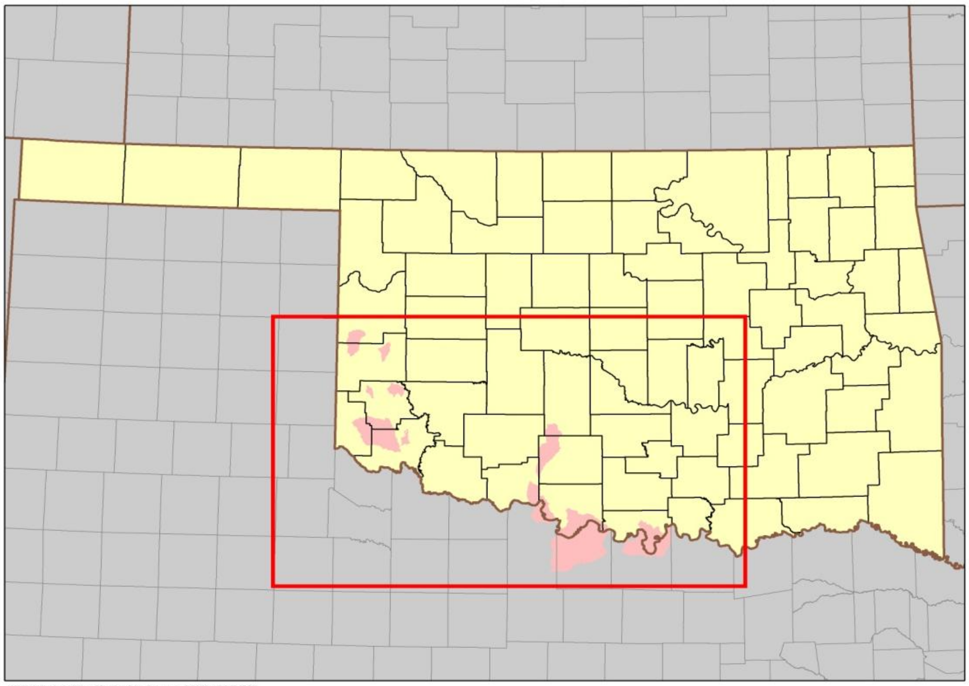
FINAL

2012 BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE RED RIVER, OKLAHOMA (OK311100, OK311200, OK311210, OK311510, OK311600, OK311800)



Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

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Prepared by:

PARSONS

AUGUST 2012

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OKWBID

OK311100010190_00, OK311100010190_20, OK311100010230_00, OK311200000010_00, OK311210000050_00, OK311510010040_00, OK311510010090_00, OK311510020090_00, OK311600030060_00, OK311600020110_05, OK311800000060_00

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AUGUST 2012

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ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
ASAE	American Society of Agricultural Engineers
BMP	Best management practices
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony-forming unit
CPP	Continuing Planning Process
CWA	Clean Water Act
DEQ	Oklahoma Department of Environmental Quality
DMR	Discharge monitoring report
E. Coli	Escherichia coli
ENT	Enterococci
EPA	U.S. Environmental Protection Agency
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
NRCS	Natural Resources Conservation Service
NRMSE	Normalized root mean square error
NTU	Nephelometric turbidity unit
OAC	Oklahoma Administrative Code
OLS	Ordinary least square
O.S.	Oklahoma statute
ODAFF	Oklahoma Department of Agriculture, Food and Forestry

OKWBID	Oklahoma Waterbody Identification Number
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWQS	Oklahoma Water Quality Standards
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
TSS	Total Suspended Solids
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WWAC	warm water aquatic community
WLA	wasteload allocation
WQM	Water quality monitoring
WQMP	Water Quality Management Plan
WQS	Water quality standard
WWTP	wastewater treatment plant

Executive Summary

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli),* Enterococci] and turbidity for certain waterbodies in the Red River basin. Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic communities. Data assessment and total maximum daily load (TMDL) calculations are conducted in accordance with requirements of Section 303(d) of the Clean Water Act (CWA), Water Quality Planning and Management Regulations (40 CFR Part 130), U.S. Environmental Protection Agency (EPA) guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to EPA for review. Approved 303(d) listed waterbody-pollutant pairs or surrogates TMDLs will receive notification of the approval or disapproval action. Once the EPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (EPA 2003).

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

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria 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 Red River Basin, identified in Table ES-1, that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC).

Elevated levels of bacteria or turbidity above the WQS necessitates the development of a TMDL. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the PBCR or fish and wildlife propagation beneficial uses 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*	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
Buffalo Creek	OK311510020090_00	20.32	2019	4	X	X	N		
Timber Creek	OK311510010090_00	12.01	2019	4	X	X	N		
Lake Creek	OK311510010040_00	13.33	2019	4	X	X	N		
Station Creek	OK311800000060_00	10.58	2019	4	X		N		
Turkey Creek	OK311600020060_00	51.64	2019	4	X	X	N		
Bitter Creek	OK311600020110_05	7.8	2016	3	X		*		
Little Beaver Creek	OK311210000050_00	39.49	2016	3	X	X	N		
Red River	OK311200000010_00	30.02	2016	3	X		N	X	N
Red River	OK311100010190_20	46.42	2016	3	X		N	X	N
Red River	OK311100010190_00	47.84	2013	2	X		N	X	N
Bills Creek	OK311100010230_00	8.4	2019	4	X		N		

ENT = Enterococci; N = Not attaining; X = Criterion exceeded
Source: 2008 Integrated Report, DEQ 2008.

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

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

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (count/100 ml)	Notes
OK311510020090_00	Buffalo Creek	EC	14	265	
		ENT	14	257	
OK311510010090_00	Timber Creek	EC	14	294	
		ENT	14	514	
OK311510010040_00	Lake Creek	EC	13	213	
		ENT	13	109	
OK311800000060_00	Station Creek	ENT	14	93	
OK311600020060_00	Turkey Creek	EC	14	319	
		ENT	14	319	
OK311600020110_05	Bitter Creek	ENT	6	662	De-list; Insufficient number of samples
OK311210000050_00	Little Beaver Creek	EC	12	215	
		ENT	12	253	
OK311200000010_00	Red River	ENT	14	71	
OK311100010190_20	Red River	ENT	26	53	
OK311100010190_00	Red River	ENT			De-list; No data
OK311100010230_00	Bills Creek	ENT	2	1612	De-list; Insufficient number of samples

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

The definition of PBCR and the bacteria WQSs for PBCR are summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

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

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

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

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

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

To implement Oklahoma's WQS for PBCR, the Oklahoma Water Resources Board (OWRB) promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011). 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) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is not met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(c) ***Enterococci.***

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to Enterococci if the geometric mean of 33 colonies per 100 ml is met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to Enterococci if the geometric mean of 33 colonies per 100 ml is not met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

Where concurrent data exist for multiple bacterial indicators on the same waterbody, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2011). As stipulated in the WQS, only the geometric mean of all samples collected over the recreation period shall be used to assess the impairment status of a stream. Therefore, only the geometric mean criteria will be used to develop TMDLs for *E. coli* and Enterococci bacteria indicators.

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

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

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

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

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

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

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

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

Assessment of Fish and Wildlife Propagation support

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

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

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

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

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

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 for turbidity and TSS under base flow conditions, which DEQ considers to be all flows less than the 25^{th} flow exceedance percentile (i.e., the lower 75% of flows). Water quality samples collected under flow conditions greater than the 25^{th} flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis.

Table ES-3 Summary of Turbidity and TSS Samples Collected During Base Flow Conditions, 1998-2011

Waterbody ID	Waterbody Name	Number of turbidity samples	Number of TSS Samples	Number of samples greater than 50 NTU	% turbidity samples exceeding criterion	2008 303(d) List	Comments
OK311510020090_00	Buffalo Creek	16	13	0	0%		
OK311510010090_00	Timber Creek	21	19	3	14%		TMDL required
OK311510010040_00	Lake Creek	24	23	1	4%		
OK311800000060_00	Station Creek	27	24	2	7%		
OK311100010230_00	Bills Creek	0	0	0			No data
OK311600020060_00	Turkey Creek	30	23	11	37%		TMDL required
OK311600020110_05	Bitter Creek	13	11	4	31%		TMDL required
OK311210000050_00	Little Beaver Creek	21	20	5	24%		TMDL required
OK311200000010_00	Red River	33	14	28	85%	X	TMDL required
OK311100010190_20	Red River	33	-	17	52%	X	TMDL required
OK311100010190_00	Red River	5	4	4	80%	X	TMDL required

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10% 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 goals as surrogates. Table ES-4 provides the results of the waterbody specific regression analysis.

Table ES-4 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)	MOS
OK311510010090_00	Timber Creek	0.668	14.9%	44	15%
OK311600020060_00	Turkey Creek	0.965	4.3%	53	10%
OK311600020110_05	Bitter Creek	0.936	6.2%	63	10%
OK311210000050_00	Little Beaver Creek	0.878	10.1%	42	15%
OK311200000010_00	Red River	0.863	8.3%	67	10%
OK311100010190_20	Red River	0.851	11.4%	39	15%
OK311100010190_00	Red River	0.851	11.4%	39	15%

Table ES-5 shows the bacteria and turbidity TMDLs that will be developed in this report:

Table ES-5 Stream and Pollutants for TMDL Development

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Turbidity
Buffalo Creek	OK311510020090_00	20.32	2019	4	X	X	
Timber Creek	OK311510010090_00	12.01	2019	4	X	X	X
Lake Creek	OK311510010040_00	13.33	2019	4	X	X	
Station Creek	OK311800000060_00	10.58	2019	4	X		
Turkey Creek	OK311600020060_00	51.64	2019	4	X	X	X
Bitter Creek	OK311600020110_05	7.8	2016	3			X
Little Beaver Creek	OK311210000050_00	39.49	2016	3	X	X	X
Red River	OK311200000010_00	30.02	2016	3	X		X
Red River	OK311100010190_20	46.42	2016	3	X		X
Red River	OK311100010190_00	47.84	2013	2			X
Bills Creek	OK311100010230_00	8.4	2019	4			

E.2 Pollutant Source Assessment

A pollutant source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Bacteria originate from warm-blooded animals and sources may be point or nonpoint in nature. 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 sanitary wastewater are required to monitor fecal coliform under the current permits and will be required to monitor *E. coli* when their permits come to renew. These facilities are also required to monitor 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 permits 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
Buffalo Creek	OK311510020090_00								Bacteria
Timber Creek	OK311510010090_00								Bacteria/Turbidity
Lake Creek	OK311510010040_00								Bacteria
Station Creek	OK311800000060_00								Bacteria
Turkey Creek	OK311600020060_00								Bacteria/Turbidity
Bitter Creek	OK311600020110_05								Turbidity
Little Beaver Creek	OK311210000050_00								Bacteria/Turbidity
Red River	OK311200000010_00								Bacteria/Turbidity
Red River	OK311100010190_20								Bacteria/Turbidity
Red River	OK311100010190_00								Turbidity

Facility present in watershed and potential as contributing pollutant source.

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

No facility present in watershed.

E.3 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool can provide some information for identifying whether impairments are associated with point or nonpoint sources. The efficiency and simplicity of the LDC method should not be considered as bad descriptors of this powerful tool for displaying the changing water quality over changing flows that provides information as to the sources of the pollutant that is not apparent in the raw data. The LDC has additional valuable uses in the post-TMDL implementation phase of the restoration of the water quality for a waterbody. Plotting future monitoring information on the LDC can show trends of improvement to sources that will identify areas for revision to the watershed restoration plan. The low cost of the LDC method allows accelerated development of TMDL plans on more waterbodies and the evaluation of the implementation of WLAs and BMPs. The technical approach for using LDCs for TMDL development includes the following steps:

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

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

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

The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the U.S. Geological Survey (USGS), or if unavailable, projected from a nearby USGS site;
- sorting the flow data and calculating flow exceedance percentiles;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- matching the water quality observations with the flow data from the same date;

- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS;
- for bacteria TMDLs, displaying and differentiating another curve derived by plotting the geometric mean of all existing bacteria samples continuously along the full spectrum of flow exceedance percentiles which represents the observed load in the stream; or
- for turbidity TMDLs, 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 = 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

unit conversion factor = 24,465,525

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 5-1

unit conversion factor = 5.39377

Historical observations of bacteria were plotted as a separate LDC based on the geometric mean of all samples. Historical observations of TSS and/or turbidity concentrations are paired with flow data and are plotted on the LDC for a stream. It is noted that the LDCs for bacteria were based on the geometric mean standards or geometric mean of all samples. It is inappropriate to compare single sample bacteria observations to a geometric mean water quality criterion in the LDC; therefore individual bacteria samples are not plotted on the LDCs.

E.4 TMDL Calculations

A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for the lack of knowledge concerning the relationship between pollutant loading and water quality.

This definition can be expressed by the following equation:

$$TMDL = WLA\_{WWTP} + WLA\_{MS4} + LA + MOS$$

For each waterbody the TMDLs presented in this report are expressed as colony forming units per day across the full range of flow conditions. For information purpose, percent reductions are also provided. The difference between existing loading and the water quality target is used to calculate the loading reductions required. For bacteria, the PRG is calculated by reducing all samples by the same percentage until the geomean of the reduced sample values meets the corresponding bacteria geomean standard (126 cfu/100 ml for *E. coli* and 33 cfu/100 ml for Enterococci) with 10% of MOS. For turbidity, the PRG is the load reduction that ensures that no more than 10% of the samples under flow-base conditions exceed the TMDL.

Table ES-7 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area.

Table ES-7 Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate	
		EC	ENT
OK311510020090_00	Buffalo Creek	46%	88%
OK311510010090_00	Timber Creek	43%	93%
OK311510010040_00	Lake Creek	52%	73%
OK311800000060_00	Station Creek	68%	57%
OK311600020060_00	Turkey Creek	89%	89%
OK311210000050_00	Little Beaver Creek	31%	86%
OK311200000010_00	Red River		58%
OK311100010190_20	Red River		44%

Similarly, PRGs for TSS are calculated as the required overall reduction so that no more than 10% of the samples exceed the water quality target for TSS. The PRGs for the waterbodies requiring turbidity TMDLs in this report are summarized in Table ES-8 and range from 43% to 99%.

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK311510010090_00	Timber Creek	43%
OK311600020060_00	Turkey Creek	65%
OK311600020110_05	Bitter Creek	79%
OK311210000050_00	Little Beaver Creek	75%
OK311200000010_00	Red River	92%
OK311100010190_20	Red River	90%
OK311100010190_00	Red River	99%

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

LA = TMDL – MOS - ∑WLA

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

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

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 MOS. The selection of MOS is based on the normalized root mean square error (NRMSE) for each waterbody (Table ES-4).

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

E.5 Reasonable Assurance

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

SECTION 1
INTRODUCTION

1.1 TMDL Program Background

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

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli)*, Enterococci] and turbidity for selected waterbodies in the Red River basin. (All future references to bacteria in this document imply these two fecal pathogen indicator bacteria groups unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. 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), EPA guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to EPA for review. Approved 303(d) listed waterbody-pollutant pairs or surrogates TMDLs will receive notification of the approval or disapproval action. Once the EPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (EPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria 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. MOS can be implicit and/or explicit. An implicit MOS is achieved by using conservative assumptions in the TMDL calculations. An explicit MOS is a percentage of the TMDL set aside to account for the lack of knowledge associated with natural process in aquatic systems, model assumptions, and data limitations.

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria 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 DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or Fish and Wildlife Propagation beneficial uses. The waterbodies considered for TMDL development in this report, which are presented upstream to downstream, include:

- Buffalo Creek OK311510020090_00
- Timber Creek OK311510010090_00
- Lake Creek OK311510010040_00
- Station Creek OK311800000060_00
- Turkey Creek OK311600020060_00
- Bitter Creek OK311600020110_05
- Little Beaver Creek OK311210000050_00
- Red River OK311200000010_00
- Red River OK311100010190_20
- Red River OK311100010190_00
- Bills Creek OK311100010230_00

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

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

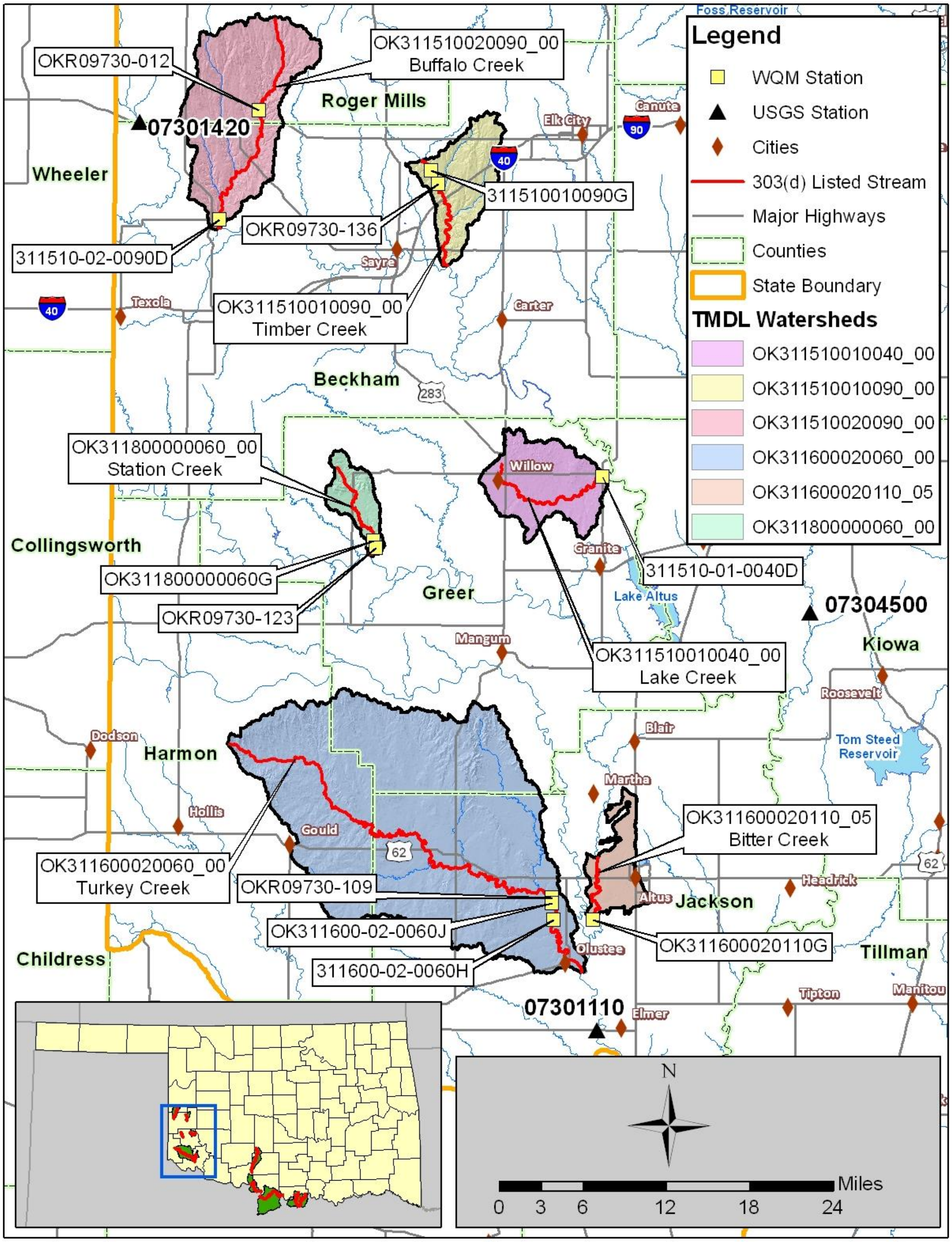
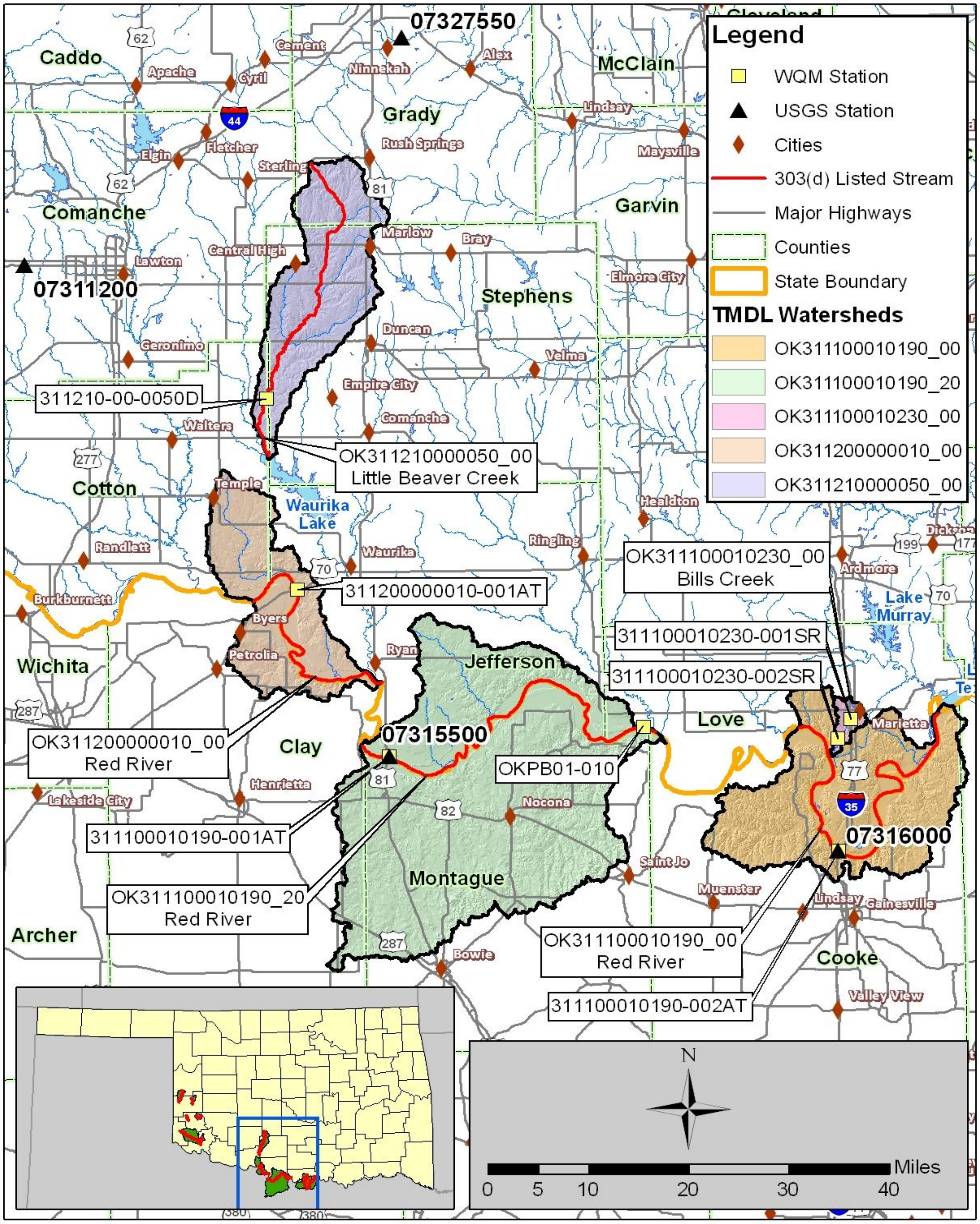


Figure 1-2 Lower Red River Watersheds Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation Use



Elevated levels of pathogen indicator bacteria or turbidity above the WQS numeric criterion result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the PBCR or fish and wildlife propagation use designated for each waterbody. Table 1-1 provides a description of the locations of WQM stations on the 303(d)-listed waterbodies.

Table 1-1 Water Quality Monitoring Stations used for Assessment of Streams

WQM Station	Waterbody Name	Station Location	Waterbody ID
OK311510-02-0090D	Buffalo Creek	Buffalo Creek, E1770 Rd.	OK311510020090_00
OKR09730-012	Buffalo Creek	Buffalo Creek, off N1770 Rd.	OK311510020090_00
OK311510-01-0090G	Timber Creek	Timber Creek, off E1130 Rd.	OK311510010090_00
OKR09730-136	Timber Creek	Timber Creek, off E1140 Rd.	OK311510010090_00
OK311510-01-0040D	Lake Creek	Lake Creek, SH 6	OK311510010040_00
OK311800-00-0060G	Station Creek	Station Creek, E1400 Rd.	OK311800000060_00
OKR09730-123	Station Creek	Station Creek, west of N1860 Rd.	OK311800000060_00
OK311600-02-0060H	Turkey Creek	Turkey Creek, E1670 Rd.	OK311600020060_00
OK311600-02-0060J	Turkey Creek	Turkey Creek, N1980 Rd.	OK311600020060_00
OKR09730-109	Turkey Creek	Turkey Creek, west of N1980 Rd.	OK311600020060_00
OK311600-02-0110G	Bitter Creek	Bitter Creek, E1670 Rd.	OK311600020110_05
OK311210-00-0050D	Little Beaver Creek	Little Beaver Creek, E1790 Rd.	OK311210000050_00
311200000010-001AT	Red River	Red River, SH 79, Waurika	OK311200000010_00
311100010190-001AT	Red River	Red River, US 81, Terral	OK311100010190_20
OKPB01-010	Red River	Red River, downstream of SH89	OK311100010190_20
311100010190-002AT	Red River	Red River at IH-35	OK311100010190_00
311100010230-001SR	Bills Creek	Bills Creek, off US 77 Marietta	OK311100010230_00
311100010230-002SR	Bills Creek	Bills Creek, off SH32, Marietta	OK311100010230_00

1.2 Watershed Description

General. The Red River basin is located in the southwestern portion of Oklahoma and the northern portion of Texas. The majority of the waterbodies addressed in this report are located in Beckham, Greer, Harmon, Jackson, Stephens and Jefferson Counties of Oklahoma and Cooke and Montague Counties of Texas. The northern section of Little Beaver Creek (OK311210000050_00) is located in Grady County, portions of Red River (OK311200000010_00) and Red River (OK311100010190_20) are located in Clay County of Texas and the eastern portion of Red River (OK311100010190_00) is located in Grayson County of Texas. These counties are part of the Southwestern Tablelands, 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 Wichita Uplift, Marietta Basin, Ardmore Basin, and the Hollis Basin geological provinces. Table 1-2, derived from the 2010 U.S. Census, demonstrates that the counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2010). Table 1-3 lists the towns and cities located in each watershed.

Table 1-2 County Population and Density

County Name	Population (2010 Census)	Population Density (per square mile)
Oklahoma		
Beckham	22,119	24
Comanche	124,098	115
Cotton	6,193	10
Grady	52,431	47
Greer	6,239	10
Harmon	2,922	5
Jackson	26,446	33
Jefferson	6,472	8
Love	9,423	18
Roger Mills	3,647	3
Stephens	45,048	51
Texas		
Clay	10,752	10
Cooke	38,437	43
Grayson	120,877	123
Montague	19,719	21

Table 1-3 Towns and Cities by Watershed

Waterbody Name	Waterbody ID	Municipalities
Lake Creek	OK311510010040_00	Willow
Turkey Creek	OK311600020060_00	Olustee
Bitter Creek	OK311600020110_05	Altus
Little Beaver Creek	OK311210000050_00	Central High, Marlow
Red River	OK311200000010_00	Temple, OK, Byers, TX
Red River	OK311100010190_20	Nocona, TX
Red River	OK311100010190_00	Thackerville
Bills Creek	OK311100010230_00	Marietta

Climate. Table 1-4 summarizes the average annual precipitation for each Oklahoma waterbody derived from a geospatial layer developed to display annual precipitation using data collected from Oklahoma weather stations between 1971 through 2000. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 25 and 38 inches (Oklahoma Climatological Survey 2005).

Table 1-4 Average Annual Precipitation by Watershed

Waterbody Name	Waterbody ID	Average Annual Precipitation (inches)
Buffalo Creek	OK311510020090_00	25.2
Timber Creek	OK311510010090_00	28.8
Lake Creek	OK311510010040_00	28.2
Station Creek	OK311800000060_00	27.3
Turkey Creek	OK311600020060_00	27.4
Bitter Creek	OK311600020110_05	29.1
Little Beaver Creek	OK311210000050_00	36.2
Red River	OK311200000010_00	31.8
Red River	OK311100010190_20	33.6
Red River	OK311100010190_00	38.2
Bills Creek	OK311100010230_00	38.3

Land Use. Tables 1-5a and 1-5b summarize the percentages and acreages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody addressed in the Study Area. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2001 National Land Cover Dataset (USGS 2007). The percentages provided in Tables 1-5a and 1-5b are rounded so in some cases may not total exactly 100%. The land use categories are displayed in Figure 1-3. The two most dominant land use category throughout the Red River Study Area is cultivated crops and grasslands/herbaceous. Two watersheds in the Study Area have a significant percentage of land use classified as shrub/scrub including Station Creek (OK311800000060_00) and Turkey Creek (OK311600020060_00). The aggregated total of low, medium, and high intensity developed land account for less than 1% of the land use in each watershed, except Bitter Creek (OK311600020110_05) and Bills Creek (OK311100010230_00) are 9.8% and 7.3%, respectively. The watersheds targeted for TMDL development in this Study Area range in size from 7,717 acres (Bills Creek, OK311100010230_00) to 464,625 acres (Red River, OK311100010190_20).

