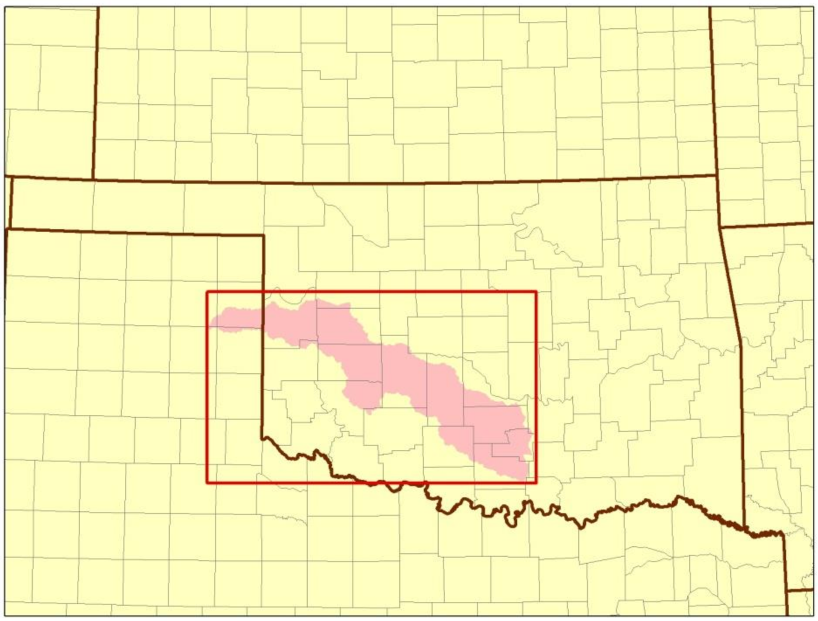
FINAL

BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE WASHITA RIVER, OKLAHOMA (OK310800, OK310810, OK310830, OK310840)



Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

PARSONS

AUGUST 2010

Revised by:

DEQ

NOVEMBER 2021

FINAL

BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE WASHITA RIVER, OKLAHOMA (OK310800, OK310810, OK310830, OK310840)

OKWBID

OK310800020010, OK310800020040, OK310810010010, OK310810010050, OK310810010190, OK310810020010, OK310810040140, OK310830010010, OK310830020020, OK310830020060, OK310830030010, OK310830060030, OK310840010010, OK310840020020

Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

PARSONS

8000 Centre Park Drive, Suite 200
Austin, TX 78754

AUGUST 2010

Oklahoma Department of Environmental Quality: FY08 106 Grant (CA# I-006400-08)

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
ASAE	American Society of Agricultural Engineers
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
HUC	Hydrologic unit code
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
NRMSE	Normalized root mean square error
NTU	Nephelometric turbidity unit
OLS	Ordinary least square
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
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow
TMDL	Total maximum daily load

USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater treatment plant

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 selected waterbodies in the Washita River basin. (All future references to bacteria in this document imply these three classes of fecal pathogen indicator bacteria unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic biological 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). 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 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 Washita River Basin, 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 the primary body contact recreation (PBCR) or warm water aquatic community (WWAC) designated uses.

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
OK310840020020_00	Sandstone Creek	14.59	2016	3	**X**	**X**		**N**	**X**	**N**
OK310840020010_00	Washita River at Site #384	61.94	2016	3					**X**	**N**
OK310840010010_00	Washita River at SH 33, McLure	18.62	2016	3					**X**	**N**
OK310830030010_00	Washita River at SH 152, Cordell	49.32	2019	4					**X**	**N**
OK310830020060_10	Rainy Mountain Creek	32.33	2019	4					**X**	**N**
OK310830020020_00	Stinking Creek	18.36	2019	4	**X**	**X**		**N**	**X**	**N**
OK310830010010_00	Washita River at US 281, Anadarko	20.68	2016	3					**X**	**N**
OK310810040140_00	Wildhorse Creek	11.13	2016	3	**X**	**X**		**N**	**X**	**N**
OK310810020010_00	Washita River at SH 19, near Alex	63.16	2019	4	**X**		**X**	**N**	**X**	**N**
OK310810010190_00	Washington Creek	6.49	2016	3					**X**	**N**
OK310810010050_00	Kickapoo Sandy Creek	10.19	2019	4	**X**	**X**		**N**	**X**	**N**
OK310810010010_10	Washita River at SH 19, Pauls Valley	32.87	2016	3					**X**	**N**
OK310800020040_00	Sand Branch	6.24	2016	3					**X**	**N**
OK310800020010_00	Washita River at US 177, Durwood	32.87	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, 2004-2009

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (count/100 mL)	Number of samples exceeding single sample criterion	% samples exceeding single sample criterion
OK310840020020_00	Sandstone Creek	EC	10	192	3	30%
		ENT	10	199	7	70%
OK310830020020_00	Stinking Creek	EC	10	213	3	30%
		ENT	10	209	8	80%
OK310810040140_00	Wildhorse Creek	EC	10	374	4	40%
		ENT	10	430	9	90%
OK310810020010_00	Washita River at SH 19, near Alex	FC	20	336	9	45%
		EC	20	77	5	25%
		ENT	20	210	10	50%
OK310810010050_00	Kickapoo Sandy Creek	EC	10	342	4	40%
		ENT	10	281	9	90%

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

Table ES-2 summarizes water quality data collected during primary body contact recreation season from the water quality monitoring (WQM) stations between 2002 and 2009 for each of three pathogen indicator bacteria classes: enterococci (ENT), *E. coli* (EC), and fecal coliform (FC). The data summary in Table ES-2 provides a general understanding of the amount of water quality data available and the severity of exceedences of the water quality criteria. This data collected during the primary contact recreation season includes the data used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2008 303(d) list (ODEQ 2008). It also includes the new date collected after the data cutoff date for the 2008 303(d) list.

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

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

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

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

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

(b) Screening levels:

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

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

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

(c) Fecal coliform:

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

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

(d) Escherichia coli (E. coli):

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

(e) Enterococci:

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

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

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

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

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

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

Waterbody ID	Waterbody Name	WQM Station	Number of Turbidity Samples	Number of Samples greater than 50 NTU	% Samples Exceeding Criterion	Average Turbidity (NTU)
OK310840020020_00	Sandstone Creek	OK310840-02-0020C	18	3	17%	46
OK310840020010_00	Washita River at Site #384	OK310840-02-0010G	19	5	25%	45
OK310840010010_00	Washita River at SH 33, McLure	310840010010-003RS	55	10	18%	51
OK310830030010_00	Washita River at SH 152, Cordell	310830030010-001AT	86	25	29%	92
OK310830020060_10	Rainy Mountain Creek	OK310830-02-0060G	16	8	50%	195
OK310830020020_00	Stinking Creek	OK310830-02-0020D	20	5	25%	42
OK310830010010_00	Washita River at US 281, Anadarko	310830010010-001AT	72	20	28%	51
OK310810040140_00	Wildhorse Creek	OK310810-04-0140D	20	10	48%	81
OK310810020010_00	Washita River at SH 19, near Alex	310810020010-001AT	31	10	32%	104
OK310810010190_00	Washington Creek	OK310810-01-0190G	12	6	50%	137
OK310810010050_00	Kickapoo Sandy Creek	OK310810-01-0050G	17	3	18%	46
OK310810010010_10	Washita River at SH 19, Pauls Valley	310810010010-001AT	69	42	61%	108
OK310800020040_00	Sand Branch	OK310800-02-0040C	20	5	25%	48
OK310800020010_00	Washita River at US 177, Durwood	310800020010-001AT	52	26	50%	118

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

Waterbody ID	Waterbody Name	WQM Station	Number of TSS Samples	Average TSS (mg/L)
OK310840020020_00	Sandstone Creek	OK310840-02-0020C	19	49
OK310840020010_00	Washita River at Site #384	OK310840-02-0010G	23	36
OK310840010010_00	Washita River at SH 33, McLure	310840010010-003RS	16	49
OK310830030010_00	Washita River at SH 152, Cordell	310830030010-001AT	37	84
OK310830020060_10	Rainy Mountain Creek	OK310830-02-0060G	16	229
OK310830020020_00	Stinking Creek	OK310830-02-0020D	19	37
OK310830010010_00	Washita River at US 281, Anadarko	310830010010-001AT	10	81
OK310810040140_00	Wildhorse Creek	OK310810-04-0140D	20	61
OK310810020010_00 *	Washita River at SH 19, near Alex	310810020010-001AT	0	-
OK310810010190_00	Washington Creek	OK310810-01-0190G	11	104
OK310810010050_00	Kickapoo Sandy Creek	OK310810-01-0050G	16	44
OK310810010010_10	Washita River at SH 19, Pauls Valley	310810010010-001AT	13	134
OK310800020040_00	Sand Branch	OK310800-02-0040C	19	41
OK310800020010_00	Washita River at US 177, Durwood	310800020010-001AT	14	158

* Only turbidity samples were collected at this site. TSS samples were not collected.

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

Assessment of Fish and Wildlife Propagation support

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

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

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

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

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

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 Goal (mg/L)[a]	MOS[b]	TSS Target (mg/L)[c]
OK310840020020_00	Sandstone Creek	0.896	8.8%	60	10%	54
OK310840020010_00	Washita River at Site #384	0.508	19.4%	55	20%	44
OK310840010010_00	Washita River at SH 33, McLure	0.873	10.5%	88	15%	75
OK310830030010_00	Washita River at SH 152, Cordell	0.773	12.5%	78	15%	66
OK310830020060_10	Rainy Mountain Creek	0.953	7.5%	58	10%	52
OK310830020020_00	Stinking Creek	0.920	7.5%	41	10%	37
OK310830010010_00	Washita River at US 281, Anadarko	0.866	15.5%	86	15%	73
OK310810040140_00	Wildhorse Creek	0.930	6.0%	63	10%	57
OK310810020010_00	Washita River at SH 19, near Alex[d]	0.721	13.2%	40	15%	34
OK310810010190_00	Washington Creek	0.568	24.8%	34	25%	26
OK310810010050_00	Kickapoo Sandy Creek	0.964	7.3%	60	10%	54
OK310810010010_10	Washita River at SH 19, Pauls Valley	0.721	13.2%	40	15%	34
OK310800020040_00	Sand Branch	0.775	23.1%	57	25%	43
OK310800020010_00	Washita River at US 177, Durwood	0.621	15.0%	54	15%	46

NMRSE = normalized root mean square error
[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
[d] Data from regression for waterbody OK310810010010_10

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-6 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
OK310840020020_00	Sandstone Creek						TSS		Bacteria, TSS
OK310840020010_00	Washita River at Site #384						TSS		TSS
OK310840010010_00	Washita River at SH 33, McLure						TSS		TSS
OK310830030010_00	Washita River at SH 152, Cordell					Bacteria			TSS
OK310830020060_10	Rainy Mountain Creek		TSS				TSS		TSS
OK310830020020_00	Stinking Creek						TSS		TSS
OK310830010010_00	Washita River at US 281, Anadarko		TSS				TSS		TSS
OK310810040140_00	Wildhorse Creek				Bacteria				Bacteria, TSS
OK310810020010_00	Washita River at SH 19, near Alex	Bacteria	TSS						Bacteria, TSS
OK310810010190_00	Washington Creek								TSS
OK310810010050_00	Kickapoo Sandy Creek						TSS		TSS
OK310810010010_10	Washita River at SH 19, Pauls Valley						TSS		TSS
OK310800020040_00	Sand Branch						TSS		TSS
OK310800020010_00	Washita River at US 177, Durwood		TSS				TSS		TSS

No facility present in watershed.

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

E.3 Using Load Duration Curves to Develop TMDLs

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

Preparing flow duration curves for gaged and ungaged WQM stations;

Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and

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

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

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

The basic steps to generating an LDC involve:

- obtaining daily flow data 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 detemined 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 water quality 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 through Figure 4-3); 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 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)

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. PRGs are calculated for each waterbody and pathogen indicator bacteria class as the reductions in load required so no 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 pathogen 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 41 to 97 percent.

Table ES-7 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
OK310840020020_00	Sandstone Creek		86%	**41%**	99%	**85%**
OK310830020020_00	Stinking Creek		64%	**47%**	91%	**86%**
OK310810040140_00	Wildhorse Creek		78%	**70%**	98%	**93%**
OK310810020010_00	Washita River at SH 19, near Alex	**82%**			99%	**86%**
OK310810010050_00	Kickapoo Sandy Creek		**64%**	67%	91%	**89%**

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 29 to 96 percent.

Table ES-8 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK310840020020_00	Sandstone Creek	56%
OK310840020010_00	Washita River at Site #384	29%
OK310840010010_00	Washita River at SH 33, McLure	74%
OK310830030010_00	Washita River at SH 152, Cordell	73%
OK310830020060_10	Rainy Mountain Creek	96%
OK310830020020_00	Stinking Creek	50%
OK310830010010_00	Washita River at US 281, Anadarko	58%
OK310810040140_00	Wildhorse Creek	51%
OK310810020010_00	Washita River at SH 19, near Alex	77%
OK310810010190_00	Washington Creek	93%
OK310810010050_00	Kickapoo Sandy Creek	64%
OK310810010010_10	Washita River at SH 19, Pauls Valley	83%
OK310800020040_00	Sand Branch	66%
OK310800020010_00	Washita River at US 177, Durwood	85%

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

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

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

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include a MOS and account for seasonal variability. The MOS, which can be implicit or explicit, is a conservative measure incorporated into the TMDL equation that accounts for the 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 ranges from 10 percent to 25 percent. Table 5-5 shows the MOS for each waterbody.

The bacteria TMDLs established in this report adhere to the seasonal application of Oklahoma WQS, which limit the PBCR use to the period of May 1st through September 30th. Similarly, the TSS TMDLs established in this report adhere to the seasonal application of Oklahoma WQS for turbidity, which apply 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, Food, and Foresty and the 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 97 percent. The ODEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation.

SECTION 1
INTRODUCTION

1.1 TMDL Program Background

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

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 selected waterbodies in the Washita River basin. (All future references to bacteria in this document imply these three classes of fecal pathogen indicator bacteria unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic biological communities. 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 instream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES). The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the 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 involving stakeholders who live and work in the watersheds, along with tribes, and local, state, and federal government agencies.

This TMDL report focuses on waterbodies that ODEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of the primary body contact recreation (PBCR) or warm water aquatic community (WWAC) designated used. The waterbodies addressed in this report, which are presented upstream to downstream, include:

Sandstone Creek (OK310840020020_00),
Washita River at Site #384 (OK310840020010_00),
Washita River at SH 33, McLure (OK310840010010_00),
Washita River at SH 152, Cordell (OK310830030010_00),
Rainy Mountain Creek (OK310830020060_10),
Stinking Creek (OK310830020020_00),
Washita River at US 281, Anadarko (OK310830010010_00),
Wildhorse Creek (OK310810040140_00),
Washita River at SH 19, near Alex (OK310810020010_00),
Washington Creek (OK310810020200_00),
Kickapoo Sandy Creek (OK310810020170_00),
Washita River at SH 19, Pauls Valley (OK310810010010_10),
Sand Branch (OK310800020040_00), and
Washita River at US 177, Durwood (OK310800020010_00).

Figures 1-1 and 1-2 are location maps showing these Oklahoma waterbodies and their contributing watersheds. These maps also display locations of the water quality monitoring (WQM) stations used as the basis for placement of these waterbodies on the Oklahoma 303(d) list. These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

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

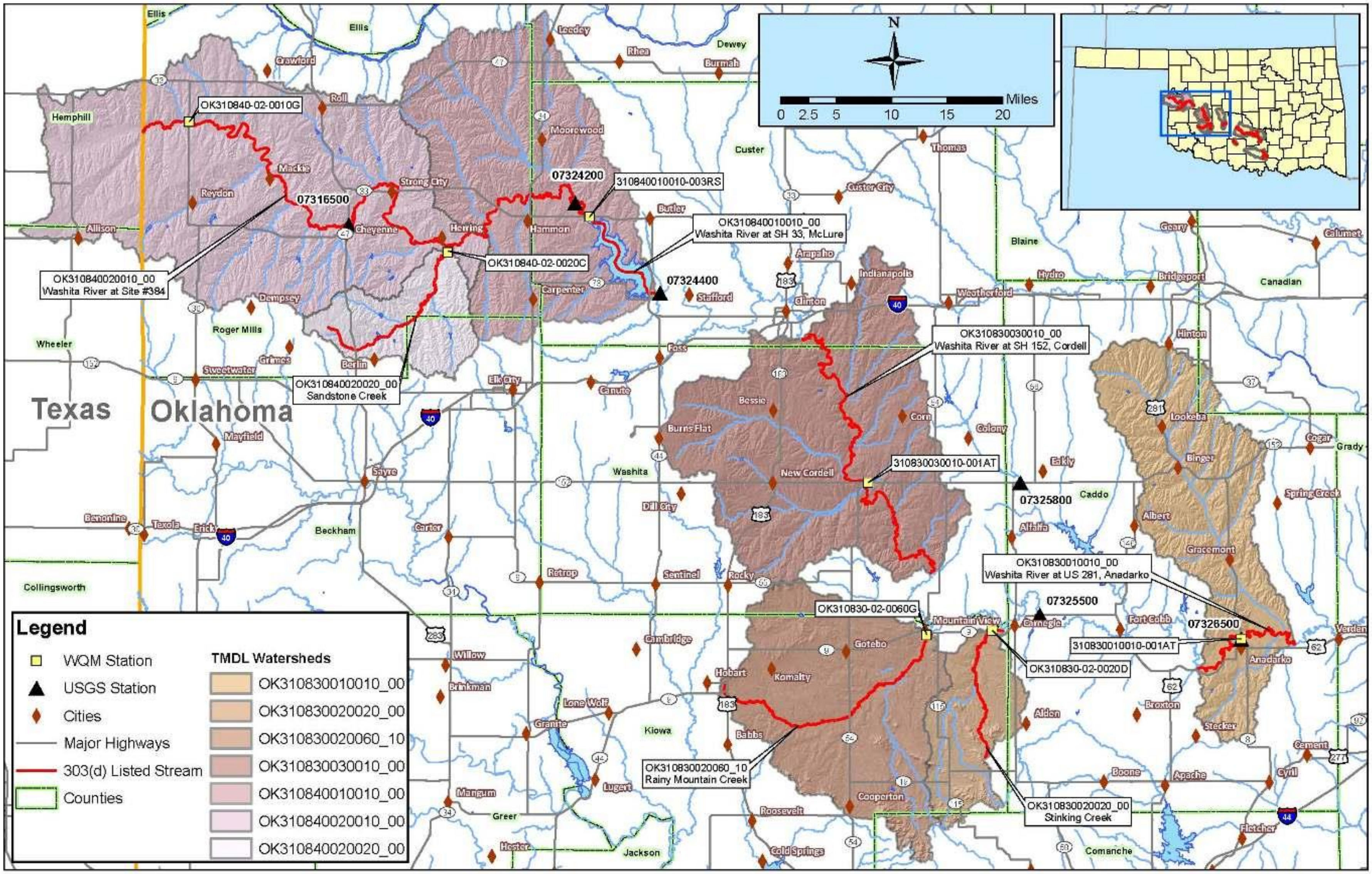
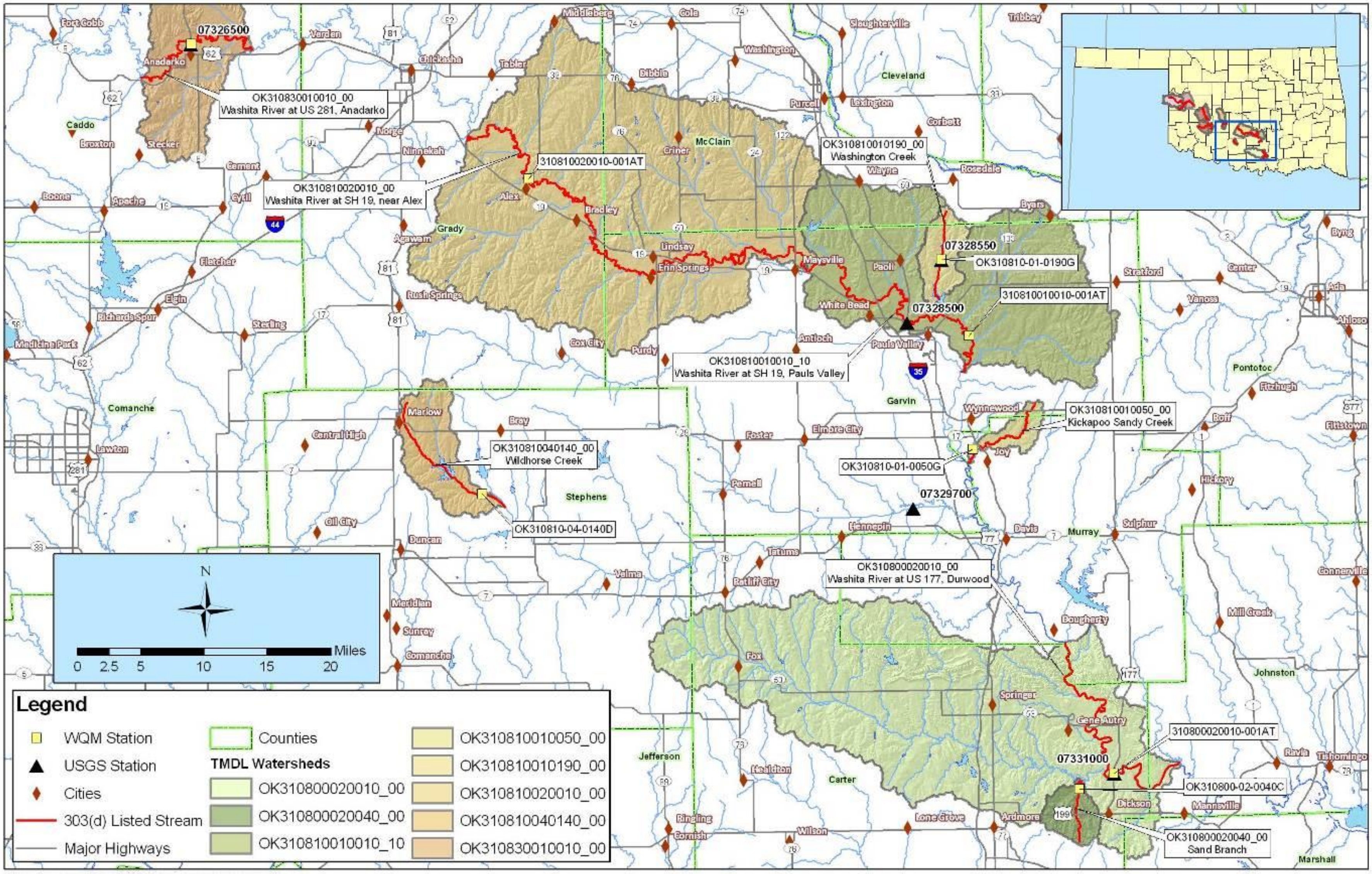


Figure 1-2 Lower Washita River Watersheds Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation Use



Elevated levels of pathogen indicator 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 uses designated for each waterbody. Table 1-1 provides a description of the locations of WQM stations on the 303(d)-listed waterbodies.

Table 1-1 Water Quality Monitoring Stations used for 2008 303(d) Listing Decision

WQM Station	Waterbody Name and Station Location	Waterbody ID
OK310840-02-0020C	Sandstone Creek at E0980 Road	OK310840020020_00
OK310840-02-0010G	Washita River at Site #384	OK310840020010_00
310840010010-003RS	Washita River at SH 33, McLure	OK310840010010_00
310830030010-001AT	Washita River at SH 152, Cordell	OK310830030010_00
OK310830-02-0060G	Rainy Mountain Creek at State Road 9	OK310830020060_10
OK310830-02-0020D	Stinking Creek at State Road 9	OK310830020020_00
310830010010-001AT	Washita River at US 281, Anadarko	OK310830010010_00
OK310810-04-0140D	Wildhorse Creek	OK310810040140_00
310810020010-001AT	Washita River at SH 19, near Alex	OK310810020010_00
OK310810-01-0190G	Washington Creek	OK310810010190_00
OK310810-01-0050G	Kickapoo Sandy Creek at SH 77	OK310810010050_00
310810010010-001AT	Washita River at SH 19, Pauls Valley	OK310810010010_10
OK310800-02-0040C	Sand Branch at County Road 199	OK310800020040_00
310800020010-001AT	Washita River at US 177, Durwood	OK310800020010_00

1.2 Watershed Description

General. The Washita River basin is located in the southwestern portion of Oklahoma. The majority of the waterbodies addressed in this report are located in Roger Mills, Custer, Washita, Caddo, Kiowa, Grady, McClain, Garvin, Murray, and Carter Counties. Wildhorse Creek (OK310810040140_00) is located in Stephens County. These counties are part of the Central Great Plains and Cross Timbers Level III ecoregions (Woods, A.J, Omerik, J.M., et al 2005). The watersheds in the Study Area are located in the Anadarko Basin geological province. Table 1-2, derived from the 2000 U.S. Census, demonstrates that the counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2000). Table 1-3 lists the towns and cities located in each watershed.

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Population Density (per square mile)
Roger Mills	3,436	3
Custer	26,142	26
Washita	11,508	12
Caddo	30,150	24
Grady	45,516	41
McClain	32,500*	49
Garvin	27,210	34
Murray	12,623	30
Carter	45,621	55
Stephens	43,182	49

* Census updated in 2006

Table 1-3 Towns and Cities by Watershed

Waterbody Name	Waterbody ID	Municipality
Sandstone Creek	OK310840020020_00	Berlin
Washita River, Site # 384	OK310840020010_00	Mackie, Reydon, Cheyenne, Strong City, Roll, Herring
Washita River, off SH 33, near McLure	OK310840010010_00	McLure, Carpenter, Hammon, Leedey, Moorewood
Washita River, SH 152, Cordell	OK310830030010_00	Bessie, Corn, New Cordell
Rainy Mountain Creek	OK310830020060_10	Komalty, Gotebo, Cooperton, Mountain View
Stinking Creek	OK310830020020_00	
Washita River, US 281, Anadarko	OK310830010010_00	Lookeba, Binger, Gracemont, Anadarko,
Wildhorse Creek	OK310810040140_00	Marlow
Washita River, off SH 19, near Alex	OK310810020010_00	Alex, Bradley, Criner, Lindsay, Erin Springs
Washington Creek	OK310810010190_00	
Kickapoo Sandy Creek	OK310810010050_00	
Washita River, SH 19, Pauls Valley	OK310810010010_10	Wayne, Byars, Pauls Valley, Paoli, White Bead
Sand Branch Creek	OK310800020040_00	
Washita River, US 177, Durwood	OK310800020010_00	Fox, Springer, Gene Autry, Dickson

Climate. Table 1-4 summarizes the average annual precipitation for each Oklahoma waterbody based on the approximate midpoint of each watershed. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 25 and 40 inches (Oklahoma Climate Survey 2007).

Table 1-4 Average Annual Precipitation by Watershed

Washita River Basin Precipitation Summary		
Waterbody Name	**Waterbody ID**	**Average Annual Precipitation (inches)**
Sandstone Creek	OK310840020020_00	27
Washita River: Site # 384	OK310840020010_00	25
Washita River, off SH 33, near McLure	OK310840010010_00	27
Washita River, SH 152, Cordell	OK310830030010_00	30
Rainy Mountain Creek	OK310830020060_10	30
Stinking Creek	OK310830020020_00	31
Washita River, US 281, Anadarko	OK310830010010_00	32
Wildhorse Creek	OK310810040140_00	36
Washita River, off SH 19, near Alex	OK310810020010_00	37
Washington Creek	OK310810010190_00	39
Kickapoo Sandy Creek	OK310810010050_00	40
Washita River, SH 19, Pauls Valley	OK310810010010_10	39
Sand Branch Creek	OK310800020040_00	39
Washita River, US 177, Durwood	OK310800020010_00	39

Land Use. Tables 1-5a and 1-5b summarize the percentages and acreages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody addressed in the Study Area. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2001 National Land Cover Dataset (USGS 2007). The land use categories are displayed in Figure 1-3. The two most dominant land use category throughout the Washita River Study Area is grasslands/herbaceous. Five watersheds in the Study Area have a significant percentage of land use classified as deciduous forest including Washita River at US 177, Durwood (OK310800020010_00), Sand Branch (OK310800020040_00), Kickapoo Sandy Creek (OK310810020170_00), Washington Creek (OK310810020200_00), and Wildhorse Creek (OK310810040140_00). Five watersheds in the Study Area have a significant percentage of land use classified as cultivated crops including Washita River at US SH 152, Cordell (OK310830030010_00), Rainy Mountain Creek (OK310830020060_00), Stinking Creek (OK310830020020_00), Washita River at U.S. 281, Anadarko (OK310830010010_00), and Wildhorse Creek (OK310810040140_00). The aggregated total of low, medium, and high intensity developed land accounts for less than 2 percent of the land use in each watershed. The watersheds targeted for TMDL development in this Study Area range in size from 7,610 acres (Kickapoo Sandy Creek) to 404,873 acres (Washita River at Site #384, OK310840020010_00).

Figure 1-3 Land Use Map

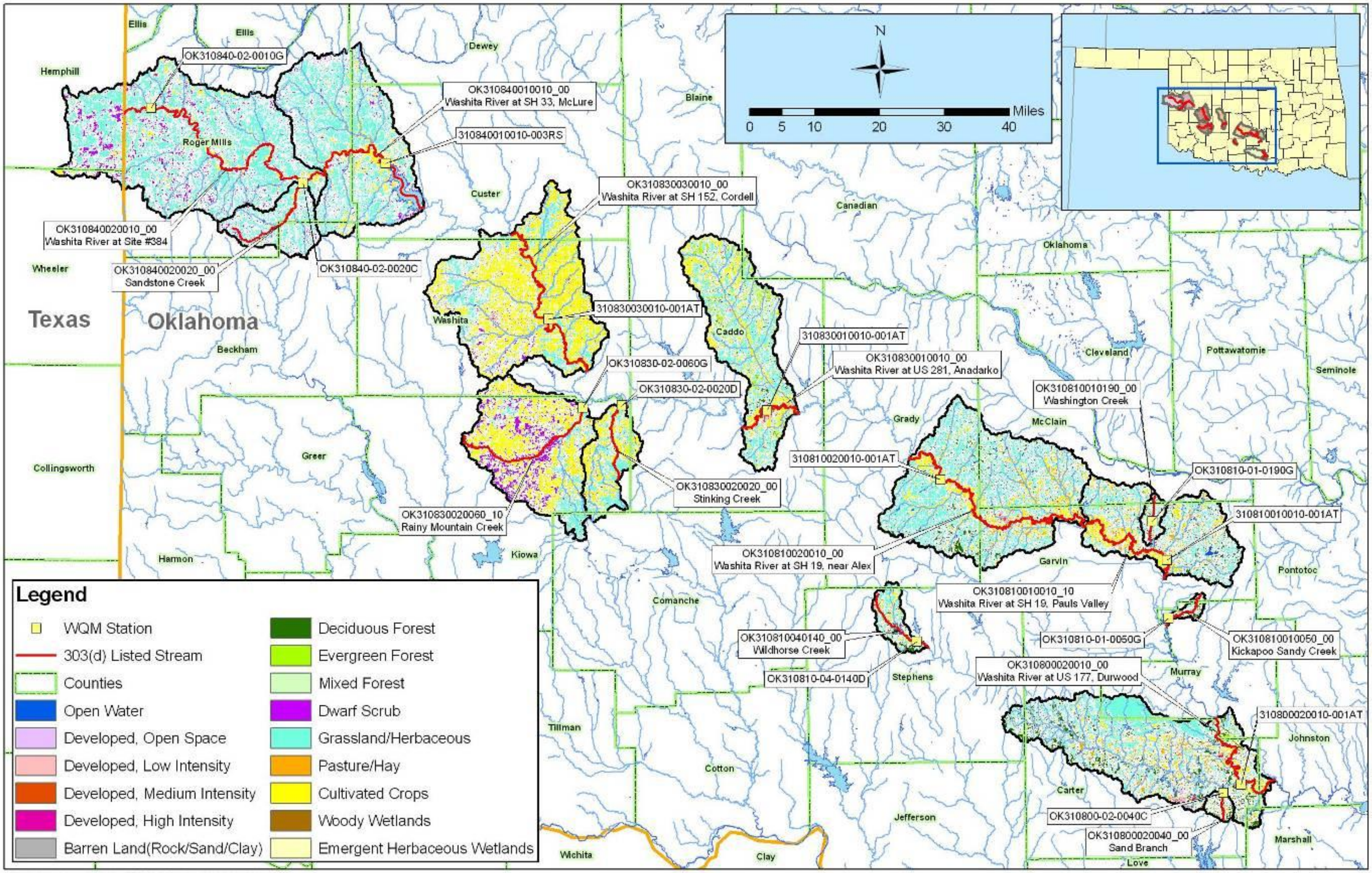


Table 1-5a Land Use Summaries by Watershed

Landuse Category	WQM Station						
	Sandstone Creek	Washita River: Site #384	Washita River at SH 33	Washita River at SH 152	Rainy Mountain Creek	Stinking Creek	Washita River at US 281
Waterbody ID	**OK310840020020_00**	**OK310840020010_00**	**OK310840010010_00**	**OK310830030010_00**	**OK310830020060_10**	**OK310830020020_00**	**OK310830010010_00**
Percent of Open Water	0.45%	0.27%	2.70%	0.27%	0.50%	0.52%	0.92%
Percent of Developed, Open Space	0.60%	0.81%	0.98%	3.63%	3.83%	4.07%	4.85%
Percent of Developed, Low Intensity	0.02%	0.05%	0.06%	0.38%	0.13%	0.04%	0.62%
Percent of Developed, Medium Intensity	0.00%	0.01%	0.02%	0.11%	0.02%	0.00%	0.18%
Percent of Developed, High Intensity	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.13%
Percent of Barren Land (Rock/Sand/Clay)	0.94%	0.23%	0.03%	0.01%	0.06%	0.03%	0.01%
Percent of Deciduous Forest	0.01%	0.02%	0.00%	0.46%	0.45%	2.34%	6.74%
Percent of Evergreen Forest	0.00%	0.00%	0.00%	0.13%	0.30%	0.10%	12.70%
Percent of Mixed Forest	1.15%	0.43%	1.31%	0.98%	1.83%	0.35%	0.00%
Percent of Shrub/Scrub	27.66%	28.24%	22.19%	8.46%	28.62%	2.58%	0.06%
Percent of Grassland/Herbaceous	64.38%	64.80%	60.32%	26.22%	20.42%	45.60%	48.72%
Percent of Pasture/Hay	0.00%	0.00%	0.00%	0.01%	0.25%	0.25%	0.33%
Percent of Cultivated Crops	4.78%	5.13%	12.30%	59.28%	43.55%	44.13%	24.76%
Percent of Woody Wetlands	0.03%	0.02%	0.08%	0.04%	0.03%	0.00%	0.00%
Percent of Emergent Herbaceous Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acres Open Water	298	1,098	7,226	827	1,010	352	1,846
Acres Developed, Open Space	397	3,264	2,610	11,319	7,675	2,741	9,697
Acres Developed, Low Intensity	11	218	173	1,176	256	24	1,236
Acres Developed, Medium Intensity	0	49	57	329	41	1	366
Acres Developed, High Intensity	0	2	3	115	7	0	250

Landuse Category	WQM Station						
	Sandstone Creek	**Washita River: Site #384**	**Washita River at SH 33**	**Washita River at SH 152**	**Rainy Mountain Creek**	**Stinking Creek**	**Washita River at US 281**
Waterbody ID	**OK310840020020_00**	**OK310840020010_00**	**OK310840010010_00**	**OK310830030010_00**	**OK310830020060_10**	**OK310830020020_00**	**OK310830010010_00**
Acres Barren Land (Rock/Sand/Clay)	621	914	80	34	121	18	12
Acres Deciduous Forest	4	68	0	1,438	905	1,579	13,473
Acres Evergreen Forest	0	13	3	393	608	64	25,405
Acres Mixed Forest	764	1,730	3,506	3,061	3,657	235	2
Acres Shrub/Scrub	18,337	114,336	59,361	26,385	57,344	1,742	112
Acres Grassland/Herbaceous	42,682	262,360	161,367	81,785	40,922	30,733	97,448
Acres Pasture/Hay	0	0	0	24	507	171	651
Acres Cultivated Crops	3,171	20,750	32,899	184,869	87,253	29,744	49,531
Acres Woody Wetlands	17	71	222	126	51	0	0
Acres Emergent Herbaceous Wetlands	0	0	0	0	5	0	4
Total (Acres)	**66,301**	**404,873**	**267,507**	**311,883**	**200,362**	**67,402**	**200,034**

Table 1-5b Land Use Summaries by Watershed

Landuse Category	WQM Station						
	Wildhorse Creek	Washita River near Alex	Washington Creek	Kickapoo Sandy Creek	Washita River near Pauls Valley	Sand Branch	Washita River at US 177
Waterbody ID	**OK310810040140_00**	**OK310810020010_00**	**OK310810010190_00**	**OK310810010050_00**	**OK310810010010_10**	**OK310800020040_00**	**OK310800020010_00**
Percent of Open Water	3.70%	1.49%	3.80%	1.07%	2.75%	0.57%	1.48%
Percent of Developed, Open Space	4.79%	3.74%	4.01%	3.52%	4.39%	4.05%	3.41%
Percent of Developed, Low Intensity	1.06%	0.29%	0.23%	0.43%	0.63%	1.57%	1.08%
Percent of Developed, Medium Intensity	0.37%	0.09%	0.02%	0.00%	0.07%	0.19%	0.28%
Percent of Developed, High Intensity	0.18%	0.03%	0.00%	0.02%	0.01%	0.00%	0.11%
Percent of Barren Land (Rock/Sand/Clay)	0.00%	0.02%	0.00%	0.04%	0.02%	0.75%	0.11%
Percent of Deciduous Forest	20.21%	14.44%	21.21%	22.06%	16.49%	37.11%	25.61%
Percent of Evergreen Forest	0.00%	0.02%	0.00%	0.00%	0.03%	0.11%	0.84%
Percent of Mixed Forest	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Shrub/Scrub	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Grassland/Herbaceous	49.48%	57.90%	53.70%	53.50%	46.56%	39.92%	49.51%
Percent of Pasture/Hay	0.87%	6.20%	9.10%	13.74%	13.65%	14.60%	12.19%
Percent of Cultivated Crops	19.33%	15.78%	7.93%	5.61%	15.40%	1.12%	5.38%
Percent of Woody Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Emergent Herbaceous Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acres Open Water	1,045	4,770	500	82	4,344	59	4,211
Acres Developed, Open Space	1,352	11,983	527	268	6,942	420	9,742
Acres Developed, Low Intensity	300	937	30	32	999	163	3,090
Acres Developed, Medium Intensity	105	278	2	0	108	20	790

Landuse Category	WQM Station						
	Wildhorse Creek	Washita River near Alex	Washington Creek	Kickapoo Sandy Creek	Washita River near Pauls Valley	Sand Branch	Washita River at US 177
Waterbody ID	**OK310810040140_00**	**OK310810020010_00**	**OK310810010190_00**	**OK310810010050_00**	**OK310810010010_10**	**OK310800020040_00**	**OK310800020010_00**
Acres Developed, High Intensity	52	85	0	2	16	0	311
Acres Barren Land (Rock/Sand/Clay)	0	59	0	3	28	78	304
Acres Deciduous Forest	5,709	46,268	2,787	1,679	26,067	3,853	73,088
Acres Evergreen Forest	0	69	0	0	46	12	2,385
Acres Mixed Forest	0	0	0	0	0	0	0
Acres Shrub/Scrub	2	16	0	0	0	0	0
Acres Grassland/Herbaceous	13,976	185,533	7,056	4,071	73,583	4,144	141,289
Acres Pasture/Hay	246	19,863	1,196	1,046	21,579	1,516	34,784
Acres Cultivated Crops	5,460	50,556	1,042	427	24,341	117	15,352
Acres Woody Wetlands	0	0	0	0	0	0	0
Acres Emergent Herbaceous Wetlands	0	5	0	0	0	0	7
Total (Acres)	**28,247**	**320,422**	**13,140**	**7,610**	**158,054**	**10,381**	**285,352**

1.3 Stream Flow Conditions

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

SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code contains Oklahoma's water quality standards and implementation procedures (OWRB 2008). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state water quality standards, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.* [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2008). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegredation Policy is provided in Appendix D. Table 2-1a, 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
OK310840020020_00	Sandstone Creek	14.59	2016	3	X	X		N	X	N
OK310840020010_00	Washita River at Site #384	61.94	2016	3					X	N
OK310840010010_00	Washita River at SH 33, McLure	18.62	2016	3					X	N
OK310830030010_00	Washita River at SH 152, Cordell	49.32	2019	4					X	N
OK310830020060_10	Rainy Mountain Creek	32.33	2019	4					X	N
OK310830020020_00	Stinking Creek	18.36	2019	4	X	X		N	X	N
OK310830010010_00	Washita River at US 281, Anadarko	20.68	2016	3					X	N
OK310810040140_00	Wildhorse Creek	11.13	2016	3	X	X		N	X	N
OK310810020010_00	Washita River at SH 19, near Alex	63.16	2019	4	X		X	N	X	N
OK310810010190_00	Washington Creek	6.49	2016	3					X	N
OK310810010050_00	Kickapoo Sandy Creek	10.19	2019	4	X	X		N	X	N
OK310810010010_10	Washita River at SH 19, Pauls Valley	32.87	2016	3					X	N
OK310800020040_00	Sand Branch	6.24	2016	3					X	N
OK310800020010_00	Washita River at US 177, Durwood	32.87	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	SBCR	PPWS	Limitation
OK310840020020_00	Sandstone Creek	F	F	N	X	N		I	
OK310840020010_00	Washita River at Site #384	F	F	N	X	I		I	
OK310840010010_00	Washita River at SH 33, McLure	I	F	N	N	N		F	
OK310830030010_00	Washita River at SH 152, Cordell	I	F	N	F	N		F	
OK310830020060_10	Rainy Mountain Creek	F	N	N	X		F		
OK310830020020_00	Stinking Creek	F	N	N	X	N		I	
OK310830010010_00	Washita River at US 281, Anadarko	I	F	N	N	N		F	
OK310810040140_00	Wildhorse Creek	F	F	N	X	N		I	SWS
OK310810020010_00	Washita River at SH 19, near Alex	I	F	N	I	N		I	
OK310810010190_00	Washington Creek	F	F	N	X	I		I	SWS
OK310810010050_00	Kickapoo Sandy Creek	F	F	N	X	N		I	
OK310810010010_10	Washita River at SH 19, Pauls Valley	I	F	N	N	N		I	
OK310800020040_00	Sand Branch	F	F	N	X	N			
OK310800020010_00	Washita River at US 177, Durwood	I	F	N	N	N		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:

(i). Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;
(ii). Lakes: 25 NTU; and
(iii). Other surface waters: 50 NTUs.

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

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

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

To implement Oklahoma's WQS for Fish and Wildlife Propagation, promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 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 exceed the applicable screening level prescribed in this Subchapter.

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

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

2.2 Problem Identification

In this subsection water quality data summarizing waterbody impairments caused by elevated levels of bacteria are summarized 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 2004 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 exceedences 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 and secondary contact recreation seasons are provided in Appendix A. For the data collected between 2004 and 2009, evidence of nonsupport of the PBCR use based on fecal coliform and *E. coli* concentrations was only observed in Washita River at SH 19, near Alex (OK310810020010_00). Evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci exceedances was observed in four waterbodies: Sandstone Creek (OK310840020020_00), Stinking Creek (OK310830020020_00), Wildhorse Creek (OK310810040140_00), and Kickapoo Sandy Creek (OK310810020170_00).

