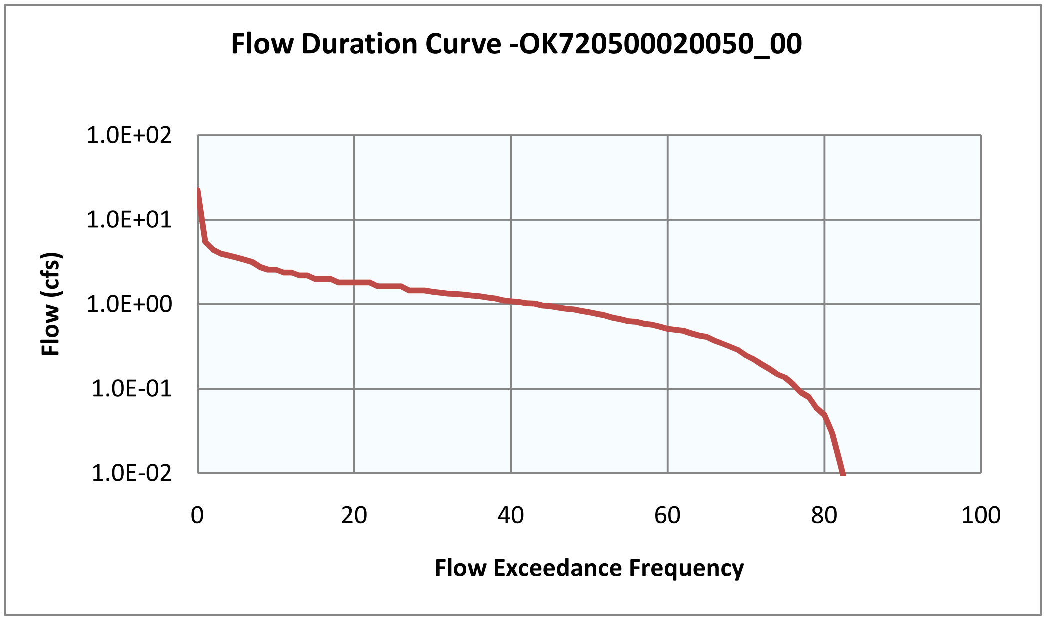


Figure 4-15 Flow Duration Curve for Palo Duro Creek

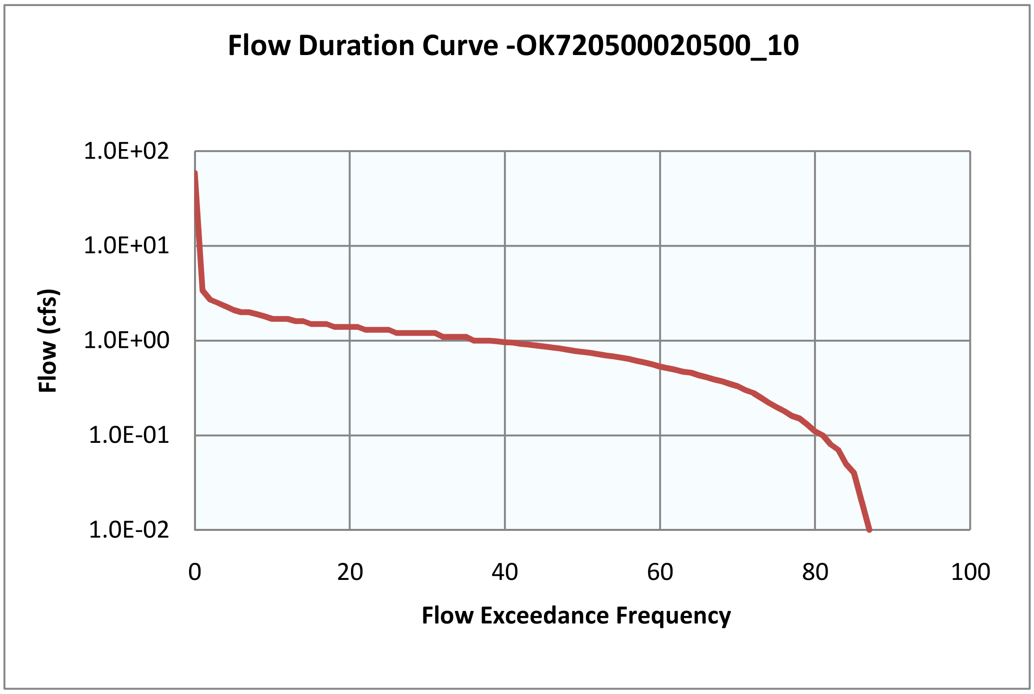


Figure 4-16 Flow Duration Curve for Palo Duro Creek

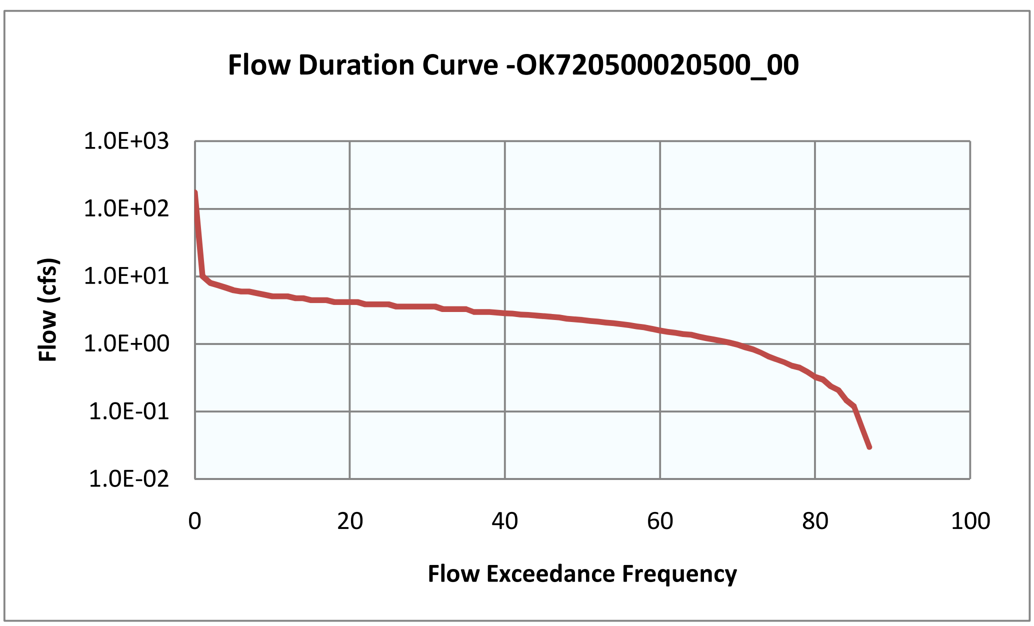


Figure 4-17 Flow Duration Curve for Spring Creek

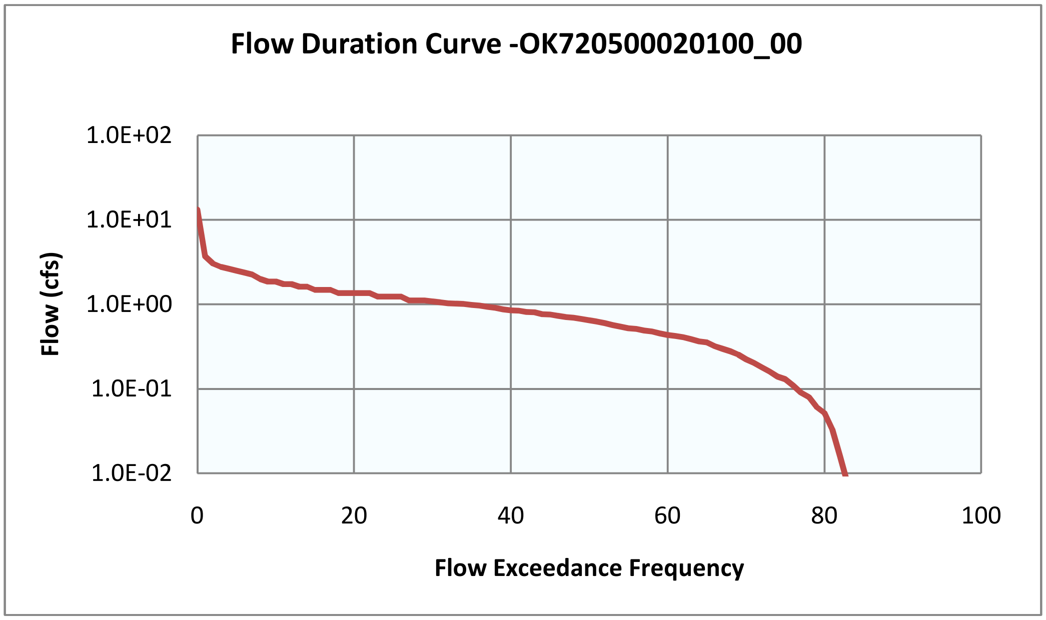


Figure 4-18 Flow Duration Curve for Upper Wolf Creek

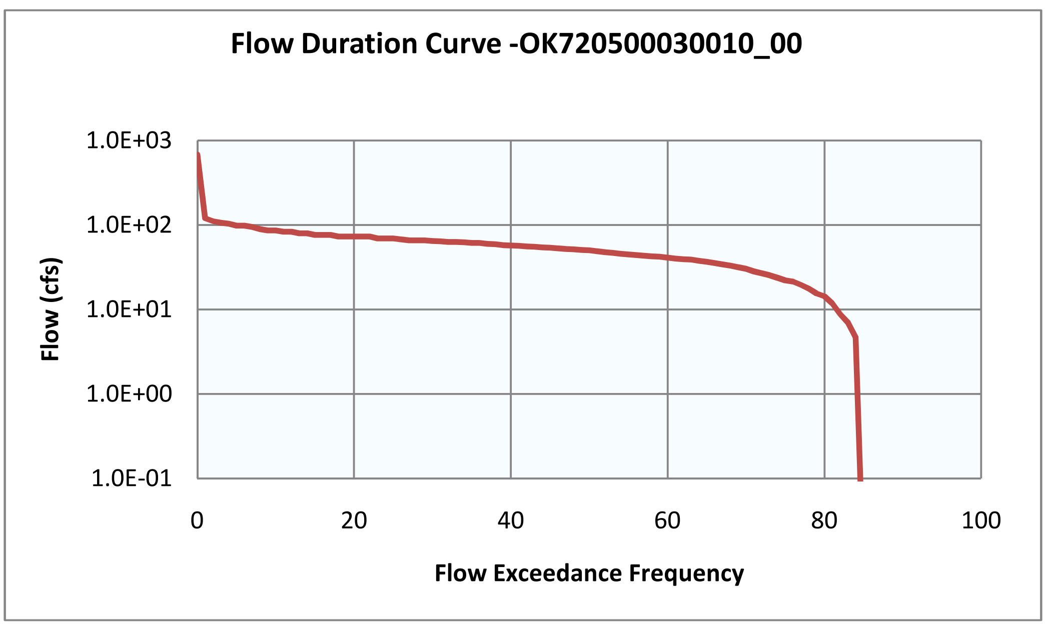
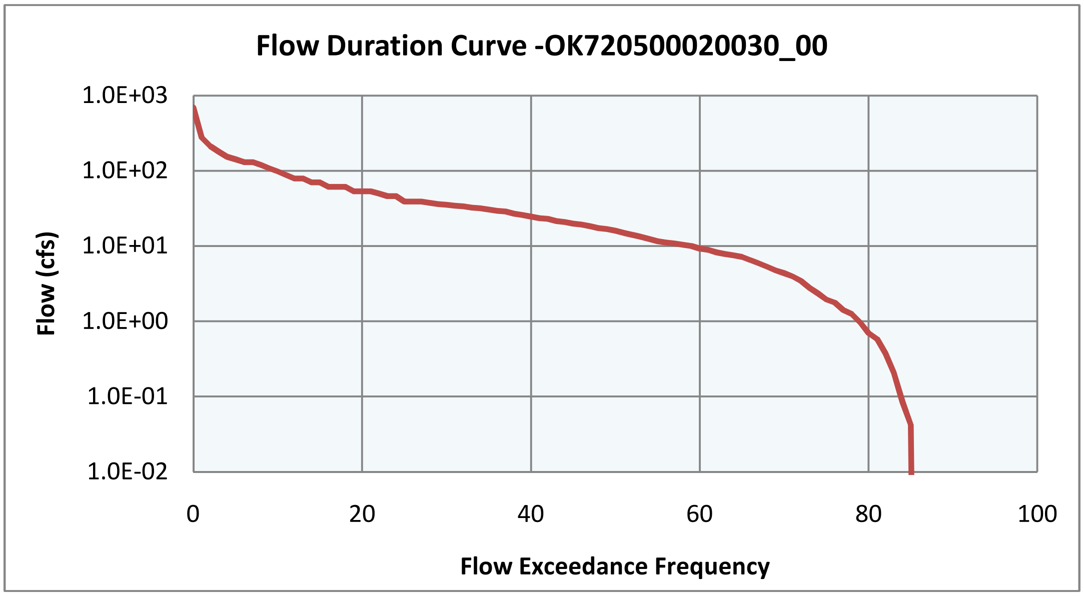


Figure 4-19 Flow Duration Curve for Lower Wolf Creek



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_{target} 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 goal * flow (cfs) * unit conversion factor

where: WQ goal = 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)

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 goal * flow * unit conversion factor (lb/day)

Where:

WQ goal is provided in Table 4-1;

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

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

WLA for Permitted Stormwater (MS4s). For bacteria TMDLs no specific portion of the WLA has been allocated for MS4s because there are no MS4 jurisdictions fall within the watersheds requiring TMDLs. In addition, the LDCs do not display a specific percentage of the bacteria load assigned to MS4s. 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 4: Calculate LA. Given the lack of data and the variability of storm events, it is difficult to quantify discharges that accurately represent projected loadings from nonpoint sources. However, 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.

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

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 target for the receiving stream, there will be no reductions;

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

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 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 5-1 through 5-35.

The LDCs for Beaver River at SH 95, near Guymon, segment OK720510000190_00 are shown in Figures 5-1 through 5-3 for E. coli, Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM station OK720510000190-001AT. The LDCs indicate that all three indicator 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.

The LDCs for Beaver River at US 83, near Boyd, segment OK720500020450_00 are shown in Figures 5-7 through 5-9 for E. coli, Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM station OK720510000450-001AT. The LDCs indicate that all three indicator levels exceed the instantaneous water quality criteria under all flow conditions for Enterococci and Fecal Coliform while E. coli levels exceed the instantaneous water quality criteria under low 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.

The LDCs for Beaver River at US 270, Beaver, segment OK720500020290_00 are shown in Figures 5-4 through 5-6 for E. coli, Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM station OK720510000290-001AT. 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.

The LDCs for Beaver River at US 64, near Rosston, segment OK720500020140_00 are shown in Figures 5-10 and 5-11 for Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM station OK720510000140-001AT. The LDCs indicates that Enterococci and Fecal Coliform levels exceed the instantaneous water quality criteria under all flow conditions, indicative of loading from both point and nonpoint sources.

The LDCs for Beaver River at US 283, Laverne, segment OK720500020010_00 are shown in Figures 5-10 and 5-11 for Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM station OK720500020010-001AT. The LDCs indicate that both indicator levels exceed the instantaneous water quality criteria under low flow conditions.

The LDC for Clear Creek, segment OK720500020300_00 is shown in Figure 5-15 Fecal Coliform. They are based on bacteria measurements at WQM stations OK720500-02-0300F and OK720500-02-0300G. The LDC indicates that Fecal Coliform levels exceed the instantaneous water quality criteria under both high and low flow conditions.

The LDCs for Clear Creek, segment OK720500020070_00 are shown in Figures 5-16 through 5-18 for E. coli, Enterococci and Fecal Coliform respectively. They are based on bacteria measurements at WQM station OK720500-02-0070G. The LDCs indicate that both E. coli and Fecal Coliform levels exceed the instantaneous water quality criteria under both high and low flow conditions. Enterococci LDC indicates that levels exceed the instantaneous water quality criteria under various flow conditions, which is indicative of loading from both point and nonpoint sources. . 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.

The LDC for Corrumpa Creek, segment OK720510000275_00 is shown in Figure 5-19 for Fecal Coliform. They are based on bacteria measurements at WQM stations OK720510-00-0275K -. The LDC indicates that Fecal Coliform levels exceed water quality targets at 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.

The LDC for Duck Pond Creek, segment OK720500020250_00 (Figures 5-20 and 5-21) shows bacteria measurements at WQM station OK720500-02-0250F. The LDC for E. coli indicates that levels exceed the instantaneous water quality criteria under low flow conditions. The LDC for Enterococci indicates that levels exceed the instantaneous water quality criteria under various flow conditions, which is indicative of loading from both point and nonpoint sources.

The LDC for Kiowa Creek, segment OK720500020130_00 (Figure 5-22 through 5-24) shows bacteria measurements at WQM stations OK720500-02-0130C, OK720500-02-0130K and OK720500-02-0130M. The LDCs for E. coli and Fecal Coliform indicates that bacteria levels exceed the instantaneous water quality criteria under both moderate and low flow conditions. The LDC for Enterococci indicates that levels exceed instantaneous water quality criteria under all flow conditions, which is indicative of loading from both point and nonpoint sources. . 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.

The LDC for Otter Creek, segment OK720500020050_00 (Figures 5-25 and 5-26) shows bacteria measurements at WQM stations OK720500-02-0050B. The LDCs indicate that both 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

The LDC for Palo Duro Creek, segment OK720500020500_10 (Figure 5-27 through 5-29) shows bacteria measurements at WQM station OK720500-02-0500G. The LDCs for E. coli and Enterococci indicate that bacteria levels exceed the instantaneous water quality criteria under both high and low flow conditions. The LDC for Fecal Coliform indicates that levels exceed instantaneous water quality criteria under low conditions.

The LDC for Palo Duro Creek, segment OK720500020500_00 (Figures 5-25 and 5-26) shows bacteria measurements at WQM stations OK720500020500-001AT. The LDCs indicate that Fecal Coliform levels exceed the instantaneous water quality criteria under moderate and low flow conditions.

The LDCs for Spring Creek, segment OK720500020100_00 are shown in Figures 5-31 and 5-32 for E. coli and Enterococci respectively. They are based on bacteria measurements at WQM station OK720500-02-0070G. The LDCs indicate that both indicator levels exceed the instantaneous water quality criteria under various flow conditions, which is indicative of loading from both point and nonpoint sources.

The LDC for Upper Wolf Creek, segment OK720500030010_00 (Figures 5-33 and 5-34) shows bacteria measurements at WQM stations OK720500-03-0010G, OK720500-03-0010T and OK720500-03-0010M. The LDC for Enterococci indicates that levels exceed the instantaneous water quality criteria under moderate and low flow conditions. The LDC for Enterococci indicates that levels exceed the instantaneous water quality criteria under moderate flow conditions.

The LDC for Upper Wolf Creek, segment OK720500020030_00 (Figures 5-35) shows bacteria measurements at WQM station OK720500-02-0030M. The LDC for Enterococci indicates that levels exceed the instantaneous water quality criteria under moderate and low flow conditions.

Figure 5-1 Load Duration Curve for *E. coli* in Beaver River at SH 95, near Guymon

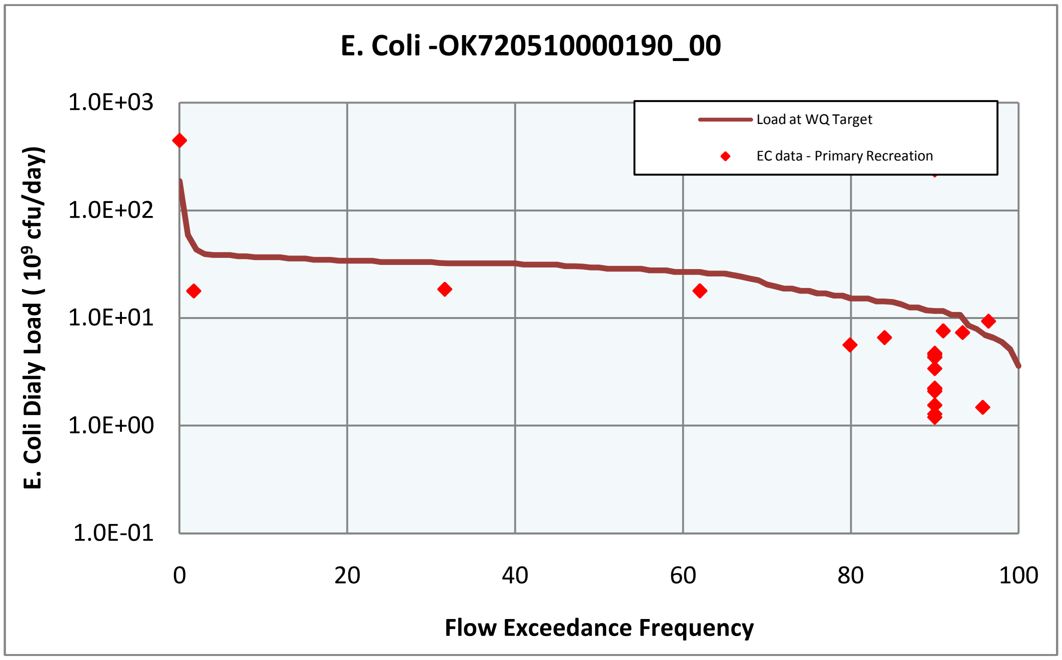


Figure 5-2 Load Duration Curve for Enterococci in Beaver River at SH 95, near Guymon

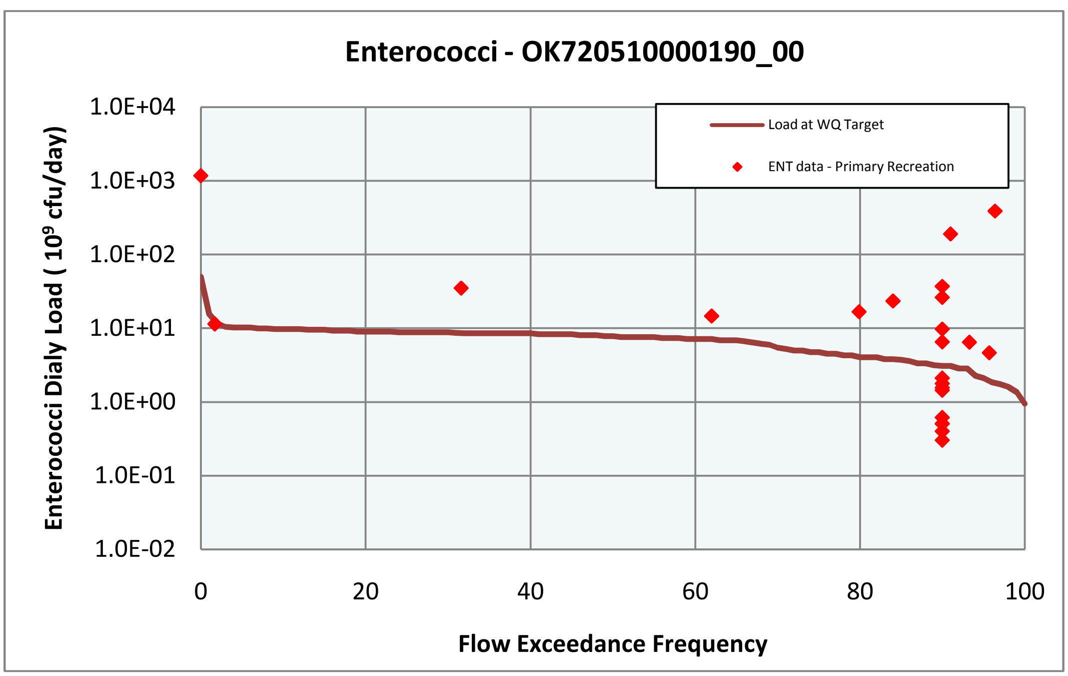


Figure 5-3 Load Duration Curve for Fecal Coliform in Beaver River at SH 95, near Guymon

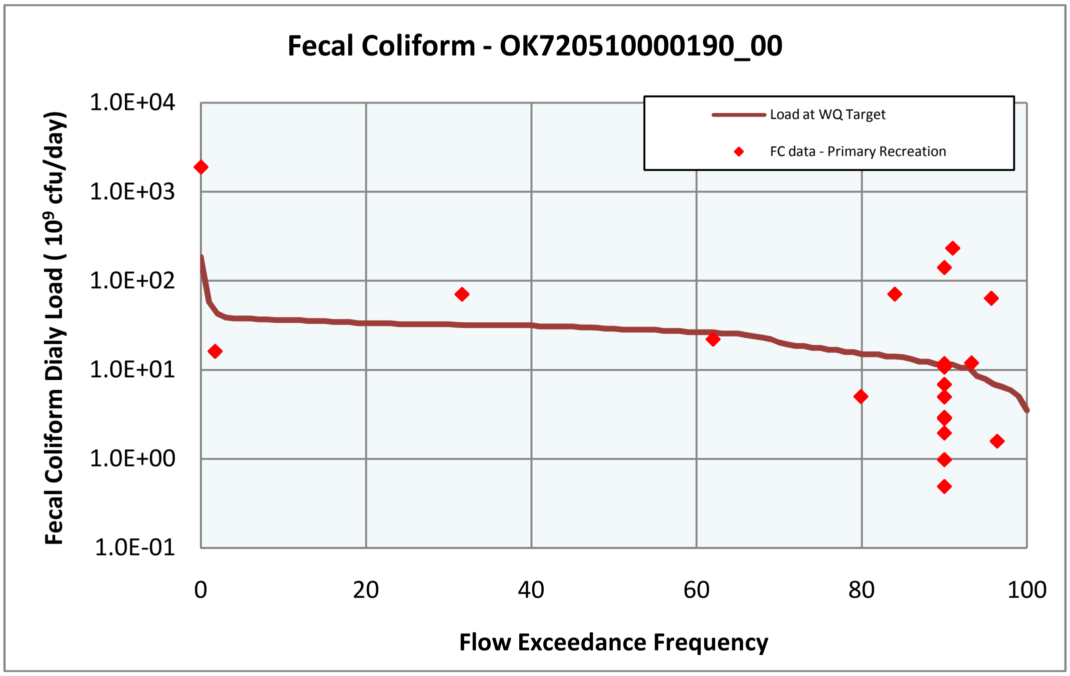


Figure 5-4 Load Duration Curve for *E. coli* in Beaver River at US 83, near Boyd

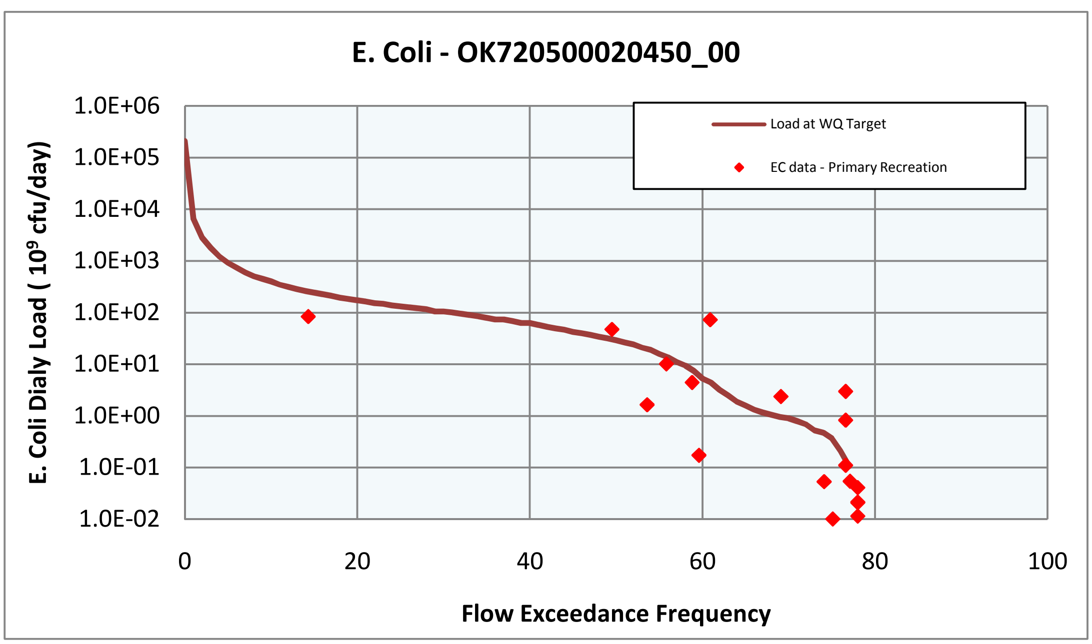


Figure 5-5 Load Duration Curve for Enterococci in Beaver River at US 83, near Boyd