Figure 1-3 Land Use Map

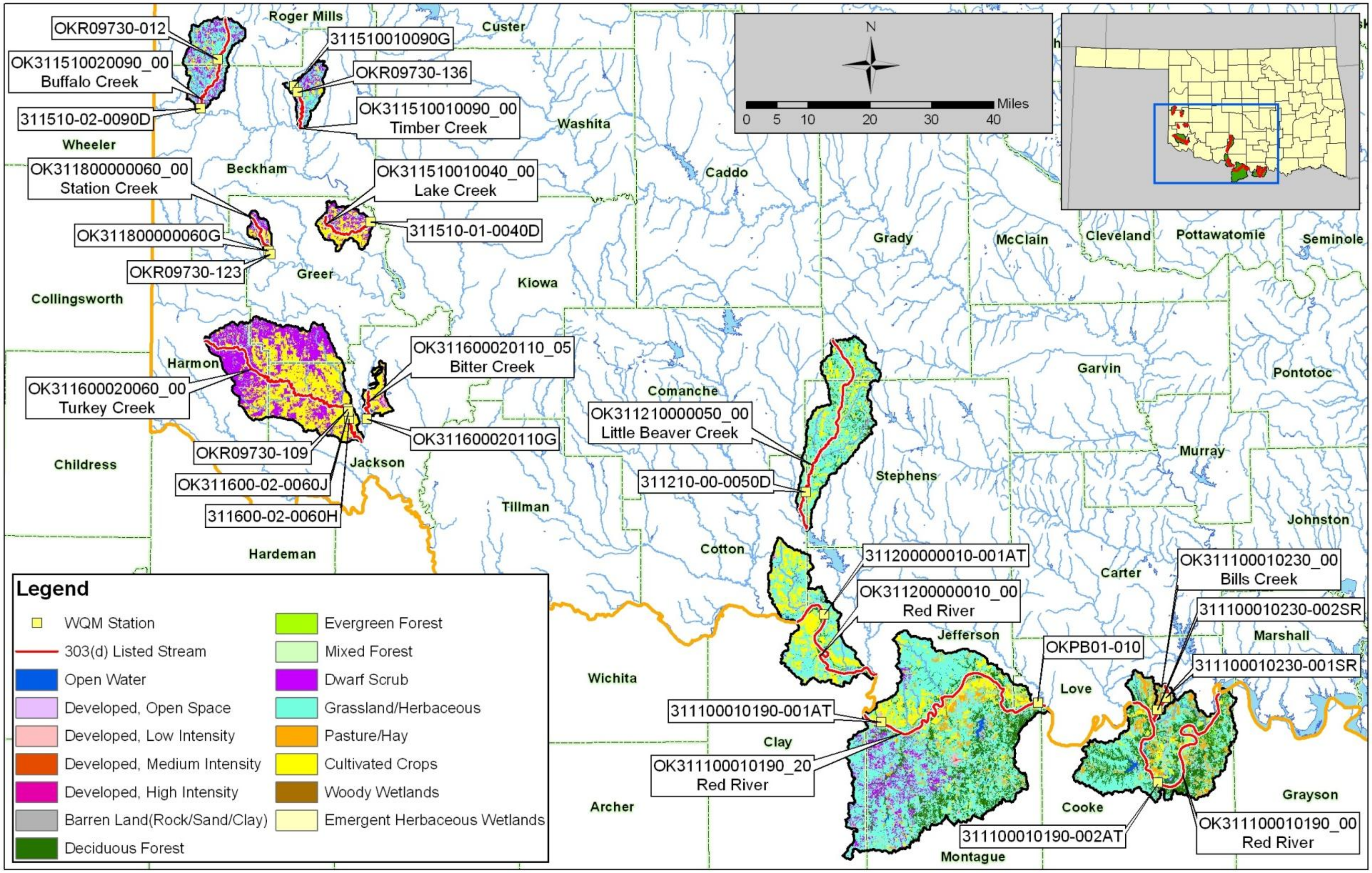


Table 1-5a Land Use Summaries by Watershed

Landuse Category	Watershed					
	Buffalo Creek	**Timber Creek**	**Lake Creek**	**Station Creek**	**Turkey Creek**	**Bitter Creek**
Waterbody ID	**OK311510020090_00**	**OK311510010090_00**	**OK311510010040_00**	**OK311800000060_00**	**OK311600020060_00**	**OK311600020110_05**
Percent of Open Water	0.07	0.25	0.00	0.03	0.20	0.97
Percent of Developed, Open Space	0.87	2.01	4.77	2.93	3.28	6.78
Percent of Developed, Low Intensity	0.01	0.35	0.09	0.04	0.14	7.47
Percent of Developed, Medium Intensity	0.00	0.04	0.01	0.00	0.01	1.47
Percent of Developed, High Intensity	0.00	0.00	0.00	0.00	0.00	0.84
Percent of Barren Land (Rock/Sand/Clay)	1.09	0.18	0.08	0.07	0.13	0.00
Percent of Deciduous Forest	0.05	0.00	0.01	0.00	0.03	0.04
Percent of Evergreen Forest	0.00	0.01	0.00	0.00	0.04	0.02
Percent of Mixed Forest	1.21	2.28	3.51	0.47	1.09	0.34
Percent of Shrub/Scrub	29.45	27.60	37.02	40.76	45.84	10.96
Percent of Grassland/Herbaceous	60.33	52.62	8.47	16.46	4.04	1.79
Percent of Pasture/Hay	0.00	0.00	0.00	0.00	0.00	0.00
Percent of Cultivated Crops	6.87	14.62	45.74	39.17	45.09	69.08
Percent of Woody Wetlands	0.04	0.05	0.32	0.07	0.13	0.24
Percent of Emergent Herbaceous Wetlands	0.00	0.00	0.00	0.00	0.00	0.00
Acres Open Water	43	58	1	3	406	140
Acres Developed, Open Space	511	470	1,381	305	6,636	983
Acres Developed, Low Intensity	5	81	25	5	276	1,082
Acres Developed, Medium Intensity	2	8	2	0	10	213
Acres Developed, High Intensity	0	0	0	0	2	122
Acres Barren Land (Rock/Sand/Clay)	646	42	22	8	263	0
Acres Deciduous Forest	28	0	2	0	59	6
Acres Evergreen Forest	0	2	0	0	73	3
Acres Mixed Forest	715	533	1,016	49	2,194	49
Acres Shrub/Scrub	17,391	6,458	10,724	4,238	92,672	1,589
Acres Grassland/Herbaceous	35,622	12,312	2,453	1,711	8,171	260
Acres Pasture/Hay	0	0	0	0	0	0
Acres Cultivated Crops	4,059	3,421	13,251	4,073	91,158	10,015
Acres Woody Wetlands	25	12	93	7	263	34
Acres Emergent Herbaceous Wetlands	0	0	0	0	0	0
Total (Acres)	**59,046**	**23,398**	**28,970**	**10,398**	**202,182**	**14,498**

Table 1-5b Land Use Summaries by Watershed

Landuse Category	Watershed				
	Little Beaver Creek	Red River	Red River	Red River	Bills Creek
Waterbody ID	**OK311210000050_00**	**OK311200000010_00**	**OK311100010190_20**	**OK311100010190_00**	**OK311100010230_00**
Percent of Open Water	0.82	1.32	1.31	2.52	0.56
Percent of Developed, Open Space	4.17	4.09	4.54	3.73	9.32
Percent of Developed, Low Intensity	0.46	0.29	0.70	0.37	5.20
Percent of Developed, Medium Intensity	0.24	0.07	0.10	0.06	1.49
Percent of Developed, High Intensity	0.05	0.02	0.02	0.01	0.64
Percent of Barren Land (Rock/Sand/Clay)	0.03	2.17	0.59	0.54	0.00
Percent of Deciduous Forest	9.77	5.55	15.15	29.12	8.29
Percent of Evergreen Forest	0.00	0.00	0.01	1.54	0.00
Percent of Mixed Forest	0.00	0.00	0.00	0.00	0.00
Percent of Shrub/Scrub	0.03	0.56	7.00	0.01	0.00
Percent of Grassland/Herbaceous	62.16	51.20	57.04	44.60	31.71
Percent of Pasture/Hay	0.24	0.00	4.82	12.49	39.49
Percent of Cultivated Crops	22.03	34.73	8.68	4.64	3.29
Percent of Woody Wetlands	0.00	0.00	0.00	0.20	0.00
Percent of Emergent Herbaceous Wetlands	0.00	0.00	0.03	0.17	0.00
Acres Open Water	1,034	1,600	6,108	5,153	43
Acres Developed, Open Space	5,269	4,976	21,098	7,621	719
Acres Developed, Low Intensity	579	348	3,242	759	402
Acres Developed, Medium Intensity	302	83	452	127	115
Acres Developed, High Intensity	68	20	75	17	50
Acres Barren Land (Rock/Sand/Clay)	42	2,636	2,760	1,104	0
Acres Deciduous Forest	12,356	6,750	70,398	59,435	640
Acres Evergreen Forest	2	5	59	3,137	0
Acres Mixed Forest	0	0	0	0	0
Acres Shrub/Scrub	40	684	32,524	10	0
Acres Grassland/Herbaceous	78,608	62,237	265,023	91,035	2,447
Acres Pasture/Hay	302	0	22,417	25,484	3,047
Acres Cultivated Crops	27,854	42,216	40,327	9,470	254
Acres Woody Wetlands	0	0	3	403	0
Acres Emergent Herbaceous Wetlands	0	2	142	349	0
Total (Acres)	**126,457**	**121,558**	**464,625**	**204,105**	**7,717**

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. Flow data from the surrounding USGS gage stations and the instantaneous flow measurement data taken with water quality samples have been used to estimate flows for ungaged streams. Flow data collected at the time of water quality sampling are included in Appendix A along with corresponding water chemistry data results. A summary of the method used to project flows for ungaged streams and flow exceedance percentiles from projected flow data are provided in Appendix B.

SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code contains Oklahoma Water Quality Standards (OWQS) and implementation procedures (OWRB 2011). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state WQS, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.* [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2011). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegradation Policy is provided in Appendix C. Table 2-1, an excerpt from the 2008 Integrated Report (DEQ 2008), lists beneficial uses designated for each bacteria and/or turbidity impaired stream segment in the Study Area. The beneficial uses include:

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

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

Waterbody ID	Waterbody Name	AES	AG	WWAC	HLAC	FISH	PBCR	PPWS
Buffalo Creek	OK311510020090_00	N	N	N		X	N	I
Timber Creek	OK311510010090_00	F	F	F		X	N	I
Lake Creek	OK311510010040_00	F	F	F		X	N	
Station Creek	OK311800000060_00	F	F	F		X	N	
Turkey Creek	OK311600020060_00	F	N	N		X	N	I
Bitter Creek	OK311600020110_05	F	N		N		*	
Little Beaver Creek	OK311210000050_00	F	I	F		X	N	I
Red River	OK311200000010_00	I	N	N		I	N	N
Red River	OK311100010190_20	I	N	N		N	N	I
Red River	OK311100010190_00	I	N	N		N	N	I
Bills Creek	OK311100010230_00	I	X	I		X	N	

F – Fully supporting; N – Not supporting; I – Insufficient information; X – Not assessed
Source: 2008 Integrated Report, DEQ 2008
* - Not supporting of Secondary Body Contact Recreation Only

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

The definition of PBCR and the bacteria WQSs for PBCR are summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

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

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

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

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

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

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011). The excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

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

(b) ***Escherichia coli (E. coli).***

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is not met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(c) ***Enterococci.***

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to Enterococci if the geometric mean of 33 colonies per 100 ml is met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to Enterococci if the geometric mean of 33 colonies per 100 ml is not met. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

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

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
Buffalo Creek	OK311510020090_00	20.32	2019	4	X	X	N		
Timber Creek	OK311510010090_00	12.01	2019	4	X	X	N		
Lake Creek	OK311510010040_00	13.33	2019	4	X	X	N		
Station Creek	OK311800000060_00	10.58	2019	4	X		N		
Turkey Creek	OK311600020060_00	51.64	2019	4	X	X	N		
Bitter Creek	OK311600020110_05	7.8	2016	3	X		*		
Little Beaver Creek	OK311210000050_00	39.49	2016	3	X	X	N		
Red River	OK311200000010_00	30.02	2016	3	X		N	X	N
Red River	OK311100010190_20	46.42	2016	3	X		N	X	N
Red River	OK311100010190_00	47.84	2013	2	X		N	X	N
Bills Creek	OK311100010230_00	8.4	2019	4	X		N		

ENT = Enterococci; N = Not attaining; X = Criterion exceeded
Source: 2008 Integrated Report, DEQ 2008
* - Not Supporting of Secondary Body Contact Recreation

Compliance with the Oklahoma WQS is based on meeting requirements for both *E. coli* and Enterococci bacterial indicators in addition to the minimum sample requirements for assessment. Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2011).

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

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

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

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

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

ii. Lakes: 25 NTU; and

iii. Other surface waters: 50 NTUs.

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

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

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

To implement Oklahoma's WQS for Fish and Wildlife Propagation, promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011). 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 2-3 summarizes water quality data collected during primary contact recreation season from the WQM stations between 2000 and 2009 for each indicator bacteria. The data summary in Table 2-3 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data collected during the primary contact recreation season was used to support the decision to place specific waterbodies within the Study Area on the DEQ 2008 303(d) list (DEQ 2008). Water quality data from the primary contact recreation season are provided in Appendix A. For the data collected between 2000 and 2009, evidence of nonsupport of the PBCR use based on elevated *E. coli* and Enterococci concentrations was observed in five waterbodies: Buffalo Creek (OK311510020090_00), Timber Creek (OK311510010090_00), Lake Creek (OK311510010040_00), Turkey Creek (OK311600020060_00), and Little Beaver Creek (OK31120000050_00). Evidence of nonsupport of the PBCR use based on Enterococci exceedances was observed in three waterbodies: Station Creek (OK311800000060_00), Red River (OK311200000010_00) and Red River (OK311100010190_20). Rows highlighted in green in Table 2-3 require TMDLs.

Three waterbodies within the Study Area will be removed from further consideration for bacteria TMDL development in this report. Detailed review of the data collected between 2000 and 2009 for Bitter Creek (OK311600020110_05) and Bills Creek (OK311100010230_00) indicated an insufficient number of samples were available. In addition, there were no data available for Red River (OK311100010190_00); therefore no bacteria TMDLs are included in this report for any of these three waterbodies.

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 2-4 summarizes water quality data collected from the WQM stations between 1998 and 2011 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 OWQS, DEQ considers base flow conditions to be all flows greater than the 25^{th} flow exceedance frequency (i.e., the lower 75 percent of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2009). Therefore, Table 2-5 was prepared to represent the subset of these data for samples collected during base flow conditions. Water quality samples collected under flow conditions less than the 25^{th} flow exceedance frequency (highest flows) were therefore excluded from the data set used for TMDL analysis. Only three of the eleven waterbodies were listed on the DEQ 2008 303(d) list (DEQ 2008) for nonsupport of the Fish and Wildlife Propagation use based on turbidity levels observed in the waterbody. The data in Table 2-5 were used to support the decision to place these three, plus an additional four waterbodies on the DEQ 2008 303(d) list (DEQ 2008) for nonsupport of the Fish and Wildlife Propagation use. Table 2-6 summarizes water quality data collected from the WQM stations between 1998 and 2011 for TSS. Table 2-7 presents a subset of these data for samples collected during base flow conditions. In using TSS as a surrogate to support TMDL development at least 10 TSS samples are required to conduct the regression analysis between turbidity and TSS. Water quality data for turbidity and TSS are provided in Appendix A.

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

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Conc (cfu/100 ml)	Notes
OK311510020090_00	Buffalo Creek	EC	14	265	
		ENT	14	257	
OK311510010090_00	Timber Creek	EC	14	294	
		ENT	14	514	
OK311510010040_00	Lake Creek	EC	13	213	
		ENT	13	109	
OK311800000060_00	Station Creek	ENT	14	93	
OK311600020060_00	Turkey Creek	EC	14	319	
		ENT	14	319	
OK311600020110_05	Bitter Creek	ENT	6	662	De-list; Insufficient number of samples
OK311210000050_00	Little Beaver Creek	EC	12	215	
		ENT	12	253	
OK311200000010_00	Red River	ENT	14	71	
OK311100010190_20	Red River	ENT	26	53	
OK311100010190_00	Red River	ENT			De-list; No data
OK311100010230_00	Bills Creek	ENT	2	1612	De-list; Insufficient number of samples

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
TMDLs will be developed for waterbodies highlighted in green

Table 2-4 Summary of All Turbidity Samples, 1998-2011

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)
OK311510020090_00	Buffalo Creek	OK311510-02-0090D, OKR09730-012	29	3	10%	43
OK311510010090_00	Timber Creek	OK311510-01-0090G, OKR09730-136	29	3	10%	18
OK311510010040_00	Lake Creek	OK311510-01-0040D	26	1	4%	14
OK311800000060_00	Station Creek	OK311800-00-0060G,OKR09730-123	29	3	10%	24
OK311600020060_00	Turkey Creek	OK311600-02-0060H, OK311600-02-0060J, OKR09730-109	31	12	39%	64
OK311600020110_05	Bitter Creek	OK311600-02-0110G	22	8	36%	91
OK311210000050_00	Little Beaver Creek	OK311210-00-0050D	25	6	24%	88
OK311200000010_00	Red River	311200000010-001AT	47	42	89%	330
OK311100010190_20	Red River	311100010190-001AT	42	26	62%	265
OK311100010190_00	Red River	311100010190-002AT	9	7	78%	387

Table 2-5 Summary of Turbidity Samples Collected During Base Flow Conditions, 1998-2011

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)	Assessment Results
OK311510020090_00	Buffalo Creek	OK311510-02-0090D, OKPB01-196, OKR09730-012	16	0	0%	11	
OK311510010090_00	Timber Creek	OK311510-01-0090G, OKR09730-136	21	3	14%	18	Not listed, but impaired
OK311510010040_00	Lake Creek	OK311510-01-0040D, OKR09730-080	24	1	4%	14	
OK311800000060_00	Station Creek	OK311800-00-0060G, OKR09730-123	27	2	7%	22	
OK311100010230_00	Bills Creek		0	0	0		No data
OK311600020060_00	Turkey Creek	OK311600-02-0060H, OK311600-02-0060J, OKR09730-109	30	11	37%	63	Not listed, but impaired
OK311600020110_05	Bitter Creek	OK311600-02-0110G	13	4	31%	101	Not listed, but impaired
OK311210000050_00	Little Beaver Creek	OK311210-00-0050D	21	5	24%	51	Not listed, but impaired
OK311200000010_00	Red River	311200000010-001AT	33	28	85%	201	
OK311100010190_20	Red River	311100010190-001AT	33	17	52%	163	
OK311100010190_00	Red River	311100010190-002AT	5	4	80%	91	only 2 years of data available, >10% exceedance rule

TMDLs will be developed for highlighted waterbodies.

Table 2-6 Summary of All TSS Samples, 1998-2011

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK311510020090_00	Buffalo Creek	OK311510-02-0090D, OKR09730-012	25	64
OK311510010090_00	Timber Creek	OK311510-01-0090G, OKR09730-136	26	18
OK311510010040_00	Lake Creek	OK311510-01-0040D	25	16
OK311800000060_00	Station Creek	OK311800-00-0060G, OKR09730-123	26	22
OK311600020060_00	Turkey Creek	OK311600-02-0060H, OK311600-02-0060J, OKR09730-109	24	60
OK311600020110_05	Bitter Creek	OK311600-02-0110G	19	93
OK311100010230_00	Bills Creek		-	-
OK311210000050_00	Little Beaver Creek	OK311210-00-0050D	24	81
OK311200000010_00	Red River	311200000010-001AT	21	466
OK311100010190_20	Red River	311100010190-001AT	-	-
OK311100010190_00	Red River	311100010190-002AT	8	921

Table 2-7 Summary of TSS Samples During Base Flow Conditions 1998-2011

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK311510020090_00	Buffalo Creek	OK311510-02-0090D, OKR09730-012	13	27
OK311510010090_00	Timber Creek	OK311510-01-0090G,OKR09730-136	19	18
OK311510010040_00	Lake Creek	OK311510-01-0040D	23	16
OK311800000060_00	Station Creek	OK311800-00-0060G,OKR09730-123	24	21
OK311600020060_00	Turkey Creek	OK311600-02-0060H, OK311600-02-060J, OKR09730-109	23	62
OK311600020110_05	Bitter Creek	OK311600-02-0110G	11	96
OK311100010230_00	Bills Creek		-	-
OK311210000050_00	Little Beaver Creek	OK311210-00-0050D	20	45
OK311200000010_00	Red River	311200000010-001AT	14	290
OK311100010190_20	Red River	311100010190-001AT	-	-
OK311100010190_00	Red River	311100010190-002AT	4	633

2.3 Water Quality Target

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." The water quality targets for *E. coli* and Enterococci are geometric mean standards of 126 cfu/100ml and 33 cfu/100ml, respectively. The TMDL for bacteria will incorporate an explicit 10 percent margin of safety.

An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2011). According to the Oklahoma WQS [785:45-5-12(f)(7)], the turbidity criterion for streams with WWAC beneficial use is 50 NTUs (OWRB 2011). 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% 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 goal 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, 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 currently required to monitor for fecal coliform and TSS in accordance with their permits. The discharges with bacteria limits will be required to monitor for *E. coli* when their permits come to renew. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria 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 permits are considered nonpoint sources.

The potential nonpoint sources for bacteria were compared based on the fecal coliform load produced in each subwatershed. Although fecal coliform is no longer used as a bacteria indicator in the Oklahoma WQS, it is still valid to use fecal coliform concentration or loading estimates to compare the potential contributions of different nonpoint sources because *E. coli* is a subset of fecal coliform. Currently there is insufficient data available in the scientific arena to quantify counts of *E. coli* in feces from warm-blooded animals discussed in Section 3.

The following nonpoint sources were considered in this report:

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

The 2008 Integrated Water Quality Assessment Report (DEQ 2008) listed potential sources of turbidity as clean sediment, grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, petroleum/natural gas activities, rangeland grazing, as well as other unknown sources. The following discussion describes what is known regarding point and nonpoint sources of bacteria in the impaired watersheds.

3.1 NPDES-Permitted Facilities

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

- NPDES municipal wastewater treatment plant (WWTP);
- NPDES Industrial WWTP Discharges;
- Municipal no-discharge WWTP;
- NPDES Concentrated Animal Feeding Operation (CAFO);
- NPDES municipal separate storm sewer system (MS4) discharges;
- 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 indicator bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates are above the disinfection capacity. While the no-discharge facilities do not discharge wastewater directly to a waterbody, it is possible that continuous point source discharges from municipal and industrial WWTPs could result in discharge of elevated concentrations of TSS if a facility is not properly maintained, is of poor design, or flow rates exceed capacity. However, in most cases suspended solids discharged by WWTPs consist primarily of organic solids rather than inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). Discharges of organic suspended solids from WWTPs are addressed by DEQ through its permitting of point sources to maintain WQS for dissolved oxygen and are not considered a potential source of turbidity in this TMDL. Discharges of TSS will be considered to be organic suspended solids if the discharge permit includes a limit for Biochemical Oxygen Demand (BOD) or Carbonaceous Biochemical Oxygen Demand (CBOD). Only WWTP discharges of inorganic suspended solids will be considered and will receive WLAs.

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 EPA as potential 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 EPA 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 EPA NPDES Program, can contain TSS. 40 C.F.R. § 130.2(h) requires that NPDES-regulated stormwater discharges must be addressed by the WLA component of a TMDL. However, any stormwater discharge by definition occurs during or immediately following periods of rainfall and elevated flow conditions when Oklahoma Water Quality Standard for turbidity does not apply. OWQS 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 is one NPDES-permitted facility in each of the contributing watersheds of Turkey Creek (OK31160020060_00) and Red River (OK311200000010_00 & OK311100010190_00). The remaining watersheds in the Study Area have no continuous NPDES-permitted facilities. There are no MS4 permitted entities within the watersheds addressed in the Study Area.

3.1.1 Continuous Point Source Dischargers

The locations of the NPDES-permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed in Figure 3-1. Other permitted dischargers such as the American Gypsum Company – Wallboard Plant (OK0043362) that do not have a TSS permit limit and are not expected to discharge bacteria are not provided in Table 3-1. The Town of Temple WWTP, which discharges seasonally to Whiskey Creek, may be a minor source of bacteria loading to the Red River, (OK311200000010_00). The City of Marietta PWA WWTP discharges to Bills Creek (OK311100010230_00), a tributary to Red River (OK31110010190_00). There are three continuous point source facilities discharging within the Study Area but they are not considered significant sources of concern for TSS loading. All three facilities discharge TSS and 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 in Table 3-1 discharges organic TSS and therefore are not considered a potential source of turbidity. Discharge monitoring report (DMR) data for TSS from American Gypsum Co. (OK0043290) are provided in Appendix D.

3.1.2 No-Discharge Facilities and Sanitary Sewer Overflows

For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute indicator bacteria 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. There are six no-discharge facilities in the Study Area which are listed in Table 3-2. The no-discharge facilities located in Lake Creek (OK311510010040_00), Turkey Creek (OK311600020060_00), Little Beaver Creek (OK311210000050_00), and Red River (OK311100010190_20) watersheds could be contributing to the elevated levels of instream indicator bacteria loading.

Sanitary sewer overflow (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacteria loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. The reporting of SSOs has been strongly encouraged by EPA, primarily through enforcement and fines. While not all sewer overflows are reported, DEQ has some data on SSOs available. SSOs were reported between 1991 and 2005. During that period 61 overflows were reported ranging from 100 to over 3 million gallons. Table 3-3 summarizes the SSO occurrences by NPDES facility. Historical data of reported SSOs are provided in Appendix E.

Table 3-1 Point Source Discharges in the Study Area

OPDES Permit No.	Name	Receiving WBID	Receiving Waterbody Name	Facility Type	SIC Code	County	Design Flow (mgd)	Facility ID	Expiration Date	Max./Avg. FC cfu/100mL	Max./Avg. TSS mg/L	Outfall
OK0043290	American Gypsum Co. - Gypsum mine	OK311600 020060_00	Turkey Creek	Nonmetallic Mining	1499	Jackson	NA[1]	33000140	8/6/14	NA	45/NA	001A
OK0020257	City of Marietta PWA WWTP	OK311100 010230_00	Bills Creek	Sewerage System	4952	Love	0.32	S10901	10/3/14	NA	135/90	001A
OK0032514	Town of Temple	OK311200 000150_00	Whiskey Creek	Sewerage System	4952	Cotton	0.25	S11317	10/3/14	NA	135/90	001A

NA = not available.
[1]This facility has reported no discharge for the last three years.

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

Facility	Facility ID	County	Facility Type	Type	Waterbody ID	Waterbody Name
Willow WWTP	11802	Greer	Lagoon (total retention)	Municipal	OK311510010040_00	Lake Creek
Olustee WWTP	11605	Jackson	Lagoon (total retention)	Municipal	OK311600020060_00	Turkey Creek
Marlow-West WWTP	11220	Stephens	Lagoon (total retention)	Municipal	OK311210000050_00	Little Beaver Creek
Battison Auto Center	0	Stephens	Total retention	Industrial	OK311210000050_00	Little Beaver Creek
Marlow Northwest Lagoon	11222	Stephens	Land Application	Municipal	OK311210000050_00	Little Beaver Creek
Terral WWTP	11101	Jefferson	Land Application	Municipal	OK311100010190_20	Red River

Table 3-3 Sanitary Sewer Overflow Summary

Facility Name	NPDES Permit No.	Receiving Water	Facility ID	Number of Occurrences	Date Range		Amount (Gallons)	
					From	To	Min	Max
Willow WWTP		OK311510010040_00	S11802	1	4/5/1997	4/5/1997	N/A	N/A
Marlow-West WWTP		OK311210000050_00	S11220	13	12/23/1991	7/18/2003	4,300	500,000
Temple WWTP	OK0032514	OK311200000010_00	S11317	31	5/4/1992	10/18/2005	100	>3,000,000
Marietta PWA WWTP	OK0020257	OK311100010230_00	S10901	16	1/13/1992	11/20/2002	100	60,000

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

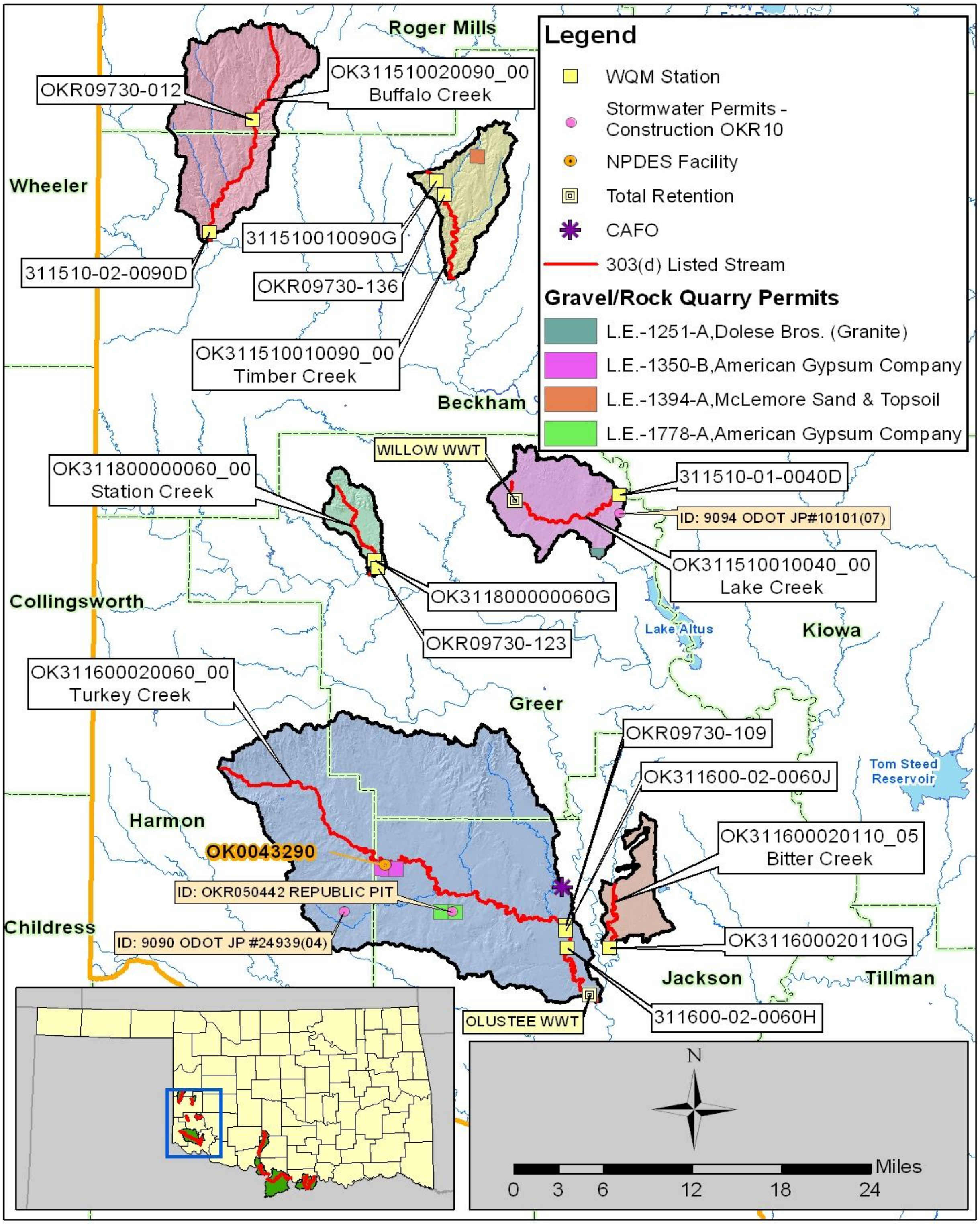
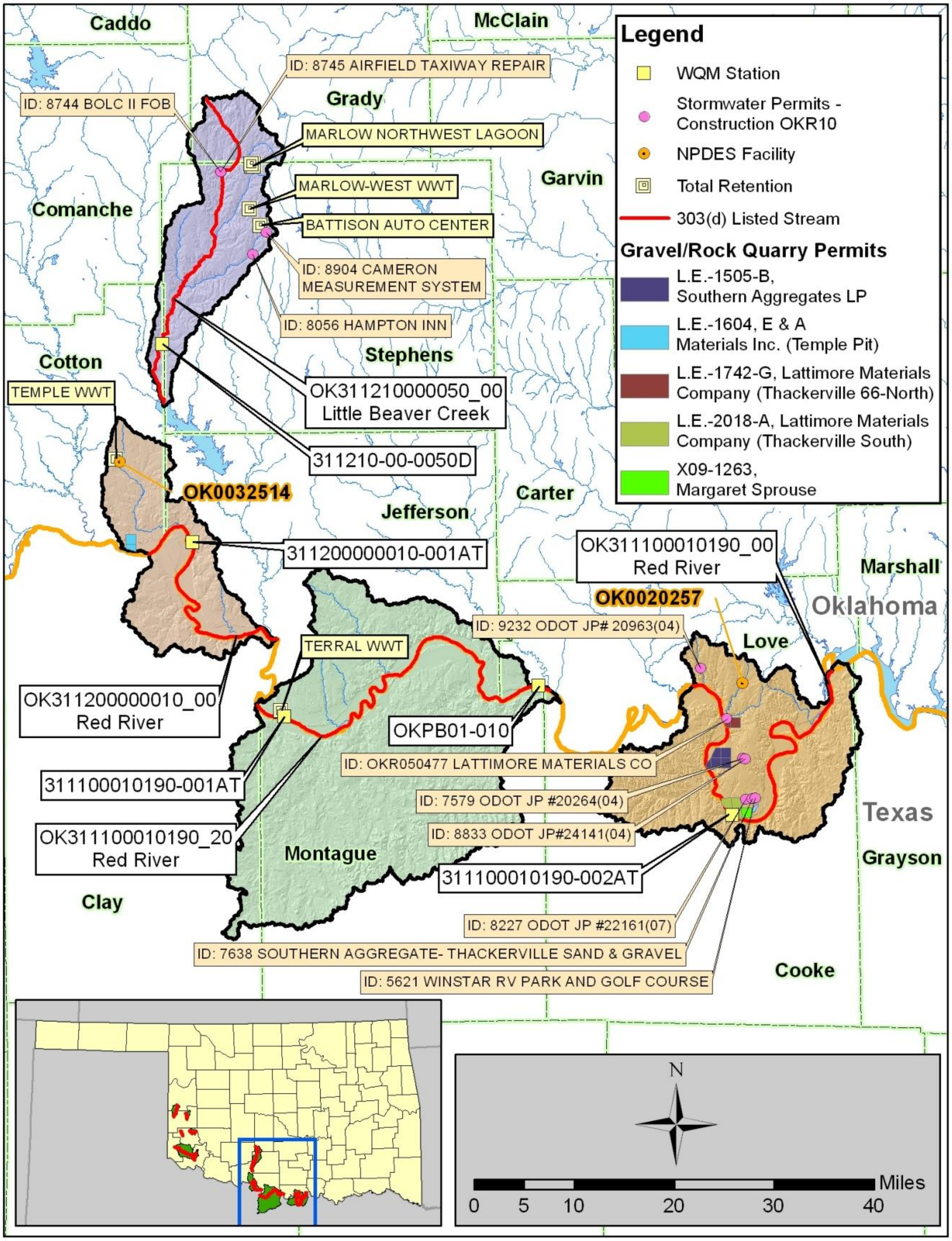


Figure 3-2 Locations of NPDES-Permitted Facilities in the Lower Study Area



3.1.3 NPDES Municipal Separate Storm Sewer System

Phase I MS4

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

Phase II MS4

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

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

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

There are no permitted Phase II MS4s in the study area.

3.1.4 Concentrated Animal Feeding Operations

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

CAFO

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 2005). 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 2005). CAFOs are considered no-discharge facilities for the purpose of the TMDL calculations in this report.

CAFOs are designated by EPA as significant sources of pollution, 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. The location of each CAFO is shown in Figure 3-1 and is listed in Table 3-4.

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

Table 3-4 NPDES-Permitted CAFOs in Study Area

ODAFF Owner ID	EPA Facility	ODAFF ID	ODAFF License Number	Max # of Slaughter Feeder Cattle units at Facility	Total # of Animal Units at Facility	County	Waterbody ID and Waterbody Name
WQ0000056	OKG010055	167	49	4000	4000	Jackson	OK311600020060_00, Turkey Creek

PFO

Poultry feeding operations not licensed under the Oklahoma Concentrated Animal Feeding Operation Act must register with the State Board of Agriculture. A registered PFO is an animal feeding operation which raises poultry and generates more than 10 tons of poultry waste (litter) per year. PFOs are required to develop an Animal Waste Management Plan (AWMP) or an equivalent document such as a Nutrient Management Plan (NMP). These plans describe how litter will be stored and applied properly in order to protect water quality of streams and lakes located in the watershed. Applicable BMPs shall be included in the Plan.

In order to comply with this TMDL, the registered PFOs in the watershed and their associated management plans must be reviewed. Further actions to reduce bacteria loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA and ODAFF for follow up.

3.1.5 Stormwater Permits

Construction Activities

A general stormwater permit (OKR10) is required by the DEQ 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 (DEQ 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 3-5.