2.2.2 Turbidity Data Summary

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

Table 2-3 summarizes water quality data collected from the WQM stations between 1998 and 2009 for turbidity. However, as stipulated in Title *785:45-5-12 (f) (7) (C)*, numeric criteria for turbidity only apply under base flow conditions. While the base flow condition is not specifically defined in the Oklahoma Water Quality Standards, 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 2009). 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 all 14 of the waterbodies listed in Table 2-1 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 1998 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. However, in rare instances, such as Washita River at SH 19, near Alex (OK310810020010_00), there is sufficient turbidity data to demonstrate nonsupport of the WWAC use but no TSS data. In these instances, a regression analysis using TSS data from an 8-digit USGS hydrologic unit code (HUC) that includes the Washita River at SH 19, near Alex (OK310810020010_00) can be used 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, 2004-2009

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (count/100 mL)	Number of samples exceeding single sample criterion	% samples exceeding single sample criterion
OK310840020020_00	Sandstone Creek	EC	10	192	3	30%
		ENT	10	199	7	70%
OK310830020020_00	Stinking Creek	EC	10	213	3	30%
		ENT	10	209	8	80%
OK310810040140_00	Wildhorse Creek	EC	10	374	4	40%
		ENT	10	430	9	90%
OK310810020010_00	Washita River at SH 19, near Alex	FC	20	336	9	45%
		EC	20	77	5	25%
		ENT	20	210	10	50%
OK310810010050_00	Kickapoo Sandy Creek	EC	10	342	4	40%
		ENT	10	281	9	90%

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

Table 2-3 Summary of All Turbidity Samples, 1998-2009

Waterbody ID	Waterbody Name	WQM Station	Number of Turbidity Samples	Number of Samples greater than 50 NTU	% Samples Exceeding Criterion	Average Turbidity (NTU)
OK310840020020_00	Sandstone Creek	OK310840-02-0020C	19	4	21%	47
OK310840020010_00	Washita River at Site #384	OK310840-02-0010G	19	5	26%	47
OK310840010010_00	Washita River at SH 33, McLure	310840010010-003RS	102	44	43%	107
OK310830030010_00	Washita River at SH 152, Cordell	310830030010-001AT	126	46	37%	96
OK310830020060_10	Rainy Mountain Creek	OK310830-02-0060G	20	11	55%	167
OK310830020020_00	Stinking Creek	OK310830-02-0020D	21	6	29%	57
OK310830010010_00	Washita River at US 281, Anadarko	310830010010-001AT	105	52	50%	177
OK310810040140_00	Wildhorse Creek	OK310810-04-0140D	20	10	50%	85
OK310810020010_00	Washita River at SH 19, near Alex	310810020010-001AT	50	27	54%	278
OK310810010190_00	Washington Creek	OK310810-01-0190G	13	7	54%	138
OK310810010050_00	Kickapoo Sandy Creek	OK310810-01-0050G	21	5	24%	66
OK310810010010_10	Washita River at SH 19, Pauls Valley	310810010010-001AT	114	84	74%	318
OK310800020040_00	Sand Branch	OK310800-02-0040C	20	5	25%	48
OK310800020010_00	Washita River at US 177, Durwood	310800020010-001AT	84	57	68%	330

Table 2-4 Summary of Turbidity Samples Collected During Base Flow Conditions, 1998-2009

Waterbody ID	Waterbody Name	WQM Station	Number of Turbidity Samples	Number of Samples greater than 50 NTU	% Samples Exceeding Criterion	Average Turbidity (NTU)
OK310840020020_00	Sandstone Creek	OK310840-02-0020C	18	3	17%	46
OK310840020010_00	Washita River at Site #384	OK310840-02-0010G	19	5	26%	47
OK310840010010_00	Washita River at SH 33, McLure	310840010010-003RS	55	10	18%	51
OK310830030010_00	Washita River at SH 152, Cordell	310830030010-001AT	85	25	29%	93
OK310830020060_10	Rainy Mountain Creek	OK310830-02-0060G	16	8	50%	195
OK310830020020_00	Stinking Creek	OK310830-02-0020D	20	5	25%	42
OK310830010010_00	Washita River at US 281, Anadarko	310830010010-001AT	72	20	28%	51
OK310810040140_00	Wildhorse Creek	OK310810-04-0140D	20	10	50%	85
OK310810020010_00	Washita River at SH 19, near Alex	310810020010-001AT	31	10	32%	104
OK310810010190_00	Washington Creek	OK310810-01-0190G	12	6	50%	137
OK310810010050_00	Kickapoo Sandy Creek	OK310810-01-0050G	17	3	18%	46
OK310810010010_10	Washita River at SH 19, Pauls Valley	310810010010-001AT	69	42	61%	108
OK310800020040_00	Sand Branch	OK310800-02-0040C	20	5	25%	48
OK310800020010_00	Washita River at US 177, Durwood	310800020010-001AT	52	26	50%	118

Table 2-5 Summary of All TSS Samples, 1998-2009

Waterbody ID	Waterbody Name	WQM Station	Number of TSS Samples	Average TSS (mg/L)
OK310840020020_00	Sandstone Creek	OK310840-02-0020C	20	49
OK310840020010_00	Washita River at Site #384	OK310840-02-0010G	23	36
OK310840010010_00	Washita River at SH 33, McLure	310840010010-003RS	35	174
OK310830030010_00	Washita River at SH 152, Cordell	310830030010-001AT	70	113
OK310830020060_10	Rainy Mountain Creek	OK310830-02-0060G	20	194
OK310830020020_00	Stinking Creek	OK310830-02-0020D	20	50
OK310830010010_00	Washita River at US 281, Anadarko	310830010010-001AT	18	360
OK310810040140_00	Wildhorse Creek	OK310810-04-0140D	20	61
OK310810020010_00	Washita River at SH 19, near Alex	310810020010-001AT	0	-
OK310810010190_00	Washington Creek	OK310810-01-0190G	12	110
OK310810010050_00	Kickapoo Sandy Creek	OK310810-01-0050G	20	72
OK310810010010_10	Washita River at SH 19, Pauls Valley	310810010010-001AT	21	516
OK310800020040_00	Sand Branch	OK310800-02-0040C	19	41
OK310800020010_00	Washita River at US 177, Durwood	310800020010-001AT	21	546

Table 2-6 Summary of TSS Samples During Base Flow Conditions 1998-2009

Waterbody ID	Waterbody Name	WQM Station	Number of TSS Samples	Average TSS (mg/L)
OK310840020020_00	Sandstone Creek	OK310840-02-0020C	19	49
OK310840020010_00	Washita River at Site #384	OK310840-02-0010G	23	36
OK310840010010_00	Washita River at SH 33, McLure	310840010010-003RS	16	49
OK310830030010_00	Washita River at SH 152, Cordell	310830030010-001AT	37	84
OK310830020060_10	Rainy Mountain Creek	OK310830-02-0060G	16	229
OK310830020020_00	Stinking Creek	OK310830-02-0020D	19	37
OK310830010010_00	Washita River at US 281, Anadarko	310830010010-001AT	10	81
OK310810040140_00	Wildhorse Creek	OK310810-04-0140D	20	61
OK310810020010_00	Washita River at SH 19, near Alex	310810020010-001AT	0	-
OK310810010190_00	Washington Creek	OK310810-01-0190G	11	104
OK310810010050_00	Kickapoo Sandy Creek	OK310810-01-0050G	16	44
OK310810010010_10	Washita River at SH 19, Pauls Valley	310810010010-001AT	13	134
OK310800020040_00	Sand Branch	OK310800-02-0040C	19	41
OK310800020010_00	Washita River at US 177, Durwood	310800020010-001AT	14	158

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. Pathogen indicator bacteria originate from the digestive tract of warm-blooded animals; some 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 pathogen 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. Where information was available on point and nonpoint sources of TSS originating in Texas (Washita River at Site #384, OK310840020010_00), data were provided and summarized as part of each category. These data were provided to demonstrate that some of the TSS loading outside of Oklahoma's jurisdiction may contribute to nonsupport of the WWAC use in Oklahoma. It is recognized that Oklahoma has no enforcement authority over TSS sources originating beyond the Oklahoma state boundary.

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 system (MS4) discharges;
- 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 Washington Creek (OK310810010190_00) and Kickapoo Sandy Creek (OK310810010050_00). The remaining twelve watersheds in the Study Area have at least one NPDES-permitted facility. There are no areas designated as MS4s within this Study Area.

3.1.1 Continuous Point Source Dischargers

The locations of the NPDES-permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed in Figures 3-1 and 3-2. For some continuous point source discharge facilities the permitted design flow was not available and therefore is not provided in Table 3-1. There are 16 NPDES facilities within the Study Area but they are not all sources of concern for indictor bacteria or TSS loading. For the purposes of the TMDLs calculated in Chapter 5, only the City of Lindsay's WWTP (OKG580021) in the Washita River at SH 19, near Alex (OK310810020010_00) watershed, is of concern for contributions of bacteria loads. The other municipal WWTP listed in Table 3-1 do discharge bacteria loads, but they are not discharging to a waterbody that requires a TMDL for bacteria. All of the facilities in Table 3-1 do discharge TSS and most have specific permit limits for TSS which are provided in Table 3-1. However, the municipal WWTPs designated with a Standard Industrial Code number 4952 or 4959 in Table 3-1 discharge organic TSS and therefore are not considered a potential source of turbidity within their respective watershed. There are seven active NPDES-permitted industrial facilities operating in the Study Area which are shown in Figures 3-1 and 3-2 and facility information is listed in Table 3-1.

Monthly Discharge Monitoring Reports (DMR) for fecal coliform analyses were not available for the City of Lindsay. Therefore it is not possible to provide an adequate evaluation on the performance of this municipal WWTP with respect to their compliance with fecal coliform permit limits over time. DMR data for TSS from the industrial facilities are provided in Appendix C. For the period January 1, 2006 through July 31, 2008 there were no permit violations for TSS reported.

Table 3-1 Point Source Discharges in the Study Area

OPDES Permit No.	Name	Receiving Water (Waterbody ID)	Facility Type	SIC Code	County	Design Flow (mgd)	Facility ID	Expiration Date	Max. FC cfu/100mL	Max./Avg. TSS mg/L
OK0031011	Clinton Public Works Authority	OK310830030010_00	Sewerage Systems	4952	Custer	1.70	S10804	12/31/2010	400/200	45/30
OK0032379	City of Cordell	OK310830030010_00	Sewerage Systems	4952	Washita	0.41	S10811	8/31/2010		135/90
OKG950036	Dolese Brothers Co.-Cooperton	OK310830020060_10	Crushed And Broken Stone	1429	Kiowa	0.54[1]	38000250	2/3/2013		45
OK0000639	Western Farmers Electric Co-Op Anadarko Station	OK310830010010_00	Electric Services	4911	Caddo	0.69[1]	08000030	11/30/2008		100/30
OK0028151	Anadarko Public Works Authority	OK310830010010_00	Sewerage Systems	4952	Caddo	1.94	S10817	2/28/2009		45/30
OK0000124	Oneok Field Services-Maysville	OK310810020010_00	Natural Gas Liquids -Stormwater Runoff	1321	Garvin	0.028[1]	25000230	6/30/2008		45
OKG580021	City of Lindsay	OK310810020010_00	Sewerage Systems	4952	Garvin	0.42	S10826	6/30/2011		135/90
OKG830039	Leonard's Sinclair	OK310810020010_00	Sanitary Services	4959	Garvin	0.079[1]	25000380	1/1/2008		N/A
OKG580024	Paoli Municipal Authority	OK310810010010_10	Sewerage Systems	4952	Garvin	0.08	S10828	6/30/2011		135/90
OK0001295	TPI Petroleum - Valero Ardmore Refinery	OK310800020010_00	Petroleum Refining	2911	Carter	1.62	10000590	10/31/09		123/84
OK0038440	City of Ardmore	OK310800020010_00	Sewerage Systems	4952	Carter	5.90	S30804	02/28/14		N/A
OK0038857	Semmaterials L.P.-Ardmore	OK310800020010_00	Asphalt Paving Mixtures and Blocks	2951	Carter	na	10000620	07/31/13		23/15
OK0044288	East Jordan Iron Works	OK310800020010_00	Iron Foundaries	3321	Carter	0.34[1]	10000900	04/30/12		45/30
OK0030422	City of Ardmore (Industrial Air Park)	OK310800020010_00	Sewerage Systems	4952	Carter	0.13	S10840	9/30/2011	400/200	45/30
OKG950033	Dolese Brothers Co.-Big Canyon	OK310800020010_00	Crushed And Broken Limestone	1422	Murray	2.0	50000150	2/3/2013		45
OKG380061	Anadarko Public Works Authority	OK310800020010_00	Water Supply	4941	Carter	0.96	W11103	1/31/2025		30/20

[1] Flow was derived by selecting highest reported monthly average flow from period 2003-2008.
NA = not available. DMR data do not have any flow measurements for this outfall.

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

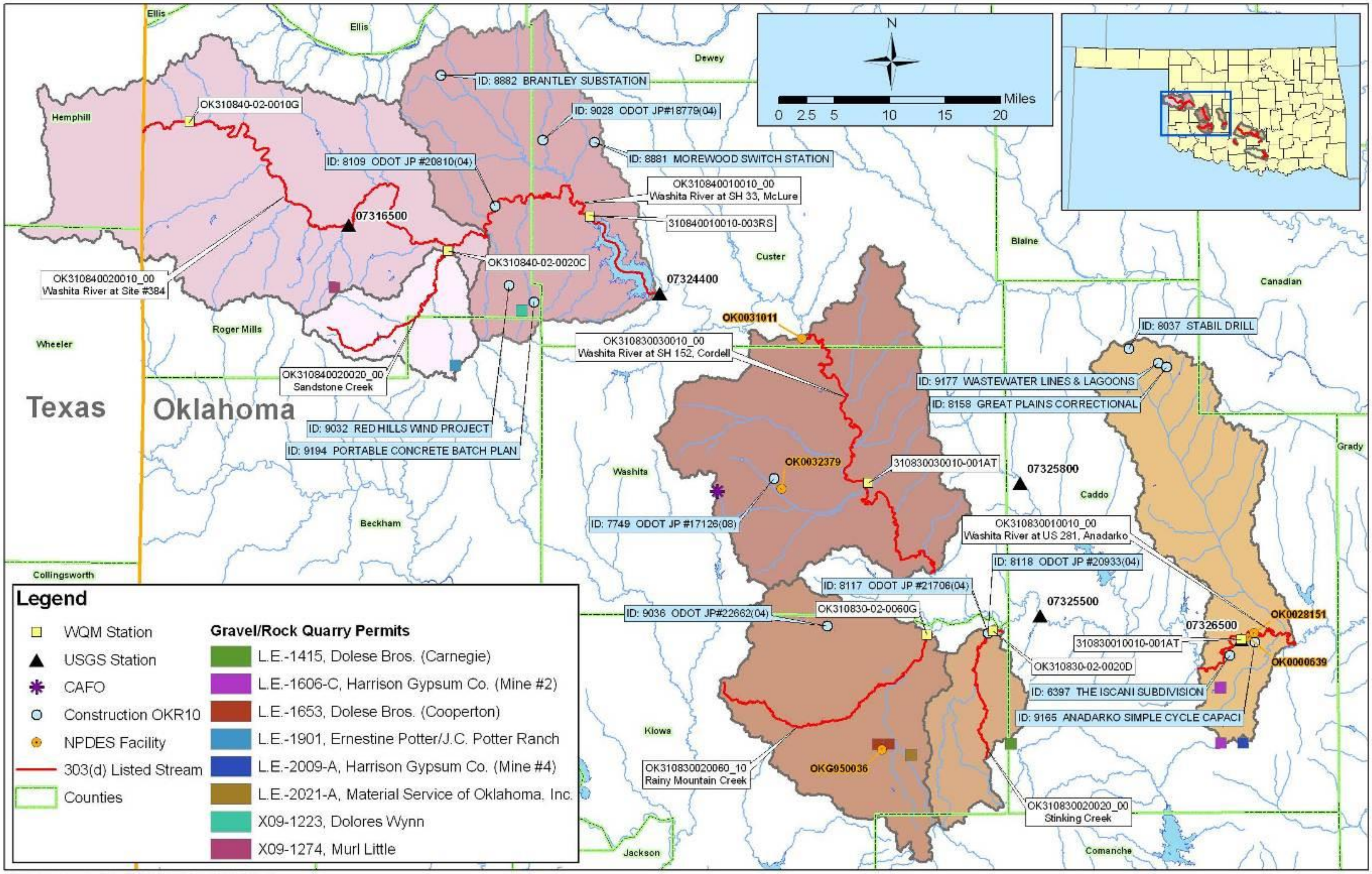
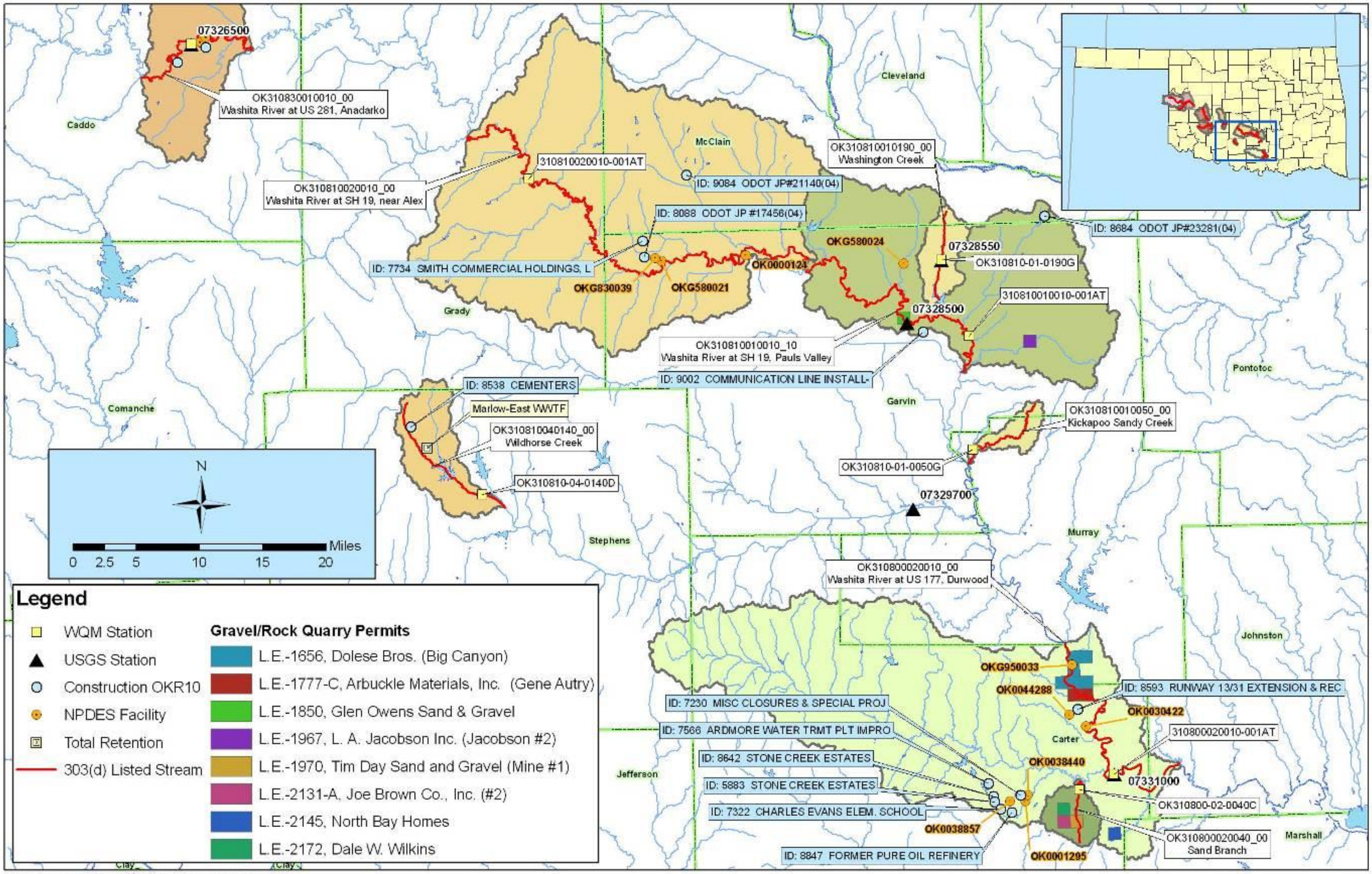


Figure 3-2 Locations of NPDES-Permitted Facilities in the Study Area



3.1.2 NPDES No-Discharge Facilities and Sanitary Sewer Overflows

For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute indicator bacteria or TSS loading. However, it is possible the wastewater collection systems associated with these no-discharge facilities could be a source of indicator bacteria loading, or that discharges from the wastewater plant may occur during large rainfall events that exceed the systems' storage capacities. The only no-discharge facility of concern that could be a source of indicator bacteria loading is the Marlow-East Wastewater Treatment Facility and its collection system, listed in Table 3-2, which is located in the Wildhorse Creek watershed.

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

Facility	Facility ID	County	Facility Type	Type	Waterbody ID and Waterbody Name
Marlow-East Wastewater Treatment Facility	10833	Stephens	Land Application	Municipal	OK310810040140_00, Wildhorse Creek

Sanitary sewer overflows (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacteria loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. The reporting of SSOs has been strongly encouraged by USEPA, primarily through enforcement and fines. While not all sewer overflows are reported, ODEQ has some data on SSOs available. SSOs were reported between 1992 and 2003 by the City of Lindsay which is located in the Washita River at SH 19, near Alex (OK310810020010_00) watershed. During that period 17 overflows were reported ranging from 0 to over 2.33 million gallons. Without more recent data it is not possible to quantify the spatial and temporal magnitude of indicator bacteria loading from SSOs in this watershed.

3.1.3 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 significant sources of pollution, and may have the potential to cause serious impacts to water quality if not managed properly (ODAFF 2009a).

Potential problems for CAFOs can include animal waste discharges to waters of the state and failure to properly operate wastewater lagoons. CAFOs are not considered a source of TSS loading. According to ODAFF, the CAFO located in the Washita River at SH 152, Cordell (OK310830030010_00) watershed has not been in operation since August 2008 and there were no reported historic performance problems at the facility. The location of the CAFO is shown in Figure 3-1 and is listed in Table 3-3.

Table 3-3 NPDES-Permitted CAFOs in Study Area

ODAFF Owner ID	EPA Facility	ODAFF ID	ODAFF License Number	Maximum Number of Swine Permitted at Facility	Total # of Animal Units at Facility	County	Waterbody ID and Waterbody Name
AGN021637	OKG010219	74	1155	3994	999	WASHITA	OK310830030010_00, Washita River at SH 152, Cordell

3.1.4 Stormwater Permits Construction Activities

A general stormwater permit (OKR10) is required for any stormwater discharges associated with construction activities that result in land disturbance of equal to or greater than one (1) acre, or less than one (1) acre if they are part of a larger common plan of development or sale that totals at least one (1) acre. The permit also authorizes any stormwater discharges from support activities (e.g. concrete or asphalt batch plants, equipment staging yards, material storage areas, excavated material disposal areas, and borrow areas) that are directly related to a construction site that is required to have permit coverage, and is not a commercial operation serving unrelated different sites (ODEQ 2007). Stormwater discharges occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply and are not considered potential contributors to turbidity impairment. The construction permits are summarized in Table 3-4.

3.1.5 Rock, Sand and Gravel Quarries

Operators of rock, sand and gravel quarries in Oklahoma are regulated with a general permit (OKG950000). The general permit does not allow discharge of wastewater to waterbodies included in Oklahoma’s 303(d) List of impaired water bodies listed for turbidity for which a TMDL has not been performed or the result of the TMDL indicates that discharge limits more stringent than 45 mg/l for TSS are required (ODEQ 2009). Table 3-5 summarizes data from the Oklahoma Department of Mines and provides the permitted mining acres for each of the quarries located within the Study Area. The locations of these quarries are shown in Figure 3-1.

3.1.6 Section 404 permits

Section 404 of the Clean Water Act (CWA) establishes a program 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 3-4 Construction Permits Summary

Company Name	County	Permit ID	Date Issued	Receiving Water	Receiving Water (Permit)	Estimated Acres
Brantley Substation	Roger Mills	8882	3/14/2008	OK310840010010_00	Unnamed Tributary to Quartermaster Creek	3
Oklahoma Department of Transportation JP #20810(04)	Roger Mills	8109	10/2/2007	OK310840010010_00	Washita River	5
Red Hills Wind Project	Roger Mills	9032	5/23/2008	OK310840010010_00	Big Kiowa Creek, Little Kiowa Creek, White Shield Creek, Panther Creek	20
Portable Concrete Batch Plan	Roger Mills	9194		OK310840010010_00	Unnamed Tributary to White Shield Creek, to White Shield Creek, to Washita River	3
Oklahoma Department of Transportation JP #18779(04)	Custer/Dewey	9028	5/23/2008	OK310840010010_00	North Branch of Quartermaster Creek	166
Morewood Switch Station	Custer	8881	3/14/2008	OK310840010010_00	Unnamed Tributary to Wild Horse Creek	3
Oklahoma Department of Transportation JP #17126(08)	Washita	7749	10/2/2007	OK310830030010_00	North Calvary Creek via Unnamed Tributary	33
Oklahoma Department of Transportation Jp#22662(04)	Kiowa	9036	5/23/2008	OK310830020060_10	Unnamed Tributary of Rainy Mountain Creek	1.97
Oklahoma Department of Transportation JP #21706(04)	Kiowa	8117	10/2/2007	OK310830020020_00	Rainy Mountain Creek	5
Oklahoma Department of Transportation JP #20933(04)	Kiowa	8118	10/2/2007	OK310830020020_00	Stinking Creek	4
Stabil Drill	Oklahoma	8037	12/27/2007	OK310830010010_00	Unnamed Tributary of Mustang Creek	2
Wastewater Lines & Lagoons	Caddo	9177		OK310830010010_00	Sugar Creek	45
Great Plains Correctional	Caddo	8158	12/26/2007	OK310830010010_00	Unnamed Tributary of Sugar Creek	10
The Iscani Subdivision	Caddo	6397	3/13/2008	OK310830010010_00	Washita River	30
Anadarko Simple Cycle Capaci	Caddo	9165	6/11/2008	OK310830010010_00	Washita River	18
Cementers	Stephens	8538	3/31/2008	OK310810040140_00	Wildhorse Creek	3
Smith Commercial Holdings, L	Garvin	7734	12/27/2007	OK310810020010_00	Hybarger Creek	2
Oklahoma Department of Transportation JP #17456(04)	Garvin	8088	12/18/2007	OK310810020010_00	Hybarger Creek	3

Company Name	County	Permit ID	Date Issued	Receiving Water	Receiving Water (Permit)	Estimated Acres
Oklahoma Department of Transportation JP #21140(04)	McClain	9084	6/11/2008	OK310810020010_00	Criner Creek	4
Communication Line Install-	Garvin	9002		OK310810010010_10	Washita River and North Canadian River	20.6
Oklahoma Department of Transportation JP#23281(04)	McClain	8684	1/8/2008	OK310810010010_10	Byars Lake	4
Ardmore Water Treatment Plant Improvement	Carter	7566	12/26/2007	OK310800020010_00	City Lake	5
Stone Creek Estates	Carter	8642	1/18/2008	OK310800020010_00	Unnamed Tributary of Bullhead Creek	20
Stone Creek Estates	Carter	5883		OK310800020010_00	Caddo Creek Tributary	10
Charles Evans Elementary School	Carter	7322	10/20/2007	OK310800020010_00	Sand Creek	5
Former Pure Oil Refinery	Carter	8847		OK310800020010_00	Unnamed Tributary of Sand Creek	2
Misc Closures & Special Proj	Carter	7230	2/20/2008	OK310800020010_00	Unnamed Tributary of Sand Creek	18
Runway 13/31 Extension & Rec	Carter	8593	3/24/2008	OK310800020010_00	Washita River	145

Table 3-5 Rock, Sand and Gravel Quarries

Company Name	County	Permit ID	Product	Permitted Acres	Permit Issue Date	Permit Renewal Date	Mining Expiration Date	Waterbody ID
Ernestine Potter/J.C. Potter Ranch	Beckham	L.E.-1901	Sand	80	2/1/2002	1/31/2009	1-31-2012	OK310840020020_00
Murl Little	Roger Mills	X09-1274	Red Shale	3	6/1/2008	N/A	5-31-2009	OK310840020020_00
Murl Little	Roger Mills	X09-1274	Red Shale	3	6/1/2008	N/A	5-31-2009	OK310840020010_00
Dolores Wynn	Roger Mills	X09-1223	Red Shale	3	1/5/2008	N/A	1-4-2009	OK310840010010_00
Material Service of Oklahoma, Inc. (Longhorn Mountain Facility)	Kiowa	L.E.-2021-A	Limestone	370	12/1/2005	11/30/2007	Life of Mine	OK310830020060_10
Dolese Bros. (Carnegie)	Caddo	L.E.-1415	Limestone	62	8/1/1995	7/31/2008	7-31-2020	OK310830020020_00
Harrison Gypsum Co. (Mine #2)	Caddo	L.E.-1606-C	Gypsum	383	7/1/1997	6/30/2009	Life of Mine	OK310830010010_00
Harrison Gypsum Co. (Mine #4)	Caddo	L.E.-2009-A	Gypsum	298	1/1/2004	12/31/2008	Life of Mine	OK310830010010_00
Harrison Gypsum Co. (Mine #2)	Caddo	L.E.-1606-C	Gypsum	383	7/1/1997	6/30/2009	Life of Mine	OK310830010010_00
Glen Owens Sand & Gravel	Garvin	L.E.-1850	Sand & Gravel	10	2/1/1999	1/31/2009	1-31-2019	OK310810010010_10
L. A. Jacobson Inc. (Jacobson #2)	Garvin	L.E.-1967	Sand & Gravel	5	3/1/2003	2/28/2009	2-28-2014	OK310810010010_10
Dale W. Wilkins	Carter	L.E.-2172	Sand & Topsoil	22	10/1/2006	9/30/2008	9-30-2031	OK310800020040_00
Joe Brown Co., Inc. (#2)	Carter	L.E.-2131-A	Sand & Gravel	24	7/1/2004	6/30/2009	Life of Mine	OK310800020040_00
Tim Day Sand and Gravel (Mine #1)	Carter	L.E.-1970	Sand & Gravel	40	4/1/2003	3/31/2004	3-31-2013	OK310800020040_00
North Bay Homes	Carter	L.E.-2145	Clay	8	4/1/2006	3/31/2009	3-31-2011	OK310800020010_00
Arbuckle Materials, Inc. (Gene Autry)	Carter	L.E.-1777-C	Sand	230	6/21/2004	3/31/2009	3-31-2020	OK310800020010_00
Arbuckle Materials, Inc. (Gene Autry)	Carter	L.E.-1777-C	Sand	230	6/21/2004	3/31/2009	3-31-2020	OK310800020010_00
Arbuckle Materials, Inc. (Gene Autry)	Carter	L.E.-1777-C	Sand	230	6/21/2004	3/31/2009	3-31-2020	OK310800020010_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 of wildlife and avian species by watershed. Consequently it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

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

According to a study conducted by the American Society of Agricultural Engineers (ASAE), deer release approximately $5x10^8$ fecal coliform units per animal per day (ASAE 1999).

Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production based on the estimated deer population provided in Table 3-6 in cfu/day provides a relative magnitude of loading in each watershed.

Table 3-6 Estimated Population and Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 10^8 cfu/day) of Deer Population
OK310840020020_00	Sandstone Creek	66,301	432	0.007	216
OK310840020010_00	Washita River at Site #384	404,873	2,395	0.006	1,197
OK310840010010_00	Washita River at SH 33, McLure	267,507	1,725	0.006	863
OK310830030010_00	Washita River at SH 152, Cordell	311,883	1,292	0.004	646
OK310830020060_10	Rainy Mountain Creek	200,362	539	0.003	269
OK310830020020_00	Stinking Creek	67,402	209	0.003	105
OK310830010010_00	Washita River at US 281, Anadarko	200,034	1,919	0.010	960
OK310810040140_00	Wildhorse Creek	28,247	152	0.005	76
OK310810020010_00	Washita River at SH 19, near Alex	320,422	1,711	0.005	855
OK310810010190_00	Washington Creek	13,140	70	0.005	35
OK310810010050_00	Kickapoo Sandy Creek	7,610	58	0.008	29
OK310810010010_10	Washita River at SH 19, Pauls Valley	158,054	845	0.005	423
OK310800020040_00	Sand Branch	10,381	77	0.007	38
OK310800020010_00	Washita River at US 177, Durwood	285,352	2,134	0.007	1,067

3.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

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

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

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

Animal often have direct access to waterbodies and can provide a concentrated source of fecal bacteria loading directly into streams or can cause unstable stream banks which can contribute TSS.

Table 3-7 provides estimated numbers of selected livestock by watershed based on the 2002 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2002).

The estimated commercially raised farm animal populations in Table 3-7 were derived by using the percentage of the watershed within each county. Because the watersheds are generally much smaller than the counties, and commercially raised farm animals are not evenly distributed across counties or constant with time, these are rough estimates only. Cattle are clearly the most abundant species of commercially raised farm animals in the Study Area and often have direct access to the impaired waterbodies or their tributaries.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application of manure from commercially raised farm animal. Nor is sufficient information available to describe or quantify the contributions of sediment loading caused by commercially raised farm animal responsible for destabilizing stream banks or erosion in pasture fields. The estimated acreage by watershed where manure was applied in 2002 is shown in Table 3-7. These estimates are also based on the county level reports from the 2002 USDA county agricultural census, and thus, represent approximations of the commercially raised farm animal populations in each watershed. Despite the lack of specific data, for the purpose of these TMDLs, land application of commercially raised farm animal manure is considered a potential source of bacteria loading to the watersheds in the Study Area.

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

Beef cattle release approximately 1.04E+11 fecal coliform counts per animal per day;

Dairy cattle release approximately 1.01E+11 per animal per day

Swine release approximately 1.08E+10 per animal per day

Chickens release approximately 1.36E+08 per animal per day

Sheep release approximately 1.20E+10 per animal per day

Horses release approximately 4.20E+08 per animal per day;

Turkey release approximately 9.30E+07 per animal per day

Ducks release approximately 2.43E+09 per animal per day

Geese release approximately 4.90E+10 per animal per day

Using the estimated animal populations and the fecal coliform production rates from ASAE, an estimate of fecal coliform production from each group of commercially raised farm animal was calculated in each watershed of the Study Area in Table 3-8. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into streams by runoff or by direct deposition from wading animals. Cattle again appear to represent the most likely commercially raised farm animal source of fecal bacteria.

Table 3-7 Livestock and Manure Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves	Dairy Cows	Horses & Ponies	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Acres of Manure Application
OK310840020020_00	Sandstone Creek	6,161	62	127	20	31	0	43	28
OK310840020010_00	Washita River at Site #384	39,221	342	636	8	138	0	231	13
OK310840010010_00	Washita River at SH 33, McLure	26,759	259	467	289	66	21	191	515
OK310830030010_00	Washita River at SH 152, Cordell	48,383	174	331	342	0	7	168	1,002
OK310830020060_10	Rainy Mountain Creek	22,158	43	216	651	111	2	43	886
OK310830020020_00	Stinking Creek	7,489	11	78	224	178	1	14	305
OK310830010010_00	Washita River at US 281, Anadarko	32,566	83	502	335	5,745	31	185	692
OK310810040140_00	Wildhorse Creek	3,865	34	115	40	46	21	102	29
OK310810020010_00	Washita River at SH 19, near Alex	50,092	4,184	1,870	1,586	5,690	139	1,056	1,815
OK310810010190_00	Washington Creek	1,922	21	86	38	37	11	15	73
OK310810010050_00	Kickapoo Sandy Creek	914	46	31	13	9	1	3	43
OK310810010010_10	Washita River at SH 19, Pauls Valley	23,228	274	1,060	488	565	122	233	907
OK310800020040_00	Sand Branch	1,147	2	45	16	13	15	40	23
OK310800020010_00	Washita River at US 177, Durwood	31,754	243	1,209	430	339	353	1,007	687

Table 3-8 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
OK310840020020_00	Sandstone Creek	640,779	6,287	53	N/A	240	333	0	5	647,697
OK310840020010_00	Washita River at Site #384	4,078,946	34,494	267	N/A	90	1,492	4	26	4,115,319
OK310840010010_00	Washita River at SH 33, McLure	2,782,965	26,136	196	N/A	3,467	711	540	22	2,814,036
OK310830030010_00	Washita River at SH 152, Cordell	5,031,796	17,592	139	N/A	4,098	0	180	19	5,053,825
OK310830020060_10	Rainy Mountain Creek	2,304,464	4,356	91	N/A	7,807	1,200	64	5	2,317,987
OK310830020020_00	Stinking Creek	778,900	1,145	33	N/A	2,683	1,925	32	2	784,718
OK310830010010_00	Washita River at US 281, Anadarko	3,386,858	8,424	211	N/A	4,022	62,047	793	21	3,462,377
OK310810040140_00	Wildhorse Creek	401,922	3,472	49	N/A	481	500	537	12	406,971
OK310810020010_00	Washita River at SH 19, near Alex	5,209,527	422,565	786	N/A	19,028	61,453	3,562	121	5,717,042
OK310810010190_00	Washington Creek	199,894	2,083	36	N/A	453	400	272	2	203,139
OK310810010050_00	Kickapoo Sandy Creek	95,035	4,603	13	N/A	152	97	37	0	99,938
OK310810010010_10	Washita River at SH 19, Pauls Valley	2,415,708	27,682	445	N/A	5,861	6,103	3,134	27	2,458,959
OK310800020040_00	Sand Branch	119,330	241	19	N/A	188	138	374	5	120,294
OK310800020010_00	Washita River at US 177, Durwood	3,302,424	24,552	508	N/A	5,155	3,659	9,065	115	3,345,478

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

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

To estimate the potential magnitude of OSWDs fecal bacteria loading, the number of OSWD systems was estimated for each watershed. The estimate of OSWD systems was derived by using data from the 1990 U.S. Census (U.S. Census Bureau 2000). The density of OSWD systems within each watershed was estimated by dividing the number of OSWD systems in each census block by the number of acres in each census block. This density was then applied to the number of acres of each census block within a WQM station watershed. Census blocks crossing a watershed boundary required additional calculation to estimate the number of OSWD systems based on the proportion of the census tracking falling within each watershed. This step involved adding all OSWD systems for each whole or partial census block.

Over time, most OSWD systems operating at full capacity will fail. OSWD system failures are proportional to the adequacy of a state’s minimum design criteria (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSWD systems experience malfunctions during the year (U.S. Census Bureau 1995). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSWD systems in east Texas and 8 percent in the Texas Panhandle were chronically malfunctioning. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSWD systems per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1986). Table 3-9 summarizes estimates of sewered and unsewered households for each watershed in the Study Area.

Table 3-9 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK310840020020_00	Sandstone Creek	423	226	6	655	65%
OK310840020010_00	Washita River at Site #384	475	591	4	1070	44%
OK310840010010_00	Washita River at SH 33, McLure	774	523	2	1299	60%
OK310830030010_00	Washita River at SH 152, Cordell	3287	1009	55	4351	76%
OK310830020060_10	Rainy Mountain Creek	1475	337	54	1866	79%
OK310830020020_00	Stinking Creek	298	135	24	457	65%
OK310830010010_00	Washita River at US 281, Anadarko	3149	1488	21	4658	68%
OK310810040140_00	Wildhorse Creek	214	330	5	549	39%
OK310810020010_00	Washita River at SH 19, near Alex	2356	2916	93	5365	44%
OK310810010190_00	Washington Creek	41	105	5	151	27%
OK310810010050_00	Kickapoo Sandy Creek	138	59	1	198	70%
OK310810010010_10	Washita River at SH 19, Pauls Valley	1997	1316	51	3364	59%
OK310800020040_00	Sand Branch	101	239	2	342	30%
OK310800020010_00	Washita River at US 177, Durwood	3841	2376	71	6288	61%

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 8 percent was used for Sandstone Creek (OK310840020020_00), Washita River at Site #384 (OK310840020010_00), Washita River at SH 33, McLure (OK310840010010_00), Washita River at SH 152, Cordell (OK310830030010_00), Rainy Mountain Creek (OK310830020060_10), Stinking Creek (OK310830020020_00), Washita River at US 281, Anadarko (OK310830010010_00). The failure rate of 12 percent was used for Wildhorse Creek (OK310810040140_00), Washita River at SH 19, near Alex (OK310810020010_00), Washington Creek (OK310810020200_00), Kickapoo Sandy Creek (OK310810020170_00), Washita River at SH 19, Pauls Valley (OK310810010010_10), Sand Branch (OK310800020040_00), and Washita River at US 177, Durwood (OK310800020010_00). Using both 8 and 12 percent failure rates, calculations were made to characterize fecal coliform loads in each watershed.

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

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

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

Table 3-10 Estimated Fecal Coliform Load from OSWD Systems

Waterbody ID	Waterbody Name	Acres	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day)
OK310840020020_00	Sandstone Creek	66,301	226	18	124
OK310840020010_00	Washita River at Site #384	404,873	591	47	323
OK310840010010_00	Washita River at SH 33, McLure	267,507	523	42	286
OK310830030010_00	Washita River at SH 152, Cordell	311,883	1009	81	552
OK310830020060_10	Rainy Mountain Creek	200,362	337	27	184
OK310830020020_00	Stinking Creek	67,402	135	11	74
OK310830010010_00	Washita River at US 281, Anadarko	200,034	1488	119	814
OK310810040140_00	Wildhorse Creek	28,247	330	40	271
OK310810020010_00	Washita River at SH 19, near Alex	320,422	2916	350	2,392
OK310810010190_00	Washington Creek	13,140	105	13	86
OK310810010050_00	Kickapoo Sandy Creek	7,610	59	7	48
OK310810010010_10	Washita River at SH 19, Pauls Valley	158,054	1316	158	1,080
OK310800020040_00	Sand Branch	10,381	239	29	196
OK310800020010_00	Washita River at US 177, Durwood	285,352	2376	285	1,949

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 3-11 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-11 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK310840020020_00	Sandstone Creek	148	167
OK310840020010_00	Washita River at Site #384	474	535
OK310840010010_00	Washita River at SH 33, McLure	425	480
OK310830030010_00	Washita River at SH 152, Cordell	1780	2008
OK310830020060_10	Rainy Mountain Creek	667	752
OK310830020020_00	Stinking Creek	82	92
OK310830010010_00	Washita River at US 281, Anadarko	3004	3389
OK310810040140_00	Wildhorse Creek	814	918
OK310810020010_00	Washita River at SH 19, near Alex	2904	3276
OK310810010190_00	Washington Creek	71	80
OK310810010050_00	Kickapoo Sandy Creek	83	93
OK310810010010_10	Washita River at SH 19, Pauls Valley	1641	1852
OK310800020040_00	Sand Branch	313	353
OK310800020010_00	Washita River at US 177, Durwood	3495	3943

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

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

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK310840020020_00	Sandstone Creek	489	90	579
OK310840020010_00	Washita River at Site #384	1,564	289	1,853
OK310840010010_00	Washita River at SH 33, McLure	1,403	259	1,662
OK310830030010_00	Washita River at SH 152, Cordell	5,873	1,084	6,957
OK310830020060_10	Rainy Mountain Creek	2,201	406	2,607
OK310830020020_00	Stinking Creek	269	50	319
OK310830010010_00	Washita River at US 281, Anadarko	9,914	1,830	11,744
OK310810040140_00	Wildhorse Creek	2,685	496	3,181
OK310810020010_00	Washita River at SH 19, near Alex	9,582	1,769	11,351
OK310810010190_00	Washington Creek	234	43	278
OK310810010050_00	Kickapoo Sandy Creek	273	50	323
OK310810010010_10	Washita River at SH 19, Pauls Valley	5,417	1,000	6,417
OK310800020040_00	Sand Branch	1,034	191	1,224
OK310800020010_00	Washita River at US 177, Durwood	11,535	2,129	13,665

3.3 Summary of Bacteria Sources

There are no continuous, permitted point sources of bacteria in the Sandstone Creek, Stinking Creek, Wildhorse Creek, and Kickapoo Sandy Creek watersheds which require bacteria TMDLs; therefore, nonsupport of PBCR use in these watersheds is caused by nonpoint sources of bacteria only. The Wahsita River at SH 19, near Alex watershed has one continuous point sources discharge which does contribute bacteria, but the available data suggests that the proportion of bacteria from point sources is minor. Therefore the various nonpoint sources are considered to be the major source of bacteria loading in each watershed that requires a bacteria TMDL.

Table 3-13 below provides a summary of the estimated fecal coliform loads in cfu/day for the four major nonpoint source categories (commercially raised farm animals, pets, deer, and septic tanks) that contribute to the elevated bacteria concentrations in each watershed. Livestock are estimated to be the largest contributors of fecal coliform loading to land surfaces. It must be noted that while no data are available to estimate populations and fecal loading of wildlife other than deer, a number of bacteria source tracking studies around the nation demonstrate that wild birds and mammals represent a major source of the fecal bacteria found in streams.

Table 3-13 Summary of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces (x10^9 counts/day)

Waterbody ID	Waterbody Name	All Commercially Raised Farm Animals	Pets	Deer	Estimated Loads from Septic Tanks
OK310840020020_00	Sandstone Creek	647,697	579	216	124
OK310840020010_00	Washita River at Site #384	4,115,319	1,853	1,197	323
OK310840010010_00	Washita River at SH 33, McLure	2,814,036	1,662	863	286
OK310830030010_00	Washita River at SH 152, Cordell	5,053,825	6,957	646	552
OK310830020060_10	Rainy Mountain Creek	2,317,987	2,607	269	184
OK310830020020_00	Stinking Creek	784,718	319	105	74
OK310830010010_00	Washita River at US 281, Anadarko	3,462,377	11,744	960	814
OK310810040140_00	Wildhorse Creek	406,971	3,181	76	271
OK310810020010_00	Washita River at SH 19, near Alex	5,717,042	11,351	855	2,392
OK310810010190_00	Washington Creek	203,139	278	35	86
OK310810010050_00	Kickapoo Sandy Creek	99,938	323	29	48
OK310810010010_10	Washita River at SH 19, Pauls Valley	2,458,959	6,417	422	1,080
OK310800020040_00	Sand Branch	120,294	1,224	38	196
OK310800020010_00	Washita River at US 177, Durwood	3,345,478	13,665	1,067	1,949

The magnitude of loading to a stream may not reflect the magnitude of loading to land surfaces. While no studies have quantified these effects, bacteria may die off or survive at different rates depending on the manure characteristics and a number of other environmental conditions. Also, the structural properties of some manure, such as cow patties, may limit their washoff into streams by runoff. In contrast, malfunctioning septic tank effluent may be present in standing water on the surface, or in shallow groundwater, which may enhance its conveyance to streams.

Of the 14 watersheds in the Study Area that require tubidity TMDLs, only two of them, Washington Creek (OK310810020200_00) and Kickapoo Sandy Creek (OK310810020170_00), have no permitted sources of TSS; therefore, nonsupport of WWAC use in these two watersheds is associated with nonpoint sources of TSS only. The other 12 watersheds have some permitted activity (industrial, contruction, or mining) that contributes some TSS loading as well as a variety of activities causing nonpoint sources of sediment loading. 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.

SECTION 4
TECHNICAL APPROACH AND METHODS

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

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

The WLA is the portion of the TMDL allocated to existing and future point sources. The LA is the portion of the TMDL allocated to nonpoint sources, including natural background sources. The MOS is intended to ensure that WQSs will be met. 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 1998 to 2008 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 *m*1 is the slope of the LOC line, *m* is the TSS on turbidity OLS slope, *m'* is the turbidity on TSS OLS slope, *r* is the TSS-turbidity correlation coefficient, s_y is the standard deviation of the TSS measurements, and s_x is the standard deviation of the turbidity measurements.

The intercept of the LOC (*b*1) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). The correlation between TSS and turbidity, along with the LOC and the OLS lines are shown in Figures 4-1 through Figure 4-13. It is noted that waterbodies OK310830010010_00 and OK310810020010_00 did not have enough turbidity-TSS paired data (a minimum of 10 points is required for the regression), so data from alternative areas were used. For waterbody OK310830010010_00, data collected within the 8-digit watershed (OK31083001) were used to develop a regression. For waterbody OK310810020010_00, the regression developed for the downstream reach (OK310810010010_00) was used in lieu of the regression from the 8-digit watershed; because downstream data are expected to be more representative of the concentrations in the reach of concern.