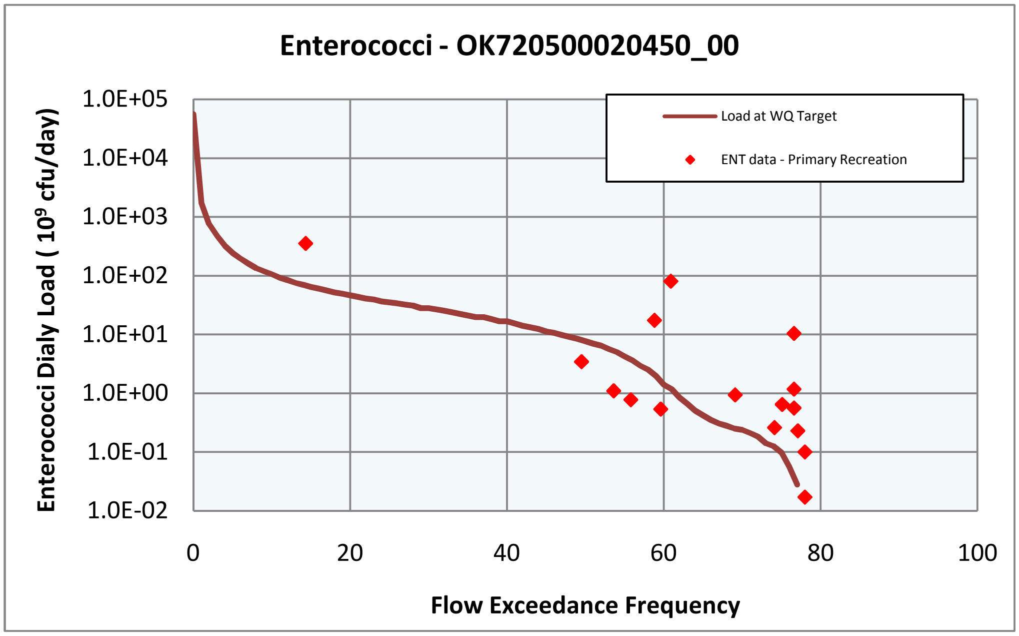


Figure 5-6 Load Duration Curve for Fecal Coliform in Beaver River at US 83, near Boyd

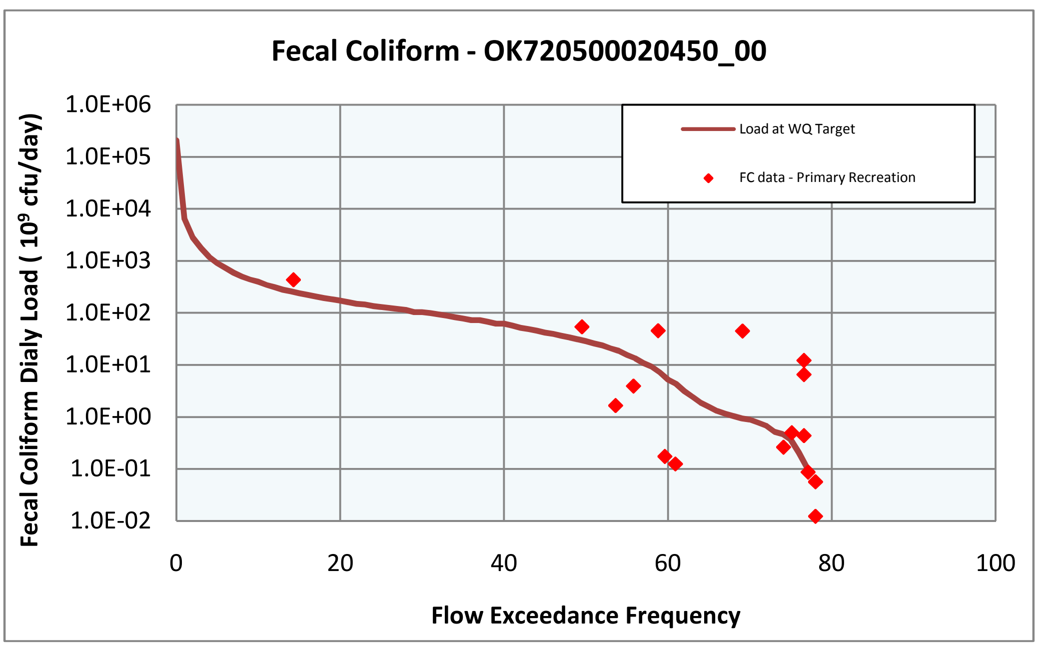


Figure 5-7 Load Duration Curve for *E. coli* in Beaver River at US 270, Beaver,

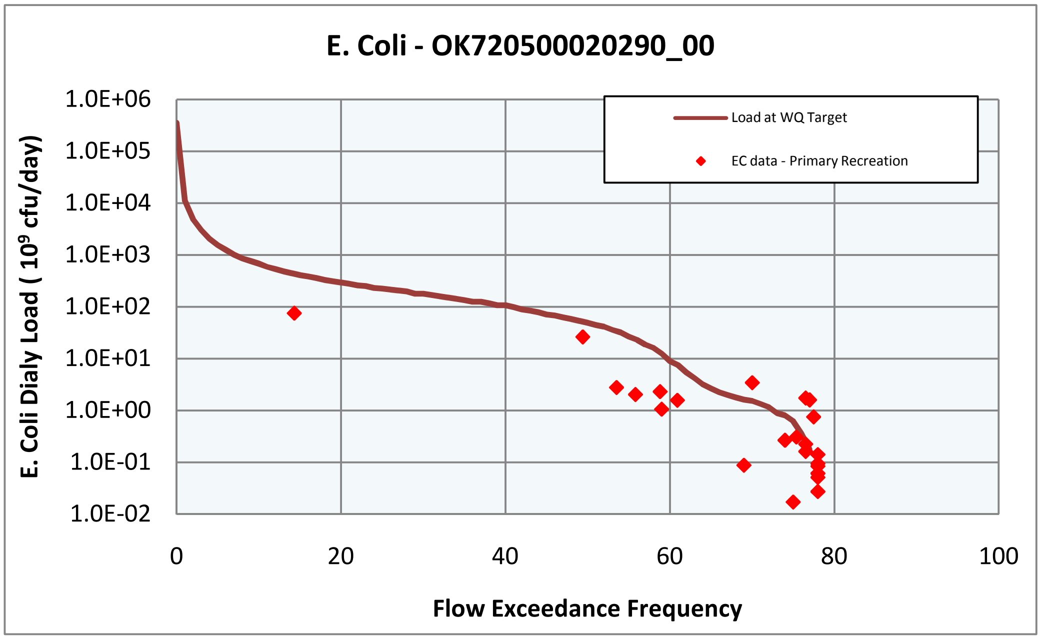


Figure 5-8 Load Duration Curve for Enterococci in Beaver River at US 270, Beaver,

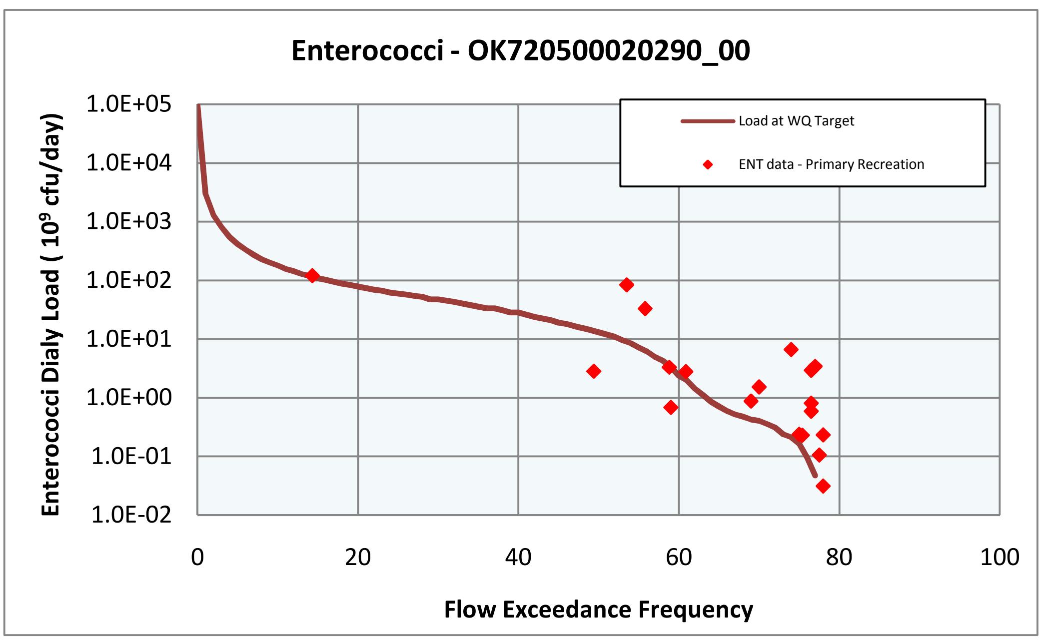


Figure 5-9 Load Duration Curve for Fecal Coliform in Beaver River at US 270, Beaver

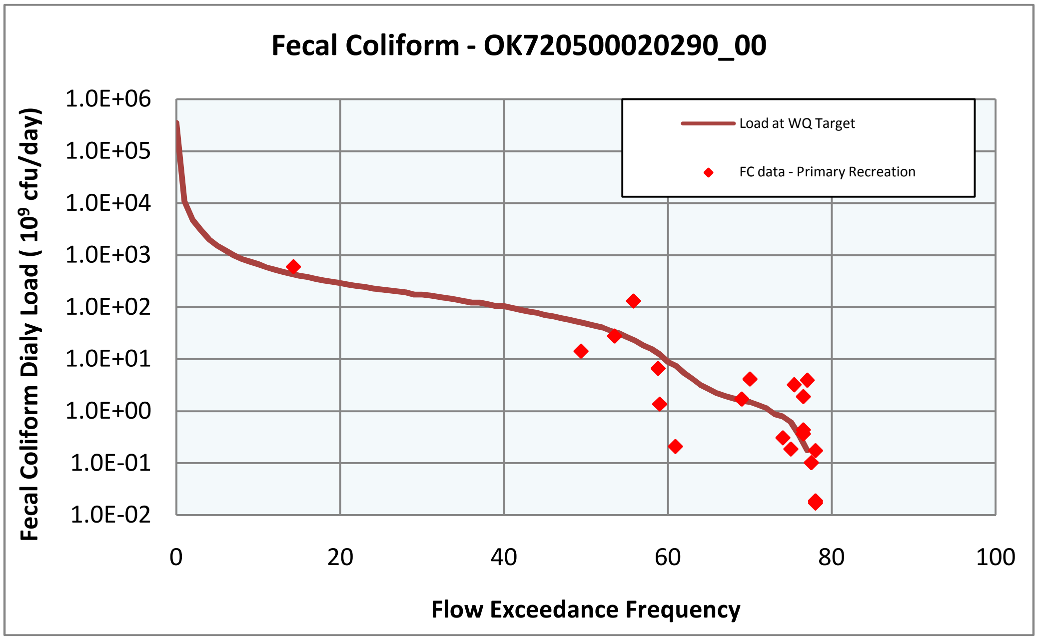


Figure 5-10 Load Duration Curve for Enterococci in Beaver River at US 64, near Rosston

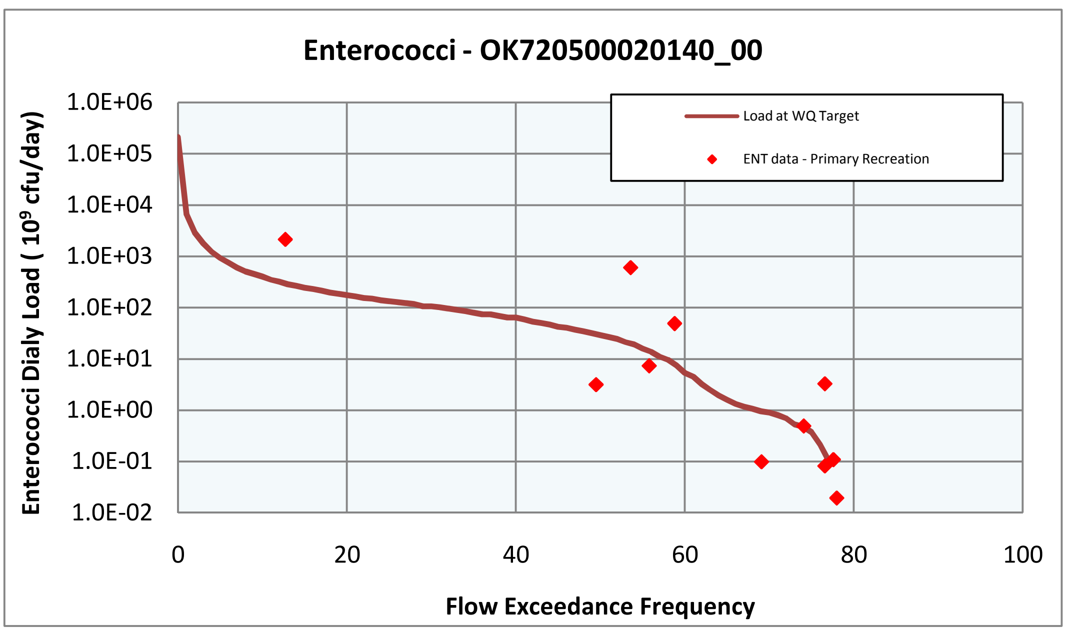


Figure 5-11Load Duration Curve for Fecal Coliform in Beaver River at US 64, near Rosston

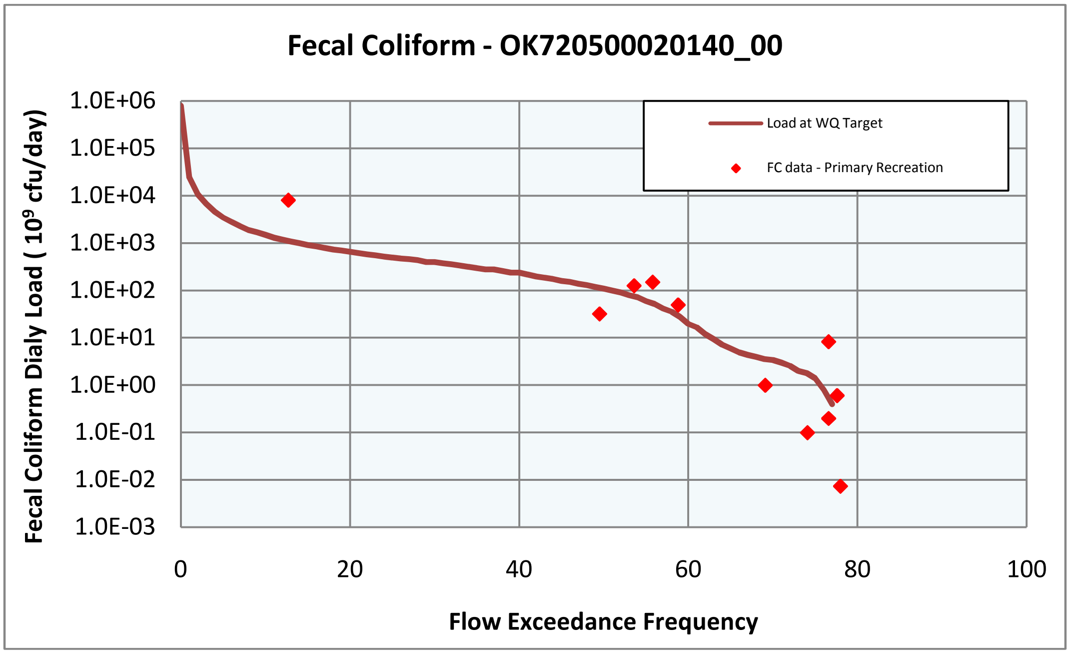


Figure 5-12 Load Duration Curve for Enterococci in Beaver River at US 283, Laverne

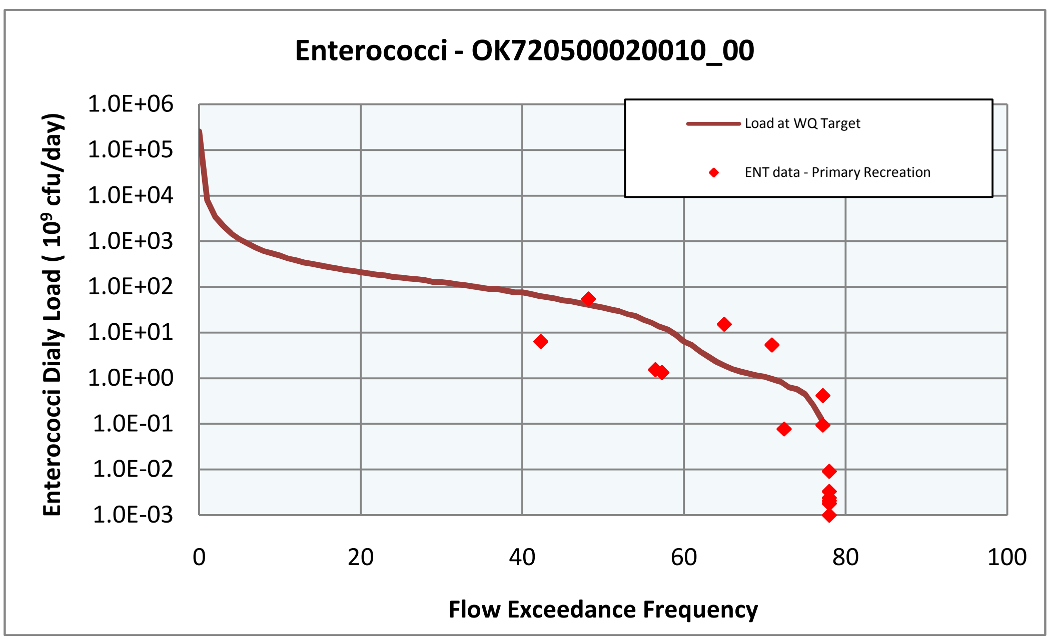


Figure 5-13 Load Duration Curve for Fecal Coliform in Beaver River at US 283, Laverne