Multi-Sector General Permits

A multi-sector industrial general permit (OKR05) is also required by the DEQ for stormwater discharges from industrial facilities (DEQ 2011). Stormwater discharges from all industrial facilities, except mine dewatering discharges at crushed stone, construction sand and gravel, or industrial sand mining facilities, occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply and therefore are not considered potential contributors of turbidity impairment. Mine dewatering discharges can happen at any time and have the following specific effluent limitations for TSS:

- Daily Maximum: 45 mg/L
- Monthly Average: 25 mg/L

If the TMDL shows that a TSS limit more stringent than 45 mg/L is required, additional TSS limitations and monitoring requirements will be required. These additional requirements will be implemented under the multi-sector general permit. There are two facilities within the Study Area with multi-sector general permits – Lattimore Materials Company (OKR050477) in the Red River (OK311100010190_00) watershed and American Gypsum Company LLC (OKR050442) in the Turkey Creek (OK311600020060_00) watershed. Facility information for both of these multi-sector general permits is provided in Table 3-5. The Lattimore Materials Company (OKR050477) in the Red River (OK311100010190_00) watershed will require a wasteload allocation as a contributing source of TSS.

3.1.6 Rock, Sand and Gravel Quarries

Operators of rock, sand and gravel quarries in Oklahoma are regulated with a general permit (OKG950000) issued by the DEQ. 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 (DEQ 2009). Table 3-6 summarizes data from the Oklahoma Department of Mines and provides the permitted mining acres for each of the quarries located within the Study Area. The locations of these quarries are shown in Figure 3-1.

3.1.7 Section 404 permits

Section 404 of the 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 (USACE). 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 CWA 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 comply with Oklahoma WQS.

Table 3-5 Permits Summary

Company Name		County	Permit ID	Date Issued	Waterbody ID	Receiving Water (Permit)	Estimated Acres
Construction General Permits (OKR10)							
	ODOT JP #10101(07)	Greer/Kiowa	9094	6/11/2008	OK311510010040_00	North Fork Of The Red River	97
	ODOT JP #24939(04)	Harmon	9090	6/11/2008	OK311600020060_00	Unnamed Tributary To Cottonwood Creek	16.38
	Bolc Ii Fob	Comanche	8744	1/19/2008	OK311210000050_00	Sitting Bear Creek	10
	Airfield Taxiway Repair	Comanche	8745	1/19/2008	OK311210000050_00	Sitting Bear Creek	2.52
	Hampton Inn	Stephens	8056	1/10/2008	OK311210000050_00	Clarity Creek	3
	Cameron Measurement System	Stephens	8904	3/24/2008	OK311210000050_00	Stagestand Creek	2.5
	ODOT JP #20264(04)	Love	7579	1/11/2008	OK311100010190_00	Walnut Bayou	25
	ODOT JP #22161(07)	Love	8227	10/2/2007	OK311100010190_00	Red River Corridor	23
	ODOT JP #24141(04)	Love	8833	3/10/2008	OK311100010190_00	Red River	30.3
	Southern Aggregate - Thackerville Sand & Gravel	Love	7638	12/27/2007	OK311100010190_00	Thackerville Lake	4
	Winstar RV Park And Golf Course	Love	5621	1/19/2008	OK311100010190_00	Leeper Lake	245
	ODOT JP #20963(04)	Love	9232		OK311100010190_00	Rock Creek	10
Multi-Sector General Permits (OKR05)							
	Lattimore Materials Company	Love	0477	6/9/2006	OK311100010190_00	Red River & Clouds Branch	N/A
	American Gypsum Company LLC – Republic Pit	Jackson	0442	6/6/2006	OK311600020060_00	Unnamed Tributary to Cottonwood Creek	N/A

Table 3-6 Rock, Sand and Gravel Quarries

Company Name	County	Permit ID	Product	Permitted Acres	Permit Issue Date	Permit Renewal Date	Mining Expiration Date	Waterbody ID
John T. McLemore dba McLemore Sand & Topsoil	Beckham	L.E.-1394-A	Sand & Gravel	60	7/1/1995	6/30/2009	6-30-2015	OK311510010090_00
Dolese Bros. (Granite)	Greer	L.E.-1251-A	Limestone	65	12/1/1993	11/30/2008	11-30-2018	OK311510010040_00
American Gypsum Company	Jackson	L.E.-1778-A	Gypsum	508	7/1/1999	6/30/2008	6-30-2015	OK311600020060_00
American Gypsum Company	Jackson	L.E.-1350-B	Gypsum	278	9/1/1994	6/30/2008	6-30-2043	OK311600020060_00
E & A Materials Inc. (Temple Pit)	Cotton	L.E.-1604	Sand & Gravel	288	10/1/1997	9/30/2008	9-30-2112	OK311200000010_00
Lattimore Materials Company (Thackerville 66-North)	Love	L.E.-1742-G	Sand, Gravel, & Clay	910	7/1/1999	6/30/2009	6-30-2028	OK311100010190_00
Lattimore Materials Company (Thackerville South)	Love	L.E.-2018-A	Sand, Gravel, & Clay	400	4/1/2004	3/31/2009	3-31-2069	OK311100010190_00
Southern Aggregates, A Limited Partnership	Love	L.E.-1505-B	Sand & Gravel	1107.28	3/8/2008	10/31/2007	10-31-2010	OK311100010190_00
Margaret Sprouse	Love	X09-1263	Sand	2	3/1/2008	NA	2-28-09	OK311100010190_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 OSWD systems and domestic pets. Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's water quality standards. A study under EPA's National Urban Runoff Project indicated that the average fecal coliform concentration from 14 watersheds in different areas within the United States was approximately 15,000/100 mL in stormwater runoff (EPA 1983). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal coliform bacteria. Water quality data collected from streams draining many of the non-permitted communities show a high level of fecal coliform bacteria. Various potential nonpoint sources of TSS as indicated in the 2008 Integrated Report include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff, non-irrigated crop production, rangeland grazing and other sources of sediment loading (DEQ 2008). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances. The following section provides general information on nonpoint sources contributing bacteria or TSS loading within the Study Area.

3.2.1 Wildlife

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

However, adequate data are available by county to estimate the number of deer by watershed. This report assumes that deer habitat includes forests, croplands, and pastures. Using Oklahoma Department of Wildlife and Conservation county data, the population of deer can be roughly estimated from the actual number of deer harvested and harvest rate estimates. Because harvest success varies from year to year based on weather and other factors, the average harvest from 2005 to 2009 was combined with an estimated annual harvest rate of 20% to predict deer population by county. Using the estimated deer population by county and the percentage of the watershed area within each county, a wild deer population can be calculated for each watershed.

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

(ASAE 1999). Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production based on the estimated deer population provided in Table 3-7 in cfu/day provides a relative magnitude of loading in each watershed.

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

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 10^9 cfu/day) of Deer Population
OK311510020090_00	Buffalo Creek	58,528	589	0.010	294
OK311510010090_00	Timber Creek	23,198	211	0.009	106
OK311510010040_00	Lake Creek	28,720	270	0.009	135
OK311800000060_00	Station Creek	10,320	97	0.009	48
OK311600020060_00	Turkey Creek	200,341	1,763	0.009	881
OK311210000050_00	Little Beaver Creek	125,855	977	0.008	488
OK311200000010_00	Red River	120,909	612	0.005	306
OK311100010190_20	Red River	462,538	2,489	0.005	1,244

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.
- Animals grazing in pastures deposit manure containing fecal bacteria onto land surfaces. These bacteria may be washed into waterbodies by runoff.
- Animals often have direct access to waterbodies and can provide a concentrated source of fecal bacteria loading directly into streams or can cause unstable stream banks which can contribute TSS.

Table 3-8 provides estimated numbers of selected livestock by watershed based on the 2007 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2007). The estimated commercially raised farm animal populations in Table 3-8 were derived by using the percentage of the watershed within each county. Because the watersheds are generally much smaller than the counties, and commercially raised farm animals are not evenly distributed across counties or constant with time, these are rough estimates only. Cattle are clearly the most abundant species of commercially raised farm animals in the Study Area and often have direct access to the waterbodies and their tributaries.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application or direct deposition of manure from commercially raised farm animal. 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 2007 is shown in Table 3-8. These estimates are also based on the county level reports from the 2007 USDA county agricultural census, and thus, represent approximations of the commercially raised farm animal populations in each watershed. Despite the lack of specific data, for the purpose of these TMDLs, land application of commercially raised farm animal manure is considered a potential source of bacteria loading to the watersheds in the Study Area.

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

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

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

Table 3-8 Commercially Raised Farm Animals and Manure Application Area Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves	Dairy Cows	Hogs & Pigs	Chickens	Sheep & Lambs	Horses & Ponies	Turkeys	Ducks	Geese	Acres of Manure Application
OK311510020090_00	Buffalo Creek	5,173	9	26	40	15	246	1	2	3	43
OK311510010090_00	Timber Creek	2,137	0	15	24	12	30	1	2	3	27
OK311510010040_00	Lake Creek	2,235	0	5	11	81	14	0	0	0	0
OK311800000060_00	Station Creek	803	0	2	4	29	5	0	0	0	0
OK311600020060_00	Turkey Creek	18,078	7	64	54	244	285	0	0	0	193
OK311210000050_00	Little Beaver Creek	16,741	653	1,502	388	173	440	6	36	19	573
OK311200000010_00	Red River	19,516	110	9	176	101	394	0	4	2	128
OK311100010190_20	Red River	62,562	406	92	1,349	668	3,795	1	52	37	1,304

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

Waterbody ID	Waterbody Name	Cattle & Calves	Dairy Cows	Hogs & Pigs	Chickens	Sheep & Lambs	Horses & Ponies	Turkeys	Ducks	Geese	Total
OK311510020090_00	Buffalo Creek	538,030	937	283	5	174	103	0	5	164	539,701
OK311510010090_00	Timber Creek	222,200	0	158	3	143	13	0	5	163	222,685
OK311510010040_00	Lake Creek	232,423	0	49	1	971	6	0	0	0	233,451
OK311800000060_00	Station Creek	83,516	0	18	1	349	2	0	0	0	83,885
OK311600020060_00	Turkey Creek	1,880,121	722	689	7	2,930	120	0	0	0	1,884,588
OK311210000050_00	Little Beaver Creek	1,741,064	65,958	16,227	53	2,072	185	1	88	930	1,826,577
OK311200000010_00	Red River	2,029,643	11,070	101	24	1,208	166	0	10	102	2,042,326
OK311100010190_20	Red River	6,506,420	40,991	994	183	8,011	1,594	0	127	1,827	6,560,147

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

DEQ is responsible for implementing the regulations of Title 252, Chapter 641 of the Oklahoma Administrative Code, which defines design standards for individual and small public onsite sewage disposal systems (DEQ 2011). OSWD systems and illicit discharges can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSWD systems can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater may discharge to creeks through springs and seeps.

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

Over time, most OSWD systems operating at full capacity will fail. OSWD system failures are proportional to the adequacy of a state's minimum design criteria (Hall 2002). The 1990 American Housing Survey for Oklahoma conducted by the U.S. Census Bureau estimates that, nationwide, 10% of occupied homes with OSWD systems experience malfunctions during the year (U.S. Department of Commerce, Bureau of the Census 1990). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12% of the OSWD systems in east Texas and 8% in the Texas Panhandle were chronically malfunctioning. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSWD systems per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1986). Table 3-10 summarizes estimates of sewered and unsewered households and the average number of septic tanks per square mile for each watershed in the Study Area.

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 8% was used in the calculations made to characterize fecal coliform loads in each watershed.

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

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

Table 3-10 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	# of Septic Tanks / Mile^2
OK311510020090_00	Buffalo Creek	0	134	16	150	1.47
OK311510010090_00	Timber Creek	64	135	0	199	3.72
OK311510010040_00	Lake Creek	22	59	3	84	1.31
OK311800000060_00	Station Creek	0	6	0	6	0.37
OK311600020060_00	Turkey Creek	373	256	4	634	0.82
OK311210000050_00	Little Beaver Creek	2,057	1,687	19	3,763	8.58
OK311200000010_00	Red River	445	280	7	732	1.48
OK311100010190_20	Red River	1,905	2,231	79	4,215	3.09

The average of number of people per household was calculated to be 2.08 for counties in the Study Area (U.S. Census Bureau 2010). Approximately 70 gallons of wastewater were estimated to be produced on average per person per day (Metcalf and Eddy 1991). The fecal coliform concentration in septic tank effluent was estimated to be 10^6 per 100 mL of effluent based on reported concentrations from a number of publications (Metcalf and Eddy 1991; Canter and Knox 1985; Cogger and Carlile 1984). Using this information, the estimated load from failing septic systems within the watersheds was summarized below in Table 3-11.

Table 3-11 Estimated Fecal Coliform Load from OSWD Systems

Waterbody ID	Waterbody Name	Acres	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day)
OK311510020090_00	Buffalo Creek	58,528	134	11	59
OK311510010090_00	Timber Creek	23,198	135	11	60
OK311510010040_00	Lake Creek	28,720	59	5	26
OK311800000060_00	Station Creek	10,320	6	0	3
OK311600020060_00	Turkey Creek	200,341	256	21	113
OK311210000050_00	Little Beaver Creek	125,855	1,687	135	744
OK311200000010_00	Red River	120,909	280	22	123
OK311100010190_20	Red River	462,538	2,231	178	984

3.2.4 Domestic Pets

Fecal matter from dogs and cats, which is transported to streams by runoff from urban and suburban areas, can be a potential source of bacteria loading. On average 37.2% of the nation's households own dogs and 32.4% own cats and in these households the average number of dogs is 1.7 and 2.2 cats per household (American Veterinary Medical Association 2007). Using the U.S. Census data at the block level (U.S. Census Bureau 2010), dog and cat populations can be estimated for each watershed. Table 3-12 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-12 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK311510020090_00	Buffalo Creek	70	79
OK311510010090_00	Timber Creek	109	123
OK311510010040_00	Lake Creek	70	79
OK311800000060_00	Station Creek	3	3
OK311600020060_00	Turkey Creek	307	346
OK311210000050_00	Little Beaver Creek	1,666	1,880
OK311200000010_00	Red River	344	388
OK311100010190_20	Red River	2,130	2,403

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

Table 3-13 Estimated Fecal Coliform Daily Production by Pets ($x10^9$ counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK311510020090_00	Buffalo Creek	230	43	273
OK311510010090_00	Timber Creek	361	67	428
OK311510010040_00	Lake Creek	232	43	274
OK311800000060_00	Station Creek	9	2	11
OK311600020060_00	Turkey Creek	1,012	187	1,199
OK311210000050_00	Little Beaver Creek	5,499	1,015	6,514
OK311200000010_00	Red River	1,136	210	1,346
OK311100010190_20	Red River	7,029	1,298	8,327

3.3 Summary of Sources of Impairments

Bacteria:

There are no continuous, permitted point sources of bacteria in the Buffalo Creek, Timber Creek, Lake Creek, Station Creek, Little Beaver Creek, or Red River (OK311100010190_20) watersheds which require bacteria TMDLs; therefore, the conclusion is that nonsupport of PBCR use in these watersheds is caused by nonpoint sources of bacteria. Turkey Creek and Red River (OK311200000010_00) each have one continuous point source discharge which contributes bacteria, but the available data suggests that the proportion of bacteria from point sources is minor. A single CAFO may be contributing bacteria loading to the Little Beaver Creek watershed. Little Beaver Creek is also influenced by bacteria loading associated with urban point source runoff associated with the Phase II MS4 jurisdiction associated with Comanche County. Therefore the various nonpoint sources are considered to be the major source of bacteria loading in each watershed that requires a bacterial TMDL.

Table 3-14 below provides a summary of the estimated fecal coliform loads in cfu/day for the four major nonpoint source categories (commercially raised farm animals, pets, deer, and septic tanks) that contribute to the elevated bacteria concentrations in each watershed. Because of their numbers and animal unit production of bacteria, livestock are estimated to be the largest contributors of fecal coliform loading to land surfaces. It must be noted that while no data are available to estimate populations and fecal loading of wildlife other than deer, a number of bacteria source tracking studies around the nation demonstrate that wild birds and mammals represent a major source of the fecal bacteria found in streams.

Table 3-14 Percentage Contribution of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces

Waterbody ID	Waterbody Name	Commercially Raised Farm Animals	Pets	Deer	Estimated Loads from Septic Tanks
OK311510020090_00	Buffalo Creek	99.88	0.05	0.05	0.01
OK311510010090_00	Timber Creek	99.73	0.19	0.05	0.03
OK311510010040_00	Lake Creek	99.81	0.12	0.06	0.01
OK311800000060_00	Station Creek	99.93	0.01	0.06	0.00
OK311600020060_00	Turkey Creek	99.88	0.06	0.05	0.01
OK311210000050_00	Little Beaver Creek	99.58	0.36	0.03	0.04
OK311200000010_00	Red River	99.91	0.07	0.01	0.01
OK311100010190_20	Red River	99.84	0.13	0.02	0.01

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.

Turbidity:

Of the seven watersheds in the Study Area that require turbidity TMDLs, only one of them, Red River (OK311200000010_00) has industrial permitted sources of TSS that will necessitate a WLA. The other watersheds have other permitted activities such as construction and/or mining that contribute some TSS loading. Therefore, nonsupport of WWAC use in all but one watershed is caused primarily by nonpoint sources of TSS. 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:

$$TMDL = WLA\_{WWTP} + WLA\_{MS4} + LA + MOS$$

The WLA is the portion of the TMDL allocated to existing and future point sources. The LA is the portion of the TMDL allocated to nonpoint sources, including natural background sources. The MOS is intended to ensure that WQSs will be met.

For *E. coli* or Enterococci bacteria, TMDLs are expressed as colony-forming units per day, and represent the maximum one-day load the stream can assimilate while still attaining the WQS. Percent reduction goals are also calculated to aid to characterizing the possible magnitude of the effort to restore the segment to meeting water quality criterion. 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 2011 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 frequency 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 (OLS) regression is applied to ascertain the best relationship between two variables (i.e., X and Y), one variable (Y) is considered "dependent" on the other variable (X), but X must be considered "independent" of the other, and known without measurement error. OLS minimizes the differences, or residuals, between measured Y values and Y values predicted based on the X variable.

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

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

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

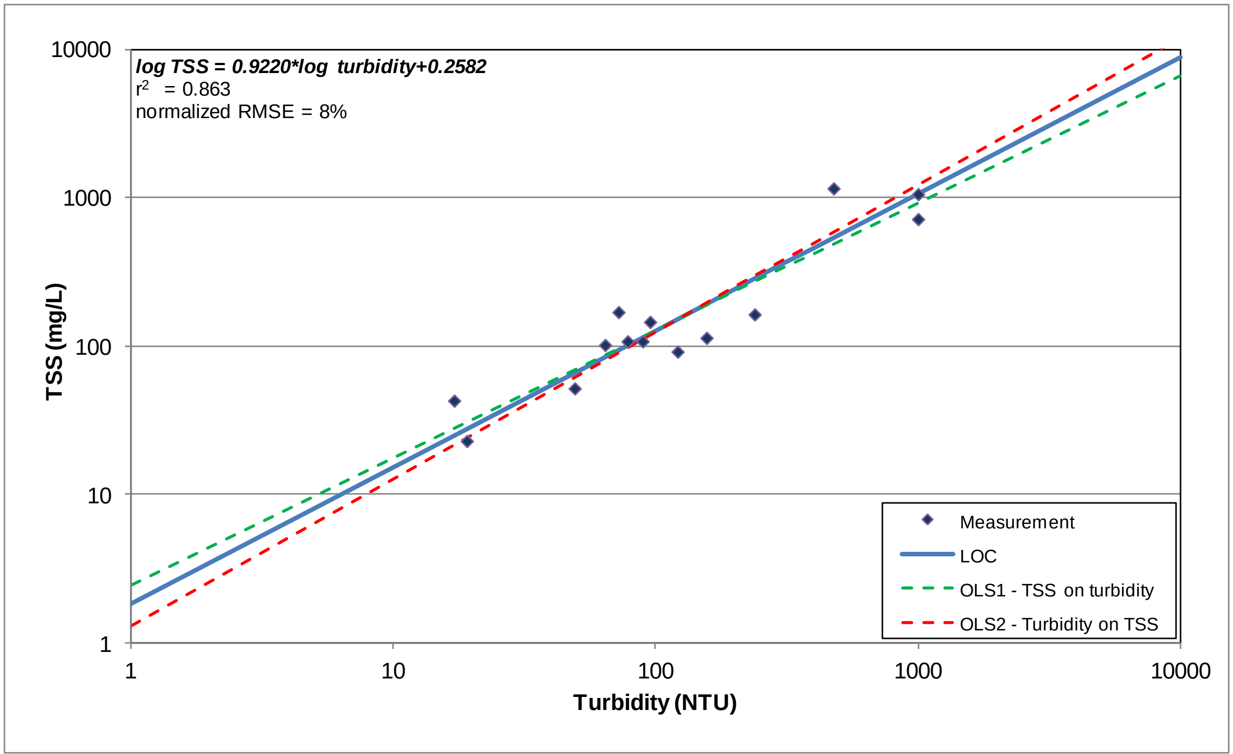
$$m1 = \sqrt{m \cdot m'} = sign[r] \cdot \frac{s_y}{s_x}$$

where $m1$ is the slope of the LOC line, m is the TSS on turbidity OLS slope, m' is the turbidity on TSS OLS slope, r is the TSS-turbidity correlation coefficient, s_y is the standard deviation of the TSS measurements, and s_x is the standard deviation of the turbidity measurements.

The intercept of the LOC ($b1$) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). Figure 4-1 shows an example of the correlation between TSS and turbidity, along with the LOC and the OLS lines.

The NRMSE and R-square (r^2) were used as the primary measures of goodness-of-fit. As shown in Figure 4-1, the LOC yields a NRMSE value of 8 which means the root mean square error (RMSE) is 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. The regression equation can be used to convert the turbidity standard of 50 NTUs to TSS goals.

Figure 4-1 Linear Regression for TSS-Turbidity for Red River (OK311200000010_00)



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.

The regression between TSS and turbidity and its statistics for each turbidity impaired stream segment is provided in Section 5.1.

4.2 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool can help identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the three following steps that are described in Subsections 4.3 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 if there is a critical condition.

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

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

4.3 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. Nine of the eleven 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 (x-axis), which is numbered from 0% to 100%, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100% indicating that flow has equaled or exceeded this value 100% of the time, while the highest measured flow is found at an exceedance frequency of 0%. The median flow occurs at a flow exceedance frequency of 50%. The flow exceedance percentiles for each waterbody addressed in this report are provided in Appendix B.

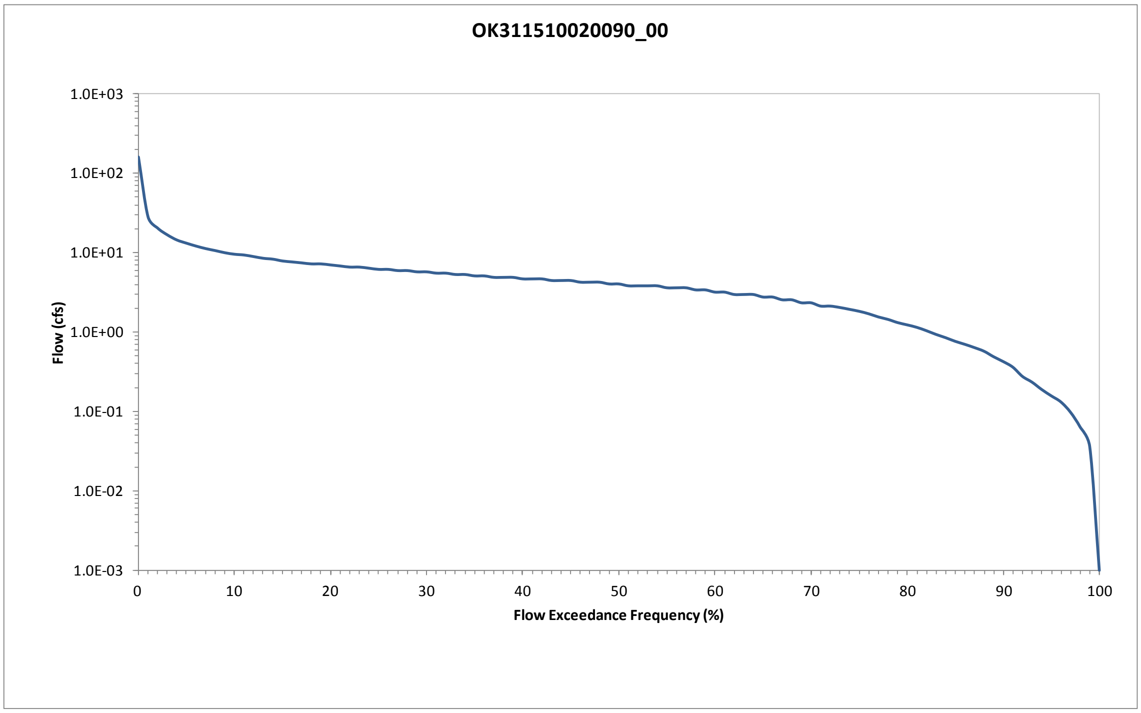
While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than one year of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gaging stations operated by the USGS are utilized (USGS 2009) to support the Oklahoma TMDL Toolbox.

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

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 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% and downward at a frequency near 100%, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100%. As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a “stair step” effect due to the USGS flow data rounding conventions near the limits of quantization. An example of a typical flow duration curve is shown in Figure 4-2.

Figure 4-2 Flow Duration Curve for Buffalo Creek (OK311510020090_00)



Flow duration curves for each impaired waterbody in the Study Area are provided in Section 5.2.

4.4 Estimating Existing Loading

Existing instream loads can be estimated using FDCs. For bacteria, this is accomplished by:

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

For TSS, 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 bacteria curve represents the geometric mean water quality criterion for *E. coli* or Enterococci bacteria expressed in terms of a load through multiplication by the continuum of flows historically observed at the site. Bacteria TMDLs are not easily expressed in mass per day, the following equation calculates a load in the units of cfu per day. The cfu is a total for the day at a specific flow for bacteria, which is the best equivalent to a mass per day of a pollutant such as sulfate. Expressing bacteria TMDLs as cfu per day is consistent with EPA's Protocol for Developing Pathogen TMDLs (EPA 2001).

For turbidity, the curve represents the water quality target for TSS from Table 5-1 expressed in terms of a load obtained through multiplication of the TSS goal 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;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS numerical criterion for each parameter (geometric mean standard for bacteria and TSS goal for turbidity); and
- for bacteria TMDLs, displaying another curve derived by plotting the geometric mean of all existing bacteria samples continuously along the full spectrum of flow exceedance percentiles which represents LDC (See Section 5); or
- for turbidity TMDLs, matching the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile (See Section 5).

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

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

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

unit conversion factor = 24,465,525

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 5-1

unit conversion factor = 5.39377

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 are equal to or exceed the measured or estimated flow. Historical observations of bacteria were plotted as a separate LDC based on the geometric mean of all samples. Historical observations of TSS and/or turbidity concentrations are paired with flow data and are plotted on the LDC for a stream. TSS loads representing exceedance of water quality criteria fall above the TMDL line. It is noted that the LDCs for bacteria were based on the geometric mean standards or geometric mean of all samples. It is inappropriate to compare single sample bacteria observations to a geometric mean water quality criterion in the LDC; therefore individual bacteria samples are not plotted on the LDCs.

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. Yet flows do not always correspond directly to runoff; high flows may occur in dry weather (e.g., lake release to provide water downstream) and runoff influence may be observed with low or moderate flows (e.g., persistent high turbidity due to previous storm).

Step 2: Define MOS. The MOS may be defined explicitly or implicitly. A typical explicit approach would reserve some specific fraction of the TMDL as the MOS. In an implicit approach, conservative assumptions used in developing the TMDL are relied upon to provide an MOS to assure that WQSs are attained. For bacteria TMDLs in this report, an explicit MOS of 10% was selected. The 10% MOS has been used in other approved bacteria TMDLs. 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 EPA 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. WLAs can be expressed in terms of a single load, or as different loads allowable under different flows. WLAs may be set to zero in cases of watersheds with no existing or planned continuous permitted point sources. 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. For watersheds with permitted point sources discharging the pollutant of concern, NPDES permit limits are used to derive WLAs for evaluation as appropriate for use in the TMDL. The permitted flow rate used for each point source discharge and the water quality concentration defined in a permit are used to estimate the WLA for each wastewater facility. In cases where a permitted flow rate is not available for a WWTP, then the average of monthly flow rates derived from DMRs can be used. WLA values for each NPDES wastewater discharger are then summed to represent the total WLA for a given segment. Using this information bacteria and TSS WLAs can be calculated using the approach as shown in the equations below.

WLA for bacteria:

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

Where:

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

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

WLA for TSS:

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

Where:

WQ goal =Waterbody specific water quality goal provided in Table 5-1, or monthlyTSS limit in the current permit, whichever is smaller

flow (mgd) = permitted flow or average monthly flow unit conversion factor = 8.3445

Step 4: Calculate LA and WLA for MS4s. Given the lack of data and the variability of storm events and discharges from storm sewer system discharges, it is difficult to establish numeric limits on stormwater discharges that accurately address projected loadings. As a result, EPA regulations and guidance recommend expressing NPDES permit limits for MS4s as BMPs.

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

LA = TMDL - WLA_WWTP - WLA_MS4 – MOS

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

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

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

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

WLA Load Reduction: The WLA load reduction for bacteria was not calculated as it was assumed that continuous dischargers (NPDES-permitted WWTPs) are adequately regulated under existing permits to achieve WQS at the end-of-pipe and, therefore, no WLA reduction would be required. Currently, bacteria limits are not required for lagoon systems. Lagoon systems located within a sub-watershed of bacteria impaired stream segment will be required to meet *E. coli* standards at the discharge when the permits are renewed.

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

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

- If permitted TSS limit is less than TSS goal for the receiving stream, there will be no reductions;
- If permitted TSS limit is greater than TSS goal for the receiving stream, the permit limit will be set at the TSS goal.

LA Load Reduction. After existing loading estimates are computed for each pollutant, nonpoint load reduction estimates for each segment are calculated by using the difference between the estimate of existing loading and the allowable loading (TMDL) under all flow conditions. This difference is expressed as the overall PRG for the impaired waterbody. The PRG serves as a guide for the amount of pollutant reduction necessary to meet the TMDL. For *E. coli* and Enterococci, because WQSs are considered to be met if the geometric mean of all future data is maintained below the geometric mean criteria (TMDL). For turbidity, the PRG is the load reduction that ensures that no more than 10% of the samples under flow-base conditions exceed the TMDL.

SECTION 5
TMDL CALCULATIONS

5.1 Surrogate TMDL Target for Turbidity

Using the LOC method described in Section 4.1, correlations between TSS and turbidity were developed for establishing the statistics of the regressions and the resulting TSS goals were provided in Table 5-1. The regression analysis for each impaired waterbody in the Study Area using the LOC method is displayed in Figures 5-1 through 5-6. No concurrent turbidity and TSS data were available for Red River (OK311100010190_20) and Red River (OK311100010190_00). Therefore, the regression statistics for these two water bodies were derived from the data within the 8-digit hydrologic unit code (HUC) (11130201).