Figure 4-1 Linear Regression for TSS-Turbidity for Sandstone Creek (OK310840020020_00)

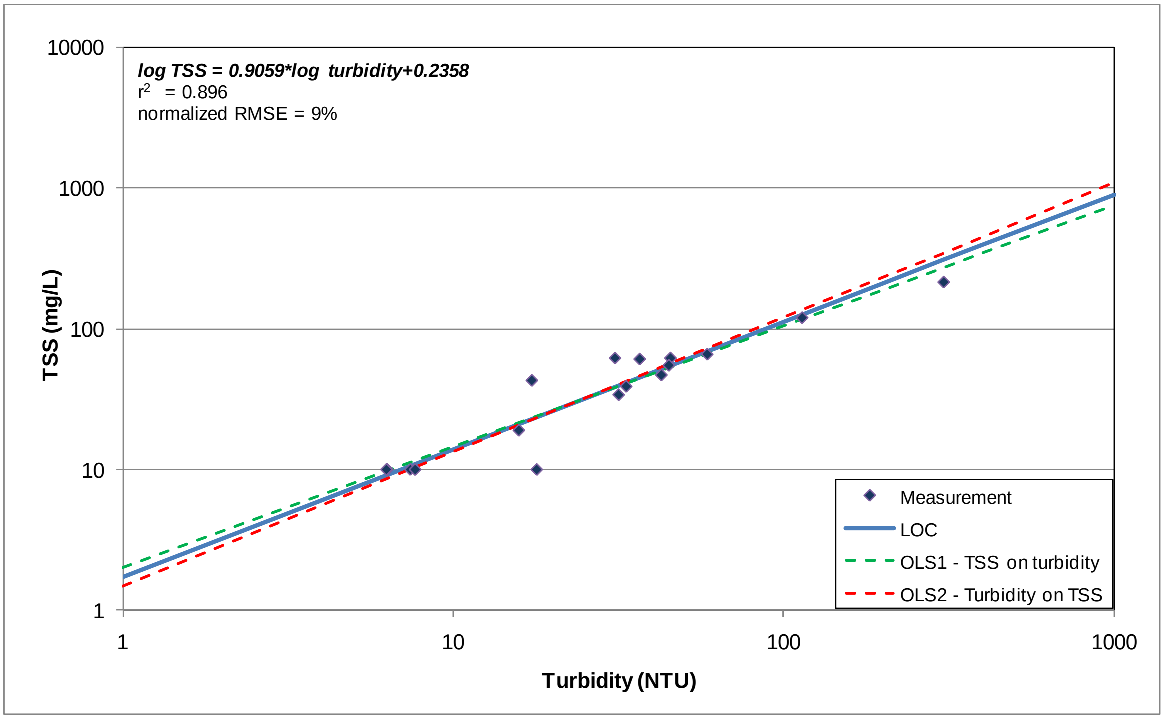


Figure 4-2 Linear Regression for TSS-Turbidity for Washita River at Site #384 (OK310840020010_00)

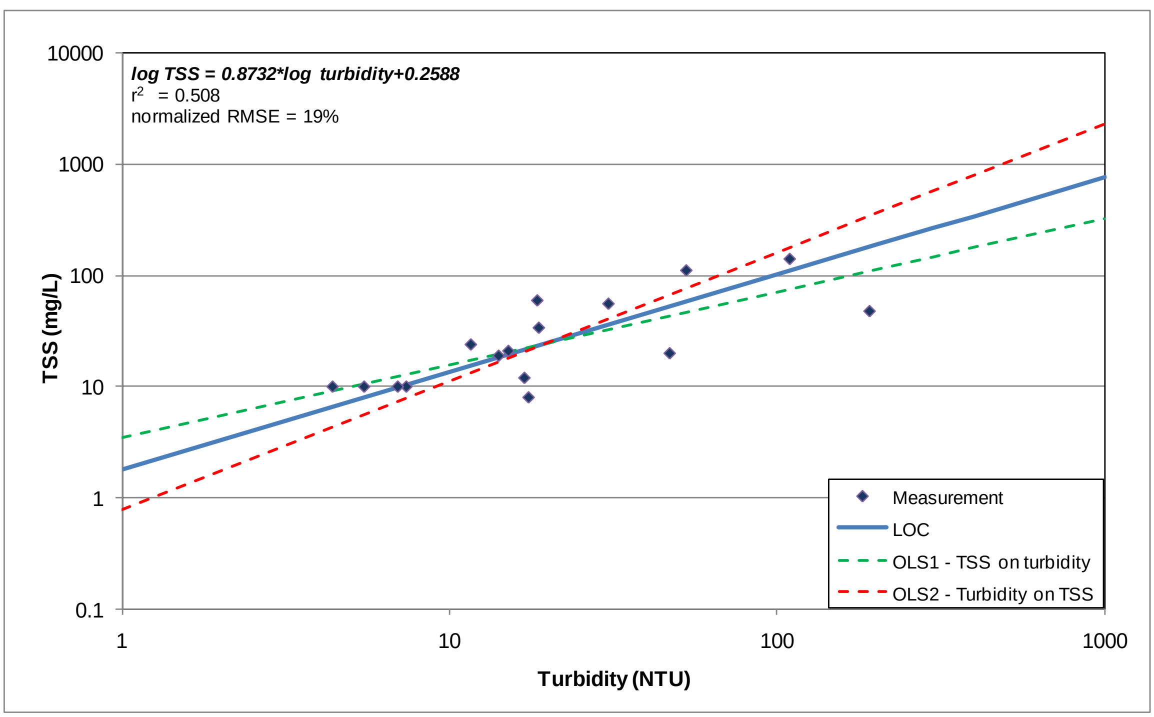


Figure 4-3 Linear Regression for TSS-Turbidity for Washita River at SH 33, McLure (OK310840010010_00)

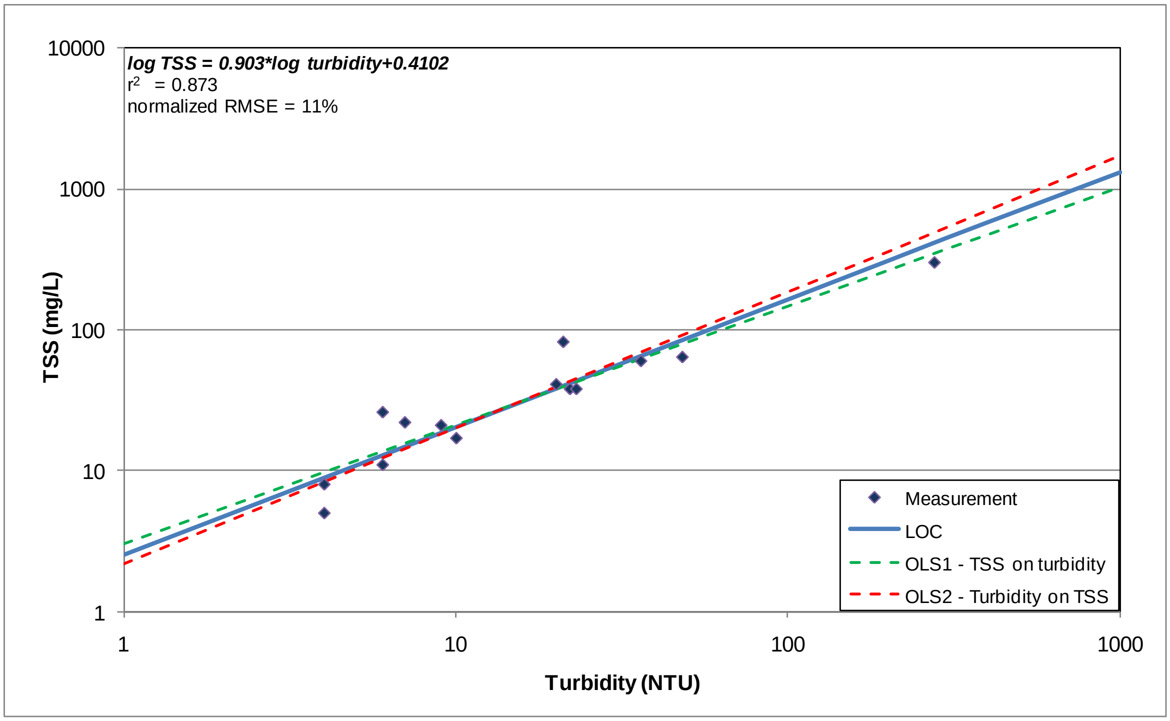


Figure 4-4 Linear Regression for TSS-Turbidity for Washita River at SH 152, Cordell (OK310830030010_00)

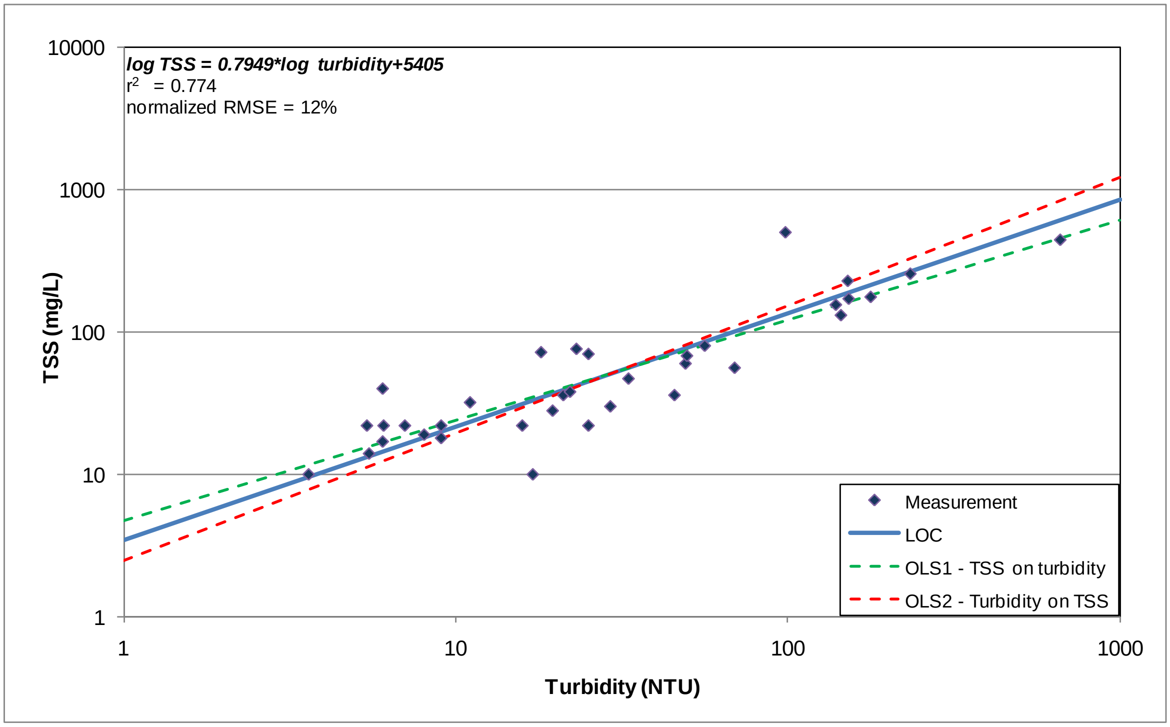


Figure 4-5 Linear Regression for TSS-Turbidity for Rainy Mountain Creek (OK310830020060_10)

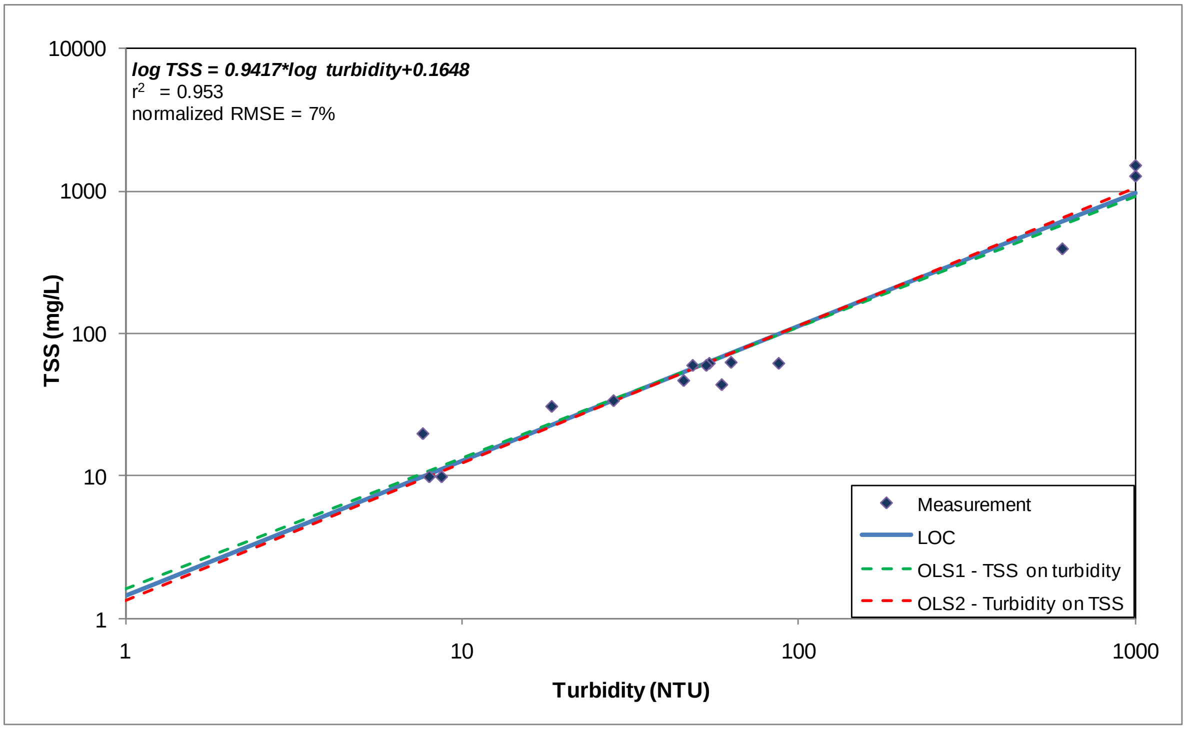


Figure 4-6 Linear Regression for TSS-Turbidity for Stinking Creek (OK310830020020_00)

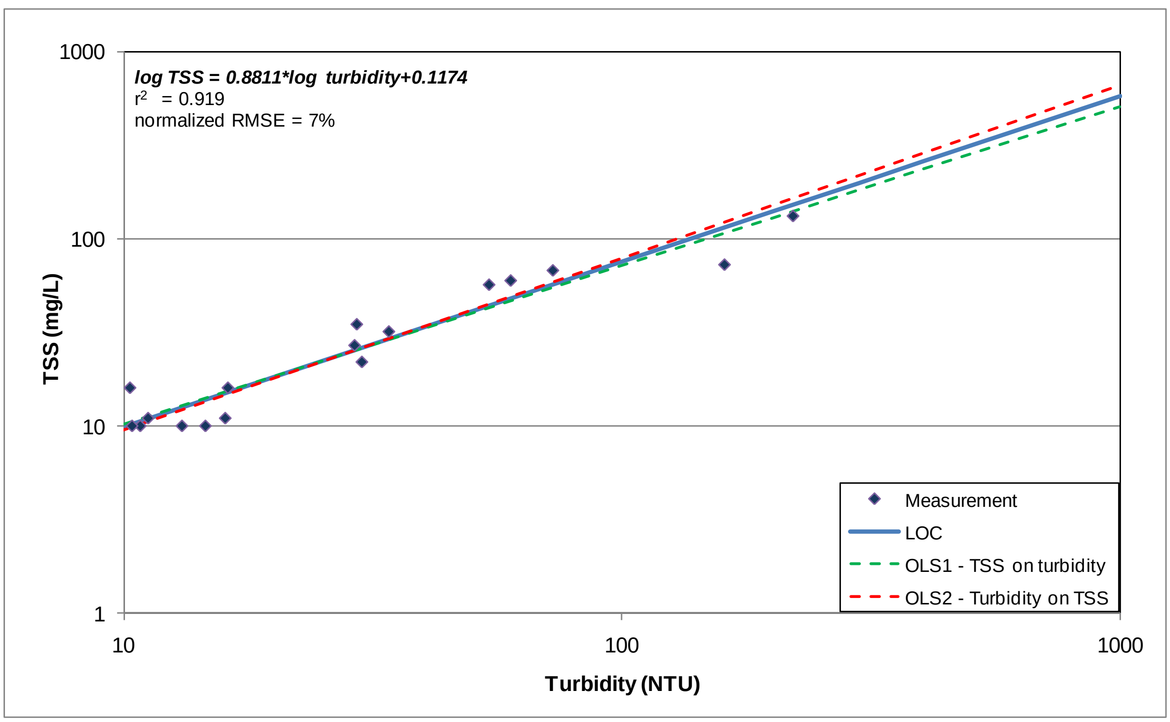
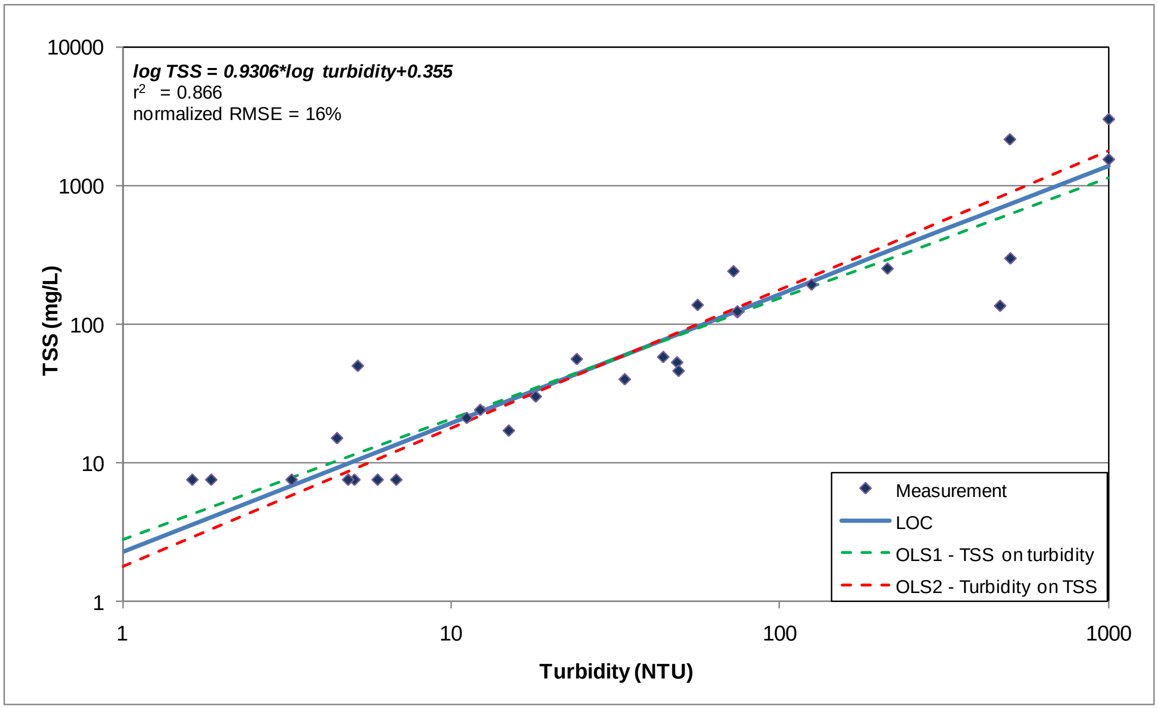


Figure 4-7 Linear Regression for TSS-Turbidity for Washita River at US 281, Anadarko (OK310830010010_00)



Data for 8-digit watershed (OK31083001)

Figure 4-8 Linear Regression for TSS-Turbidity for Wildhorse Creek (OK310810040140_00)

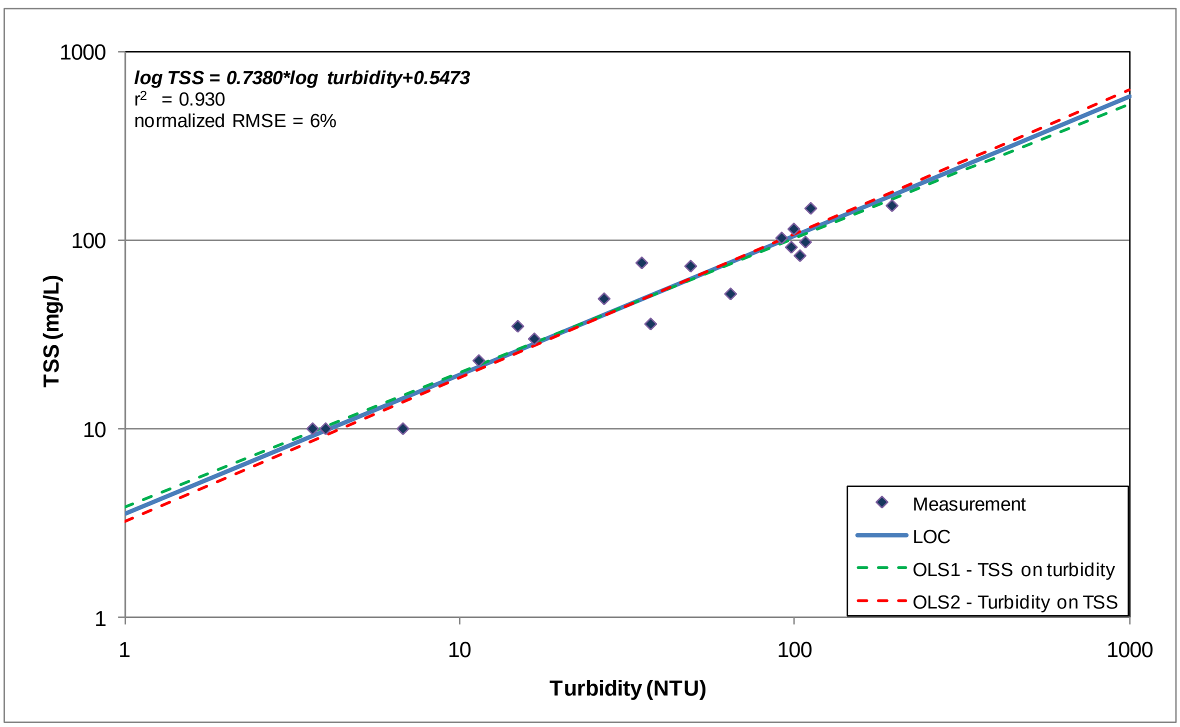


Figure 4-9 Linear Regression for TSS-Turbidity for Washington Creek (OK310810010190_00)

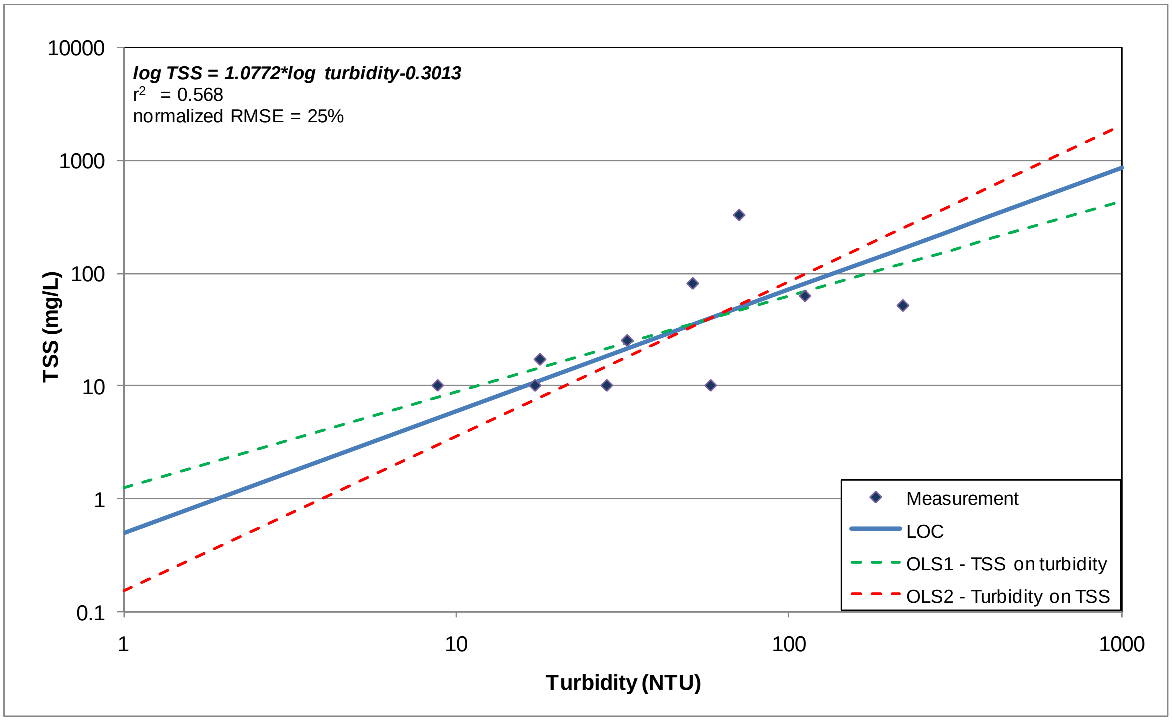


Figure 4-10 Linear Regression for TSS-Turbidity for Kickapoo Sandy Creek (OK310810010050_00)

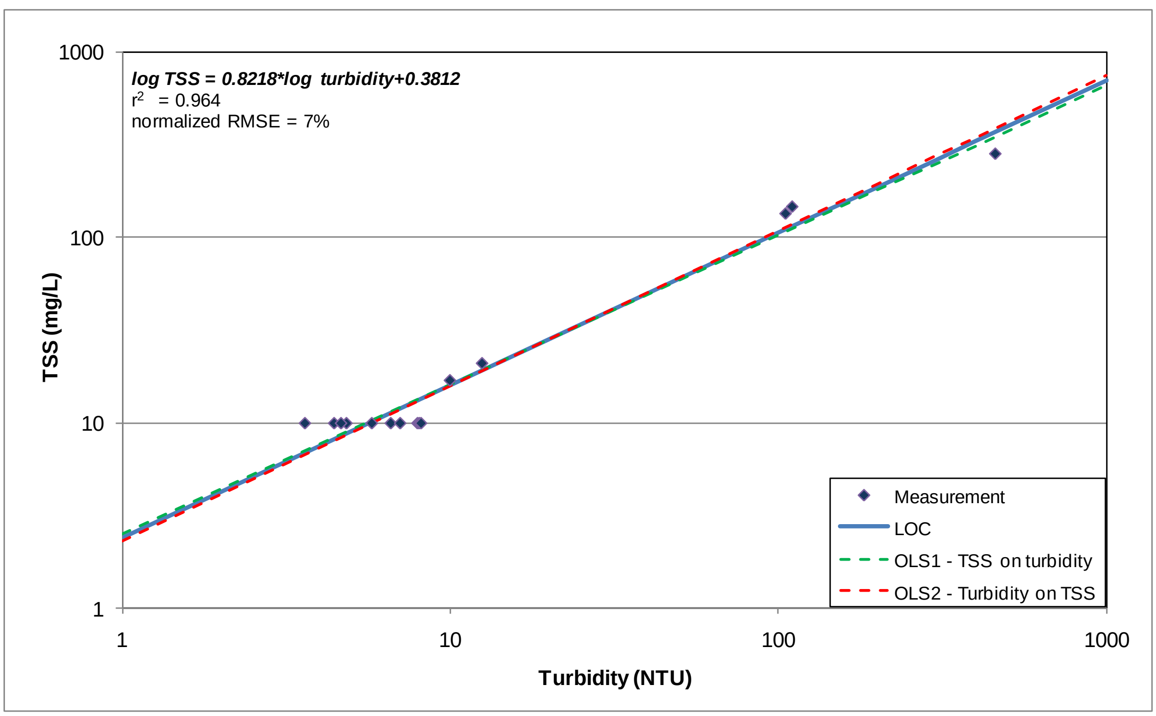
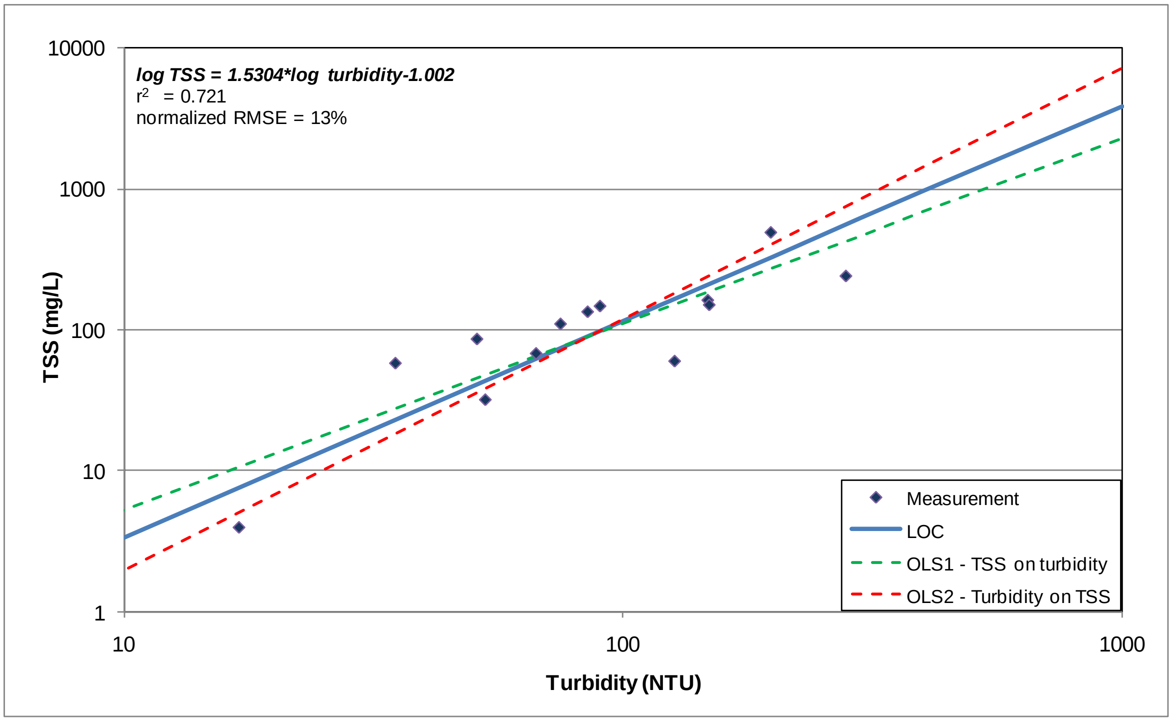


Figure 4-11 Linear Regression for TSS-Turbidity for Washita River at SH 19, Pauls Valley (OK310810010010_10)



Data from this regression were used to define WQ target and MOS for waterbody OK310810020010_00

Figure 4-12 Linear Regression for TSS-Turbidity for Sand Branch (OK310800020040_00)

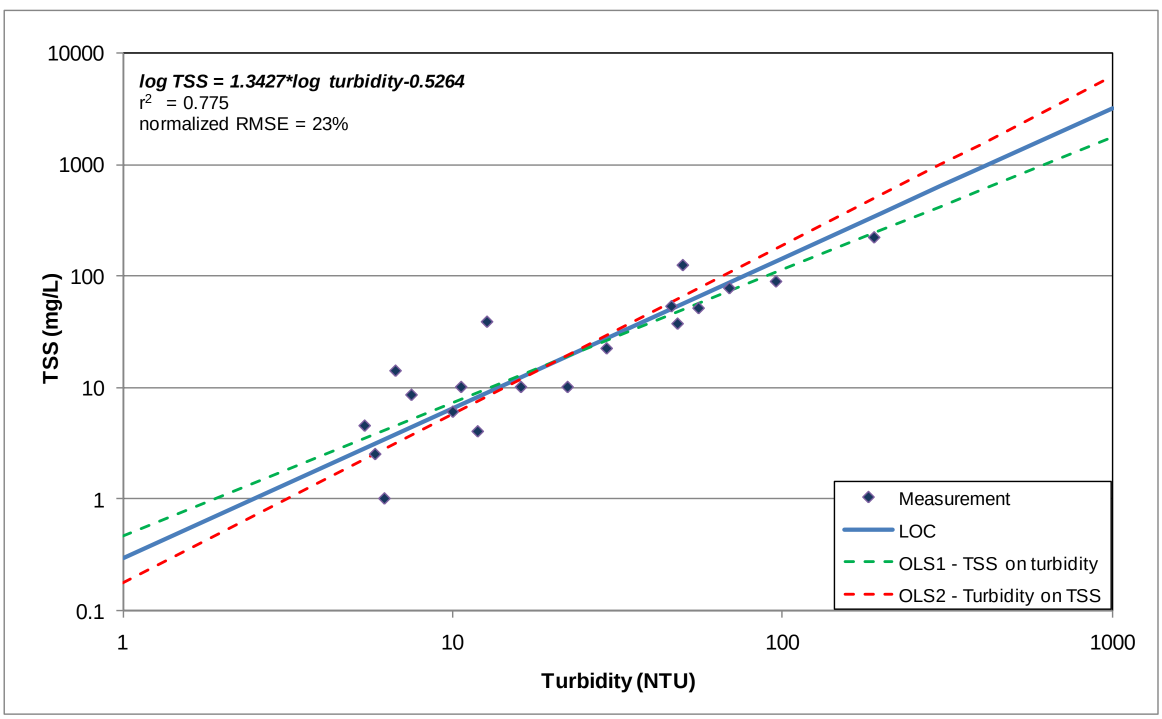
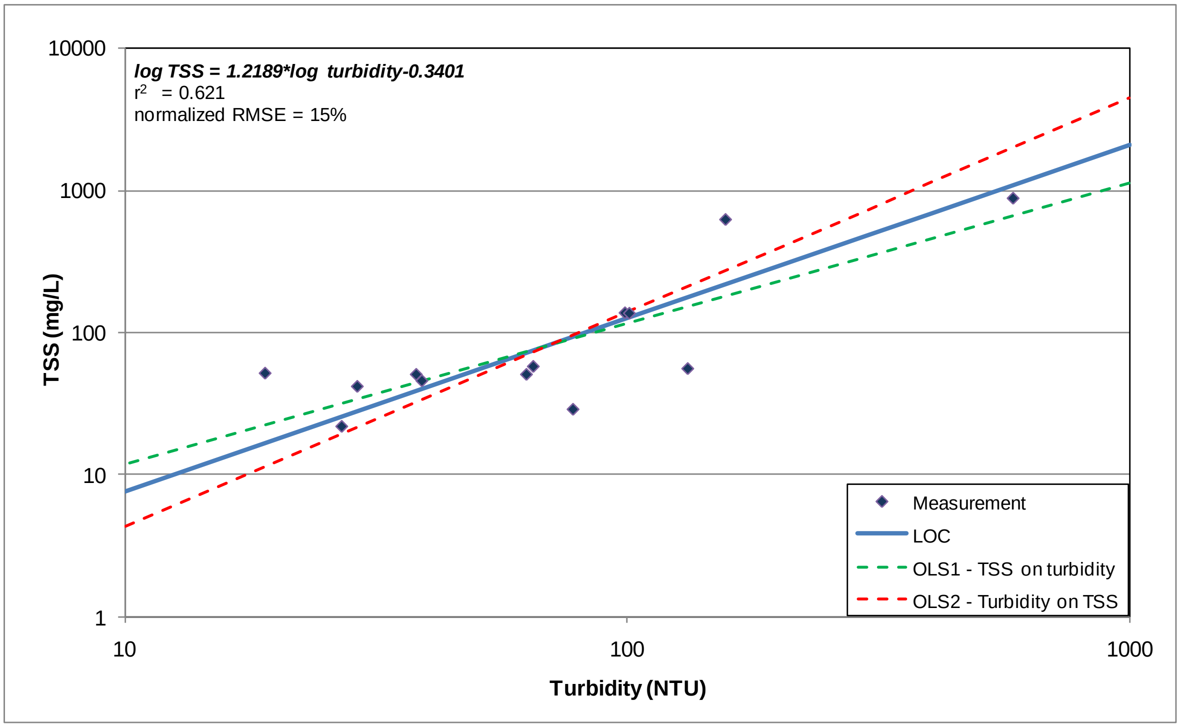


Figure 4-13 Linear Regression for TSS-Turbidity for Washita River at US 177, Durwood (OK310800020010_00)



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 8.8 which means the root mean square error (RMSE) is 8.8% of the average of the measured TSS values. The R-square (r^2) value indicates the fraction of the total variance in TSS or turbidity observations that is explained by the LOC. 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]
OK310840020020_00	Sandstone Creek	0.896	8.8%	60	10%	54
OK310840020010_00	Washita River at Site #384	0.508	19.4%	55	20%	44
OK310840010010_00	Washita River at SH 33, McLure	0.873	10.5%	88	15%	75
OK310830030010_00	Washita River at SH 152, Cordell	0.773	12.5%	78	15%	66
OK310830020060_10	Rainy Mountain Creek	0.953	7.5%	58	10%	52
OK310830020020_00	Stinking Creek	0.920	7.5%	41	10%	37
OK310830010010_00	Washita River at US 281, Anadarko	0.866	15.5%	86	15%	73
OK310810040140_00	Wildhorse Creek	0.930	6.0%	63	10%	57
OK310810020010_00	Washita River at SH 19, near Alex[d]	0.721	13.2%	40	15%	34

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]	TSS Target (mg/L)[c]
OK310810010190_00	Washington Creek	0.568	24.8%	34	25%	26
OK310810010050_00	Kickapoo Sandy Creek	0.964	7.3%	60	10%	54
OK310810010010_10	Washita River at SH 19, Pauls Valley	0.721	13.2%	40	15%	34
OK310800020040_00	Sand Branch	0.775	23.1%	57	25%	43
OK310800020010_00	Washita River at US 177, Durwood	0.621	15.0%	54	15%	46

[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
[d] Data from regression for waterbody OK310810010010_10

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 percentile (Q_3) and 25th percentile (Q_1) of distances between observed points and the LOC. Using the Tukey method, any point with an error greater than Q_3 + 1.5* IQR or less than Q_1 – 1.5*IQR was identified as an outlier and removed from the regression dataset. The above regressions were calculated using the dataset with outliers removed.

The Tukey Method is equivalent to using three times the standard deviation to identify outliers if the residuals (observed - predicted) follow a normal distribution. The probability of sampling results being within three standard deviations of the mean is 99.73% while the probability for the Tukey Method is 99.65%. If three times the standard deviation is used to identify outliers, it is necessary to first confirm that the residuals are indeed normally distributed. This is difficult to do because of the size limitations of the existing turbidity & TSS dataset. Tukey's method does not rely on any assumption about the distribution of the residuals. It can be used regardless of the shape of distribution.

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

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 2009) to support the Oklahoma TMDL Toolbox.

The USGS National Water Information System serves as the primary source of flow measurements for the Oklahoma TMDL Toolbox. All available daily average flow values for all gages in Oklahoma, as well as the nearest upstream and downstream gages in adjacent states, were retrieved for use in the Oklahoma TMDL Toolbox to generate flow duation 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 4-14 through 4-27 are flow duration curves for each impaired waterbody.