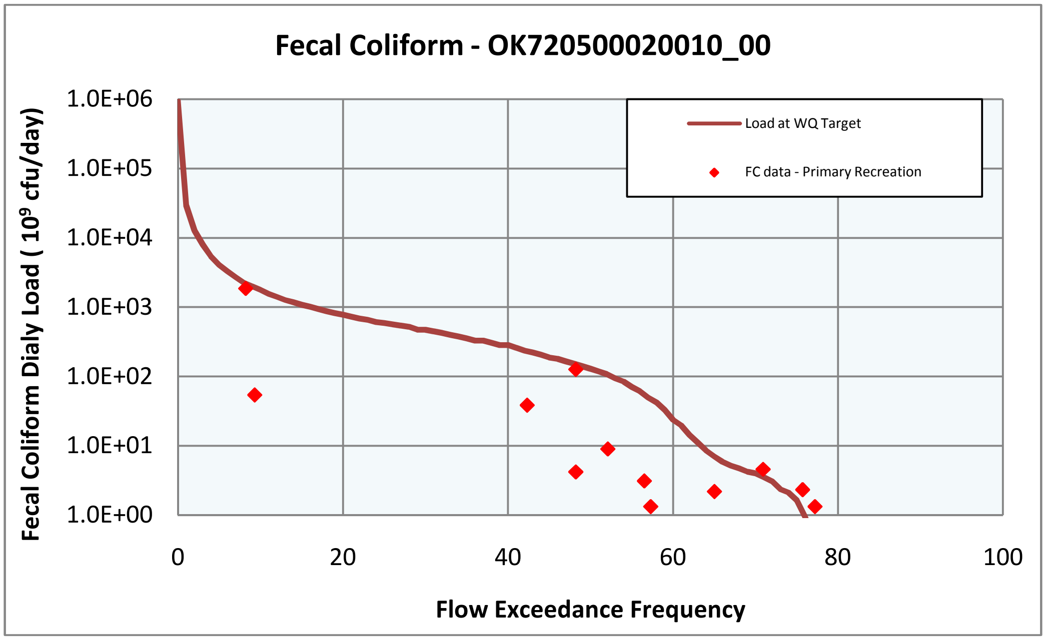


Figure 5-14 Load Duration Curve for Enterococci in Clear Creek

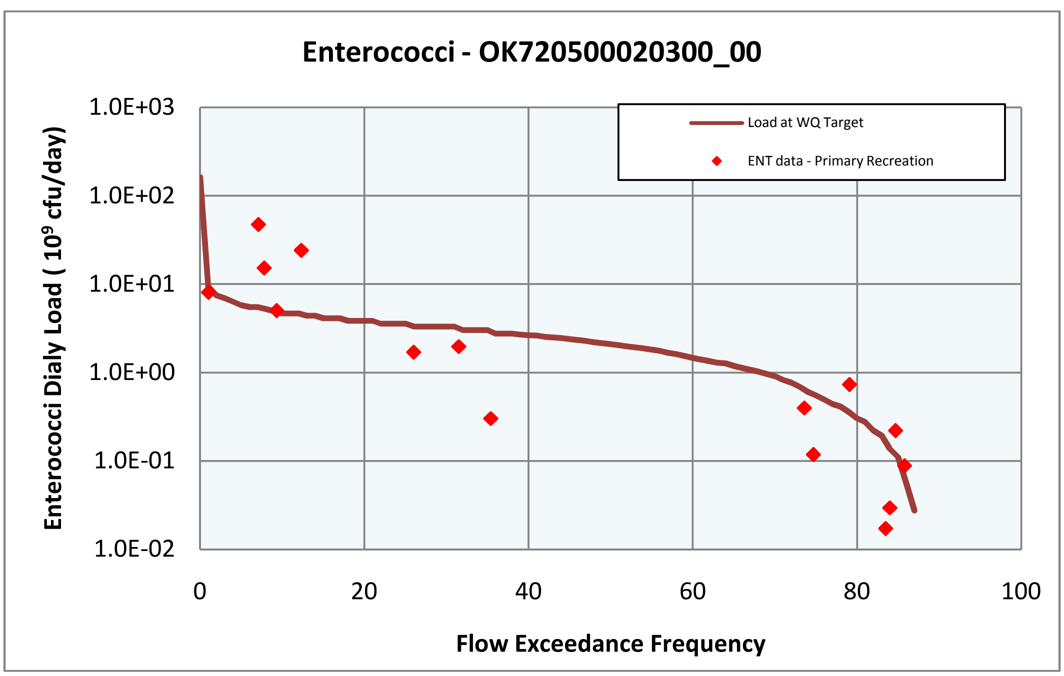


Figure 5-15 Load Duration Curve for *E. coli* in Clear Creek

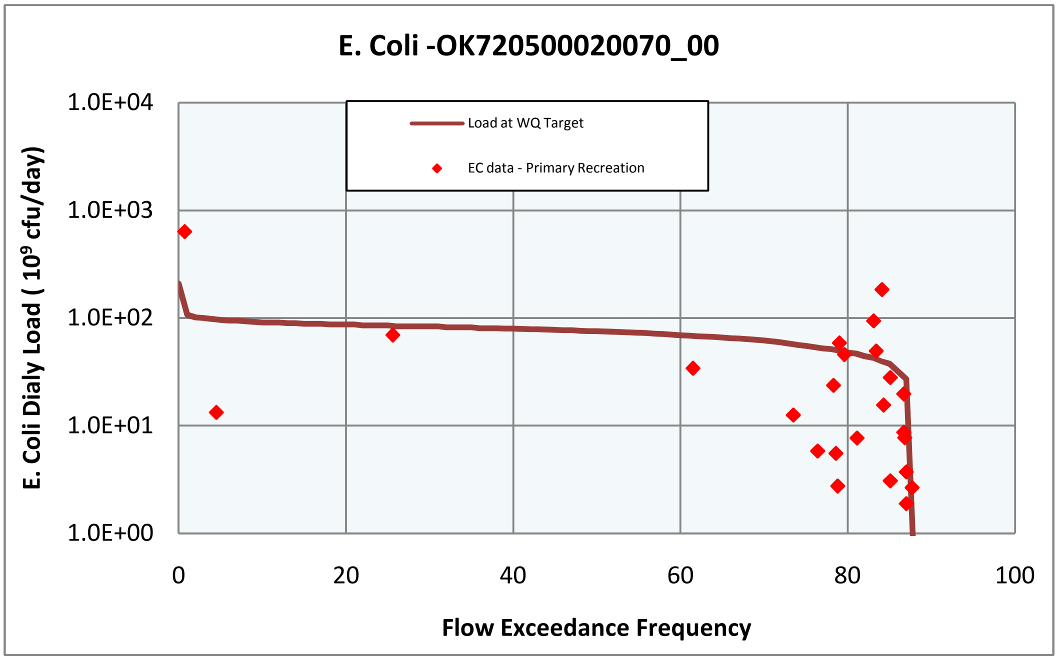


Figure 5-16 Load Duration Curve for Enterococci in Clear Creek

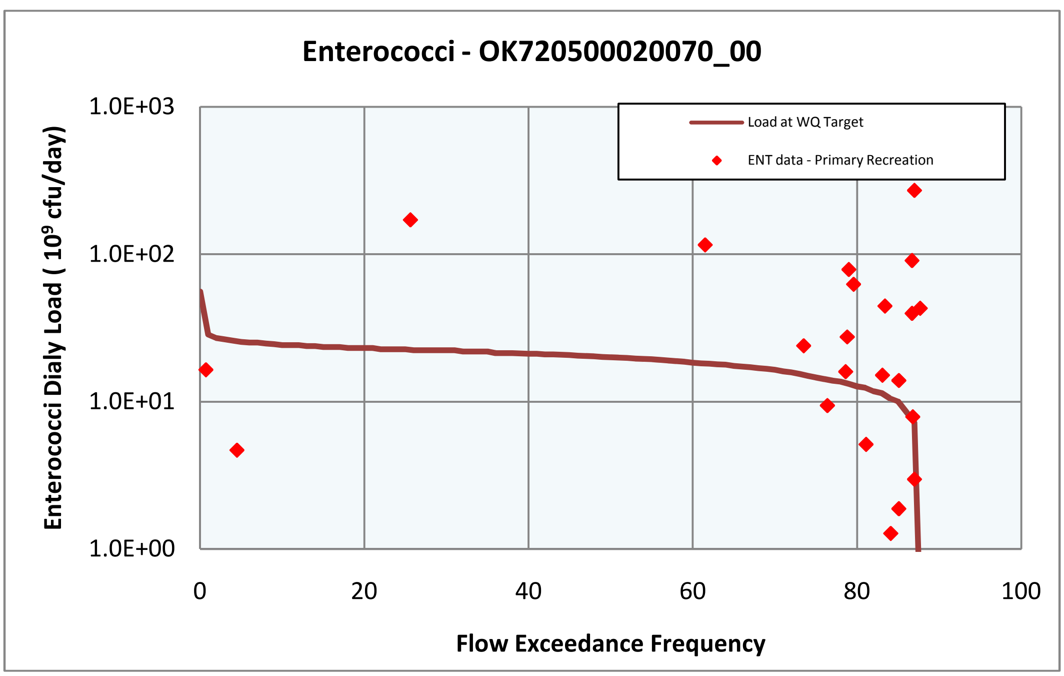


Figure 5-17 Load Duration Curve for Fecal Coliform in Clear Creek

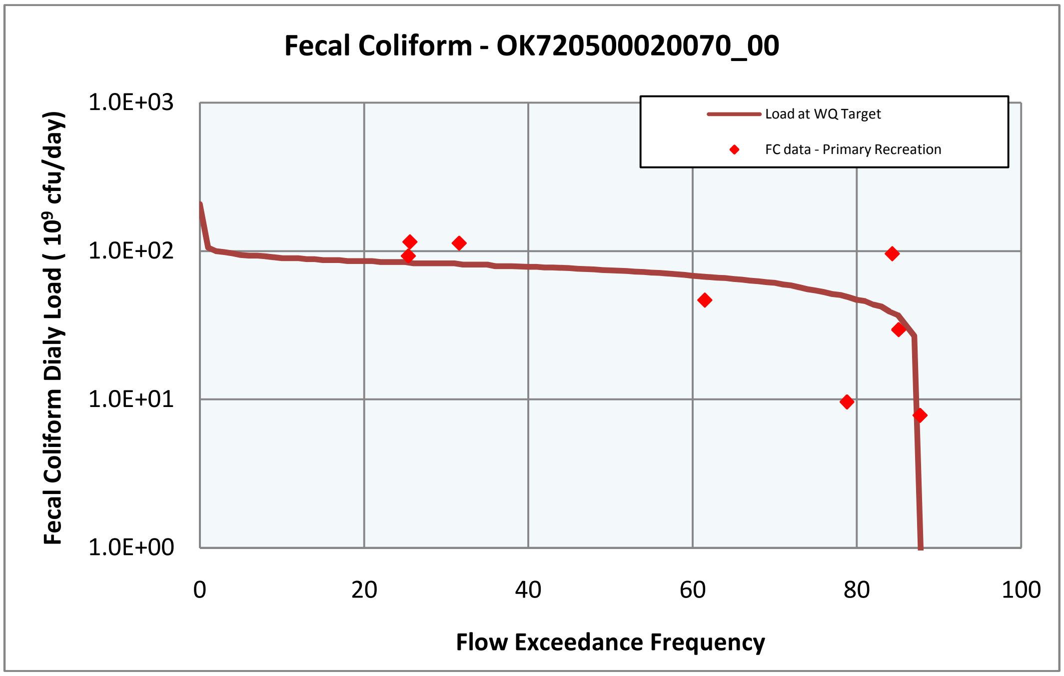


Figure 5-18 Load Duration Curve for Fecal Coliform in Corrumpa Creek

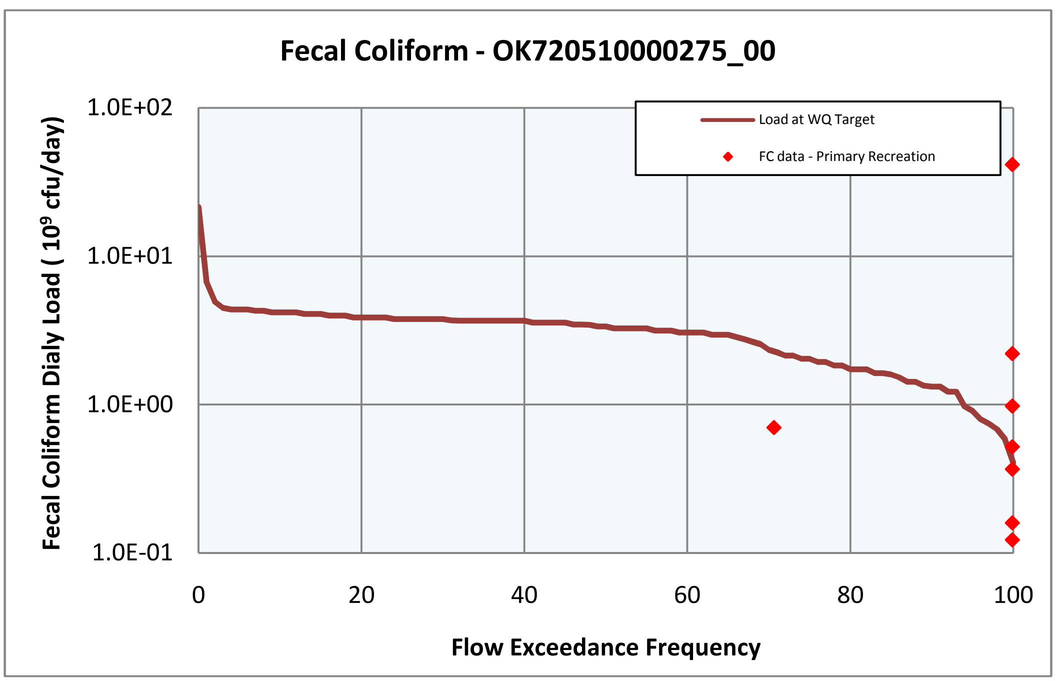


Figure 5-19 Load Duration Curve for *E. coli* in Duck Pond Creek

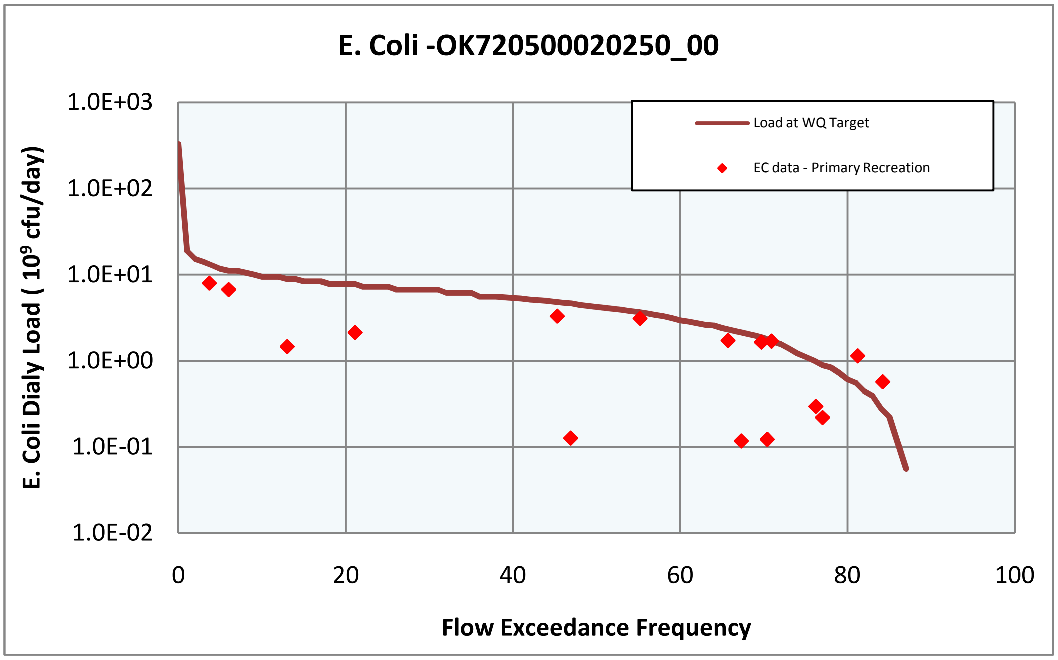


Figure 5-20 Load Duration Curve for Enterococci in Duck Pond Creek

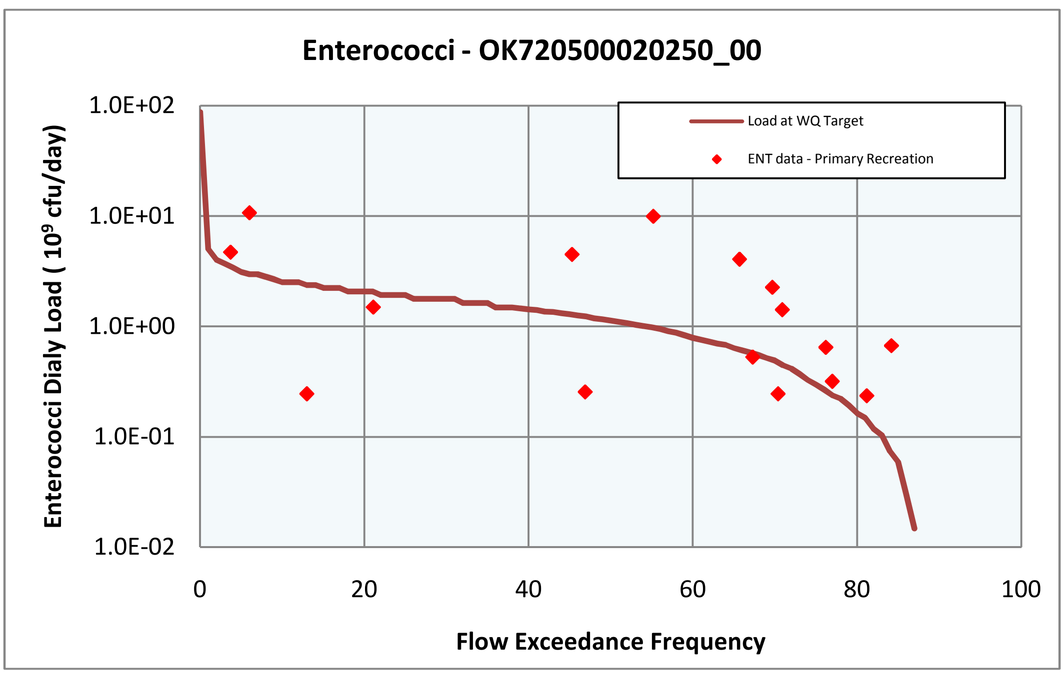


Figure 5-21 Load Duration Curve for *E. coli* in Kiowa Creek

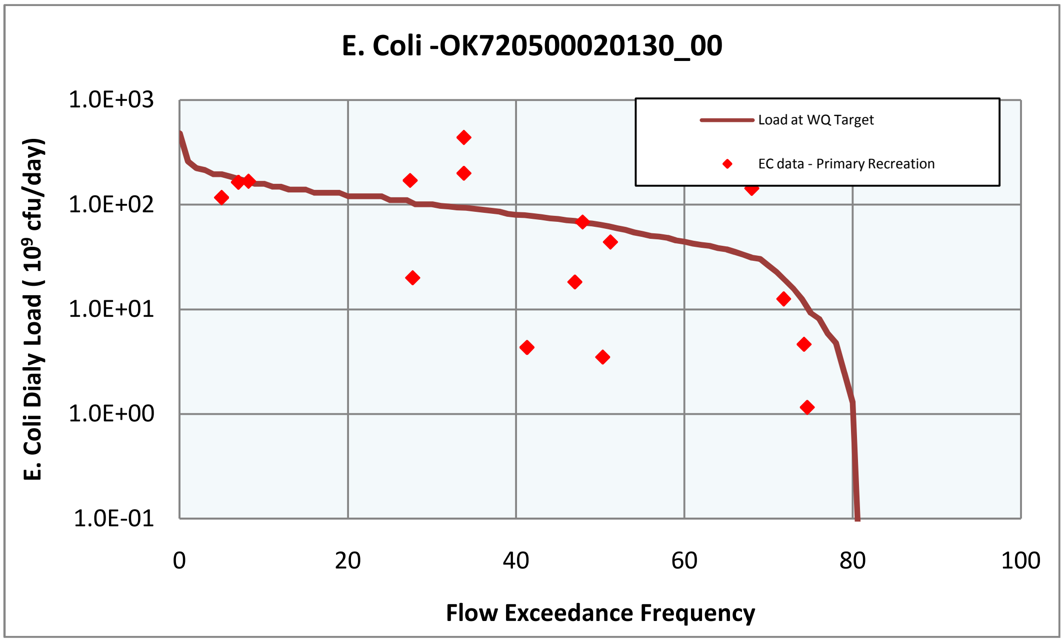


Figure 5-22 Load Duration Curve for Enterococci in Kiowa Creek

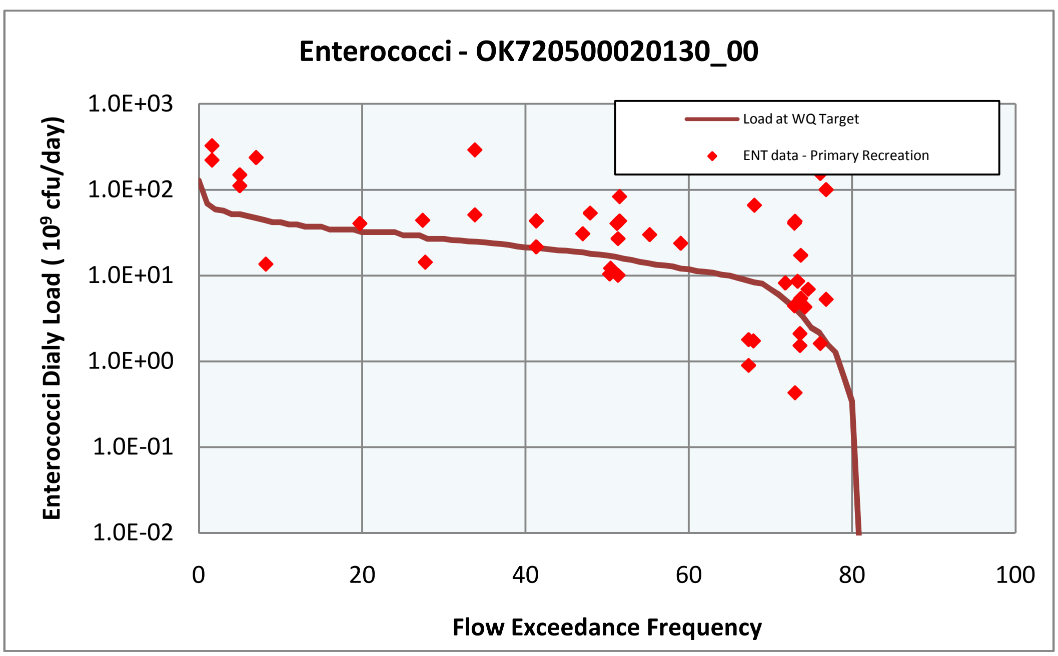


Figure 5-23 Load Duration Curve for Fecal Coliform in Kiowa Creek

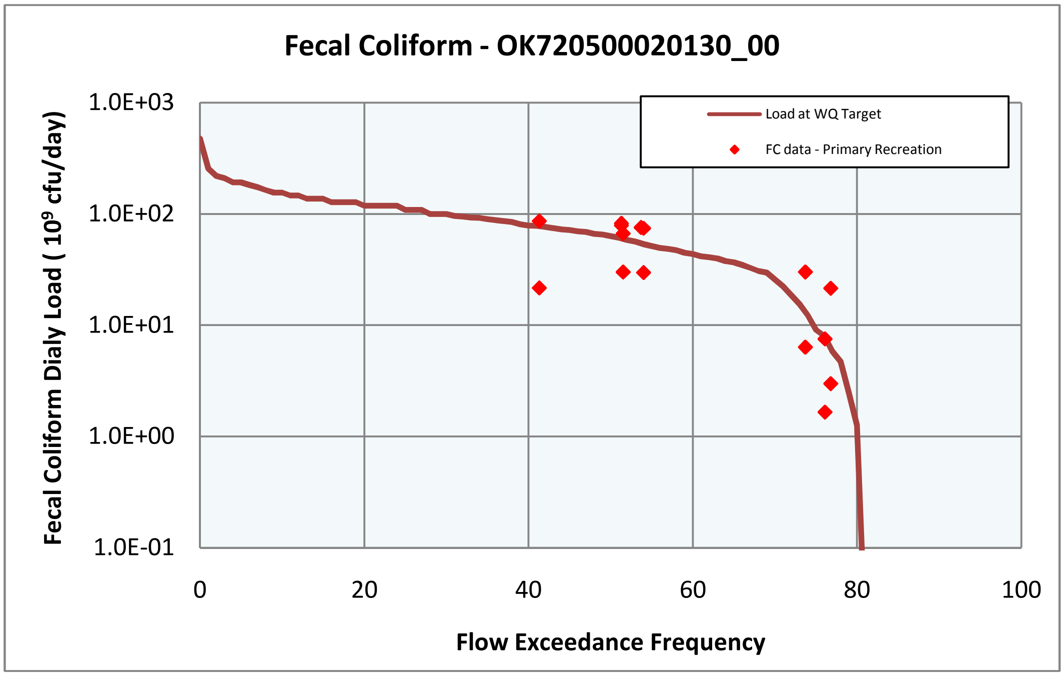


Figure 5-24 Load Duration Curve for *E. coli* in Otter Creek

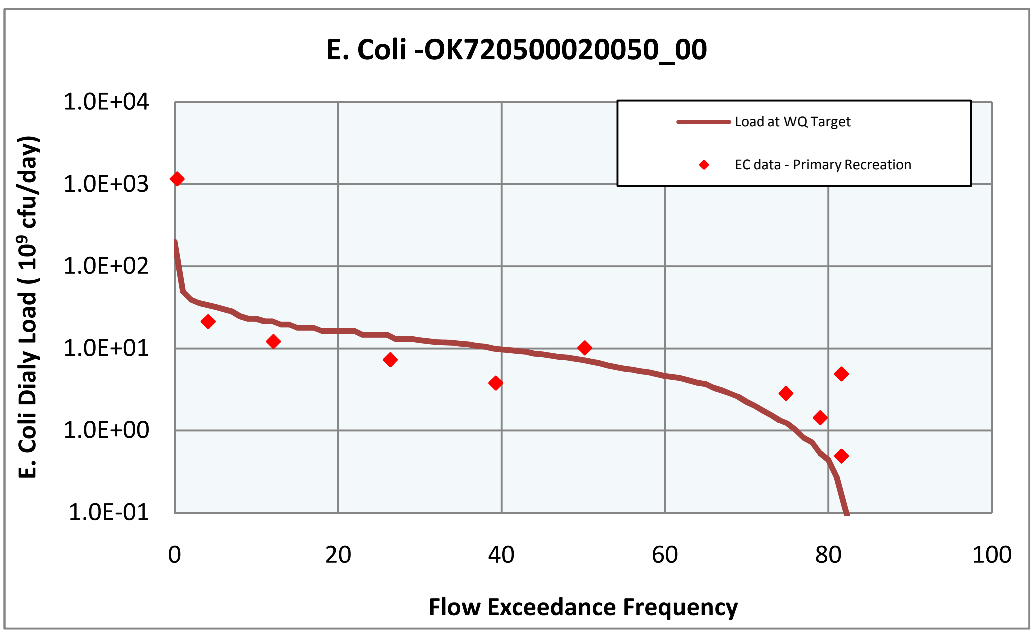


Figure 5-25 Load Duration Curve for Enterococci in Otter Creek

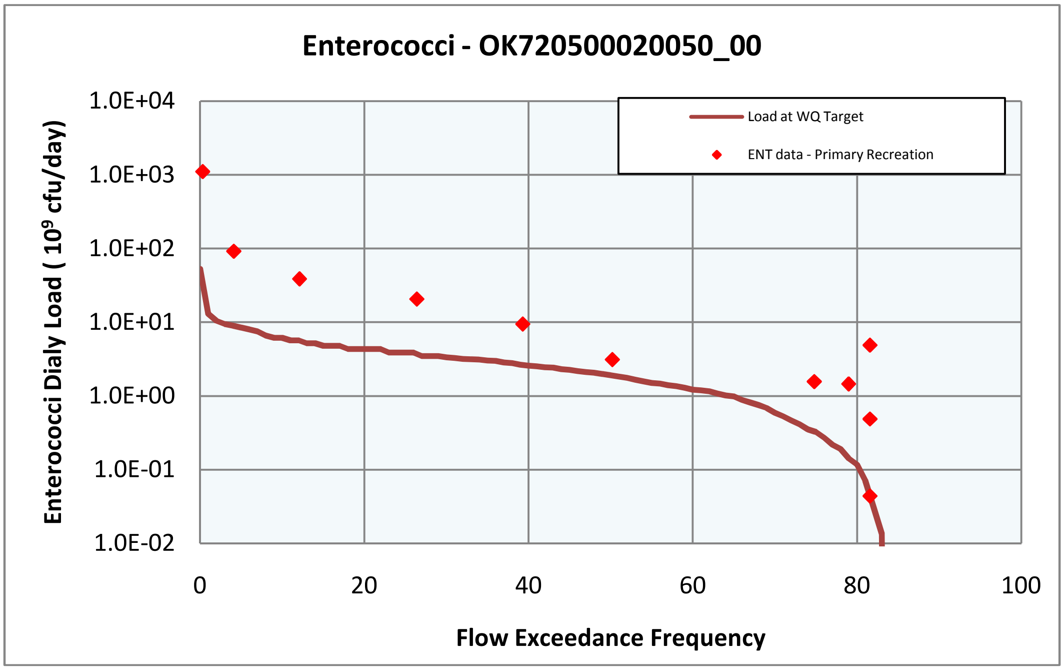


Figure 5-26 Load Duration Curve for *E. coli* in Palo Duro Creek

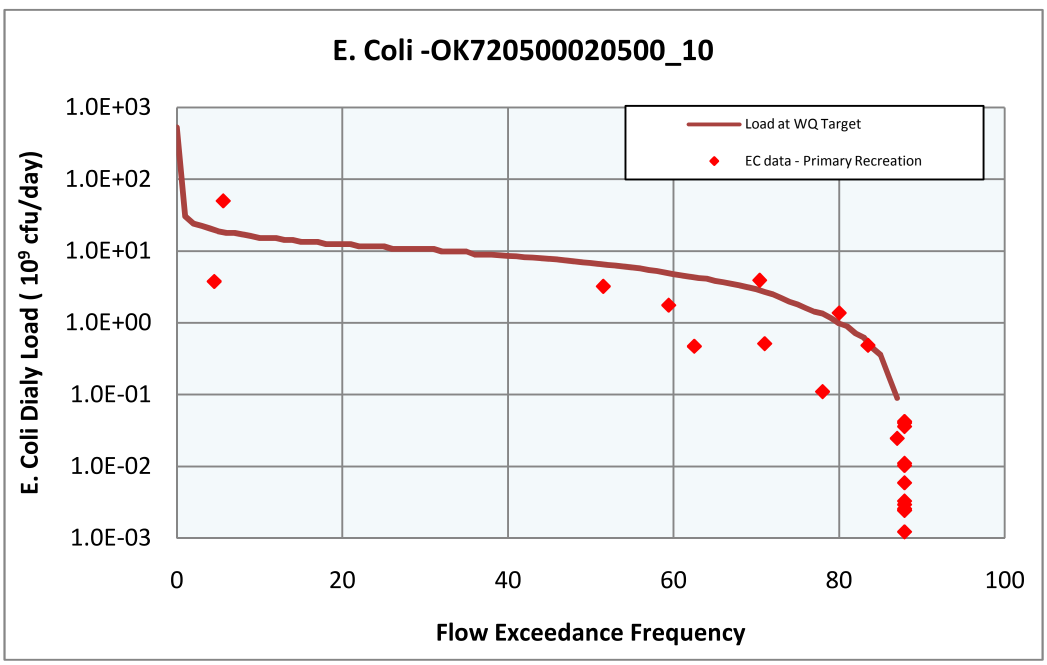


Figure 5-27 Load Duration Curve for Enterococci in Palo Duro Creek

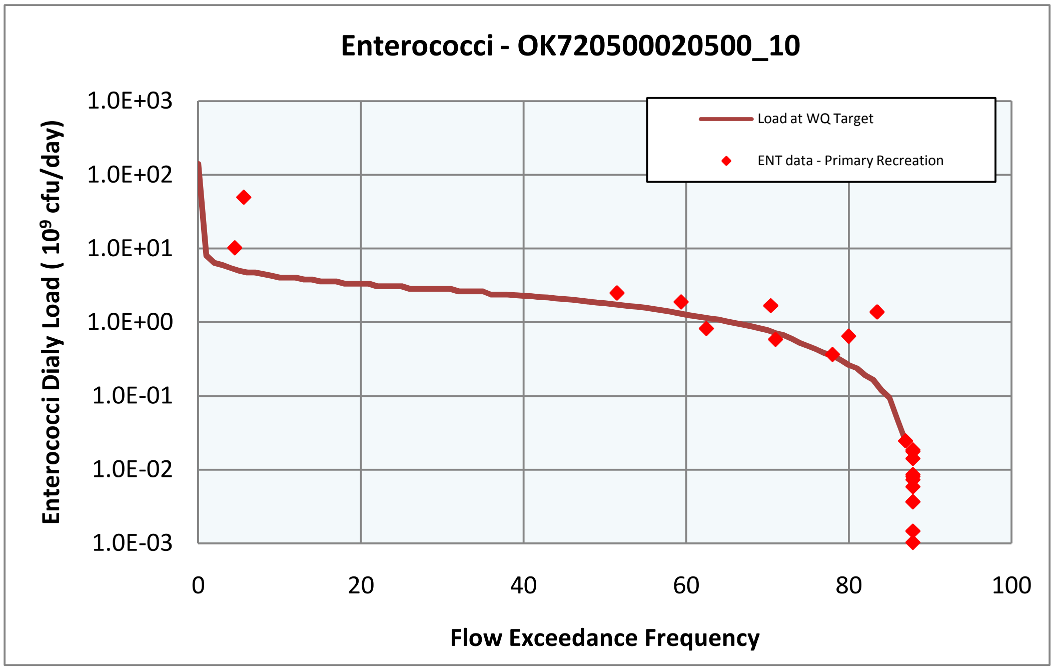


Figure 5-28 Load Duration Curve for Fecal Coliform in Palo Duro Creek

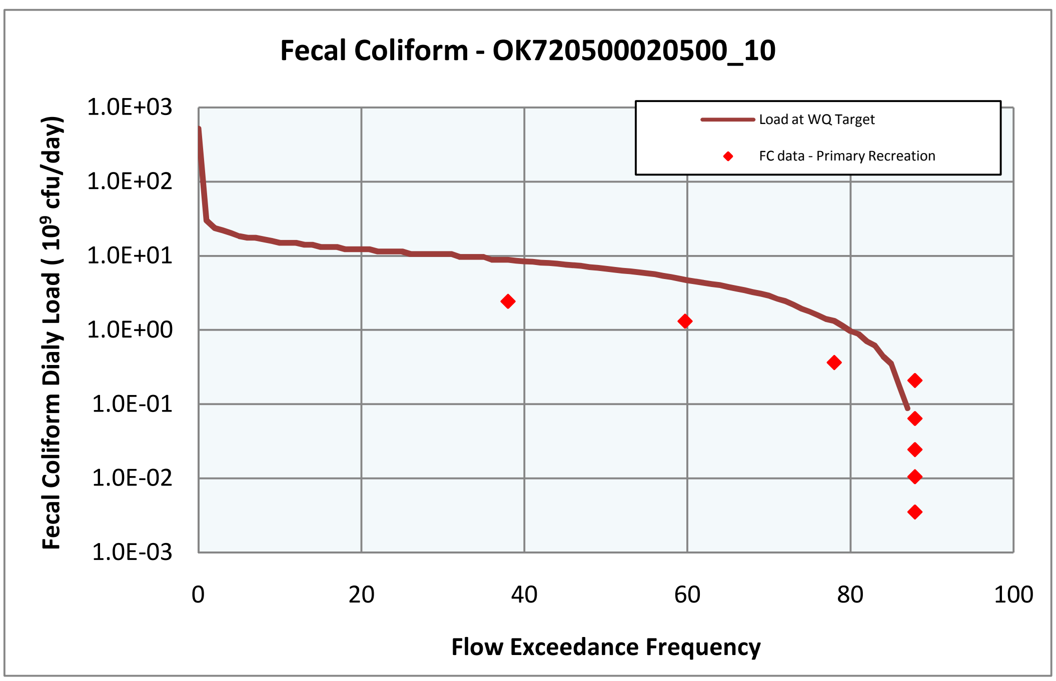


Figure 5-29 Load Duration Curve for Fecal Coliform in Palo Duro Creek

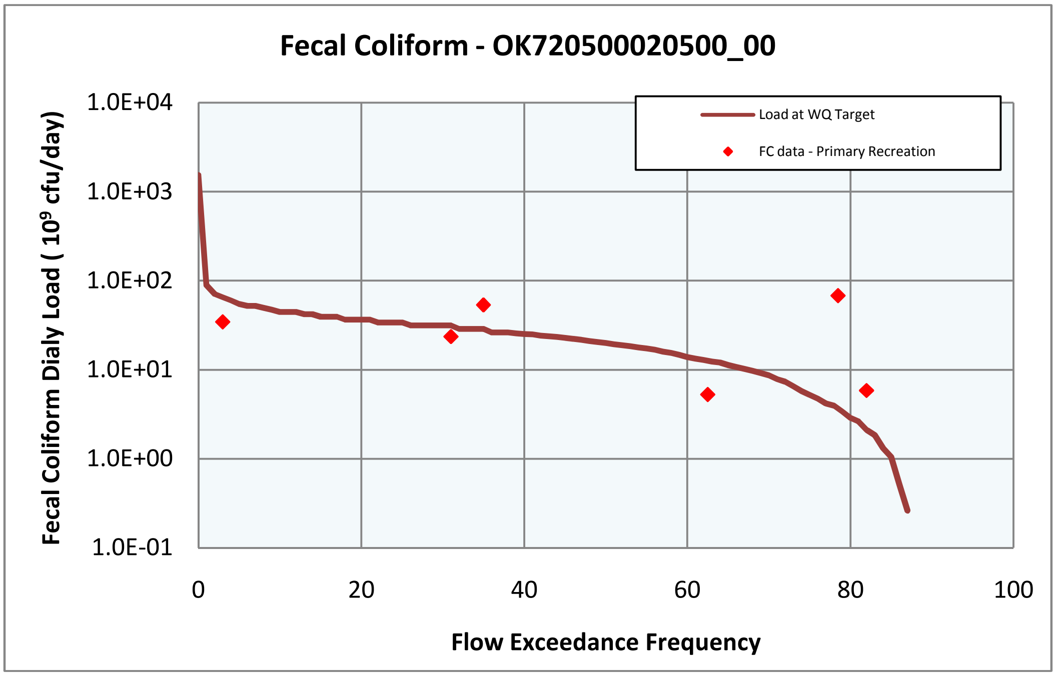


Figure 5-30 Load Duration Curve for *E. coli* in Spring Creek

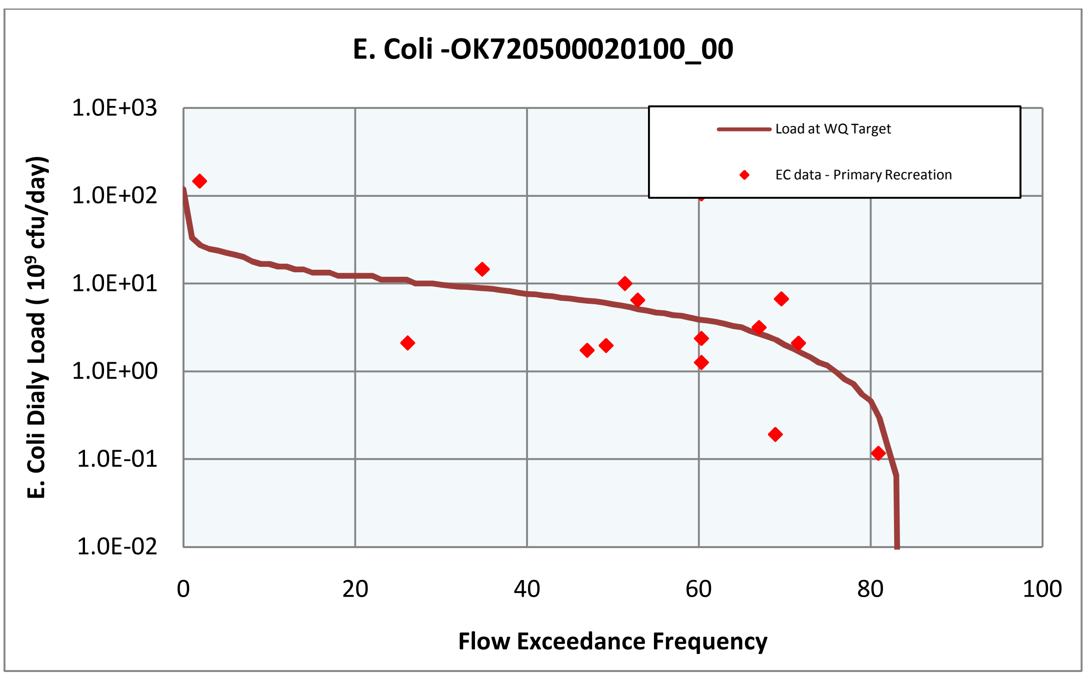


Figure 5-31 Load Duration Curve for Enterococci in Spring Creek

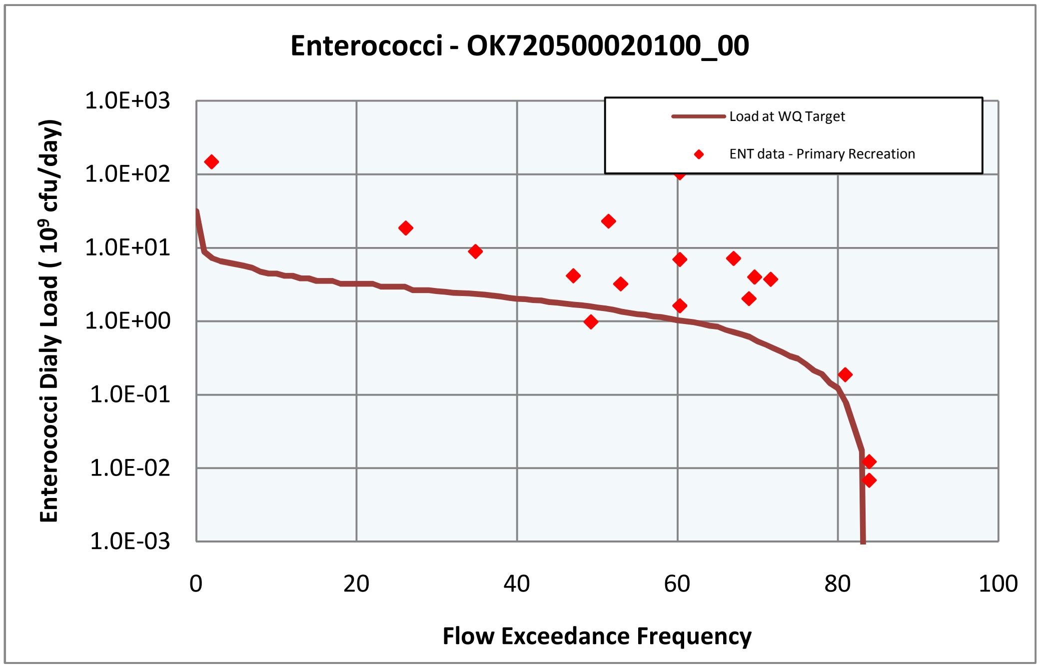


Figure 5-32 Load Duration Curve for Enterococci in Upper Wolf Creek

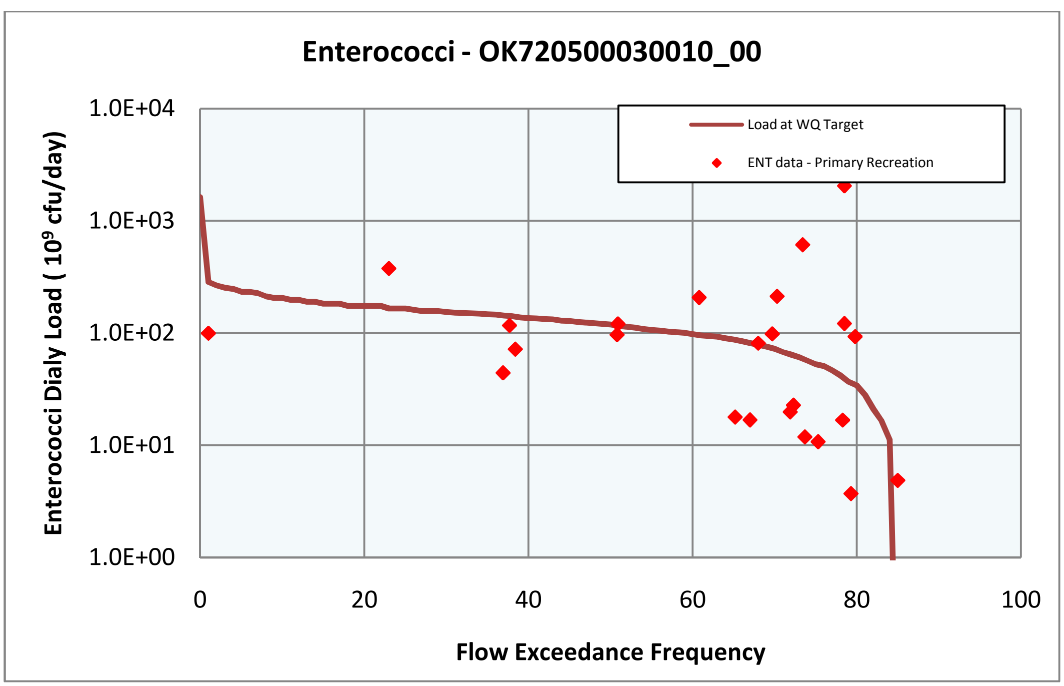


Figure 5-33 Load Duration Curve for Enterococci in Upper Wolf Creek

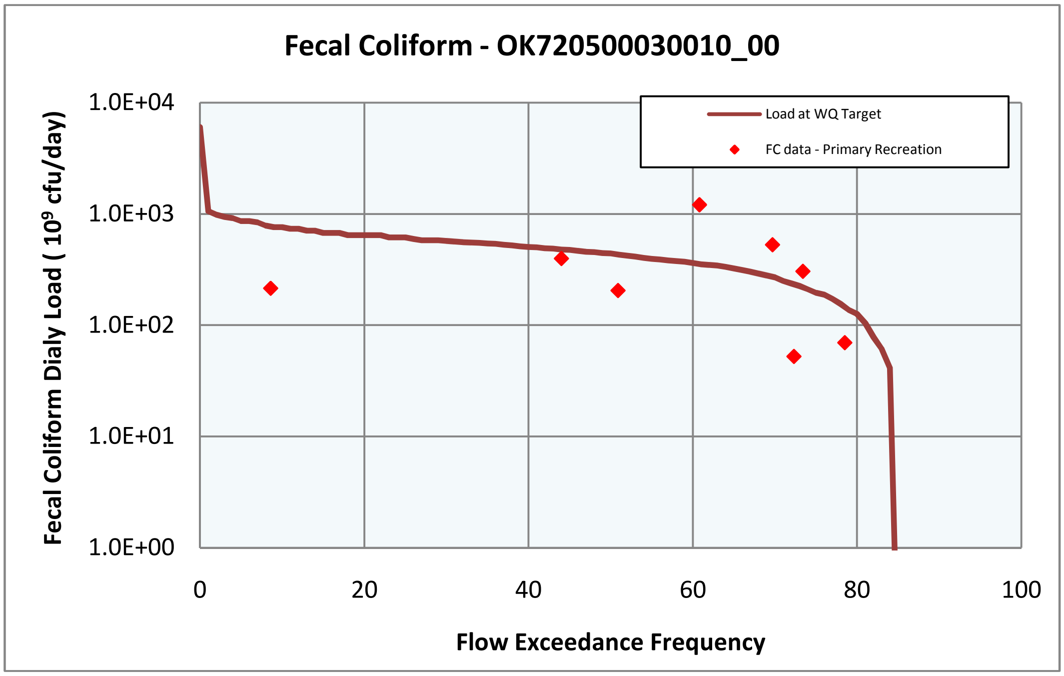
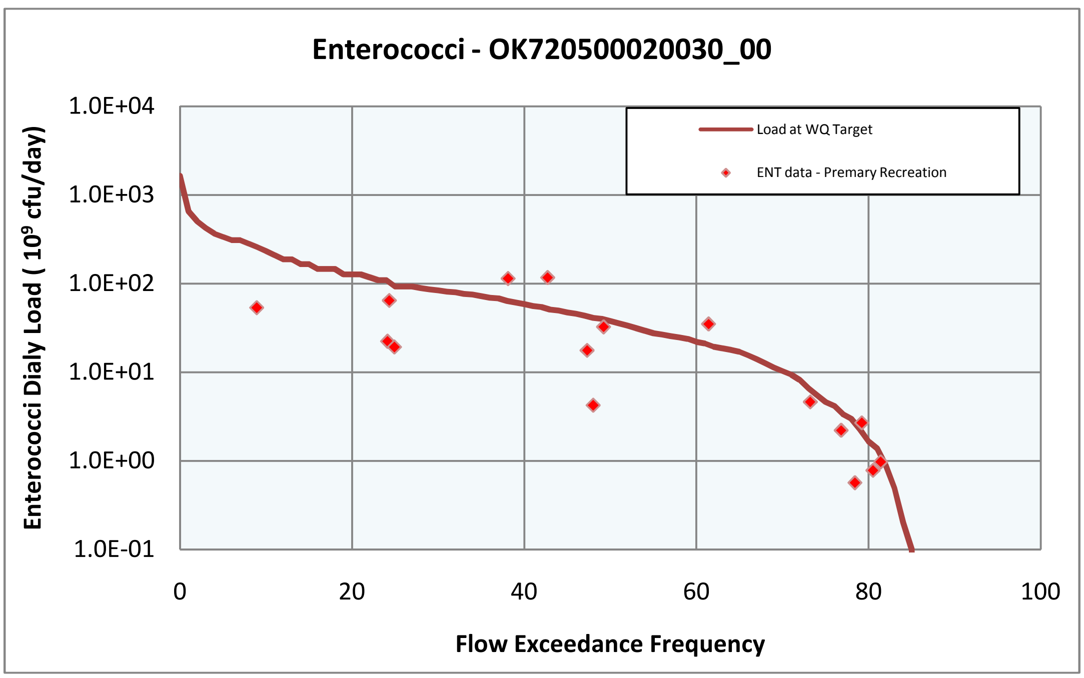


Figure 5-34 Load Duration Curve for Enterococci in Lower Wolf Creek



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 /ft*^{3}*/day/mg*) and the TSS goal (TSS target minus margin of safety) 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 1999 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 target was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample did not exceed the TSS target.

Figures 5-36 and Figure 5-37 show the TSS LDCs developed for Palo Duro Creek and Lower Wolf Creek. Data in the figures indicate that for most 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 5-35 Load Duration Curve for Total Suspended Solids in Palo Duro Creek

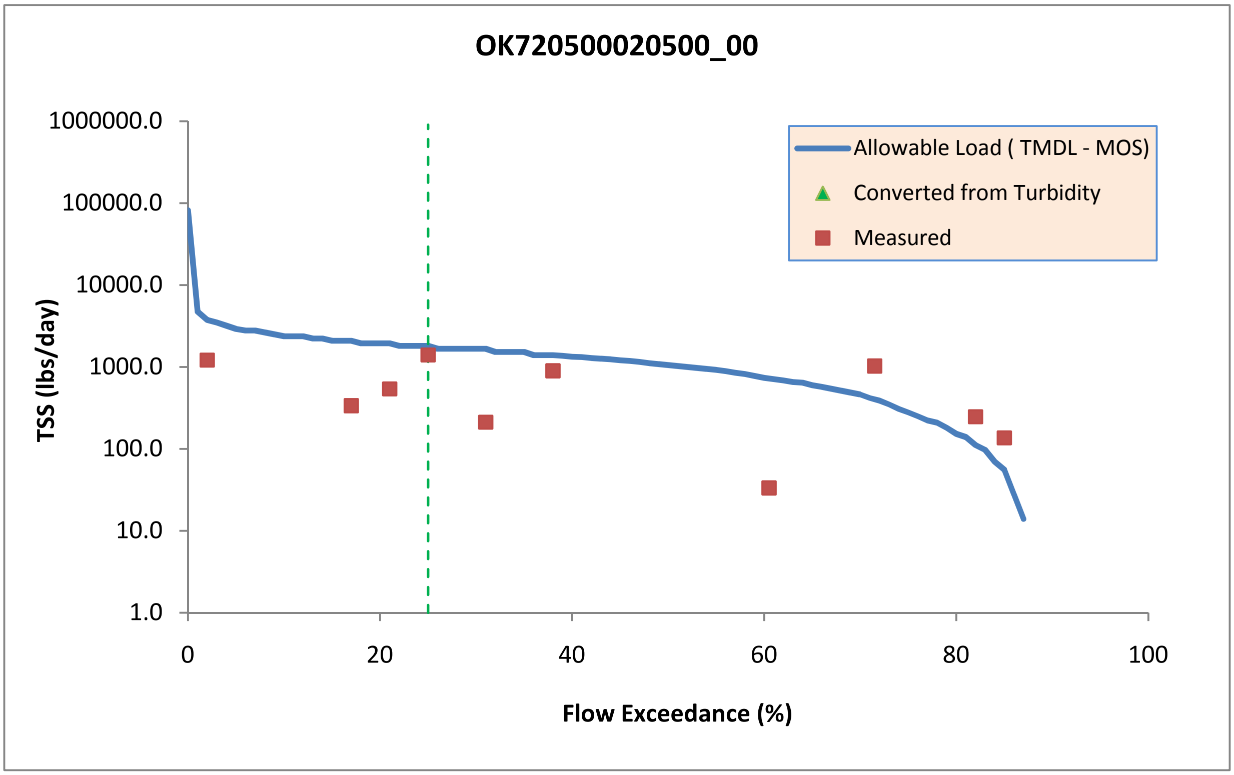
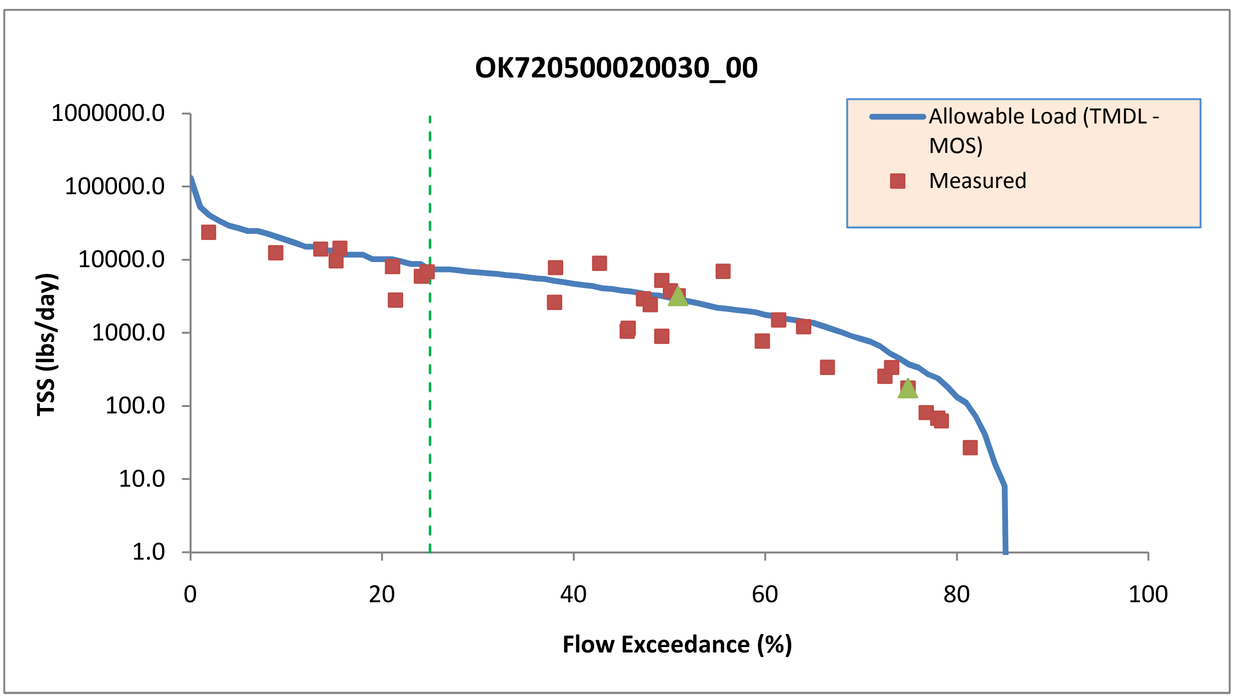


Figure 5-36 Load Duration Curve for Total Suspended Solids in Lower Wolf Creek



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 5-1 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 5-1 is denoted by the bold text.

Table 5-1 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
OK720510000190_00	Beaver River at SH 95, near Guymon	**71%**	99%	**62%**	99.8%	**92%**