Table 5-1 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
OK311510010090_00	Timber Creek	0.668	14.9%	44	15%
OK311600020060_00	Turkey Creek	0.965	4.3%	53	10%
OK311600020110_05	Bitter Creek	0.936	6.2%	63	10%
OK311210000050_00	Little Beaver Creek	0.878	10.1%	42	15%
OK311200000010_00	Red River	0.863	8.3%	67	10%
OK311100010190_20	Red River	0.851	11.4%	39	15%
OK311100010190_00	Red River	0.851	11.4%	39	15%

[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)

Figure 5-1 Linear Regression for TSS-Turbidity for Timber Creek (OK311510010090_00)

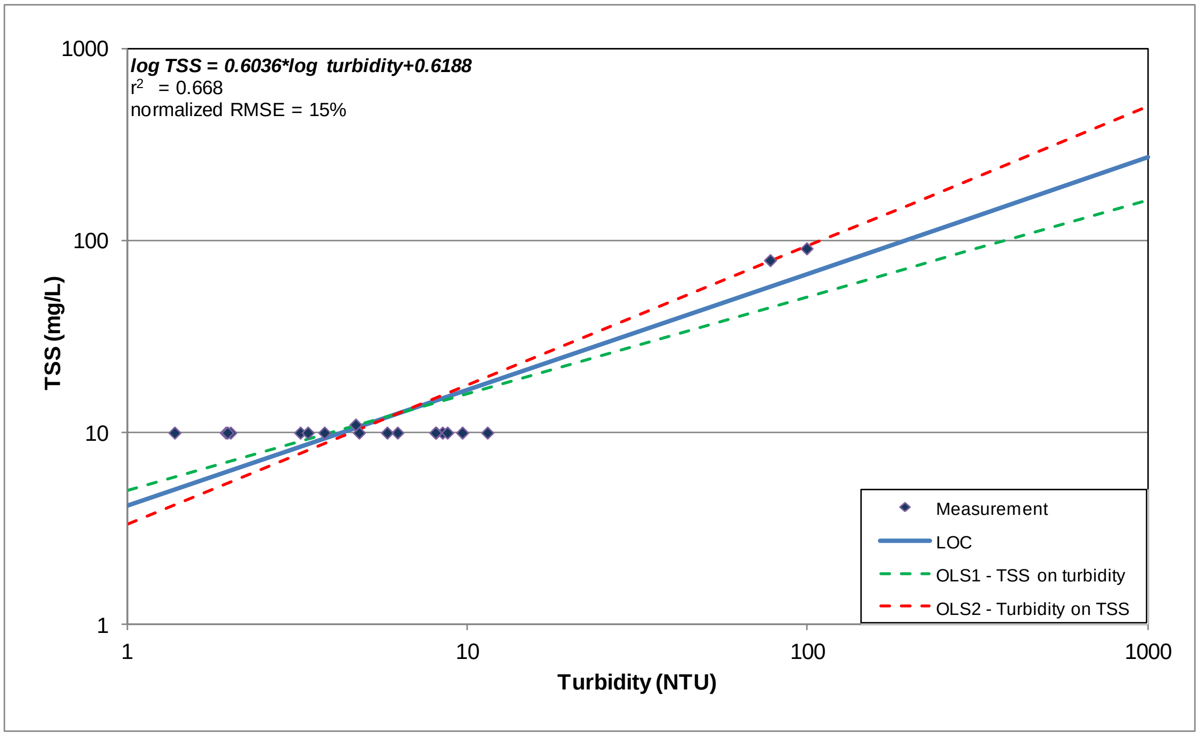


Figure 5-2 Linear Regression for TSS-Turbidity for Turkey Creek (OK311600020060_00)

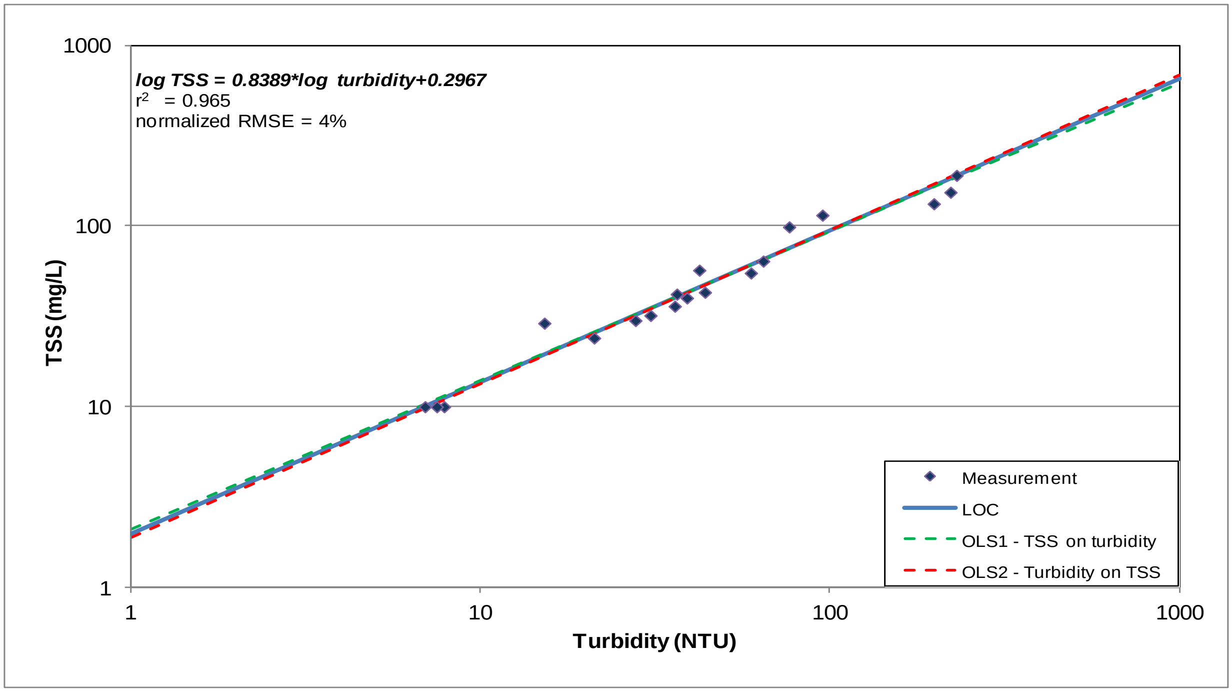


Figure 5-3 Linear Regression for TSS-Turbidity for Bitter Creek (OK311600020110_05)

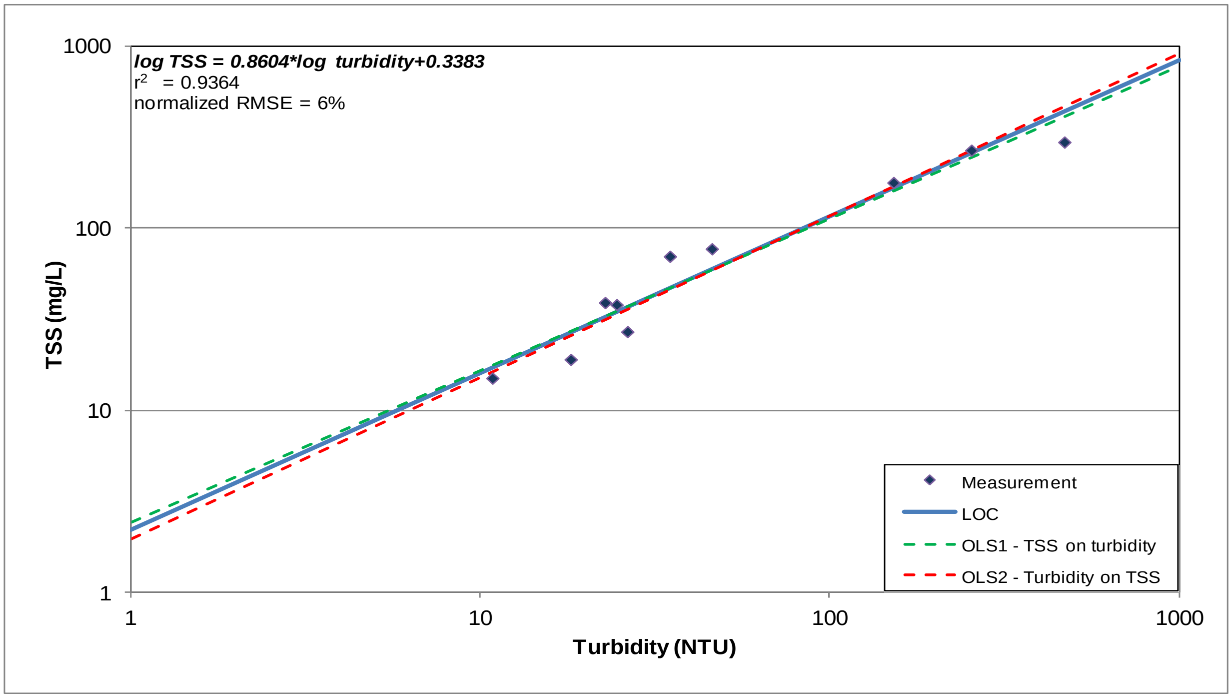


Figure 5-4 Linear Regression for TSS-Turbidity for Little Beaver Creek (OK311210000050_00)

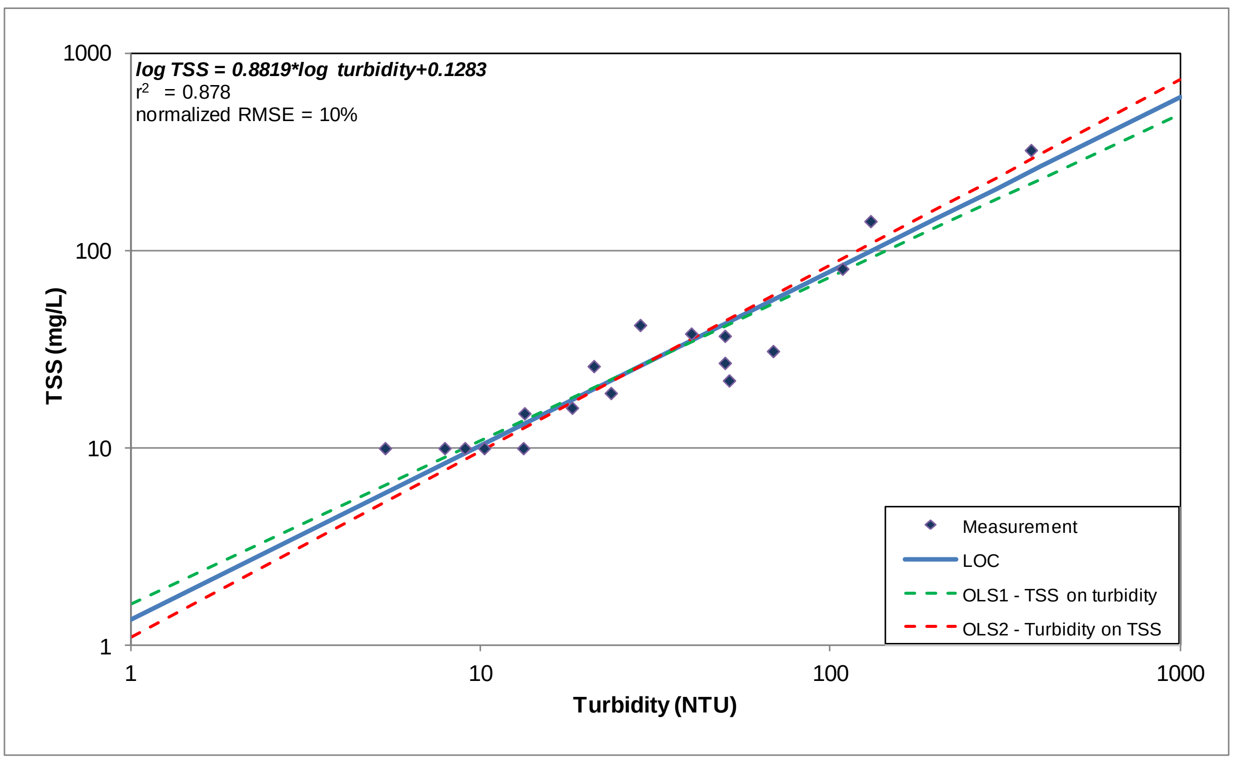


Figure 5-5 Linear Regression for TSS-Turbidity for Red River (OK311200000010_00)

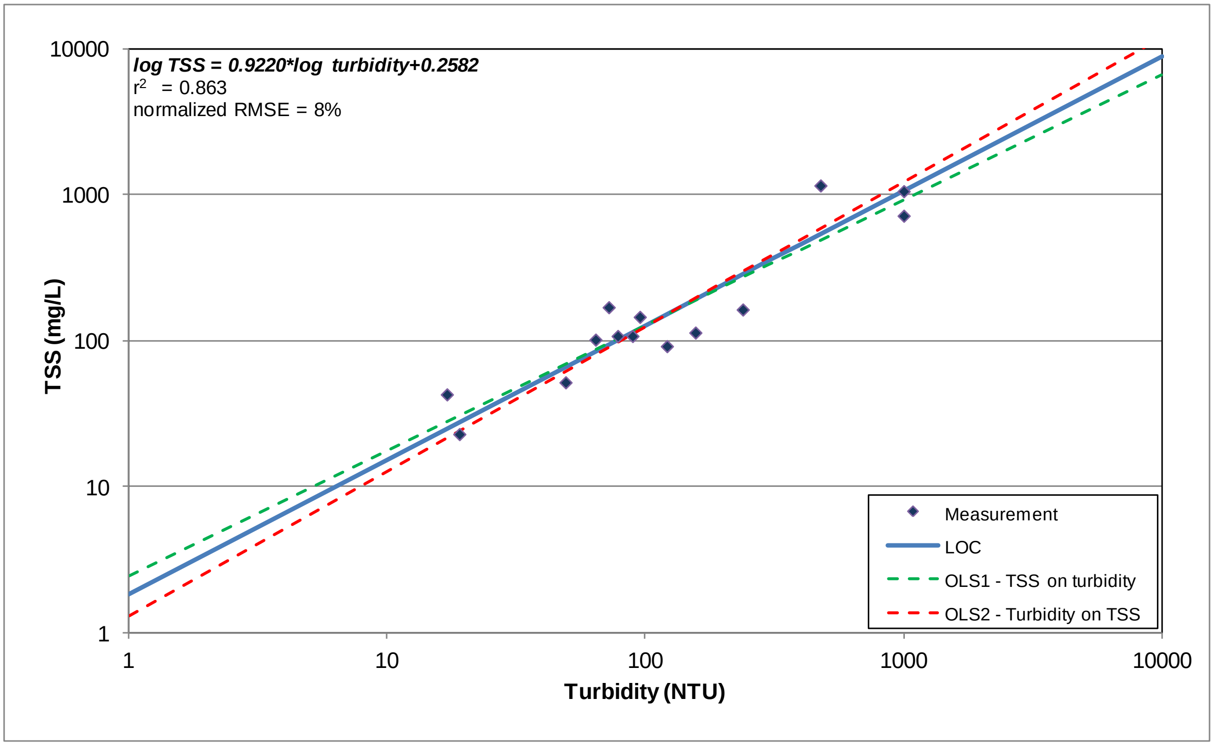
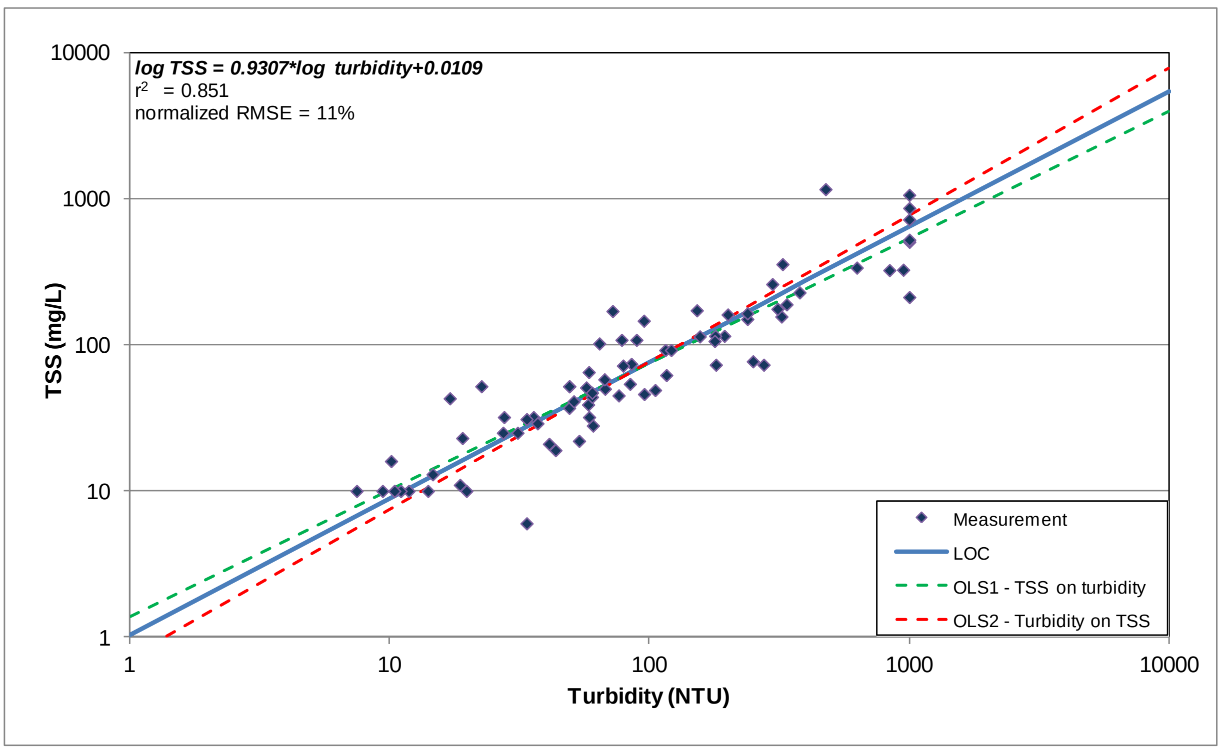


Figure 5-6 Linear Regression for TSS-Turbidity for Red River (OK311100010190_20 and OK311100010190_00)



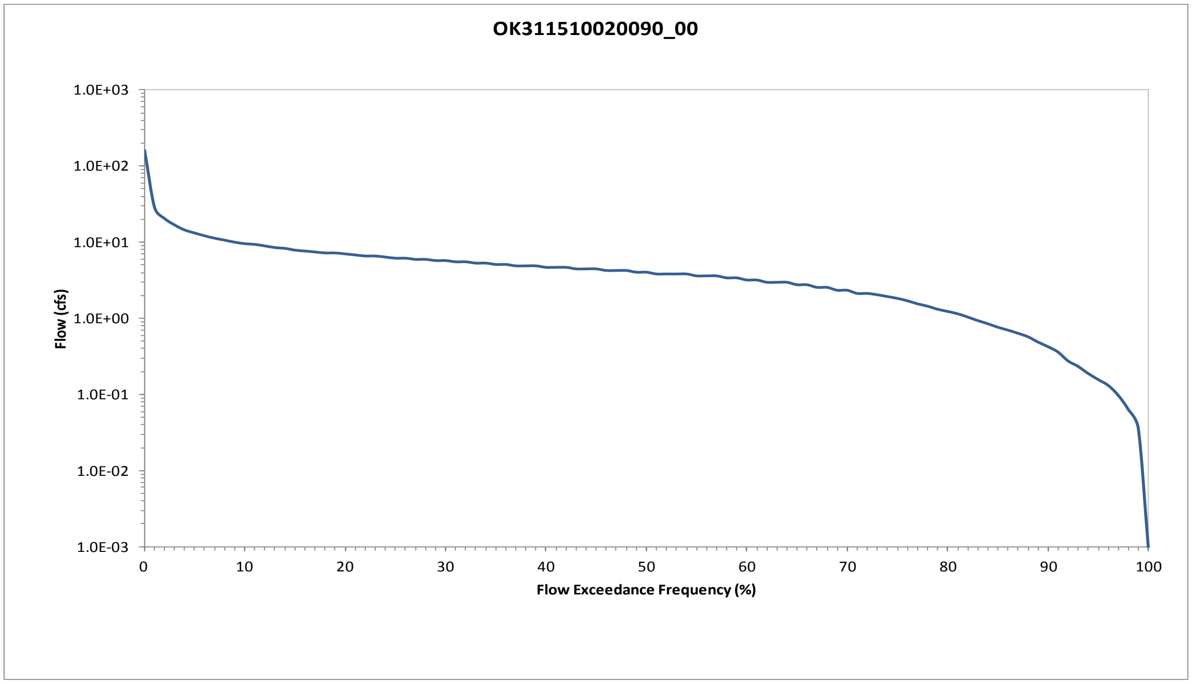
Note: The regression for WBIDs OK311100010190_20 and OK311100010190_00 were developed using data for the 8-digit HUC (11130201) due to the lack of WBID-specific TSS-turbidity paired data.

5.2 Flow Duration Curve

Following the same procedures described in Section 4.3, a flow duration curve for each stream segment in this study was developed. These are shown in Figures 5-7 through Figure 5-16.

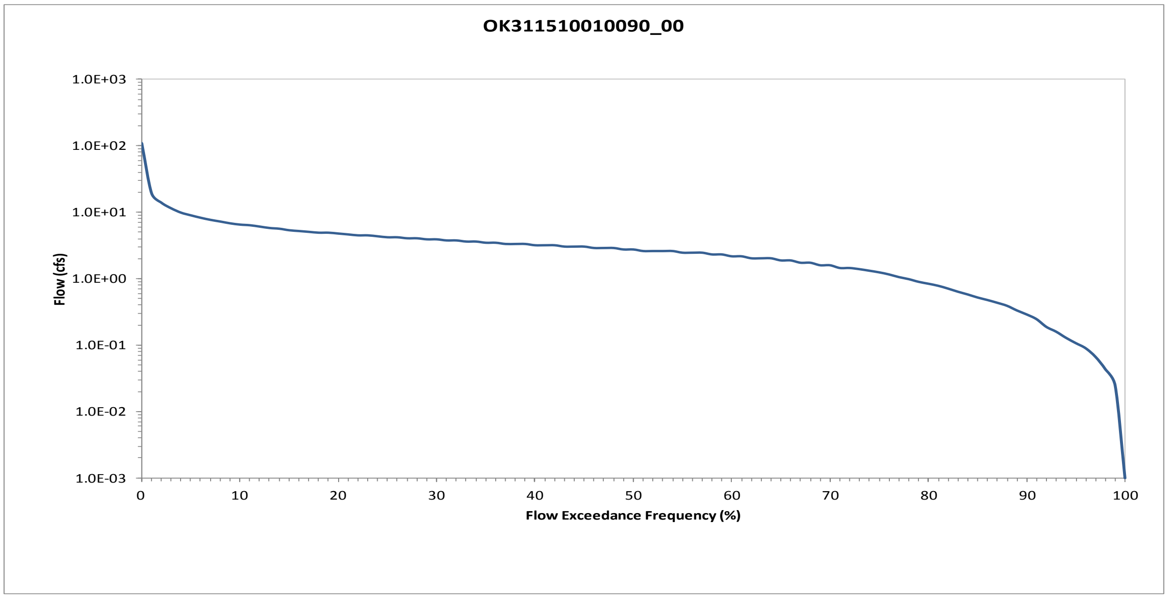
No flow gage exists on Buffalo Creek, segment OK311510020090_00. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07301420 located in an adjacent watershed (Sweetwater Creek, near Sweetwater, OK). The flow duration curve was based on measured flows from 1986 to 2009.

Figure 5-7 Flow Duration Curve for Buffalo Creek (OK311510020090_00)



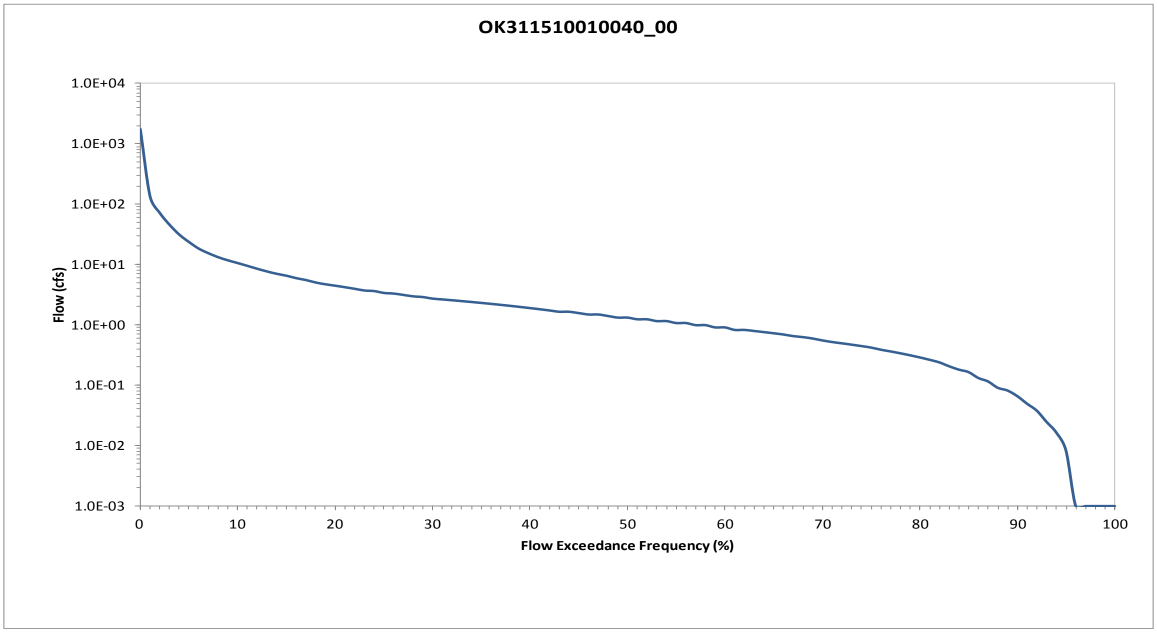
No flow gage exists on Timber Creek, segment OK311510010090_00. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07301420 (Sweetwater Creek, near Sweetwater, OK). The flow duration curve was based on measured flows from 1986 to 2009.

Figure 5-8 Flow Duration Curve for Timber Creek (OK311510010090_00)



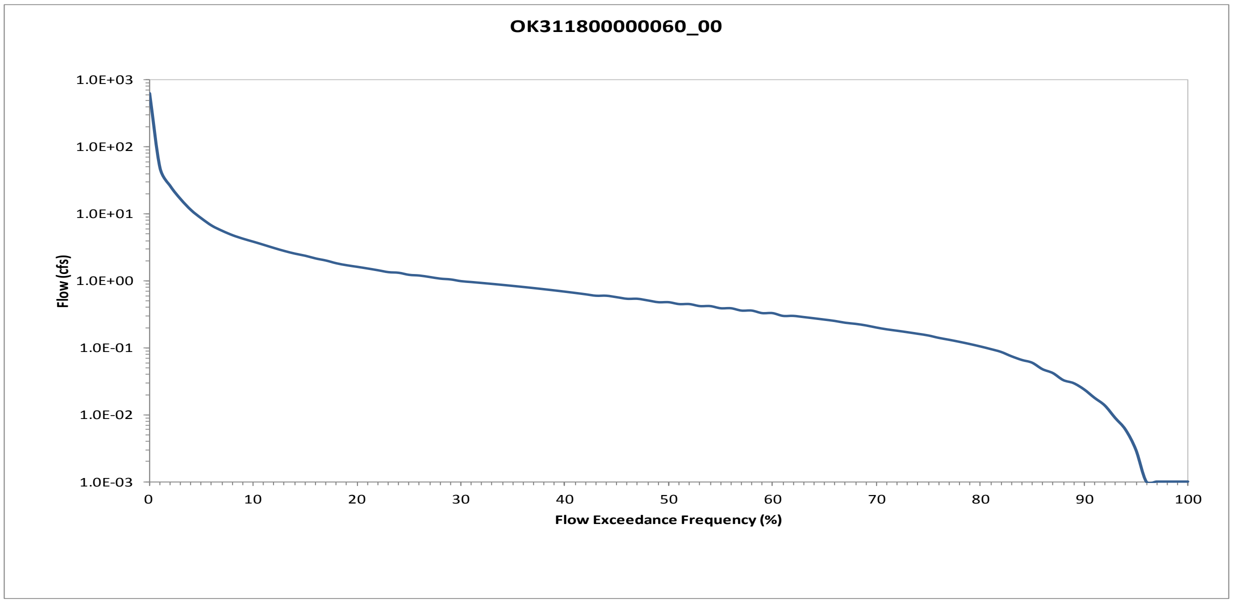
No flow gage exists on Lake Creek, segment OK311510010040_00. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07304500 located in an adjacent watershed (Elk Creek off US183 near Hobart, OK). The flow duration curve was based on measured flows from 1904 to 1993.

Figure 5-9 Flow Duration Curve for Lake Creek (OK311510010040_00)



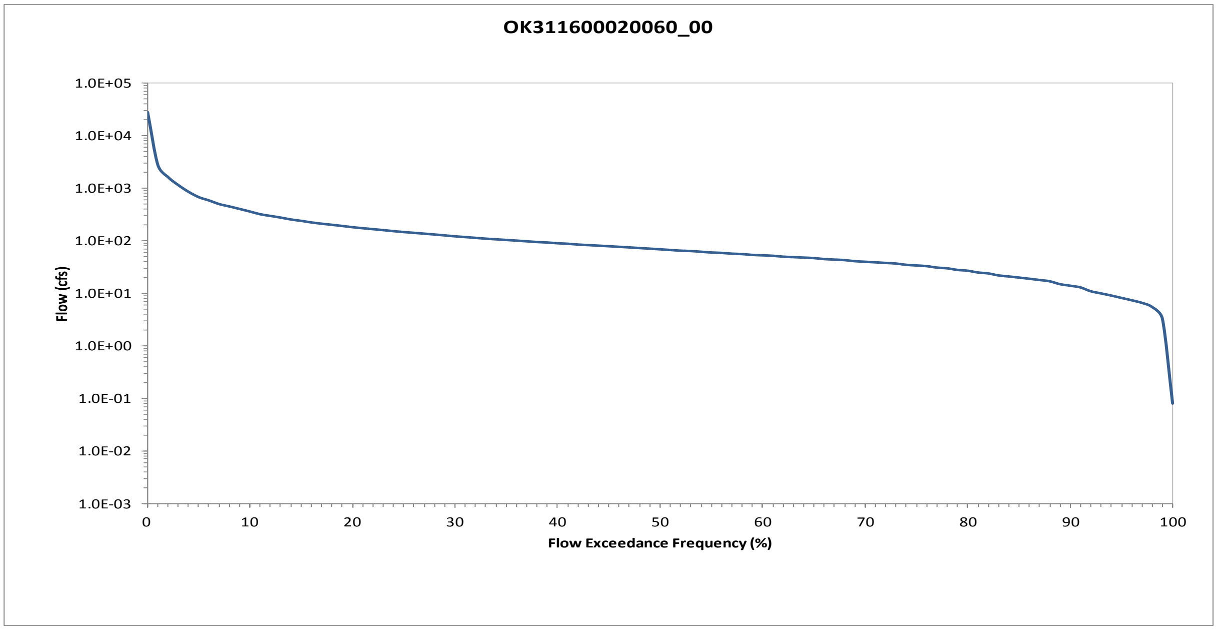
No flow gage exists on Station Creek, segment OK311800000060_00. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07304500 located in an adjacent watershed (Elk Creek off US183 near Hobart, OK). The flow duration curve was based on measured flows from 1904 to 1993.

Figure 5-10 Flow Duration Curve for Station Creek (OK311800000060_00)



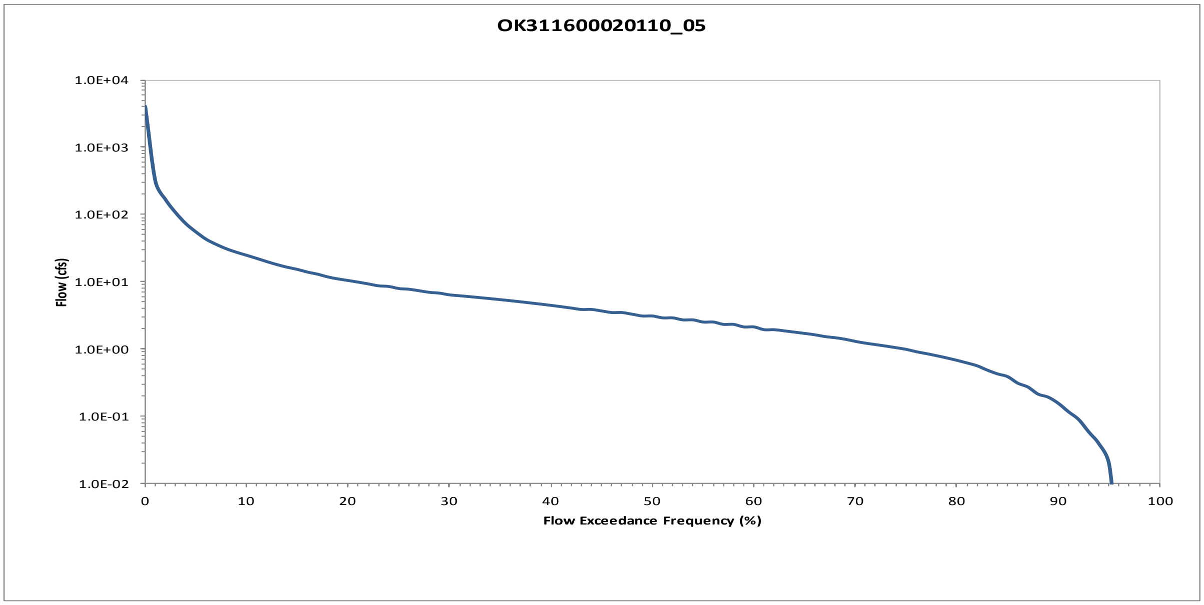
No flow gage exists on Turkey Creek, segment OK311600020060_00. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07301110 (Salt Fork Red River off US283, near Elmer, OK). The flow duration curve was based on measured flows from 1979 to 2009.

Figure 5-11 Flow Duration Curve for Turkey Creek (OK311600020060_00)



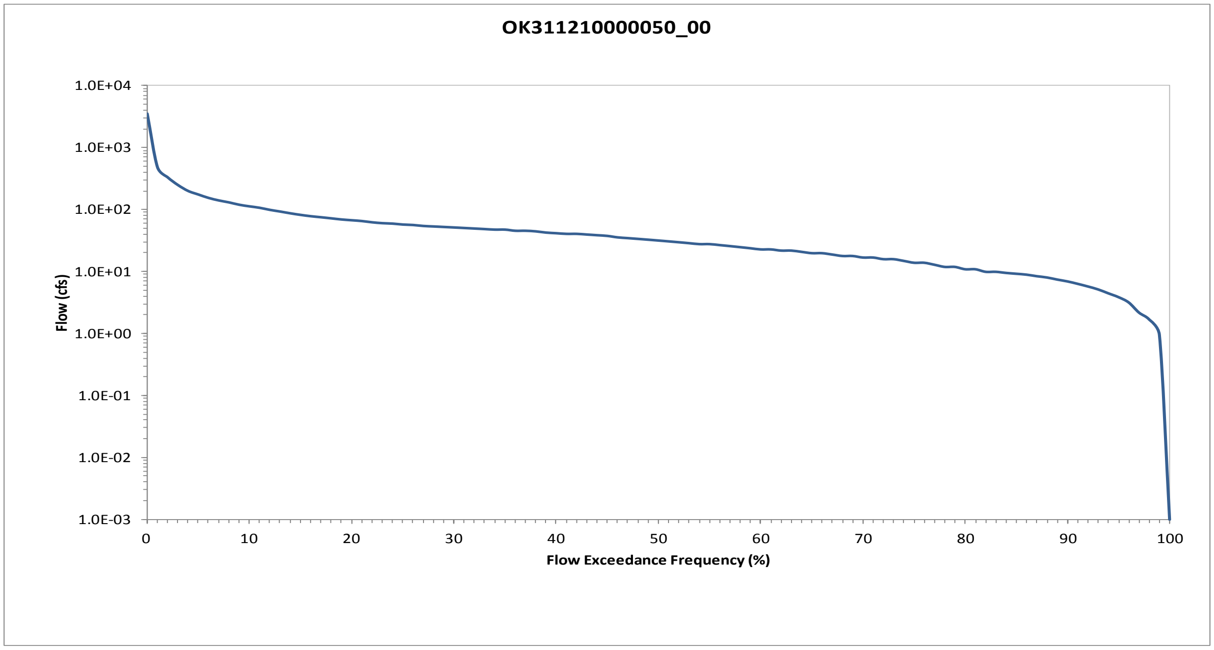
No flow gage exists on Bitter Creek, segment OK311600020110_05. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07304500 located in an adjacent watershed (Elk Creek off US183 near Hobart, OK). The flow duration curve was based on measured flows from 1904 to 1993.