Figure 4-14 Flow Duration Curve for Sandstone Creek

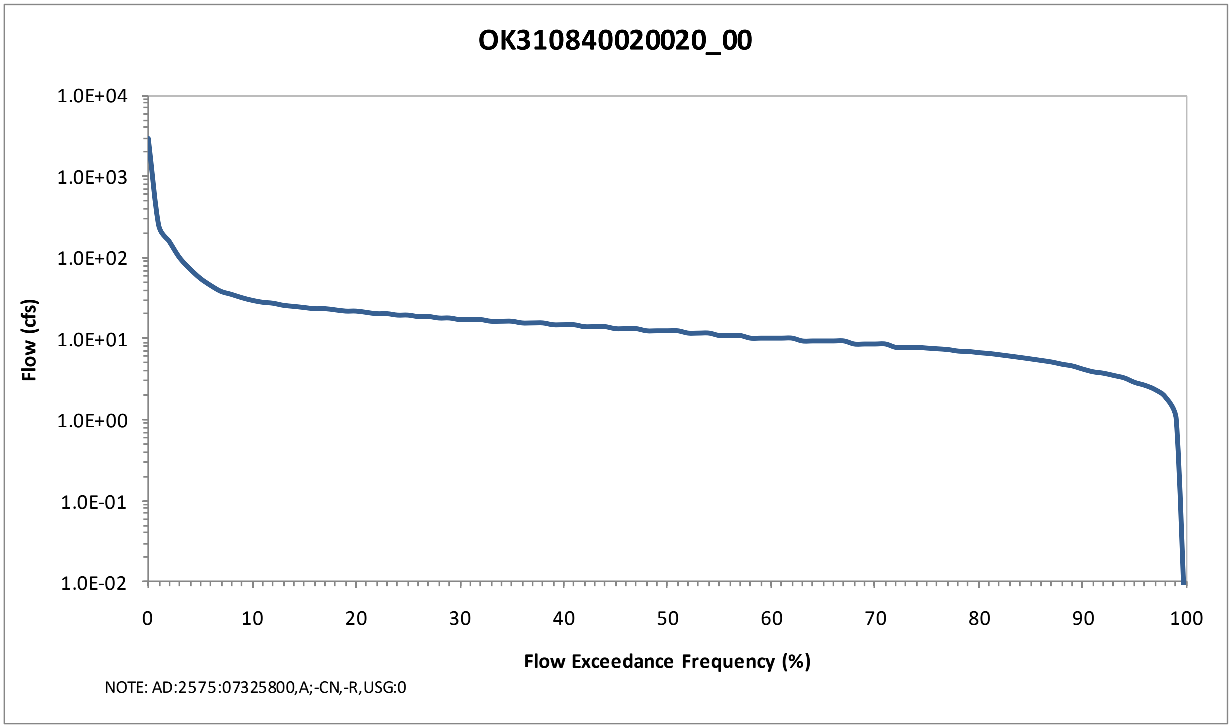


Figure 4-15 Flow Duration Curve for Washita River at Site #384

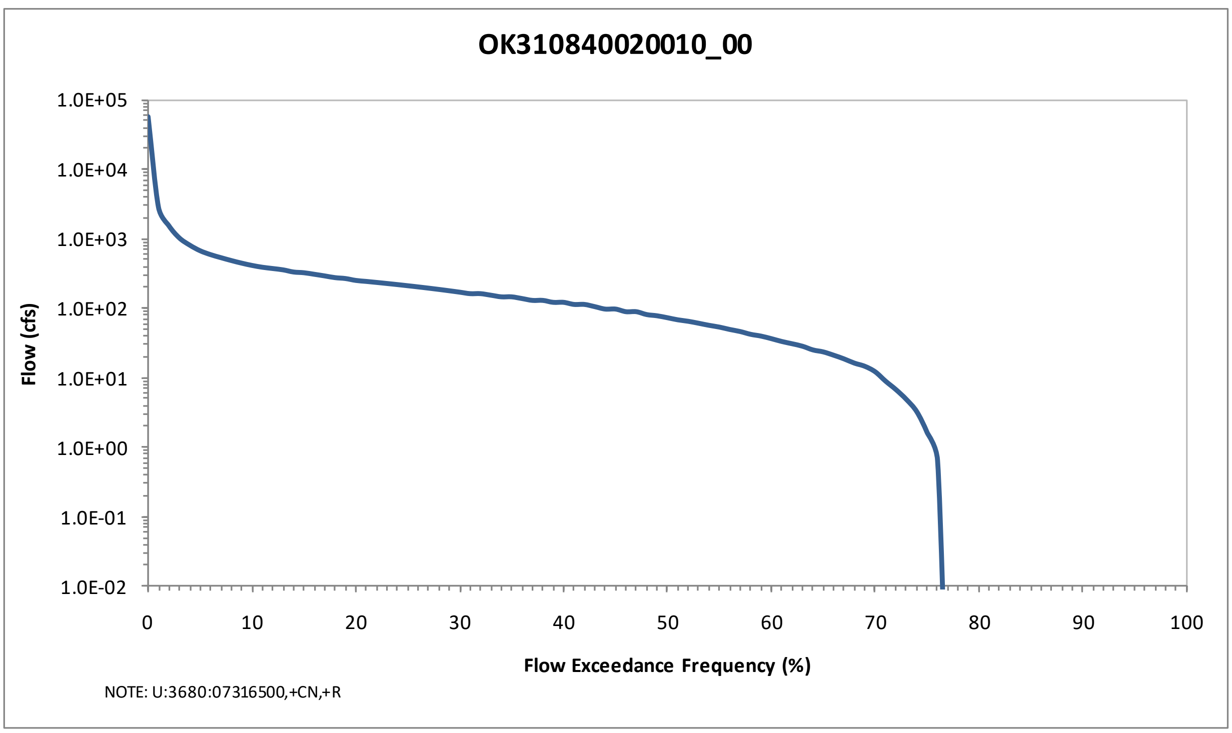


Figure 4-16 Flow Duration Curve for Washita River at SH 33, McLure

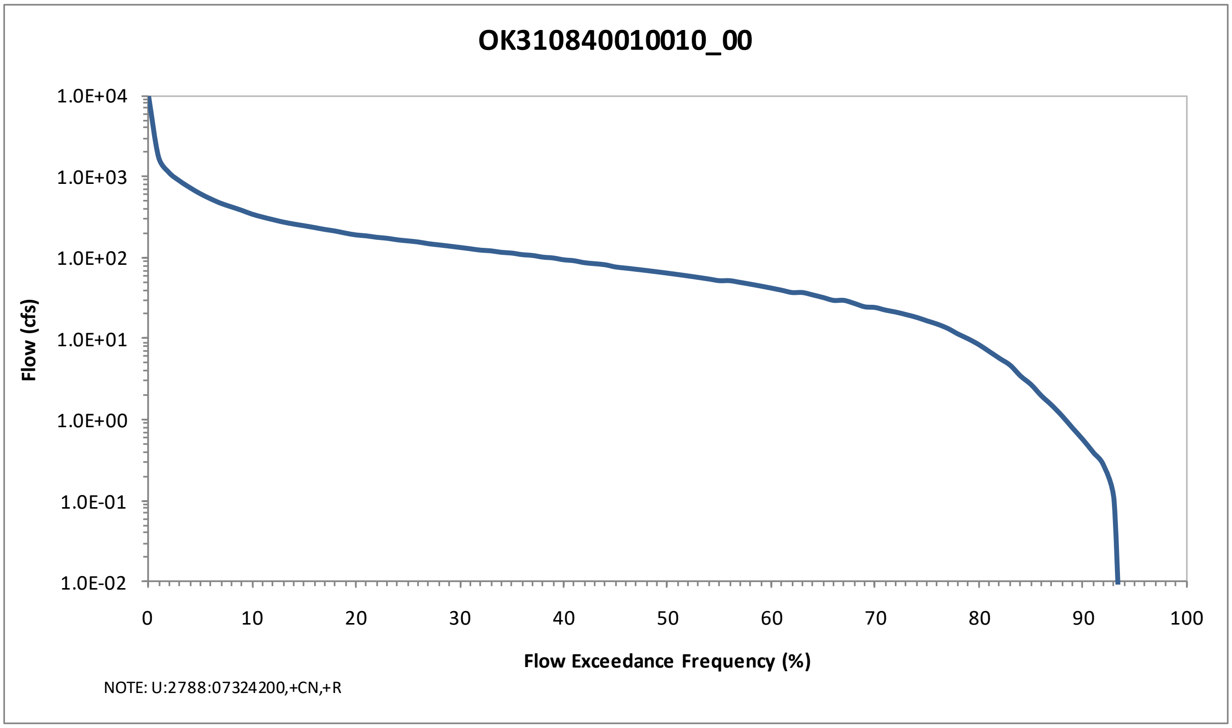


Figure 4-17 Flow Duration Curve for Washita River at SH 152, Cordell

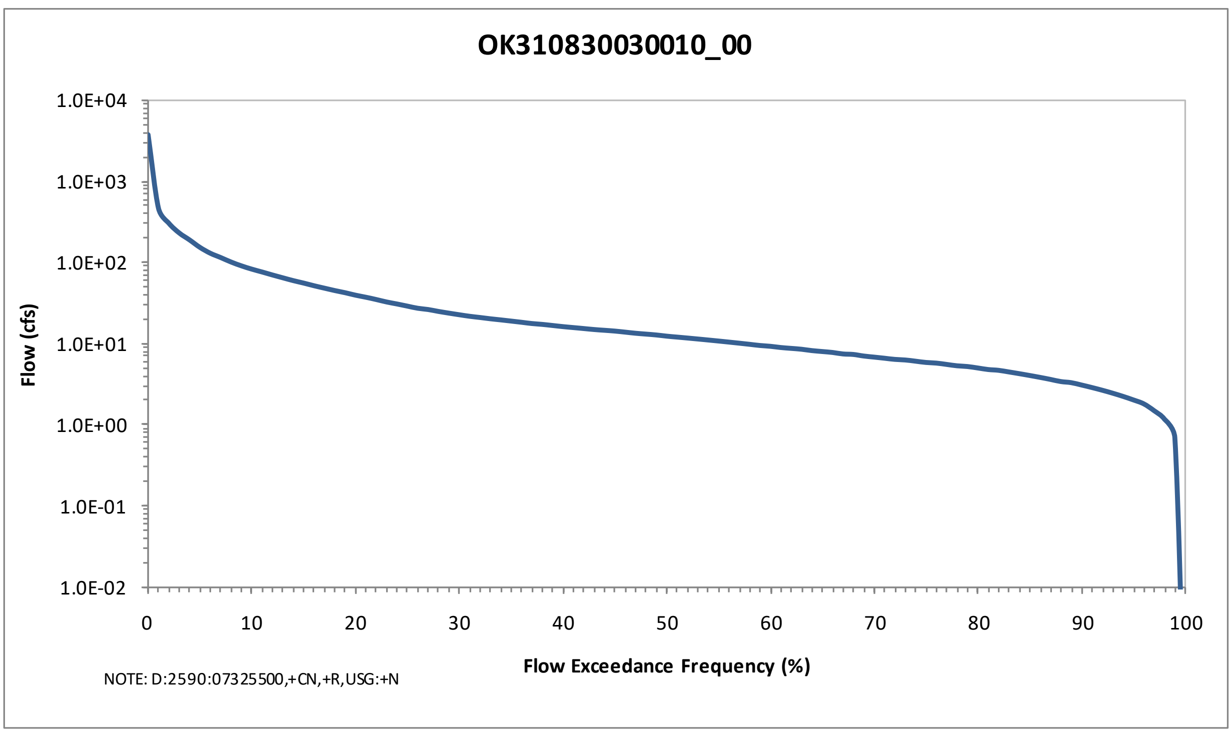


Figure 4-18 Flow Duration Curve for Rainy Mountain Creek

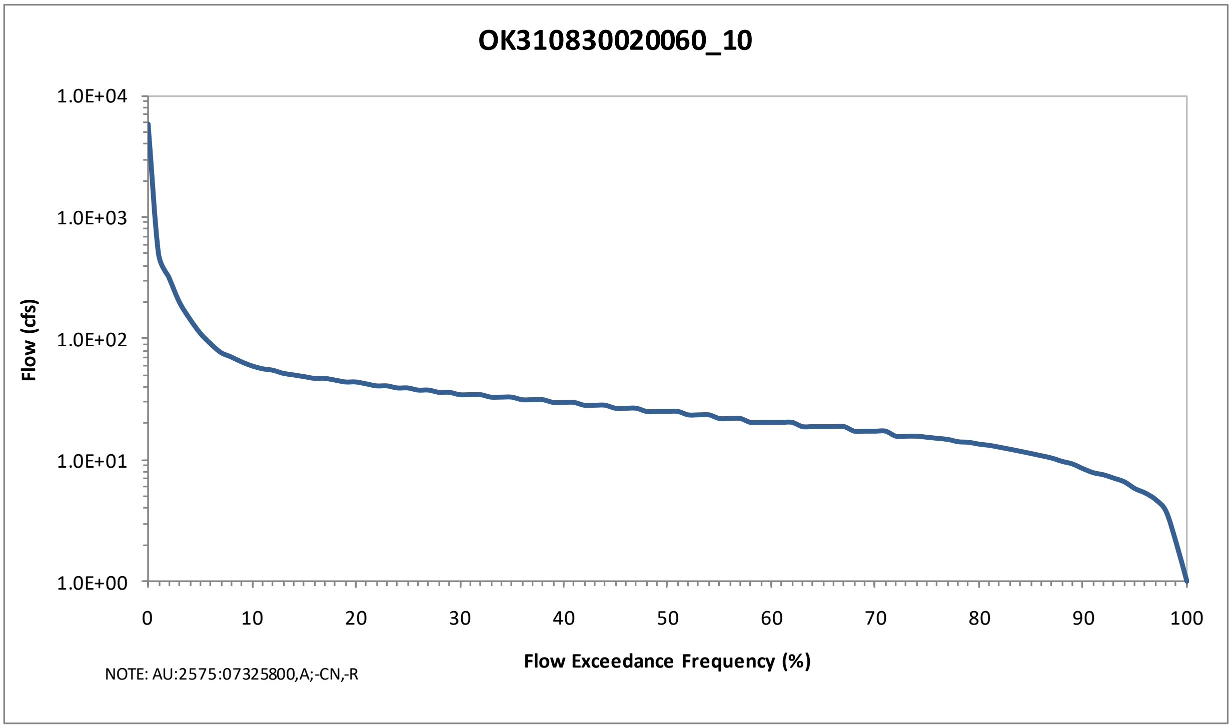


Figure 4-19 Flow Duration Curve for Stinking Creek

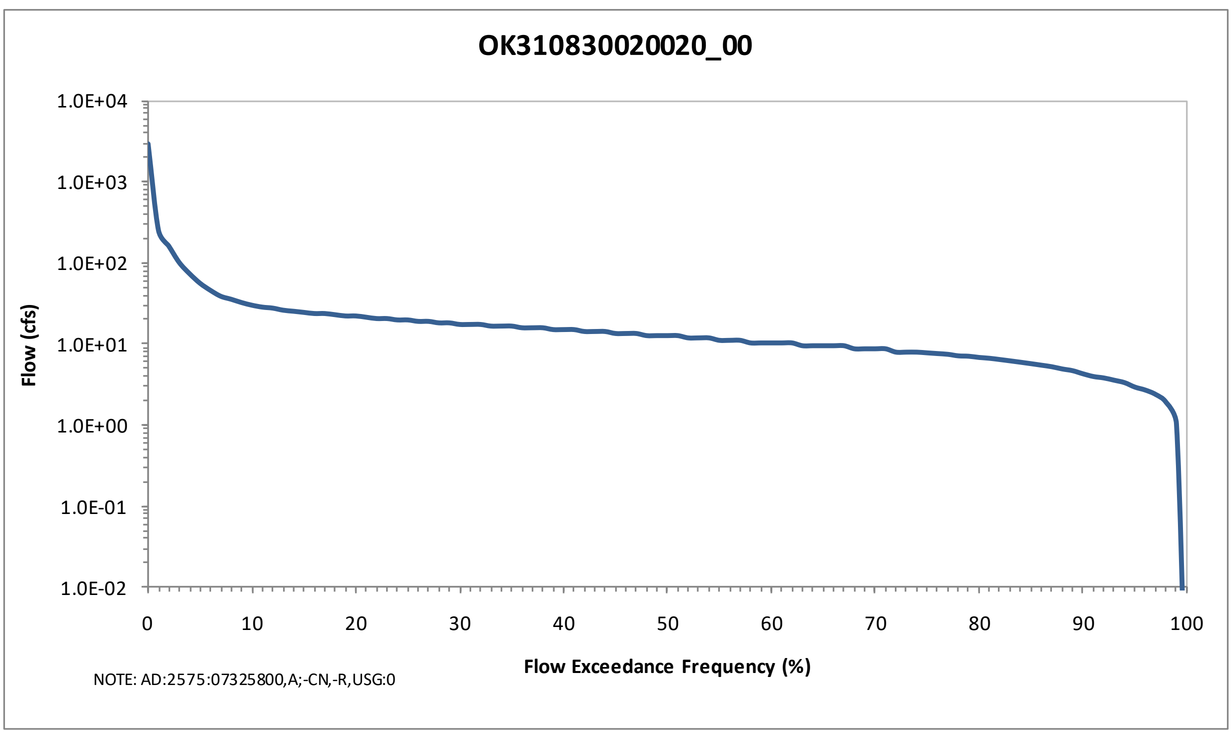


Figure 4-20 Flow Duration Curve for Washita River at US 281, Anadarko

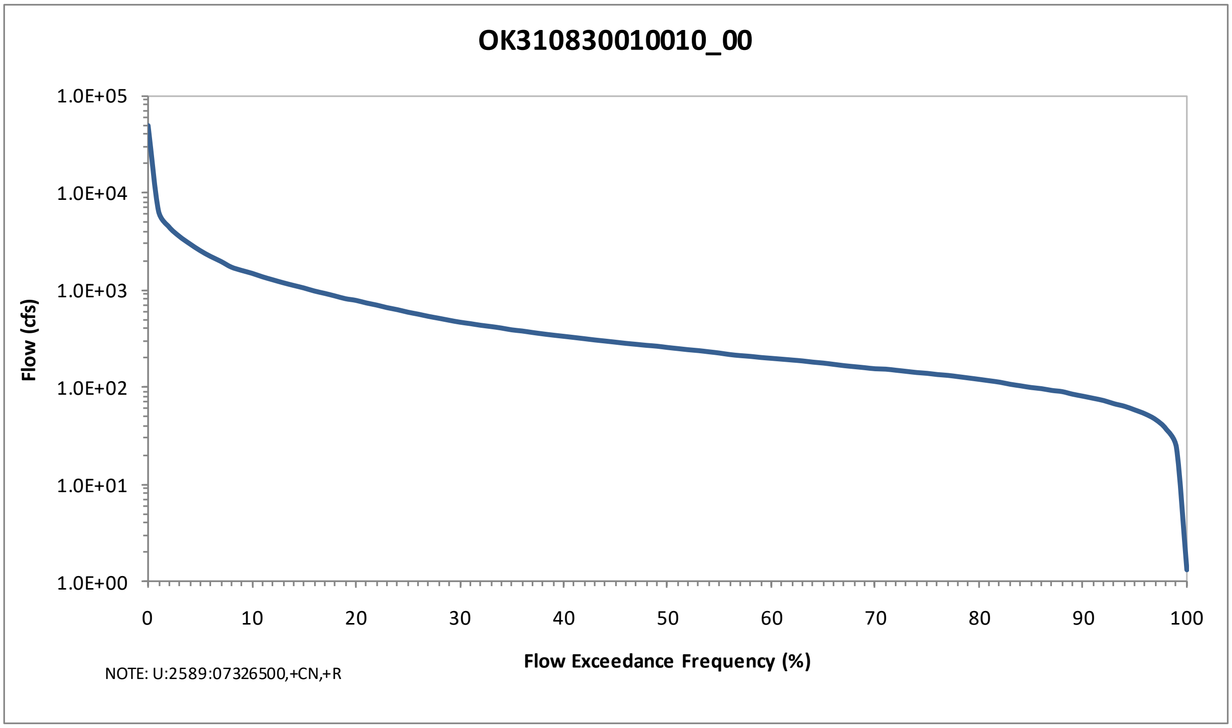


Figure 4-21 Flow Duration Curve for Wildhorse Creek

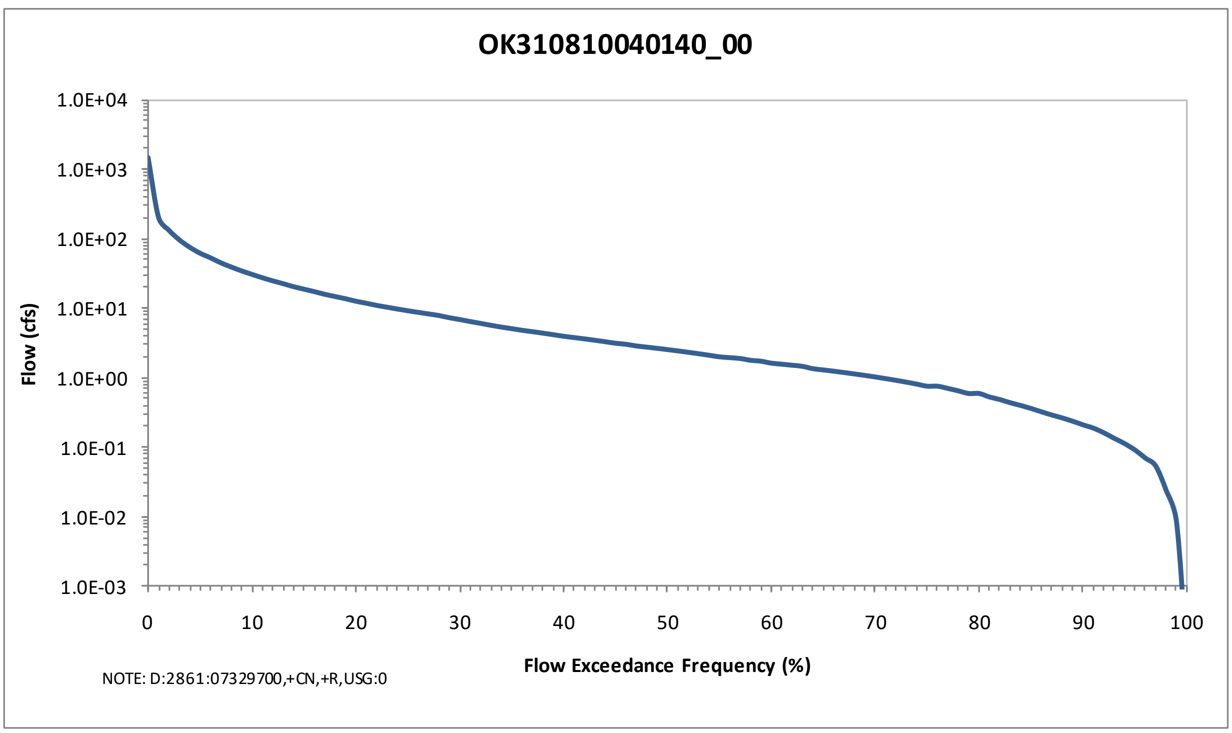


Figure 4-22 Flow Duration Curve for Washita River at SH 19, near Alex

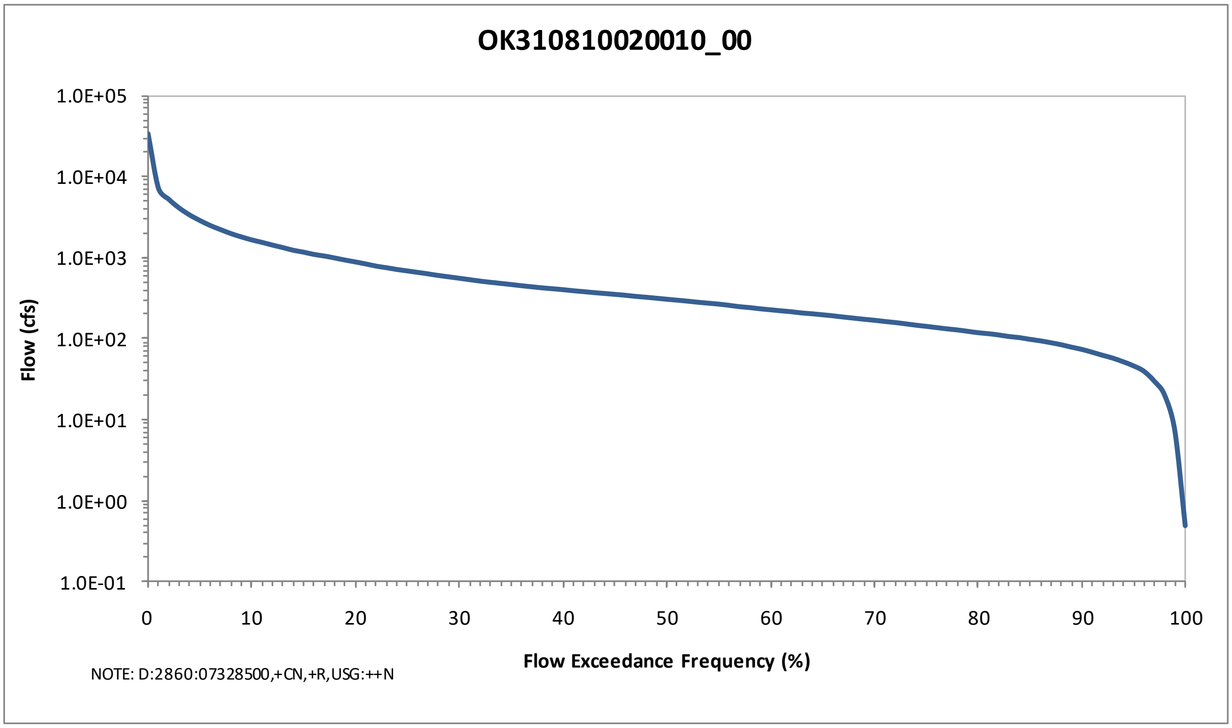


Figure 4-23 Flow Duration Curve for Washington Creek

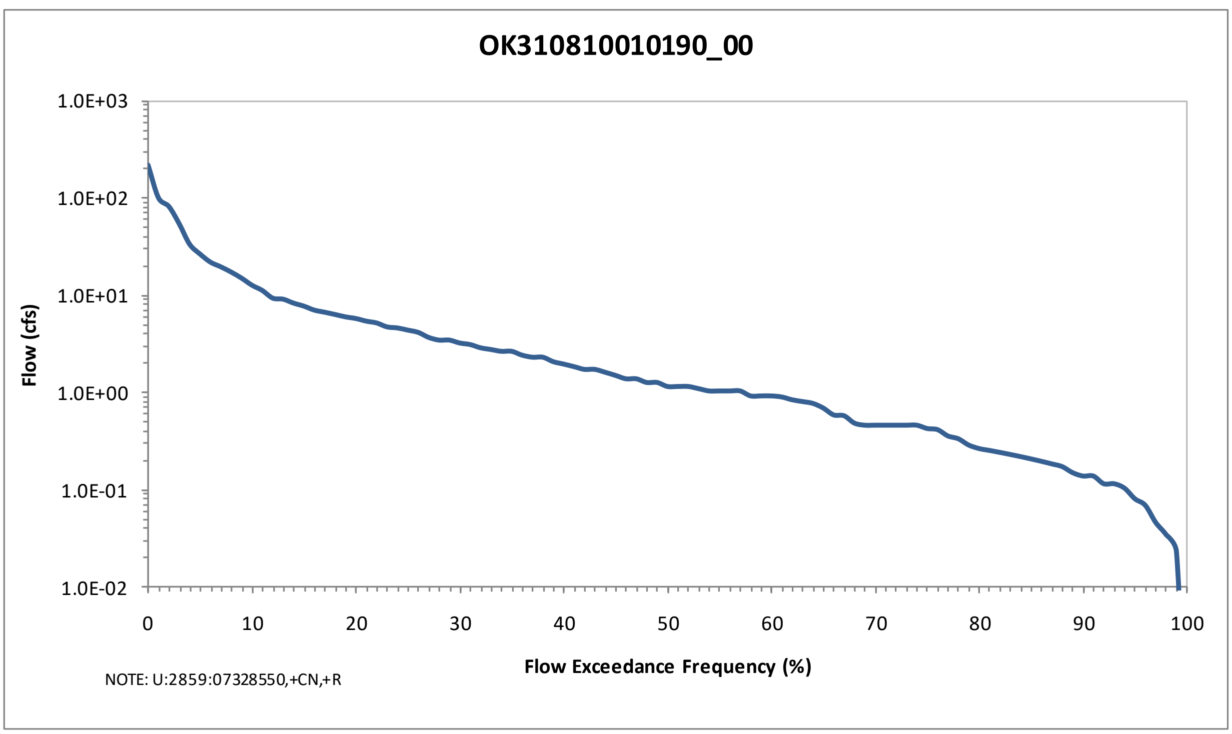


Figure 4-24 Flow Duration Curve for Kickapoo Sandy Creek

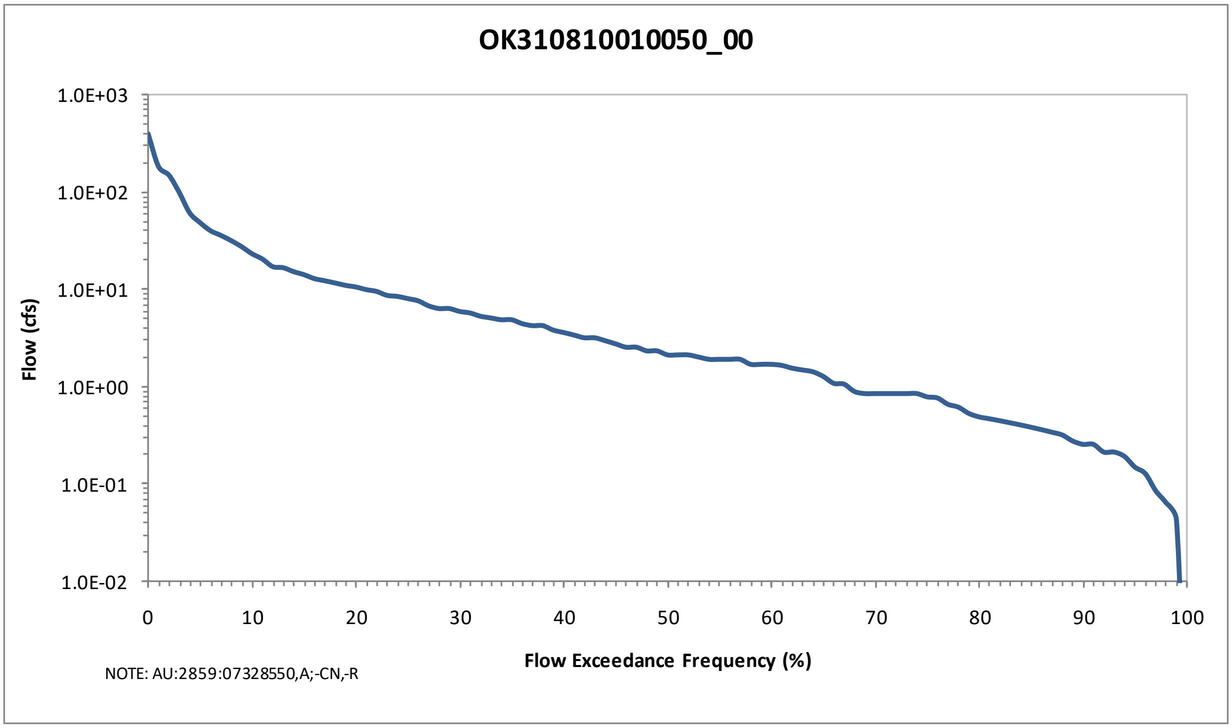


Figure 4-25 Flow Duration Curve for Washita River at SH 19, Pauls Valley

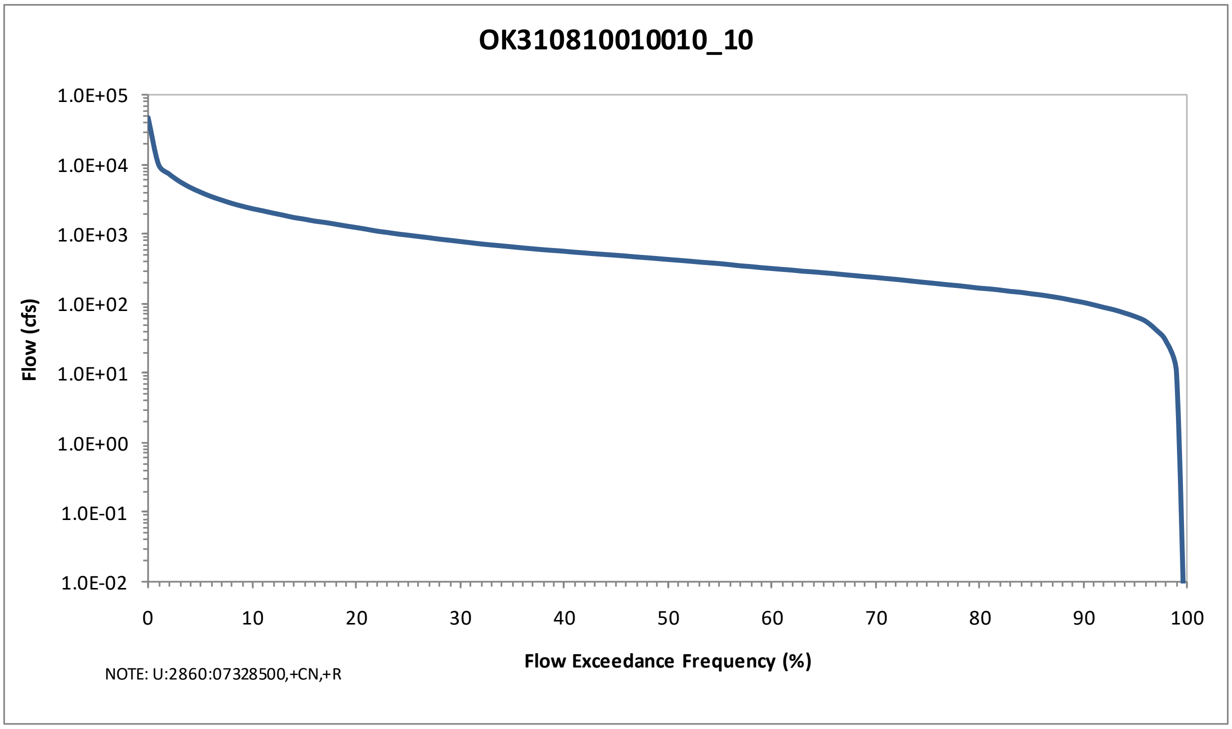


Figure 4-26 Flow Duration Curve for Sand Branch

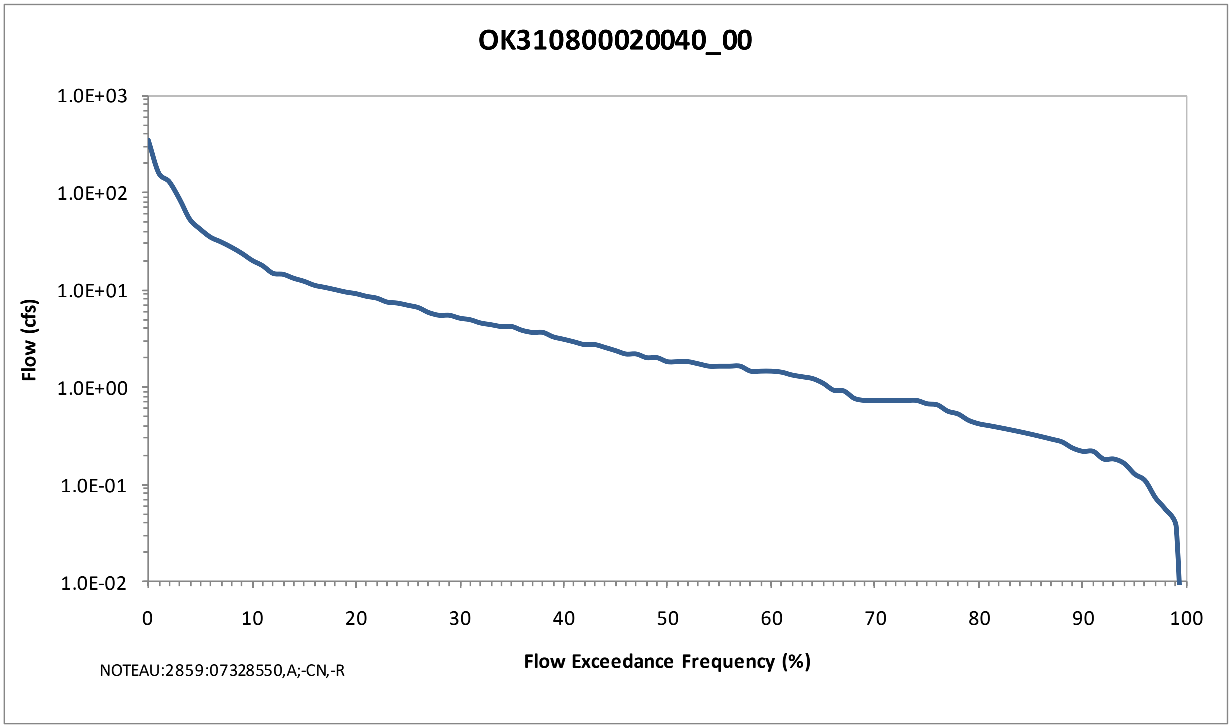
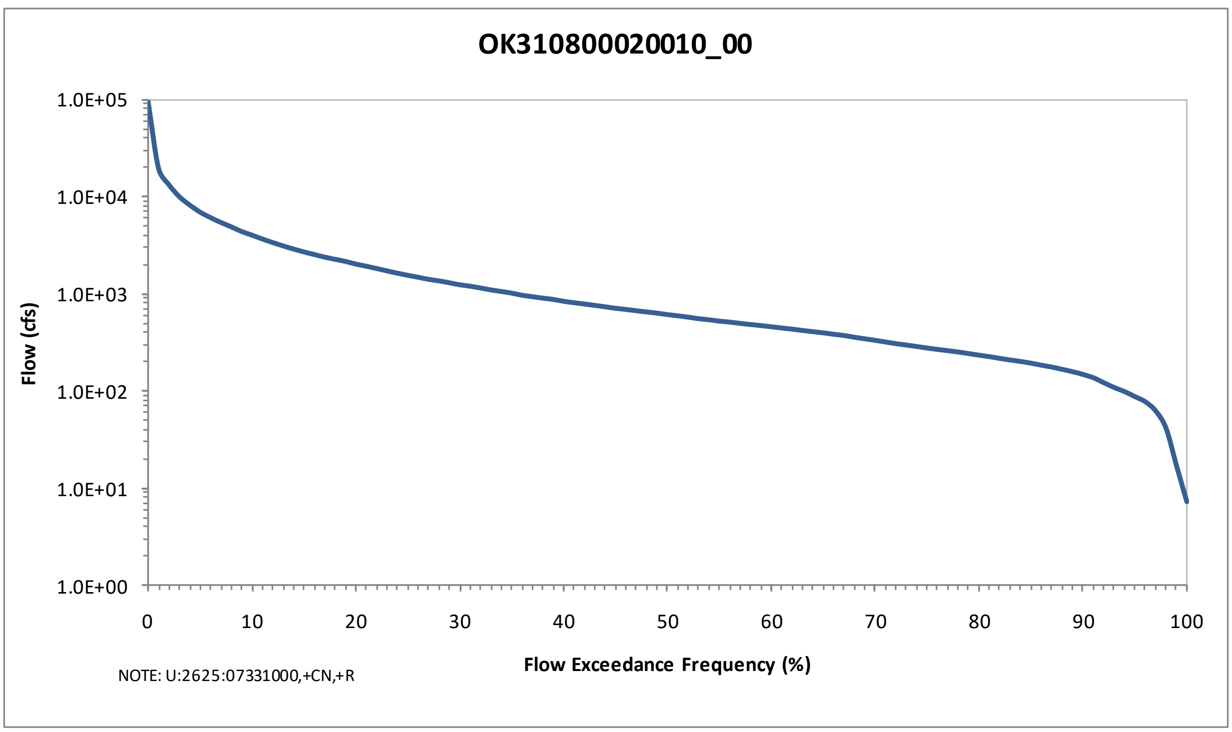


Figure 4-27 Flow Duration Curve for Washita River at US 177



4.4 Estimating Existing Loading

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 detemined 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 1^{st} through September 30^{th}) from 2002 to 2009 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 B. 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 2002 through 2009) are shown in Figures 5-1 through 5-10. Each waterbody has two LDCs: one for either *E. coli* or fecal coliform and a second one for Enterococci. This is because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

The LDCs for Sandstone Creek are shown in Figures 5-1 and 5-2 for *E. coli* and Enterococcus, respectively. They are based on bacteria measurements during primary contact recreation season at WQM station OK310840-02-0020C. The LDCs indicate that *E.coli* and Enterococcus levels exceed the instantaneous water quality criteria under moderate and low flow conditions.

Figure 5-1 Load Duration Curve for *E. coli* in Sandstone Creek

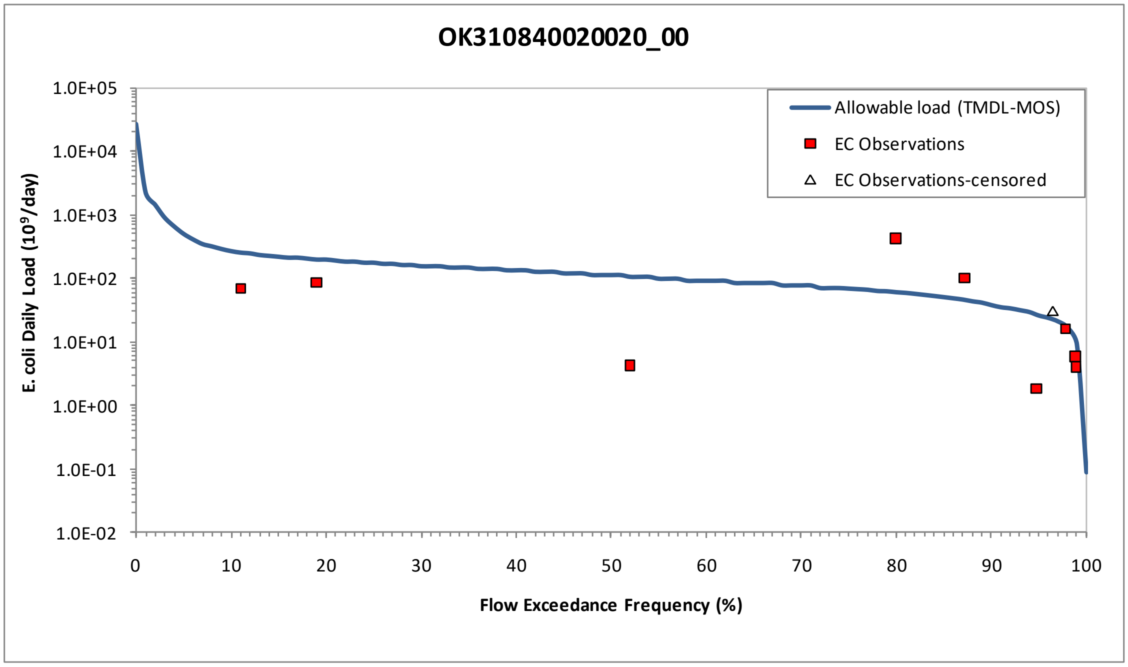
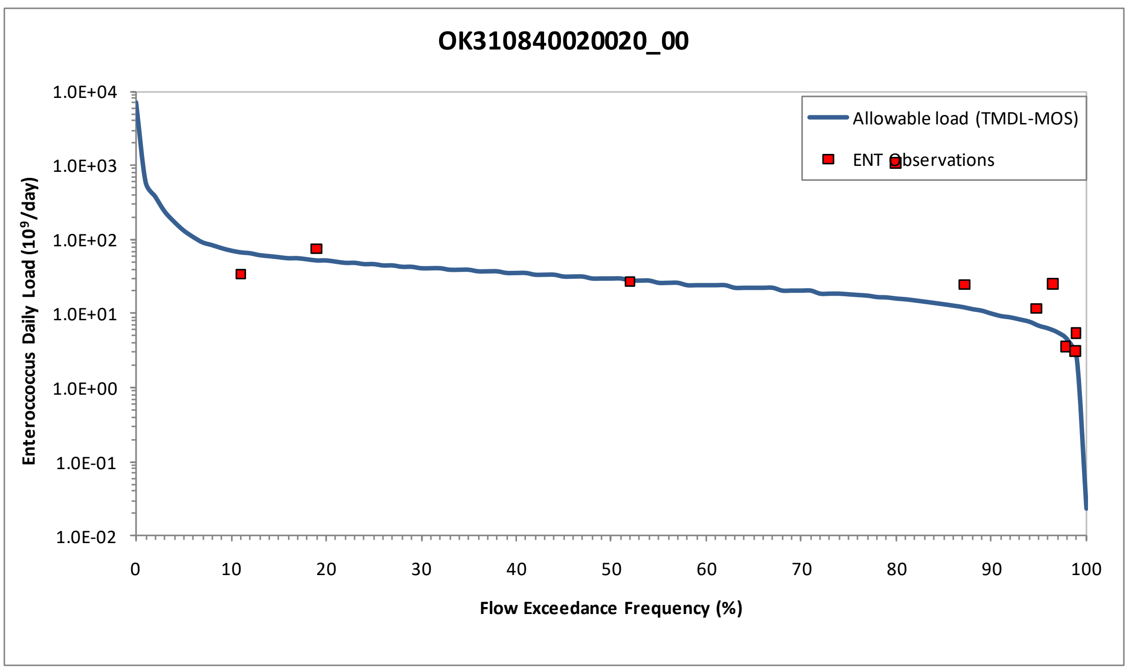


Figure 5-2 Load Duration Curve for Enterococci in Sandstone Creek



The LDCs for Stinking Creek (Figures 5-3 and 5-4) are based on *E. coli* and Enterococcus measurements during primary contact recreation season at WQM station OK310830-02-0020D. The LDC indicates that *E. coli* and Enterococcus levels exceed the instantaneous water quality criteria during all flow conditions.

Figure 5-3 Load Duration Curve for *E.coli* in Stinking Creek

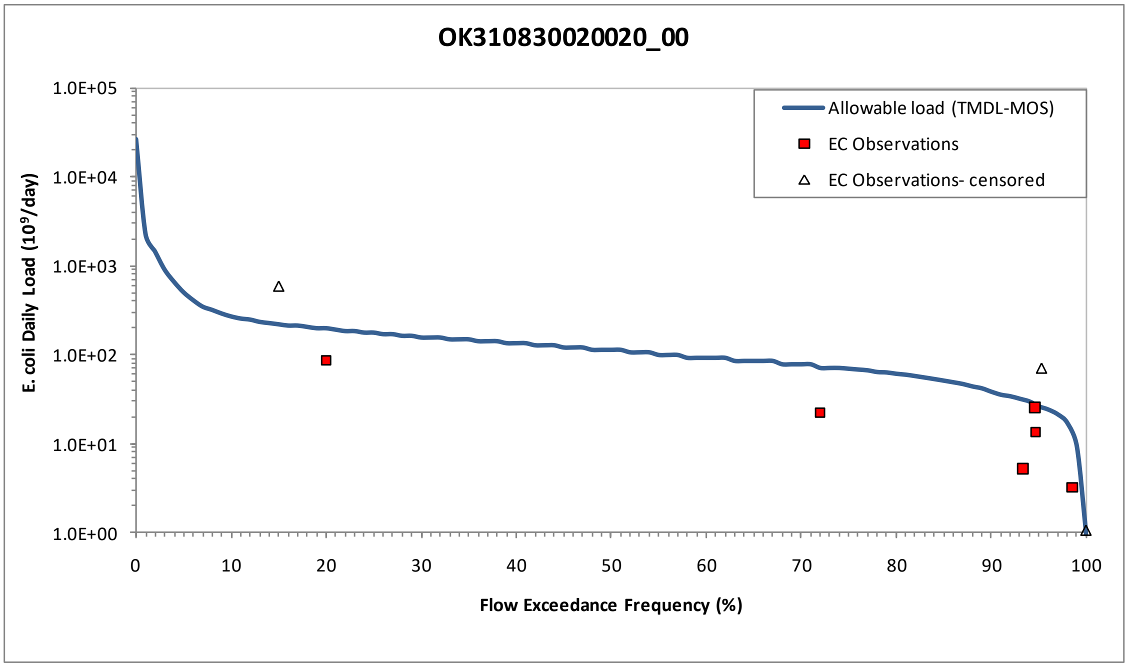
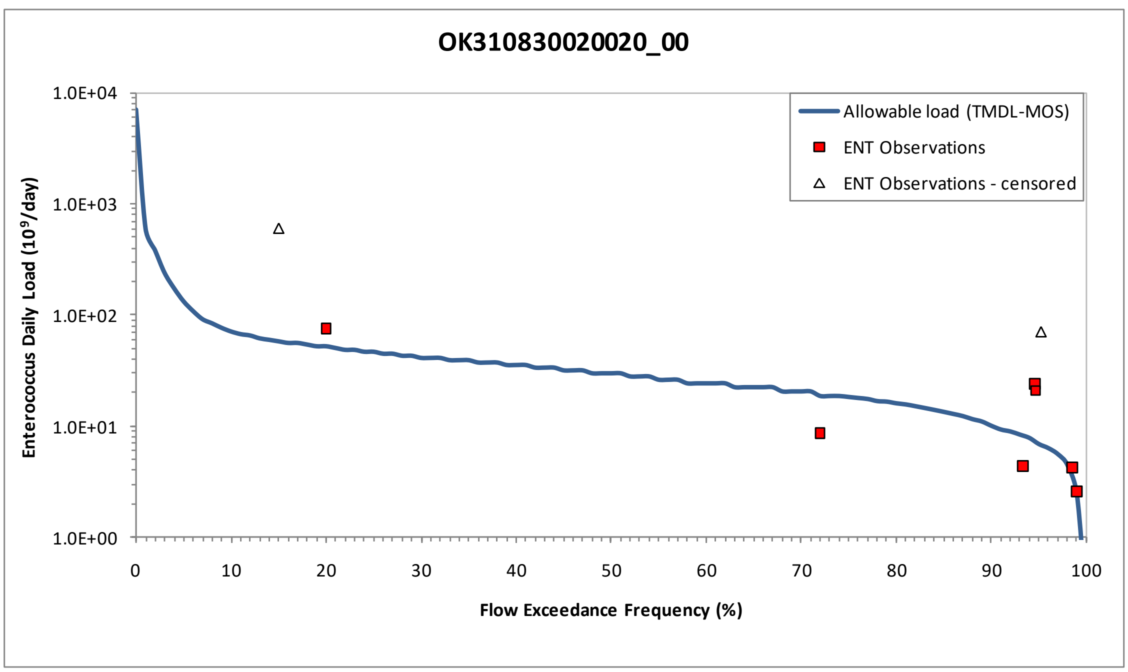


Figure 5-4 Load Duration Curve for Enterococci in Stinking Creek



Figures 5-5 and 5-6 show the *E. coli* and Enterococci LDCs for Wildhorse Creek and are based on measurements during primary contact recreation season at WQM station OK310810-04-0140D. The LDC indicates that *E. coli* levels exceed the water quality target at low and moderate flows while Enterococcus levels exceed the instantaneous water quality criterion under all flow conditions.