OK720500020450_00	Beaver River at US 83, near Boyd	**83%**	95%	**57%**	100%	**89%**
OK720500020290_00	Beaver River at US 270, Beaver	**64%**	94%	**65%**	99.0%	**91%**
OK720500020140_00	Beaver River at US 64, near Rosston	**64%**			97%	**82%**
OK720500020010_00	Beaver River at US 283, Laverne	**22%**			87%	**49%**
OK720500020300_00	Clear Creek				89%	**45%**
OK720500020070_00	Clear Creek	**28%**	79%	**22%**	99%	**84%**
OK720510000275_00	Corrumpa Creek	**56%**				
OK720500020250_00	Duck Pond Creek		53%	**13%**	90%	**82%**
OK720500020130_00	Kiowa Creek	**28%**	81%	**13%**	99%	**82%**
OK720500020050_00	Otter Creek		96%	**77%**	99.9%	**95%**
OK720500020500_10	Palo Duro Creek	**65%**	79%	**41%**	90%	**84%**
OK720500020500_00	Palo Duro Creek	**64%**				
OK720500020100_00	Spring Creek		96%	**64%**	99%	**94%**
OK720500030010_00	Upper Wolf Creek	**28%**			98%	**69%**
OK720500020030_00	Lower Wolf Creek				56%	**43%**

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 5-2 and are 44 and 86 percent respectively.

Table 5-2 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK720500020500_00	Palo Duro Creek	**86%**
OK720500020030_00	Lower Wolf Creek	**44%**

5.2 Wasteload Allocation

5.2.1 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. 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

There are no NPDES WWTPs discharging into any contributing watersheds, therefore all bacteria TMDLs in this report have zero WLA.

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.

5.2.2 Total Suspended Solids

The WLA for the Study Area is zero.

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.

5.2.3 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 404 permits 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.

- Submit to the ODEQ a BMP turbidity reduction plan which should include all practicable turbidity control techniques. The turbidity reduction plan must be approved first before a Section 404 permit can be issued.

5.3 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

5.4 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The 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 1^{st} through September 30^{th}. 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.

5.5 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. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for the lack of knowledge, then the MOS is considered explicit.

For bacteria TMDLs, an explicit MOS of 10 percent was selected. The 10 percent MOS was applied by setting the water quality targets for calculating reduction goals at the 90% of the water quality criteria for each pathogen. Therefore, the water quality targets for load reduction goals are 360 cfu/100 mL, 365.4 cfu/100 mL, and 97.2/100 mL for fecal coliform, *E. coli*, and Enterococci, respectively.

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 5-3 shows the MOS for each waterbody.

Table 5-3 Explicit Margin of Safety for Total Suspended Solids TMDLs

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK720500020500_00	Palo Duro Creek	13.6%	15%
OK720500020030_00	Lower Wolf Creek	9.1%	10%

The explicit MOS is applied by reducing the water quality target of TSS by the percentage of the MOS. For example, the water quality target of TSS for Lower Wolf Creek is 39 mg/L and the MOS is 10%. The resulting water quality target will be 35.1 mg/L (39x (1 - 0.1) = 35.1). This target will be used to calculate the reduction rate for TSS.