Figure 5-12 Flow Duration Curve for Bitter Creek (OK311600020110_05)



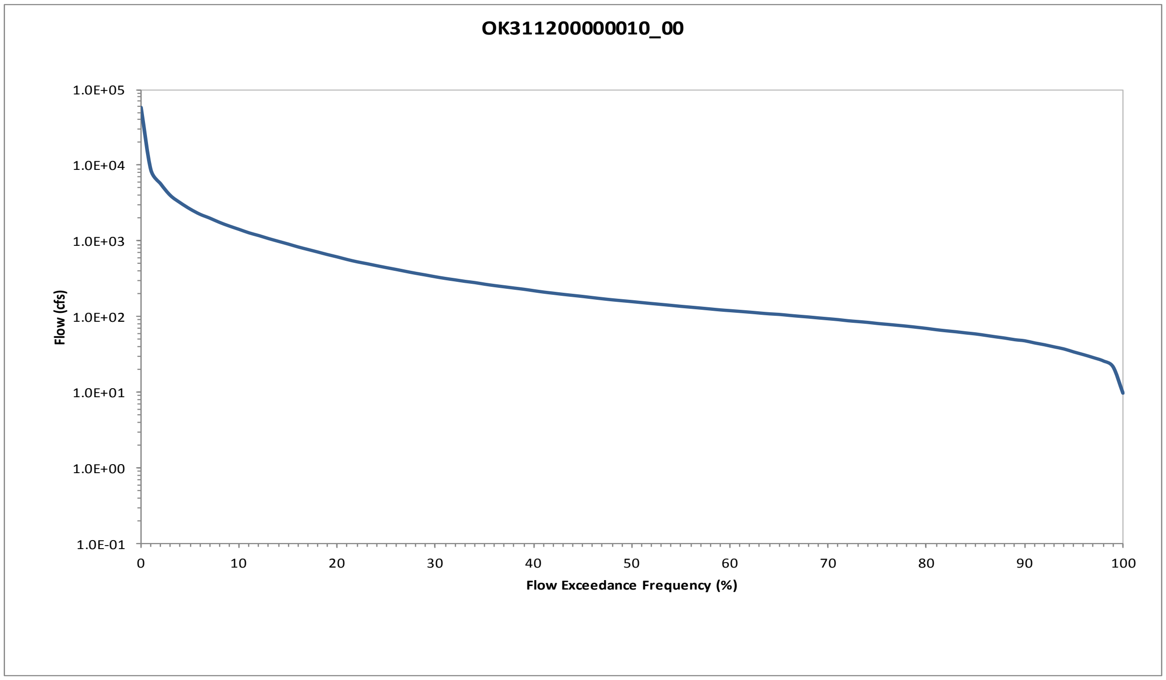
No flow gage exists on Little Beaver Creek, segment OK311210000050_00. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07327550 located in an adjacent watershed (Little Washita River east of Ninnekah, OK). The flow duration curve was based on measured flows from 1992 to 2010.

Figure 5-13 Flow Duration Curve for Little Beaver Creek (OK311210000050_00)



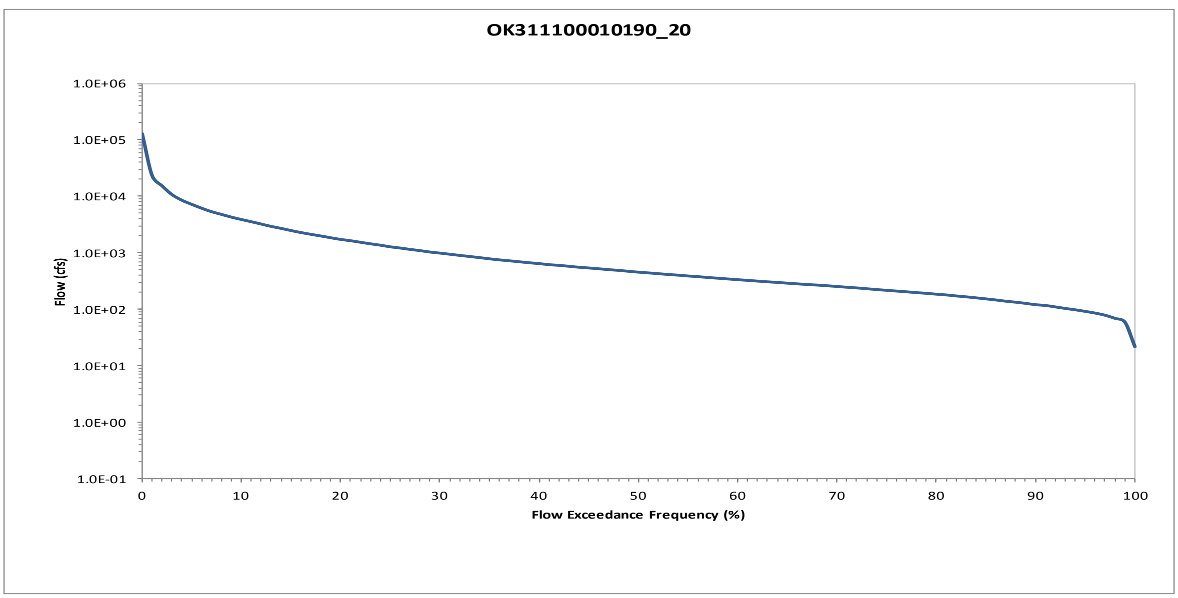
No flow gage exists on Red River, segment OK311200000010_00. Therefore, flows for this waterbody were estimated using the watershed area ration method based on measured flows at USGS gage station 07315500 (Red River at US81 near Terral, OK). The flow duration curve was based on measured flows from 1938 to 2009.

Figure 5-14 Flow Duration Curve for Red River (OK311200000010_00)



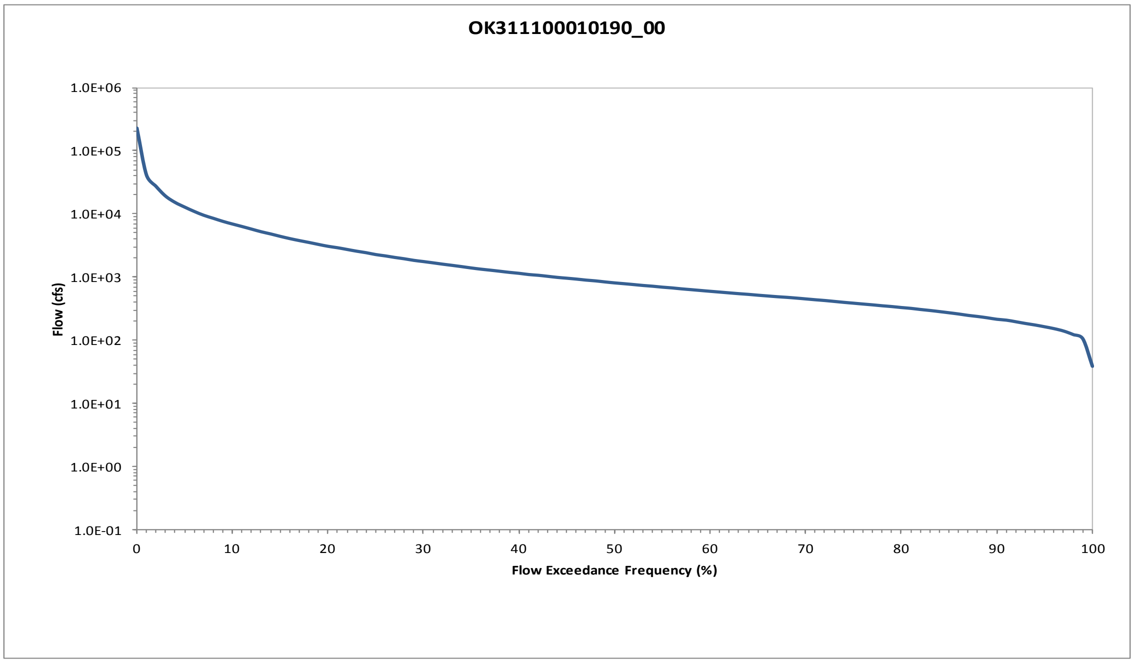
The flow duration curve for Red River, segment OK311100010190_20 was based on flows at USGS gage station 07316000 (Red River, near Gainesville, TX). The flow duration curve was based on measured flows from 1936 to 2009.

Figure 5-15 Flow Duration Curve for Red River (OK311100010190_20)



The flow duration curve for Red River, segment OK311100010190_00 was based on flows at USGS gage station 07316000 (Red River, near Gainesville, TX). The flow duration curve was based on measured flows from 1936 to 2009.

Figure 5-16 Flow Duration Curve for Red River (OK311100010190_00)



5.3 Estimated Loading and Critical Conditions

EPA regulations at 40 CFR 130.7(c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and all applicable WQS. To accomplish this, available instream WQM data were evaluated with respect to flows and magnitude of water quality criteria exceedance using LDCs.

Bacteria LDC: To calculate the allowable bacteria load, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*24,465,525*) and the geometric mean water quality criterion for each bacterial indicator. This calculation produces the maximum bacteria load in the stream over the range of flow conditions. The allowable bacteria (*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, the geometric mean of all bacteria observations (concentrations) for the primary contact recreation season (May 1st through September 30th) from 2002 to 2009 are paired with the flows measured or estimated in that waterbody. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor of *24,465,756*.

The bacteria LDCs developed for each impaired waterbody (representing the primary contact recreation season from 2002 through 2009) are shown in Figures 5-17 through 5-29. Each waterbody had an LDC for *E. coli*, Enterococci or both. This is because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

The LDCs for Buffalo Creek (Figures 5-17 and 5-18) are based on *E. coli* and Enterococci bacteria measurements collected during primary contact recreation season at WQM stations OK311510-02-0090D and OKR09730-012.

Figure 5-17 Load Duration Curve for *E. coli* in Buffalo Creek (OK311510020090_00)

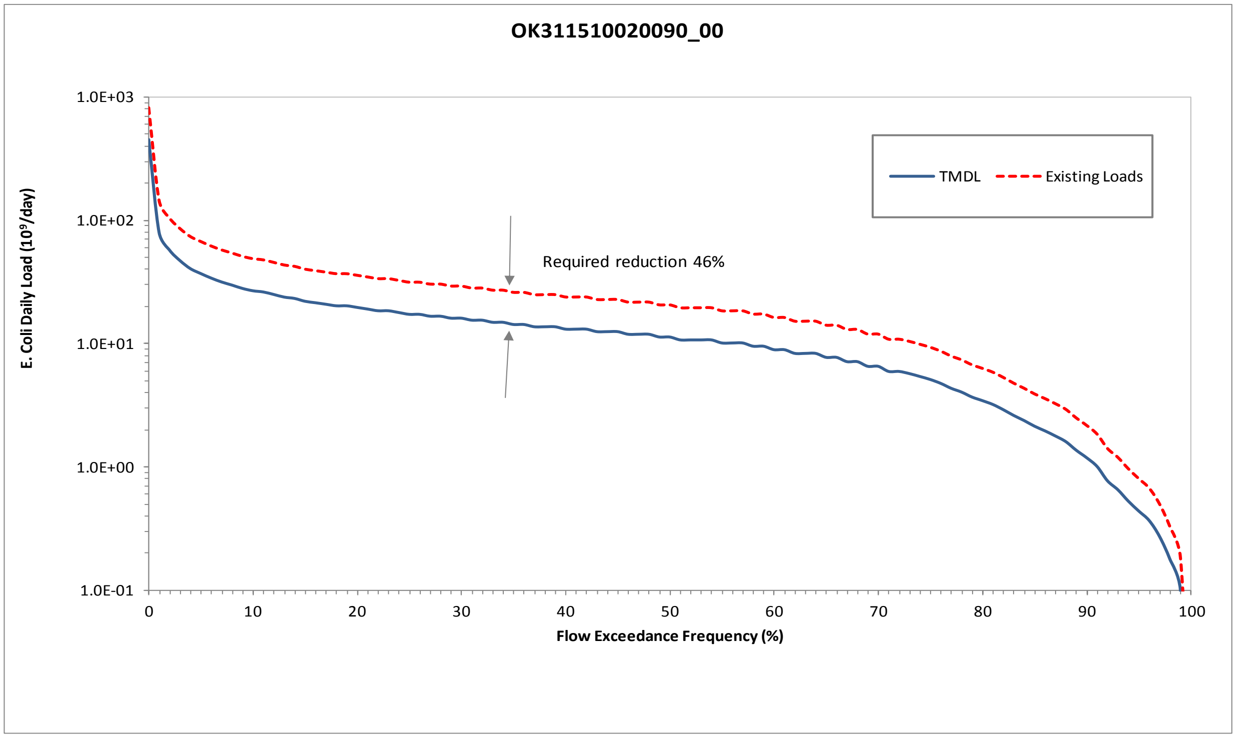
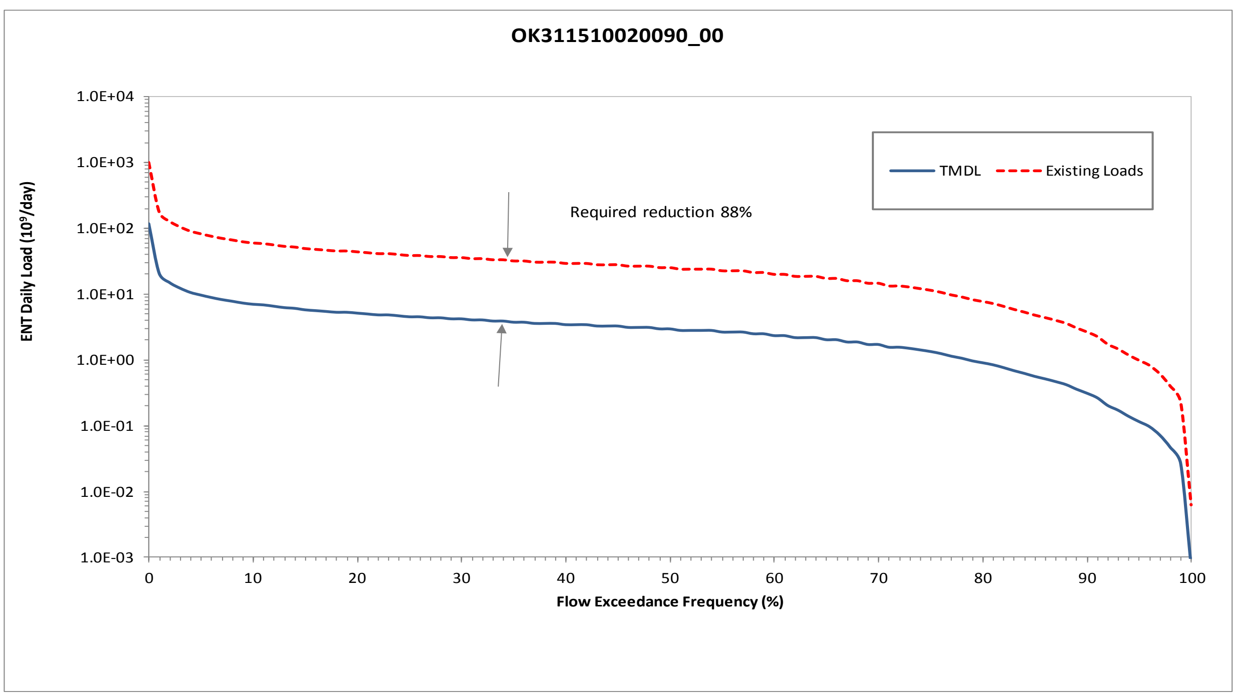


Figure 5-18 Load Duration Curve for Enterococci in Buffalo Creek (OK311510020090_00)



The LDC for Timber Creek (Figures 5-19 and 5-20) are based on *E. coli* and Enterococci measurements during primary contact recreation season at WQM stations OK311510-01-0090G and OKR09730-136.

Figure 5-19 Load Duration Curve for *E. coli* in Timber Creek (OK311510010090_00)

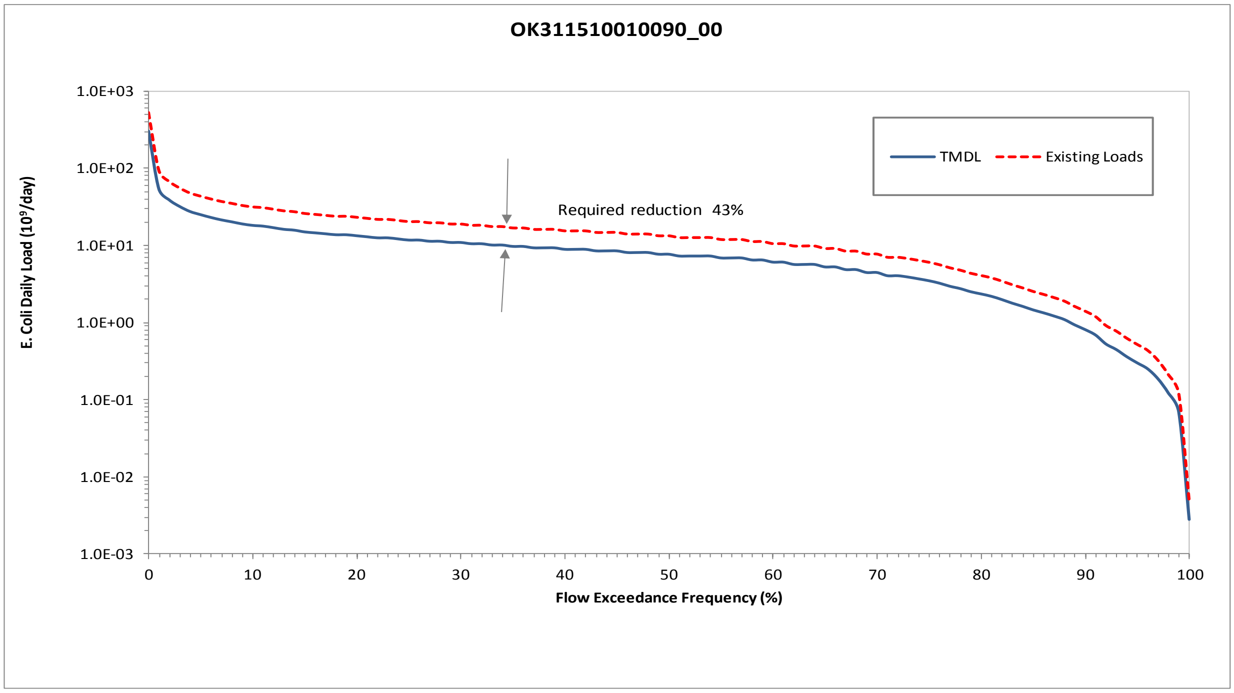
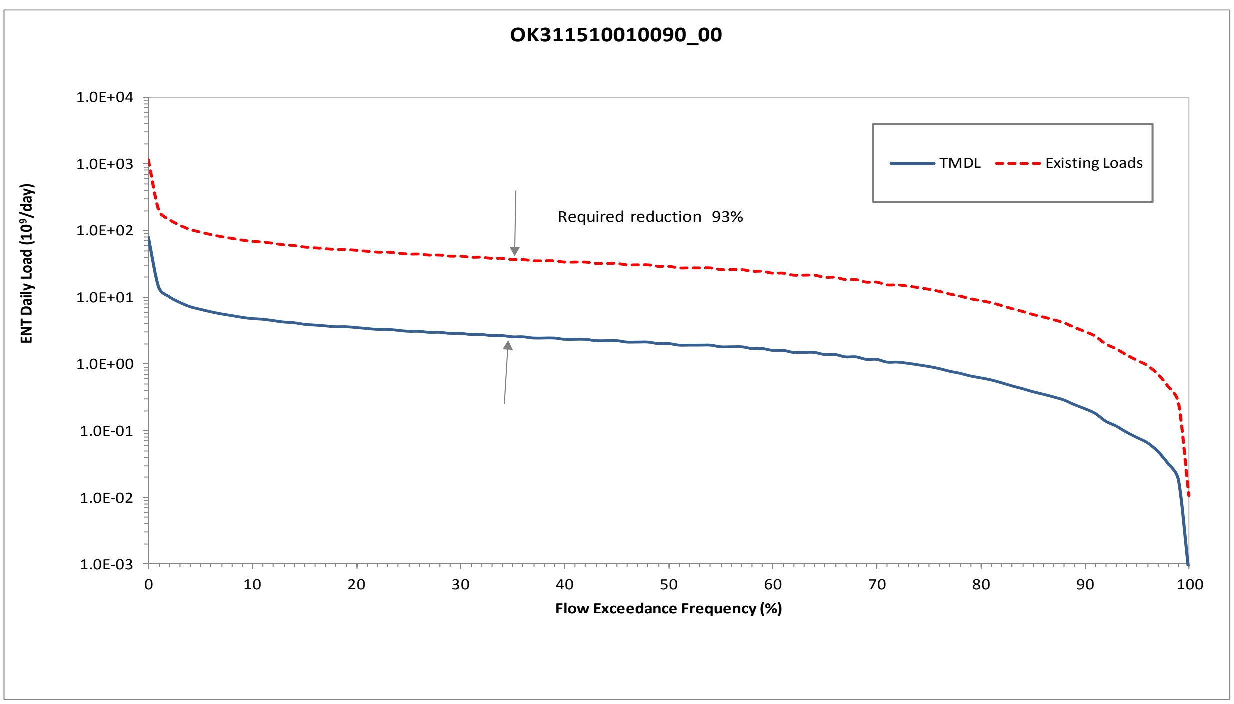


Figure 5-20 Load Duration Curve for Enterococci in Timber Creek (OK311510010090_00)



The LDCs for Lake Creek (Figures 5-21 and 5-22) are based on *E. coli* and Enterococci bacteria measurements collected during primary contact recreation season at WQM station OK311510-01-0040D.

Figure 5-21 Load Duration Curve for *E. coli* in Lake Creek (OK311510010040_00)

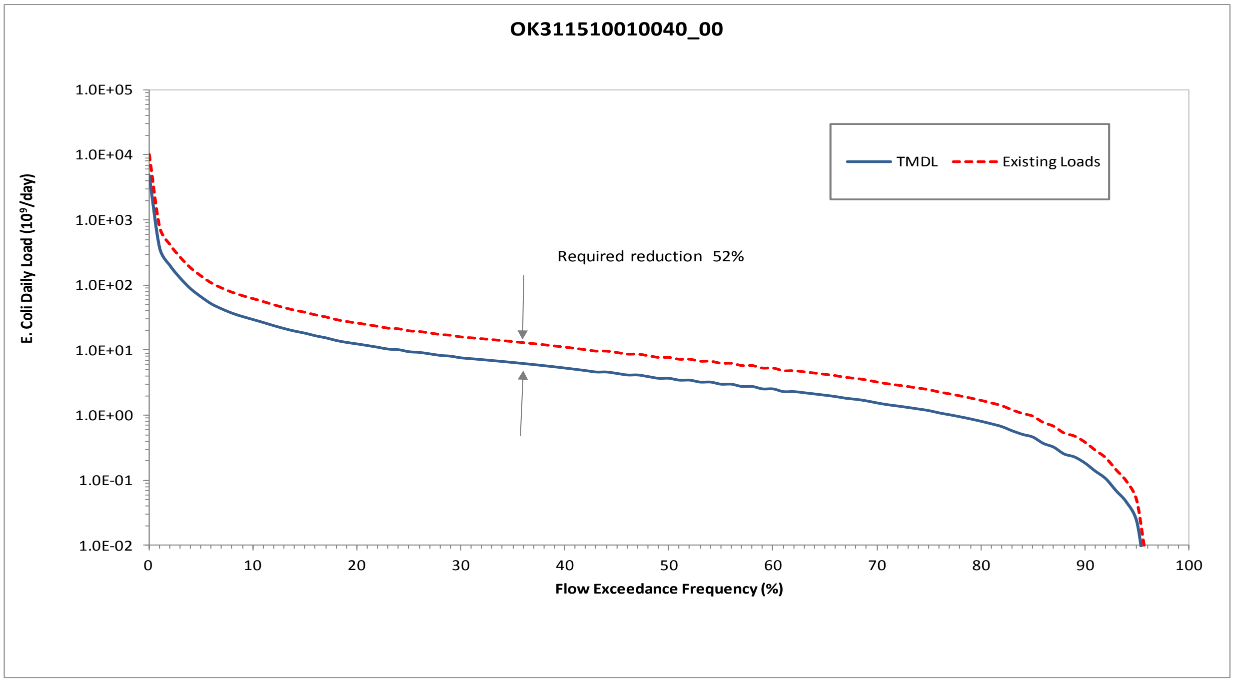
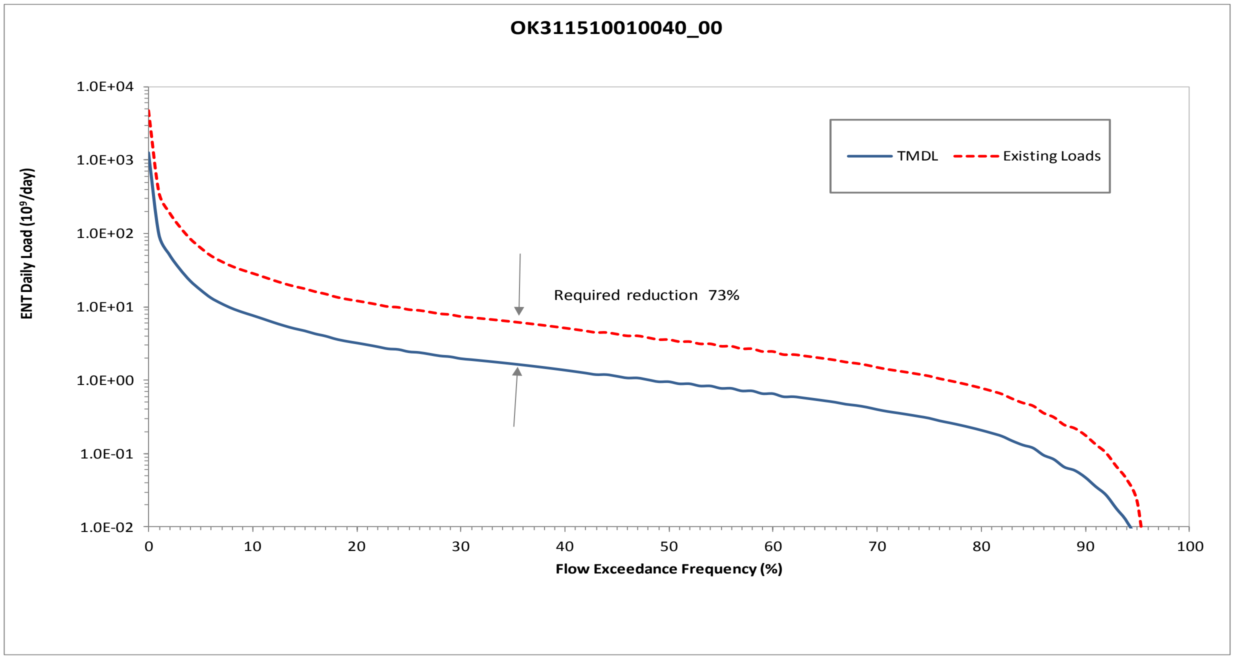
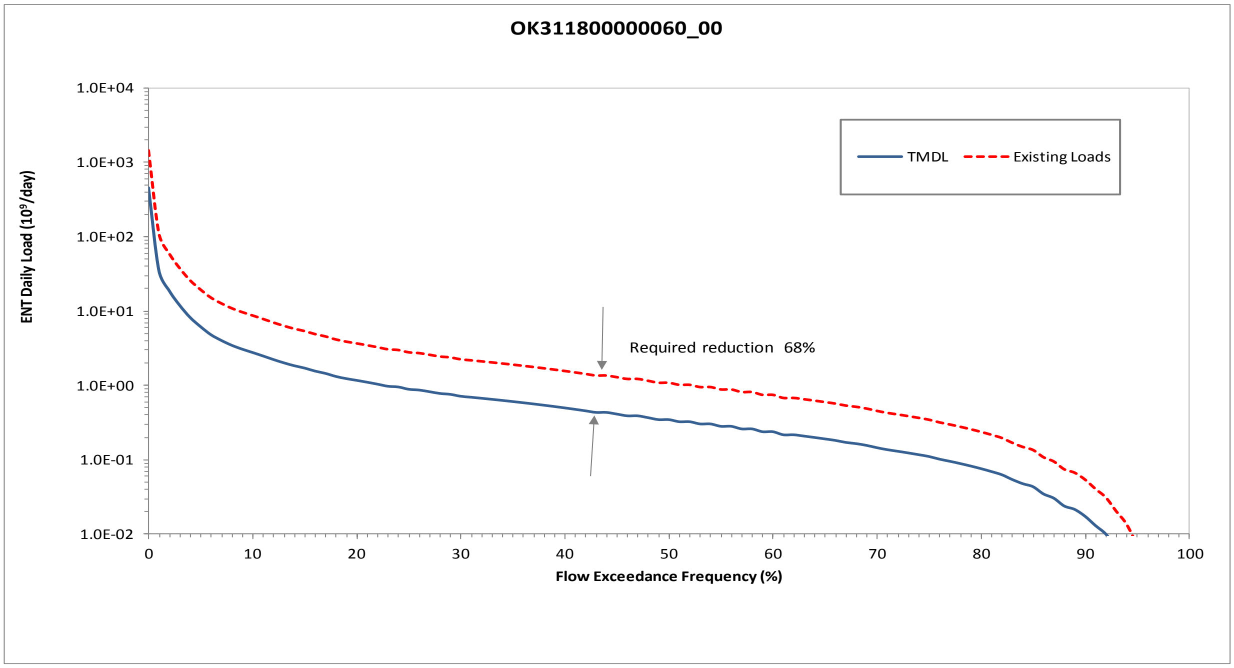


Figure 5-22 Load Duration Curve for Enterococci in Lake Creek (OK311510010040_00)



The LDC for the Station Creek (Figure 5-23) is based on Enterococci measurements during primary contact recreation season at WQM stations OK311800-00-0060G and OKR09730-123.

Figure 5-23 Load Duration Curve for Enterococci in Station Creek (OK31180000060_00)



The LDCs for Turkey Creek (Figures 5-24 and 5-25) are based on *E. coli* and Enterococci bacteria measurements collected during primary contact recreation season at WQM stations OK311600-02-0060H, OK311600-02-0060J, and OKR09730-109.