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

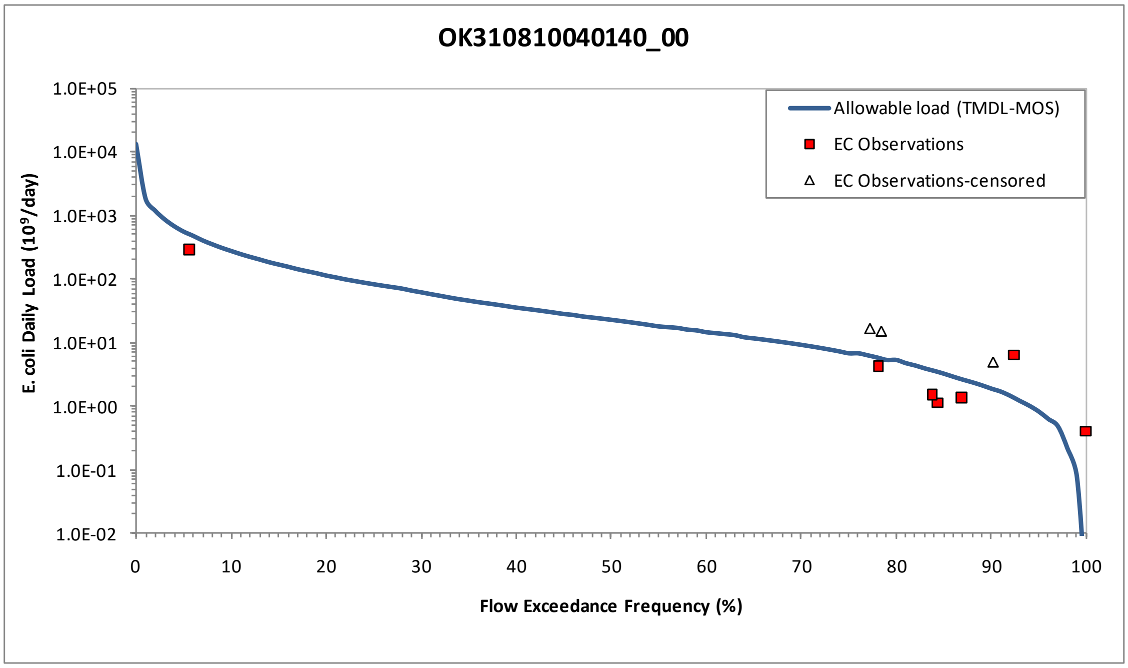
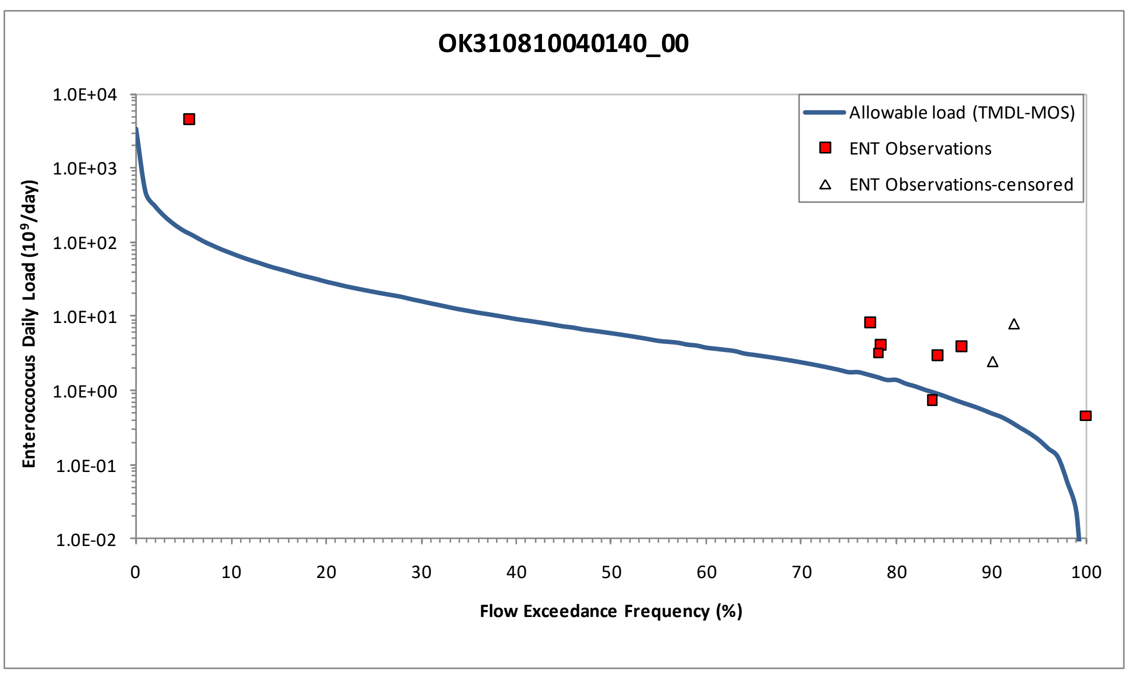


Figure 5-6 Load Duration Curve for Enterococci in Wildhorse Creek



The LDCs for Washita River at SH 19, near Alex (Figures 5-7 and 5-8) are based on fecal coliform and Enterococcus measurements during primary contact recreation season at WQM station 310810020010-001AT. The LDC indicates that both indicator levels exceed the instantaneous water quality criteria under a wide range of hydrologic conditions, indicative of loading from both point and nonpoint sources. The WLA for the City of Lindsay WWTP is shown in both LDCs.

Figure 5-7 Load Duration Curve for Fecal Coliform in Washita River at SH 19, near Alex

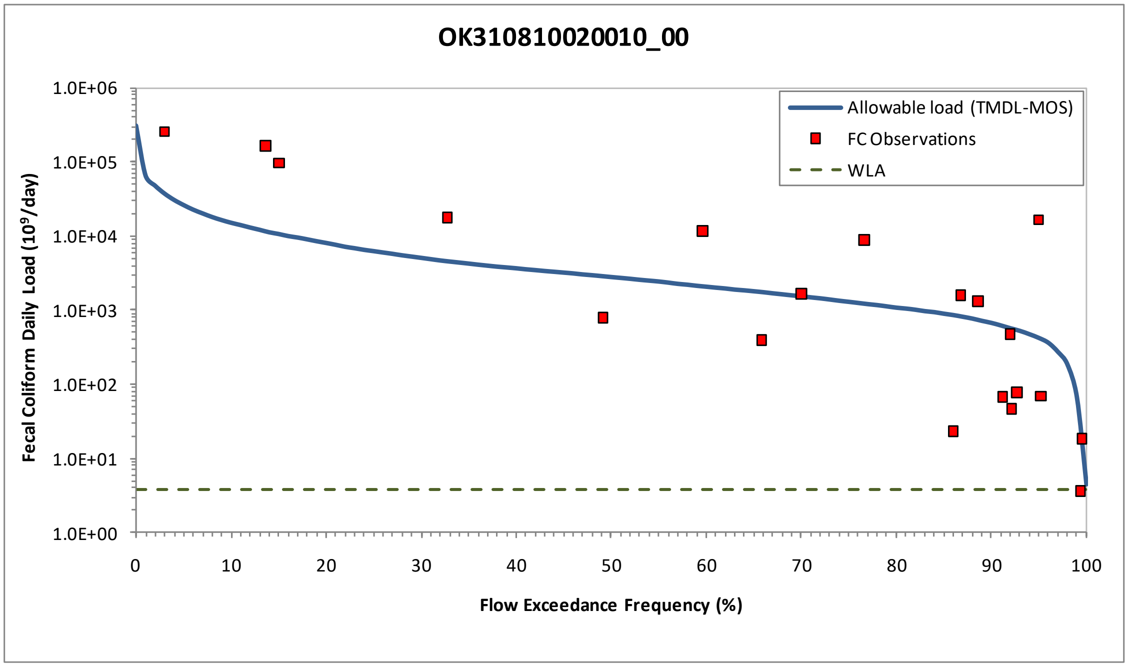
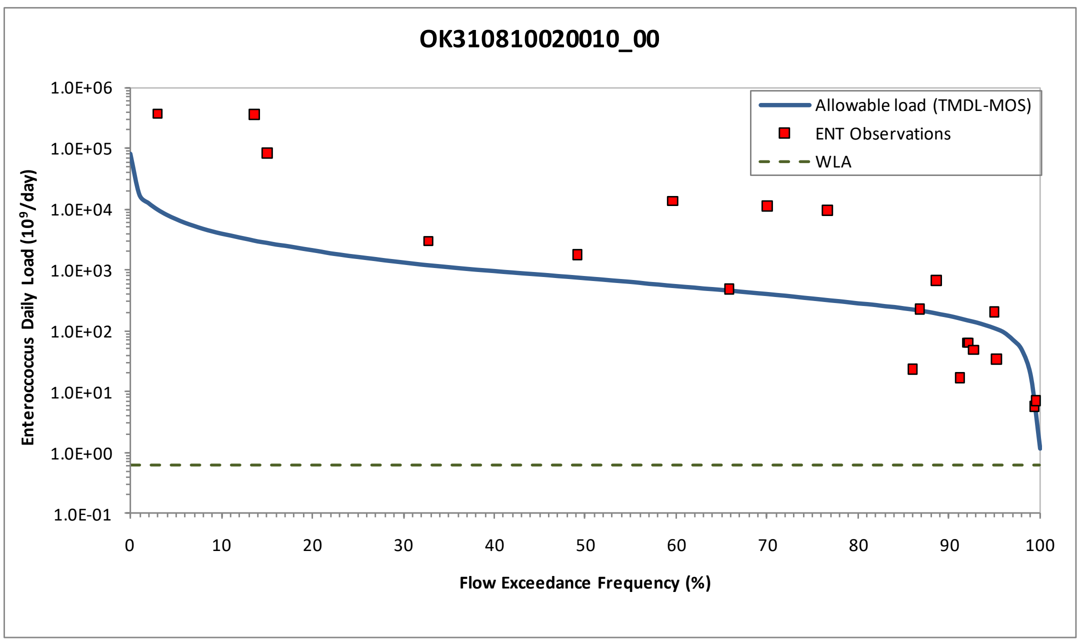


Figure 5-8 Load Duration Curve for Enterococci in Washita River at SH 19, near Alex



The LDCs for Kickapoo Sandy Creek (Figures 5-9 and 5-10) are based on *E. coli* and Enterococcus bacteria measurements collected during primary contact recreation season at WQM station OK310810-01-0050G. The LDC indicates that both indicator levels exceed the instantaneous water quality criteria under high flow conditions. As seen in the figures, the samples were collected under high-flow conditions only, an indication of bacteria loading from nonpoint sources under wet weather conditions.

Figure 5-9 Load Duration Curve for *E.coli* in Kickapoo Sandy Creek

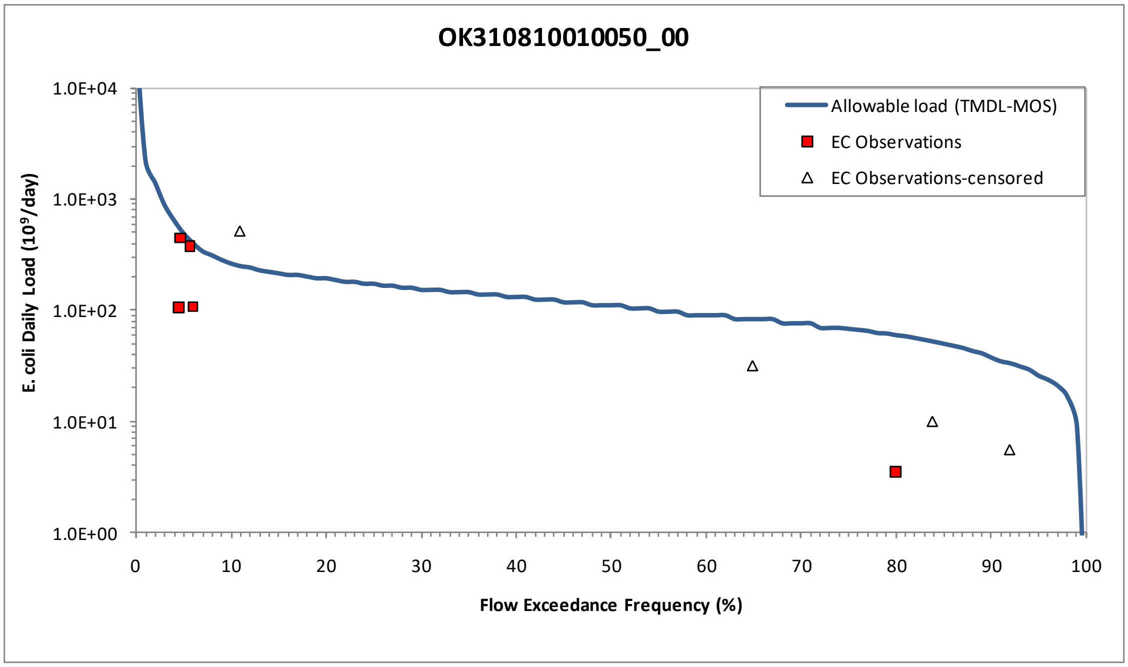
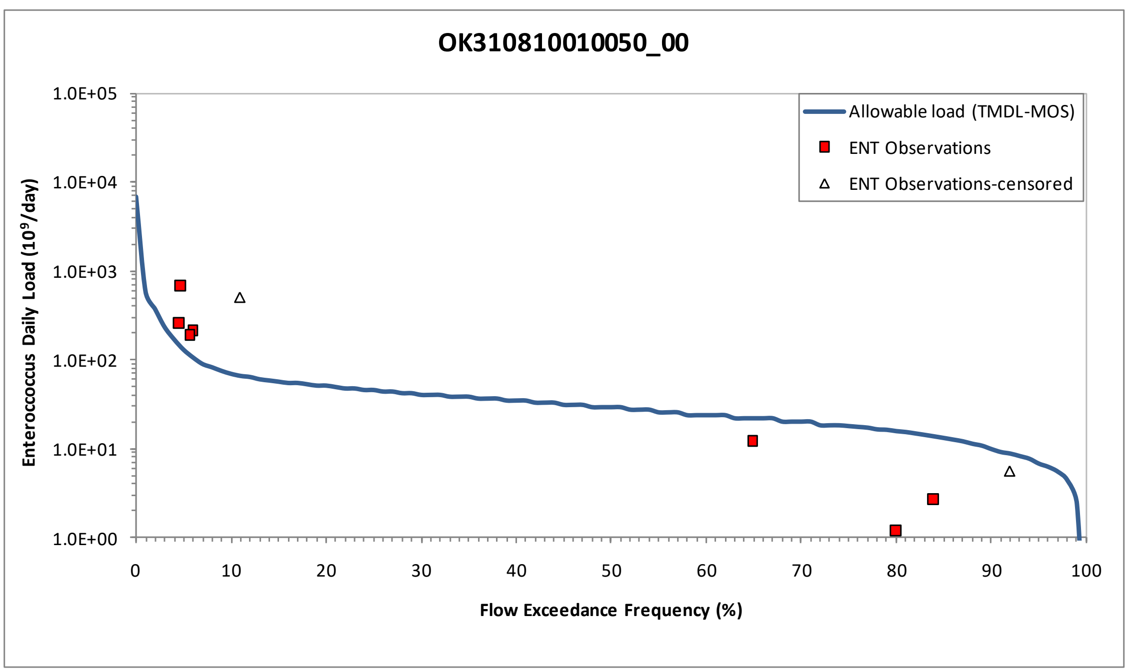


Figure 5-10 Load Duration Curve for Enterococci in Kickapoo Sandy Creek



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 target (TSS goal 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 1998 to 2009 are paired with the flows measured on the same date or projected for the waterbody. For sampling events with both TSS and turbidity data, the measured TSS value is used. For Washita River at SH 19, near Alex (OK310810020010_00), where only turbidity was measured, all values were converted to TSS using the regression equation for the downstream reach (Figure 4-11). 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 B. 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 5-11 through Figure 5-24 show the TSS LDCs developed for the fourteen waterbodies addressed in this TMDL report. 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 5-11 Load Duration Curve for Total Suspended Solids in Sandstone Creek

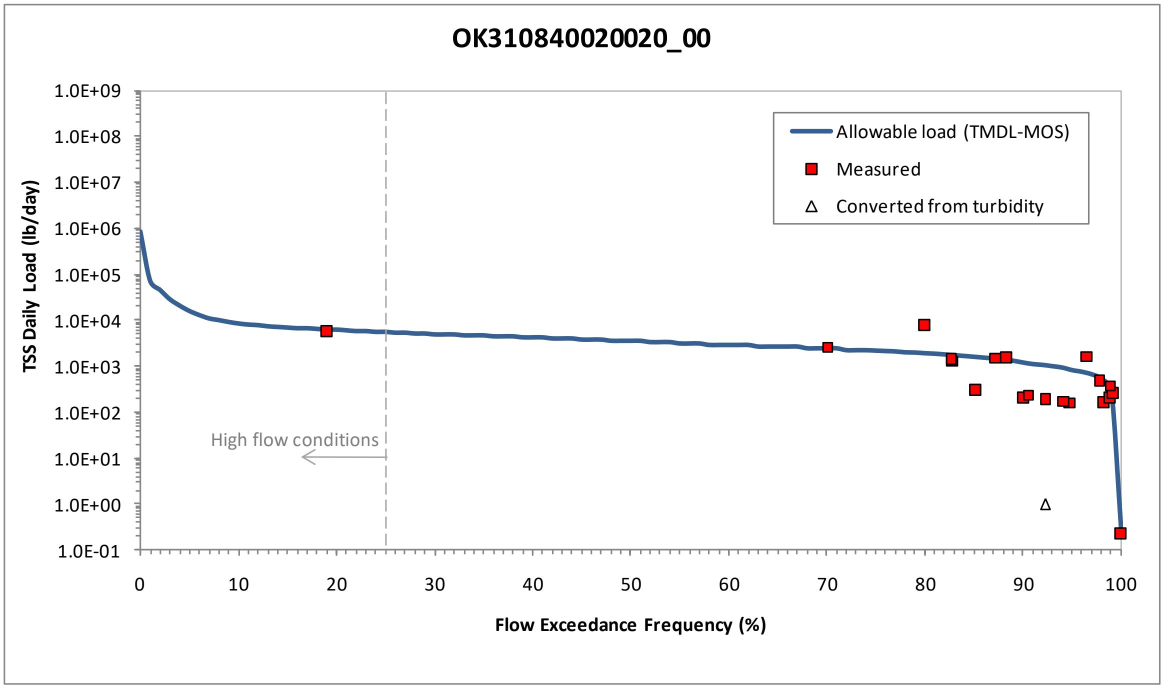


Figure 5-12 Load Duration Curve for Total Suspended Solids in Washita River at Site #384

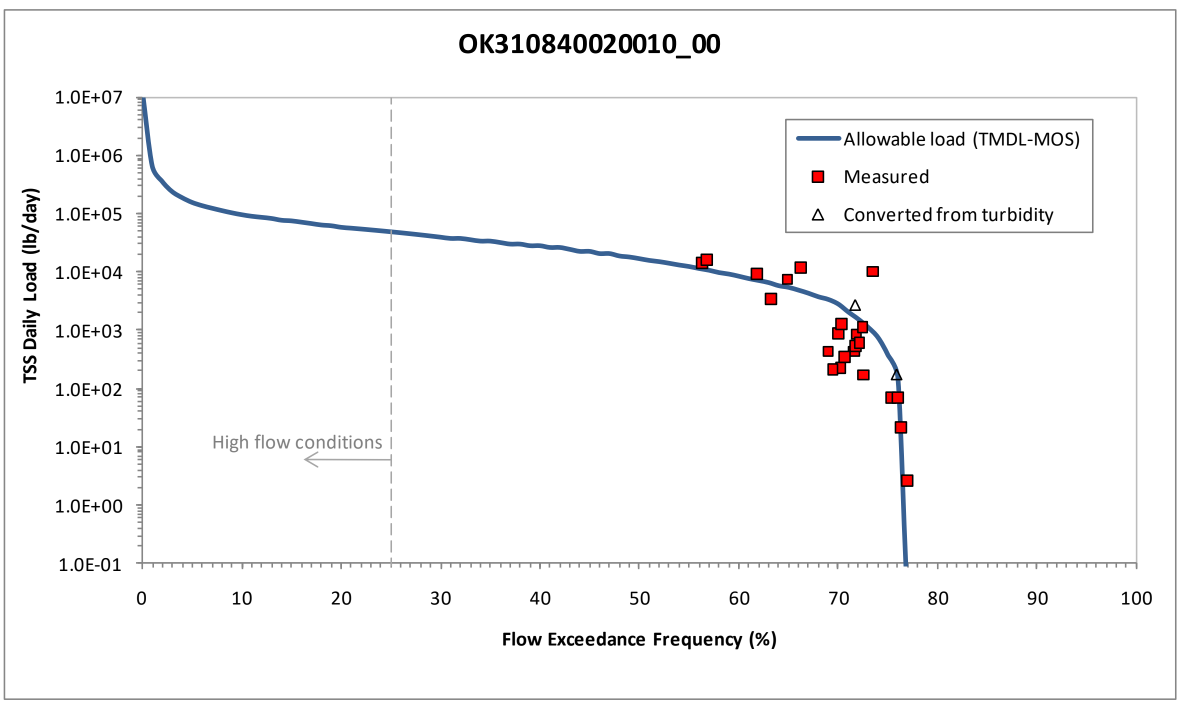


Figure 5-13 Load Duration Curve for Total Suspended Solids in Washita River at SH 33, McLure

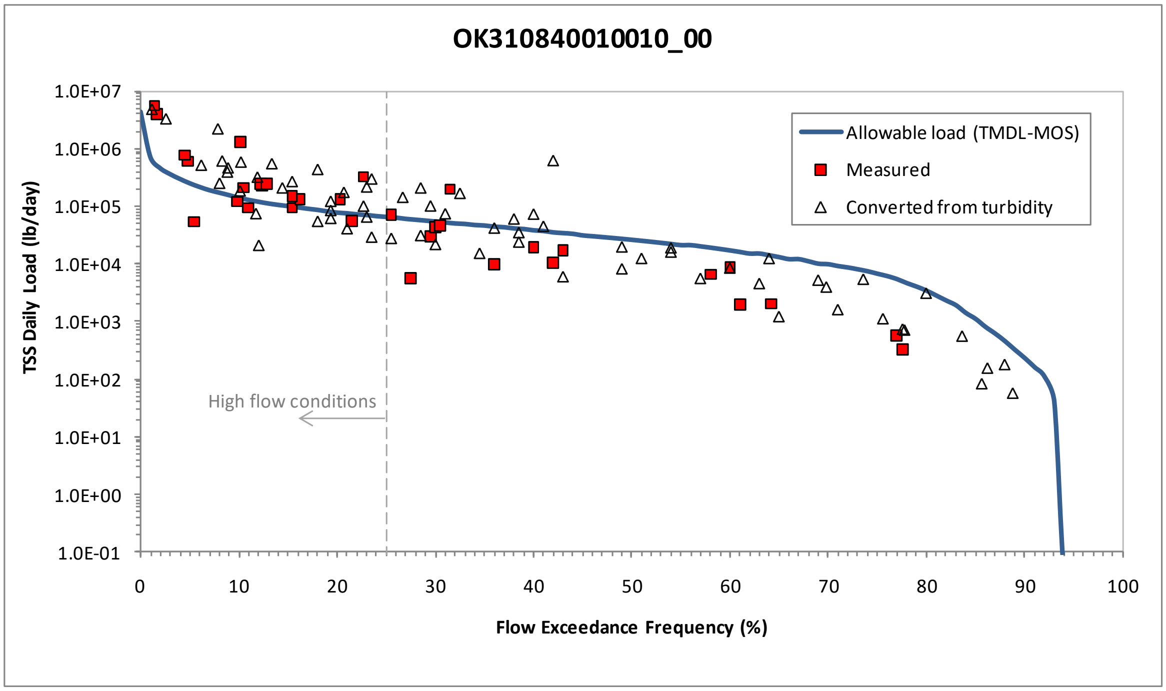


Figure 5-14 Load Duration Curve for Total Suspended Solids in Washita River at SH 152, Cordell

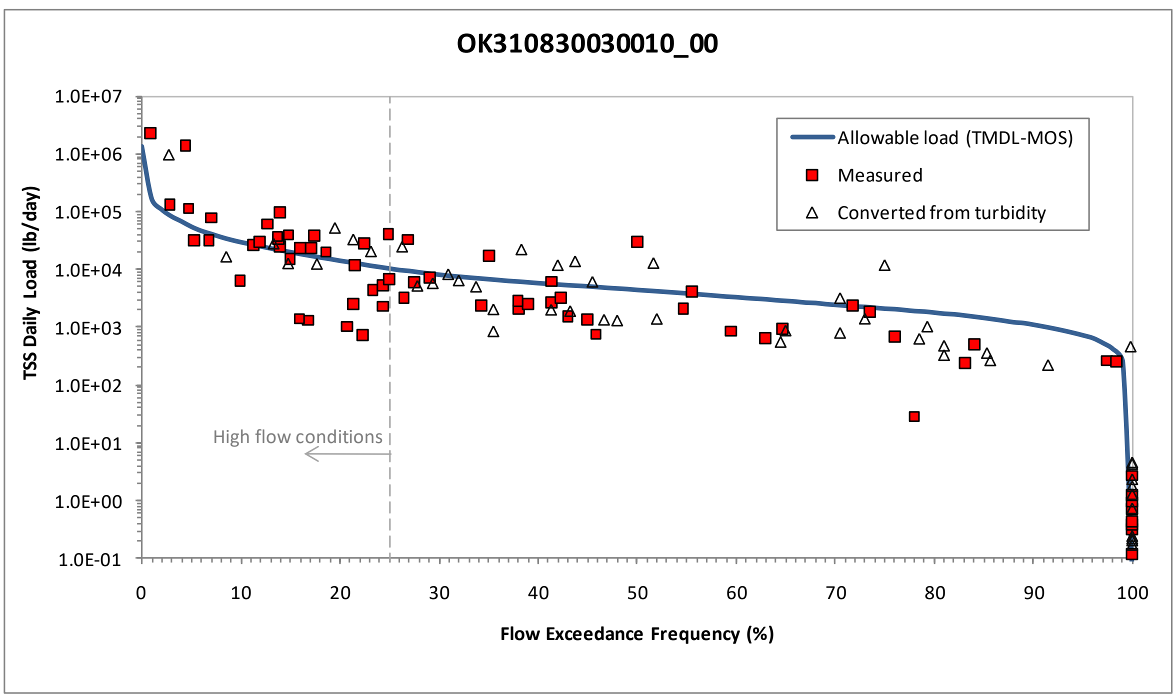


Figure 5-15 Load Duration Curve for Total Suspended Solids in Rainy Mountain Creek

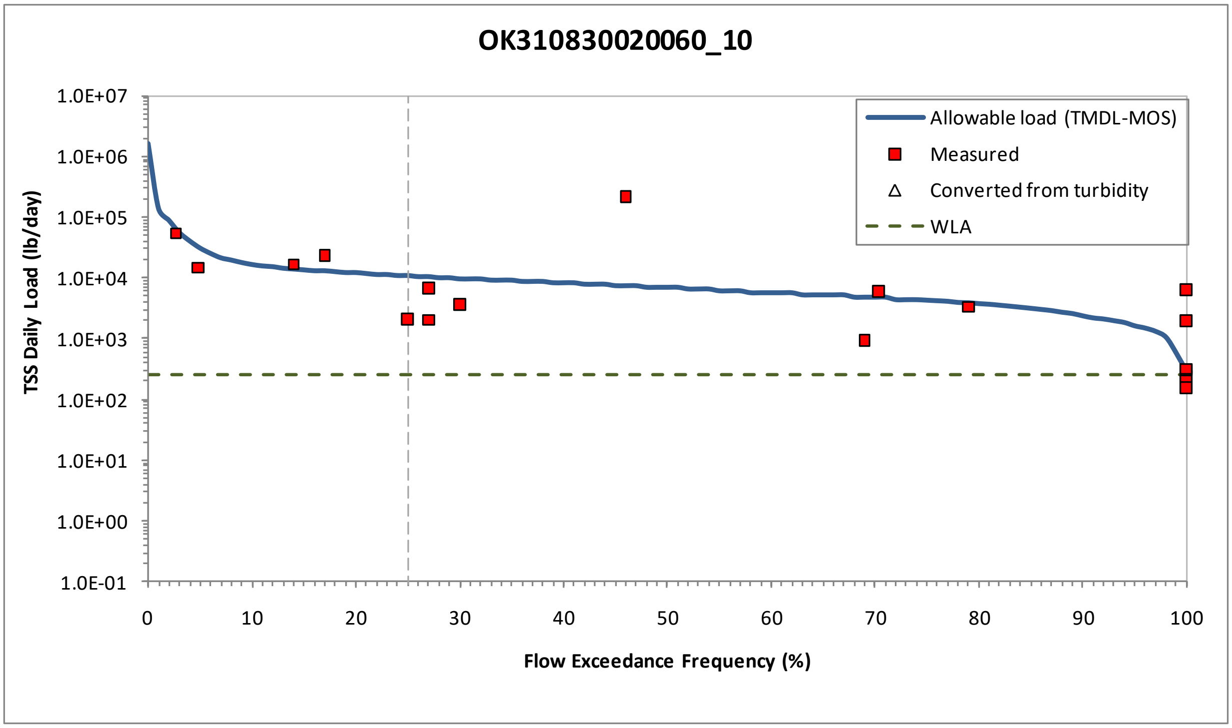


Figure 5-16 Load Duration Curve for Total Suspended Solids in Stinking Creek

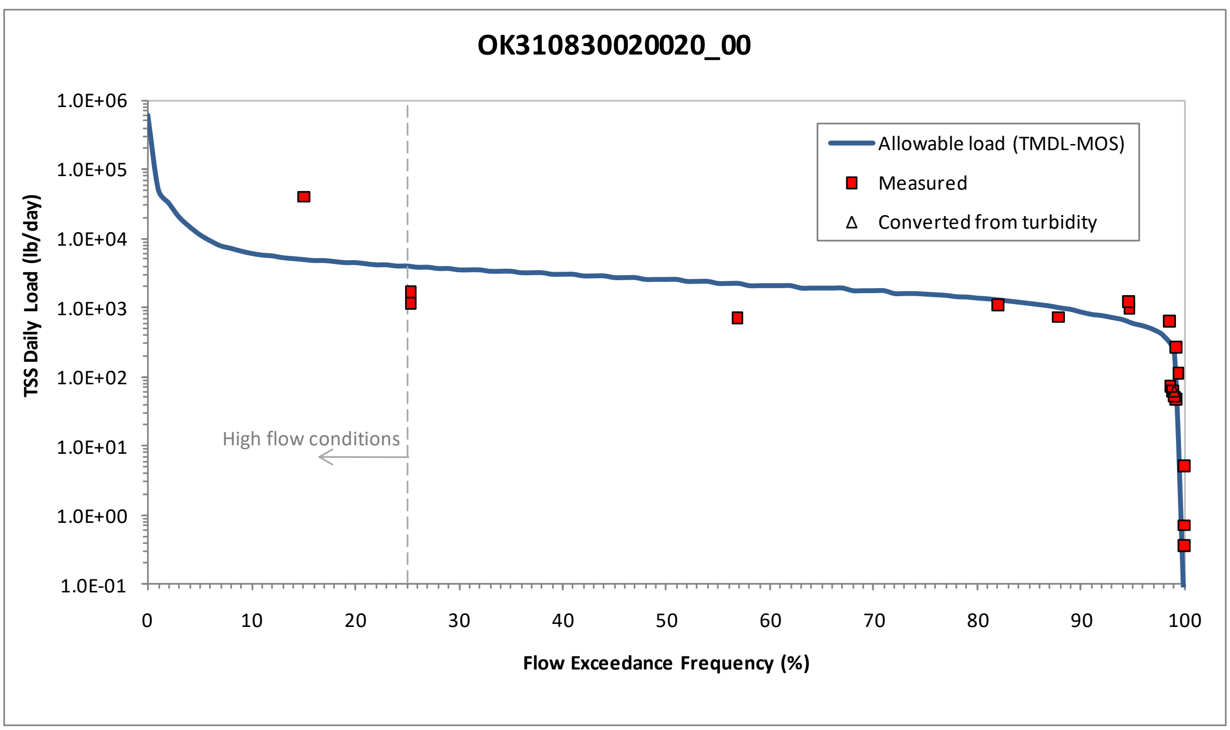


Figure 5-17 Load Duration Curve for Total Suspended Solids in Washita River at US 281, Anadarko

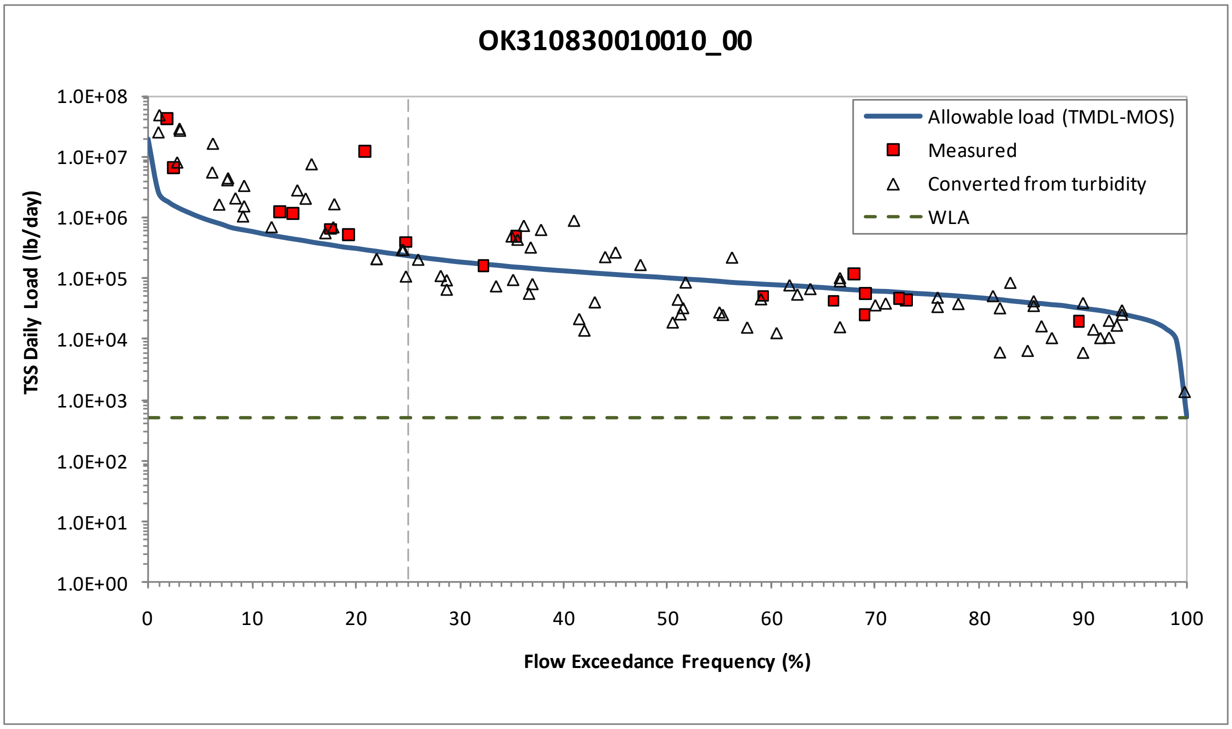


Figure 5-18 Load Duration Curve for Total Suspended Solids in Wildhorse Creek

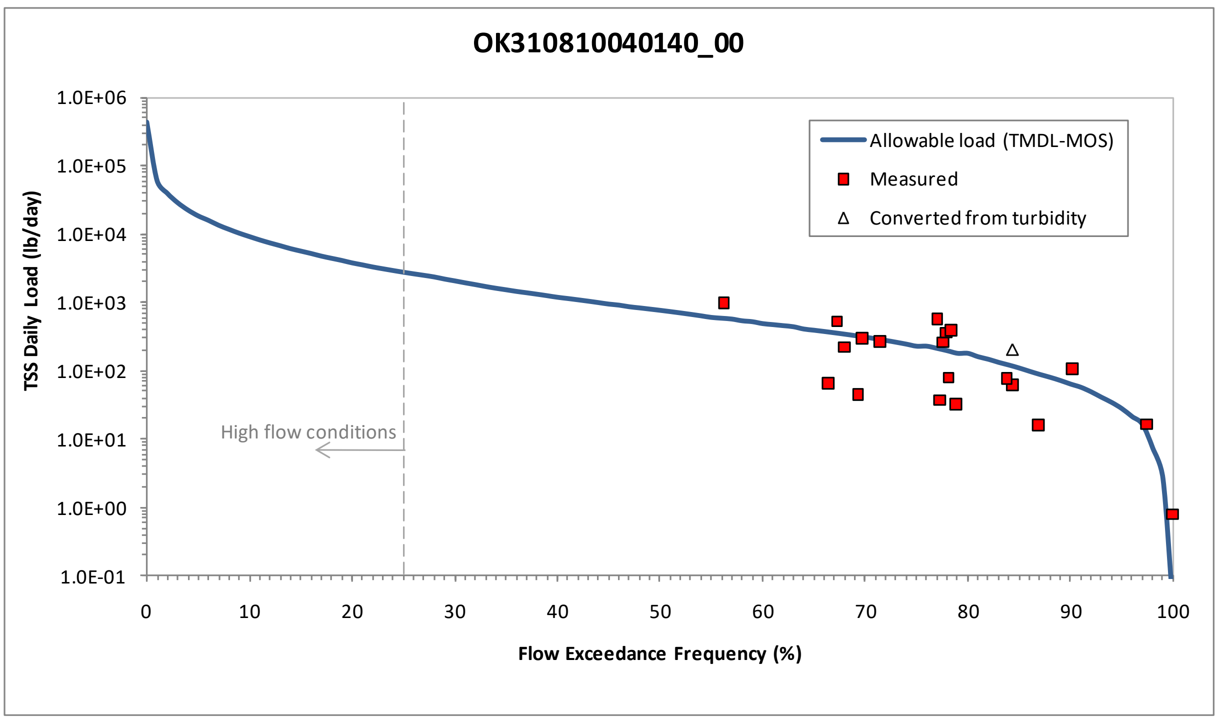


Figure 5-19 Load Duration Curve for Total Suspended Solids in Washita River at SH 19, near Alex

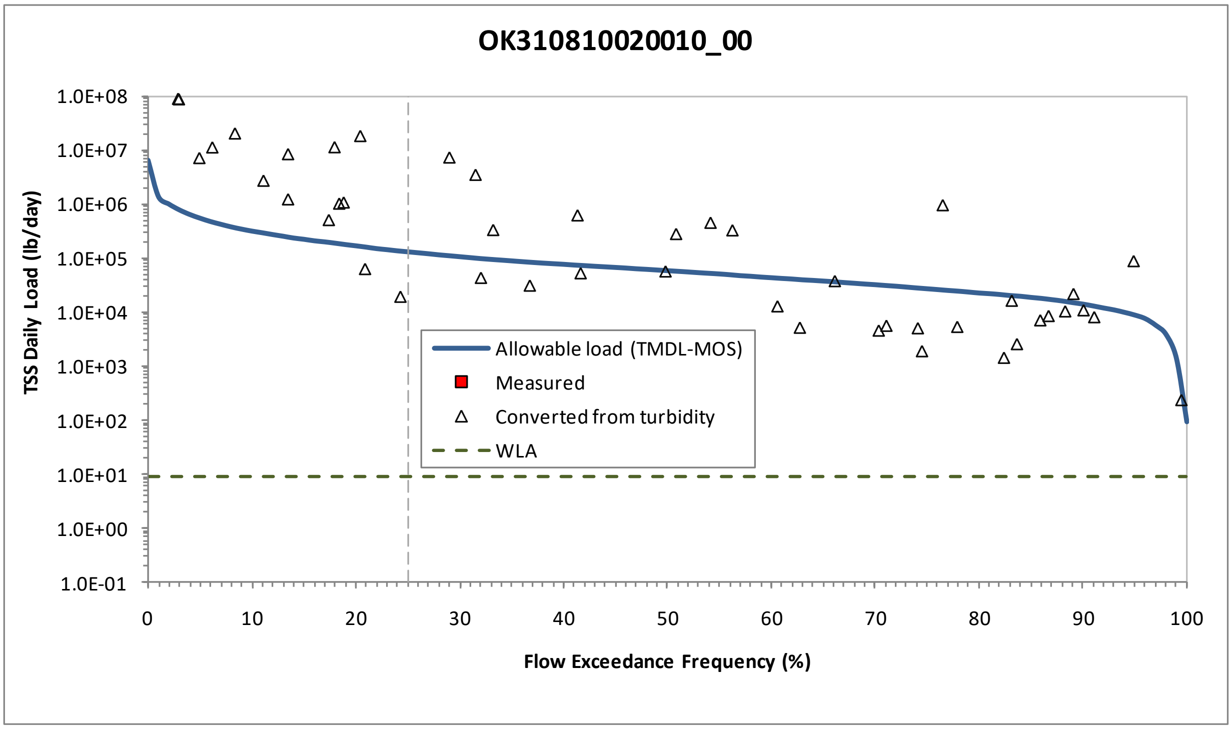


Figure 5-20 Load Duration Curve for Total Suspended Solids in Washington Creek

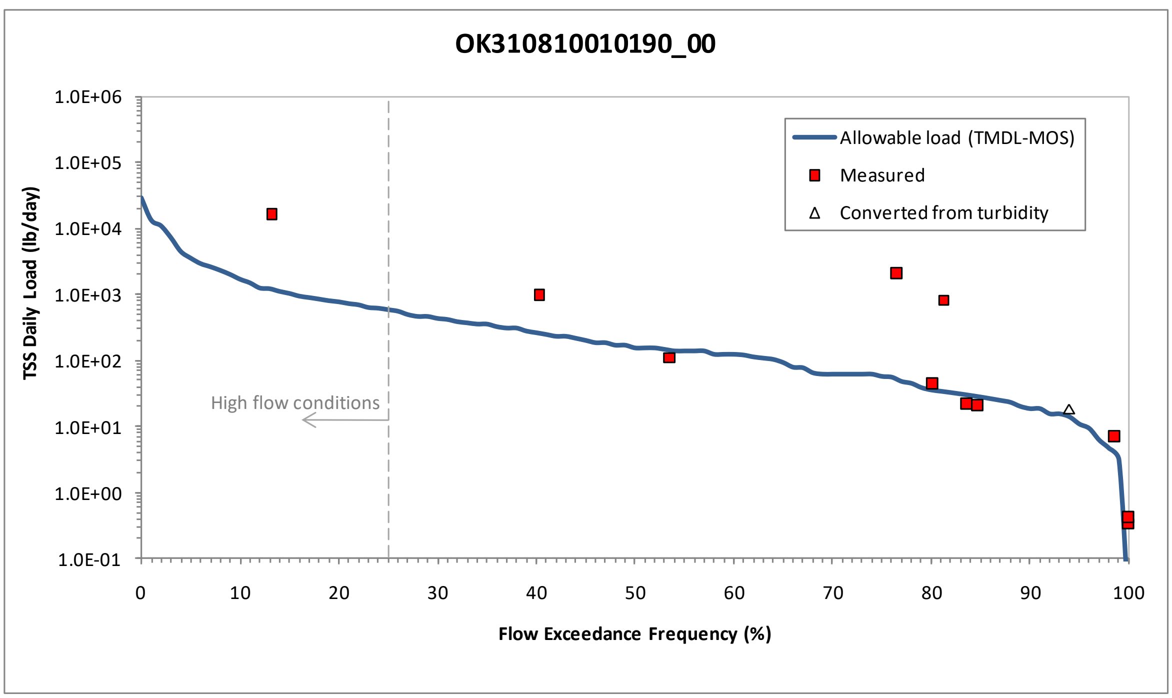


Figure 5-21 Load Duration Curve for Total Suspended Solids in Kickapoo Sandy Creek

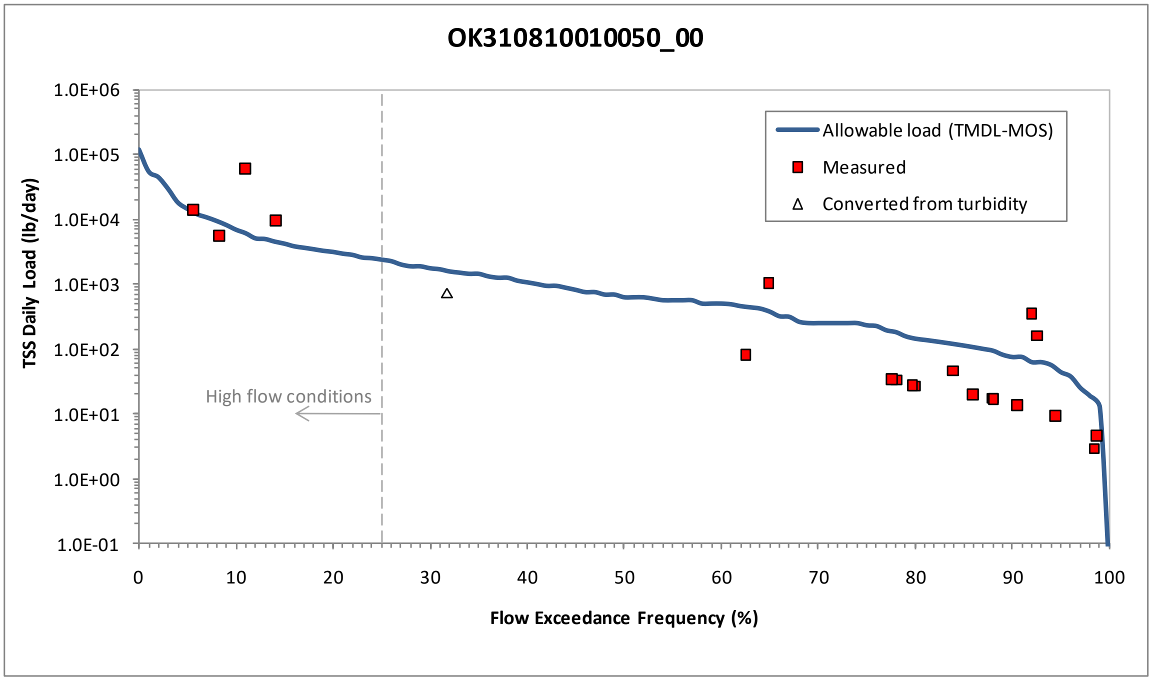


Figure 5-22 Load Duration Curve for Total Suspended Solids in Washita River at SH 19, Pauls Valley

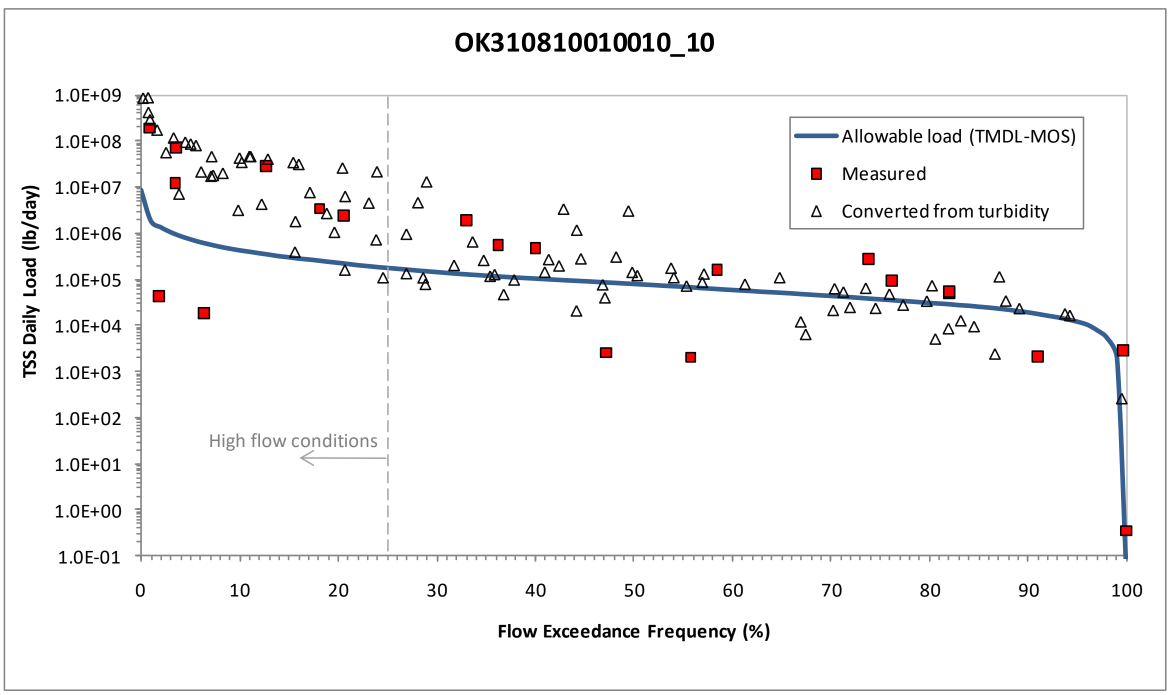


Figure 5-23 Load Duration Curve for Total Suspended Solids in Sand Branch

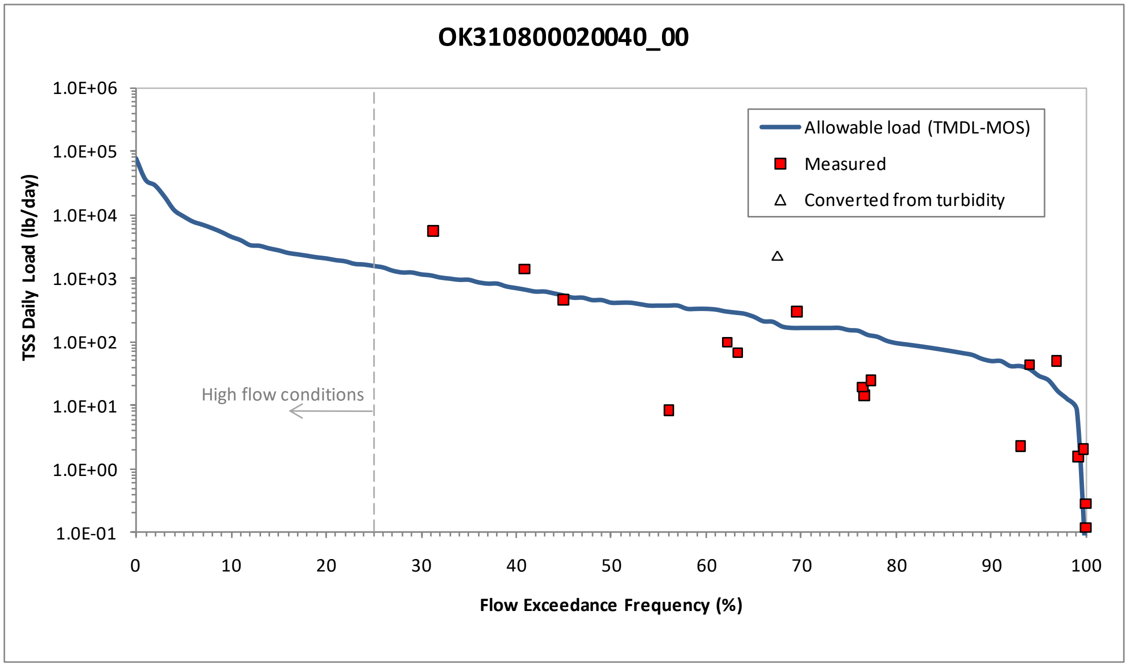
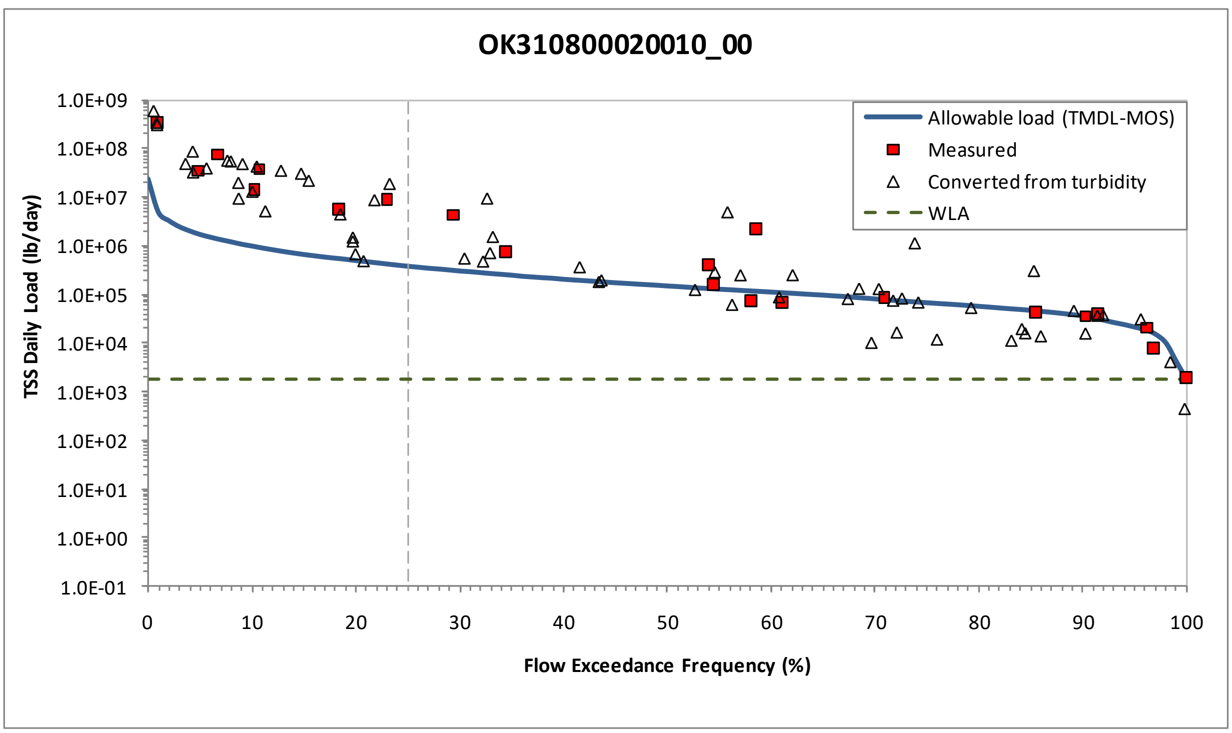


Figure 5-24 Load Duration Curve for Total Suspended Solids in Washita River at US 177, Durwood



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 no 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 PRGs range from 41 to 97 percent.