5.6 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 5-4 through 5-37 summarize the allocations for indicator bacteria and Tables 5-38 and 5-39 present the allocations for total suspended solids.

Table 5-4 E. coli TMDL Calculations for Beaver River at SH 95, near Guymon (OK720510000190_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	21.00	2.09E+11	0	1.88E+11	2.09E+10
5	4.30	4.27E+10	0	3.84E+10	4.27E+09
10	4.10	4.07E+10	0	3.67E+10	4.07E+09
15	4.00	3.97E+10	0	3.58E+10	3.97E+09
20	3.80	3.77E+10	0	3.40E+10	3.77E+09
25	3.70	3.68E+10	0	3.31E+10	3.68E+09
30	3.70	3.68E+10	0	3.31E+10	3.68E+09
35	3.60	3.58E+10	0	3.22E+10	3.58E+09
40	3.60	3.58E+10	0	3.22E+10	3.58E+09
45	3.50	3.48E+10	0	3.13E+10	3.48E+09
50	3.30	3.28E+10	0	2.95E+10	3.28E+09
55	3.20	3.18E+10	0	2.86E+10	3.18E+09
60	3.00	2.98E+10	0	2.68E+10	2.98E+09
65	2.90	2.88E+10	0	2.59E+10	2.88E+09
70	2.30	2.28E+10	0	2.06E+10	2.28E+09
75	2.00	1.99E+10	0	1.79E+10	1.99E+09
80	1.70	1.69E+10	0	1.52E+10	1.69E+09
85	1.57	1.56E+10	0	1.40E+10	1.56E+09
90	1.30	1.29E+10	0	1.16E+10	1.29E+09
95	0.89	8.81E+09	0	7.93E+09	8.81E+08
100	0.40	3.97E+09	0	3.58E+09	3.97E+08

Table 5-5 Enterococci TMDL Calculations for Beaver River at SH 95, near Guymon (OK720510000190_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	21.00	5.55E+10	0	4.99E+10	5.55E+09
5	4.30	1.14E+10	0	1.02E+10	1.14E+09
10	4.10	1.08E+10	0	9.75E+09	1.08E+09
15	4.00	1.06E+10	0	9.51E+09	1.06E+09
20	3.80	1.00E+10	0	9.04E+09	1.00E+09
25	3.70	9.78E+09	0	8.80E+09	9.78E+08
30	3.70	9.78E+09	0	8.80E+09	9.78E+08
35	3.60	9.51E+09	0	8.56E+09	9.51E+08
40	3.60	9.51E+09	0	8.56E+09	9.51E+08
45	3.50	9.25E+09	0	8.32E+09	9.25E+08
50	3.30	8.72E+09	0	7.85E+09	8.72E+08
55	3.20	8.46E+09	0	7.61E+09	8.46E+08
60	3.00	7.93E+09	0	7.13E+09	7.93E+08
65	2.90	7.66E+09	0	6.90E+09	7.66E+08
70	2.30	6.08E+09	0	5.47E+09	6.08E+08
75	2.00	5.28E+09	0	4.76E+09	5.28E+08
80	1.70	4.49E+09	0	4.04E+09	4.49E+08
85	1.57	4.15E+09	0	3.73E+09	4.15E+08
90	1.30	3.43E+09	0	3.09E+09	3.43E+08
95	0.89	2.34E+09	0	2.11E+09	2.34E+08
100	0.40	1.06E+09	0	9.51E+08	1.06E+08

Table 5-6 Fecal Coliform TMDL Calculations for Beaver River at SH 95, near Guymon (OK720510000190_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	21.00	2.06E+11	0	1.85E+11	2.06E+10
5	4.30	4.21E+10	0	3.79E+10	4.21E+09
10	4.10	4.01E+10	0	3.61E+10	4.01E+09
15	4.00	3.91E+10	0	3.52E+10	3.91E+09
20	3.80	3.72E+10	0	3.35E+10	3.72E+09
25	3.70	3.62E+10	0	3.26E+10	3.62E+09
30	3.70	3.62E+10	0	3.26E+10	3.62E+09
35	3.60	3.52E+10	0	3.17E+10	3.52E+09
40	3.60	3.52E+10	0	3.17E+10	3.52E+09
45	3.50	3.43E+10	0	3.08E+10	3.43E+09
50	3.30	3.23E+10	0	2.91E+10	3.23E+09
55	3.20	3.13E+10	0	2.82E+10	3.13E+09
60	3.00	2.94E+10	0	2.64E+10	2.94E+09
65	2.90	2.84E+10	0	2.55E+10	2.84E+09
70	2.30	2.25E+10	0	2.03E+10	2.25E+09
75	2.00	1.96E+10	0	1.76E+10	1.96E+09
80	1.70	1.66E+10	0	1.50E+10	1.66E+09
85	1.57	1.54E+10	0	1.38E+10	1.54E+09
90	1.30	1.27E+10	0	1.14E+10	1.27E+09
95	0.89	8.68E+09	0	7.81E+09	8.68E+08
100	0.40	3.91E+09	0	3.52E+09	3.91E+08

Table 5-7 E. coli TMDL Calculations for Beaver River at US 83, near Boyd (OK720500020450_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	23546	2.34E+14	0	2.10E+14	2.34E+13
5	103	1.02E+12	0	9.18E+11	1.02E+11
10	45	4.46E+11	0	4.01E+11	4.46E+10
15	27	2.70E+11	0	2.43E+11	2.70E+10
20	19	1.93E+11	0	1.74E+11	1.93E+10
25	15	1.47E+11	0	1.32E+11	1.47E+10
30	12	1.17E+11	0	1.06E+11	1.17E+10
35	9	8.79E+10	0	7.91E+10	8.79E+09
40	7	7.03E+10	0	6.33E+10	7.03E+09
45	5	4.69E+10	0	4.22E+10	4.69E+09
50	3	3.22E+10	0	2.90E+10	3.22E+09
55	1.77	1.76E+10	0	1.58E+10	1.76E+09
60	0.59	5.86E+09	0	5.28E+09	5.86E+08
65	0.18	1.76E+09	0	1.58E+09	1.76E+08
70	0.10	9.97E+08	0	8.97E+08	9.97E+07
75	0.04	4.10E+08	0	3.69E+08	4.10E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-8 Enterococci TMDL Calculations for Beaver River at US 83, near Boyd (OK720500020450_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	23546	6.22E+13	0	5.60E+13	6.22E+12
5	103	2.71E+11	0	2.44E+11	2.71E+10
10	45	1.19E+11	0	1.07E+11	1.19E+10
15	27	7.17E+10	0	6.46E+10	7.17E+09
20	19	5.15E+10	0	4.63E+10	5.15E+09
25	15	3.90E+10	0	3.51E+10	3.90E+09
30	12	3.12E+10	0	2.81E+10	3.12E+09
35	9	2.34E+10	0	2.11E+10	2.34E+09
40	7	1.87E+10	0	1.68E+10	1.87E+09
45	5	1.25E+10	0	1.12E+10	1.25E+09
50	3	8.58E+09	0	7.72E+09	8.58E+08
55	1.77	4.68E+09	0	4.21E+09	4.68E+08
60	0.59	1.56E+09	0	1.40E+09	1.56E+08
65	0.18	4.68E+08	0	4.21E+08	4.68E+07
70	0.10	2.65E+08	0	2.39E+08	2.65E+07
75	0.04	1.09E+08	0	9.82E+07	1.09E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-9 Fecal Coliform TMDL Calculations for Beaver River at US 83, near Boyd (OK720500020450_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	23546	2.30E+14	0	2.07E+14	2.30E+13
5	103	1.00E+12	0	9.04E+11	1.00E+11
10	45	4.39E+11	0	3.95E+11	4.39E+10
15	27	2.66E+11	0	2.39E+11	2.66E+10
20	19	1.91E+11	0	1.72E+11	1.91E+10
25	15	1.44E+11	0	1.30E+11	1.44E+10
30	12	1.16E+11	0	1.04E+11	1.16E+10
35	9	8.66E+10	0	7.80E+10	8.66E+09
40	7	6.93E+10	0	6.24E+10	6.93E+09
45	5	4.62E+10	0	4.16E+10	4.62E+09
50	3	3.18E+10	0	2.86E+10	3.18E+09
55	1.77	1.73E+10	0	1.56E+10	1.73E+09
60	0.59	5.78E+09	0	5.20E+09	5.78E+08
65	0.18	1.73E+09	0	1.56E+09	1.73E+08
70	0.10	9.82E+08	0	8.84E+08	9.82E+07
75	0.04	4.04E+08	0	3.64E+08	4.04E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-10 E. coli TMDL Calculations for Beaver River at US 270, Beaver(OK720500020290_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	39900	3.96E+14	0	3.57E+14	3.96E+13
5	174	1.73E+12	0	1.56E+12	1.73E+11
10	76	7.55E+11	0	6.79E+11	7.55E+10
15	46	4.57E+11	0	4.11E+11	4.57E+10
20	33	3.28E+11	0	2.95E+11	3.28E+10
25	25	2.48E+11	0	2.23E+11	2.48E+10
30	20	1.99E+11	0	1.79E+11	1.99E+10
35	15	1.49E+11	0	1.34E+11	1.49E+10
40	12	1.19E+11	0	1.07E+11	1.19E+10
45	8	7.95E+10	0	7.15E+10	7.95E+09
50	6	5.46E+10	0	4.92E+10	5.46E+09
55	3	2.98E+10	0	2.68E+10	2.98E+09
60	1	9.93E+09	0	8.94E+09	9.93E+08
65	0.3	2.98E+09	0	2.68E+09	2.98E+08
70	0.2	1.69E+09	0	1.52E+09	1.69E+08
75	0.1	6.95E+08	0	6.26E+08	6.95E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-11 Enterococci TMDL Calculations for Beaver River at US 270, Beaver(OK720500020290_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	39900	1.05E+14	0	9.49E+13	1.05E+13
5	174	4.60E+11	0	4.14E+11	4.60E+10
10	76	2.01E+11	0	1.81E+11	2.01E+10
15	46	1.22E+11	0	1.09E+11	1.22E+10
20	33	8.72E+10	0	7.85E+10	8.72E+09
25	25	6.61E+10	0	5.95E+10	6.61E+09
30	20	5.28E+10	0	4.76E+10	5.28E+09
35	15	3.96E+10	0	3.57E+10	3.96E+09
40	12	3.17E+10	0	2.85E+10	3.17E+09
45	8	2.11E+10	0	1.90E+10	2.11E+09
50	6	1.45E+10	0	1.31E+10	1.45E+09
55	3	7.93E+09	0	7.13E+09	7.93E+08
60	1	2.64E+09	0	2.38E+09	2.64E+08
65	0.3	7.93E+08	0	7.13E+08	7.93E+07
70	0.2	4.49E+08	0	4.04E+08	4.49E+07
75	0.1	1.85E+08	0	1.66E+08	1.85E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-12 Fecal Coliform TMDL Calculations for Beaver River at US 270, Beaver(OK720500020290_00))

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	39900	3.90E+14	0	3.51E+14	3.90E+13
5	174	1.70E+12	0	1.53E+12	1.70E+11
10	76	7.44E+11	0	6.69E+11	7.44E+10
15	46	4.50E+11	0	4.05E+11	4.50E+10
20	33	3.23E+11	0	2.91E+11	3.23E+10
25	25	2.45E+11	0	2.20E+11	2.45E+10
30	20	1.96E+11	0	1.76E+11	1.96E+10
35	15	1.47E+11	0	1.32E+11	1.47E+10
40	12	1.17E+11	0	1.06E+11	1.17E+10
45	8	7.83E+10	0	7.05E+10	7.83E+09
50	6	5.38E+10	0	4.84E+10	5.38E+09
55	3	2.94E+10	0	2.64E+10	2.94E+09
60	1	9.79E+09	0	8.81E+09	9.79E+08
65	0.3	2.94E+09	0	2.64E+09	2.94E+08
70	0.2	1.66E+09	0	1.50E+09	1.66E+08
75	0.1	6.85E+08	0	6.17E+08	6.85E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-13 Enterococci TMDL Calculations for Beaver River at US 64, near Rosston (OK720500020140_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	89611	2.37E+14	0	2.13E+14	2.37E+13
5	391	1.03E+12	0	9.29E+11	1.03E+11
10	171	4.51E+11	0	4.06E+11	4.51E+10
15	103	2.73E+11	0	2.46E+11	2.73E+10
20	74	1.96E+11	0	1.76E+11	1.96E+10
25	56	1.48E+11	0	1.34E+11	1.48E+10
30	45	1.19E+11	0	1.07E+11	1.19E+10
35	34	8.90E+10	0	8.01E+10	8.90E+09
40	27	7.12E+10	0	6.41E+10	7.12E+09
45	18	4.75E+10	0	4.27E+10	4.75E+09
50	12	3.26E+10	0	2.94E+10	3.26E+09
55	6.74	1.78E+10	0	1.60E+10	1.78E+09
60	2.25	5.93E+09	0	5.34E+09	5.93E+08
65	0.67	1.78E+09	0	1.60E+09	1.78E+08
70	0.38	1.01E+09	0	9.08E+08	1.01E+08
75	0.16	4.15E+08	0	3.74E+08	4.15E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-14 Fecal Coliform TMDL Calculations for Beaver River at US 64, near Rosston (OK720500020140_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	89611	8.77E+14	0	7.89E+14	8.77E+13
5	391	3.82E+12	0	3.44E+12	3.82E+11
10	171	1.67E+12	0	1.50E+12	1.67E+11
15	103	1.01E+12	0	9.10E+11	1.01E+11
20	74	7.25E+11	0	6.53E+11	7.25E+10
25	56	5.49E+11	0	4.95E+11	5.49E+10
30	45	4.40E+11	0	3.96E+11	4.40E+10
35	34	3.30E+11	0	2.97E+11	3.30E+10
40	27	2.64E+11	0	2.37E+11	2.64E+10
45	18	1.76E+11	0	1.58E+11	1.76E+10
50	12	1.21E+11	0	1.09E+11	1.21E+10
55	6.74	6.59E+10	0	5.93E+10	6.59E+09
60	2.25	2.20E+10	0	1.98E+10	2.20E+09
65	0.67	6.59E+09	0	5.93E+09	6.59E+08
70	0.38	3.74E+09	0	3.36E+09	3.74E+08
75	0.16	1.54E+09	0	1.38E+09	1.54E+08
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-15 Enterococci TMDL Calculations for Beaver River at US 283, Laverne (OK720500020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	106806	2.82E+14	0	2.54E+14	2.82E+13
5	466	1.23E+12	0	1.11E+12	1.23E+11
10	203	5.38E+11	0	4.84E+11	5.38E+10
15	123	3.25E+11	0	2.93E+11	3.25E+10
20	88	2.33E+11	0	2.10E+11	2.33E+10
25	67	1.77E+11	0	1.59E+11	1.77E+10
30	54	1.41E+11	0	1.27E+11	1.41E+10
35	40	1.06E+11	0	9.55E+10	1.06E+10
40	32	8.49E+10	0	7.64E+10	8.49E+09
45	21	5.66E+10	0	5.09E+10	5.66E+09
50	15	3.89E+10	0	3.50E+10	3.89E+09
55	8	2.12E+10	0	1.91E+10	2.12E+09
60	2.7	7.07E+09	0	6.37E+09	7.07E+08
65	0.8	2.12E+09	0	1.91E+09	2.12E+08
70	0.5	1.20E+09	0	1.08E+09	1.20E+08
75	0.2	4.95E+08	0	4.46E+08	4.95E+07
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-16 Fecal Coliform TMDL Calculations for Beaver River at US 283, Laverne (OK720500020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	106806	1.05E+15	0	9.41E+14	1.05E+14
5	466	4.56E+12	0	4.10E+12	4.56E+11
10	203	1.99E+12	0	1.79E+12	1.99E+11
15	123	1.21E+12	0	1.08E+12	1.21E+11
20	88	8.64E+11	0	7.78E+11	8.64E+10
25	67	6.55E+11	0	5.89E+11	6.55E+10
30	54	5.24E+11	0	4.72E+11	5.24E+10
35	40	3.93E+11	0	3.54E+11	3.93E+10
40	32	3.14E+11	0	2.83E+11	3.14E+10
45	21	2.10E+11	0	1.89E+11	2.10E+10
50	15	1.44E+11	0	1.30E+11	1.44E+10
55	8	7.86E+10	0	7.07E+10	7.86E+09
60	2.7	2.62E+10	0	2.36E+10	2.62E+09
65	0.8	7.86E+09	0	7.07E+09	7.86E+08
70	0.5	4.45E+09	0	4.01E+09	4.45E+08
75	0.2	1.83E+09	0	1.65E+09	1.83E+08
80	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-17 Enterococci TMDL Calculations for Clear Creek (OK720500020300_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	68	1.80E+11	0	1.62E+11	1.80E+10
5	2	6.42E+09	0	5.77E+09	6.42E+08
10	2	5.19E+09	0	4.67E+09	5.19E+08
15	2	4.58E+09	0	4.12E+09	4.58E+08
20	2	4.28E+09	0	3.85E+09	4.28E+08
25	2	3.97E+09	0	3.57E+09	3.97E+08
30	1	3.67E+09	0	3.30E+09	3.67E+08
35	1	3.36E+09	0	3.02E+09	3.36E+08
40	1	2.93E+09	0	2.64E+09	2.93E+08
45	1	2.66E+09	0	2.39E+09	2.66E+08
50	1	2.32E+09	0	2.09E+09	2.32E+08
55	1	2.02E+09	0	1.81E+09	2.02E+08
60	0.6	1.62E+09	0	1.46E+09	1.62E+08
65	0.5	1.31E+09	0	1.18E+09	1.31E+08
70	0.4	1.01E+09	0	9.07E+08	1.01E+08
75	0.2	6.11E+08	0	5.50E+08	6.11E+07
80	0.1	3.36E+08	0	3.02E+08	3.36E+07
85	0.05	1.22E+08	0	1.10E+08	1.22E+07
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-18 E. coli TMDL Calculations for Clear Creek (OK720500020070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	23	2.33E+11	0	2.10E+11	2.33E+10
5	11	1.06E+11	0	9.56E+10	1.06E+10
10	10	1.01E+11	0	9.10E+10	1.01E+10
15	10	9.82E+10	0	8.84E+10	9.82E+09
20	10	9.66E+10	0	8.69E+10	9.66E+09
25	10	9.49E+10	0	8.54E+10	9.49E+09
30	9	9.31E+10	0	8.38E+10	9.31E+09
35	9	9.13E+10	0	8.21E+10	9.13E+09
40	9	8.84E+10	0	7.95E+10	8.84E+09
45	9	8.64E+10	0	7.77E+10	8.64E+09
50	8	8.36E+10	0	7.53E+10	8.36E+09
55	8	8.09E+10	0	7.28E+10	8.09E+09
60	7.7	7.68E+10	0	6.92E+10	7.68E+09
65	7.4	7.31E+10	0	6.58E+10	7.31E+09
70	6.9	6.87E+10	0	6.18E+10	6.87E+09
75	6.1	6.11E+10	0	5.50E+10	6.11E+09
80	5.3	5.30E+10	0	4.77E+10	5.30E+09
85	4.2	4.18E+10	0	3.76E+10	4.18E+09
90	0.04	4.02E+08	0	3.62E+08	4.02E+07
95	0.04	4.02E+08	0	3.62E+08	4.02E+07
100	0	0	0	0	0

Table 5-19 Enterococci TMDL Calculations for Clear Creek (OK720500020070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	23	6.20E+10	0	5.58E+10	6.20E+09
5	11	2.83E+10	0	2.54E+10	2.83E+09
10	10	2.69E+10	0	2.42E+10	2.69E+09
15	10	2.61E+10	0	2.35E+10	2.61E+09
20	10	2.57E+10	0	2.31E+10	2.57E+09
25	10	2.52E+10	0	2.27E+10	2.52E+09
30	9	2.48E+10	0	2.23E+10	2.48E+09
35	9	2.43E+10	0	2.18E+10	2.43E+09
40	9	2.35E+10	0	2.12E+10	2.35E+09
45	9	2.30E+10	0	2.07E+10	2.30E+09
50	8	2.22E+10	0	2.00E+10	2.22E+09
55	8	2.15E+10	0	1.94E+10	2.15E+09
60	7.7	2.04E+10	0	1.84E+10	2.04E+09
65	7.4	1.95E+10	0	1.75E+10	1.95E+09
70	6.9	1.83E+10	0	1.65E+10	1.83E+09
75	6.1	1.62E+10	0	1.46E+10	1.62E+09
80	5.3	1.41E+10	0	1.27E+10	1.41E+09
85	4.2	1.11E+10	0	1.00E+10	1.11E+09
90	0.04	1.07E+08	0	9.62E+07	1.07E+07
95	0.04	1.07E+08	0	9.62E+07	1.07E+07
100	0	0	0	0	0

Table 5-20 Fecal Coliform TMDL Calculations for Clear Creek (OK720500020070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	23	2.30E+11	0	2.07E+11	2.30E+10
5	11	1.05E+11	0	9.42E+10	1.05E+10
10	10	9.96E+10	0	8.97E+10	9.96E+09
15	10	9.67E+10	0	8.71E+10	9.67E+09
20	10	9.52E+10	0	8.56E+10	9.52E+09
25	10	9.35E+10	0	8.42E+10	9.35E+09
30	9	9.18E+10	0	8.26E+10	9.18E+09
35	9	8.99E+10	0	8.09E+10	8.99E+09
40	9	8.71E+10	0	7.84E+10	8.71E+09
45	9	8.51E+10	0	7.66E+10	8.51E+09
50	8	8.24E+10	0	7.42E+10	8.24E+09
55	8	7.97E+10	0	7.17E+10	7.97E+09
60	7.7	7.57E+10	0	6.81E+10	7.57E+09
65	7.4	7.21E+10	0	6.49E+10	7.21E+09
70	6.9	6.77E+10	0	6.09E+10	6.77E+09
75	6.1	6.02E+10	0	5.42E+10	6.02E+09
80	5.3	5.23E+10	0	4.70E+10	5.23E+09
85	4.2	4.12E+10	0	3.71E+10	4.12E+09
90	0.04	3.96E+08	0	3.56E+08	3.96E+07
95	0.04	3.96E+08	0	3.56E+08	3.96E+07
100	0	0	0	0	0

Table 5-21 Fecal Coliform TMDL Calculations for Corrumpa Creek (OK720510000275_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2.43	2.38E+10	0	2.14E+10	2.38E+09
5	0.50	4.87E+09	0	4.38E+09	4.87E+08
10	0.47	4.65E+09	0	4.18E+09	4.65E+08
15	0.46	4.53E+09	0	4.08E+09	4.53E+08
20	0.44	4.31E+09	0	3.87E+09	4.31E+08
25	0.43	4.19E+09	0	3.77E+09	4.19E+08
30	0.43	4.19E+09	0	3.77E+09	4.19E+08
35	0.42	4.08E+09	0	3.67E+09	4.08E+08
40	0.42	4.08E+09	0	3.67E+09	4.08E+08
45	0.41	3.97E+09	0	3.57E+09	3.97E+08
50	0.38	3.74E+09	0	3.36E+09	3.74E+08
55	0.37	3.63E+09	0	3.26E+09	3.63E+08
60	0.35	3.40E+09	0	3.06E+09	3.40E+08
65	0.34	3.29E+09	0	2.96E+09	3.29E+08
70	0.27	2.61E+09	0	2.35E+09	2.61E+08
75	0.23	2.27E+09	0	2.04E+09	2.27E+08
80	0.20	1.93E+09	0	1.73E+09	1.93E+08
85	0.18	1.78E+09	0	1.60E+09	1.78E+08
90	0.15	1.47E+09	0	1.33E+09	1.47E+08
95	0.10	1.00E+09	0	9.04E+08	1.00E+08
100	0.05	4.53E+08	0	4.08E+08	4.53E+07

Table 5-22 E. coli TMDL Calculations for Duck Pond Creek (OK720500020250_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	37	3.66E+11	0	3.29E+11	3.66E+10
5	1.31	1.30E+10	0	1.17E+10	1.30E+09
10	1.06	1.05E+10	0	9.49E+09	1.05E+09
15	0.94	9.31E+09	0	8.37E+09	9.31E+08
20	0.87	8.68E+09	0	7.82E+09	8.68E+08
25	0.81	8.06E+09	0	7.26E+09	8.06E+08
30	0.75	7.44E+09	0	6.70E+09	7.44E+08
35	0.69	6.82E+09	0	6.14E+09	6.82E+08
40	0.60	5.96E+09	0	5.36E+09	5.96E+08
45	0.54	5.40E+09	0	4.86E+09	5.40E+08
50	0.47	4.71E+09	0	4.24E+09	4.71E+08
55	0.41	4.09E+09	0	3.68E+09	4.09E+08
60	0.33	3.29E+09	0	2.96E+09	3.29E+08
65	0.27	2.67E+09	0	2.40E+09	2.67E+08
70	0.21	2.05E+09	0	1.84E+09	2.05E+08
75	0.12	1.24E+09	0	1.12E+09	1.24E+08
80	0.07	6.82E+08	0	6.14E+08	6.82E+07
85	0.02	2.48E+08	0	2.23E+08	2.48E+07
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-23 Enterococci TMDL Calculations for Duck Pond Creek (OK720500020250_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	37	9.74E+10	0	8.76E+10	9.74E+09
5	1.31	3.47E+09	0	3.12E+09	3.47E+08
10	1.06	2.81E+09	0	2.52E+09	2.81E+08
15	0.94	2.48E+09	0	2.23E+09	2.48E+08
20	0.87	2.31E+09	0	2.08E+09	2.31E+08
25	0.81	2.15E+09	0	1.93E+09	2.15E+08
30	0.75	1.98E+09	0	1.78E+09	1.98E+08
35	0.69	1.82E+09	0	1.63E+09	1.82E+08
40	0.60	1.58E+09	0	1.43E+09	1.58E+08
45	0.54	1.44E+09	0	1.29E+09	1.44E+08
50	0.47	1.25E+09	0	1.13E+09	1.25E+08
55	0.41	1.09E+09	0	9.80E+08	1.09E+08
60	0.33	8.75E+08	0	7.87E+08	8.75E+07
65	0.27	7.10E+08	0	6.39E+08	7.10E+07
70	0.21	5.45E+08	0	4.90E+08	5.45E+07
75	0.12	3.30E+08	0	2.97E+08	3.30E+07
80	0.07	1.82E+08	0	1.63E+08	1.82E+07
85	0.02	6.60E+07	0	5.94E+07	6600681
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-24 E. coli TMDL Calculations for Kiowa Creek (OK720500020130_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	54	5.36E+11	0	4.82E+11	5.36E+10
5	22	2.17E+11	0	1.95E+11	2.17E+10
10	18	1.75E+11	0	1.58E+11	1.75E+10
15	16	1.54E+11	0	1.39E+11	1.54E+10
20	13	1.33E+11	0	1.20E+11	1.33E+10
25	12	1.23E+11	0	1.11E+11	1.23E+10
30	11	1.12E+11	0	1.01E+11	1.12E+10
35	10	1.02E+11	0	9.14E+10	1.02E+10
40	9	8.87E+10	0	7.98E+10	8.87E+09
45	8	8.12E+10	0	7.30E+10	8.12E+09
50	7	7.14E+10	0	6.42E+10	7.14E+09
55	6	5.82E+10	0	5.24E+10	5.82E+09
60	5.0	4.93E+10	0	4.44E+10	4.93E+09
65	4.2	4.15E+10	0	3.74E+10	4.15E+09
70	2.9	2.90E+10	0	2.61E+10	2.90E+09
75	1.0	1.02E+10	0	9.22E+09	1.02E+09
80	0.14	1.43E+09	0	1.28E+09	1.43E+08
85	0.002	1.81E+07	0	1.63E+07	1.81E+06
90	0.002	1.81E+07	0	1.63E+07	1.81E+06
95	0.002	1.81E+07	0	1.63E+07	1.81E+06
100	0	0	0	0	0