Figure 5-24 Load Duration Curve for *E. coli* in Turkey Creek (OK311600020060_00)

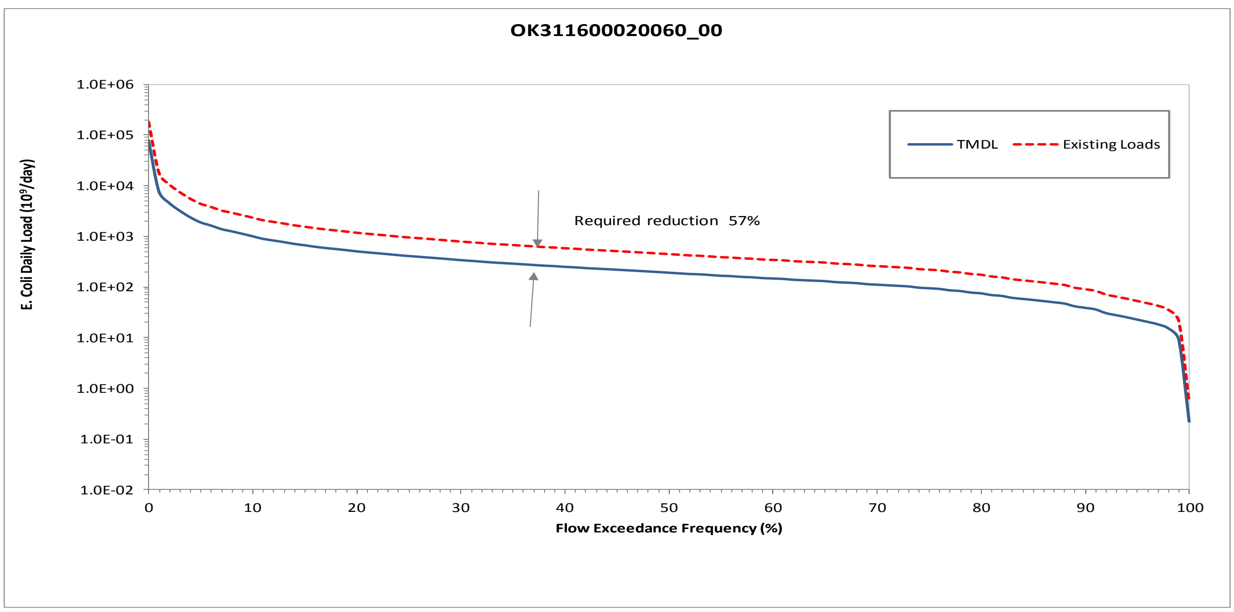
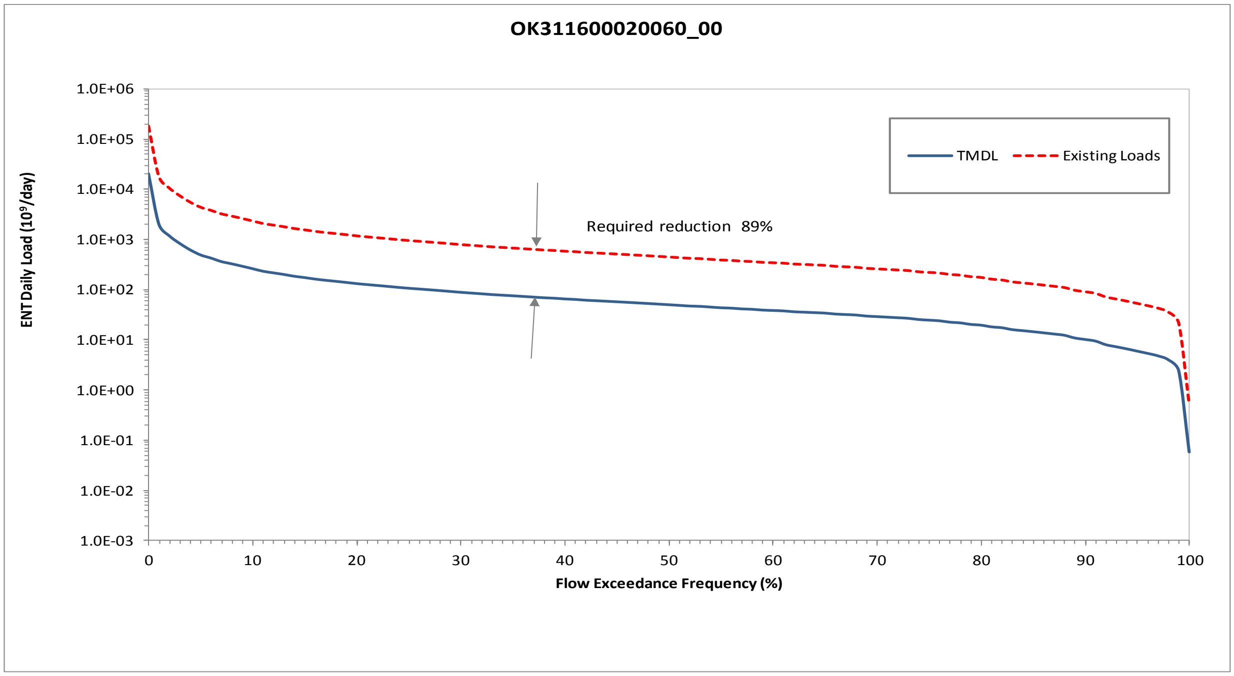


Figure 5-25 Load Duration Curve for Enterococci in Turkey Creek (OK311600020060_00)



The LDCs for Little Beaver Creek (Figures 5-26 and 5-27) are based on *E. coli* and Enterococci measurements during primary contact recreation season at WQM station OK311210-00-0050D.

Figure 5-26 Load Duration Curve for *E. coli* in Little Beaver Creek (OK311210000050_00)

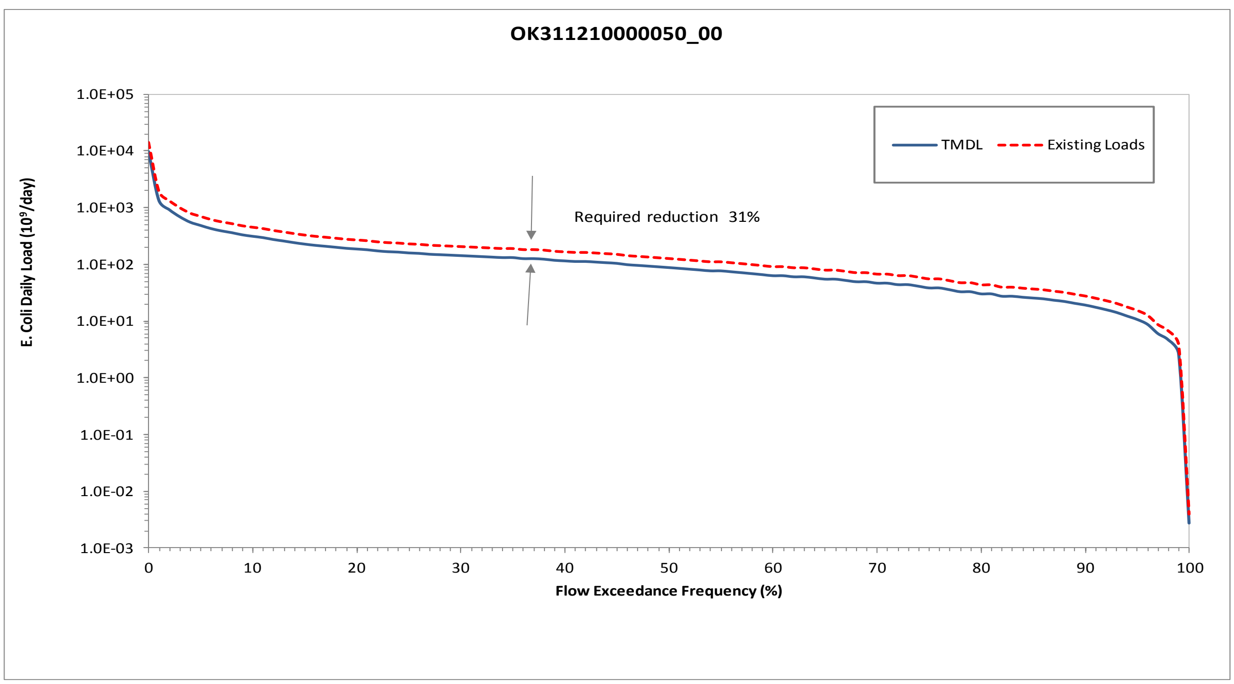
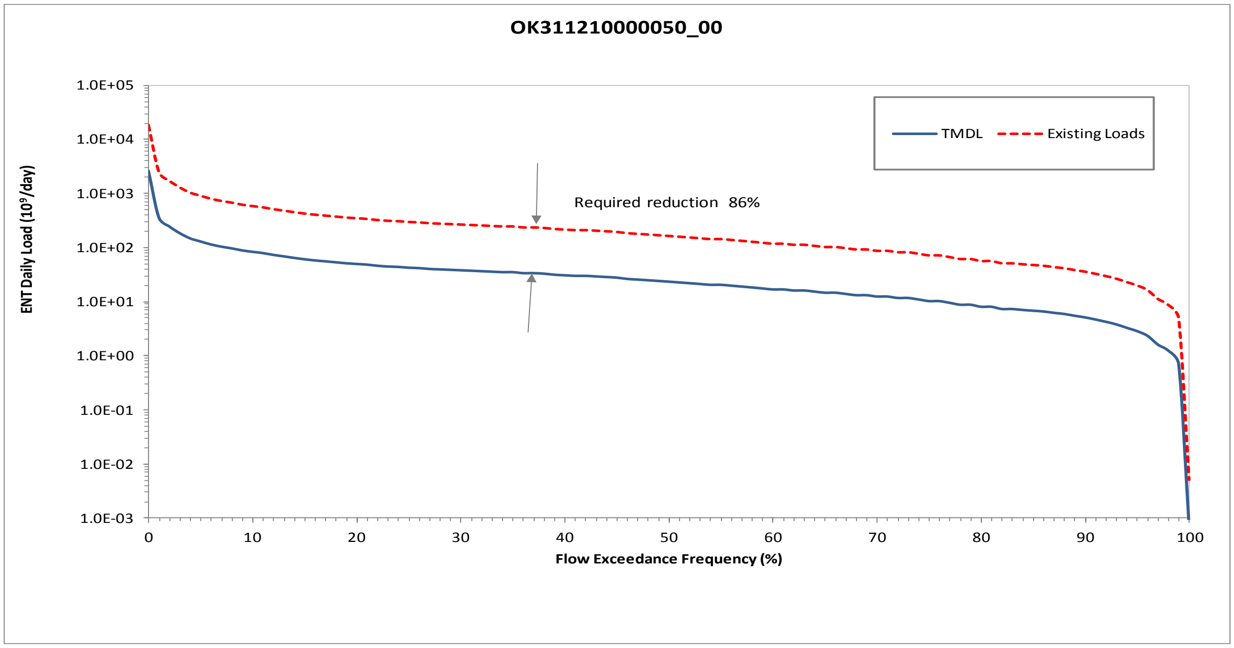
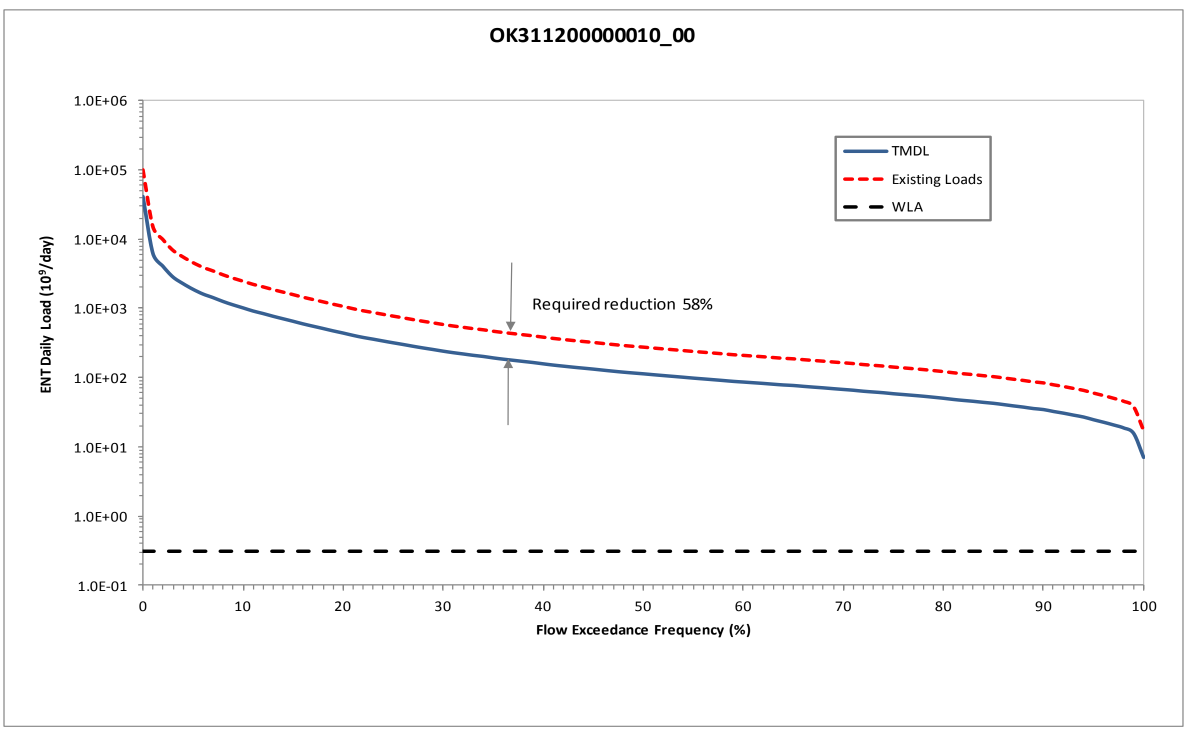


Figure 5-27 Load Duration Curve for Enterococci in Little Beaver Creek (OK311210000050_00)



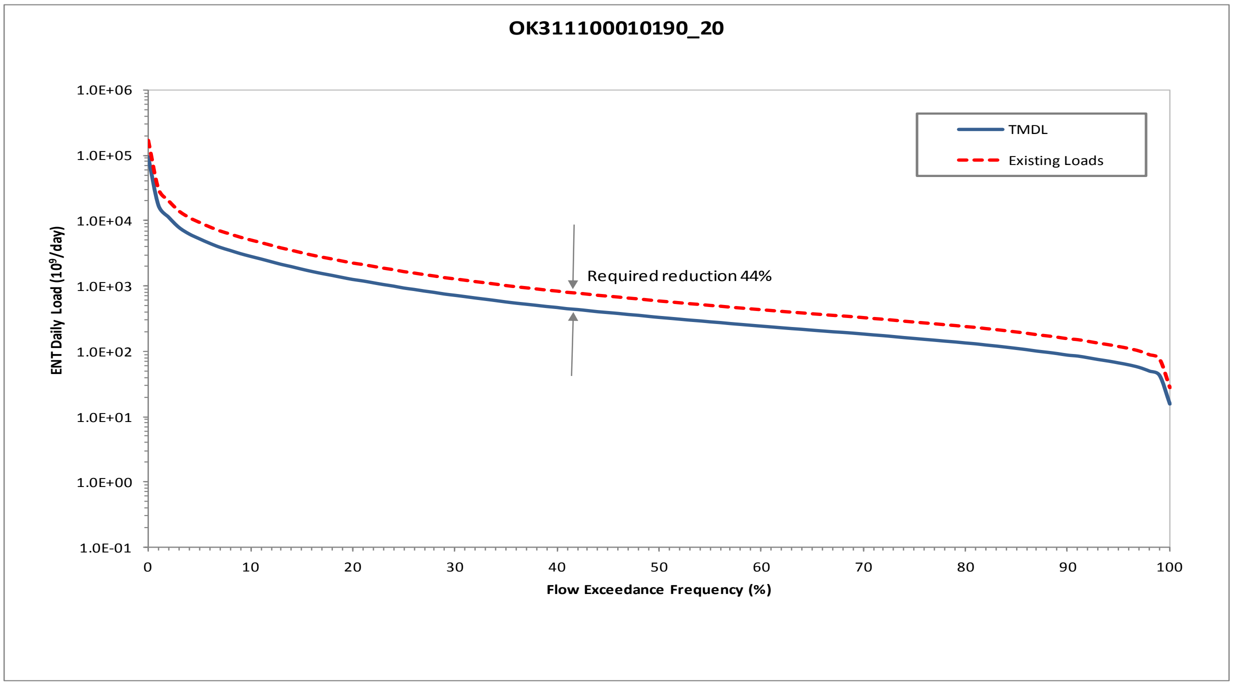
The LDC for Red River (Figure 5-28) is based on Enterococci measurements during primary contact recreation season at WQM station OK31100000010-001AT.

Figure 5-28 Load Duration Curve for Enterococci in Red River (OK311200000010_00)



The LDCs for Red Creek (Figure 5-29) for Enterococci measurements during primary contact recreation season at WQM station OK311100010190-001AT.

Figure 5-29 Load Duration Curve for Enterococci in Red River (OK311100010190_20)



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*) and the TSS goal for each waterbody. This calculation produces the maximum TSS load in the waterbody that will result in attainment of the 50 NTU target for turbidity. The allowable TSS loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a TSS load in pounds per day.

To estimate existing loading, TSS and turbidity observations from 1998 to 2011 are paired with the flows measured or projected on the same date for the waterbody. For sampling events with both TSS and turbidity data, the measured TSS value is used. 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 goal was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample did not exceed the TSS goal.

Figures 5-30 through Figure 5-36 show the TSS LDCs developed for the 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. Wet weather influenced samples found during low flow conditions can be caused by an isolated rainfall event during dry weather conditions. 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 5-30 Load Duration Curve for Total Suspended Solids in Timber Creek (OK311510010090_00)

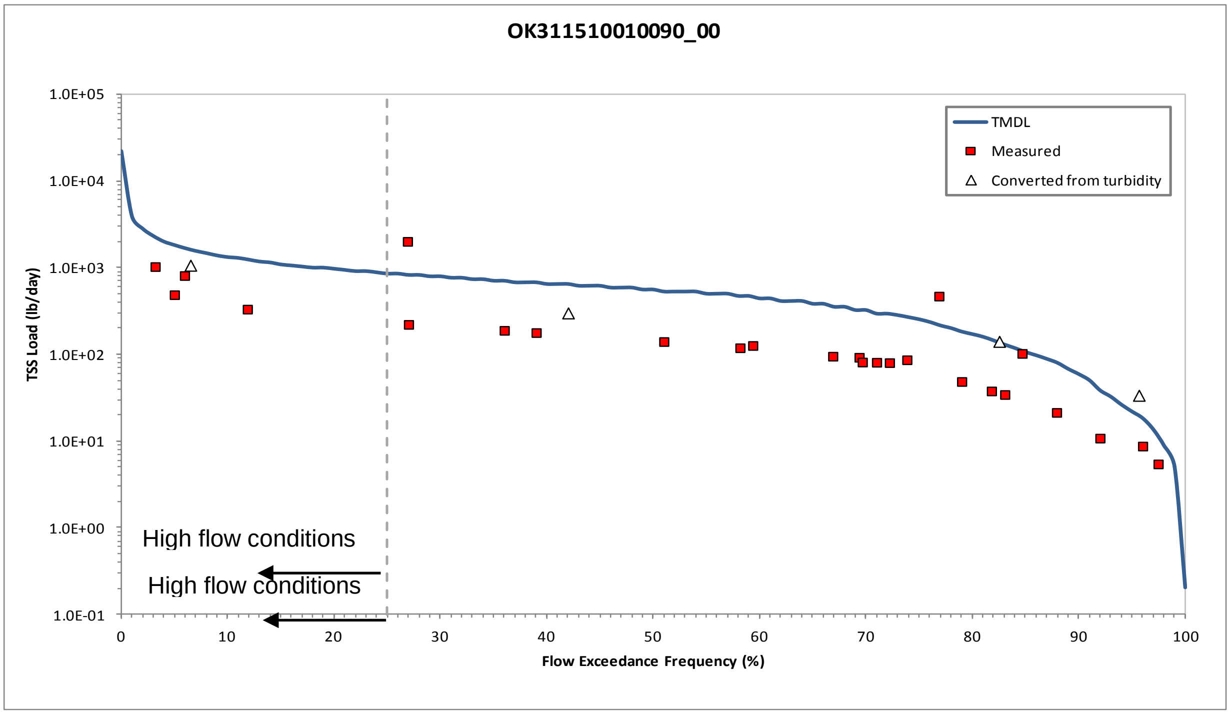


Figure 5-31 Load Duration Curve for Total Suspended Solids in Turkey Creek (OK311600020060_00)

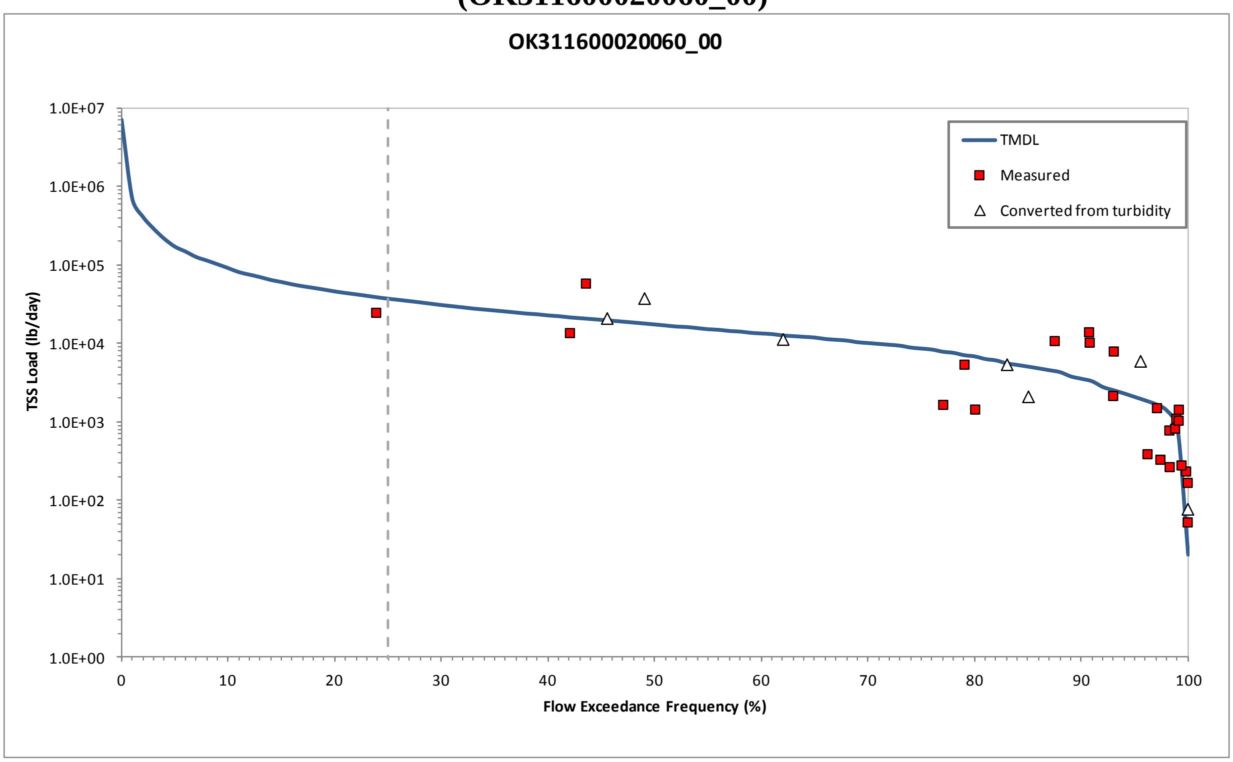


Figure 5-32 Load Duration Curve for Total Suspended Solids in Bitter Creek (OK311600020110_05)

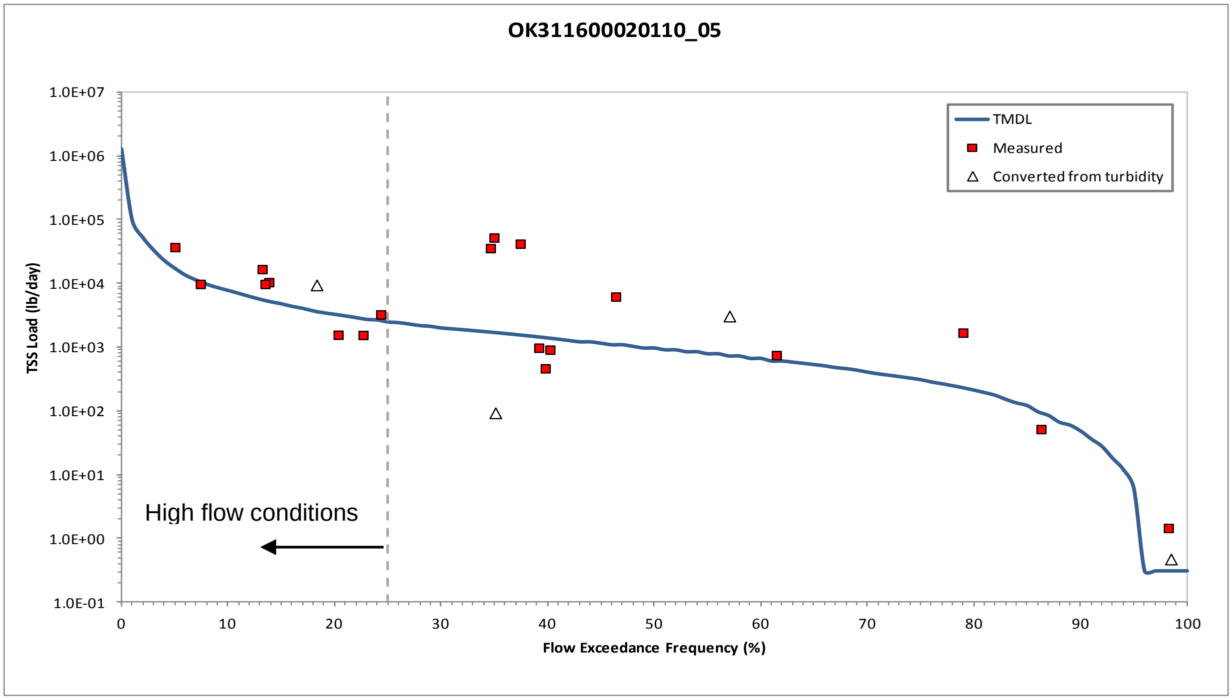


Figure 5-33 Load Duration Curve for Total Suspended Solids in Little Beaver Creek (OK311210000050_00)

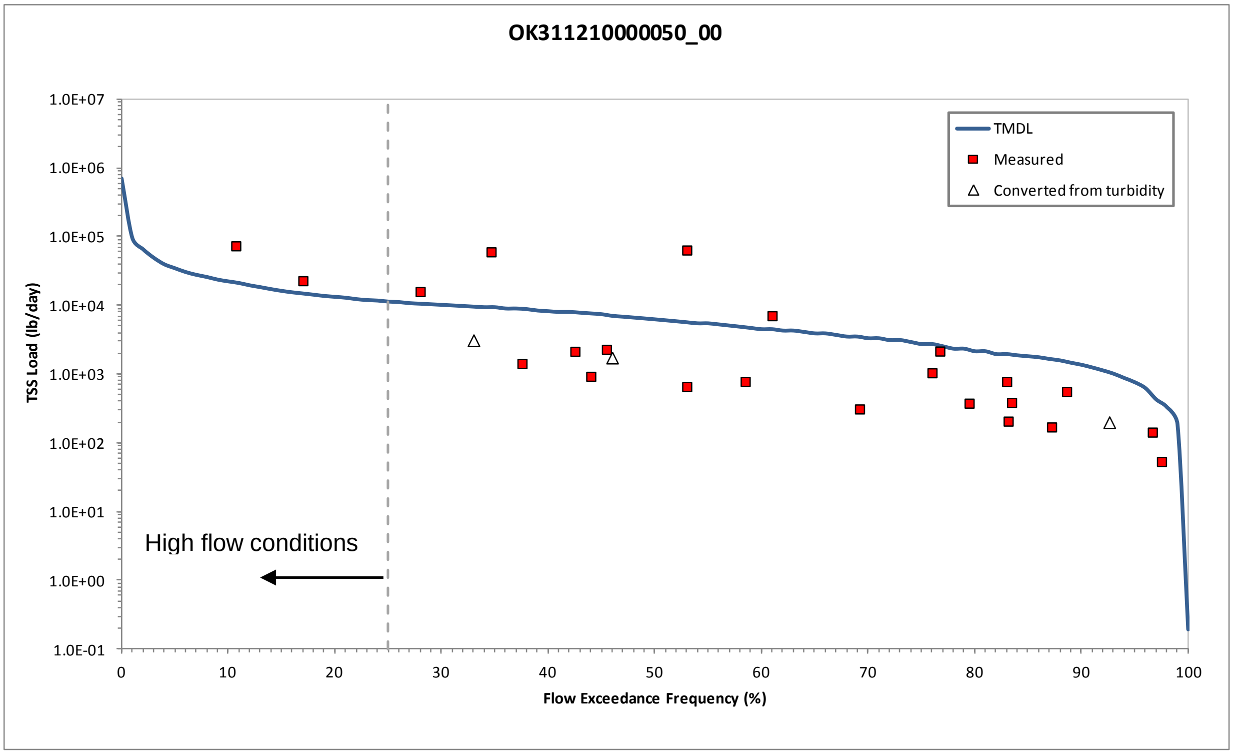


Figure 5-34 Load Duration Curve for Total Suspended Solids in Red River (OK311200000010_00)

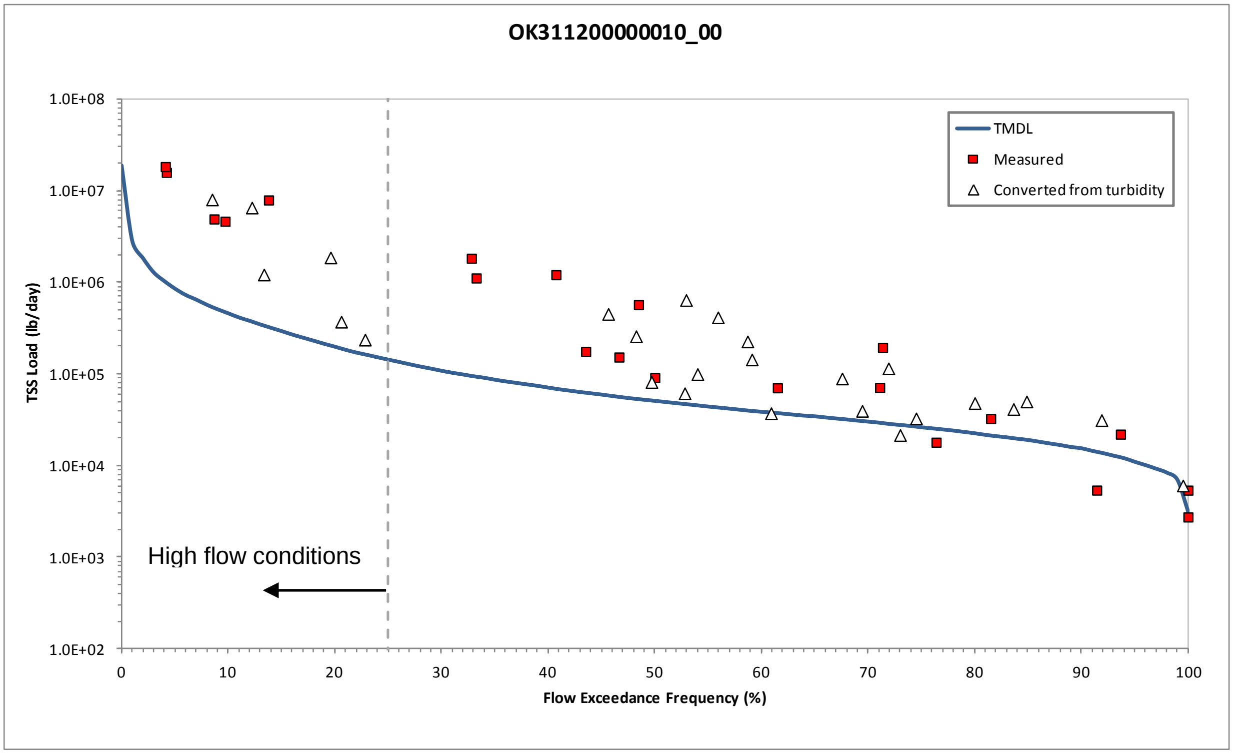


Figure 5-35 Load Duration Curve for Total Suspended Solids in Red River (OK311100010190_20)

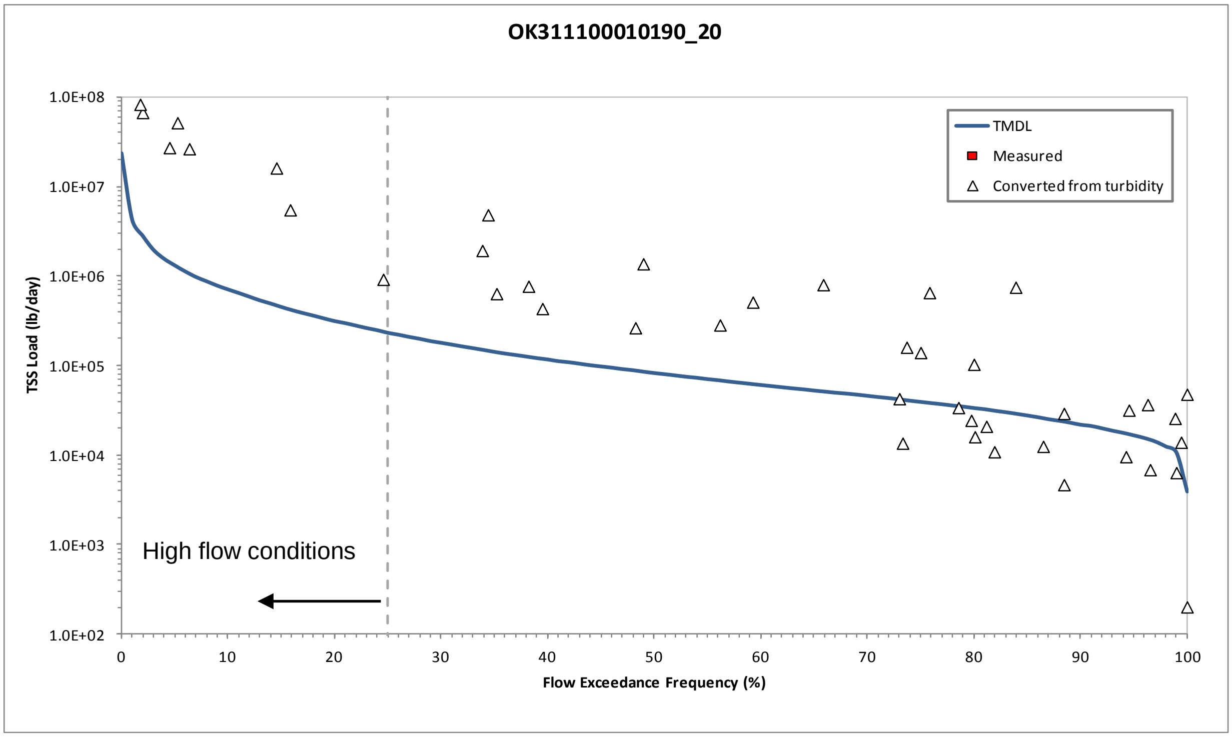
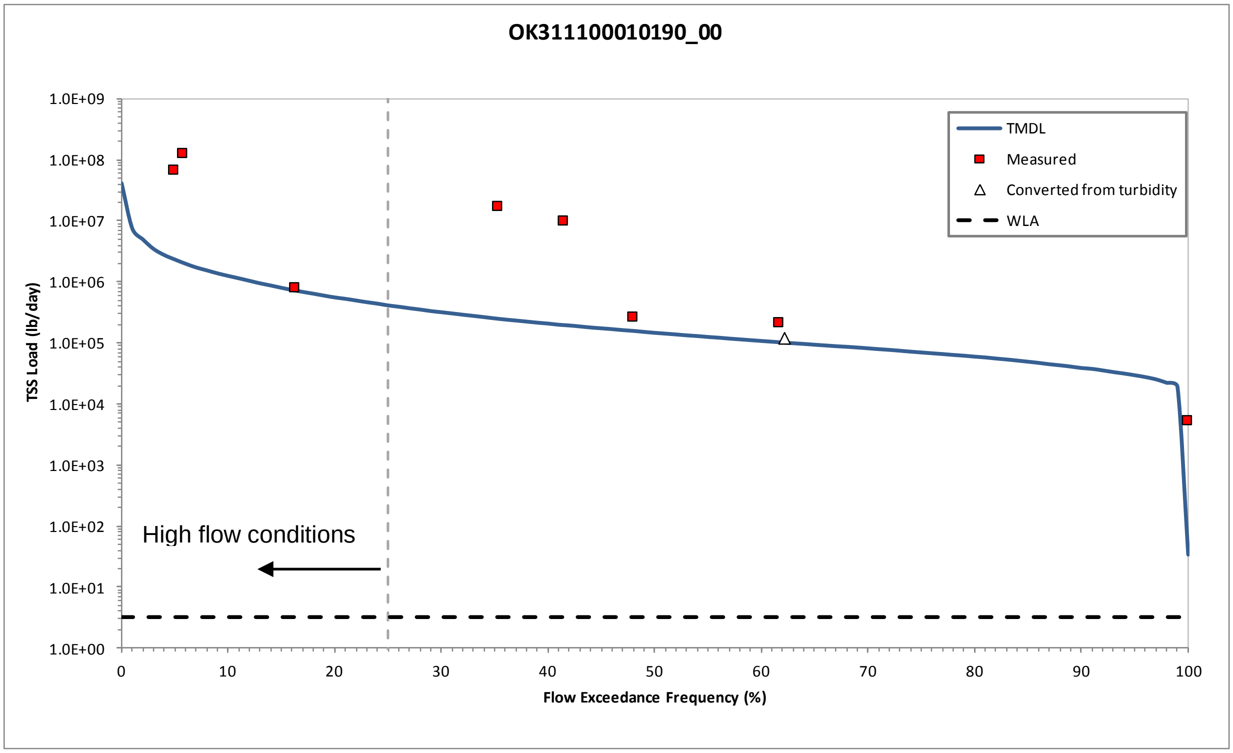


Figure 5-36 Load Duration Curve for Total Suspended Solids in Red River (OK311100010190_00)



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 can also be calculated under different flow conditions. The difference between existing loading and the TMDL is used to calculate the loading reductions required. PRGs are calculated through an iterative process of taking a series of percent reduction values, applying each value uniformly to the concentrations of samples and verifying if the geometric mean of the reduced values of all samples is less than the WQS geometric mean. Table 5-2 represents the percent reductions necessary to meet the TMDL water quality target for each bacterial indicator in each of the impaired waterbodies in the Study Area. The PRGs range from 31% to 93%.