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
OK310840020020_00	Sandstone Creek		86%	**41%**	99%	**85%**
OK310830020020_00	Stinking Creek		64%	**47%**	91%	**86%**
OK310810040140_00	Wildhorse Creek		78%	**70%**	98%	**93%**
OK310810020010_00	Washita River at SH 19, near Alex	**82%**			99%	**86%**
OK310810010050_00	Kickapoo Sandy Creek		**64%**	67%	91%	**89%**

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 5-2 and range from 29 to 96 percent.

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK310840020020_00	Sandstone Creek	56%
OK310840020010_00	Washita River at Site #384	29%
OK310840010010_00	Washita River at SH 33, McLure	74%
OK310830030010_00	Washita River at SH 152, Cordell	73%
OK310830020060_10	Rainy Mountain Creek	96%
OK310830020020_00	Stinking Creek	50%
OK310830010010_00	Washita River at US 281, Anadarko	58%
OK310810040140_00	Wildhorse Creek	51%
OK310810020010_00	Washita River at SH 19, near Alex	77%
OK310810010190_00	Washington Creek	93%
OK310810010050_00	Kickapoo Sandy Creek	64%
OK310810010010_10	Washita River at SH 19, Pauls Valley	83%
OK310800020040_00	Sand Branch	66%
OK310800020010_00	Washita River at US 177, Durwood	85%

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. Table 5-3 summarizes the WLA for the NPDES-permitted facilities within the Washita River Study Area. The WLA for each facility discharging to a bacteria-impaired reach is derived from the following equation:

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

Where:

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

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

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

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES WWTPs discharging into the contributing watershed of a WQM station, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform limits and disinfection requirements of NPDES permits. Table 5-3 indicates which point source dischargers within Oklahoma currently have a disinfection requirement in their permit. Certain facilities that utilize lagoons for treatment have not been required to provide disinfection since storage time and exposure to ultraviolet radiation from sunlight should reduce bacteria levels. In the future, all point source dischargers which are assigned a wasteload allocation but do not currently have a bacteria limit in their permit will receive a permit limit consistent with the wasteload allocation as their permits are reissued. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacteria load from existing discharges will be considered consistent with the TMDL provided that the NPDES permit requires instream criteria to be met.

Table 5-3 Bacteria Wasteload Allocations for NPDES-Permitted Facilities

Waterbody ID	NPDES Permit No.	Name	Dis-infection	Design Flow (mgd)	Wasteload Allocation (cfu/day)		
					Fecal Coliform	*E. Coli*	Enterococci
OK310810020010_00	OKG580021	City of Lindsay	No	0.42	3.18E+09	-	5.25E+08
	OKG830039	Leonard's Sinclair	No	0.079[a]	5.98E+08	-	9.87E+07

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

5.2.2 Total Suspended Solids

NPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated by using the maximum self-reported monthly average flow multiplied by the water quality target. In other words, the facilities are required to meet instream criteria in their discharge. If the current monthly TSS limits of a facility are greater than instream TSS criteria, the new limits equal to instream criteria will be applied to the facility as their permit is renewed. Table 5-4 summarizes the WLA for the seven NPDES-permitted facilities within the Washita River Study Area. The WLA for each facility is derived as follows:

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

Where:

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

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

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

Table 5-4 Total Suspended Solids Wasteload Allocations for NPDES-Permitted Facilities

Waterbody ID	Instream TSS Criteria (mg/L)	NPDES Permit No.	Name	Maximum Monthly Average Flow (mgd)	Wasteload Allocation (lb/day)
OK310830020060_10	52	OKG950036	Dolese Brothers Co.-Cooperton	0.54	262
OK310830010010_00	73	OK0000639	Western Farmers Electric Co-Op Anadarko Station	0.69	497
OK310810020010_00	34	OK0000124	Oneok Field Services-Maysville	0.03	9
OK310800020010_00	46	OK0001295	TPI Petroleum – Valero Ardmore Refinery	1.62	623
		OKG270054	Ergon Asphalt	0.12	46
		OK0044288	East Jordan Iron Works	0.34	153
		OKG950033	Dolese Brothers Co.-Big Canyon	2.1	773
		OKG380061	Ardmore WTP	0.96	160

[a] DMR for this facility only reported no discharge conditions for the period 2007-2008, so a small flow was assumed for the WLA

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 401 certification 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 401 certification 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 1st through September 30th. Similarly, the TSS TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.5 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 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 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 NRMSE for each waterbody. The explicit MOS ranges from 10 percent to 25 percent. Table 5-5 shows the MOS for each waterbody.

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

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK310840020020_00	Sandstone Creek	8.8%	10%
OK310840020010_00	Washita River at Site #384	19.4%	20%
OK310840010010_00	Washita River at SH 33, McLure	10.5%	15%

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK310830030010_00	Washita River at SH 152, Cordell	12.5%	15%
OK310830020060_10	Rainy Mountain Creek	7.5%	10%
OK310830020020_00	Stinking Creek	7.5%	10%
OK310830010010_00	Washita River at US 281, Anadarko	15.5%	15%
OK310810040140_00	Wildhorse Creek	6.0%	10%
OK310810020010_00	Washita River at SH 19, near Alex	14.9%	15%
OK310810010190_00	Washington Creek	24.8%	25%
OK310810010050_00	Kickapoo Sandy Creek	7.3%	10%
OK310810010010_10	Washita River at SH 19, Pauls Valley	13.2%	15%
OK310800020040_00	Sand Branch	23.1%	25%
OK310800020010_00	Washita River at US 177, Durwood	15.0%	15%

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 Kickapoo Sandy Creek is 60 mg/L and the MOS is 10%. The resulting water quality target will be 54 mg/L (60 x (1 - 0.1) = 54). 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 5-6 through 5-15 summarize the allocations for indicator bacteria and Tables 5-16 to 5-29 present the allocations for total suspended solids.

Table 5-6 *E. coli* TMDL Calculations for Sandstone Creek (OK310840020020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,918	2.90E+13	0	2.61E+13	2.90E+12
5	55	5.49E+11	0	4.94E+11	5.49E+10
10	30	2.94E+11	0	2.64E+11	2.94E+10
15	24	2.40E+11	0	2.16E+11	2.40E+10
20	22	2.16E+11	0	1.95E+11	2.16E+10
25	19	1.93E+11	0	1.74E+11	1.93E+10
30	17	1.70E+11	0	1.53E+11	1.70E+10
35	16	1.62E+11	0	1.46E+11	1.62E+10
40	15	1.47E+11	0	1.32E+11	1.47E+10
45	13	1.31E+11	0	1.18E+11	1.31E+10
50	12	1.24E+11	0	1.11E+11	1.24E+10
55	11	1.08E+11	0	9.74E+10	1.08E+10
60	10	1.00E+11	0	9.04E+10	1.00E+10
65	9	9.28E+10	0	8.35E+10	9.28E+09
70	9	8.50E+10	0	7.65E+10	8.50E+09
75	8	7.58E+10	0	6.82E+10	7.58E+09
80	7	6.65E+10	0	5.98E+10	6.65E+09
85	6	5.57E+10	0	5.01E+10	5.57E+09
90	4	4.17E+10	0	3.76E+10	4.17E+09
95	3	2.86E+10	0	2.57E+10	2.86E+09
100	0	0	0	0	0

Table 5-7 Enterococci TMDL Calculations for Sandstone Creek (OK310840020020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,918	7.71E+12	0	6.94E+12	7.71E+11
5	55	1.46E+11	0	1.31E+11	1.46E+10
10	30	7.81E+10	0	7.03E+10	7.81E+09
15	24	6.37E+10	0	5.74E+10	6.37E+09
20	22	5.76E+10	0	5.18E+10	5.76E+09
25	19	5.14E+10	0	4.63E+10	5.14E+09
30	17	4.52E+10	0	4.07E+10	4.52E+09
35	16	4.32E+10	0	3.89E+10	4.32E+09
40	15	3.91E+10	0	3.52E+10	3.91E+09
45	13	3.50E+10	0	3.15E+10	3.50E+09
50	12	3.29E+10	0	2.96E+10	3.29E+09
55	11	2.88E+10	0	2.59E+10	2.88E+09
60	10	2.67E+10	0	2.41E+10	2.67E+09
65	9	2.47E+10	0	2.22E+10	2.47E+09
70	9	2.26E+10	0	2.04E+10	2.26E+09
75	8	2.02E+10	0	1.81E+10	2.02E+09
80	7	1.77E+10	0	1.59E+10	1.77E+09
85	6	1.48E+10	0	1.33E+10	1.48E+09
90	4	1.11E+10	0	9.99E+09	1.11E+09
95	3	7.61E+09	0	6.85E+09	7.61E+08
100	0	0	0	0	0

Table 5-8 *E.coli* TMDL Calculations for Stinking Creek (OK310830020020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,967	2.95E+13	0	2.65E+13	2.95E+12
5	56	5.58E+11	0	5.02E+11	5.58E+10
10	30	2.99E+11	0	2.69E+11	2.99E+10
15	25	2.44E+11	0	2.19E+11	2.44E+10
20	22	2.20E+11	0	1.98E+11	2.20E+10
25	20	1.97E+11	0	1.77E+11	1.97E+10
30	17	1.73E+11	0	1.56E+11	1.73E+10
35	17	1.65E+11	0	1.49E+11	1.65E+10
40	15	1.49E+11	0	1.34E+11	1.49E+10
45	13	1.34E+11	0	1.20E+11	1.34E+10
50	13	1.26E+11	0	1.13E+11	1.26E+10
55	11	1.10E+11	0	9.90E+10	1.10E+10
60	10	1.02E+11	0	9.20E+10	1.02E+10
65	9	9.43E+10	0	8.49E+10	9.43E+09
70	9	8.65E+10	0	7.78E+10	8.65E+09
75	8	7.70E+10	0	6.93E+10	7.70E+09
80	7	6.76E+10	0	6.08E+10	6.76E+09
85	6	5.66E+10	0	5.09E+10	5.66E+09
90	4	4.24E+10	0	3.82E+10	4.24E+09
95	3	2.91E+10	0	2.62E+10	2.91E+09
100	0	0	0	0	0

Table 5-9 Enterococci TMDL Calculations for Stinking Creek (OK310830020020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,967	7.84E+12	0	7.06E+12	7.84E+11
5	56	1.48E+11	0	1.34E+11	1.48E+10
10	30	7.95E+10	0	7.15E+10	7.95E+09
15	25	6.48E+10	0	5.83E+10	6.48E+09
20	22	5.85E+10	0	5.27E+10	5.85E+09
25	20	5.23E+10	0	4.70E+10	5.23E+09
30	17	4.60E+10	0	4.14E+10	4.60E+09
35	17	4.39E+10	0	3.95E+10	4.39E+09
40	15	3.97E+10	0	3.58E+10	3.97E+09
45	13	3.55E+10	0	3.20E+10	3.55E+09
50	13	3.35E+10	0	3.01E+10	3.35E+09
55	11	2.93E+10	0	2.63E+10	2.93E+09
60	10	2.72E+10	0	2.45E+10	2.72E+09
65	9	2.51E+10	0	2.26E+10	2.51E+09
70	9	2.30E+10	0	2.07E+10	2.30E+09
75	8	2.05E+10	0	1.84E+10	2.05E+09
80	7	1.80E+10	0	1.62E+10	1.80E+09
85	6	1.51E+10	0	1.35E+10	1.51E+09
90	4	1.13E+10	0	1.02E+10	1.13E+09
95	3	7.74E+09	0	6.96E+09	7.74E+08
100	0	0	0	0	0

Table 5-10 *E.coli* TMDL Calculations for Wildhorse Creek (OK310810040140_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,452	1.44E+13	0	1.30E+13	1.44E+12
5	61	6.09E+11	0	5.48E+11	6.09E+10
10	30	3.02E+11	0	2.72E+11	3.02E+10
15	19	1.85E+11	0	1.67E+11	1.85E+10
20	13	1.24E+11	0	1.12E+11	1.24E+10
25	9	9.08E+10	0	8.17E+10	9.08E+09
30	7	6.78E+10	0	6.11E+10	6.78E+09
35	5	5.02E+10	0	4.52E+10	5.02E+09
40	4	3.90E+10	0	3.51E+10	3.90E+09
45	3	3.10E+10	0	2.79E+10	3.10E+09
50	3	2.51E+10	0	2.26E+10	2.51E+09
55	2	1.98E+10	0	1.78E+10	1.98E+09
60	2	1.60E+10	0	1.44E+10	1.60E+09
65	1	1.28E+10	0	1.15E+10	1.28E+09
70	1	1.02E+10	0	9.14E+09	1.02E+09
75	1	7.48E+09	0	6.73E+09	7.48E+08
80	1	5.88E+09	0	5.29E+09	5.88E+08
85	0.4	3.58E+09	0	3.22E+09	3.58E+08
90	0.2	2.08E+09	0	1.88E+09	2.08E+08
95	0.09	9.08E+08	0	8.17E+08	9.08E+07
100	0	0	0	0	0

Table 5-11 Enterococci TMDL Calculations for Wildhorse Creek (OK310810040140_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,452	3.84E+12	0	3.45E+12	3.84E+11
5	61	1.62E+11	0	1.46E+11	1.62E+10
10	30	8.04E+10	0	7.24E+10	8.04E+09
15	19	4.93E+10	0	4.44E+10	4.93E+09
20	13	3.31E+10	0	2.98E+10	3.31E+09
25	9	2.42E+10	0	2.17E+10	2.42E+09
30	7	1.80E+10	0	1.62E+10	1.80E+09
35	5	1.34E+10	0	1.20E+10	1.34E+09
40	4	1.04E+10	0	9.34E+09	1.04E+09
45	3	8.24E+09	0	7.42E+09	8.24E+08
50	3	6.68E+09	0	6.01E+09	6.68E+08
55	2	5.26E+09	0	4.73E+09	5.26E+08
60	2	4.26E+09	0	3.84E+09	4.26E+08
65	1	3.41E+09	0	3.07E+09	3.41E+08
70	1	2.70E+09	0	2.43E+09	2.70E+08
75	1	1.99E+09	0	1.79E+09	1.99E+08
80	1	1.56E+09	0	1.41E+09	1.56E+08
85	0.4	9.52E+08	0	8.57E+08	9.52E+07
90	0.2	5.54E+08	0	4.99E+08	5.54E+07
95	0.09	2.42E+08	0	2.17E+08	2.42E+07
100	0	0	0	0	0

Table 5-12 Fecal Coliform TMDL Calculations for Washita River at SH 19, near Alex (OK310810020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	34,479	3.37E+14	3.78E+09	3.04E+14	3.37E+13
5	2,927	2.86E+13	3.78E+09	2.58E+13	2.86E+12
10	1,687	1.65E+13	3.78E+09	1.49E+13	1.65E+12
15	1,191	1.17E+13	3.78E+09	1.05E+13	1.17E+12
20	901	8.82E+12	3.78E+09	7.93E+12	8.82E+11
25	699	6.84E+12	3.78E+09	6.15E+12	6.84E+11
30	567	5.55E+12	3.78E+09	4.99E+12	5.55E+11
35	475	4.64E+12	3.78E+09	4.18E+12	4.64E+11
40	410	4.01E+12	3.78E+09	3.61E+12	4.01E+11
45	359	3.51E+12	3.78E+09	3.16E+12	3.51E+11
50	313	3.06E+12	3.78E+09	2.75E+12	3.06E+11
55	272	2.66E+12	3.78E+09	2.39E+12	2.66E+11
60	232	2.27E+12	3.78E+09	2.04E+12	2.27E+11
65	201	1.97E+12	3.78E+09	1.77E+12	1.97E+11
70	172	1.68E+12	3.78E+09	1.51E+12	1.68E+11
75	145	1.42E+12	3.78E+09	1.27E+12	1.42E+11
80	121	1.18E+12	3.78E+09	1.06E+12	1.18E+11
85	100	9.79E+11	3.78E+09	8.77E+11	9.79E+10
90	75	7.36E+11	3.78E+09	6.59E+11	7.36E+10
95	47	4.61E+11	3.78E+09	4.11E+11	4.61E+10
100	0.5	4.89E+09	3.78E+09	6.25E+08	4.89E+08

Table 5-13 Enterococci TMDL Calculations for Washita River at SH 19, near Alex (OK310810020010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	34,479	9.11E+13	6.24E+08	8.20E+13	9.11E+12
5	2,927	7.73E+12	6.24E+08	6.96E+12	7.73E+11
10	1,687	4.46E+12	6.24E+08	4.01E+12	4.46E+11
15	1,191	3.15E+12	6.24E+08	2.83E+12	3.15E+11
20	901	2.38E+12	6.24E+08	2.14E+12	2.38E+11
25	699	1.85E+12	6.24E+08	1.66E+12	1.85E+11
30	567	1.50E+12	6.24E+08	1.35E+12	1.50E+11
35	475	1.25E+12	6.24E+08	1.13E+12	1.25E+11
40	410	1.08E+12	6.24E+08	9.75E+11	1.08E+11
45	359	9.48E+11	6.24E+08	8.53E+11	9.48E+10
50	313	8.26E+11	6.24E+08	7.43E+11	8.26E+10
55	272	7.19E+11	6.24E+08	6.46E+11	7.19E+10
60	232	6.12E+11	6.24E+08	5.50E+11	6.12E+10
65	201	5.31E+11	6.24E+08	4.77E+11	5.31E+10
70	172	4.54E+11	6.24E+08	4.08E+11	4.54E+10
75	145	3.82E+11	6.24E+08	3.43E+11	3.82E+10
80	121	3.19E+11	6.24E+08	2.86E+11	3.19E+10
85	100	2.64E+11	6.24E+08	2.37E+11	2.64E+10
90	75	1.99E+11	6.24E+08	1.78E+11	1.99E+10
95	47	1.25E+11	6.24E+08	1.11E+11	1.25E+10
100	0.5	1.32E+09	6.24E+08	5.66E+08	1.32E+08

Table 5-14 *E.coli* TMDL Calculations for Kickapoo Sandy Creek (OK310810010050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	404	4.02E+12	0	3.62E+12	4.02E+11
5	49	4.89E+11	0	4.40E+11	4.89E+10
10	24	2.34E+11	0	2.10E+11	2.34E+10
15	14	1.42E+11	0	1.28E+11	1.42E+10
20	11	1.06E+11	0	9.56E+10	1.06E+10
25	8	8.08E+10	0	7.27E+10	8.08E+09
30	6	5.95E+10	0	5.36E+10	5.95E+09
35	5	4.89E+10	0	4.40E+10	4.89E+09
40	4	3.61E+10	0	3.25E+10	3.61E+09
45	3	2.76E+10	0	2.49E+10	2.76E+09
50	2.1	2.13E+10	0	1.91E+10	2.13E+09
55	1.9	1.91E+10	0	1.72E+10	1.91E+09
60	1.7	1.70E+10	0	1.53E+10	1.70E+09
65	1.3	1.28E+10	0	1.15E+10	1.28E+09
70	0.9	8.50E+09	0	7.65E+09	8.50E+08
75	0.8	7.86E+09	0	7.08E+09	7.86E+08
80	0.5	4.89E+09	0	4.40E+09	4.89E+08
85	0.4	3.83E+09	0	3.44E+09	3.83E+08
90	0.3	2.55E+09	0	2.30E+09	2.55E+08
95	0.1	1.49E+09	0	1.34E+09	1.49E+08
100	0	0	0	0	0

Table 5-15 Enterococci TMDL Calculations for Kickapoo Sandy Creek (OK310810010050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	404	1.07E+12	0	9.62E+11	1.07E+11
5	49	1.30E+11	0	1.17E+11	1.30E+10
10	24	6.22E+10	0	5.60E+10	6.22E+09
15	14	3.79E+10	0	3.41E+10	3.79E+09
20	11	2.83E+10	0	2.54E+10	2.83E+09
25	8	2.15E+10	0	1.93E+10	2.15E+09
30	6	1.58E+10	0	1.42E+10	1.58E+09
35	5	1.30E+10	0	1.17E+10	1.30E+09
40	4	9.61E+09	0	8.65E+09	9.61E+08
45	3	7.35E+09	0	6.61E+09	7.35E+08
50	2.1	5.65E+09	0	5.09E+09	5.65E+08
55	1.9	5.09E+09	0	4.58E+09	5.09E+08
60	1.7	4.52E+09	0	4.07E+09	4.52E+08
65	1.3	3.39E+09	0	3.05E+09	3.39E+08
70	0.9	2.26E+09	0	2.04E+09	2.26E+08
75	0.8	2.09E+09	0	1.88E+09	2.09E+08
80	0.5	1.30E+09	0	1.17E+09	1.30E+08
85	0.4	1.02E+09	0	9.16E+08	1.02E+08
90	0.3	6.78E+08	0	6.11E+08	6.78E+07
95	0.1	3.96E+08	0	3.56E+08	3.96E+07
100	0	0	0	0	0

Table 5-16 Total Suspended Solids TMDL Calculations for Sandstone Creek (OK310840020020_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	2,918	NA	NA	NA	NA	NA
5	55	NA	NA	NA	NA	NA
10	30	NA	NA	NA	NA	NA
15	24	NA	NA	NA	NA	NA
20	22	NA	NA	NA	NA	NA
25	19	6,255	0	63	5,567	625
30	17	5,504	0	55	4,899	550
35	16	5,254	0	53	4,676	525
40	15	4,753	0	48	4,231	475
45	13	4,253	0	43	3,785	425
50	12	4,003	0	40	3,563	400
55	11	3,503	0	35	3,117	350
60	10	3,252	0	33	2,895	325
65	9	3,002	0	30	2,672	300
70	9	2,752	0	28	2,449	275
75	8	2,452	0	25	2,182	245
80	7	2,152	0	22	1,915	215
85	6	1,801	0	18	1,603	180
90	4	1,351	0	14	1,202	135
95	3	926	0	9	824	93
100	0	0	0	0	0	0

NA = Not applicable

Table 5-17 Total Suspended Solids TMDL Calculations for Washita River at Site #384 (OK310840020010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	55,907	NA	NA	NA	NA	NA
5	658	NA	NA	NA	NA	NA
10	404	NA	NA	NA	NA	NA
15	317	NA	NA	NA	NA	NA
20	246	NA	NA	NA	NA	NA
25	206	61,499	0	615	48,584	12,300
30	167	49,672	0	497	39,241	9,934
35	143	42,576	0	426	33,635	8,515
40	119	35,480	0	355	28,029	7,096
45	95	28,384	0	284	22,424	5,677
50	71	21,288	0	213	16,818	4,258
55	52	15,611	0	156	12,333	3,122
60	36	10,644	0	106	8,409	2,129
65	23	6,860	0	69	5,419	1,372
70	12	3,548	0	35	2,803	710
75	2	473	0	5	374	95
80	0	0	0	0	0	0
85	0	0	0	0	0	0
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 5-18 Total Suspended Solids TMDL Calculations for Washita River at SH 33, McLure (OK310840010010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	10,766	NA	NA	NA	NA	NA
5	618	NA	NA	NA	NA	NA
10	345	NA	NA	NA	NA	NA
15	248	NA	NA	NA	NA	NA
20	191	NA	NA	NA	NA	NA
25	161	76,534	0	765	64,288	11,480
30	134	63,582	0	636	53,409	9,537
35	114	54,162	0	542	45,496	8,124
40	94	44,743	0	447	37,584	6,711
45	77	36,501	0	365	30,661	5,475
50	64	30,614	0	306	25,715	4,592
55	52	24,726	0	247	20,770	3,709
60	42	20,017	0	200	16,814	3,002
65	32	15,307	0	153	12,858	2,296
70	24	11,539	0	115	9,693	1,731
75	17	7,889	0	79	6,627	1,183
80	8	4,003	0	40	3,363	600
85	3	1,295	0	13	1,088	194
90	1	271	0	3	227	41
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not applicable

Table 5-19 Total Suspended Solids TMDL Calculations for Washita River at SH 152, Cordell (OK310830030010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	3,748	NA	NA	NA	NA	NA
5	153	NA	NA	NA	NA	NA
10	83	NA	NA	NA	NA	NA
15	56	NA	NA	NA	NA	NA
20	39	NA	NA	NA	NA	NA
25	29	12,120	0	121	10,181	1,818
30	23	9,491	0	95	7,972	1,424
35	19	7,931	0	79	6,662	1,190
40	16	6,773	0	68	5,689	1,016
45	14	5,971	0	60	5,015	896
50	12	5,169	0	52	4,342	775
55	11	4,500	0	45	3,780	675
60	9	3,877	0	39	3,256	581
65	8	3,342	0	33	2,807	501
70	7	2,852	0	29	2,395	428
75	6	2,451	0	25	2,059	368
80	5	2,094	0	21	1,759	314
85	4	1,693	0	17	1,422	254
90	3	1,292	0	13	1,085	194
95	2	847	0	8	711	127
100	0	0	0	0	0	0

NA = Not applicable

Table 5-20 Total Suspended Solids TMDL Calculations for Rainy Mountain Creek (OK310830020060_10)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	5,884	NA	NA	NA	NA	NA
5	111	NA	NA	NA	NA	NA
10	60	NA	NA	NA	NA	NA
15	49	NA	NA	NA	NA	NA
20	44	NA	NA	NA	NA	NA
25	39	12,314	262	123	10,697	1,231
30	35	10,837	262	108	9,382	1,084
35	33	10,344	262	103	8,944	1,034
40	30	9,359	262	94	8,067	936
45	27	8,374	262	84	7,190	837
50	25	7,881	262	79	6,752	788
55	22	6,896	262	69	5,875	690
60	20	6,403	262	64	5,437	640
65	19	5,911	262	59	4,998	591
70	17	5,418	262	54	4,560	542
75	15	4,827	262	48	4,034	483
80	13	4,236	262	42	3,508	424
85	11	3,546	262	35	2,894	355
90	8	2,660	262	27	2,105	266
95	6	1,823	262	18	1,360	182
100	1	314	262	3	17	31

NA = Not applicable

Table 5-21 Total Suspended Solids TMDL Calculations for Stinking Creek (OK310830020020_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	2,967	NA	NA	NA	NA	NA
5	56	NA	NA	NA	NA	NA
10	30	NA	NA	NA	NA	NA
15	25	NA	NA	NA	NA	NA
20	22	NA	NA	NA	NA	NA
25	20	4,386	0	44	3,903	439
30	17	3,859	0	39	3,435	386
35	17	3,684	0	37	3,279	368
40	15	3,333	0	33	2,966	333
45	13	2,982	0	30	2,654	298
50	13	2,807	0	28	2,498	281
55	11	2,456	0	25	2,186	246
60	10	2,281	0	23	2,030	228
65	9	2,105	0	21	1,874	211
70	9	1,930	0	19	1,717	193
75	8	1,719	0	17	1,530	172
80	7	1,509	0	15	1,343	151
85	6	1,263	0	13	1,124	126
90	4	947	0	9	843	95
95	3	649	0	6	578	65
100	0	0	0	0	0	0

NA = Not applicable

Table 5-22 Total Suspended Solids TMDL Calculations for Washita River at US 281, Anadarko (OK310830010010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	49,588	NA	NA	NA	NA	NA
5	2,552	NA	NA	NA	NA	NA
10	1,486	NA	NA	NA	NA	NA
15	1,048	NA	NA	NA	NA	NA
20	781	NA	NA	NA	NA	NA
25	591	274,908	497	2,749	230,426	41,236
30	466	216,742	497	2,167	181,567	32,511
35	388	180,619	497	1,806	151,223	27,093
40	333	154,904	497	1,549	129,622	23,236
45	289	134,699	497	1,347	112,650	20,205
50	255	118,780	497	1,188	99,278	17,817
55	224	104,085	497	1,041	86,935	15,613
60	197	91,840	497	918	76,649	13,776
65	176	82,044	497	820	68,420	12,307
70	154	71,635	497	716	59,677	10,745
75	138	64,288	497	643	53,505	9,643
80	120	55,716	497	557	46,305	8,357
85	99	45,920	497	459	38,076	6,888
90	80	37,348	497	373	30,876	5,602
95	58	26,940	497	269	22,132	4,041
100	1	605	497	5	12	91

NA = Not applicable

Table 5-23 Total Suspended Solids TMDL Calculations for Wildhorse Creek (OK310810040140_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	1,452	NA	NA	NA	NA	NA
5	61	NA	NA	NA	NA	NA
10	30	NA	NA	NA	NA	NA
15	19	NA	NA	NA	NA	NA
20	13	NA	NA	NA	NA	NA
25	9	3,122	0	31	2,778	312
30	7	2,332	0	23	2,076	233
35	5	1,726	0	17	1,536	173
40	4	1,340	0	13	1,193	134
45	3	1,065	0	11	948	107
50	2.5	863	0	9	768	86
55	2.0	679	0	7	605	68
60	1.6	551	0	6	490	55
65	1.3	441	0	4	392	44
70	1.0	349	0	3	311	35
75	0.8	257	0	3	229	26
80	0.6	202	0	2	180	20
85	0.4	123	0	1	109	12
90	0.2	72	0	1	64	7
95	0.1	31	0	0	28	3
100	0	0	0	0	0	0

NA = Not applicable

Table 5-24 Total Suspended Solids TMDL Calculations for Washita River at SH 19, near Alex (OK310810020010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	34,479	NA	NA	NA	NA	NA
5	2,927	NA	NA	NA	NA	NA
10	1,687	NA	NA	NA	NA	NA
15	1,191	NA	NA	NA	NA	NA
20	901	NA	NA	NA	NA	NA
25	699	149,232	9	1,492	125,346	22,385
30	567	121,152	9	1,212	101,758	18,173
35	475	101,372	9	1,014	85,143	15,206
40	410	87,596	9	876	73,572	13,139
45	359	76,647	9	766	64,374	11,497
50	313	66,757	9	668	56,067	10,014
55	272	58,103	9	581	48,798	8,715
60	232	49,450	9	494	41,528	7,417
65	201	42,915	9	429	36,040	6,437
70	172	36,734	9	367	30,847	5,510
75	145	30,906	9	309	25,952	4,636
80	121	25,784	9	258	21,650	3,868
85	100	21,369	9	214	17,941	3,205
90	75	16,071	9	161	13,490	2,411
95	47	10,067	9	101	8,447	1,510
100	0.5	107	9	1	81	16

NA = Not applicable

Table 5-25 Total Suspended Solids TMDL Calculations for Washington Creek (OK310810010190_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	216	NA	NA	NA	NA	NA
5	26	NA	NA	NA	NA	NA
10	13	NA	NA	NA	NA	NA
15	8	NA	NA	NA	NA	NA
20	6	NA	NA	NA	NA	NA
25	4	793	0	8	587	198
30	3	584	0	6	432	146
35	3	480	0	5	355	120
40	2	355	0	4	263	89
45	1.5	271	0	3	201	68
50	1.1	209	0	2	154	52
55	1.0	188	0	2	139	47
60	0.9	167	0	2	124	42
65	0.7	125	0	1	93	31
70	0.5	83	0	1	62	21
75	0.4	77	0	1	57	19
80	0.3	48	0	0	36	12
85	0.2	38	0	0	28	9
90	0.14	25	0	0	19	6
95	0.08	15	0	0	11	4
100	0	0	0	0	0	0

NA = Not applicable

Table 5-26 Total Suspended Solids TMDL Calculations for Kickapoo Sandy Creek (OK310810010050_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	404	NA	NA	NA	NA	NA
5	49	NA	NA	NA	NA	NA
10	24	NA	NA	NA	NA	NA
15	14	NA	NA	NA	NA	NA
20	11	NA	NA	NA	NA	NA
25	8	2,627	0	26	2,338	263
30	6	1,936	0	19	1,723	194
35	5	1,590	0	16	1,415	159
40	4	1,175	0	12	1,046	118
45	3	899	0	9	800	90
50	2.1	691	0	7	615	69
55	1.9	622	0	6	554	62
60	1.7	553	0	6	492	55
65	1.3	415	0	4	369	41
70	0.9	277	0	3	246	28
75	0.8	256	0	3	228	26
80	0.5	159	0	2	142	16
85	0.4	124	0	1	111	12
90	0.3	83	0	1	74	8
95	0.1	48	0	0	43	5
100	0	0	0	0	0	0

NA = Not applicable

Table 5-27 Total Suspended Solids TMDL Calculations for Washita River at SH 19, Pauls Valley (OK310810010010_10)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	48,537	NA	NA	NA	NA	NA
5	4,120	NA	NA	NA	NA	NA
10	2,374	NA	NA	NA	NA	NA
15	1,676	NA	NA	NA	NA	NA
20	1,269	NA	NA	NA	NA	NA
25	984	210,077	0	2,101	176,464	31,511
30	798	170,547	0	1,705	143,260	25,582
35	668	142,703	0	1,427	119,870	21,405
40	577	123,311	0	1,233	103,581	18,497
45	505	107,897	0	1,079	90,634	16,185
50	440	93,975	0	940	78,939	14,096
55	383	81,793	0	818	68,706	12,269
60	326	69,611	0	696	58,473	10,442
65	283	60,413	0	604	50,747	9,062
70	242	51,711	0	517	43,437	7,757
75	204	43,507	0	435	36,546	6,526
80	170	36,297	0	363	30,490	5,445
85	141	30,082	0	301	25,269	4,512
90	106	22,624	0	226	19,004	3,394
95	66	14,171	0	142	11,904	2,126
100	0	0	0	0	0	0

NA = Not applicable

Table 5-28 Total Suspended Solids TMDL Calculations for Sand Branch (OK310800020040_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	340	NA	NA	NA	NA	NA
5	41	NA	NA	NA	NA	NA
10	20	NA	NA	NA	NA	NA
15	12	NA	NA	NA	NA	NA
20	9	NA	NA	NA	NA	NA
25	7	2,099	0	21	1,553	525
30	5	1,547	0	15	1,144	387
35	4	1,270	0	13	940	318
40	3	939	0	9	695	235
45	2.3	718	0	7	531	180
50	1.8	552	0	6	409	138
55	1.6	497	0	5	368	124
60	1.4	442	0	4	327	110
65	1.1	331	0	3	245	83
70	0.7	221	0	2	163	55
75	0.7	204	0	2	151	51
80	0.4	127	0	1	94	32
85	0.3	99	0	1	74	25
90	0.2	66	0	1	49	17
95	0.1	39	0	0	29	10
100	0	0	0	0	0	0

NA = Not applicable

Table 5-29 Total Suspended Solids TMDL Calculations for Washita River at US 177, Durwood (OK310800020010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future Growth		
0	94,400	NA	NA	NA	NA	NA
5	6,890	NA	NA	NA	NA	NA
10	3,990	NA	NA	NA	NA	NA
15	2,680	NA	NA	NA	NA	NA
20	2,010	NA	NA	NA	NA	NA
25	1,540	446,885	1,755	4,469	373,628	67,033
30	1,230	356,928	1,755	3,569	298,064	53,539
35	1,010	293,087	1,755	2,931	244,438	43,963
40	832	241,434	1,755	2,414	201,049	36,215
45	705	204,581	1,755	2,046	170,092	30,687
50	607	176,142	1,755	1,761	146,204	26,421
55	520	150,896	1,755	1,509	124,998	22,634
60	455	132,034	1,755	1,320	109,153	19,805
65	394	114,333	1,755	1,143	94,284	17,150
70	330	95,761	1,755	958	78,684	14,364
75	275	79,801	1,755	798	65,277	11,970
80	232	67,323	1,755	673	54,796	10,098
85	192	55,716	1,755	557	45,046	8,357
90	147	42,657	1,755	427	34,077	6,399
95	87	25,246	1,755	252	19,451	3,787
100	7	2,089	1,755	19	2	313

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 2006). The CPP can be viewed from ODEQ's website at http://www.deq.state.ok.us/WQDnew/pubs.html Table 5-30 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 5-30 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. The Oklahoma Conservation Commission. works with state partners such as ODAFF and federal partners such as the USEPA and the National Resources Conservation Service of the U.S Department of Agriculture, to address water quality problems similar to those seen in the Study Area. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach. Other programs include regulations and permits for CAFOs. The CAFO Act, as administered by the ODAFF, provides CAFO operators the necessary tools and information to deal with the manure and wastewater animals produce so streams, lakes, ponds, and groundwater sources are not polluted.

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 96 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 Draft; and Ambient Water Quality Criteria for Bacteria-1986, January 1986). However, those guidelines have received much criticism and USEPA studies that could result in revisions to their recommendations are ongoing. The use of the three indicators specified in Oklahoma's standards should be evaluated. The numeric criteria values should also be evaluated using a risk-based method such as that found in USEPA guidance.

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

SECTION 6
PUBLIC PARTICIPATION

This report was submitted to EPA for technical review on June 09, 2010 and was technicaly accepted. A public notice was circulated on July 15, 2010 to local newspapers and/or other publications in the area affected by this TMDL and persons on the DEQ contact list. The public comment period ended on August 30, 2010. No requests for a public meeting were received. One comment letter from Oklahoma Farm Bureau was received. The responses to comments are included in Appendix E. as part of this TMDL report.

SECTION 7
REFERENCES

American Veterinary Medical Association 2007. U.S. Pet Ownership and Demographics Sourcebook (2007 Edition). Schaumberg, IL.

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

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

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

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

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

Helsel, D.R. and R.M. Hirsch 2002. Statistical Methods in Water Resources. U.S. Department of the Interior, U.S. Geological Survey, September 2002.

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

ODAFF 2009. http://www.ok.gov/~okag/aems/cafo.htm

ODAFF 2009a, Agricultural Environmental Management Services, http://www.ok.gov/~okag/aems/

ODEQ 2006. The State of Oklahoma 2006 Continuing Planning Process. 2006 Edition.

ODEQ 2007. Reissuance of General Permit OKR10 for Storm Water Discharges from Construction Activities within the State of Oklahoma. Fact Sheet. July 24, 2007.

ODEQ 2008. *Water Quality in Oklahoma, 2008 Integrated Report*. 2008.

Oklahoma Climate Survey. 2005. Viewed August 29, 2005 in

http://climate.ocs.ou.edu/county_climate/Products/County_Climatologies/

OWRB 2008. Oklahoma Water Resources Board. *2008 Water Quality Standards*.

OWRB 2008a. Oklahoma Water Resources Board. Implementation of Oklahoma's Water Quality Standards (Chapter 46). May 27, 2008.

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

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

Tukey, J.W. 1977. Exploratory Data Analysis. Addison-Wesely.

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

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

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

USDA 2002. Census of Agriculture, National Agricultural Statistics Service, United States Department of Agriculture. http://www.nass.usda.gov/Census/Create_Census_US_CNTY.jsp

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

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

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

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

USEPA 2005. U.S. Environmental Protection Agency, Office of Water. Stormwater Phase II Final Rule. EPA833-F-00-002 Fact Sheet 2.0. December 2005.

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

USGS 2009. USGS Daily Streamflow Data. http://waterdata.usgs.gov/nwis/sw

Woods, A.J., Omernik, J.M., Butler, D.R., Ford, J.G., Henley, J.E., Hoagland, B.W., Arndt, D.S., and Moran, B.C., 2005. Ecoregions of Oklahoma (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,250,000).