Table 5-25 Enterococci TMDL Calculations for Kiowa Creek (OK720500020130_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	54	1.43E+11	0	1.28E+11	1.43E+10
5	22	5.76E+10	0	5.19E+10	5.76E+09
10	18	4.66E+10	0	4.20E+10	4.66E+09
15	16	4.11E+10	0	3.70E+10	4.11E+09
20	13	3.55E+10	0	3.20E+10	3.55E+09
25	12	3.27E+10	0	2.94E+10	3.27E+09
30	11	2.99E+10	0	2.69E+10	2.99E+09
35	10	2.70E+10	0	2.43E+10	2.70E+09
40	9	2.36E+10	0	2.12E+10	2.36E+09
45	8	2.16E+10	0	1.94E+10	2.16E+09
50	7	1.90E+10	0	1.71E+10	1.90E+09
55	6	1.55E+10	0	1.39E+10	1.55E+09
60	5.0	1.31E+10	0	1.18E+10	1.31E+09
65	4.2	1.10E+10	0	9.94E+09	1.10E+09
70	2.9	7.72E+09	0	6.95E+09	7.72E+08
75	1.0	2.72E+09	0	2.45E+09	2.72E+08
80	0.14	3.79E+08	0	3.42E+08	3.79E+07
85	0.002	4.82E+06	0	4.34E+06	4.82E+05
90	0.002	4.82E+06	0	4.34E+06	4.82E+05
95	0.002	4.82E+06	0	4.34E+06	4.82E+05
100	0	0	0	0	0

Table 5-26 Fecal Coliform TMDL Calculations for Kiowa Creek (OK720500020130_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	54	5.28E+11	0	4.75E+11	5.28E+10
5	22	2.13E+11	0	1.92E+11	2.13E+10
10	18	1.73E+11	0	1.55E+11	1.73E+10
15	16	1.52E+11	0	1.37E+11	1.52E+10
20	13	1.31E+11	0	1.18E+11	1.31E+10
25	12	1.21E+11	0	1.09E+11	1.21E+10
30	11	1.11E+11	0	9.96E+10	1.11E+10
35	10	1.00E+11	0	9.01E+10	1.00E+10
40	9	8.74E+10	0	7.87E+10	8.74E+09
45	8	8.00E+10	0	7.20E+10	8.00E+09
50	7	7.03E+10	0	6.33E+10	7.03E+09
55	6	5.73E+10	0	5.16E+10	5.73E+09
60	5.0	4.86E+10	0	4.37E+10	4.86E+09
65	4.2	4.09E+10	0	3.68E+10	4.09E+09
70	2.9	2.86E+10	0	2.57E+10	2.86E+09
75	1.0	1.01E+10	0	9.08E+09	1.01E+09
80	0.14	1.41E+09	0	1.26E+09	1.41E+08
85	0.002	1.79E+07	0	1.61E+07	1.79E+06
90	0.002	1.79E+07	0	1.61E+07	1.79E+06
95	0.002	1.79E+07	0	1.61E+07	1.79E+06
100	0	0	0	0	0

Table 5-27 E. coli TMDL Calculations for Otter Creek (OK720500020050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	22	2.22E+11	0	1.99E+11	2.22E+10
5	4	3.55E+10	0	3.20E+10	3.55E+09
10	3	2.56E+10	0	2.30E+10	2.56E+09
15	2	1.99E+10	0	1.79E+10	1.99E+09
20	2	1.81E+10	0	1.63E+10	1.81E+09
25	2	1.63E+10	0	1.47E+10	1.63E+09
30	1	1.40E+10	0	1.26E+10	1.40E+09
35	1	1.26E+10	0	1.14E+10	1.26E+09
40	1	1.08E+10	0	9.69E+09	1.08E+09
45	1	9.45E+09	0	8.50E+09	9.45E+08
50	1	8.01E+09	0	7.20E+09	8.01E+08
55	1	6.30E+09	0	5.67E+09	6.30E+08
60	0.5	5.11E+09	0	4.60E+09	5.11E+08
65	0.4	4.10E+09	0	3.69E+09	4.10E+08
70	0.2	2.47E+09	0	2.22E+09	2.47E+08
75	0.1	1.36E+09	0	1.22E+09	1.36E+08
80	0.05	4.89E+08	0	4.41E+08	4.89E+07
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-28 Enterococci TMDL Calculations for Otter Creek (OK720500020050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	22	5.90E+10	0	5.31E+10	5.90E+09
5	4	9.45E+09	0	8.50E+09	9.45E+08
10	3	6.81E+09	0	6.13E+09	6.81E+08
15	2	5.30E+09	0	4.77E+09	5.30E+08
20	2	4.81E+09	0	4.33E+09	4.81E+08
25	2	4.33E+09	0	3.90E+09	4.33E+08
30	1	3.72E+09	0	3.35E+09	3.72E+08
35	1	3.36E+09	0	3.02E+09	3.36E+08
40	1	2.86E+09	0	2.58E+09	2.86E+08
45	1	2.51E+09	0	2.26E+09	2.51E+08
50	1	2.13E+09	0	1.92E+09	2.13E+08
55	1	1.68E+09	0	1.51E+09	1.68E+08
60	0.5	1.36E+09	0	1.22E+09	1.36E+08
65	0.4	1.09E+09	0	9.81E+08	1.09E+08
70	0.2	6.57E+08	0	5.92E+08	6.57E+07
75	0.1	3.61E+08	0	3.25E+08	3.61E+07
80	0.05	1.30E+08	0	1.17E+08	1.30E+07
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-29 E. coli TMDL Calculations for Palo Duro Creek (OK720500020500_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	59.00	5.86E+11	0	5.27E+11	5.86E+10
5	2.10	2.09E+10	0	1.88E+10	2.09E+09
10	1.70	1.69E+10	0	1.52E+10	1.69E+09
15	1.50	1.49E+10	0	1.34E+10	1.49E+09
20	1.40	1.39E+10	0	1.25E+10	1.39E+09
25	1.30	1.29E+10	0	1.16E+10	1.29E+09
30	1.20	1.19E+10	0	1.07E+10	1.19E+09
35	1.10	1.09E+10	0	9.83E+09	1.09E+09
40	0.96	9.54E+09	0	8.58E+09	9.54E+08
45	0.87	8.64E+09	0	7.78E+09	8.64E+08
50	0.76	7.55E+09	0	6.79E+09	7.55E+08
55	0.66	6.56E+09	0	5.90E+09	6.56E+08
60	0.53	5.26E+09	0	4.74E+09	5.26E+08
65	0.43	4.27E+09	0	3.84E+09	4.27E+08
70	0.33	3.28E+09	0	2.95E+09	3.28E+08
75	0.20	1.99E+09	0	1.79E+09	1.99E+08
80	0.11	1.09E+09	0	9.83E+08	1.09E+08
85	0.04	3.97E+08	0	3.58E+08	3.97E+07
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-30 Enterococci TMDL Calculations for Palo Duro Creek (OK720500020500_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	59	1.56E+11	0	1.40E+11	1.56E+10
5	2	5.55E+09	0	4.99E+09	5.55E+08
10	2	4.49E+09	0	4.04E+09	4.49E+08
15	2	3.96E+09	0	3.57E+09	3.96E+08
20	1	3.70E+09	0	3.33E+09	3.70E+08
25	1	3.43E+09	0	3.09E+09	3.43E+08
30	1	3.17E+09	0	2.85E+09	3.17E+08
35	1	2.91E+09	0	2.62E+09	2.91E+08
40	1	2.54E+09	0	2.28E+09	2.54E+08
45	1	2.30E+09	0	2.07E+09	2.30E+08
50	1	2.01E+09	0	1.81E+09	2.01E+08
55	1	1.74E+09	0	1.57E+09	1.74E+08
60	1	1.40E+09	0	1.26E+09	1.40E+08
65	0	1.14E+09	0	1.02E+09	1.14E+08
70	0	8.72E+08	0	7.85E+08	8.72E+07
75	0	5.28E+08	0	4.76E+08	5.28E+07
80	0	2.91E+08	0	2.62E+08	2.91E+07
85	0	1.06E+08	0	9.51E+07	1.06E+07
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-31 Fecal Coliform TMDL Calculations for Palo Duro Creek (OK720500020500_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	59.00	5.77E+11	0	5.20E+11	5.77E+10
5	2.10	2.06E+10	0	1.85E+10	2.06E+09
10	1.70	1.66E+10	0	1.50E+10	1.66E+09
15	1.50	1.47E+10	0	1.32E+10	1.47E+09
20	1.40	1.37E+10	0	1.23E+10	1.37E+09
25	1.30	1.27E+10	0	1.14E+10	1.27E+09
30	1.20	1.17E+10	0	1.06E+10	1.17E+09
35	1.10	1.08E+10	0	9.69E+09	1.08E+09
40	0.96	9.39E+09	0	8.46E+09	9.39E+08
45	0.87	8.51E+09	0	7.66E+09	8.51E+08
50	0.76	7.44E+09	0	6.69E+09	7.44E+08
55	0.66	6.46E+09	0	5.81E+09	6.46E+08
60	0.53	5.19E+09	0	4.67E+09	5.19E+08
65	0.43	4.21E+09	0	3.79E+09	4.21E+08
70	0.33	3.23E+09	0	2.91E+09	3.23E+08
75	0.20	1.96E+09	0	1.76E+09	1.96E+08
80	0.11	1.08E+09	0	9.69E+08	1.08E+08
85	0.04	3.91E+08	0	3.52E+08	3.91E+07
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-32 Fecal Coliform TMDL Calculations for Palo Duro Creek (OK720500020500_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	175.47	1.72E+12	0	1.55E+12	1.72E+11
5	6.25	6.11E+10	0	5.50E+10	6.11E+09
10	5.06	4.95E+10	0	4.45E+10	4.95E+09
15	4.46	4.37E+10	0	3.93E+10	4.37E+09
20	4.16	4.07E+10	0	3.67E+10	4.07E+09
25	3.87	3.78E+10	0	3.41E+10	3.78E+09
30	3.57	3.49E+10	0	3.14E+10	3.49E+09
35	3.27	3.20E+10	0	2.88E+10	3.20E+09
40	2.86	2.79E+10	0	2.51E+10	2.79E+09
45	2.59	2.53E+10	0	2.28E+10	2.53E+09
50	2.26	2.21E+10	0	1.99E+10	2.21E+09
55	1.96	1.92E+10	0	1.73E+10	1.92E+09
60	1.58	1.54E+10	0	1.39E+10	1.54E+09
65	1.28	1.25E+10	0	1.13E+10	1.25E+09
70	0.98	9.60E+09	0	8.64E+09	9.60E+08
75	0.59	5.82E+09	0	5.24E+09	5.82E+08
80	0.33	3.20E+09	0	2.88E+09	3.20E+08
85	0.12	1.16E+09	0	1.05E+09	1.16E+08
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-33 E. coli TMDL Calculations for Spring Creek (OK720500020100_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	13	1.32E+11	0	1.19E+11	1.32E+10
5	3	2.50E+10	0	2.25E+10	2.50E+09
10	2	1.86E+10	0	1.67E+10	1.86E+09
15	1	1.48E+10	0	1.33E+10	1.48E+09
20	1	1.36E+10	0	1.22E+10	1.36E+09
25	1	1.23E+10	0	1.11E+10	1.23E+09
30	1	1.07E+10	0	9.66E+09	1.07E+09
35	1	9.77E+09	0	8.80E+09	9.77E+08
40	1	8.46E+09	0	7.61E+09	8.46E+08
45	1	7.52E+09	0	6.76E+09	7.52E+08
50	1	6.47E+09	0	5.82E+09	6.47E+08
55	1	5.20E+09	0	4.68E+09	5.20E+08
60	0.4	4.30E+09	0	3.87E+09	4.30E+08
65	0.4	3.52E+09	0	3.17E+09	3.52E+08
70	0.2	2.23E+09	0	2.00E+09	2.23E+08
75	0.1	1.29E+09	0	1.16E+09	1.29E+08
80	0.1	5.12E+08	0	4.61E+08	5.12E+07
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-34 Enterococci TMDL Calculations for Spring Creek (OK720500020100_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	13	3.50E+10	0	3.15E+10	3.50E+09
5	3	6.65E+09	0	5.98E+09	6.65E+08
10	2	4.94E+09	0	4.44E+09	4.94E+08
15	1	3.93E+09	0	3.54E+09	3.93E+08
20	1	3.61E+09	0	3.24E+09	3.61E+08
25	1	3.28E+09	0	2.95E+09	3.28E+08
30	1	2.86E+09	0	2.57E+09	2.86E+08
35	1	2.60E+09	0	2.34E+09	2.60E+08
40	1	2.25E+09	0	2.03E+09	2.25E+08
45	1	2.00E+09	0	1.80E+09	2.00E+08
50	1	1.72E+09	0	1.55E+09	1.72E+08
55	1	1.38E+09	0	1.25E+09	1.38E+08
60	0.4	1.14E+09	0	1.03E+09	1.14E+08
65	0.4	9.37E+08	0	8.43E+08	9.37E+07
70	0.2	5.92E+08	0	5.33E+08	5.92E+07
75	0.1	3.44E+08	0	3.10E+08	3.44E+07
80	0.1	1.36E+08	0	1.23E+08	1.36E+07
85	0	0	0	0	0
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-35 Enterococci TMDL Calculations for Upper Wolf Creek (OK720500030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	686	1.81E+12	0	1.63E+12	1.81E+11
5	98	2.60E+11	0	2.34E+11	2.60E+10
10	87	2.29E+11	0	2.06E+11	2.29E+10
15	77	2.03E+11	0	1.83E+11	2.03E+10
20	73	1.94E+11	0	1.74E+11	1.94E+10
25	70	1.84E+11	0	1.66E+11	1.84E+10
30	65	1.72E+11	0	1.54E+11	1.72E+10
35	62	1.63E+11	0	1.47E+11	1.63E+10
40	57	1.51E+11	0	1.36E+11	1.51E+10
45	54	1.42E+11	0	1.28E+11	1.42E+10
50	50	1.33E+11	0	1.19E+11	1.33E+10
55	45	1.19E+11	0	1.07E+11	1.19E+10
60	41.2	1.09E+11	0	9.81E+10	1.09E+10
65	36.8	9.71E+10	0	8.74E+10	9.71E+09
70	30.5	8.06E+10	0	7.25E+10	8.06E+09
75	22.2	5.88E+10	0	5.29E+10	5.88E+09
80	14.4	3.80E+10	0	3.42E+10	3.80E+09
85	0.01	1.68E+07	0	1.51E+07	1.68E+06
90	0.01	1.68E+07	0	1.51E+07	1.68E+06
95	0.01	1.68E+07	0	1.51E+07	1.68E+06
100	0	0	0	0	0

Table 5-36 Fecal Coliform TMDL Calculations for Upper Wolf Creek (OK720500030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	686	6.71E+12	0	6.04E+12	6.71E+11
5	98	9.62E+11	0	8.66E+11	9.62E+10
10	87	8.47E+11	0	7.62E+11	8.47E+10
15	77	7.52E+11	0	6.76E+11	7.52E+10
20	73	7.18E+11	0	6.46E+11	7.18E+10
25	70	6.83E+11	0	6.15E+11	6.83E+10
30	65	6.35E+11	0	5.72E+11	6.35E+10
35	62	6.05E+11	0	5.44E+11	6.05E+10
40	57	5.61E+11	0	5.05E+11	5.61E+10
45	54	5.27E+11	0	4.74E+11	5.27E+10
50	50	4.91E+11	0	4.42E+11	4.91E+10
55	45	4.39E+11	0	3.95E+11	4.39E+10
60	41.2	4.04E+11	0	3.63E+11	4.04E+10
65	36.8	3.60E+11	0	3.24E+11	3.60E+10
70	30.5	2.98E+11	0	2.69E+11	2.98E+10
75	22.2	2.18E+11	0	1.96E+11	2.18E+10
80	14.4	1.41E+11	0	1.27E+11	1.41E+10
85	0.01	6.22E+07	0	5.60E+07	6.22E+06
90	0.01	6.22E+07	0	5.60E+07	6.22E+06
95	0.01	6.22E+07	0	5.60E+07	6.22E+06
100	0	0	0	0	0

Table 5-37 Enterococci TMDL Calculations for Lower Wolf Creek (OK720500020030_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	691	1.83E+12	0	1.64E+12	1.83E+11
5	142	3.75E+11	0	3.38E+11	3.75E+10
10	98	2.59E+11	0	2.33E+11	2.59E+10
15	70	1.85E+11	0	1.66E+11	1.85E+10
20	53	1.41E+11	0	1.27E+11	1.41E+10
25	39	1.03E+11	0	9.24E+10	1.03E+10
30	35	9.30E+10	0	8.37E+10	9.30E+09
35	30	8.05E+10	0	7.25E+10	8.05E+09
40	25	6.51E+10	0	5.86E+10	6.51E+09
45	20	5.24E+10	0	4.71E+10	5.24E+09
50	16	4.21E+10	0	3.79E+10	4.21E+09
55	12	3.06E+10	0	2.76E+10	3.06E+09
60	9.3	2.45E+10	0	2.20E+10	2.45E+09
65	7.2	1.90E+10	0	1.71E+10	1.90E+09
70	4.3	1.15E+10	0	1.03E+10	1.15E+09
75	1.9	5.14E+09	0	4.63E+09	5.14E+08
80	0.7	1.84E+09	0	1.66E+09	1.84E+08
85	0.04	1.11E+08	0	9.99E+07	1.11E+07
90	0	0	0	0	0
95	0	0	0	0	0
100	0	0	0	0	0

Table 5-38 Total Suspended Solids TMDL Calculation for Palo Duro Creek (OK720500020500_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	175.47	N/A	0	0	N/A	N/A
5	6.25	N/A	0	0	N/A	N/A
10	5.06	N/A	0	0	N/A	N/A
15	4.46	N/A	0	0	N/A	N/A
20	4.16	N/A	0	0	N/A	N/A
25	3.87	771	0	8	647	116
30	3.57	711	0	7	598	107
35	3.27	652	0	7	548	98
40	2.86	569	0	6	478	85
45	2.59	516	0	5	433	77
50	2.26	451	0	5	378	68
55	1.96	391	0	4	329	59
60	1.58	314	0	3	264	47
65	1.28	255	0	3	214	38
70	0.98	196	0	2	164	29
75	0.59	119	0	1	100	18
80	0.33	65	0	1	55	10
85	0.12	24	0	0.2	20	4
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not applicable

Table 5-39 Total Suspended Solids TMDL Calculations for Lower Wolf Creek (OK720500020030_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	691.30	N/A	0	0	N/A	N/A
5	141.95	N/A	0	0	N/A	N/A
10	98.16	N/A	0	0	N/A	N/A
15	69.94	N/A	0	0	N/A	N/A
20	53.43	N/A	0	0	N/A	N/A
25	38.87	7957	0	80	7082	796
30	35.21	7209	0	72	6416	721
35	30.48	6240	0	62	5553	624
40	24.63	5042	0	50	4487	504
45	19.82	4058	0	41	3612	406
50	15.93	3262	0	33	2903	326
55	11.59	2372	0	24	2111	237
60	9.27	1898	0	19	1689	190
65	7.18	1469	0	15	1308	147
70	4.34	889	0	9	791	89
75	1.95	399	0	4	355	40
80	0.70	143	0	1	127	14
85	0.04	9	0	0	8	1
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not applicable

5.7 Reasonable Assurances

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

Table 5-40 Partial List of Oklahoma Water Quality Management Agencies

Agency	Web Link
Oklahoma Conservation Commission	http://www.ok.gov/conservation/Agency_Divisions/Water_Quality_Division
Oklahoma Department of Wildlife Conservation	http://www.wildlifedepartment.com/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 ODEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by State Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES Program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES Program. Implementation of point source WLAs is done through permits issued under the OPDES program.

The reduction rates called for in this TMDL report are as high as 95 percent. The ODEQ recognizes that achieving such high reductions 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 Final; 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 is submitted to EPA for technical review. After the technical approval, a public notice will be circulated to the local newspapers and/or other publications in the area affected by this TMDL. The public will have opportunities to review the TMDL report and make written comments. The public comment period lasts 45 days. Depending on the interest and responses from the public, a public meeting may be held within the watershed affected by this TMDL. If a public meeting is held, the public will also have opportunities to ask questions and make formal oral comments at the meeting and/or to submit written comments at the public meeting.

All written comments received during the public notice period become a part of the record of this TMDL. All comments will be considered and the TMDL report will be revised according to the comments if necessary in the ultimate completion of this TMDL for submission to EPA for final approval.

SECTION 7
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APPENDIX A
AMBIENT WATER QUALITY DATA – 1999 TO 2009

FOR BACTERIA AND TURBIDITY

Appendix A

Ambient Water Quality Bacteria Data – 1999 to 2008

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720510000190-001AT	Beaver River at SH 95, near Guymon	9/12/2006	122	52	50
OK720510000190-001AT	Beaver River at SH 95, near Guymon	8/8/2006	213	148	100
OK720510000190-001AT	Beaver River at SH 95, near Guymon	8/1/2006	439	183	1200
OK720510000190-001AT	Beaver River at SH 95, near Guymon	7/19/2006	158	63	300
OK720510000190-001AT	Beaver River at SH 95, near Guymon	7/11/2006	24192	2700	1440
OK720510000190-001AT	Beaver River at SH 95, near Guymon	6/27/2006	223	31	10
OK720510000190-001AT	Beaver River at SH 95, near Guymon	6/13/2006	443	41	510
OK720510000190-001AT	Beaver River at SH 95, near Guymon	5/31/2006	228	216	290
OK720510000190-001AT	Beaver River at SH 95, near Guymon	5/2/2006	132	85	120
OK720510000190-001AT	Beaver River at SH 95, near Guymon	9/22/2004	74	233	3180
OK720510000190-001AT	Beaver River at SH 95, near Guymon	9/14/2004	262	233	430
OK720510000190-001AT	Beaver River at SH 95, near Guymon	8/10/2004	480	670	510
OK720510000190-001AT	Beaver River at SH 95, near Guymon	7/27/2004	209	400	800
OK720510000190-001AT	Beaver River at SH 95, near Guymon	7/6/2004	869	2300	3700
OK720510000190-001AT	Beaver River at SH 95, near Guymon	6/22/2004	345	1000	1100
OK720510000190-001AT	Beaver River at SH 95, near Guymon	6/2/2004	464	3800	700
OK720510000190-001AT	Beaver River at SH 95, near Guymon	5/18/2004	131	160	200
OK720510000190-001AT	Beaver River at SH 95, near Guymon	8/13/2002	500	21000	85
OK720510000190-001AT	Beaver River at SH 95, near Guymon	7/16/2002	238	6000	7318
OK720510000190-001AT	Beaver River at SH 95, near Guymon	6/18/2002	168	600	1810
OK720510000190-001AT	Beaver River at SH 95, near Guymon	5/15/2002	243	200	300
OK720510000190-001AT	Beaver River at SH 95, near Guymon	6/4/2001	134	400	120
OK720500020450-001AT	Beaver River at US 83, near Boyd	9/12/2006	860	10	150
OK720500020450-001AT	Beaver River at US 83, near Boyd	7/19/2006	471	30	180
OK720500020450-001AT	Beaver River at US 83, near Boyd	6/27/2006	10	10	390
OK720500020450-001AT	Beaver River at US 83, near Boyd	5/31/2006	911	359	1720
OK720500020450-001AT	Beaver River at US 83, near Boyd	5/2/2006	561	41	640
OK720500020450-001AT	Beaver River at US 83, near Boyd	9/22/2004	5794	6488	10
OK720500020450-001AT	Beaver River at US 83, near Boyd	9/14/2004	10	31	10
OK720500020450-001AT	Beaver River at US 83, near Boyd	8/10/2004	10	640	490
OK720500020450-001AT	Beaver River at US 83, near Boyd	7/27/2004	30	20	30
OK720500020450-001AT	Beaver River at US 83, near Boyd	7/6/2004	118	500	610
OK720500020450-001AT	Beaver River at US 83, near Boyd	6/22/2004	1674	4100	2300
OK720500020450-001AT	Beaver River at US 83, near Boyd	6/2/2004	257	1300	1510
OK720500020450-001AT	Beaver River at US 83, near Boyd	5/18/2004	41	200	200
OK720500020450-001AT	Beaver River at US 83, near Boyd	5/4/2004	259	20	100