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

Waterbody ID	Waterbody Name	Required Reduction Rate	
		EC	ENT
OK311510020090_00	Buffalo Creek	46%	88%
OK311510010090_00	Timber Creek	43%	93%
OK311510010040_00	Lake Creek	52%	73%
OK311800000060_00	Station Creek	68%	57%
OK311600020060_00	Turkey Creek	89%	89%
OK311210000050_00	Little Beaver Creek	31%	86%
OK311200000010_00	Red River		58%
OK311100010190_20	Red River		44%

PRGs for TSS are calculated as the required overall reduction so that no more than 10% of the samples exceed the water quality target for TSS. The PRGs for the seven waterbodies included in this TMDL report are summarized in Table 5-3 and range from 43% to 99%.

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK311510010090_00	Timber Creek	43%
OK311600020060_00	Turkey Creek	65%
OK311600020110_05	Bitter Creek	79%
OK311210000050_00	Little Beaver Creek	75%
OK311200000010_00	Red River	92%
OK311100010190_20	Red River	90%
OK311100010190_00	Red River	99%

5.4 Wasteload Allocation

5.4.1 Indicator Bacteria

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

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

Where:

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

flow (mgd) = permitted flow

unit conversion factor = 37,854,120

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES WWTPs discharging into the contributing watershed of a stream segment, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform or *E. coli* limits and disinfection requirements of NPDES permits. Currently, facilities that discharge treated wastewater are currently required to monitor for fecal coliform. These discharges or any other discharges with a bacterial WLA will be required to monitor for *E. coli* as their permits are renewed.

Table 5-4 shows that Town of Temple is the only permitted point source discharger within the study area. However, because it is not permitted to discharge in the spring and summer when bacteria standards apply, the bacteria WLA for the facility was set to zero. Certain facilities that utilize lagoons for treatment have not been required to provide disinfection since storage time and exposure to ultraviolet radiation from sunlight should reduce bacteria levels.

In the future, all point source dischargers which are assigned a wasteload allocation but do not currently have a bacteria limit in their permit will receive a permit limit consistent with the wasteload allocation as their permits are reissued. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacteria load from existing discharges will be considered consistent with the TMDL provided that the NPDES permit requires instream criteria to be met.

Table 5-4 Bacteria Wasteload Allocations for NPDES-Permitted Facilities

Waterbody ID	NPDES Permit No.	Name	Disinfection?	Design Flow (mg/d)	ENT Wasteload Allocation (cfu/day)
OK311200000010_00	OK0032514	Town of Temple	No	0.25	0

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

5.4.2 Total Suspended Solids

NPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated by using the average of self-reported monthly 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 5-5 summarizes the WLA for the NPDES-permitted facilities within the Red 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 5-1, or monthly TSS limit in the current permit, whichever is smaller

flow (mgd) = average monthly flow

unit conversion factor = 8.3445

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

Waterbody ID	Instream TSS Criteria (mg/L)	NPDES Permit No.	Name	Average Monthly Flow (mgd)	Wasteload Allocation (lb/day)
OK311100010190_00	39.1	OKR050477	Lattimore Materials Co.	0.01[a]	3.3

[a] Flow was assumed equal to 0.01 MGD for allocation purposes.

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

5.4.3 Section 404 permits

No TSS WLAs were set aside for Section 404 permits. The state will use its Section 401 Certification authority to ensure Section 404 permits protect Oklahoma WQS 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 standards and TSS TMDLs; or
- Submit to the DEQ a BMP turbidity reduction plan which should include all practicable turbidity control techniques. The turbidity reduction plan must be approved first before a Section 401 Certification can be issued.

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

5.5 Load Allocation

As discussed in Section 3, nonpoint source bacteria loading to each waterbody emanate from a number of different sources. The data analysis and the LDCs indicate that exceedances for each waterbody are the result of a variety of nonpoint source loading. The LAs for each bacterial indicator in waterbodies not supporting the PBCR use are calculated as the difference between the TMDL, MOS, and WLA, as follows:

LA = TMDL – WLA_WWTP – WLA_MS4 – MOS

This equation is used to calculate the LA for TSS however the LA is further reduced by allocating 1% of the TMDL as part of the WLA:

LA = TMDL – WLA_WWTP – WLA_MS4 – WLA_growth – MOS

5.6 Seasonal Variability

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

5.7 Margin of Safety

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

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 MOS. The selection of MOS is based on the NRMSE for each waterbody. The explicit MOS ranges from 10% to 15%. Table 5-6 shows the MOS for each waterbody.

Table 5-6 Explicit Margin of Safety for Total Suspended Solids TMDLs

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK311510010090_00	Timber Creek	14.9%	15%
OK311600020060_00	Turkey Creek	4.3%	10%
OK311600020110_05	Bitter Creek	6.2%	10%
OK311210000050_00	Little Beaver Creek	10.1%	15%
OK311200000010_00	Red River	8.3%	10%
OK311100010190_20	Red River	11.4%	15%
OK311100010190_00	Red River	11.4%	15%

5.8 TMDL Calculations

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

This definition can be expressed by the following equation:

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

The TMDL represents a continuum of desired load over all flow conditions, rather than fixed at a single value, because loading capacity varies as a function of the flow present in the stream. The higher the flow is, the more wasteload the stream can handle without violating WQS. 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 5-7 through 5-19 summarize the allocations for indicator bacteria. The bacteria TMDLs calculated in these tables apply to the recreation season (May 1 through September 30) only. Tables 5-20 to 5-26 present the allocations for total suspended solids.

Table 5-7 *E. coli* TMDL Calculations for Buffalo Creek (OK311510020090_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	161	4.97E+11	0	0	4.47E+11	4.97E+10
5	13	4.08E+10	0	0	3.67E+10	4.08E+09
10	10	2.96E+10	0	0	2.67E+10	2.96E+09
15	7.9	2.44E+10	0	0	2.19E+10	2.44E+09
20	7.0	2.17E+10	0	0	1.96E+10	2.17E+09
25	6.2	1.91E+10	0	0	1.72E+10	1.91E+09
30	5.8	1.78E+10	0	0	1.60E+10	1.78E+09
35	5.1	1.58E+10	0	0	1.42E+10	1.58E+09
40	4.7	1.45E+10	0	0	1.30E+10	1.45E+09
45	4.5	1.38E+10	0	0	1.24E+10	1.38E+09
50	4.1	1.25E+10	0	0	1.13E+10	1.25E+09
55	3.6	1.12E+10	0	0	1.01E+10	1.12E+09
60	3.2	9.88E+09	0	0	8.89E+09	9.88E+08
65	2.8	8.56E+09	0	0	7.70E+09	8.56E+08
70	2.3	7.24E+09	0	0	6.52E+09	7.24E+08
75	1.8	5.66E+09	0	0	5.10E+09	5.66E+08
80	1.2	3.82E+09	0	0	3.44E+09	3.82E+08
85	0.8	2.37E+09	0	0	2.13E+09	2.37E+08
90	0.4	1.32E+09	0	0	1.19E+09	1.32E+08
95	0.2	4.87E+08	0	0	4.39E+08	4.87E+07
100	0.0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-8 Enterococci TMDL Calculations for Buffalo Creek (OK311510020090_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	161	1.30E+11	0	0	1.17E+11	1.30E+10
5	13	1.07E+10	0	0	9.62E+09	1.07E+09
10	10	7.76E+09	0	0	6.98E+09	7.76E+08
15	7.9	6.38E+09	0	0	5.74E+09	6.38E+08
20	7.0	5.69E+09	0	0	5.12E+09	5.69E+08
25	6.2	5.00E+09	0	0	4.50E+09	5.00E+08
30	5.8	4.66E+09	0	0	4.19E+09	4.66E+08
35	5.1	4.14E+09	0	0	3.73E+09	4.14E+08
40	4.7	3.79E+09	0	0	3.41E+09	3.79E+08
45	4.5	3.62E+09	0	0	3.26E+09	3.62E+08
50	4.1	3.28E+09	0	0	2.95E+09	3.28E+08
55	3.6	2.93E+09	0	0	2.64E+09	2.93E+08
60	3.2	2.59E+09	0	0	2.33E+09	2.59E+08
65	2.8	2.24E+09	0	0	2.02E+09	2.24E+08
70	2.3	1.90E+09	0	0	1.71E+09	1.90E+08
75	1.8	1.48E+09	0	0	1.33E+09	1.48E+08
80	1.2	1.00E+09	0	0	9.00E+08	1.00E+08
85	0.8	6.21E+08	0	0	5.59E+08	6.21E+07
90	0.4	3.45E+08	0	0	3.10E+08	3.45E+07
95	0.2	1.28E+08	0	0	1.15E+08	1.28E+07
100	0.0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-9 *E. coli* TMDL Calculations for Timber Creek (OK311510010090_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	110	3.38E+11	0	0	3.05E+11	3.38E+10
5	9.0	2.78E+10	0	0	2.50E+10	2.78E+09
10	6.5	2.02E+10	0	0	1.82E+10	2.02E+09
15	5.4	1.66E+10	0	0	1.49E+10	1.66E+09
20	4.8	1.48E+10	0	0	1.33E+10	1.48E+09
25	4.2	1.30E+10	0	0	1.17E+10	1.30E+09
30	3.9	1.21E+10	0	0	1.09E+10	1.21E+09
35	3.5	1.08E+10	0	0	9.68E+09	1.08E+09
40	3.2	9.86E+09	0	0	8.88E+09	9.86E+08
45	3.1	9.41E+09	0	0	8.47E+09	9.41E+08
50	2.8	8.52E+09	0	0	7.66E+09	8.52E+08
55	2.5	7.62E+09	0	0	6.86E+09	7.62E+08
60	2.2	6.72E+09	0	0	6.05E+09	6.72E+08
65	1.9	5.83E+09	0	0	5.24E+09	5.83E+08
70	1.6	4.93E+09	0	0	4.44E+09	4.93E+08
75	1.3	3.85E+09	0	0	3.47E+09	3.85E+08
80	0.8	2.60E+09	0	0	2.34E+09	2.60E+08
85	0.5	1.61E+09	0	0	1.45E+09	1.61E+08
90	0.3	8.96E+08	0	0	8.07E+08	8.96E+07
95	0.1	3.32E+08	0	0	2.99E+08	3.32E+07
100	0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-10 Enterococci TMDL Calculations for Timber Creek (OK311510010090_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	110	8.86E+10	0	0	7.98E+10	8.86E+09
5	9.0	7.28E+09	0	0	6.55E+09	7.28E+08
10	6.5	5.28E+09	0	0	4.75E+09	5.28E+08
15	5.4	4.34E+09	0	0	3.91E+09	4.34E+08
20	4.8	3.87E+09	0	0	3.49E+09	3.87E+08
25	4.2	3.40E+09	0	0	3.06E+09	3.40E+08
30	3.9	3.17E+09	0	0	2.85E+09	3.17E+08
35	3.5	2.82E+09	0	0	2.54E+09	2.82E+08
40	3.2	2.58E+09	0	0	2.32E+09	2.58E+08
45	3.1	2.47E+09	0	0	2.22E+09	2.47E+08
50	2.8	2.23E+09	0	0	2.01E+09	2.23E+08
55	2.5	2.00E+09	0	0	1.80E+09	2.00E+08
60	2.2	1.76E+09	0	0	1.58E+09	1.76E+08
65	1.9	1.53E+09	0	0	1.37E+09	1.53E+08
70	1.6	1.29E+09	0	0	1.16E+09	1.29E+08
75	1.3	1.01E+09	0	0	9.09E+08	1.01E+08
80	0.8	6.81E+08	0	0	6.13E+08	6.81E+07
85	0.5	4.23E+08	0	0	3.80E+08	4.23E+07
90	0.3	2.35E+08	0	0	2.11E+08	2.35E+07
95	0.1	8.69E+07	0	0	7.82E+07	8.69E+06
100	0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-11 *E. coli* TMDL Calculations for Lake Creek (OK311510010040_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,749	5.39E+12	0	0	4.85E+12	5.39E+11
5	24	7.28E+10	0	0	6.55E+10	7.28E+09
10	11	3.27E+10	0	0	2.94E+10	3.27E+09
15	6.5	2.02E+10	0	0	1.82E+10	2.02E+09
20	4.5	1.38E+10	0	0	1.24E+10	1.38E+09
25	3.4	1.05E+10	0	0	9.43E+09	1.05E+09
30	2.7	8.43E+09	0	0	7.59E+09	8.43E+08
35	2.3	7.16E+09	0	0	6.44E+09	7.16E+08
40	1.9	5.88E+09	0	0	5.29E+09	5.88E+08
45	1.6	4.86E+09	0	0	4.37E+09	4.86E+08
50	1.3	4.09E+09	0	0	3.68E+09	4.09E+08
55	1.1	3.32E+09	0	0	2.99E+09	3.32E+08
60	0.9	2.81E+09	0	0	2.53E+09	2.81E+08
65	0.7	2.25E+09	0	0	2.02E+09	2.25E+08
70	0.6	1.71E+09	0	0	1.54E+09	1.71E+08
75	0.4	1.30E+09	0	0	1.17E+09	1.30E+08
80	0.3	8.94E+08	0	0	8.05E+08	8.94E+07
85	0.2	5.11E+08	0	0	4.60E+08	5.11E+07
90	0.1	2.04E+08	0	0	1.84E+08	2.04E+07
95	0	0.00E+00	0	0	0.00E+00	0.00E+00
100	0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-12 Enterococci TMDL Calculations for the Lake Creek (OK311510010040_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,749	1.41E+12	0	0	1.27E+12	1.41E+11
5	24	1.91E+10	0	0	1.72E+10	1.91E+09
10	11	8.57E+09	0	0	7.71E+09	8.57E+08
15	6.5	5.29E+09	0	0	4.76E+09	5.29E+08
20	4.5	3.61E+09	0	0	3.25E+09	3.61E+08
25	3.4	2.74E+09	0	0	2.47E+09	2.74E+08
30	2.7	2.21E+09	0	0	1.99E+09	2.21E+08
35	2.3	1.87E+09	0	0	1.69E+09	1.87E+08
40	1.9	1.54E+09	0	0	1.39E+09	1.54E+08
45	1.6	1.27E+09	0	0	1.14E+09	1.27E+08
50	1.3	1.07E+09	0	0	9.64E+08	1.07E+08
55	1.1	8.70E+08	0	0	7.83E+08	8.70E+07
60	0.9	7.36E+08	0	0	6.63E+08	7.36E+07
65	0.7	5.89E+08	0	0	5.30E+08	5.89E+07
70	0.6	4.48E+08	0	0	4.04E+08	4.48E+07
75	0.4	3.41E+08	0	0	3.07E+08	3.41E+07
80	0.3	2.34E+08	0	0	2.11E+08	2.34E+07
85	0.2	1.34E+08	0	0	1.20E+08	1.34E+07
90	0.1	5.35E+07	0	0	4.82E+07	5.35E+06
95	0	0.00E+00	0	0	0.00E+00	0.00E+00
100	0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-13 Enterococci TMDL Calculations for Station Creek (OK311800000060_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	629	5.08E+11	0	0	4.57E+11	5.08E+10
5	8.5	6.86E+09	0	0	6.17E+09	6.86E+08
10	3.8	3.08E+09	0	0	2.77E+09	3.08E+08
15	2.4	1.90E+09	0	0	1.71E+09	1.90E+08
20	1.6	1.30E+09	0	0	1.17E+09	1.30E+08
25	1.2	9.87E+08	0	0	8.88E+08	9.87E+07
30	1.0	7.94E+08	0	0	7.15E+08	7.94E+07
35	0.8	6.74E+08	0	0	6.06E+08	6.74E+07
40	0.7	5.53E+08	0	0	4.98E+08	5.53E+07
45	0.6	4.57E+08	0	0	4.11E+08	4.57E+07
50	0.5	3.85E+08	0	0	3.47E+08	3.85E+07
55	0.4	3.13E+08	0	0	2.82E+08	3.13E+07
60	0.33	2.65E+08	0	0	2.38E+08	2.65E+07
65	0.26	2.12E+08	0	0	1.91E+08	2.12E+07
70	0.20	1.61E+08	0	0	1.45E+08	1.61E+07
75	0.15	1.23E+08	0	0	1.10E+08	1.23E+07
80	0.10	8.42E+07	0	0	7.58E+07	8.42E+06
85	0.06	4.81E+07	0	0	4.33E+07	4.81E+06
90	0.02	1.93E+07	0	0	1.73E+07	1.93E+06
95	0	0.00E+00	0	0	0.00E+00	0.00E+00
100	0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-14 *E. coli* TMDL Calculations for Turkey Creek (OK311600020060_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLAMS4 (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	28,200	8.69E+13	0	0	7.82E+13	8.69E+12
5	678	2.09E+12	0	0	1.88E+12	2.09E+11
10	361	1.11E+12	0	0	1.00E+12	1.11E+11
15	240	7.40E+11	0	0	6.66E+11	7.40E+10
20	182	5.61E+11	0	0	5.05E+11	5.61E+10
25	147	4.53E+11	0	0	4.08E+11	4.53E+10
30	122	3.76E+11	0	0	3.38E+11	3.76E+10
35	104	3.21E+11	0	0	2.89E+11	3.21E+10
40	90	2.77E+11	0	0	2.50E+11	2.77E+10
45	79	2.44E+11	0	0	2.19E+11	2.44E+10
50	69	2.13E+11	0	0	1.91E+11	2.13E+10
55	60	1.85E+11	0	0	1.66E+11	1.85E+10
60	53	1.63E+11	0	0	1.47E+11	1.63E+10
65	47	1.45E+11	0	0	1.30E+11	1.45E+10
70	40	1.23E+11	0	0	1.11E+11	1.23E+10
75	34	1.05E+11	0	0	9.43E+10	1.05E+10
80	27	8.32E+10	0	0	7.49E+10	8.32E+09
85	20	6.17E+10	0	0	5.55E+10	6.17E+09
90	14	4.32E+10	0	0	3.88E+10	4.32E+09
95	8	2.53E+10	0	0	2.28E+10	2.53E+09
100	0.1	2.47E+08	0	0	2.22E+08	2.47E+07

Table 5-15 Enterococci TMDL Calculations for Turkey Creek (OK311600020060_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	28,200	2.28E+13	0	0	2.05E+13	2.28E+12
5	678	5.47E+11	0	0	4.93E+11	5.47E+10
10	361	2.91E+11	0	0	2.62E+11	2.91E+10
15	240	1.94E+11	0	0	1.74E+11	1.94E+10
20	182	1.47E+11	0	0	1.32E+11	1.47E+10
25	147	1.19E+11	0	0	1.07E+11	1.19E+10
30	122	9.85E+10	0	0	8.86E+10	9.85E+09
35	104	8.40E+10	0	0	7.56E+10	8.40E+09
40	90	7.27E+10	0	0	6.54E+10	7.27E+09
45	79	6.38E+10	0	0	5.74E+10	6.38E+09
50	69	5.57E+10	0	0	5.01E+10	5.57E+09
55	60	4.84E+10	0	0	4.36E+10	4.84E+09
60	53	4.28E+10	0	0	3.85E+10	4.28E+09
65	47	3.79E+10	0	0	3.42E+10	3.79E+09
70	40	3.23E+10	0	0	2.91E+10	3.23E+09
75	34	2.75E+10	0	0	2.47E+10	2.75E+09
80	27	2.18E+10	0	0	1.96E+10	2.18E+09
85	20	1.61E+10	0	0	1.45E+10	1.61E+09
90	14	1.13E+10	0	0	1.02E+10	1.13E+09
95	8	6.62E+09	0	0	5.96E+09	6.62E+08
100	0.1	6.46E+07	0	0	5.81E+07	6.46E+06

Table 5-16 *E. coli* TMDL Calculations for Little Beaver Creek (OK311210000050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	3,570	1.10E+13	0	0	9.90E+12	1.10E+12
5	177	5.46E+11	0	0	4.91E+11	5.46E+10
10	114	3.51E+11	0	0	3.16E+11	3.51E+10
15	83	2.56E+11	0	0	2.30E+11	2.56E+10
20	68	2.10E+11	0	0	1.89E+11	2.10E+10
25	58	1.79E+11	0	0	1.61E+11	1.79E+10
30	52	1.60E+11	0	0	1.44E+11	1.60E+10
35	48	1.48E+11	0	0	1.33E+11	1.48E+10
40	42	1.29E+11	0	0	1.17E+11	1.29E+10
45	38	1.17E+11	0	0	1.05E+11	1.17E+10
50	32	9.86E+10	0	0	8.88E+10	9.86E+09
55	28	8.63E+10	0	0	7.77E+10	8.63E+09
60	23	7.09E+10	0	0	6.38E+10	7.09E+09
65	20	6.17E+10	0	0	5.55E+10	6.17E+09
70	17	5.24E+10	0	0	4.72E+10	5.24E+09
75	14	4.32E+10	0	0	3.88E+10	4.32E+09
80	11	3.39E+10	0	0	3.05E+10	3.39E+09
85	9	2.87E+10	0	0	2.58E+10	2.87E+09
90	7	2.16E+10	0	0	1.94E+10	2.16E+09
95	4	1.20E+10	0	0	1.08E+10	1.20E+09
100	0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-17 Enterococci TMDL Calculations for Little Beaver Creek (OK311210000050_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	3,570	2.88E+12	0	0	2.59E+12	2.88E+11
5	177	1.43E+11	0	0	1.29E+11	1.43E+10
10	114	9.20E+10	0	0	8.28E+10	9.20E+09
15	83	6.70E+10	0	0	6.03E+10	6.70E+09
20	68	5.49E+10	0	0	4.94E+10	5.49E+09
25	58	4.68E+10	0	0	4.21E+10	4.68E+09
30	52	4.20E+10	0	0	3.78E+10	4.20E+09
35	48	3.88E+10	0	0	3.49E+10	3.88E+09
40	42	3.39E+10	0	0	3.05E+10	3.39E+09
45	38	3.07E+10	0	0	2.76E+10	3.07E+09
50	32	2.58E+10	0	0	2.33E+10	2.58E+09
55	28	2.26E+10	0	0	2.03E+10	2.26E+09
60	23	1.86E+10	0	0	1.67E+10	1.86E+09
65	20	1.61E+10	0	0	1.45E+10	1.61E+09
70	17	1.37E+10	0	0	1.24E+10	1.37E+09
75	14	1.13E+10	0	0	1.02E+10	1.13E+09
80	11	8.88E+09	0	0	7.99E+09	8.88E+08
85	9	7.51E+09	0	0	6.76E+09	7.51E+08
90	7	5.65E+09	0	0	5.09E+09	5.65E+08
95	4	3.15E+09	0	0	2.83E+09	3.15E+08
100	0	0.00E+00	0	0	0.00E+00	0.00E+00

Table 5-18 Enterococci TMDL Calculations for Red River (OK311200000010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	57,687	4.66E+13	0	0	4.19E+13	4.66E+12
5	2,619	2.11E+12	0	0	1.90E+12	2.11E+11
10	1,409	1.14E+12	0	0	1.03E+12	1.14E+11
15	902	7.28E+11	0	0	6.55E+11	7.28E+10
20	609	4.92E+11	0	0	4.43E+11	4.92E+10
25	440	3.55E+11	0	0	3.20E+11	3.55E+10
30	333	2.69E+11	0	0	2.42E+11	2.69E+10
35	266	2.15E+11	0	0	1.94E+11	2.15E+10
40	218	1.76E+11	0	0	1.58E+11	1.76E+10
45	183	1.48E+11	0	0	1.33E+11	1.48E+10
50	156	1.26E+11	0	0	1.13E+11	1.26E+10
55	135	1.09E+11	0	0	9.81E+10	1.09E+10
60	119	9.60E+10	0	0	8.64E+10	9.60E+09
65	106	8.56E+10	0	0	7.70E+10	8.56E+09
70	93	7.50E+10	0	0	6.75E+10	7.50E+09
75	80	6.50E+10	0	0	5.85E+10	6.50E+09
80	69	5.59E+10	0	0	5.03E+10	5.59E+09
85	58	4.72E+10	0	0	4.25E+10	4.72E+09
90	47	3.83E+10	0	0	3.45E+10	3.83E+09
95	34	2.73E+10	0	0	2.46E+10	2.73E+09
100	10	7.80E+09	0	0	7.02E+09	7.80E+08

Table 5-19 Enterococci TMDL Calculations for Red River (OK311100010190_20)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	129,950	1.05E+14	0	0	9.44E+13	1.05E+13
5	7,282	5.88E+12	0	0	5.29E+12	5.88E+11
10	3,927	3.17E+12	0	0	2.85E+12	3.17E+11
15	2,504	2.02E+12	0	0	1.82E+12	2.02E+11
20	1,742	1.41E+12	0	0	1.27E+12	1.41E+11
25	1,288	1.04E+12	0	0	9.36E+11	1.04E+11
30	997	8.05E+11	0	0	7.24E+11	8.05E+10
35	790	6.38E+11	0	0	5.74E+11	6.38E+10
40	650	5.25E+11	0	0	4.72E+11	5.25E+10
45	543	4.39E+11	0	0	3.95E+11	4.39E+10
50	458	3.70E+11	0	0	3.33E+11	3.70E+10
55	392	3.17E+11	0	0	2.85E+11	3.17E+10
60	337	2.72E+11	0	0	2.45E+11	2.72E+10
65	292	2.36E+11	0	0	2.12E+11	2.36E+10
70	255	2.06E+11	0	0	1.86E+11	2.06E+10
75	218	1.76E+11	0	0	1.59E+11	1.76E+10
80	187	1.51E+11	0	0	1.36E+11	1.51E+10
85	154	1.24E+11	0	0	1.12E+11	1.24E+10
90	122	9.81E+10	0	0	8.83E+10	9.81E+09
95	92	7.46E+10	0	0	6.72E+10	7.46E+09
100	22	1.76E+10	0	0	1.59E+10	1.76E+09

Table 5-20 Total Suspended Solids TMDL Calculations for Timber Creek (OK311510010090_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	110	NA	NA	NA	NA	NA
5	9	NA	NA	NA	NA	NA
10	7	NA	NA	NA	NA	NA
15	5.4	NA	NA	NA	NA	NA
20	4.8	NA	NA	NA	NA	NA
25	4.2	1,003	0	10	842	150
30	3.9	934	0	9	784	140
35	3.5	830	0	8	697	124
40	3.2	761	0	8	639	114
45	3.1	726	0	7	610	109
50	2.8	657	0	7	552	99
55	2.5	588	0	6	494	88
60	2.2	519	0	5	436	78
65	1.9	450	0	4	378	67
70	1.6	380	0	4	320	57
75	1.3	297	0	3	250	45
80	0.8	201	0	2	168	30
85	0.5	124	0	1	105	19
90	0.3	69	0	1	58	10
95	0.1	26	0	0	21	4
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-21 Total Suspended Solids TMDL Calculations for Turkey Creek (OK311600020060_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	28,200	NA	NA	NA	NA	NA
5	678	NA	NA	NA	NA	NA
10	361	NA	NA	NA	NA	NA
15	240	NA	NA	NA	NA	NA
20	182	NA	NA	NA	NA	NA
25	147	41,796	4	418	37,194	4,180
30	122	34,688	4	347	30,868	3,469
35	104	29,570	4	296	26,313	2,957
40	90	25,589	4	256	22,770	2,559
45	79	22,462	4	225	19,987	2,246
50	69	19,618	4	196	17,456	1,962
55	60	17,060	4	171	15,179	1,706
60	53	15,069	4	151	13,407	1,507
65	47	13,363	4	134	11,889	1,336
70	40	11,373	4	114	10,118	1,137
75	34	9,667	4	97	8,599	967
80	27	7,677	4	77	6,828	768
85	20	5,687	4	57	5,057	569
90	14	3,981	4	40	3,538	398
95	8	2,331	4	23	2,071	233
100	0.1	23	4	0	16	2

NA = Not Applicable

Table 5-22 Total Suspended Solids TMDL Calculations for Bitter Creek (OK311600020110_05)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	4,110	NA	NA	NA	NA	NA
5	56	NA	NA	NA	NA	NA
10	25	NA	NA	NA	NA	NA
15	15	NA	NA	NA	NA	NA
20	11	NA	NA	NA	NA	NA
25	8.0	2,719	0	27	2,420	272
30	6.4	2,189	0	22	1,948	219
35	5.5	1,857	0	19	1,653	186
40	4.5	1,526	0	15	1,358	153
45	3.7	1,260	0	13	1,122	126
50	3.1	1,061	0	11	944	106
55	2.5	862	0	9	767	86
60	2.1	730	0	7	649	73
65	1.7	584	0	6	519	58
70	1.3	444	0	4	396	44
75	1.0	338	0	3	301	34
80	0.7	232	0	2	207	23
85	0.4	133	0	1	118	13
90	0.2	53	0	1	47	5
95	0.02	7	0	0	6	1
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-23 Total Suspended Solids TMDL Calculations for Little Beaver Creek (OK311210000050_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	3,570	NA	NA	NA	NA	NA
5	177	NA	NA	NA	NA	NA
10	114	NA	NA	NA	NA	NA
15	83	NA	NA	NA	NA	NA
20	68	NA	NA	NA	NA	NA
25	58	13,241	0	132	11,123	1,986
30	52	11,871	0	119	9,972	1,781
35	48	10,958	0	110	9,205	1,644
40	42	9,588	0	96	8,054	1,438
45	38	8,675	0	87	7,287	1,301
50	32	7,305	0	73	6,137	1,096
55	28	6,392	0	64	5,370	959
60	23	5,251	0	53	4,411	788
65	20	4,566	0	46	3,835	685
70	17	3,881	0	39	3,260	582
75	14	3,196	0	32	2,685	479
80	11	2,511	0	25	2,109	377
85	9	2,123	0	21	1,783	318
90	7	1,598	0	16	1,342	240
95	4	890	0	9	748	134
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-24 Total Suspended Solids TMDL Calculations for Red River (OK311200000010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	57,687	NA	NA	NA	NA	NA
5	2,619	NA	NA	NA	NA	NA
10	1,409	NA	NA	NA	NA	NA
15	902	NA	NA	NA	NA	NA
20	609	NA	NA	NA	NA	NA
25	440	158,492	0	1,585	141,058	15,849
30	333	119,835	0	1,198	106,653	11,984
35	266	95,772	0	958	85,237	9,577
40	218	78,569	0	786	69,927	7,857
45	183	65,909	0	659	58,659	6,591
50	156	56,342	0	563	50,144	5,634
55	135	48,804	0	488	43,435	4,880
60	119	42,812	0	428	38,103	4,281
65	106	38,173	0	382	33,974	3,817
70	93	33,438	0	334	29,760	3,344
75	80	28,992	0	290	25,803	2,899
80	69	24,933	0	249	22,191	2,493
85	58	21,068	0	211	18,750	2,107
90	47	17,106	0	171	15,224	1,711
95	34	12,177	0	122	10,837	1,218
100	10	3,479	0	35	3,096	348

NA = Not Applicable

Table 5-25 Total Suspended Solids TMDL Calculations for Red River (OK311100010190_20)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	129,950	NA	NA	NA	NA	NA
5	7,282	NA	NA	NA	NA	NA
10	3,927	NA	NA	NA	NA	NA
15	2,504	NA	NA	NA	NA	NA
20	1,742	NA	NA	NA	NA	NA
25	1,288	271,701	0	2,717	228,229	40,755
30	997	210,273	0	2,103	176,629	31,541
35	790	166,564	0	1,666	139,914	24,985
40	650	137,032	0	1,370	115,107	20,555
45	543	114,587	0	1,146	96,253	17,188
50	458	96,631	0	966	81,170	14,495
55	392	82,692	0	827	69,461	12,404
60	337	71,115	0	711	59,736	10,667
65	292	61,664	0	617	51,798	9,250
70	255	53,868	0	539	45,249	8,080
75	218	46,071	0	461	38,700	6,911
80	187	39,338	0	393	33,044	5,901
85	154	32,486	0	325	27,288	4,873
90	122	25,634	0	256	21,533	3,845
95	92	19,492	0	195	16,373	2,924
100	22	4,607	0	46	3,870	691

NA = Not Applicable

Table 5-26 Total Suspended Solids TMDL Calculations for Red River (OK311100010190_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	232,000	NA	NA	NA	NA	NA
5	13,000	NA	NA	NA	NA	NA
10	7,010	NA	NA	NA	NA	NA
15	4,470	NA	NA	NA	NA	NA
20	3,110	NA	NA	NA	NA	NA
25	2,300	485,069	3	4,851	407,455	72,760
30	1,780	375,401	3	3,754	315,334	56,310
35	1,410	297,368	3	2,974	249,786	44,605
40	1,160	244,643	3	2,446	205,497	36,697
45	970	204,573	3	2,046	171,838	30,686
50	818	172,516	3	1,725	144,911	25,877
55	700	147,630	3	1,476	124,007	22,144
60	602	126,962	3	1,270	106,645	19,044
65	522	110,090	3	1,101	92,473	16,513
70	456	96,170	3	962	80,779	14,426
75	390	82,251	3	823	69,087	12,338
80	333	70,230	3	702	58,991	10,534
85	275	57,997	3	580	48,714	8,700
90	217	45,765	3	458	38,439	6,865
95	165	34,798	3	348	29,227	5,220
100	39	8,225	3	82	6,906	1,234

NA = Not Applicable

5.9 TMDL Implementation

DEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources will be utilized so that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. DEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (DEQ 2006). The CPP can be viewed from DEQ's website at http://www.deq.state.ok.us/wqdnew/pubs/2006_CPP_final.pdf. Table 5-27 provides a partial list of the state partner agencies DEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-27 Partial List of Oklahoma Water Quality Management Agencies

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

Point Sources

As authorized by Section 402 of the CWA, DEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture (retained by State Department of Agriculture) and the oil & gas industry (retained by the Oklahoma Corporation Commission), for which the EPA has retained permitting authority. The NPDES Program in Oklahoma, in accordance with an agreement between DEQ and EPA, is implemented via the Oklahoma Pollutant Discharge Elimination System (OPDES) Act [Title 252, Chapter 606 (http://www.deq.state.ok.us/rules/611.pdf)]. Point source WLAs are outlined in Oklahoma Water Quality Management Plan (aka the 208 Plan).