APPENDIX A

AMBIENT WATER QUALITY DATA

BACTERIA DATA — 2004 TO 2009

TURBIDITY AND TOTAL SUSPENDED SOLIDS DATA — 1998 TO 2009

Ambient Water Quality Bacteria Data, 2004-2009

Waterbody ID	WQM Station	Date[1]	FC[2]	EC[2]	ENT[2]
OK310840020020_00	OK310840-02-0020C	8/23/2004		205	110
OK310840020020_00	OK310840-02-0020C	9/27/2004		155	210
OK310840020020_00	OK310840-02-0020C	4/25/2005		280	20
OK310840020020_00	OK310840-02-0020C	5/31/2005		820	200
OK310840020020_00	OK310840-02-0020C	7/12/2005		25	160
OK310840020020_00	OK310840-02-0020C	8/15/2005		2600	6500
OK310840020020_00	OK310840-02-0020C	9/19/2005		>500	415
OK310840020020_00	OK310840-02-0020C	5/1/2006		340	75
OK310840020020_00	OK310840-02-0020C	6/26/2006		160	140
OK310840020020_00	OK310840-02-0020C	5/18/2009		100	50
OK310840020020_00	OK310840-02-0020C	6/22/2009		15	95
OK310830020020_00	OK310830-02-0020D	8/23/2004		340	320
OK310830020020_00	OK310830-02-0020D	10/5/2004		65	230
OK310830020020_00	OK310830-02-0020D	11/2/2004		90	435
OK310830020020_00	OK310830-02-0020D	4/25/2005		275	85
OK310830020020_00	OK310830-02-0020D	5/31/2005		180	280
OK310830020020_00	OK310830-02-0020D	7/5/2005		>1000	>1000
OK310830020020_00	OK310830-02-0020D	8/8/2005		>1000	>1000
OK310830020020_00	OK310830-02-0020D	9/12/2005		95	125
OK310830020020_00	OK310830-02-0020D	5/2/2006		30	110
OK310830020020_00	OK310830-02-0020D	5/30/2006		>1000	410
OK310830020020_00	OK310830-02-0020D	7/10/2006		60	50
OK310830020020_00	OK310830-02-0020D	5/19/2009		160	140
OK310830020020_00	OK310830-02-0020D	6/22/2009		115	45
OK310810040140_00	OK310810-04-0140D	8/31/2004		165	185
OK310810040140_00	OK310810-04-0140D	10/5/2004		>1000	>1000
OK310810040140_00	OK310810-04-0140D	5/10/2005		>1000	>500
OK310810040140_00	OK310810-04-0140D	6/7/2005		>1000	490
OK310810040140_00	OK310810-04-0140D	7/6/2005		>1000	270
OK310810040140_00	OK310810-04-0140D	8/8/2005		120	320
OK310810040140_00	OK310810-04-0140D	9/12/2005		155	75
OK310810040140_00	OK310810-04-0140D	4/25/2006		380	90

Waterbody ID	WQM Station	Date[1]	FC[2]	EC[2]	ENT[2]
OK310810040140_00	OK310810-04-0140D	6/5/2006		270	205
OK310810040140_00	OK310810-04-0140D	7/10/2006		190	550
OK310810040140_00	OK310810-04-0140D	5/26/2009		210	3300
OK310810040140_00	OK310810-04-0140D	9/14/2009		1620	>2000
OK310810020010_00	USGS_07328100	5/5/2004	5000	712	11000
OK310810020010_00	USGS_07328100	5/19/2004	80	10	100
OK310810020010_00	USGS_07328100	6/2/2004	700	109	100
OK310810020010_00	USGS_07328100	6/30/2004	3300	934	2900
OK310810020010_00	USGS_07328100	7/7/2004	2500	10	3600
OK310810020010_00	USGS_07328100	7/28/2004	400	41	2700
OK310810020010_00	USGS_07328100	8/11/2004	2610	155	2890
OK310810020010_00	USGS_07328100	9/1/2004	630	131	318
OK310810020010_00	USGS_07328100	9/15/2004	40	10	10
OK310810020010_00	USGS_07328100	9/22/2004	60	10	30
OK310810020010_00	USGS_07328100	5/3/2006	1400	794	231
OK310810020010_00	USGS_07328100	5/30/2006	300	41	41
OK310810020010_00	USGS_07328100	6/14/2006	30	31	41
OK310810020010_00	USGS_07328100	6/26/2006	2000	1455	2310
OK310810020010_00	USGS_07328100	7/12/2006	14400	9208	179
OK310810020010_00	USGS_07328100	7/17/2006	50	10	31
OK310810020010_00	USGS_07328100	8/8/2006	20	10	31
OK310810020010_00	USGS_07328100	8/14/2006	250	86	97
OK310810020010_00	USGS_07328100	8/31/2006	100	74	223
OK310810020010_00	USGS_07328100	9/27/2006	10	10	10
OK310810010050_00	OK310810-01-0050G	8/24/2004		130	130
OK310810010050_00	OK310810-01-0050G	9/27/2004		90	180
OK310810010050_00	OK310810-01-0050G	4/25/2005		>500	210
OK310810010050_00	OK310810-01-0050G	5/31/2005		>1000	390
OK310810010050_00	OK310810-01-0050G	7/5/2005		>1000	>1000
OK310810010050_00	OK310810-01-0050G	8/8/2005		>1000	270
OK310810010050_00	OK310810-01-0050G	9/12/2005		290	100
OK310810010050_00	OK310810-01-0050G	4/24/2006		560	150
OK310810010050_00	OK310810-01-0050G	5/30/2006		315	160

Waterbody ID	WQM Station	Date[1]	FC[2]	EC[2]	ENT[2]
OK310810010050_00	OK310810-01-0050G	6/26/2006		>1000	>1000
OK310810010050_00	OK310810-01-0050G	5/18/2009		70	170
OK310810010050_00	OK310810-01-0050G	6/22/2009		295	450

FC = fecal coliform (STORET Code: 31610); EC = E. coli (STORET Code: 31609); ENT = enterococci (STORET Code: 31649)

> 1000 reported as 1000.001 in data analysis

[1] Samples collected during secondary contact recreation season (October 1st and April 30th) are included in Appendix A but were not used in TMDL calculations.

[2] Units = counts/100 mL

Ambient Water Quality Turbidity and TSS Data, 1998-2009

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310800020010_00	310800020010-001AT	12/15/1998	99	138	
OK310800020010_00	310800020010-001AT	2/2/1999	599	484	high flow
OK310800020010_00	310800020010-001AT	3/2/1999	63	51	
OK310800020010_00	310800020010-001AT	4/28/1999	1000	1850	high flow
OK310800020010_00	310800020010-001AT	6/1/1999	1000	1870	high flow
OK310800020010_00	310800020010-001AT	6/29/1999	1000	676	high flow
OK310800020010_00	310800020010-001AT	7/27/1999	132	56	
OK310800020010_00	310800020010-001AT	8/31/1999	65	58	
OK310800020010_00	310800020010-001AT	9/28/1999	673	28	
OK310800020010_00	310800020010-001AT	10/12/1999	29	42	
OK310800020010_00	310800020010-001AT	11/9/1999	38	51	
OK310800020010_00	310800020010-001AT	12/7/1999	587	880	
OK310800020010_00	310800020010-001AT	1/19/2000	78	29	
OK310800020010_00	310800020010-001AT	2/15/2000	101	137	
OK310800020010_00	310800020010-001AT	3/15/2000	185		
OK310800020010_00	310800020010-001AT	4/12/2000	1000		high flow
OK310800020010_00	310800020010-001AT	5/9/2000	1000	2480	high flow
OK310800020010_00	310800020010-001AT	6/13/2000	469	1000	high flow
OK310800020010_00	310800020010-001AT	7/19/2000	157	624	
OK310800020010_00	310800020010-001AT	8/16/2000	39	46	
OK310800020010_00	310800020010-001AT	9/12/2000	27	22	
OK310800020010_00	310800020010-001AT	10/10/2000	19	52	
OK310800020010_00	310800020010-001AT	11/7/2000	795	900	high flow
OK310800020010_00	310800020010-001AT	2/13/2001	466		high flow
OK310800020010_00	310800020010-001AT	3/13/2001	366		high flow
OK310800020010_00	310800020010-001AT	4/10/2001	107		high flow
OK310800020010_00	310800020010-001AT	5/15/2001	791		high flow
OK310800020010_00	310800020010-001AT	6/12/2001	1000		high flow
OK310800020010_00	310800020010-001AT	7/17/2001	80		
OK310800020010_00	310800020010-001AT	8/14/2001	23		
OK310800020010_00	310800020010-001AT	9/5/2001	63		
OK310800020010_00	310800020010-001AT	10/16/2001	188		high flow
OK310800020010_00	310800020010-001AT	11/27/2001	13		
OK310800020010_00	310800020010-001AT	2/27/2002	44		
OK310800020010_00	310800020010-001AT	3/27/2002	57		high flow

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310800020010_00	310800020010-001AT	4/24/2002	254		high flow
OK310800020010_00	310800020010-001AT	5/22/2002	98		
OK310800020010_00	310800020010-001AT	6/18/2002	1000		high flow
OK310800020010_00	310800020010-001AT	7/24/2002	52		
OK310800020010_00	310800020010-001AT	8/20/2002	73		
OK310800020010_00	310800020010-001AT	9/24/2002	66		
OK310800020010_00	310800020010-001AT	11/18/2002	90		
OK310800020010_00	310800020010-001AT	1/13/2003	45		high flow
OK310800020010_00	310800020010-001AT	3/24/2003	92		high flow
OK310800020010_00	310800020010-001AT	4/29/2003	69		
OK310800020010_00	310800020010-001AT	6/3/2003	25		
OK310800020010_00	310800020010-001AT	7/14/2003	41		
OK310800020010_00	310800020010-001AT	8/18/2003	50		
OK310800020010_00	310800020010-001AT	10/21/2003	17		
OK310800020010_00	310800020010-001AT	11/22/2003	49		
OK310800020010_00	310800020010-001AT	1/5/2004	11		
OK310800020010_00	310800020010-001AT	2/17/2004	13		
OK310800020010_00	310800020010-001AT	3/31/2004	74		
OK310800020010_00	310800020010-001AT	4/26/2004	499		high flow
OK310800020010_00	310800020010-001AT	6/8/2004	1000		high flow
OK310800020010_00	310800020010-001AT	7/12/2004	1000		high flow
OK310800020010_00	310800020010-001AT	8/16/2004	44		
OK310800020010_00	310800020010-001AT	9/20/2004	64		
OK310800020010_00	310800020010-001AT	10/18/2004	1000		high flow
OK310800020010_00	310800020010-001AT	1/11/2005	614		high flow
OK310800020010_00	310800020010-001AT	2/16/2005	248		high flow
OK310800020010_00	310800020010-001AT	3/15/2005	47		
OK310800020010_00	310800020010-001AT	5/24/2005	85		
OK310800020010_00	310800020010-001AT	7/12/2005	37		
OK310800020010_00	310800020010-001AT	8/8/2005	54		
OK310800020010_00	310800020010-001AT	9/6/2005	801		
OK310800020010_00	310800020010-001AT	10/18/2005	890		
OK310800020010_00	310800020010-001AT	11/28/2005	21		
OK310800020010_00	310800020010-001AT	1/17/2006	18		
OK310800020010_00	310800020010-001AT	2/21/2006	41		
OK310800020010_00	310800020010-001AT	3/27/2006	44		

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310800020010_00	310800020010-001AT	5/1/2006	1000		high flow
OK310800020010_00	310800020010-001AT	6/5/2006	8		
OK310800020010_00	310800020010-001AT	7/11/2006	28		
OK310800020010_00	310800020010-001AT	8/14/2006	34		
OK310800020010_00	310800020010-001AT	9/25/2006	430		
OK310800020010_00	310800020010-001AT	10/30/2006	207		
OK310800020010_00	310800020010-001AT	1/22/2007	559		high flow
OK310800020010_00	310800020010-001AT	3/5/2007	41		
OK310800020010_00	310800020010-001AT	5/14/2007	1001		high flow
OK310800020010_00	310800020010-001AT	6/11/2007	448		high flow
OK310800020010_00	310800020010-001AT	7/9/2007	1001		high flow
OK310800020010_00	310800020010-001AT	8/22/2007	1000		high flow
OK310800020010_00	310800020010-001AT	9/17/2007	1000		high flow
OK310800020040_00	OK310800-02-0040C	4/19/1999	5.4	4.5	
OK310800020040_00	OK310800-02-0040C	5/17/1999	95.7	88.5	
OK310800020040_00	OK310800-02-0040C	6/14/1999	5.81	2.5	
OK310800020040_00	OK310800020040C	6/29/1999	254		
OK310800020040_00	OK310800-02-0040C	7/12/1999	16.1	10	
OK310800020040_00	OK310800-02-0040C	8/16/1999	46.1	53	
OK310800020040_00	OK310800-02-0040C	9/27/1999	10.6	10	
OK310800020040_00	OK310800-02-0040C	11/1/1999	12.7	38.5	
OK310800020040_00	OK310800-02-0040C	12/6/1999	29.3	22.2	
OK310800020040_00	OK310800-02-0040C	1/10/2000	55.7	51	
OK310800020040_00	OK310800-02-0040C	2/14/2000	10	6	
OK310800020040_00	OK310800-02-0040C	3/20/2000	7.49	8.5	
OK310800020040_00	OK310800-02-0040C	5/1/2000	190	220	
OK310800020040_00	OK310800-02-0040C	6/5/2000	69.1	77	
OK310800020040_00	OK310800-02-0040C	7/10/2000	11.9	4	
OK310800020040_00	OK310800-02-0040C	10/23/2000	49.9	124	
OK310800020040_00	OK310800-02-0040C	11/27/2000	48.1	37	
OK310800020040_00	OK310800-02-0040C	1/8/2001	22.3	10	
OK310800020040_00	OK310800-02-0040C	2/12/2001	6.2	1	
OK310800020040_00	OK310800-02-0040C	3/19/2001	6.7	14	
OK310810010010_10	310810010010-001AT	12/15/1998	148	162	
OK310810010010_10	310810010010-001AT	2/2/1999	444	256	high flow
OK310810010010_10	310810010010-001AT	3/2/1999	75	110	

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310810010010_10	310810010010-001AT	4/28/1999	1000	2180	high flow
OK310810010010_10	310810010010-001AT	6/1/1999	1000	2650	high flow
OK310810010010_10	OK310810010010-001AT	6/2/1999	0	1	high flow
OK310810010010_10	310810010010-001AT	6/29/1999	999	608	high flow
OK310810010010_10	310810010010-001AT	7/27/1999	127	60	
OK310810010010_10	310810010010-001AT	8/31/1999	67	68	
OK310810010010_10	310810010010-001AT	9/28/1999	280	240	
OK310810010010_10	310810010010-001AT	10/12/1999	53	32	
OK310810010010_10	310810010010-001AT	11/9/1999	51	86	
OK310810010010_10	310810010010-001AT	12/7/1999	149	150	
OK310810010010_10	310810010010-001AT	1/19/2000	90	147	
OK310810010010_10	310810010010-001AT	2/15/2000	85	134	
OK310810010010_10	OK310830010010-001AT	3/14/2000	25		
OK310810010010_10	OK310830030010-001AT	3/14/2000	350		high flow
OK310810010010_10	310810010010-001AT	3/15/2000	141		
OK310810010010_10	OK310830030010-001AT	4/11/2000	172		high flow
OK310810010010_10	310810010010-001AT	4/12/2000	963		high flow
OK310810010010_10	310810010010-001AT	5/9/2000	1000	2540	high flow
OK310810010010_10	310810010010-001AT	6/12/2000	198	488	
OK310810010010_10	310810010010-001AT	7/18/2000	180	448	high flow
OK310810010010_10	310810010010-001AT	8/16/2000	35	58	
OK310810010010_10	310810010010-001AT	10/10/2000	17	4	
OK310810010010_10	310810010010-001AT	11/7/2000	489	420	high flow
OK310810010010_10	OK310830010010-001AT	2/12/2001	793		high flow
OK310810010010_10	310810010010-001AT	2/13/2001	498		high flow
OK310810010010_10	OK310830010010-001AT	3/12/2001	163		high flow
OK310810010010_10	310810010010-001AT	3/13/2001	416		high flow
OK310810010010_10	OK310830010010-001AT	4/9/2001	54		high flow
OK310810010010_10	310810010010-001AT	4/10/2001	147		high flow
OK310810010010_10	OK310830010010-001AT	5/14/2001	1000		high flow
OK310810010010_10	310810010010-001AT	5/15/2001	903		high flow
OK310810010010_10	OK310830010010-001AT	6/11/2001	552		high flow

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310810010010_10	310810010010-001AT	6/12/2001	1000		high flow
OK310810010010_10	OK310830010010-001AT	7/16/2001	104		
OK310810010010_10	310810010010-001AT	7/17/2001	80		
OK310810010010_10	OK310830010010-001AT	8/13/2001	233		
OK310810010010_10	310810010010-001AT	8/14/2001	47		
OK310810010010_10	OK310830010010-001AT	9/4/2001	32		
OK310810010010_10	310810010010-001AT	9/5/2001	85		
OK310810010010_10	310810010010-001AT	10/16/2001	453		
OK310810010010_10	OK310830010010-001AT	11/26/2001	12		
OK310810010010_10	310810010010-001AT	11/27/2001	28		
OK310810010010_10	310810010010-001AT	2/27/2002	48		
OK310810010010_10	310810010010-001AT	2/27/2002	48		
OK310810010010_10	310810010010-001AT	3/27/2002	59		
OK310810010010_10	310810010010-001AT	4/24/2002	399		high flow
OK310810010010_10	310810010010-001AT	5/22/2002	56		
OK310810010010_10	310810010010-001AT	6/18/2002	1000		high flow
OK310810010010_10	310810010010-001AT	7/24/2002	39		
OK310810010010_10	310810010010-001AT	8/20/2002	62		
OK310810010010_10	310810010010-001AT	9/23/2002	71		
OK310810010010_10	310810010010-001AT	11/18/2002	92		
OK310810010010_10	310810010010-001AT	1/13/2003	58		
OK310810010010_10	OK310830010010-001AT	1/14/2003	29		
OK310810010010_10	310810010010-001AT	3/24/2003	119		high flow
OK310810010010_10	310810010010-001AT	4/29/2003	47		
OK310810010010_10	310810010010-001AT	6/3/2003	54		
OK310810010010_10	310810010010-001AT	7/14/2003	59		
OK310810010010_10	310810010010-001AT	8/18/2003	59		
OK310810010010_10	310810010010-001AT	9/22/2003	1000		
OK310810010010_10	310810010010-001AT	10/20/2003	27		
OK310810010010_10	310810010010-001AT	11/22/2003	23		
OK310810010010_10	310810010010-001AT	1/5/2004	14		
OK310810010010_10	310810010010-001AT	2/17/2004	18		
OK310810010010_10	310810010010-001AT	3/31/2004	108		high flow
OK310810010010_10	310810010010-001AT	4/26/2004	73		

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310810010010_10	310810010010-001AT	6/7/2004	1000		high flow
OK310810010010_10	310810010010-001AT	7/12/2004	1000		high flow
OK310810010010_10	310810010010-001AT	8/16/2004	54		
OK310810010010_10	310810010010-001AT	9/20/2004	52		
OK310810010010_10	310810010010-001AT	10/18/2004	1000		high flow
OK310810010010_10	OK310830010010-001AT	11/21/2004	976		high flow
OK310810010010_10	310810010010-001AT	1/11/2005	1000		high flow
OK310810010010_10	310810010010-001AT	2/16/2005	214		high flow
OK310810010010_10	310810010010-001AT	3/15/2005	44		
OK310810010010_10	310810010010-001AT	5/24/2005	41		
OK310810010010_10	310810010010-001AT	7/12/2005	65		
OK310810010010_10	310810010010-001AT	8/8/2005	49		
OK310810010010_10	310810010010-001AT	9/6/2005	826		
OK310810010010_10	310810010010-001AT	10/18/2005	478		
OK310810010010_10	310810010010-001AT	11/28/2005	33		
OK310810010010_10	310810010010-001AT	2/21/2006	57		
OK310810010010_10	310810010010-001AT	3/27/2006	55		
OK310810010010_10	310810010010-001AT	5/1/2006	1000		high flow
OK310810010010_10	310810010010-001AT	6/5/2006	1000		high flow
OK310810010010_10	310810010010-001AT	7/11/2006	53		
OK310810010010_10	310810010010-001AT	8/14/2006	22		
OK310810010010_10	310810010010-001AT	9/25/2006	79		
OK310810010010_10	310810010010-001AT	10/30/2006	127		
OK310810010010_10	310810010010-001AT	12/4/2006	20		
OK310810010010_10	310810010010-001AT	1/22/2007	409		
OK310810010010_10	310810010010-001AT	1/24/2007	27		
OK310810010010_10	310810010010-001AT	3/5/2007	52		
OK310810010010_10	310810010010-001AT	4/2/2007	1560		high flow
OK310810010010_10	310810010010-001AT	5/14/2007	1001		high flow
OK310810010010_10	310810010010-001AT	6/11/2007	433		high flow
OK310810010010_10	310810010010-001AT	7/9/2007	1001		high flow
OK310810010010_10	310810010010-001AT	8/22/2007	1000		high flow
OK310810010010_10	310810010010-001AT	9/17/2007	793		high flow
OK310810010010_10	310810010010-001AT	10/29/2007	398		high flow
OK310810010010_10	310810010010-001AT	12/3/2007	32		high flow
OK310810010010_10	310810010010-001AT	1/22/2008	36		high flow

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310810010010_10	310810010010-001AT	3/5/2008	1000		high flow
OK310810010010_10	310810010010-001AT	4/29/2008	443		high flow
OK310810010010_10	310810010010-001AT	5/19/2008	223		high flow
OK310810010010_10	310810010010-001AT	7/21/2008	70.3		
OK310810010010_10	310810010010-001AT	9/15/2008	41		
OK310810010010_10	310810010010-001AT	11/5/2008	39		
OK310810010010_10	310810010010-001AT	2/17/2009	35.67		
OK310810010010_10	310810010010-001AT	3/2/2009	16.75		
OK310810010010_10	310810010010-001AT	4/6/2009	130.3		
OK310810010050_00	OK310810-01-0050G	6/28/2004	17.2		
OK310810010050_00	OK310810-01-0050G	8/24/2004	4.83	10	
OK310810010050_00	OK310810-01-0050G	9/27/2004	4.43	10	
OK310810010050_00	OK310810-01-0050G	11/1/2004	105	134	
OK310810010050_00	OK310810-01-0050G	12/7/2004	52.9	57	high flow
OK310810010050_00	OK310810-01-0050G	1/11/2005	31.6	33	high flow
OK310810010050_00	OK310810-01-0050G	2/22/2005	7.95	10	
OK310810010050_00	OK310810-01-0050G	3/21/2005	8.05	10	
OK310810010050_00	OK310810-01-0050G	4/25/2005	5.77	10	
OK310810010050_00	OK310810-01-0050G	5/31/2005	110	146	
OK310810010050_00	OK310810-01-0050G	7/5/2005	470	523	high flow
OK310810010050_00	OK310810-01-0050G	8/8/2005	12.5	21	
OK310810010050_00	OK310810-01-0050G	9/12/2005	8.15	10	
OK310810010050_00	OK310810-01-0050G	10/17/2005	6.59	10	
OK310810010050_00	OK310810-01-0050G	11/29/2005	2.07	10	
OK310810010050_00	OK310810-01-0050G	1/9/2006	3.61	10	
OK310810010050_00	OK310810-01-0050G	2/13/2006	7.04	10	
OK310810010050_00	OK310810-01-0050G	3/20/2006	47.1	114	high flow
OK310810010050_00	OK310810-01-0050G	4/24/2006	4.65	10	
OK310810010050_00	OK310810-01-0050G	5/30/2006	9.98	17	
OK310810010050_00	OK310810-01-0050G	6/26/2006	457	281	
OK310810010190_00	USGS_07328550	6/25/2004	27.5		
OK310810010190_00	OK310810-01-0190G	8/24/2004	8.75	10	
OK310810010190_00	OK310810-01-0190G	11/2/2004	221	51	
OK310810010190_00	OK310810-01-0190G	12/8/2004	58.2	10	
OK310810010190_00	OK310810-01-0190G	2/22/2005	28.3	10	
OK310810010190_00	OK310810-01-0190G	3/21/2005	147	183	high flow

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310810010190_00	OK310810-01-0190G	4/25/2005	17.2	10	
OK310810010190_00	OK310810-01-0190G	5/31/2005	32.6	25	
OK310810010190_00	OK310810-01-0190G	7/5/2005	1000.99	543	
OK310810010190_00	OK310810-01-0190G	8/8/2005	112	62	
OK310810010190_00	OK310810-01-0190G	3/20/2006	70.9	323	
OK310810010190_00	OK310810-01-0190G	4/24/2006	17.8	17	
OK310810010190_00	OK310810-01-0190G	5/30/2006	51.4	80	
OK310810020010_00	310810020010-001AT	1/14/2003	27		
OK310810020010_00	310810020010-001AT	2/19/2003	37		
OK310810020010_00	310810020010-001AT	3/26/2003	86		high flow
OK310810020010_00	310810020010-001AT	4/30/2003	185		
OK310810020010_00	310810020010-001AT	6/4/2003	160		
OK310810020010_00	310810020010-001AT	8/20/2003	39		
OK310810020010_00	310810020010-001AT	9/24/2003	47		
OK310810020010_00	310810020010-001AT	10/20/2003	40		
OK310810020010_00	310810020010-001AT	11/24/2003	12		
OK310810020010_00	310810020010-001AT	1/7/2004	17		
OK310810020010_00	310810020010-001AT	2/10/2004	12		
OK310810020010_00	310810020010-001AT	3/16/2004	638		high flow
OK310810020010_00	310810020010-001AT	4/27/2004	105		
OK310810020010_00	310810020010-001AT	6/2/2004	29		
OK310810020010_00	310810020010-001AT	7/7/2004	1000		high flow
OK310810020010_00	310810020010-001AT	8/11/2004	490		
OK310810020010_00	310810020010-001AT	9/15/2004	34		
OK310810020010_00	310810020010-001AT	10/19/2004	713		
OK310810020010_00	310810020010-001AT	11/21/2004	1000		high flow
OK310810020010_00	310810020010-001AT	1/12/2005	668		high flow
OK310810020010_00	310810020010-001AT	2/16/2005	148		high flow
OK310810020010_00	310810020010-001AT	3/16/2005	24		
OK310810020010_00	310810020010-001AT	5/25/2005	130		
OK310810020010_00	310810020010-001AT	7/12/2005	45		
OK310810020010_00	310810020010-001AT	8/8/2005	59		
OK310810020010_00	310810020010-001AT	9/7/2005	470		
OK310810020010_00	310810020010-001AT	10/19/2005	189		
OK310810020010_00	310810020010-001AT	11/29/2005	8		
OK310810020010_00	310810020010-001AT	1/17/2006	15		

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310810020010_00	310810020010-001AT	2/21/2006	13		
OK310810020010_00	310810020010-001AT	3/28/2006	21		
OK310810020010_00	310810020010-001AT	5/1/2006	198		high flow
OK310810020010_00	310810020010-001AT	6/5/2006	1000		high flow
OK310810020010_00	310810020010-001AT	7/12/2006	207		
OK310810020010_00	310810020010-001AT	8/14/2006	26		
OK310810020010_00	310810020010-001AT	9/27/2006	25		
OK310810020010_00	310810020010-001AT	10/31/2006	35		
OK310810020010_00	310810020010-001AT	12/6/2006	8		
OK310810020010_00	310810020010-001AT	3/7/2007	15		
OK310810020010_00	310810020010-001AT	4/4/2007	1520		high flow
OK310810020010_00	310810020010-001AT	5/16/2007	1001		high flow
OK310810020010_00	310810020010-001AT	6/13/2007	369		high flow
OK310810020010_00	310810020010-001AT	7/11/2007	1000		high flow
OK310810020010_00	310810020010-001AT	8/20/2007	1000		high flow
OK310810020010_00	310810020010-001AT	10/31/2007	141		high flow
OK310810020010_00	310810020010-001AT	12/5/2007	13		high flow
OK310810020010_00	310810020010-001AT	1/23/2008	25		high flow
OK310810020010_00	310810020010-001AT	3/3/2008	465		high flow
OK310810020010_00	310810020010-001AT	4/28/2008	245		high flow
OK310810020010_00	310810020010-001AT	5/21/2008	132		high flow
OK310810040140_00	OK310810-04-0140D	8/3/2004	90.3		
OK310810040140_00	OK310810-04-0140D	8/31/2004	112	148	
OK310810040140_00	OK310810-04-0140D	10/5/2004	196	153	
OK310810040140_00	OK310810-04-0140D	11/16/2004	104	83	
OK310810040140_00	OK310810-04-0140D	12/7/2004	98	92	
OK310810040140_00	OK310810-04-0140D	1/19/2005		10	
OK310810040140_00	OK310810-04-0140D	2/22/2005	37.2	36	
OK310810040140_00	OK310810-04-0140D	3/29/2005	27	49	
OK310810040140_00	OK310810-04-0140D	5/10/2005	108	98	
OK310810040140_00	OK310810-04-0140D	6/7/2005	524	10	
OK310810040140_00	OK310810-04-0140D	7/6/2005	99.7	115	
OK310810040140_00	OK310810-04-0140D	8/8/2005	16.7	30	
OK310810040140_00	OK310810-04-0140D	9/12/2005	14.9	35	
OK310810040140_00	OK310810-04-0140D	10/17/2005	6.76	10	
OK310810040140_00	OK310810-04-0140D	11/28/2005	3.63	10	

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310810040140_00	OK310810-04-0140D	1/10/2006	64.5	52	
OK310810040140_00	OK310810-04-0140D	2/13/2006	49	73	
OK310810040140_00	OK310810-04-0140D	3/20/2006	35	76	
OK310810040140_00	OK310810-04-0140D	4/25/2006	91.7	103	
OK310810040140_00	OK310810-04-0140D	6/5/2006	11.4	23	
OK310810040140_00	OK310810-04-0140D	7/10/2006	3.97	10	
OK310810040140_00	OK310810-04-0140D	5/26/2009			high flow
OK310830010010_00	310830010010-001AT	2/10/1999	74	122	high flow
OK310830010010_00	310830010010-001AT	3/30/1999		189	high flow
OK310830010010_00	310830010010-001AT	4/7/1999	467	136	high flow
OK310830010010_00	310830010010-001AT	6/16/1999	249	194	high flow
OK310830010010_00	310830010010-001AT	7/12/1999	1000	1560	high flow
OK310830010010_00	310830010010-001AT	8/18/1999	49	46	
OK310830010010_00	310830010010-001AT	9/27/1999	44	58	
OK310830010010_00	310830010010-001AT	10/11/1999	24	56	
OK310830010010_00	310830010010-001AT	11/8/1999	18	30	
OK310830010010_00	310830010010-001AT	12/6/1999	1000	3050	high flow
OK310830010010_00	310830010010-001AT	1/18/2000	23	75	
OK310830010010_00	310830010010-001AT	2/14/2000	27	46	
OK310830010010_00	310830010010-001AT	4/11/2000	313		high flow
OK310830010010_00	310830010010-001AT	5/8/2000	502	300	high flow
OK310830010010_00	310830010010-001AT	6/12/2000	72	242	
OK310830010010_00	310830010010-001AT	7/18/2000	74	124	high flow
OK310830010010_00	310830010010-001AT	8/15/2000	56	138	
OK310830010010_00	310830010010-001AT	9/11/2000	34	44	
OK310830010010_00	310830010010-001AT	11/28/2000		70	
OK310830010010_00	310830010010-001AT	2/12/2001	793		high flow
OK310830010010_00	310830010010-001AT	3/12/2001	163		high flow
OK310830010010_00	310830010010-001AT	4/9/2001	54		high flow
OK310830010010_00	310830010010-001AT	5/14/2001	1000		high flow
OK310830010010_00	310830010010-001AT	6/11/2001	552		high flow
OK310830010010_00	310830010010-001AT	7/16/2001	104		
OK310830010010_00	310830010010-001AT	8/13/2001	233		
OK310830010010_00	310830010010-001AT	9/4/2001	23		
OK310830010010_00	310830010010-001AT	10/15/2001	26		
OK310830010010_00	310830010010-001AT	10/15/2001	26		

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310830010010_00	OK310830030010-001AT	3/25/2002	4		
OK310830010010_00	310830010010-001AT	3/26/2002	18		
OK310830010010_00	OK310830030010-001AT	4/22/2002	52		high flow
OK310830010010_00	310830010010-001AT	4/23/2002	146		
OK310830010010_00	310830010010-001AT	4/23/2002	146		
OK310830010010_00	OK310830030010-001AT	5/20/2002	336		
OK310830010010_00	310830010010-001AT	5/21/2002	73		
OK310830010010_00	310830010010-001AT	5/21/2002	58		
OK310830010010_00	310830010010-001AT	5/21/2002	66		
OK310830010010_00	OK310830010010-001AT	6/18/2002	111		high flow
OK310830010010_00	310830010010-001AT	6/18/2002	355		high flow
OK310830010010_00	310830010010-001AT	6/18/2002	254		high flow
OK310830010010_00	OK310830030010-001AT	7/23/2002	24		
OK310830010010_00	310830010010-001AT	7/23/2002	38		
OK310830010010_00	310830010010-001AT	7/23/2002	46		
OK310830010010_00	310830010010-001AT	8/19/2002	42		
OK310830010010_00	310830010010-001AT	8/19/2002	50		
OK310830010010_00	310830010010-001AT	8/19/2002	57		
OK310830010010_00	OK310830030010-001AT	8/21/2002	31		
OK310830010010_00	310830010010-001AT	9/16/2002	53		
OK310830010010_00	310830010010-001AT	10/21/2002	38		
OK310830010010_00	310830010010-001AT	11/19/2002	18		
OK310830010010_00	310830010010-001AT	1/13/2003	19		
OK310830010010_00	310830010010-001AT	2/19/2003	13		
OK310830010010_00	310830010010-001AT	3/26/2003	99		
OK310830010010_00	310830010010-001AT	4/30/2003	130		
OK310830010010_00	310830010010-001AT	6/4/2003	43		
OK310830010010_00	310830010010-001AT	7/15/2003	30		
OK310830010010_00	310830010010-001AT	8/20/2003	19		
OK310830010010_00	310830010010-001AT	9/24/2003	26		
OK310830010010_00	310830010010-001AT	10/20/2003	14		
OK310830010010_00	310830010010-001AT	11/24/2003	7		
OK310830010010_00	310830010010-001AT	1/7/2004	17		
OK310830010010_00	310830010010-001AT	2/10/2004	5		

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310830010010_00	310830010010-001AT	3/16/2004	274		high flow
OK310830010010_00	310830010010-001AT	4/27/2004	84		
OK310830010010_00	310830010010-001AT	6/2/2004	30		
OK310830010010_00	310830010010-001AT	7/7/2004	1000		high flow
OK310830010010_00	310830010010-001AT	8/11/2004	48		
OK310830010010_00	310830010010-001AT	9/15/2004	30		
OK310830010010_00	310830010010-001AT	10/19/2004	233		
OK310830010010_00	310830010010-001AT	1/12/2005	227		high flow
OK310830010010_00	310830010010-001AT	3/16/2005	15		
OK310830010010_00	310830010010-001AT	5/25/2005	104		
OK310830010010_00	310830010010-001AT	7/12/2005	67		
OK310830010010_00	310830010010-001AT	8/8/2005	89		
OK310830010010_00	310830010010-001AT	9/7/2005	236		high flow
OK310830010010_00	310830010010-001AT	10/19/2005	210		
OK310830010010_00	310830010010-001AT	11/29/2005	7		
OK310830010010_00	310830010010-001AT	1/17/2006	12		
OK310830010010_00	310830010010-001AT	2/21/2006	6		
OK310830010010_00	310830010010-001AT	3/28/2006	13		
OK310830010010_00	310830010010-001AT	5/1/2006	39		
OK310830010010_00	310830010010-001AT	6/5/2006	25		
OK310830010010_00	310830010010-001AT	7/12/2006	26		
OK310830010010_00	310830010010-001AT	8/14/2006	27		
OK310830010010_00	310830010010-001AT	9/27/2006	15		
OK310830010010_00	310830010010-001AT	10/31/2006	11		
OK310830010010_00	310830010010-001AT	12/6/2006	6		
OK310830010010_00	310830010010-001AT	1/24/2007	10		
OK310830010010_00	310830010010-001AT	3/7/2007	9		
OK310830010010_00	310830010010-001AT	4/4/2007	1075		high flow
OK310830010010_00	310830010010-001AT	5/16/2007	1001		high flow
OK310830010010_00	310830010010-001AT	6/13/2007	299		high flow
OK310830010010_00	310830010010-001AT	7/11/2007	483		high flow
OK310830010010_00	310830010010-001AT	8/20/2007	1000		high flow
OK310830010010_00	310830010010-001AT	10/30/2007	88		high flow
OK310830010010_00	310830010010-001AT	12/5/2007	18		high flow
OK310830010010_00	310830010010-001AT	1/23/2008	13		
OK310830010010_00	310830010010-001AT	3/3/2008	1000		high flow

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310830010010_00	310830010010-001AT	4/28/2008	91		high flow
OK310830010010_00	310830010010-001AT	5/21/2008	52		high flow
OK310830010010_00	310830010010-001AT	7/22/2008	37		
OK310830010010_00	310830010010-001AT	9/16/2008	1000		high flow
OK310830010010_00	310830010010-001AT	11/6/2008	66		high flow
OK310830010010_00	310830010010-001AT	2/18/2009	22.5		
OK310830010010_00	310830010010-001AT	3/3/2009	6.25		
OK310830010010_00	310830010010-001AT	4/7/2009	18		
OK310830020020_00	OK310830-02-0020D	8/4/2004	11.3		
OK310830020020_00	OK310830-02-0020D	8/23/2004	161	73	
OK310830020020_00	OK310830-02-0020D	10/5/2004	29.4	35	
OK310830020020_00	OK310830-02-0020D	11/2/2004	14.6	10	
OK310830020020_00	OK310830-02-0020D	12/13/2004	16.2	16	
OK310830020020_00	OK310830-02-0020D	1/18/2005	11.2	11	
OK310830020020_00	OK310830-02-0020D	2/14/2005	10.3	16	
OK310830020020_00	OK310830-02-0020D	3/21/2005	16	11	
OK310830020020_00	OK310830-02-0020D	4/25/2005	34.1	32	
OK310830020020_00	OK310830-02-0020D	5/31/2005	59.9	60	
OK310830020020_00	OK310830-02-0020D	7/5/2005	350	302	high flow
OK310830020020_00	OK310830-02-0020D	8/8/2005	72.8	68	
OK310830020020_00	OK310830-02-0020D	9/12/2005	36	86	
OK310830020020_00	OK310830-02-0020D	10/17/2005	54.2	57	
OK310830020020_00	OK310830-02-0020D	11/29/2005	10.8	10	
OK310830020020_00	OK310830-02-0020D	1/9/2006	10.4	10	
OK310830020020_00	OK310830-02-0020D	2/13/2006	13.1	10	
OK310830020020_00	OK310830-02-0020D	3/20/2006	29.1	27	
OK310830020020_00	OK310830-02-0020D	5/2/2006	8.36	10	
OK310830020020_00	OK310830-02-0020D	5/30/2006	30.1	22	
OK310830020020_00	OK310830-02-0020D	7/10/2006	221	133	
OK310830020060_10	OK310830-02-0060G	8/23/2004	62.8	63	
OK310830020060_10	OK310830-02-0060G	10/5/2004	54.1	62	
OK310830020060_10	OK310830-02-0060G	11/2/2004	87	62	
OK310830020060_10	OK310830-02-0060G	12/13/2004	51.7	41	high flow
OK310830020060_10	OK310830-02-0060G	1/18/2005	45.4	47	
OK310830020060_10	OK310830-02-0060G	2/14/2005	15	23	high flow
OK310830020060_10	OK310830-02-0060G	3/21/2005	18.4	31	

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310830020060_10	OK310830-02-0060G	4/25/2005	53	60	
OK310830020060_10	OK310830-02-0060G	5/31/2005	48.3	60	
OK310830020060_10	OK310830-02-0060G	7/5/2005	1000.99	1262	
OK310830020060_10	OK310830-02-0060G	8/8/2005	606	392	
OK310830020060_10	OK310830-02-0060G	9/12/2005	24.5	9.99	
OK310830020060_10	OK310830-02-0060G	10/17/2005	109	93	high flow
OK310830020060_10	OK310830-02-0060G	11/29/2005	8.66	9.99	
OK310830020060_10	OK310830-02-0060G	1/9/2006	7.96	9.99	
OK310830020060_10	OK310830-02-0060G	2/13/2006	7.62	20	
OK310830020060_10	OK310830-02-0060G	3/20/2006	52.7	61	high flow
OK310830020060_10	OK310830-02-0060G	5/2/2006	28.1	34	
OK310830020060_10	OK310830-02-0060G	5/30/2006	1000.99	1499	
OK310830020060_10	OK310830-02-0060G	7/10/2006	58.9	44	
OK310830030010_00	OK310830030010-001AT	11/11/1998	151	228	
OK310830030010_00	310830030010-001AT	12/8/1998	144	131	
OK310830030010_00	310830030010-001AT	4/7/1999	98	500	
OK310830030010_00	310830030010-001AT	4/19/1999	49	60	
OK310830030010_00	310830030010-001AT	6/16/1999	56	80	
OK310830030010_00	310830030010-001AT	7/12/1999	177	176	
OK310830030010_00	310830030010-001AT	8/18/1999	25	70	
OK310830030010_00	310830030010-001AT	9/27/1999	9	22	
OK310830030010_00	310830030010-001AT	10/11/1999	6	17	
OK310830030010_00	310830030010-001AT	11/8/1999	21	36	
OK310830030010_00	310830030010-001AT	12/6/1999	27	40	high flow
OK310830030010_00	310830030010-001AT	1/18/2000	11	32	
OK310830030010_00	310830030010-001AT	2/14/2000	6	40	
OK310830030010_00	310830030010-001AT	5/8/2000	63	128	high flow
OK310830030010_00	OK310830030010G	5/22/2000	18.2	49	high flow
OK310830030010_00	310830030010-001AT	6/12/2000	63	256	high flow
OK310830030010_00	310830030010-001AT	7/18/2000	64	152	high flow
OK310830030010_00	OK310830030010G	7/31/2000	59.9	14	high flow
OK310830030010_00	310830030010-001AT	8/15/2000	18	72	
OK310830030010_00	OK310830030010G	9/5/2000	8.58	4	high flow
OK310830030010_00	310830030010-001AT	9/11/2000	7	22	
OK310830030010_00	310830030010-001AT	10/9/2000	3	1	
OK310830030010_00	OK310830030010G	10/9/2000	6.04	22	

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310830030010_00	310830030010-001AT	11/6/2000	146	150	high flow
OK310830030010_00	OK310830030010G	11/13/2000	67.2	50	high flow
OK310830030010_00	OK310830030010G	12/18/2000	45.2	44	high flow
OK310830030010_00	OK310830030010G	2/1/2001	46.2	100	high flow
OK310830030010_00	OK310830030010G	3/5/2001	84.3	126	high flow
OK310830030010_00	OK310830030010G	4/9/2001	47	80	high flow
OK310830030010_00	OK310830030010G	5/14/2001	233	294	high flow
OK310830030010_00	OK310830030010G	6/18/2001	133	388	high flow
OK310830030010_00	OK310830030010G	7/18/2001	20		
OK310830030010_00	OK310830030010G	7/23/2001	8.46	66	high flow
OK310830030010_00	OK310830030010G	8/17/2001	22.2		high flow
OK310830030010_00	OK310830030010G	8/27/2001	11.9	32	high flow
OK310830030010_00	OK310830030010G	10/1/2001	4.88	13	high flow
OK310830030010_00	OK310830030010G	11/5/2001	29.1	30	
OK310830030010_00	310830030010-001AT	11/26/2001	10		
OK310830030010_00	OK310830030010G	12/17/2001	3.59	10	
OK310830030010_00	OK310830030010G	1/22/2002	4.17	5	high flow
OK310830030010_00	OK310830030010G	2/25/2002	4.39	5	high flow
OK310830030010_00	310830030010-001AT	2/27/2002	11		
OK310830030010_00	OK310830030010G	4/1/2002	4.11	5	high flow
OK310830030010_00	310830030010-001AT	9/25/2002	57		
OK310830030010_00	310830030010-001AT	10/23/2002	82		high flow
OK310830030010_00	310830030010-001AT	11/20/2002	51		
OK310830030010_00	310830030010-001AT	1/13/2003	28		high flow
OK310830030010_00	310830030010-001AT	2/19/2003	9		
OK310830030010_00	310830030010-001AT	3/26/2003	202		
OK310830030010_00	310830030010-001AT	4/30/2003	197		high flow
OK310830030010_00	310830030010-001AT	6/4/2003	357		
OK310830030010_00	310830030010-001AT	7/15/2003	33		
OK310830030010_00	310830030010-001AT	8/20/2003	22		
OK310830030010_00	310830030010-001AT	9/22/2003	6		
OK310830030010_00	310830030010-001AT	10/20/2003	5		
OK310830030010_00	310830030010-001AT	11/24/2003	5		
OK310830030010_00	310830030010-001AT	1/7/2004	10		
OK310830030010_00	310830030010-001AT	2/10/2004	9		
OK310830030010_00	310830030010-001AT	3/15/2004	52		high flow

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310830030010_00	310830030010-001AT	4/27/2004	26		
OK310830030010_00	310830030010-001AT	6/1/2004	5		
OK310830030010_00	310830030010-001AT	7/7/2004	787		high flow
OK310830030010_00	OK310830030010-001AT	7/15/2004	19.2		
OK310830030010_00	310830030010-001AT	8/10/2004	10		
OK310830030010_00	OK310830030010-001AT	8/23/2004	33	47	
OK310830030010_00	310830030010-001AT	9/15/2004	7		
OK310830030010_00	OK310830030010-001AT	10/5/2004	45.4	36	
OK310830030010_00	OK310830030010-001AT	11/2/2004	15.8	22	
OK310830030010_00	310830030010-001AT	11/3/2004	16		high flow
OK310830030010_00	310830030010-001AT	12/6/2004	66	89	high flow
OK310830030010_00	310830030010-001AT	12/7/2004	67	81	high flow
OK310830030010_00	310830030010-001AT	1/10/2005	149	171	high flow
OK310830030010_00	310830030010-001AT	1/11/2005	85	101	high flow
OK310830030010_00	310830030010-001AT	1/12/2005	46	129	high flow
OK310830030010_00	310830030010-001AT	2/14/2005	77	120	high flow
OK310830030010_00	310830030010-001AT	2/15/2005	45	82	high flow
OK310830030010_00	310830030010-001AT	3/21/2005	15	17	high flow
OK310830030010_00	310830030010-001AT	3/22/2005	15	14	high flow
OK310830030010_00	310830030010-001AT	4/25/2005	22	38	
OK310830030010_00	310830030010-001AT	4/26/2005	19.5	28	
OK310830030010_00	310830030010-001AT	5/13/2005	135		
OK310830030010_00	310830030010-001AT	5/14/2005	105		
OK310830030010_00	310830030010-001AT	5/31/2005	233	256	
OK310830030010_00	310830030010-001AT	6/1/2005	152	171	
OK310830030010_00	310830030010-001AT	6/13/2005	1000	1890	high flow
OK310830030010_00	310830030010-001AT	7/6/2005	53	86	high flow
OK310830030010_00	310830030010-001AT	8/8/2005	659	443	
OK310830030010_00	310830030010-001AT	8/9/2005	139	155	
OK310830030010_00	310830030010-001AT	9/12/2005		44	
OK310830030010_00	310830030010-001AT	9/13/2005	23	76	
OK310830030010_00	310830030010-001AT	10/17/2005	25	22	
OK310830030010_00	310830030010-001AT	10/31/2005	8	19	
OK310830030010_00	310830030010-001AT	11/28/2005	9	18	