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500020450-001AT	Beaver River at US 83, near Boyd	6/18/2002	6867	24000	2800
OK720500020450-001AT	Beaver River at US 83, near Boyd	5/15/2002	189	800	300
OK720500020450-001AT	Beaver River at US 83, near Boyd	8/7/2001	882	700	500
OK720500020450-001AT	Beaver River at US 83, near Boyd	7/10/2001	1904	2700	1000
OK720500020450-001AT	Beaver River at US 83, near Boyd	6/5/2001	204	800	2100
OK720500020290-001AT	Beaver River at US 270, Beaver	8/5/2008	2501	143	20
OK720500020290-001AT	Beaver River at US 270, Beaver	7/15/2008	1115	9506	770
OK720500020290-001AT	Beaver River at US 270, Beaver	6/24/2008	2097	1283	7150
OK720500020290-001AT	Beaver River at US 270, Beaver	6/3/2008	210	157	2190
OK720500020290-001AT	Beaver River at US 270, Beaver	5/12/2008	827	368	995
OK720500020290-001AT	Beaver River at US 270, Beaver	9/12/2006	3873	110	370
OK720500020290-001AT	Beaver River at US 270, Beaver	7/19/2006	3448	142	390
OK720500020290-001AT	Beaver River at US 270, Beaver	6/27/2006	5794	86	700
OK720500020290-001AT	Beaver River at US 270, Beaver	6/13/2006	3076	435	420
OK720500020290-001AT	Beaver River at US 270, Beaver	5/31/2006	20	199	390
OK720500020290-001AT	Beaver River at US 270, Beaver	5/2/2006	185	20	100
OK720500020290-001AT	Beaver River at US 270, Beaver	9/22/2004	75	132	10
OK720500020290-001AT	Beaver River at US 270, Beaver	9/13/2004	31	20	40
OK720500020290-001AT	Beaver River at US 270, Beaver	8/10/2004	10	140	110
OK720500020290-001AT	Beaver River at US 270, Beaver	7/27/2004	30	900	300
OK720500020290-001AT	Beaver River at US 270, Beaver	7/6/2004	63	100	500
OK720500020290-001AT	Beaver River at US 270, Beaver	6/2/2004	221	800	600
OK720500020290-001AT	Beaver River at US 270, Beaver	5/18/2004	121	3000	140
OK720500020290-001AT	Beaver River at US 270, Beaver	5/4/2004	31	500	2000
OK720500020290-001AT	Beaver River at US 270, Beaver	6/18/2002	307	1100	500
OK720500020290-001AT	Beaver River at US 270, Beaver	5/15/2002	3282	7000	8000
OK720500020290-001AT	Beaver River at US 270, Beaver	7/10/2001	2382	4000	2600
OK720500020290-001AT	Beaver River at US 270, Beaver	6/5/2001	63	90	180
OK720500020140-001AT	Beaver River at US 64, near Rosston	6/27/2006	10	41	40
OK720500020140-001AT	Beaver River at US 64, near Rosston	6/13/2006	278	201	1100
OK720500020140-001AT	Beaver River at US 64, near Rosston	5/31/2006	10	10	100
OK720500020140-001AT	Beaver River at US 64, near Rosston	5/2/2006	142	10	100
OK720500020140-001AT	Beaver River at US 64, near Rosston	7/27/2004	120	2900	600
OK720500020140-001AT	Beaver River at US 64, near Rosston	7/5/2004	496	700	2600
OK720500020140-001AT	Beaver River at US 64, near Rosston	6/22/2004	10	800	300
OK720500020140-001AT	Beaver River at US 64, near Rosston	5/18/2004	10	100	20
OK720500020140-001AT	Beaver River at US 64, near Rosston	5/4/2004	171	50	1000
OK720500020140-001AT	Beaver River at US 64, near Rosston	5/14/2002	350	2000	5000
OK720500020140-001AT	Beaver River at US 64, near Rosston	7/10/2001	31	50	120

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500020140-001AT	Beaver River at US 64, near Rosston	6/5/2001	31	600	600
OK720500020010-001AT	Beaver River at US 283, Laverne	9/12/2006	41	41	80
OK720500020010-001AT	Beaver River at US 283, Laverne	8/8/2006	30	98	460
OK720500020010-001AT	Beaver River at US 283, Laverne	8/1/2006	601	74	290
OK720500020010-001AT	Beaver River at US 283, Laverne	7/19/2006	391	374	540
OK720500020010-001AT	Beaver River at US 283, Laverne	7/11/2006	2400	135	4300
OK720500020010-001AT	Beaver River at US 283, Laverne	6/27/2006	143	85	480
OK720500020010-001AT	Beaver River at US 283, Laverne	6/13/2006	620	85	700
OK720500020010-001AT	Beaver River at US 283, Laverne	6/13/2006	794	379	1200
OK720500020010-001AT	Beaver River at US 283, Laverne	5/31/2006	410	767	110
OK720500020010-001AT	Beaver River at US 283, Laverne	5/2/2006	216	10	60
OK720500020010-001AT	Beaver River at US 283, Laverne	9/14/2004	10	10	10
OK720500020010-001AT	Beaver River at US 283, Laverne	9/13/2004	41	10	20
OK720500020010-001AT	Beaver River at US 283, Laverne	8/10/2004	10	10	10
OK720500020010-001AT	Beaver River at US 283, Laverne	8/9/2004	323	540	460
OK720500020010-001AT	Beaver River at US 283, Laverne	7/27/2004	146	130	300
OK720500020010-001AT	Beaver River at US 283, Laverne	7/27/2004	10	10	10
OK720500020010-001AT	Beaver River at US 283, Laverne	7/6/2004	10	10	10
OK720500020010-001AT	Beaver River at US 283, Laverne	7/5/2004	144	300	300
OK720500020010-001AT	Beaver River at US 283, Laverne	6/22/2004	5	100	400
OK720500020010-001AT	Beaver River at US 283, Laverne	6/22/2004	10	10	10
OK720500020010-001AT	Beaver River at US 283, Laverne	6/2/2004	10	10	10
OK720500020010-001AT	Beaver River at US 283, Laverne	6/1/2004	313	200	700
OK720500020010-001AT	Beaver River at US 283, Laverne	5/18/2004	20	100	100
OK720500020010-001AT	Beaver River at US 283, Laverne	5/18/2004	10	10	10
OK720500020010-001AT	Beaver River at US 283, Laverne	5/4/2004	110	100	30
OK720500-03-0080G	Buzzard Creek	9/25/2001	90	300	410
OK720500-03-0080G	Buzzard Creek	7/17/2001	160	98	120
OK720500-03-0080G	Buzzard Creek	6/12/2001	97	200	170
OK720500-03-0080G	Buzzard Creek	5/8/2001	428	200	2000
OK720500-03-0080G	Buzzard Creek	6/20/2000			400
OK720500-03-0080G	Buzzard Creek	5/16/2000			100
OK720500-02-0300F	Clear Creek	9/29/2008	50	10	
OK720500-02-0300F	Clear Creek	8/25/2008	40	40	
OK720500-02-0300F	Clear Creek	7/21/2008	20	10	
OK720500-02-0300F	Clear Creek	7/15/2008	60	10	
OK720500-02-0300F	Clear Creek	6/16/2008	180	120	
OK720500-02-0300F	Clear Creek	5/12/2008	60	10	
OK720500-02-0300F	Clear Creek	9/10/2007	10	10	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500-02-0300F	Clear Creek	8/6/2007	40	10	
OK720500-02-0300F	Clear Creek	7/9/2007	60	40	
OK720500-02-0300F	Clear Creek	6/25/2007	380	840	
OK720500-02-0300F	Clear Creek	6/4/2007	240	280	
OK720500-02-0300F	Clear Creek	6/7/2004	110	60	
OK720500-02-0300F	Clear Creek	9/15/2003	75	50	
OK720500-02-0300F	Clear Creek	8/18/2003	40	30	
OK720500-02-0300F	Clear Creek	7/14/2003	30	180	
OK720500-02-0300F	Clear Creek	6/9/2003	200	510	
OK720500-02-0300F	Clear Creek	9/30/2002	20		
OK720500-02-0300F	Clear Creek	8/26/2002	20	20	
OK720500-02-0300F	Clear Creek	7/23/2002	210	200	
OK720500-02-0300G	Clear Creek	9/25/2001	160	150	240
OK720500-02-0300G	Clear Creek	8/20/2001	180	20	410
OK720500-02-0300G	Clear Creek	7/17/2001	104	88	118
OK720500-02-0300G	Clear Creek	6/11/2001	20	60	160
OK720500-02-0300G	Clear Creek	5/7/2001	52	100	300
OK720500-02-0300G	Clear Creek	8/29/2000	52	150	50
OK720500-02-0300G	Clear Creek	6/20/2000			300
OK720500-02-0300G	Clear Creek	5/16/2000			100
OK720500-02-0070G	Clear Creek	9/30/2008	40	130	
OK720500-02-0070G	Clear Creek	8/26/2008	40	110	
OK720500-02-0070G	Clear Creek	7/22/2008	25	125	
OK720500-02-0070G	Clear Creek	7/15/2008	50	40	
OK720500-02-0070G	Clear Creek	6/17/2008	1700	2500	
OK720500-02-0070G	Clear Creek	5/13/2008	60	10	
OK720500-02-0070G	Clear Creek	9/11/2007	30	50	
OK720500-02-0070G	Clear Creek	8/7/2007	100	180	
OK720500-02-0070G	Clear Creek	7/10/2007	110	100	
OK720500-02-0070G	Clear Creek	6/26/2007	50	150	
OK720500-02-0070G	Clear Creek	6/5/2007	80	30	
OK720500-02-0070G	Clear Creek	6/8/2004	345	180	
OK720500-02-0070G	Clear Creek	9/16/2003	430	460	
OK720500-02-0070G	Clear Creek	8/19/2003	250	1000	
OK720500-02-0070G	Clear Creek	7/15/2003	430	790	
OK720500-02-0070G	Clear Creek	6/10/2003	170	320	
OK720500-02-0070G	Clear Creek	8/27/2002	1600	2660	
OK720500-02-0070G	Clear Creek	7/23/2002	800	140	
OK720500-02-0070G	Clear Creek	9/25/2001	20	110	70

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500-02-0070G	Clear Creek	8/21/2001	275	270	290
OK720500-02-0070G	Clear Creek	7/17/2001	96	68	282
OK720500-02-0070G	Clear Creek	6/12/2001	183	230	250
OK720500-02-0070G	Clear Creek	5/8/2001	301	500	500
OK720500-02-0070G	Clear Creek	8/29/2000	145	1600	900
OK720500-02-0070G	Clear Creek	6/20/2000			400
OK720500-02-0070G	Clear Creek	5/16/2000			500
OK720510-00-0275K	Corrumpa Creek	9/24/2001	160	340	130
OK720510-00-0275K	Corrumpa Creek	8/20/2001	358	123	425
OK720510-00-0275K	Corrumpa Creek	7/16/2001	400	114	300
OK720510-00-0275K	Corrumpa Creek	6/11/2001	9804	4000	3400
OK720510-00-0275K	Corrumpa Creek	5/7/2001	122	200	110
OK720510-00-0275K	Corrumpa Creek	8/28/2000	1354	270	1800
OK720510-00-0275K	Corrumpa Creek	6/19/2000			100
OK720510-00-0275K	Corrumpa Creek	5/15/2000			800
OK720500-02-0250F	Duck Pond Creek	9/29/2008	60	10	
OK720500-02-0250F	Duck Pond Creek	8/25/2008	220	130	
OK720500-02-0250F	Duck Pond Creek	7/21/2008	25	50	
OK720500-02-0250F	Duck Pond Creek	7/15/2008	50	80	
OK720500-02-0250F	Duck Pond Creek	6/16/2008	120	240	
OK720500-02-0250F	Duck Pond Creek	5/12/2008	10	20	
OK720500-02-0250F	Duck Pond Creek	9/10/2007	20	90	
OK720500-02-0250F	Duck Pond Creek	8/7/2007	310	990	
OK720500-02-0250F	Duck Pond Creek	7/10/2007	250	340	
OK720500-02-0250F	Duck Pond Creek	6/25/2007	220	350	
OK720500-02-0250F	Duck Pond Creek	6/5/2007	100	70	
OK720500-02-0250F	Duck Pond Creek	6/8/2004	365	305	
OK720500-02-0250F	Duck Pond Creek	9/16/2003	270	640	
OK720500-02-0250F	Duck Pond Creek	8/19/2003	90	130	
OK720500-02-0250F	Duck Pond Creek	7/15/2003	110	240	
OK720500-02-0250F	Duck Pond Creek	6/10/2003	780	910	
OK720500-02-0250F	Duck Pond Creek	8/27/2002	320	440	
OK720500-02-0250F	Duck Pond Creek	7/23/2002	780	160	
OK720500-02-0130M	Kiowa Creek	9/30/2008	30	10	
OK720500-02-0130C	Kiowa Creek: Harper Co.	9/30/2008	1000	1000	
OK720500-02-0130M	Kiowa Creek	8/26/2008	100	500	
OK720500-02-0130C	Kiowa Creek: Harper Co.	8/26/2008	130	340	
OK720500-02-0130M	Kiowa Creek	7/22/2008	5	40	
OK720500-02-0130C	Kiowa Creek: Harper Co.	7/22/2008	20	55	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500-02-0130M	Kiowa Creek	7/15/2008	10	70	
OK720500-02-0130C	Kiowa Creek: Harper Co.	7/15/2008	10	20	
OK720500-02-0130M	Kiowa Creek	6/17/2008	20	100	
OK720500-02-0130C	Kiowa Creek: Harper Co.	6/17/2008	1320	920	
OK720500-02-0130M	Kiowa Creek	5/13/2008	50	20	
OK720500-02-0130C	Kiowa Creek: Harper Co.	5/13/2008	90	10	
OK720500-02-0130M	Kiowa Creek	9/11/2007	80	20	
OK720500-02-0130C	Kiowa Creek: Harper Co.	9/10/2007	290	70	
OK720500-02-0130M	Kiowa Creek	8/7/2007	280	190	
OK720500-02-0130C	Kiowa Creek: Harper Co.	8/6/2007	420	120	
OK720500-02-0130M	Kiowa Creek	7/10/2007	60	210	
OK720500-02-0130C	Kiowa Creek: Harper Co.	7/9/2007	370	30	
OK720500-02-0130M	Kiowa Creek	6/26/2007	220	210	
OK720500-02-0130C	Kiowa Creek: Harper Co.	6/26/2007	220	280	
OK720500-02-0130M	Kiowa Creek	6/5/2007	340	490	
OK720500-02-0130C	Kiowa Creek: Harper Co.	6/4/2007	160	90	
OK720500-02-0130K	Kiowa Creek: Beaver Co.	6/8/2004	95	160	
OK720500-02-0130C	Kiowa Creek: Harper Co.	6/7/2004	70	50	
OK720500-02-0130K	Kiowa Creek: Beaver Co.	9/16/2003	260	240	
OK720500-02-0130C	Kiowa Creek: Harper Co.	9/15/2003	20	60	
OK720500-02-0130K	Kiowa Creek: Beaver Co.	8/19/2003	140	130	
OK720500-02-0130K	Kiowa Creek: Beaver Co.	7/15/2003	230	150	
OK720500-02-0130C	Kiowa Creek: Harper Co.	7/14/2003	40	240	
OK720500-02-0130K	Kiowa Creek: Beaver Co.	6/10/2003	370	290	
OK720500-02-0130C	Kiowa Creek: Harper Co.	6/9/2003	580	150	
OK720500-02-0130C	Kiowa Creek: Harper Co.	9/30/2002	20		
OK720500-02-0130K	Kiowa Creek: Beaver Co.	8/27/2002	780	200	
OK720500-02-0130C	Kiowa Creek: Harper Co.	8/27/2002	1720	1140	
OK720500-02-0130K	Kiowa Creek: Beaver Co.	7/23/2002	1670	770	
OK720500-02-0130C	Kiowa Creek: Harper Co.	7/22/2002	500	210	
OK720500-02-0130K	Kiowa Creek: Beaver Co.	9/25/2001	210	60	470
OK720500-02-0130C	Kiowa Creek: Harper Co.	9/25/2001	230	160	490
OK720500-02-0130K	Kiowa Creek: Beaver Co.	8/21/2001	30	145	170
OK720500-02-0130C	Kiowa Creek: Harper Co.	8/21/2001	490	460	805
OK720500-02-0130K	Kiowa Creek: Beaver Co.	7/17/2001	90	74	76
OK720500-02-0130C	Kiowa Creek: Harper Co.	7/17/2001	52	7120	346
OK720500-02-0130K	Kiowa Creek: Beaver Co.	6/12/2001	169	260	180
OK720500-02-0130C	Kiowa Creek: Harper Co.	6/12/2001	72	500	400
OK720500-02-0130K	Kiowa Creek: Beaver Co.	5/8/2001	209	100	400

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500-02-0130C	Kiowa Creek: Harper Co.	5/8/2001	135	200	100
OK720500-02-0130K	Kiowa Creek: Beaver Co.	8/29/2000	74	300	170
OK720500-02-0130C	Kiowa Creek: Harper Co.	8/29/2000	253	5700	1220
OK720500-02-0130K	Kiowa Creek: Beaver Co.	6/20/2000			200
OK720500-02-0130C	Kiowa Creek: Harper Co.	6/20/2000			500
OK720500-02-0130K	Kiowa Creek: Beaver Co.	5/16/2000			500
OK720500-02-0050B	Otter Creek	7/23/2002	830	460	
OK720500-02-0050B	Otter Creek	8/27/2002	2667	2566	
OK720500-02-0050B	Otter Creek	6/10/2003	140	350	
OK720500-02-0050B	Otter Creek	6/5/2007	210	670	
OK720500-02-0050B	Otter Creek	6/26/2007	230	1000	
OK720500-02-0050B	Otter Creek	7/10/2007	190	540	
OK720500-02-0050B	Otter Creek	8/7/2007	980	1000	
OK720500-02-0050B	Otter Creek	5/13/2008	520	160	
OK720500-02-0050B	Otter Creek	6/17/2008	10000	10000	
OK720500-02-0050B	Otter Creek	7/15/2008	540	330	
OK720500-02-0050B	Otter Creek	7/21/2008	120	90	
OK720500-02-0050B	Otter Creek	8/26/2008	1000	1000	
OK720500-02-0050B	Otter Creek	9/2/2008	560	100	
OK720500-02-0050B	Otter Creek	9/30/2008	100	330	
OK720500-02-0500G	Palo Duro Creek	9/29/2008	100	350	
OK720500-02-0500G	Palo Duro Creek	8/25/2008	100	100	
OK720500-02-0500G	Palo Duro Creek	7/21/2008	420	720	
OK720500-02-0500G	Palo Duro Creek	7/15/2008	40	330	
OK720500-02-0500G	Palo Duro Creek	6/16/2008	1720	760	
OK720500-02-0500G	Palo Duro Creek	5/12/2008	40	70	
OK720500-02-0500G	Palo Duro Creek	9/10/2007	510	240	
OK720500-02-0500G	Palo Duro Creek	8/6/2007	330	940	
OK720500-02-0500G	Palo Duro Creek	7/9/2007	1000	1000	
OK720500-02-0500G	Palo Duro Creek	6/26/2007	70	190	
OK720500-02-0500G	Palo Duro Creek	6/4/2007	180	140	
OK720500-02-0500G	Palo Duro Creek	6/7/2004	500	215	
OK720500-02-0500G	Palo Duro Creek	9/15/2003	70	80	
OK720500-02-0500G	Palo Duro Creek	8/18/2003	120	150	
OK720500-02-0500G	Palo Duro Creek	7/14/2003	50	240	
OK720500-02-0500G	Palo Duro Creek	6/9/2003	130	140	
OK720500-02-0500G	Palo Duro Creek	9/30/2002	100		
OK720500-02-0500G	Palo Duro Creek	8/26/2002	450	60	
OK720500-02-0500G	Palo Duro Creek	7/23/2002	1470	580	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500-02-0500G	Palo Duro Creek	8/20/2001	105	20	430
OK720500-02-0500G	Palo Duro Creek	7/16/2001	134	42	144
OK720500-02-0500G	Palo Duro Creek	6/11/2001	30	100	100
OK720500-02-0500G	Palo Duro Creek	5/7/2001	240	300	1000
OK720500-02-0500G	Palo Duro Creek	8/28/2000	1638	150	8600
OK720500-02-0500G	Palo Duro Creek	7/24/2000			2630
OK720500-02-0500G	Palo Duro Creek	6/19/2000			100
OK720500-02-0500G	Palo Duro Creek	5/15/2000			100
OK720500020500-001AT	Palo Duro Creek	7/12/2000	2700	431	1000
OK720500020500-001AT	Palo Duro Creek	6/7/2000	110	20	150
OK720500020500-001AT	Palo Duro Creek	5/3/2000	200	231	190
OK720500020500-001AT	Palo Duro Creek	9/15/1999	670	17329	6700
OK720500020500-001AT	Palo Duro Creek	7/13/1999	5	457	270
OK720500020500-001AT	Palo Duro Creek	6/15/1999	110	1354	670
OK720500-02-0100D	Spring Creek	7/22/2002	1135	680	
OK720500-02-0100D	Spring Creek	8/27/2002	1900	1920	
OK720500-02-0100D	Spring Creek	6/10/2003	660	1520	
OK720500-02-0100D	Spring Creek	7/15/2003	450	805	
OK720500-02-0100D	Spring Creek	9/15/2003	30	320	
OK720500-02-0100D	Spring Creek	6/8/2004	225	155	
OK720500-02-0100D	Spring Creek	6/5/2007	100	240	
OK720500-02-0100D	Spring Creek	6/26/2007	460	230	
OK720500-02-0100D	Spring Creek	7/10/2007	600	370	
OK720500-02-0100D	Spring Creek	8/7/2007	430	980	
OK720500-02-0100D	Spring Creek	9/11/2007	120	660	
OK720500-02-0100D	Spring Creek	5/13/2008	120	60	
OK720500-02-0100D	Spring Creek	6/17/2008	10000	10000	
OK720500-02-0100D	Spring Creek	7/15/2008	130	280	
OK720500-02-0100D	Spring Creek	7/22/2008	275	500	
OK720500-02-0100D	Spring Creek	8/26/2008	70	620	
OK720500-02-0100D	Spring Creek	9/30/2008	130	210	
OK720500-03-0010G	Wolf Creek: Upper	9/3/2008	80	10	
OK720500-03-0010G	Wolf Creek: Upper	7/28/2008	25	260	
OK720500-03-0010G	Wolf Creek: Upper	7/16/2008	440	230	
OK720500-03-0010G	Wolf Creek: Upper	6/23/2008	200	20	
OK720500-03-0010G	Wolf Creek: Upper	5/20/2008	30	30	
OK720500-03-0010G	Wolf Creek: Upper	9/17/2007	70	20	
OK720500-03-0010G	Wolf Creek: Upper	8/6/2007	20	50	
OK720500-03-0010G	Wolf Creek: Upper	7/9/2007	60	30	

WQM Station	Waterbody Name	Date	EC[1]	Ent[1]	FC[1]
OK720500-03-0010G	Wolf Creek: Upper	6/18/2007	250	220	
OK720500-03-0010G	Wolf Creek: Upper	6/4/2007	440	1000	
OK720500-03-0010G	Wolf Creek: Upper	6/2/2004	90	30	
OK720500-03-0010G	Wolf Creek: Upper	9/15/2003	10	20	
OK720500-03-0010G	Wolf Creek: Upper	8/12/2003	160	20	
OK720500-03-0010G	Wolf Creek: Upper	7/8/2003	60	80	
OK720500-03-0010G	Wolf Creek: Upper	6/3/2003	275	300	
OK720500-03-0010G	Wolf Creek: Upper	6/3/2003	70	100	
OK720500-03-0010G	Wolf Creek: Upper	5/6/2003	4000	80	
OK720500-03-0010G	Wolf Creek: Upper	9/4/2002	40	40	
OK720500-03-0010G	Wolf Creek: Upper	7/30/2002	1800	290	
OK720500-03-0010G	Wolf Creek: Upper	8/27/2001	1070	210	1230
OK720500-03-0010G	Wolf Creek: Upper	7/23/2001	70	35	80
OK720500-03-0010G	Wolf Creek: Upper	6/18/2001	20	100	170
OK720500-03-0010G	Wolf Creek: Upper	5/15/2001	253	1000	500
OK720500-03-0010G	Wolf Creek: Upper	9/6/2000	72	5000	170
OK720500-03-0010G	Wolf Creek: Upper	8/1/2000	31	130	700
OK720500-03-0010G	Wolf Creek: Upper	6/27/2000			100
OK720500-03-0010G	Wolf Creek: Upper	5/23/2000			300
OK720500-02-0030M	Wolf Creek: Lower	9/2/2008	50	120	
OK720500-02-0030M	Wolf Creek: Lower	7/28/2008	40	50	
OK720500-02-0030M	Wolf Creek: Lower	7/16/2008	20	40	
OK720500-02-0030M	Wolf Creek: Lower	6/23/2008	20	20	
OK720500-02-0030M	Wolf Creek: Lower	5/20/2008	10	60	
OK720500-02-0030M	Wolf Creek: Lower	9/17/2007	110	70	
OK720500-02-0030M	Wolf Creek: Lower	8/6/2007	50	10	
OK720500-02-0030M	Wolf Creek: Lower	7/9/2007	10	20	
OK720500-02-0030M	Wolf Creek: Lower	6/18/2007	60	20	
OK720500-02-0030M	Wolf Creek: Lower	6/4/2007	40	80	
OK720500-02-0030M	Wolf Creek: Lower	6/2/2004	145	165	
OK720500-02-0030M	Wolf Creek: Lower	9/16/2003	60	220	
OK720500-02-0030M	Wolf Creek: Lower	8/12/2003	40	80	
OK720500-02-0030M	Wolf Creek: Lower	7/8/2003	10	175	
OK720500-02-0030M	Wolf Creek: Lower	5/6/2003	20	40	
OK720500-02-0030M	Wolf Creek: Lower	9/3/2002	20	20	
OK720500-02-0030M	Wolf Creek: Lower	7/30/2002	60	60	

[1] Units = counts/100 mL

Appendix A

Ambient Water Quality Turbidity and TSS Data – 1999 to 2009

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK720500020500-001AT	Palo Duro Creek	7/11/2000	61	192	
OK720500020500-001AT	Palo Duro Creek	6/6/2000	5	4	
OK720500020500-001AT	Palo Duro Creek	5/2/2000	5	14	High Flow
OK720500020500-001AT	Palo Duro Creek	3/7/2000	10	24	High Flow
OK720500020500-001AT	Palo Duro Creek	2/8/2000	16	67	
OK720500020500-001AT	Palo Duro Creek	1/5/2000	4	11	
OK720500020500-001AT	Palo Duro Creek	12/1/1999	3	28	High Flow
OK720500020500-001AT	Palo Duro Creek	11/3/1999	52	56	
OK720500020500-001AT	Palo Duro Creek	10/6/1999	134	220	
OK720500020500-001AT	Palo Duro Creek	9/14/1999	136	212	
OK720500-02-0030M	Wolf Creek: Lower	4/13/2009	19.2	20	High Flow
OK720500-02-0030M	Wolf Creek: Lower	2/9/2009	36.4	21	High Flow
OK720500-02-0030M	Wolf Creek: Lower	4/14/2008	39.8	35	High Flow
OK720500-02-0030M	Wolf Creek: Lower	3/10/2008	17.4	26	High Flow
OK720500-02-0030M	Wolf Creek: Lower	2/4/2008	41.2	41	High Flow
OK720500-02-0030M	Wolf Creek: Lower	1/7/2008	30.2	28	High Flow
OK720500-02-0030M	Wolf Creek: Lower	11/26/2007	9.05	<10	High Flow
OK720500-02-0030M	Wolf Creek: Lower	10/22/2007	25	24	High Flow
OK720500-02-0030M	Wolf Creek: Lower	9/17/2007	80	31	High Flow
OK720500-02-0030M	Wolf Creek: Lower	9/5/2007	26.7	18	
OK720500-02-0030M	Wolf Creek: Lower	08/06/07	67	54	
OK720500-02-0030M	Wolf Creek: Lower	7/9/2007	79.6	76	
OK720500-02-0030M	Wolf Creek: Lower	6/4/2007	17.1	10	
OK720500-02-0030M	Wolf Creek: Lower	6/2/2004	46	11	
OK720500-02-0030M	Wolf Creek: Lower	4/26/2004	36.3	30	
OK720500-02-0030M	Wolf Creek: Lower	3/15/2004	40.9	26	
OK720500-02-0030M	Wolf Creek: Lower	2/10/2004	11.5	<10	
OK720500-02-0030M	Wolf Creek: Lower	1/6/2004	72.5	58	
OK720500-02-0030M	Wolf Creek: Lower	12/2/2003	37.1	44	
OK720500-02-0030M	Wolf Creek: Lower	10/21/2003	50.2		
OK720500-02-0030M	Wolf Creek: Lower	09/16/2003	59.7	113	
OK720500-02-0030M	Wolf Creek: Lower	08/12/2003	13.2	15	
OK720500-02-0030M	Wolf Creek: Lower	07/08/2003	53.1	32	
OK720500-02-0030M	Wolf Creek: Lower	05/06/2003	25	30	
OK720500-02-0030M	Wolf Creek: Lower	03/25/2003	11.5	10	

WQM Station	Waterbody Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK720500-02-0030M	Wolf Creek: Lower	03/12/2003	8.02	15	
OK720500-02-0030M	Wolf Creek: Lower	12/10/2002	26.2	23	
OK720500-02-0030M	Wolf Creek: Lower	11/13/2002	15.8		
OK720500-02-0030M	Wolf Creek: Lower	10/08/2002	11	<10	
OK720500-02-0030M	Wolf Creek: Lower	09/03/2002	4.58	10	
OK720500-02-0030M	Wolf Creek: Lower	07/30/2002	6.03	<10	
OK720500-02-0030M	Wolf Creek: Lower	07/03/2002	26.5	<10	

APPENDIX B
ESTIMATED FLOW EXCEEDANCE FREQUENCIES

Appendix B

Estimated Flow Exceedance Frequencies

	Beaver River	Beaver River	Beaver River	Beaver River	Beaver River	Buzzard Creek	Clear Creek	Clear Creek	Corrumpa Creek	Duck Pond Creek	Kiowa Creek	Otter Creek	Palo Duro Creek	Palo Duro Creek	Spring Creek	Upper Wolf Creek	Lower Wolf Creek
WBID Segment	OK720510000190_00	OK720500020450_00	OK720500020290_00	OK720500020140_00	OK720500020010_00	OK720500030080_00	OK720500020300_00	OK720500020070_00	OK720510000275_00	OK720500020250_00	OK720500020130_00	OK720500020050_00	OK720500020500_10	OK720500020500_00	OK720500020100_00	OK720500030010_00	OK720500020030_00
USGS Gage Reference	7232470	7234000	7234000	7234000	7234000	7233650	7233650	7233650	7232470	7233650	7233650	7233650	7233650	7233650	7233650	7233650	7233650
Drainage Area (sq. mile)	770.04	965.56	1553.79	3666.27	4856.63	46.03	209.62	115.35	204.47	104.76	284.61	44.02	154.20	538.10	41.72	765.96	732.33
NRCS Curve Number	66.15	70.44	68.81	59.99	61.80	59.47	70.33	65.14	65.19	70.69	65.69	67.55	73.59	69.57	67.23	60.91	53.37
Average Annual Rainfall (inch)	17.56	19.47	20.24	22.61	23.95	24.38	21.30	23.45	16.63	21.93	22.88	23.97	20.13	19.61	22.98	24.02	24.94
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)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
0	21.00	20366.86	39900.00	82807.11	97949.79	40.75	68.22	23.48	2.43	36.85	53.95	22.32	59.00	175.47	13.26	685.61	691.30
1	6.56	638.06	1250.00	2594.21	3068.60	25.71	3.93	11.99	0.76	2.12	28.98	5.49	3.40	10.11	3.72	120.34	276.30
2	4.85	275.64	540.00	1120.70	1325.64	19.47	3.12	11.35	0.56	1.69	24.90	4.41	2.70	8.03	3.04	111.76	213.12
3	4.40	173.44	339.79	705.19	834.14	17.79	2.89	11.15	0.51	1.56	23.87	3.99	2.50	7.44	2.78	106.54	179.22
4	4.30	117.40	230.00	477.33	564.62	17.79	2.66	10.93	0.50	1.44	21.81	3.78	2.30	6.84	2.65	103.86	153.96
5	4.30	88.82	174.00	361.11	427.15	16.17	2.43	10.70	0.50	1.31	21.81	3.57	2.10	6.25	2.52	98.33	141.95
6	4.30	71.46	140.00	290.55	343.68	16.17	2.31	10.58	0.50	1.25	20.77	3.37	2.00	5.95	2.39	98.33	130.36
7	4.20	58.19	114.00	236.59	279.86	14.60	2.31	10.58	0.49	1.25	19.73	3.17	2.00	5.95	2.26	95.48	130.36
8	4.20	49.00	96.00	199.24	235.67	14.60	2.20	10.45	0.49	1.19	18.69	2.77	1.90	5.65	2.00	89.57	119.19
9	4.10	43.39	85.00	176.41	208.66	14.60	2.08	10.32	0.47	1.12	17.65	2.58	1.80	5.35	1.87	86.51	108.46
10	4.10	38.79	76.00	157.73	186.57	14.60	1.97	10.18	0.47	1.06	17.65	2.58	1.70	5.06	1.87	86.51	98.16
11	4.10	33.69	66.00	136.97	162.02	13.09	1.97	10.18	0.47	1.06	16.60	2.38	1.70	5.06	1.74	83.37	88.30
12	4.10	30.63	60.00	124.52	147.29	13.09	1.97	10.18	0.47	1.06	16.60	2.38	1.70	5.06	1.74	83.37	78.89
13	4.00	27.56	54.00	112.07	132.56	13.09	1.85	10.04	0.46	1.00	15.55	2.19	1.60	4.76	1.61	80.13	78.89
14	4.00	25.52	50.00	103.77	122.74	13.09	1.85	10.04	0.46	1.00	15.55	2.19	1.60	4.76	1.61	80.13	69.94
15	4.00	23.48	46.00	95.47	112.92	11.62	1.73	9.88	0.46	0.94	15.55	2.01	1.50	4.46	1.49	76.79	69.94
16	3.90	21.95	43.00	89.24	105.56	11.62	1.73	9.88	0.45	0.94	14.50	2.01	1.50	4.46	1.49	76.79	61.45
17	3.90	20.42	40.00	83.01	98.20	11.62	1.73	9.88	0.45	0.94	14.50	2.01	1.50	4.46	1.49	76.79	61.45
18	3.90	18.89	37.00	76.79	90.83	11.62	1.62	9.72	0.45	0.87	14.50	1.82	1.40	4.16	1.36	73.35	61.45
19	3.80	17.87	35.00	72.64	85.92	11.62	1.62	9.72	0.44	0.87	14.50	1.82	1.40	4.16	1.36	73.35	53.43
20	3.80	16.84	33.00	68.49	81.01	11.62	1.62	9.72	0.44	0.87	13.44	1.82	1.40	4.16	1.36	73.35	53.43
21	3.80	15.82	31.00	64.34	76.10	10.22	1.62	9.72	0.44	0.87	13.44	1.82	1.40	4.16	1.36	73.35	53.43
22	3.80	14.80	29.00	60.19	71.19	10.22	1.50	9.56	0.44	0.81	13.44	1.82	1.30	3.87	1.36	73.35	49.67
23	3.80	14.29	28.00	58.11	68.74	10.22	1.50	9.56	0.44	0.81	13.44	1.64	1.30	3.87	1.24	69.77	45.90

	Beaver River	Beaver River	Beaver River	Beaver River	Beaver River	Buzzard Creek	Clear Creek	Clear Creek	Corrumpa Creek	Duck Pond Creek	Kiowa Creek	Otter Creek	Palo Duro Creek	Palo Duro Creek	Spring Creek	Upper Wolf Creek	Lower Wolf Creek
WBID Segment	OK720510000190_00	OK720500020450_00	OK720500020290_00	OK720500020140_00	OK720500020010_00	OK720500030080_00	OK720500020300_00	OK720500020070_00	OK720510000275_00	OK720500020250_00	OK720500020130_00	OK720500020050_00	OK720500020500_10	OK720500020500_00	OK720500020100_00	OK720500030010_00	OK720500020030_00
USGS Gage Reference	7232470	7234000	7234000	7234000	7234000	7233650	7233650	7233650	7232470	7233650	7233650	7233650	7233650	7233650	7233650	7233650	7233650
Drainage Area (sq. mile)	770.04	965.56	1553.79	3666.27	4856.63	46.03	209.62	115.35	204.47	104.76	284.61	44.02	154.20	538.10	41.72	765.96	732.33
NRCS Curve Number	66.15	70.44	68.81	59.99	61.80	59.47	70.33	65.14	65.19	70.69	65.69	67.55	73.59	69.57	67.23	60.91	53.37
Average Annual Rainfall (inch)	17.56	19.47	20.24	22.61	23.95	24.38	21.30	23.45	16.63	21.93	22.88	23.97	20.13	19.61	22.98	24.02	24.94
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)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
24	3.70	13.27	26.00	53.96	63.83	10.22	1.50	9.56	0.43	0.81	13.44	1.64	1.30	3.87	1.24	69.77	45.90
25	3.70	12.76	25.00	51.88	61.37	10.22	1.50	9.56	0.43	0.81	12.37	1.64	1.30	3.87	1.24	69.77	38.87
26	3.70	12.25	24.00	49.81	58.92	9.22	1.39	9.38	0.43	0.75	12.37	1.64	1.20	3.57	1.24	67.69	38.87
27	3.70	11.74	23.00	47.73	56.46	8.87	1.39	9.38	0.43	0.75	12.37	1.46	1.20	3.57	1.12	66.06	38.87
28	3.70	11.23	22.00	45.66	54.01	8.87	1.39	9.38	0.43	0.75	11.30	1.46	1.20	3.57	1.12	66.06	37.52
29	3.70	10.21	20.00	41.51	49.10	8.87	1.39	9.38	0.43	0.75	11.30	1.46	1.20	3.57	1.12	66.06	36.19
30	3.70	10.21	20.00	41.51	49.10	8.65	1.39	9.38	0.43	0.75	11.30	1.41	1.20	3.57	1.08	64.92	35.21
31	3.62	9.70	19.00	39.43	46.64	8.46	1.39	9.38	0.42	0.75	10.87	1.37	1.20	3.57	1.06	64.14	34.24
32	3.60	9.19	18.00	37.36	44.19	8.22	1.27	9.19	0.42	0.69	10.77	1.34	1.10	3.27	1.03	63.37	33.60
33	3.60	8.68	17.00	35.28	41.73	8.08	1.27	9.19	0.42	0.69	10.55	1.32	1.10	3.27	1.02	62.97	32.34
34	3.60	8.17	16.00	33.21	39.28	7.63	1.27	9.19	0.42	0.69	10.44	1.31	1.10	3.27	1.01	62.58	31.71
35	3.60	7.66	15.00	31.13	36.82	7.34	1.27	9.19	0.42	0.69	10.23	1.27	1.10	3.27	0.98	61.79	30.48
36	3.60	7.15	14.00	29.06	34.37	6.98	1.16	8.98	0.42	0.62	10.01	1.25	1.00	2.97	0.97	61.39	29.26
37	3.60	7.15	14.00	29.06	34.37	6.38	1.16	8.98	0.42	0.62	9.80	1.20	1.00	2.97	0.94	60.18	28.67
38	3.60	6.64	13.00	26.98	31.91	6.14	1.16	8.98	0.42	0.62	9.58	1.17	1.00	2.97	0.91	59.36	26.90
39	3.60	6.13	12.00	24.90	29.46	6.14	1.13	8.94	0.42	0.61	9.15	1.12	0.98	2.91	0.88	58.12	25.75
40	3.60	6.13	12.00	24.90	29.46	5.91	1.11	8.90	0.42	0.60	8.93	1.08	0.96	2.86	0.85	57.28	24.63
41	3.50	5.61	11.00	22.83	27.00	5.80	1.10	8.88	0.41	0.59	8.88	1.07	0.95	2.83	0.84	56.86	23.52
42	3.50	5.10	10.00	20.75	24.55	5.68	1.06	8.81	0.41	0.57	8.71	1.03	0.92	2.74	0.82	56.01	22.98
43	3.50	4.80	9.40	19.51	23.08	5.46	1.05	8.79	0.41	0.57	8.50	1.02	0.91	2.71	0.80	55.58	21.37
44	3.50	4.49	8.80	18.26	21.60	5.34	1.03	8.74	0.41	0.56	8.28	0.97	0.89	2.65	0.77	54.27	20.85
45	3.50	4.08	8.00	16.60	19.64	5.12	1.01	8.69	0.41	0.54	8.17	0.95	0.87	2.59	0.76	53.83	19.82
46	3.40	3.88	7.60	15.77	18.66	5.01	0.98	8.65	0.39	0.53	7.95	0.92	0.85	2.53	0.73	52.95	19.32
47	3.40	3.57	7.00	14.53	17.18	4.90	0.96	8.60	0.39	0.52	7.84	0.89	0.83	2.47	0.71	52.05	18.32
48	3.38	3.32	6.50	13.49	15.96	4.69	0.93	8.52	0.39	0.50	7.51	0.87	0.80	2.38	0.70	51.59	17.35
49	3.30	3.06	6.00	12.45	14.73	4.58	0.90	8.47	0.38	0.49	7.40	0.84	0.78	2.32	0.67	50.68	16.87
50	3.30	2.81	5.50	11.41	13.50	4.48	0.88	8.42	0.38	0.47	7.18	0.81	0.76	2.26	0.65	50.21	15.93

	Beaver River	Beaver River	Beaver River	Beaver River	Beaver River	Buzzard Creek	Clear Creek	Clear Creek	Corrumpa Creek	Duck Pond Creek	Kiowa Creek	Otter Creek	Palo Duro Creek	Palo Duro Creek	Spring Creek	Upper Wolf Creek	Lower Wolf Creek
WBID Segment	OK720510000190_00	OK720500020450_00	OK720500020290_00	OK720500020140_00	OK720500020010_00	OK720500030080_00	OK720500020300_00	OK720500020070_00	OK720510000275_00	OK720500020250_00	OK720500020130_00	OK720500020050_00	OK720500020500_10	OK720500020500_00	OK720500020100_00	OK720500030010_00	OK720500020030_00
USGS Gage Reference	7232470	7234000	7234000	7234000	7234000	7233650	7233650	7233650	7232470	7233650	7233650	7233650	7233650	7233650	7233650	7233650	7233650
Drainage Area (sq. mile)	770.04	965.56	1553.79	3666.27	4856.63	46.03	209.62	115.35	204.47	104.76	284.61	44.02	154.20	538.10	41.72	765.96	732.33
NRCS Curve Number	66.15	70.44	68.81	59.99	61.80	59.47	70.33	65.14	65.19	70.69	65.69	67.55	73.59	69.57	67.23	60.91	53.37
Average Annual Rainfall (inch)	17.56	19.47	20.24	22.61	23.95	24.38	21.30	23.45	16.63	21.93	22.88	23.97	20.13	19.61	22.98	24.02	24.94
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)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
51	3.20	2.55	5.00	10.38	12.27	4.37	0.86	8.37	0.37	0.46	6.96	0.77	0.74	2.20	0.63	49.01	15.02
52	3.20	2.35	4.60	9.55	11.29	4.12	0.83	8.31	0.37	0.45	6.63	0.74	0.72	2.14	0.60	47.85	14.12
53	3.20	2.04	4.00	8.30	9.82	3.96	0.81	8.26	0.37	0.44	6.41	0.70	0.70	2.08	0.57	46.88	13.25
54	3.20	1.84	3.60	7.47	8.84	3.56	0.79	8.20	0.37	0.42	6.08	0.66	0.68	2.02	0.55	45.89	12.41
55	3.20	1.53	3.00	6.23	7.36	3.27	0.76	8.15	0.37	0.41	5.86	0.63	0.66	1.96	0.52	44.89	11.59
56	3.10	1.33	2.60	5.40	6.38	2.99	0.74	8.09	0.36	0.40	5.64	0.62	0.64	1.90	0.51	44.38	11.19
57	3.10	1.07	2.10	4.36	5.16	2.90	0.71	8.00	0.36	0.38	5.53	0.59	0.61	1.81	0.49	43.35	10.79
58	3.10	0.92	1.80	3.74	4.42	2.59	0.68	7.93	0.36	0.37	5.38	0.57	0.59	1.75	0.48	42.83	10.40
59	3.00	0.71	1.40	2.91	3.44	2.46	0.65	7.84	0.35	0.35	5.08	0.54	0.56	1.67	0.46	42.31	10.02
60	3.00	0.51	1.00	2.08	2.45	2.37	0.61	7.74	0.35	0.33	4.97	0.51	0.53	1.58	0.43	41.24	9.27
61	3.00	0.43	0.84	1.74	2.06	2.29	0.59	7.67	0.35	0.32	4.74	0.50	0.51	1.52	0.42	40.16	8.91
62	3.00	0.31	0.61	1.26	1.49	2.20	0.57	7.59	0.35	0.31	4.63	0.48	0.49	1.46	0.41	39.61	8.19
63	2.90	0.24	0.47	0.98	1.15	2.12	0.54	7.52	0.34	0.29	4.52	0.46	0.47	1.40	0.39	39.05	7.85
64	2.90	0.18	0.36	0.75	0.88	2.01	0.53	7.48	0.34	0.29	4.29	0.43	0.46	1.37	0.37	37.92	7.51
65	2.90	0.15	0.30	0.62	0.74	1.89	0.50	7.36	0.34	0.27	4.18	0.41	0.43	1.28	0.35	36.76	7.18
66	2.80	0.13	0.25	0.52	0.61	1.80	0.47	7.28	0.32	0.26	3.95	0.37	0.41	1.22	0.32	35.57	6.53
67	2.70	0.11	0.22	0.46	0.54	1.66	0.45	7.20	0.31	0.24	3.72	0.34	0.39	1.16	0.30	34.36	5.91
68	2.60	0.10	0.20	0.42	0.49	1.54	0.43	7.11	0.30	0.23	3.50	0.32	0.37	1.10	0.28	33.11	5.32
69	2.50	0.09	0.18	0.37	0.44	1.23	0.40	7.01	0.29	0.22	3.38	0.29	0.35	1.04	0.26	31.82	4.75
70	2.30	0.09	0.17	0.35	0.42	0.86	0.38	6.92	0.27	0.21	2.92	0.25	0.33	0.98	0.22	30.50	4.34
71	2.20	0.08	0.15	0.31	0.37	0.59	0.35	6.76	0.25	0.19	2.54	0.22	0.30	0.89	0.20	28.42	3.95
72	2.10	0.07	0.13	0.27	0.32	0.42	0.32	6.66	0.24	0.17	2.11	0.20	0.28	0.83	0.18	26.98	3.45
73	2.10	0.05	0.10	0.21	0.25	0.29	0.29	6.48	0.24	0.16	1.75	0.17	0.25	0.74	0.16	25.47	2.76
74	2.00	0.05	0.09	0.19	0.22	0.21	0.25	6.29	0.23	0.14	1.39	0.15	0.22	0.65	0.14	23.90	2.34
75	2.00	0.04	0.07	0.15	0.17	0.17	0.23	6.15	0.23	0.12	1.03	0.14	0.20	0.59	0.13	22.24	1.95
76	1.90	0.02	0.04	0.08	0.10	0.14	0.21	6.00	0.22	0.11	0.91	0.11	0.18	0.54	0.11	21.38	1.76
77	1.90	0.01	0.02	0.04	0.05	0.11	0.19	5.83	0.22	0.10	0.66	0.09	0.16	0.48	0.09	19.57	1.42

	Beaver River	Beaver River	Beaver River	Beaver River	Beaver River	Buzzard Creek	Clear Creek	Clear Creek	Corrumpa Creek	Duck Pond Creek	Kiowa Creek	Otter Creek	Palo Duro Creek	Palo Duro Creek	Spring Creek	Upper Wolf Creek	Lower Wolf Creek
WBID Segment	OK720510000190_00	OK720500020450_00	OK720500020290_00	OK720500020140_00	OK720500020010_00	OK720500030080_00	OK720500020300_00	OK720500020070_00	OK720510000275_00	OK720500020250_00	OK720500020130_00	OK720500020050_00	OK720500020500_10	OK720500020500_00	OK720500020100_00	OK720500030010_00	OK720500020030_00
USGS Gage Reference	7232470	7234000	7234000	7234000	7234000	7233650	7233650	7233650	7232470	7233650	7233650	7233650	7233650	7233650	7233650	7233650	7233650
Drainage Area (sq. mile)	770.04	965.56	1553.79	3666.27	4856.63	46.03	209.62	115.35	204.47	104.76	284.61	44.02	154.20	538.10	41.72	765.96	732.33
NRCS Curve Number	66.15	70.44	68.81	59.99	61.80	59.47	70.33	65.14	65.19	70.69	65.69	67.55	73.59	69.57	67.23	60.91	53.37
Average Annual Rainfall (inch)	17.56	19.47	20.24	22.61	23.95	24.38	21.30	23.45	16.63	21.93	22.88	23.97	20.13	19.61	22.98	24.02	24.94
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)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
78	1.80	0.00	0.00	0.00	0.00	0.08	0.17	5.75	0.21	0.09	0.53	0.08	0.15	0.45	0.08	17.63	1.26
79	1.80	0.00	0.00	0.00	0.00	0.05	0.15	5.55	0.21	0.08	0.28	0.06	0.13	0.39	0.06	15.51	0.96
80	1.70	0.00	0.00	0.00	0.00	0.03	0.13	5.34	0.20	0.07	0.14	0.05	0.11	0.33	0.05	14.36	0.70
81	1.70	0.00	0.00	0.00	0.00	0.01	0.12	5.22	0.20	0.06	0.00	0.03	0.10	0.30	0.03	11.84	0.58
82	1.70	0.00	0.00	0.00	0.00	0.01	0.09	4.95	0.20	0.05	0.00	0.01	0.08	0.24	0.02	8.83	0.37
83	1.60	0.00	0.00	0.00	0.00	0.00	0.08	4.80	0.19	0.04	0.00	0.01	0.07	0.21	0.01	7.00	0.21
84	1.60	0.00	0.00	0.00	0.00	0.00	0.06	4.44	0.19	0.03	0.00	0.00	0.05	0.15	0.00	4.70	0.09
85	1.57	0.00	0.00	0.00	0.00	0.00	0.05	4.21	0.18	0.02	0.00	0.00	0.04	0.12	0.00	0.01	0.04
86	1.50	0.00	0.00	0.00	0.00	0.00	0.02	3.57	0.17	0.01	0.00	0.00	0.02	0.06	0.00	0.01	0.00
87	1.40	0.00	0.00	0.00	0.00	0.00	0.01	3.04	0.16	0.01	0.00	0.00	0.01	0.03	0.00	0.01	0.00
88	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
89	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
90	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
91	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
92	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
93	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
94	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
95	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
96	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
97	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
98	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
99	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
100	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

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 Waters.

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

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

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

785:46-13-2. Definitions

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

"Specified pollutants" means

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

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

(C) Phosphorus;

(D) Total Suspended Solids (TSS); and

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

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

(a) General.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX E

RESPONSE TO COMMENTS

Randy Frazer, Town Administrator, Town of Beaver received on August 17, 2010:

Comment #1: I recently received a public notice in regards to a draft document describing reductions needed to improve water quality in the Beaver River. I would like to know how this might affect our town and what kinds of new requirements might be added. Our effluent for the waste water system is not released in to the river but is used to water the golf course which is in the Beaver River watershed, our storm water does end up in the river. I would also like to request a public meeting so that the landowners in the affected area can have a better understanding of what this all means to them.

Response #1: *No new requirement will be added since there is no discharge to the Beaver River. Our records show that the Town of Beaver does not have a stormwater permit; hence no new requirements will be added. According to the Oklahoma Continuous Planning Process, after the public comment period is over, if public comments are received, the DEQ will determine if there is significant public interest or if a meeting is otherwise appropriate. In this case, there was only one request of which no new requirements will be added; hence DEQ determined that a public meeting is not required.*

Comments from Oklahoma Farm Bureau were received on September 7, 2010:

Comment #2: We appreciate the opportunity to provide comments on these FINAL TMDLs. As we have on their FINAL TMDLs, we continue to comment that sewer overflows and bypasses should be included into the point source allocation as a contributor to bacteria impairment.

Response #2: *Sewer overflows and bypasses are not permitted and therefore cannot be added to the point source allocations. All SSOs are considered unpermitted discharges under State statute and DEQ regulations and will be dealt through enforcement actions as described in the last paragraph of Section 3.1.2. No changes were made.*

Comment #3: With regard to these bacteria TMDLs, we concur three approaches to revising the pathogen provisions of Oklahoma's water quality standards -- removing the primary body contact recreation use, modifying application of the existing criteria, and revising the existing numeric criteria – should be considered.

Response #3: *Thank you for the comments*.

Comments from the Texas County Conservation District received on September 7, 2010:

Comment #4: First, while the Texas County Conservation District (TCCD) board and staff support protecting and improving water quality, we feel that the percent reduction in Total Maximum Daily Loads (TMDLS) for the Beaver River and Palo Duro Creek in Texas County will not be attainable throughout the year. This is due to the fact that stream flows continue to decline throughout the warmer months, resulting in extended periods, particularly in the summer, in which there is no flowing water in the stream beds. A lack of flowing water results in stagnant pools that will yield higher Total Suspended Solids. It is the request of the TCCD that the DEQ consider establishing TMDLS tied to a minimum stream flow quantity.

***Response #4**: The ODEQ allows for high flow exclusion but there are no flow exclusions for low flows. For the purpose of this TMDL, high flows were excluded. Also the lack of flowing water will yield lower TSS since the solids will tend to settle.*

Comment #5: Secondly, page 4 of the public notice lists the WQM Station OK720510000190-001AT location as SW1/4 Section 7-4N-24E. This description would place the WQM Station in Beaver County, OK where US Hwy 270 crosses the Beaver River, not at SH 95 in Guymon. DEQ needs to confirm the location of this WQM Station for use in future reports and make corrections as needed.

***Response #5**: The legal location has been corrected to S22-T03N-R13E.*

Comment #6: The Texas County Conservation District understands the need to protect and improve our water quality, and hopes that the comments provided above will be of assistance in conserving the Beaver River Watershed for our future generations.

***Response #6**: Thank you for your comments.*

Anonymous Caller

Comment #7: This concern citizen pointed out errors in the one testing site location; specifically, Beaver River at US 64, Beaver with legal address S16-T04N-R04E.

***Response #7**: The change has been made to "Beaver River at US 270, Beaver with legal address S07-T04-R24E".*