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310830030010_00	OK310830030010-001AT	1/9/2006	5.46	14	
OK310830030010_00	310830030010-001AT	1/17/2006	8		
OK310830030010_00	OK310830030010-001AT	2/13/2006	5.38	22	
OK310830030010_00	310830030010-001AT	2/21/2006	8		
OK310830030010_00	OK310830030010-001AT	3/20/2006	24.4	61	high flow
OK310830030010_00	310830030010-001AT	3/27/2006	11		
OK310830030010_00	310830030010-001AT	5/1/2006	130		
OK310830030010_00	OK310830030010-001AT	5/2/2006	49.5	68	
OK310830030010_00	OK310830030010-001AT	5/30/2006	68.9	56	
OK310830030010_00	310830030010-001AT	6/5/2006	3		
OK310830030010_00	OK310830030010-001AT	7/10/2006	17	10	
OK310830030010_00	310830030010-001AT	9/27/2006	8		
OK310830030010_00	310830030010-001AT	10/31/2006	5		
OK310830030010_00	310830030010-001AT	12/5/2006	4		
OK310830030010_00	310830030010-001AT	1/24/2007	20		
OK310830030010_00	310830030010-001AT	3/7/2007	7		
OK310830030010_00	310830030010-001AT	4/4/2007	203		
OK310830030010_00	310830030010-001AT	5/16/2007	918		
OK310830030010_00	310830030010-001AT	6/13/2007	162		
OK310830030010_00	310830030010-001AT	7/11/2007	302		
OK310830030010_00	310830030010-001AT	8/20/2007	1000		
OK310830030010_00	310830030010-001AT	9/19/2007	128		high flow
OK310830030010_00	310830030010-001AT	10/30/2007	25		
OK310830030010_00	310830030010-001AT	12/4/2007	8		
OK310830030010_00	310830030010-001AT	1/23/2008	16		
OK310830030010_00	310830030010-001AT	3/3/2008	1000		
OK310830030010_00	310830030010-001AT	4/28/2008	25		
OK310830030010_00	310830030010-001AT	5/21/2008	43		
OK310830030010_00	310830030010-001AT	7/22/2008	22		
OK310830030010_00	310830030010-001AT	9/16/2008	430		
OK310830030010_00	310830030010-001AT	11/6/2008	100		
OK310830030010_00	310830030010-001AT	2/18/2009	7.75		
OK310830030010_00	310830030010-001AT	3/3/2009	4		
OK310830030010_00	310830030010-001AT	4/7/2009	5		

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310840010010_00	310840010010-003RS	12/8/1998	22	117	high flow
OK310840010010_00	310840010010-003RS	1/26/1999	32	55	high flow
OK310840010010_00	310840010010-003RS	2/23/1999	30	64	high flow
OK310840010010_00	310840010010-003RS	3/16/1999	50	17	high flow
OK310840010010_00	310840010010-003RS	4/29/1999	349	528	high flow
OK310840010010_00	310840010010-003RS	5/25/1999	185	208	high flow
OK310840010010_00	310840010010-003RS	6/22/1999	210	174	high flow
OK310840010010_00	310840010010-003RS	7/20/1999	23	56	high flow
OK310840010010_00	310840010010-003RS	8/17/1999	22	38	
OK310840010010_00	310840010010-003RS	9/27/1999	23	38	
OK310840010010_00	310840010010-003RS	10/11/1999	7	22	
OK310840010010_00	310840010010-003RS	11/8/1999	10	17	
OK310840010010_00	310840010010-003RS	12/6/1999	20	41	
OK310840010010_00	310840010010-003RS	1/18/2000	19	7	
OK310840010010_00	310840010010-003RS	2/14/2000	21	82	
OK310840010010_00	310840010010-003RS	3/14/2000	90		high flow
OK310840010010_00	310840010010-003RS	4/11/2000	57		high flow
OK310840010010_00	310840010010-003RS	5/8/2000	97	144	high flow
OK310840010010_00	310840010010-003RS	6/12/2000	453	724	high flow
OK310840010010_00	310840010010-003RS	7/18/2000	110	342	high flow
OK310840010010_00	310840010010-003RS	8/15/2000	6	26	
OK310840010010_00	310840010010-003RS	9/11/2000	4	8	
OK310840010010_00	310840010010-003RS	10/9/2000	4	5	
OK310840010010_00	310840010010-003RS	11/6/2000	108	112	high flow
OK310840010010_00	310840010010-003RS	2/27/2001	111		high flow
OK310840010010_00	310840010010-003RS	3/20/2001	63		high flow
OK310840010010_00	310840010010-003RS	4/17/2001	24		high flow
OK310840010010_00	310840010010-003RS	5/21/2001	424		high flow
OK310840010010_00	310840010010-003RS	6/27/2001	6		high flow
OK310840010010_00	310840010010-003RS	7/23/2001	6		
OK310840010010_00	310840010010-003RS	8/20/2001	3		
OK310840010010_00	310840010010-003RS	9/17/2001	85		
OK310840010010_00	310840010010-003RS	10/22/2001	19		
OK310840010010_00	310840010010-003RS	11/13/2001	29		
OK310840010010_00	310840010010-003RS	2/27/2002	12		
OK310840010010_00	310840010010-003RS	3/25/2002	15		

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310840010010_00	310840010010-003RS	4/22/2002	61		high flow
OK310840010010_00	310840010010-003RS	5/20/2002	137		high flow
OK310840010010_00	310840010010-003RS	7/23/2002	11		
OK310840010010_00	310840010010-003RS	8/21/2002	5		
OK310840010010_00	310840010010-003RS	9/25/2002	5		
OK310840010010_00	310840010010-003RS	10/23/2002	688		high flow
OK310840010010_00	310840010010-003RS	11/20/2002	66		high flow
OK310840010010_00	310840010010-003RS	1/13/2003	44		high flow
OK310840010010_00	310840010010-003RS	2/19/2003	31		high flow
OK310840010010_00	310840010010-003RS	3/26/2003	249		high flow
OK310840010010_00	310840010010-003RS	4/30/2003	106		
OK310840010010_00	310840010010-003RS	6/4/2003	1000		
OK310840010010_00	310840010010-003RS	7/15/2003	39		
OK310840010010_00	310840010010-003RS	8/20/2003	6		
OK310840010010_00	310840010010-003RS	9/22/2003	10		
OK310840010010_00	310840010010-003RS	10/20/2003	35		
OK310840010010_00	310840010010-003RS	11/24/2003	19		
OK310840010010_00	310840010010-003RS	1/7/2004	11		
OK310840010010_00	310840010010-003RS	2/10/2004	61		
OK310840010010_00	310840010010-003RS	3/15/2004	126		high flow
OK310840010010_00	310840010010-003RS	4/27/2004	81		
OK310840010010_00	310840010010-003RS	6/1/2004	20		
OK310840010010_00	310840010010-003RS	7/6/2004	210		high flow
OK310840010010_00	310840010010-003RS	8/10/2004	6		
OK310840010010_00	310840010010-003RS	9/14/2004	15		
OK310840010010_00	310840010010-003RS	11/3/2004	35		
OK310840010010_00	310840010010-003RS	12/6/2004	104	131	high flow
OK310840010010_00	310840010010-003RS	1/11/2005	125	157	high flow
OK310840010010_00	310840010010-003RS	1/12/2005	131	163	high flow
OK310840010010_00	310840010010-003RS	2/15/2005	55	114	high flow
OK310840010010_00	310840010010-003RS	3/22/2005	63	73	high flow
OK310840010010_00	310840010010-003RS	4/25/2005	48	64	
OK310840010010_00	310840010010-003RS	4/26/2005	36	60	
OK310840010010_00	310840010010-003RS	5/31/2005	276	300	
OK310840010010_00	310840010010-003RS	6/13/2005	1000	1460	high flow
OK310840010010_00	310840010010-003RS	6/14/2005	1000	675	high flow

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310840010010_00	310840010010-003RS	8/8/2005	6	11	
OK310840010010_00	310840010010-003RS	9/12/2005	9	21	
OK310840010010_00	OK310840-01-0010L	9/28/2005	37		
OK310840010010_00	310840010010-003RS	10/31/2005		38	
OK310840010010_00	310840010010-003RS	3/27/2006	159		
OK310840010010_00	310840010010-003RS	5/1/2006	36		
OK310840010010_00	310840010010-003RS	6/5/2006	28		
OK310840010010_00	310840010010-003RS	7/18/2006	15		
OK310840010010_00	310840010010-003RS	8/15/2006	6		
OK310840010010_00	310840010010-003RS	9/26/2006	7		
OK310840010010_00	310840010010-003RS	10/31/2006	3		
OK310840010010_00	310840010010-003RS	12/5/2006	13		
OK310840010010_00	310840010010-003RS	1/23/2007	51		
OK310840010010_00	310840010010-003RS	3/7/2007	29		
OK310840010010_00	310840010010-003RS	4/4/2007	206		high flow
OK310840010010_00	310840010010-003RS	5/15/2007	363		high flow
OK310840010010_00	310840010010-003RS	6/12/2007	174		high flow
OK310840010010_00	310840010010-003RS	7/11/2007	122		high flow
OK310840010010_00	310840010010-003RS	8/20/2007	23		
OK310840010010_00	310840010010-003RS	9/19/2007	113		high flow
OK310840010010_00	310840010010-003RS	10/30/2007	21		
OK310840010010_00	310840010010-003RS	1/23/2008	38		high flow
OK310840010010_00	310840010010-003RS	3/4/2008	21		high flow
OK310840010010_00	310840010010-003RS	4/21/2008	104		high flow
OK310840010010_00	310840010010-003RS	5/21/2008	173		
OK310840010010_00	310840010010-003RS	7/28/2008	63		
OK310840010010_00	310840010010-003RS	9/23/2008	144		high flow
OK310840010010_00	310840010010-003RS	11/18/2008	25		high flow
OK310840010010_00	310840010010-003RS	2/25/2009	16		high flow
OK310840010010_00	310840010010-003RS	3/24/2009	16.25		
OK310840010010_00	310840010010-003RS	4/21/2009	247		high flow
OK310840020010_00	OK310840-02-0010G	5/22/2000	18.7	34	
OK310840020010_00	OK310840-02-0010G	6/26/2000	109	142	
OK310840020010_00	OK310840-02-0010G	7/31/2000	191	48	
OK310840020010_00	OK310840-02-0010G	11/14/2000	17.4	8	
OK310840020010_00	OK310840-02-0010G	12/19/2000	16.9	12	

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310840020010_00	OK310840-02-0010G	1/30/2001	30.5	56	
OK310840020010_00	OK310840-02-0010G	3/6/2001	11.6	24	
OK310840020010_00	OK310840-02-0010G	4/9/2001	18.5	60	
OK310840020010_00	OK310840-02-0010G	5/14/2001	52.7	112	
OK310840020010_00	OK310840-02-0010G	6/18/2001	46.9	20	
OK310840020010_00	OK310840020010G	6/26/2001	57		
OK310840020010_00	OK310840-02-0010G	7/23/2001	15.1	21	
OK310840020010_00	OK310840-02-0010G	10/2/2001	231	10	
OK310840020010_00	OK310840-02-0010G	11/6/2001	7.37	10	
OK310840020010_00	OK310840-02-0010G	12/18/2001	6.94	10	
OK310840020010_00	OK310840-02-0010G	1/23/2002	5.48	10	
OK310840020010_00	OK310840-02-0010G	2/25/2002	4.39	10	
OK310840020010_00	OK310840-02-0010G	4/2/2002	14.1	19	
OK310840020010_00	WABA_AIF_STA0.0	6/29/2002		14.155	
OK310840020010_00	WABA_AIF_STA0.4	6/29/2002		25.4	
OK310840020010_00	WABA_AIF_STA0.6	6/29/2002		23.9	
OK310840020010_00	WABA_AIF_STA0.2	11/12/2002		55.5	
OK310840020010_00	WABA_AIF_STA0.4	11/12/2002		49.9	
OK310840020010_00	OK310840-02-0020C	5/25/2004	40		
OK310840020010_00	OK310840-02-0020C	1/10/2005		43	
OK310840020020_00	OK310840-02-0020C	5/30/2002	45.5	62	
OK310840020020_00	OK310840-02-0020C	8/23/2004	31.7	34	
OK310840020020_00	OK310840-02-0020C	9/27/2004	58.8	66	
OK310840020020_00	OK310840-02-0020C	11/1/2004	15.8	19	
OK310840020020_00	OK310840-02-0020C	11/29/2004	17.9	10	
OK310840020020_00	OK310840-02-0020C	1/10/2005		43	
OK310840020020_00	OK310840-02-0020C	2/14/2005	17.3	43	
OK310840020020_00	OK310840-02-0020C	3/21/2005	30.9	62	
OK310840020020_00	OK310840-02-0020C	4/25/2005	33.4	39	
OK310840020020_00	OK310840-02-0020C	5/31/2005	45	55	
OK310840020020_00	OK310840-02-0020C	7/12/2005	6.31	10	
OK310840020020_00	OK310840-02-0020C	8/15/2005	306	215	
OK310840020020_00	OK310840-02-0020C	9/19/2005	114	120	
OK310840020020_00	OK310840-02-0020C	10/24/2005	7.41	10	
OK310840020020_00	OK310840-02-0020C	12/5/2005	6.29	10	
OK310840020020_00	OK310840-02-0020C	1/17/2006	7.66	10	

Waterbody ID	WQM Station	Date	Turbidity (NTU) 82079	TSS (mg/L) 00530	Flow condition
OK310840020020_00	OK310840-02-0020C	2/21/2006	6.27	10	
OK310840020020_00	OK310840-02-0020C	3/27/2006	36.7	61	
OK310840020020_00	OK310840-02-0020C	5/1/2006	42.7	47	
OK310840020020_00	OK310840-02-0020C	6/26/2006	58.7	50	high flow

APPENDIX B

GENERAL METHOD FOR ESTIMATING FLOW FOR UNGAGED STREAMS

AND

ESTIMATED FLOW EXCEEDANCE PERCENTILES

Appendix B
General Method for Estimating Flow for Ungaged Streams

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

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

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

b. If flow measurements at the coincident gage are missing for some dates on which water quality samples were collected, the gaps in the flow record will be filled, or the record will be extended, by estimating flow based on measured streamflows at a nearby gages. All gages within 150 km radius are identified. For each of the identified gage with a minimum of 99 flow measurements on matching dates, four different regressions are calculated including linear, log linear, logarithmic and exponential regressions. The regression with the lowest root mean square error (RMSE) is chosen for each gage. The potential filling gages are ranked by RMSE from lowest to highest. The record is filled from the first gage (lowest RMSE) for those dates that exist in both records. If dates remain unfilled in the desired timespan of the timeseries, the filling process is repeated with the next gage with the next lowest RMSE and proceeds in this fashion until all missing values in the desired timespan are filled.

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

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

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

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

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

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

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

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

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

<u>Furness Method</u>

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

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

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

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

<u>Wurbs Modified NRCS Method</u>

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

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

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

where:

Q = runoff depth (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

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

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

Thus, the runoff curve number equation can be rewritten:

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

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

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

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

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

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

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

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

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

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

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

Generalized Flow Projection Methodology

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

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

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

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

References

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

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

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

Estimated Flow Exceedance Percentiles

WBID	OK310840020020_00	OK310840020010_00	OK310840010010_00	OK310830030010_00	OK310830020060_10	OK310830020020_00	OK310830010010_00	OK310810040140_00	OK310810020010_00	OK310810010190_00	OK310810010050_00	OK310810010010_10	OK310800020040_00	OK310800020010_00
ProjGage	2575	3680	2788	2590	2575	2575	2589	2861	2860	2859	2859	2860	2859	2625
Area (sq. mile)	39.0	314.5	96.5	116.2	158.6	48.5	35.5	31.3	68.3	20.5	11.9	60.6	16.2	59.0
CN	66.9	58.7	69.3	72.7	76.1	74.4	70.2	67.6	70.7	68.7	70.4	73.8	63.7	67.2
Rain (inch)	27.0	25.7	28.1	30.5	30.1	30.9	32.6	35.9	36.7	38.9	39.4	38.6	39.3	40.4
ProjType	A	U	U	D	A	A	U	D	D	U	A	U	A	U
NN	8612	20612	14002	12258	31343	8612	7989	11160	22920	1009	1009	22920	1009	11413
QAQC	AD:2575:07325800,A;-CN,-R,USG:0	U:3680:07316500,+CN,+R	U:2788:07324200,+CN,+R	D:2590:07325500,+CN,+R,USG:+N	AU:2575:07325800,A;-CN,-R	AD:2575:07325800,A;-CN,-R,USG:0	U:2589:07326500,+CN,+R	D:2861:07329700,+CN,+R,USG:0	D:2860:07328500,+CN,+R,USG:++N	U:2859:07328550,+CN,+R	AU:2859:07328550,A;-CN,-R	U:2860:07328500,+CN,+R	AU:2859:07328550,A;-CN,-R	U:2625:07331000,+CN,+R
Percentile	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	2,918.43	55,907.07	10,765.99	3,748.26	5,884.14	2,967.48	49,588.20	1,452.12	34,478.86	216.37	404.39	48,536.54	340.16	94,400.00
1	249.04	2,775.53	1,753.81	465.08	502.11	253.22	6,537.23	202.22	7,325.73	99.60	186.15	10,312.56	156.58	19,500.00
2	158.76	1,506.72	1,126.21	303.68	320.10	161.43	4,485.30	131.23	5,341.33	81.28	151.91	7,519.09	127.78	13,200.00
3	99.62	1,007.12	890.55	230.42	200.85	101.29	3,577.72	95.73	4,175.50	53.81	100.56	5,877.93	84.59	9,940.00
4	72.38	793.01	734.27	189.01	145.93	73.59	2,998.97	74.76	3,431.35	33.20	62.05	4,830.38	52.19	8,150.00
5	55.26	658.20	617.68	152.90	111.41	56.18	2,551.75	61.31	2,926.98	26.33	49.21	4,120.37	41.39	6,890.00
6	45.14	578.90	533.34	129.54	91.01	45.90	2,222.92	52.71	2,538.37	21.75	40.65	3,573.31	34.20	6,050.00
7	38.13	523.39	468.84	114.68	76.89	38.78	1,973.01	44.64	2,257.25	19.46	36.37	3,177.57	30.60	5,390.00
8	35.02	475.80	424.19	100.98	70.61	35.61	1,723.09	38.88	2,017.47	17.17	32.09	2,840.03	27.00	4,860.00
9	31.91	436.15	384.50	90.57	64.33	32.44	1,591.56	34.15	1,835.57	14.88	27.82	2,583.96	23.40	4,350.00
10	29.57	404.43	344.81	82.50	59.63	30.07	1,486.33	30.44	1,686.74	12.59	23.54	2,374.45	19.80	3,990.00
11	28.02	380.64	317.52	76.03	56.49	28.49	1,367.95	27.21	1,570.98	11.10	20.75	2,211.50	17.46	3,640.00
12	27.24	364.78	295.20	69.87	54.92	27.70	1,273.25	24.58	1,455.22	9.27	17.33	2,048.54	14.58	3,350.00
13	25.68	348.92	275.35	64.45	51.78	26.11	1,187.75	22.37	1,356.00	9.04	16.90	1,908.87	14.22	3,090.00
14	24.90	325.13	260.47	59.57	50.21	25.32	1,114.09	20.28	1,256.78	8.24	15.41	1,769.20	12.96	2,870.00
15	24.13	317.20	248.06	55.53	48.64	24.53	1,048.32	18.66	1,190.64	7.67	14.34	1,676.08	12.06	2,680.00
16	23.35	301.34	235.66	51.50	47.07	23.74	975.98	17.21	1,116.22	6.98	13.05	1,571.33	10.98	2,520.00
17	23.35	285.48	223.26	48.10	47.07	23.74	922.05	15.76	1,066.61	6.64	12.41	1,501.49	10.44	2,370.00
18	22.57	269.62	213.34	44.92	45.50	22.95	866.81	14.63	1,008.73	6.30	11.77	1,420.01	9.90	2,250.00
19	21.79	261.69	200.93	42.26	43.93	22.16	812.88	13.61	950.86	5.95	11.13	1,338.54	9.36	2,140.00
20	21.79	245.83	191.01	39.39	43.93	22.16	781.31	12.53	901.25	5.72	10.70	1,268.70	9.00	2,010.00
21	21.01	237.90	186.05	37.16	42.37	21.37	735.27	11.72	851.64	5.38	10.06	1,198.86	8.46	1,910.00
22	20.23	229.97	178.61	34.83	40.80	20.57	698.44	10.92	800.37	5.15	9.63	1,126.70	8.10	1,810.00
23	20.23	222.04	173.65	32.49	40.80	20.57	657.67	10.27	764.82	4.69	8.77	1,076.65	7.38	1,710.00
24	19.46	214.11	166.20	30.69	39.23	19.78	626.10	9.68	727.61	4.58	8.56	1,024.27	7.20	1,620.00
25	19.46	206.18	161.24	28.88	39.23	19.78	590.59	9.14	698.67	4.35	8.13	983.53	6.84	1,540.00
26	18.68	198.25	156.28	27.18	37.66	18.99	562.96	8.66	669.73	4.12	7.70	942.80	6.48	1,470.00
27	18.68	190.32	148.84	26.23	37.66	18.99	534.03	8.23	642.45	3.66	6.85	904.39	5.76	1,400.00
28	17.90	182.39	143.88	24.85	36.09	18.20	510.35	7.80	613.51	3.43	6.42	863.65	5.40	1,350.00
29	17.90	174.46	138.92	23.68	36.09	18.20	486.67	7.26	590.36	3.43	6.42	831.06	5.40	1,290.00
30	17.12	166.53	133.95	22.62	34.52	17.41	465.63	6.83	567.21	3.21	5.99	798.47	5.04	1,230.00
31	17.12	158.60	128.99	21.66	34.52	17.41	449.85	6.40	544.88	3.09	5.78	767.04	4.86	1,190.00
32	17.12	158.60	124.03	20.92	34.52	17.41	432.75	6.02	523.38	2.86	5.35	736.78	4.50	1,140.00
33	16.34	150.67	121.55	20.17	32.95	16.62	419.59	5.65	506.02	2.75	5.14	712.33	4.32	1,090.00
34	16.34	142.74	116.59	19.54	32.95	16.62	405.12	5.32	490.31	2.63	4.92	690.22	4.14	1,050.00
35	16.34	142.74	114.11	18.90	32.95	16.62	388.02	5.06	474.60	2.63	4.92	668.10	4.14	1,010.00
36	15.56	134.81	109.15	18.26	31.38	15.83	377.50	4.79	458.89	2.40	4.49	645.99	3.78	960.00
37	15.56	126.88	106.67	17.63	31.38	15.83	364.35	4.57	444.84	2.29	4.28	626.20	3.60	928.00
38	15.56	126.88	101.71	17.20	31.38	15.83	352.51	4.36	431.61	2.29	4.28	607.58	3.60	896.00
39	14.79	118.95	99.23	16.67	29.81	15.04	341.99	4.14	420.86	2.06	3.85	592.45	3.24	870.00
40	14.79	118.95	94.26	16.14	29.81	15.04	332.78	3.93	410.11	1.95	3.64	577.32	3.06	832.00
41	14.79	111.02	91.78	15.72	29.81	15.04	323.57	3.76	397.71	1.83	3.42	559.86	2.88	805.00
42	14.01	111.02	86.82	15.29	28.24	14.24	314.37	3.60	387.78	1.72	3.21	545.89	2.70	780.00
43	14.01	103.09	84.34	14.87	28.24	14.24	305.16	3.44	377.04	1.72	3.21	530.76	2.70	755.00
44	14.01	95.16	81.86	14.55	28.24	14.24	297.27	3.28	367.94	1.60	3.00	517.96	2.52	730.00
45	13.23	95.16	76.90	14.23	26.67	13.45	289.37	3.12	358.84	1.49	2.78	505.15	2.34	705.00
46	13.23	87.23	74.42	13.80	26.67	13.45	281.48	3.01	349.75	1.37	2.57	492.35	2.16	686.00
47	13.23	87.23	71.94	13.38	26.67	13.45	274.91	2.85	339.00	1.37	2.57	477.22	2.16	665.00
48	12.45	79.30	69.46	13.06	25.11	12.66	268.33	2.74	330.73	1.26	2.35	465.58	1.98	646.00
49	12.45	76.13	66.98	12.74	25.11	12.66	263.07	2.64	321.64	1.26	2.35	452.77	1.98	628.00

WBID	OK310840020020_00	OK310840020010_00	OK310840010010_00	OK310830030010_00	OK310830020060_10	OK310830020020_00	OK310830010010_00	OK310810040140_00	OK310810020010_00	OK310810010190_00	OK310810010050_00	OK310810010010_10	OK310800020040_00	OK310800020010_00
ProjGage	2575	3680	2788	2590	2575	2575	2589	2861	2860	2859	2859	2860	2859	2625
Area (sq. mile)	39.0	314.5	96.5	116.2	158.6	48.5	35.5	31.3	68.3	20.5	11.9	60.6	16.2	59.0
CN	66.9	58.7	69.3	72.7	76.1	74.4	70.2	67.6	70.7	68.7	70.4	73.8	63.7	67.2
Rain (inch)	27.0	25.7	28.1	30.5	30.1	30.9	32.6	35.9	36.7	38.9	39.4	38.6	39.3	40.4
ProjType	A	U	U	D	A	A	U	D	D	U	A	U	A	U
NN	8612	20612	14002	12258	31343	8612	7989	11160	22920	1009	1009	22920	1009	11413
QAQC	AD:2575:07325800,A;-CN,-R,USG:0	U:3680:07316500,+CN,+R	U:2788:07324200,+CN,+R	D:2590:07325500,+CN,+R,USG:+N	AU:2575:07325800,A;-CN,-R	AD:2575:07325800,A;-CN,-R,USG:0	U:2589:07326500,+CN,+R	D:2861:07329700,+CN,+R,USG:0	D:2860:07328500,+CN,+R,USG:++N	U:2859:07328550,+CN,+R	AU:2859:07328550,A;-CN,-R	U:2860:07328500,+CN,+R	AU:2859:07328550,A;-CN,-R	U:2625:07331000,+CN,+R
Percentile	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)
50	12.45	71.37	64.50	12.32	25.11	12.66	255.18	2.53	312.54	1.14	2.14	439.97	1.80	607.00
51	12.45	66.61	62.02	12.00	25.11	12.66	248.60	2.42	304.27	1.14	2.14	428.33	1.80	590.00
52	11.67	63.44	59.54	11.68	23.54	11.87	242.02	2.31	296.01	1.14	2.14	416.69	1.80	571.00
53	11.67	59.48	57.05	11.36	23.54	11.87	236.76	2.21	286.91	1.09	2.03	403.89	1.71	551.00
54	11.67	55.51	54.57	11.04	23.54	11.87	230.18	2.10	279.47	1.03	1.93	393.41	1.62	537.00
55	10.90	52.34	52.09	10.72	21.97	11.08	223.61	1.99	272.03	1.03	1.93	382.94	1.62	520.00
56	10.90	48.37	52.09	10.41	21.97	11.08	215.72	1.94	262.93	1.03	1.93	370.13	1.62	508.00
57	10.90	45.20	49.61	10.09	21.97	11.08	210.45	1.88	253.01	1.03	1.93	356.17	1.62	493.00
58	10.12	41.24	47.13	9.77	20.40	10.29	206.51	1.77	246.40	0.92	1.71	346.86	1.44	480.00
59	10.12	38.86	44.65	9.45	20.40	10.29	201.25	1.72	238.13	0.92	1.71	335.22	1.44	468.00
60	10.12	35.69	42.17	9.24	20.40	10.29	197.30	1.61	231.51	0.92	1.71	325.90	1.44	455.00
61	10.12	32.51	39.69	8.92	20.40	10.29	193.35	1.56	224.90	0.89	1.67	316.59	1.40	442.00
62	10.12	30.13	37.21	8.71	20.40	10.29	189.41	1.51	219.11	0.84	1.56	308.45	1.31	430.00
63	9.34	27.76	37.21	8.49	18.83	9.50	185.46	1.45	211.67	0.80	1.50	297.97	1.26	417.00
64	9.34	24.58	34.73	8.18	18.83	9.50	180.20	1.34	206.71	0.77	1.43	290.99	1.21	405.00
65	9.34	23.00	32.25	7.96	18.83	9.50	176.26	1.29	200.92	0.69	1.28	282.84	1.08	394.00
66	9.34	20.62	29.77	7.75	18.83	9.50	170.99	1.24	195.13	0.58	1.09	274.69	0.92	381.00
67	9.34	18.24	29.77	7.43	18.83	9.50	165.73	1.18	188.52	0.57	1.07	265.38	0.90	370.00
68	8.56	15.86	27.29	7.33	17.26	8.70	161.79	1.13	182.73	0.48	0.90	257.23	0.76	355.00
69	8.56	14.27	24.81	7.01	17.26	8.70	157.84	1.08	176.94	0.46	0.86	249.08	0.72	342.00
70	8.56	11.90	24.31	6.80	17.26	8.70	153.89	1.02	171.98	0.46	0.86	242.10	0.72	330.00
71	8.56	8.72	22.57	6.58	17.26	8.70	152.58	0.97	166.19	0.46	0.86	233.95	0.72	317.00
72	7.78	6.58	21.33	6.37	15.69	7.91	148.63	0.91	161.23	0.46	0.86	226.97	0.72	305.00
73	7.78	4.76	19.85	6.26	15.69	7.91	144.69	0.86	155.44	0.46	0.86	218.82	0.72	295.00
74	7.78	3.17	18.36	6.05	15.69	7.91	140.74	0.81	149.66	0.46	0.86	210.67	0.72	285.00
75	7.63	1.59	16.62	5.84	15.38	7.76	138.11	0.75	144.70	0.42	0.79	203.69	0.67	275.00
76	7.47	0.63	15.13	5.73	15.06	7.60	134.16	0.75	139.73	0.41	0.77	196.71	0.65	266.00
77	7.32	0.00	13.40	5.52	14.75	7.44	131.53	0.70	134.77	0.35	0.66	189.72	0.56	258.00
78	7.00	0.00	11.41	5.31	14.12	7.12	127.59	0.65	130.64	0.33	0.62	183.90	0.52	250.00
79	6.93	0.00	9.92	5.20	13.97	7.04	123.64	0.59	125.68	0.29	0.53	176.92	0.45	241.00
80	6.69	0.00	8.43	4.99	13.49	6.81	119.70	0.59	120.72	0.26	0.49	169.94	0.41	232.00
81	6.54	0.00	6.95	4.78	13.18	6.65	115.75	0.53	117.41	0.25	0.47	165.28	0.40	224.00
82	6.30	0.00	5.71	4.67	12.71	6.41	111.80	0.48	113.28	0.24	0.45	159.46	0.38	215.00
83	6.07	0.00	4.71	4.46	12.24	6.17	106.54	0.44	108.31	0.23	0.43	152.48	0.36	207.00
84	5.84	0.00	3.47	4.25	11.77	5.93	102.60	0.40	105.01	0.22	0.41	147.82	0.34	200.00
85	5.60	0.00	2.73	4.03	11.30	5.70	98.65	0.36	100.05	0.21	0.39	140.84	0.32	192.00
86	5.37	0.00	1.98	3.82	10.83	5.46	96.02	0.32	95.91	0.19	0.36	135.02	0.31	183.00
87	5.14	0.00	1.51	3.61	10.36	5.22	92.07	0.29	90.95	0.18	0.34	128.03	0.29	175.00
88	4.83	0.00	1.12	3.40	9.73	4.91	89.44	0.26	85.99	0.17	0.32	121.05	0.27	166.00
89	4.59	0.00	0.79	3.29	9.26	4.67	84.18	0.24	80.20	0.15	0.28	112.90	0.23	157.00
90	4.20	0.00	0.57	3.08	8.47	4.27	80.24	0.21	75.24	0.14	0.26	105.92	0.22	147.00
91	3.89	0.00	0.40	2.87	7.85	3.96	76.29	0.19	69.45	0.14	0.26	97.77	0.22	136.00
92	3.74	0.00	0.27	2.65	7.53	3.80	72.34	0.16	63.67	0.11	0.21	89.62	0.18	121.00
93	3.50	0.00	0.10	2.44	7.06	3.56	67.08	0.13	58.71	0.11	0.21	82.64	0.18	108.00
94	3.27	0.00	0.00	2.23	6.59	3.32	63.14	0.11	52.92	0.10	0.19	74.49	0.16	98.00
95	2.88	0.00	0.00	2.02	5.81	2.93	57.87	0.09	47.13	0.08	0.15	66.34	0.13	87.00
96	2.65	0.00	0.00	1.81	5.33	2.69	52.61	0.07	40.51	0.07	0.13	57.03	0.11	77.00
97	2.33	0.00	0.00	1.49	4.71	2.37	46.04	0.05	30.59	0.05	0.09	43.07	0.07	62.00
98	1.87	0.00	0.00	1.17	3.77	1.90	36.83	0.02	20.67	0.03	0.06	29.10	0.05	41.00
99	1.01	0.00	0.00	0.69	2.04	1.03	23.68	0.01	7.44	0.02	0.04	10.48	0.04	17.00
100	0.00	0.00	0.00	0.0001	0.75	0.00	0.68	0.00	0.5	0.00	0.00	0.00	0.00	6.1

APPENDIX C

NPDES DISCHARGE MONITORING REPORT DATA

NPDES Discharge Monitoring Data Report

NPDES Permit No.	Monitoring Date	Maximum Flow (mgd)	Average Flow (MGD)	Max TSS Concentration (mg/L)	Avgerage TSS Concentration (mg/L)
OK0001295	10/31/2007	1.12	0.07	12	9
OK0001295	9/30/2007	0.18	0.01	19	14
OK0001295	8/31/2007	1.22	0.07	23	16
OK0001295	7/31/2007	1.21	0.18	19	14
OK0001295	6/30/2007	1.22	0.36	32	17
OK0001295	5/31/2007	1.2	0.25	28	19
OK0001295	4/30/2007	1.15	0.16	36	25
OK0001295	3/31/2007	0.59	0.03	34	22
OK0001295	2/28/2007	0.25	0.01	31	18
OK0001295	1/31/2007	1.14	0.16	32	22
OK0001295	12/31/2006	1.13	0.073		
OK0001295	11/30/2006	0.686	0.043		
OK0001295	10/31/2006	1.15	0.135		
OK0001295	9/30/2006	NR	NR		
OK0001295	8/31/2006	NR	NR		
OK0001295	7/31/2006	0.92	0.06		
OK0001295	6/30/2006	0.97	0.03		
OK0001295	5/31/2006	2	0.16		
OK0001295	4/30/2006	0	0.02		
OK0001295	3/31/2006	2	0.18		
OK0001295	2/28/2006	NR	NR		
OK0001295	1/31/2006	NR	NR		
OK0001295	12/31/2005	NR	NR		
OK0001295	11/30/2005	NR	NR		
OK0001295	10/31/2005	1.151	0.064		
OK0001295	9/30/2005	1.097	0.07		
OK0001295	8/31/2005	1.092	0.206		
OK0001295	7/31/2005	1.201	0.102		
OK0001295	6/30/2005	1.184	0.091		
OK0001295	5/31/2005	0.689	0.022		
OK0001295	4/30/2005	0.229	0.008		
OK0001295	3/31/2005	0.358	0.025		
OK0001295	2/28/2005	0.554	0.018		
OK0001295	1/31/2005	0.76	0.105		
OK0001295	12/31/2004	0.519	0.058		
OK0001295	11/30/2004	1.22	0.165		
OK0000639	7/31/2008	0.93	0.68	17	16
OK0000639	6/30/2008	0.95	0.69	15.5	14.75
OK0000639	5/31/2008	0.64	0.45	17	15
OK0000639	4/30/2008	0.58	0.34	33	19.25
OK0000639	3/31/2008	0.28	0.2	8	7
OK0000639	2/29/2008	0.36	0.23	9	7

NPDES Permit No.	Monitoring Date	Maximum Flow (mgd)	Average Flow (MGD)	Max TSS Concentration (mg/L)	Avgerage TSS Concentration (mg/L)
OK0000639	1/31/2008	0.39	0.26	18	16.5
OK0000639	12/31/2007	0.47	0.31	31	22.5
OK0000639	11/30/2007	0.6	0.4	24	18.5
OK0000639	10/31/2007	0.66	0.36	16	14.5
OK0000639	9/30/2007	0.58	0.42	16	12
OK0000639	8/31/2007	1.03	0.61	30	20.75
OK0000639	7/31/2007	0.76	0.54	16	15
OK0000639	6/30/2007	1.66	0.64	17	11.5
OK0000639	5/31/2007	0.95	0.55	21	13.25
OK0000639	4/30/2007	0.77	0.5	22	21.5
OK0000639	3/31/2007	0.52	0.29	22	21.5
OK0000639	2/28/2007	0.48	0.26	16.5	14.75
OK0000639	1/31/2007	0.51	0.36	19.5	17.25
OK0000639	12/31/2006	0.51	0.33		
OK0000639	11/30/2006	0.69	0.32		
OK0000639	10/31/2006	1.12	0.38		
OK0000639	9/30/2006	0.64	0.44		
OK0000639	8/31/2006	0.8	0.57		
OK0000639	7/31/2006	0.76	0.56		
OK0000639	6/30/2006	0.76	0.54		
OK0000639	5/31/2006	0.83	0.46		
OK0000639	4/30/2006	0.73	0.44		
OK0000639	3/31/2006	0.5	0.31		
OK0000639	2/28/2006	0.69	0.35		
OK0000639	1/31/2006	0.32	0.23		
OK0000639	12/31/2005	0.69	0.25		
OK0000639	11/30/2005	0.35	0.26		
OK0000639	10/31/2005	0.45	0.3		
OK0000639	9/30/2005	0.5	0.39		
OK0000639	8/31/2005	0.78	0.44		
OK0000639	7/31/2005	0.56	0.41		
OK0000639	6/30/2005	0.62	0.32		
OK0000639	5/31/2005	0.56	0.26		
OK0000639	4/30/2005	0.53	0.25		
OK0000639	3/31/2005	0.22	0.13		
OK0000639	2/28/2005	0.25	0.14		
OK0000639	1/31/2005	0.2	0.2		
OK0000639	12/31/2004	0.22	0.1		
OK0000639	11/30/2004	0.27	0.15		
OK0000639	10/31/2004	0.41	0.27		
OK0000639	9/30/2004	0.69	0.37		
OK0000639	8/31/2004	0.8	0.36		
OK0000639	7/31/2004	0.59	0.32		

NPDES Permit No.	Monitoring Date	Maximum Flow (mgd)	Average Flow (MGD)	Max TSS Concentration (mg/L)	Avgerage TSS Concentration (mg/L)
OK0000639	6/30/2004	0.53	0.29		
OK0000639	5/31/2004	0.75	0.3		
OK0000639	4/30/2004	0.62	0.29		
OK0000639	3/31/2004	0.4	0.24		
OK0000639	2/29/2004	0.28	0.19		
OK0000639	1/31/2004	0.64	0.27		
OK0000639	12/31/2003	0.73	0.2		
OKG950036	7/31/2008	NR	NR		
OKG950036	6/30/2008	NR	NR		
OKG950036	5/31/2008	NR	NR		
OKG950036	4/30/2008	43.3541	43.3541	28	28
OKG950036	3/31/2008	0.5386	0.5386	4	4
OK0000124	6/30/2008	0.034483	0.01517		
OK0000124	5/31/2008	0.045706	0.0198	11	11
OK0000124	4/30/2008	0.026265	0.015711		
OK0000124	3/31/2008	0.021226	0.013866		
OK0000124	2/29/2008	0.024187	0.01187		
OK0000124	1/31/2008	0.035471	0.010217		
OK0000124	12/31/2007	0.015941	0.010485		
OK0000124	11/30/2007	0.027164	0.012055		
OK0000124	10/31/2007	0.029282	0.018145		
OK0000124	9/30/2007	0.047175	0.01828		
OK0000124	8/31/2007	0.038136	0.025059		
OK0000124	7/31/2007	0.036797	0.02213		
OK0000124	6/30/2007	0.048285	0.021825		
OK0000124	5/31/2007	0.036096	0.021389		
OK0000124	4/30/2007	0.036801	0.02118		
OK0000124	3/31/2007	0.061347	0.015152		
OK0000124	2/28/2007	0.017718	0.012492		
OK0000124	1/31/2007	0.018474	0.00994		
OK0000124	12/31/2006	0.023612	0.011001		
OK0000124	11/30/2006	0.02948	0.014515		
OK0000124	10/31/2006	0.030192	0.01326		
OK0000124	9/30/2006	0.050505	0.024247		
OK0000124	8/31/2006	0.050505	0.024247		
OK0000124	7/31/2006	0.05738	0.015145		
OK0000124	6/30/2006	0.037463	0.025678		
OK0000124	5/31/2006	0.039268	0.017752		
OK0000124	4/30/2006	0.02238	0.016058		
OK0000124	3/31/2006	0.024033	0.013375		
OK0000124	2/28/2006	0.020141	0.013291		
OK0000124	1/31/2006	0.020363	0.011379		
OK0000124	12/31/2005	0.02148	0.010946		

NPDES Permit No.	Monitoring Date	Maximum Flow (mgd)	Average Flow (MGD)	Max TSS Concentration (mg/L)	Avgerage TSS Concentration (mg/L)
OK0000124	11/30/2005	0.016692	0.012767		
OK0000124	10/31/2005	0.021365	0.013603		
OK0000124	9/30/2005	0.024122	0.018801		
OK0000124	8/31/2005	0.050304	0.020866		
OK0000124	7/31/2005	0.046265	0.018743		
OK0000124	6/30/2005	0.030491	0.018307		
OK0000124	5/31/2005	0.022414	0.014426		
OK0000124	4/30/2005	0.040783	0.019229		
OK0000124	3/31/2005	0.026393	0.013279		
OK0000124	2/28/2005	0.020456	0.012719		
OK0000124	1/31/2005	0.022695	0.010438		
OK0000124	12/31/2004	0.018309	0.010632		
OK0000124	11/30/2004	0.017251	0.01241		
OK0000124	10/31/2004	0.042997	0.014139		
OK0000124	9/30/2004	0.030994	0.022251		
OK0000124	8/31/2004	0.031662	0.022193		
OK0000124	7/31/2004	0.033525	0.02223		
OK0000124	6/30/2004	0.030461	0.020647		
OK0000124	5/31/2004	0.030774	0.020199		
OK0000124	4/30/2004	0.032029	0.017623		
OK0000124	3/31/2004	0.036772	0.015467		
OK0000124	2/29/2004	0.016272	0.011547		
OK0000124	1/31/2004	0.020234	0.01164		
OK0000124	12/31/2003	0.024146	0.016537		
OK0000124	11/30/2003	0.042692	0.018652		
OK0000124	10/31/2003	0.035157	0.021169		
OK0000124	9/30/2003	0.042144	0.023081		
OK0000124	8/31/2003	0.051763	0.027745		
OK0000124	7/31/2003	0.049749	0.02331		
OK0044288	6/30/2008	0.317	0.16	7	6
OK0044288	5/31/2008	0.279	0.17	9.3	9.15
OK0044288	4/30/2008	0.309	0.202	12.5	8.75
OK0044288	3/31/2008	0.558	0.24	< 5.0	< 5.0
OK0044288	2/29/2008	0.955	0.322	< 5.0	< 5.0
OK0044288	1/31/2008	0.93	0.338	< 5.0	< 5.0
OK0044288	12/31/2007	0.85	0.309	6	5
OK0044288	11/30/2007	1.04	0.338	3.5	3
OK0044288	10/31/2007	0.77	0.274	5	3.5
OK0044288	9/30/2007	0.553	0.262	7.5	3.75
OK0044288	8/31/2007	0.633	0.298	11	7.75
OK0044288	7/31/2007	0.508	0.274	7.5	5.3
OK0044288	6/30/2007	0.404	0.231	5.5	5.5
OK0044288	5/31/2007	0.377	0.2	18	13

NPDES Permit No.	Monitoring Date	Maximum Flow (mgd)	Average Flow (MGD)	Max TSS Concentration (mg/L)	Avgerage TSS Concentration (mg/L)
OKG950033	7/31/2008	NR	NR		
OKG950033	6/30/2008	1.8465	1.8465		
OKG950033	5/31/2008	NR	NR		
OKG950033	4/30/2008	NR	NR		
OKG950033	3/31/2008	3.2314	3.2314		

APPENDIX D

STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix D
State of Oklahoma Antidegradation Policy

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

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

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

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

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

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

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

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

785:46-13-1. Applicability and scope

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

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

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

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

(3) Tier 3. No degradation of water quality allowed in Outstanding Resource Waters.

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

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

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

785:46-13-2. Definitions

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

"Specified pollutants" means

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

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

(C) Phosphorus;

(D) Total Suspended Solids (TSS); and

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

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

(a) General.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX E

RESPONSE TO COMMENTS

Comments from Oklahoma Farm Bureau were received on August 30, 2010:

Comment #1: We appreciate the opportunity to provide comments on these draft TMDLs. As we have on their draft 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 #1: *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 #2: 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 #2*: Thank you for the comments*.