Nonpoint Sources

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

The reduction rates called for in this TMDL report are as high as 99%. DEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of a waterbody should be reviewed. For example, the Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the EPA. Additionally, EPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the near future.

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

- Removing the PBCR use: This revision would require documentation in a Use Attainability Analysis that the use is not an existing use and cannot be attained. It is unlikely that this approach would be successful since there is evidence that people do swim in this segment of the river, thus constituting an existing use. Existing uses cannot be removed.

- Modifying application of the existing criteria: This approach would include considerations such as an exemption under certain high flow conditions, an allowance for wildlife or "natural conditions," a sub-category of the use or other special provision for urban areas, or other special provisions for storm flows. Since large bacteria violations occur over all flow ranges, it is likely that large reductions would still be necessary. However, this approach may have merit and should be considered.

- Revising the existing numeric criteria: Oklahoma's current pathogen criteria were revised in 2011 are based on EPA guidelines (See 2012 Draft Recreational Water Quality Criteria, December 2011; Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft; and Ambient Water Quality Criteria for Bacteria, January 1986). These EPA guidelines could result in revisions to their recommendations are ongoing. The numeric criteria values should also be evaluated using a risk-based method such as that found in EPA guidance.

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

5.10 Reasonable Assurances

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

SECTION 6
PUBLIC PARTICIPATION

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

The public comment period lasted 45 days. During that time, the public had the opportunity to review the TMDL report and make written comments. One written comment was received during the public notice period. The comment and response will become a part of the record of this TMDL report.

After EPA's final approval, each TMDL will be adopted into the Water Quality Management Plan (WQMP). These TMDLs provide a mathematical solution to meet ambient water quality criteria with a given set of facts. The adoption of these TMDLs into the WQMP provides a mechanism to recalculate acceptable loads when information changes in the future. Updates to the WQMP demonstrate compliance with the water quality criteria. The updates to the WQMP are also useful when the water quality criteria change and the loading scenario is reviewed to ensure that the instream criterion is predicted to be met.

SECTION 7
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APPENDIX A

AMBIENT WATER QUALITY DATA

Table A-1 Bacteria Data-2000 to 2009

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK311600020110_05	OK311600-02-0110G	08/29/00	168	7000
OK311600020110_05	OK311600-02-0110G	05/07/01	527	19000
OK311600020110_05	OK311600-02-0110G	06/11/01	52	200
OK311200000010_00	311200000010-001AT	06/11/01	31	120
OK311100010190_20	311100010190-001AT	06/12/01	10	120
OK311100010230_00	311100010230-001SR	06/20/01	404	2000
OK311100010230_00	311100010230-002SR	06/20/01	74	1300
OK311600020110_05	OK311600-02-0110G	07/16/01		82
OK311100010190_20	311100010190-001AT	07/17/01	10	40
OK311600020110_05	OK311600-02-0110G	08/20/01	400	385
OK311100010190_20	311100010190-001AT	09/05/01	20	20
OK311600020110_05	OK311600-02-0110G	09/24/01	10	100
OK311200000010_00	311200000010-001AT	05/29/02	40	300
OK311100010190_20	311100010190-001AT	05/29/02	52	300
OK311200000010_00	311200000010-001AT	06/25/02	10	10
OK311100010190_20	311100010190-001AT	06/26/02	10	10
OK311200000010_00	311200000010-001AT	08/06/02	85	100
OK311100010190_20	311100010190-001AT	08/06/02	10	200
OK311100010190_20	311100010190-001AT	08/19/02	20	80
OK311200000010_00	311200000010-001AT	08/21/02	10	20
OK311100010190_20	311100010190-001AT	09/23/02	10	10
OK311200000010_00	311200000010-001AT	05/07/03	20	100
OK311200000010_00	311200000010-001AT	05/19/03	41	10
OK311200000010_00	311200000010-001AT	06/04/03	31	700
OK311200000010_00	311200000010-001AT	06/23/03	30	10
OK311200000010_00	311200000010-001AT	07/15/03	10	10
OK311200000010_00	311200000010-001AT	07/28/03	158	100
OK311200000010_00	311200000010-001AT	08/19/03	10	100
OK311200000010_00	311200000010-001AT	09/02/03	10	1300
OK311200000010_00	311200000010-001AT	09/23/03	158	130
OK311100010190_20	311100010190-001AT	05/10/04	75	150
OK311100010190_20	311100010190-001AT	05/25/04	155	700
OK311100010190_20	311100010190-001AT	06/15/04	408	500
OK311100010190_20	311100010190-001AT	06/28/04	209	2100
OK311100010190_20	311100010190-001AT	08/03/04	10	10
OK311100010190_20	311100010190-001AT	08/16/04	31	10
OK311510020090_00	OK311510-02-0090D	08/23/04	50	130
OK311510010090_00	OK311510-01-0090G	08/24/04	120	410

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK311510010040_00	OK311510-01-0040D	08/24/04	65	100
OK311800000060_00	OK311800-00-0060G	08/24/04	5	30
OK311600020060_00	OK311600-02-0060H	08/30/04	570	270
OK311210000050_00	OK311210-00-0050D	08/31/04	50	90
OK311100010190_20	311100010190-001AT	09/08/04	10	10
OK311100010190_20	311100010190-001AT	09/20/04	31	10
OK311510020090_00	OK311510-02-0090D	09/27/04	115	320
OK311510010090_00	OK311510-01-0090G	09/27/04	265	680
OK311510010040_00	OK311510-01-0040D	09/28/04	130	100
OK311800000060_00	OK311800-00-0060G	09/28/04	145	110
OK311600020060_00	OK311600-02-0060H	05/10/05	75	80
OK311210000050_00	OK311210-00-0050D	05/10/05	145	20
OK311510020090_00	OK311510-02-0090D	05/31/05	790	270
OK311510010090_00	OK311510-01-0090G	05/31/05	1000	1000
OK311510010040_00	OK311510-01-0040D	06/01/05	1000	1000
OK311800000060_00	OK311800-00-0060G	06/01/05	1000	690
OK311600020060_00	OK311600-02-0060H	06/07/05	100	280
OK311210000050_00	OK311210-00-0050D	06/07/05	1220	1880
OK311210000050_00	OK311210-00-0050D	07/06/05	2000	2000
OK311510010040_00	OK311510-01-0040D	07/11/05	1000	50
OK311800000060_00	OK311800-00-0060G	07/11/05	60	170
OK311510020090_00	OK311510-02-0090D	07/12/05	570	270
OK311510010090_00	OK311510-01-0090G	07/12/05	580	460
OK311600020060_00	OK311600-02-0060H	07/12/05	80	130
OK311210000050_00	OK311210-00-0050D	08/08/05	210	360
OK311510020090_00	OK311510-02-0090D	08/15/05	920	1580
OK311510010090_00	OK311510-01-0090G	08/15/05	1300	1900
OK311510010040_00	OK311510-01-0040D	08/16/05	660	400
OK311800000060_00	OK311800-00-0060G	08/16/05	160	400
OK311600020060_00	OK311600-02-0060H	08/16/05	580	400
OK311210000050_00	OK311210-00-0050D	09/12/05	135	90
OK311510020090_00	OK311510-02-0090D	09/19/05	105	135
OK311510010090_00	OK311510-01-0090G	09/19/05	125	280
OK311510010040_00	OK311510-01-0040D	09/20/05	415	105
OK311800000060_00	OK311800-00-0060G	09/20/05	100	120
OK311600020060_00	OK311600-02-0060H	09/20/05	310	280
OK311510020090_00	OK311510-02-0090D	05/01/06	155	15
OK311510010090_00	OK311510-01-0090G	05/01/06	75	130
OK311510010040_00	OK311510-01-0040D	05/02/06	500	200
OK311800000060_00	OK311800-00-0060G	05/02/06	135	110

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK311600020060_00	OK311600-02-0060H	05/02/06	420	75
OK311100010190_20	311100010190-001AT	05/02/06	354	169
OK311510020090_00	OK311510-02-0090D	05/30/06	210	110
OK311100010190_20	311100010190-001AT	05/30/06	10	10
OK311510010090_00	OK311510-01-0090G	05/31/06	1000	1000
OK311510010040_00	OK311510-01-0040D	05/31/06	520	60
OK311800000060_00	OK311800-00-0060G	05/31/06	730	260
OK311210000050_00	OK311210-00-0050D	06/05/06	1000	390
OK311600020060_00	OK311600-02-0060H	06/06/06	130	120
OK311100010190_20	311100010190-001AT	06/06/06	10	10
OK311100010190_20	311100010190-001AT	06/12/06	10	31
OK311510020090_00	OK311510-02-0090D	06/26/06	140	185
OK311510010090_00	OK311510-01-0090G	06/26/06	450	375
OK311510010040_00	OK311510-01-0040D	06/27/06	405	230
OK311800000060_00	OK311800-00-0060G	06/27/06	15	5
OK311210000050_00	OK311210-00-0050D	07/10/06	40	830
OK311600020060_00	OK311600-02-0060H	07/11/06	1000	620
OK311100010190_20	311100010190-001AT	07/17/06	10	31
OK311100010190_20	311100010190-001AT	08/07/06	10	10
OK311100010190_20	311100010190-001AT	08/14/06	20	10
OK311100010190_20	311100010190-001AT	09/20/06	1106	3654
OK311100010190_20	311100010190-001AT	09/25/06	73	60
OK311510020090_00	OK311510-02-0090D	05/18/09	410	180
OK311510010090_00	OK311510-01-0090G	05/18/09	60	500
OK311510010040_00	OK311510-01-0040D	05/19/09	480	10
OK311800000060_00	OK311800-00-0060G	05/19/09	60	10
OK311210000050_00	OK311210-00-0050D	05/26/09	370	230
OK311600020060_00	OK311600-02-0060J	05/27/09	2800	1200
OK311510020090_00	OKR09730-012	06/10/09	590	630
OK311510020090_00	OK311510-02-0090D	06/22/09	60	135
OK311510010090_00	OK311510-01-0090G	06/22/09	85	215
OK311510010040_00	OK311510-01-0040D	06/23/09	5	20
OK311800000060_00	OK311800-00-0060G	06/23/09	20	45
OK311510010090_00	OKR09730-136	06/24/09	880	880
OK311600020060_00	OK311600-02-0060J	06/30/09	1000	1000
OK311800000060_00	OKR09730-123	07/21/09	5	105
OK311600020060_00	OKR09730-109	07/21/09	160	190
OK311510020090_00	OK311510-02-0090D	07/27/09	7300	5700
OK311510010090_00	OK311510-01-0090G	07/27/09	1000	1000
OK311510010040_00	OK311510-01-0040D	07/28/09	70	840

Waterbody ID	WQM Station	Date	EC[1]	ENT[1]
OK311800000060_00	OK311800-00-0060G	07/28/09	40	270
OK311210000050_00	OK311210-00-0050D	08/03/09	60	40
OK311600020060_00	OK311600-02-0060J	08/04/09	410	1000
OK311510020090_00	OK311510-02-0090D	08/31/09	70	320
OK311510010090_00	OK311510-01-0090G	08/31/09	80	285
OK311510010040_00	OK311510-01-0040D	09/01/09	45	30
OK311800000060_00	OK311800-00-0060G	09/01/09	400	110
OK311210000050_00	OK311210-00-0050D	09/08/09	80	120
OK311210000050_00	OK311210-00-0050D	09/14/09	280	880
OK311600020060_00	OK311600-02-0060J	09/16/09	180	1000

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

Table A-2 Turbidity and Total Suspended Solids Data – 1998-2011

Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK311510010090_00	OK311510-01-0090G	05/31/05	99.1	91	low
OK311510010090_00	OK311510-01-0090G	07/12/05	11.4	10	low
OK311510010090_00	OK311510-01-0090G	08/15/05	28.9	35	high
OK311510010090_00	OK311510-01-0090G	09/19/05	4.78	10	low
OK311510010090_00	OK311510-01-0090G	10/24/05	4.67	11	low
OK311510010090_00	OK311510-01-0090G	12/05/05	1.37	10	low
OK311510010090_00	OK311510-01-0090G	01/17/06	1.94	10	low
OK311510010090_00	OK311510-01-0090G	02/21/06	6.2	10	low
OK311510010090_00	OK311510-01-0090G	03/27/06	2	10	low
OK311510010090_00	OK311510-01-0090G	05/01/06	3.78	10	low
OK311510010090_00	OK311510-01-0090G	05/31/06	17.6	18	high
OK311510010090_00	OK311510-01-0090G	06/26/06	8.41	10	low
OK311510010090_00	OK311510-01-0090G	05/18/09	3.21	10	low
OK311510010090_00	OK311510-01-0090G	06/04/09	40.4		high
OK311510010090_00	OKR09730-136	06/17/09	95.1		low
OK311510010090_00	OK311510-01-0090G	06/22/09	9.62	10	low
OK311510010090_00	OKR09730-136	06/24/09	77.4	79	low
OK311510010090_00	OK311510-01-0090G	07/27/09	32.5	18	high
OK311510010090_00	OK311510-01-0090G	08/31/09	5.78	10	low
OK311510010090_00	OK311510-01-0090G	10/05/09	3.38	10	low
OK311510010090_00	OK311510-01-0090G	11/03/09	8.05	10	low
OK311510010090_00	OK311510-01-0090G	12/15/09	1.96	10	low
OK311510010090_00	OK311510-01-0090G	01/25/10	8.69	10	low
OK311510010090_00	OK311510-01-0090G	03/01/10	8.02	10	low
OK311510010090_00	OK311510-01-0090G	04/05/10	10.7		low
OK311510010090_00	OK311510-01-0090G	05/17/10	19.1		high
OK311600020060_00	OK311600-02-0060H	06/07/05	144	135	low
OK311600020060_00	OK311600-02-0060H	07/12/05	59.3	55	low
OK311600020060_00	OK311600-02-0060H	07/25/05	42.3		low
OK311600020060_00	OK311600-02-0060H	08/16/05	95	115	low
OK311600020060_00	OK311600-02-0060H	09/20/05	230	191	low
OK311600020060_00	OK311600-02-0060H	10/25/05	7.85	10	low
OK311600020060_00	OK311600-02-0060H	12/06/05	3.21	10	low
OK311600020060_00	OK311600-02-0060H	01/18/06	15.2	29	low
OK311600020060_00	OK311600-02-0060H	01/23/06	15.4		low
OK311600020060_00	OK311600-02-0060H	02/22/06	6.92	10	low
OK311600020060_00	OK311600-02-0060H	03/28/06	38.9	40	low
OK311600020060_00	OK311600-02-0060H	05/02/06	42.2	57	low
OK311600020060_00	OK311600-02-0060H	06/06/06	21.1	24	low

Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK311600020060_00	OK311600-02-0060H	07/11/06	12.3	90	low
OK311600020060_00	OK311600-02-0060J	05/27/09	221	154	low
OK311600020060_00	OK311600-02-0060J	05/28/09	164		low
OK311600020060_00	OK311600-02-0060J	06/30/09	30.6	32	low
OK311600020060_00	OKR09730-109	07/15/09	56		low
OK311600020060_00	OKR09730-109	07/21/09	76.3	99	low
OK311600020060_00	OK311600-02-0060J	08/04/09	64.3	64	low
OK311600020060_00	OK311600-02-0060J	09/16/09	198	133	low
OK311600020060_00	OK311600-02-0060J	10/13/09	35.9	36	low
OK311600020060_00	OK311600-02-0060J	11/17/09	10.1	10	low
OK311600020060_00	OK311600-02-0060J	12/22/09	7.48	10	low
OK311600020060_00	OK311600-02-0060J	02/09/10	78.5	30	high
OK311600020060_00	OK311600-02-0060J	03/09/10	47.1		low
OK311600020060_00	OK311600-02-0060J	04/13/10	38.4		low
OK311600020060_00	OK311600-02-0060J	05/25/10	106		low
OK311600020110_05	OK311600-02-0110G	08/20/01	105	115	low
OK311600020110_05	OK311600-02-0110G	09/24/01	29.4	32	low
OK311600020110_05	OK311600-02-0110G	10/29/01	18.1	19	low
OK311600020110_05	OK311600-02-0110G	12/10/01	22.7	39	low
OK311600020110_05	OK311600-02-0110G	01/15/02	24.5	38	low
OK311600020110_05	OK311600-02-0110G	02/19/02	26.3	27	low
OK311600020110_05	OK311600-02-0110G	03/25/02		32	low
OK311600020110_05	OK311600-02-0110G	06/13/05	244		low
OK311600020110_05	OK311600-02-0110G	07/25/05	1.56		low
OK311600020110_05	OK311600-02-0110G	01/23/06	5.06		low
OK311210000050_00	OK311210-00-0050D	05/10/05	39.9	38	low
OK311210000050_00	OK311210-00-0050D	06/07/05	374	323	low
OK311210000050_00	OK311210-00-0050D	07/06/05	1000	971	high
OK311210000050_00	OK311210-00-0050D	08/08/05	51.2	22	low
OK311210000050_00	OK311210-00-0050D	09/12/05	28.5	42	low
OK311210000050_00	OK311210-00-0050D	10/17/05	23.5	19	low
OK311210000050_00	OK311210-00-0050D	11/28/05	13.2	10	low
OK311210000050_00	OK311210-00-0050D	01/10/06	5.31	10	low
OK311210000050_00	OK311210-00-0050D	02/13/06	8.98	10	low
OK311210000050_00	OK311210-00-0050D	03/20/06	130	141	low
OK311210000050_00	OK311210-00-0050D	04/24/06	34.3	36	high
OK311210000050_00	OK311210-00-0050D	06/05/06	108	81	low
OK311210000050_00	OK311210-00-0050D	07/10/06	49.8	27	low
OK311210000050_00	OK311210-00-0050D	05/26/09	29.6	25	high
OK311210000050_00	OK311210-00-0050D	06/30/09	13.3	15	low

Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK311210000050_00	OK311210-00-0050D	08/03/09	18.2	16	low
OK311210000050_00	OK311210-00-0050D	08/11/09	21.2		low
OK311210000050_00	OK311210-00-0050D	09/08/09	49.8	37	low
OK311210000050_00	OK311210-00-0050D	09/14/09			low
OK311210000050_00	OK311210-00-0050D	10/12/09	68.4	31	low
OK311210000050_00	OK311210-00-0050D	11/16/09	7.86	10	low
OK311210000050_00	OK311210-00-0050D	01/04/10		10	low
OK311210000050_00	OK311210-00-0050D	02/08/10	48.7	13	high
OK311210000050_00	OK311210-00-0050D	03/03/10	14		low
OK311210000050_00	OK311210-00-0050D	04/12/10	21.8		low
OK311200000010_00	311200000010-001AT	11/10/1998	1000	720	low
OK311200000010_00	311200000010-001AT	12/14/1998	74		low
OK311200000010_00	311200000010-001AT	2/1/1999	1000	1470	high
OK311200000010_00	311200000010-001AT	3/1/1999	49	52	low
OK311200000010_00	311200000010-001AT	4/27/1999	1000	648	high
OK311200000010_00	311200000010-001AT	6/1/1999	1000	960	high
OK311200000010_00	311200000010-001AT	6/28/1999	1000	1090	high
OK311200000010_00	311200000010-001AT	7/26/1999	1000	1060	low
OK311200000010_00	311200000010-001AT	8/30/1999	238	164	low
OK311200000010_00	311200000010-001AT	9/21/1999	121	92	low
OK311200000010_00	311200000010-001AT	11/1/1999	449	404	high
OK311200000010_00	311200000010-001AT	11/29/1999	19	23	low
OK311200000010_00	311200000010-001AT	12/21/1999	156	114	low
OK311200000010_00	311200000010-001AT	1/25/2000	17	43	low
OK311200000010_00	311200000010-001AT	3/1/2000	64	102	low
OK311200000010_00	311200000010-001AT	4/26/2000	89	108	low
OK311200000010_00	311200000010-001AT	5/23/2000	72	170	low
OK311200000010_00	311200000010-001AT	6/27/2000	476	1160	low
OK311200000010_00	311200000010-001AT	8/1/2000	95	146	low
OK311200000010_00	311200000010-001AT	8/30/2000	78	108	low
OK311200000010_00	311200000010-001AT	9/27/2000	55		low
OK311200000010_00	311200000010-001AT	11/1/2000	387	592	high
OK311200000010_00	311200000010-001AT	11/28/2000	860	562	high
OK311200000010_00	311200000010-001AT	2/12/2001	180		high
OK311200000010_00	311200000010-001AT	3/12/2001	837		high
OK311200000010_00	311200000010-001AT	4/9/2001	67		high
OK311200000010_00	311200000010-001AT	5/14/2001	493		high
OK311200000010_00	311200000010-001AT	6/11/2001	93		high
OK311200000010_00	311200000010-001AT	7/16/2001	59		low
OK311200000010_00	311200000010-001AT	8/13/2001	56		low

Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK311200000010_00	311200000010-001AT	9/4/2001	522		high
OK311200000010_00	311200000010-001AT	10/15/2001	135		low
OK311200000010_00	311200000010-001AT	11/26/2001	765		low
OK311200000010_00	311200000010-001AT	2/19/2002	44		low
OK311200000010_00	311200000010-001AT	4/2/2002	413		low
OK311200000010_00	311200000010-001AT	4/29/2002	1000		high
OK311200000010_00	311200000010-001AT	5/28/2002	294		low
OK311200000010_00	311200000010-001AT	8/5/2002	105		low
OK311200000010_00	311200000010-001AT	8/21/2002	102		low
OK311200000010_00	311200000010-001AT	9/24/2002	99		low
OK311200000010_00	311200000010-001AT	11/19/2002	182		low
OK311200000010_00	311200000010-001AT	1/14/2003	60		low
OK311200000010_00	311200000010-001AT	3/25/2003	34		low
OK311200000010_00	311200000010-001AT	6/4/2003	247		low
OK311200000010_00	311200000010-001AT	7/15/2003	127		low
OK311200000010_00	311200000010-001AT	8/19/2003	109		low
OK311200000010_00	311200000010-001AT	9/23/2003	203		low
OK311100010190_20	311100010190-001AT	5/2/2006	430		high
OK311100010190_20	311100010190-001AT	6/6/2006	4		low
OK311100010190_20	311100010190-001AT	7/11/2006	57		low
OK311100010190_20	311100010190-001AT	8/14/2006	43		low
OK311100010190_20	311100010190-001AT	9/25/2006	474		low
OK311100010190_20	311100010190-001AT	10/30/2006	214		low
OK311100010190_20	311100010190-001AT	12/4/2006	20		low
OK311100010190_20	311100010190-001AT	1/22/2007	710		high
OK311100010190_20	311100010190-001AT	3/5/2007	76		low
OK311100010190_20	311100010190-001AT	4/2/2007	1210		high
OK311100010190_20	311100010190-001AT	5/14/2007	997		low
OK311100010190_20	311100010190-001AT	6/11/2007	354		high
OK311100010190_20	311100010190-001AT	7/9/2007	531		high
OK311100010190_20	311100010190-001AT	8/22/2007	673		high
OK311100010190_20	311100010190-001AT	9/17/2007	1000		low
OK311100010190_20	311100010190-001AT	10/29/2007	59		low
OK311100010190_20	311100010190-001AT	12/3/2007	13		low
OK311100010190_20	311100010190-001AT	1/22/2008	6		low
OK311100010190_20	311100010190-001AT	3/4/2008	100		low
OK311100010190_20	311100010190-001AT	4/29/2008	115		low
OK311100010190_20	311100010190-001AT	5/19/2008	90		low
OK311100010190_20	311100010190-001AT	7/21/2008	88		low
OK311100010190_20	311100010190-001AT	9/15/2008	1000		high

Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK311100010190_20	311100010190-001AT	11/5/2008	75		low
OK311100010190_20	311100010190-001AT	2/17/2009	16		low
OK311100010190_20	311100010190-001AT	3/2/2009	10.5		low
OK311100010190_20	311100010190-001AT	4/6/2009	28.6		low
OK311100010190_20	311100010190-001AT	6/2/2009	95		high
OK311100010190_20	311100010190-001AT	8/10/2009	750		low
OK311100010190_20	311100010190-001AT	9/21/2009	427		low
OK311100010190_20	311100010190-001AT	12/7/2009	14.3		low
OK311100010190_20	311100010190-001AT	1/25/2010	10.3		low
OK311100010190_20	311100010190-001AT	4/19/2010	750.3		high
OK311100010190_20	311100010190-001AT	6/22/2010	161		low
OK311100010190_20	311100010190-001AT	9/14/2010	341.8		low
OK311100010190_20	311100010190-001AT	10/18/2010	21.8		low
OK311100010190_20	311100010190-001AT	12/13/2010	5.8		low
OK311100010190_20	311100010190-001AT	1/25/2011	7.3		low
OK311100010190_20	311100010190-001AT	4/18/2011	44.25		low
OK311100010190_00	311100010190-002AT	11/9/1998	218	2380	low
OK311100010190_00	311100010190-002AT	12/14/1998	51		low
OK311100010190_00	311100010190-002AT	2/2/1999	24	38	high
OK311100010190_00	311100010190-002AT	3/1/1999	41	21	low
OK311100010190_00	311100010190-002AT	4/27/1999	1000	1750	high
OK311100010190_00	311100010190-002AT	6/1/1999	1000	2080	high
OK311100010190_00	311100010190-002AT	6/28/1999	1000	970	high
OK311100010190_00	311100010190-002AT	7/26/1999	67	58	low
OK311100010190_00	311100010190-002AT	8/30/1999	79	72	low

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 Natural Resources Conservation Service (NRCS) runoff curve numbers and antecedent rainfall condition. Drainage subbasins will first be delineated for all impaired 303(d)-listed WQM stations, along with all USGS flow stations located in the 8-digit HUCs with impaired streams. Parsons will then identify all the USGS gage stations upstream and downstream of the subwatersheds with 303(d) listed WQM stations.

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

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

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

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

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

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

Furness Method

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

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

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

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

Wurbs Modified NRCS Method

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

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

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

where:

Q = runoff depth (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

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

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

Thus, the runoff curve number equation can be rewritten:

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

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

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

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

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

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

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.

<u>Generalized Flow Projection Methodology</u>

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 <u>and</u> no gages are present upstream or downstream, flows will be estimated for the WQM station from a gage on an adjacent watershed of similar size and properties, via the same procedure described above for upstream or downstream gages.

References

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

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

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

Table B-2 Estimated Flow Exceedance Percentiles

WBID	OK311510020090_00	OK311510010090_00	OK311510010040_00	OK311800000060_00	OK311600020060_00	OK311600020110_05	OK31121000050_00	OK311200000010_00	OK311100010190_20	OK311100010190_00
USGS Gage Reference	7301420 (adjacent)	7301420 (downstream)	7304500 (adjacent)	7304500 (adjacent)	7301110 (downstream)	7304500 (adjacent)	7327550 (adjacent)	7315500 (downstream)	7316000 (downstream)	7316000 (downstream)
Projected Gage	2552	2552	3027	3027	2936	3027	2873	2950	3128	3128
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
0	161.3	109.8	1,749.2	628.9	28,200.0	4,110.3	3,570.0	215,000.0	232,000.0	232,000.0
1	28.4	19.3	134.3	48.3	2,770.0	315.6	489.0	32,600.0	42,400.0	42,000.0
2	20.5	14.0	71.7	25.8	1,630.0	168.5	335.0	21,200.0	28,000.0	27,700.0
3	16.9	11.5	45.7	16.4	1,150.0	107.3	252.0	14,800.0	19,700.0	19,400.0
4	14.5	9.9	31.4	11.3	856.0	73.8	202.0	11,800.0	15,500.0	15,400.0
5	13.2	9.0	23.6	8.5	678.0	55.5	177.0	9,820.0	13,100.0	13,000.0
6	12.2	8.3	18.4	6.6	587.0	43.2	156.0	8,460.0	11,100.0	11,100.0
7	11.3	7.7	15.4	5.5	500.0	36.2	142.0	7,480.0	9,720.0	9,640.0
8	10.7	7.3	13.3	4.8	451.0	31.2	132.0	6,580.0	8,700.0	8,630.0
9	10.0	6.8	11.8	4.2	404.0	27.7	121.0	5,890.0	7,760.0	7,720.0
10	9.6	6.5	10.6	3.8	361.0	24.9	114.0	5,300.0	7,080.0	7,010.0
11	9.4	6.4	9.5	3.4	321.0	22.4	108.0	4,810.0	6,450.0	6,400.0
12	9.0	6.1	8.5	3.1	298.0	20.1	100.0	4,410.0	5,860.0	5,820.0
13	8.5	5.8	7.7	2.8	277.0	18.1	94.0	4,040.0	5,330.0	5,290.0
14	8.3	5.7	7.0	2.5	255.0	16.6	88.0	3,700.0	4,920.0	4,880.0
15	7.9	5.4	6.5	2.4	240.0	15.4	83.0	3,420.0	4,510.0	4,470.0
16	7.7	5.2	6.0	2.1	224.0	14.0	79.0	3,130.0	4,150.0	4,120.0
17	7.5	5.1	5.6	2.0	212.0	13.1	76.0	2,900.0	3,870.0	3,830.0
18	7.3	4.9	5.1	1.8	202.0	11.9	73.0	2,680.0	3,600.0	3,580.0
19	7.3	4.9	4.7	1.7	192.0	11.1	70.0	2,500.0	3,370.0	3,330.0
20	7.0	4.8	4.5	1.6	182.0	10.5	68.0	2,300.0	3,150.0	3,110.0
21	6.8	4.7	4.2	1.5	174.0	9.9	66.0	2,140.0	2,970.0	2,950.0
22	6.6	4.5	4.0	1.4	167.0	9.4	63.0	2,000.0	2,800.0	2,770.0
23	6.6	4.5	3.7	1.3	160.0	8.8	61.0	1,860.0	2,620.0	2,600.0
24	6.4	4.4	3.6	1.3	153.0	8.6	60.0	1,770.0	2,490.0	2,460.0
25	6.2	4.2	3.4	1.2	147.0	8.0	58.0	1,670.0	2,330.0	2,300.0
26	6.2	4.2	3.3	1.2	142.0	7.8	57.0	1,570.0	2,210.0	2,190.0
27	6.0	4.1	3.2	1.1	137.0	7.4	55.0	1,480.0	2,090.0	2,070.0

WBID	OK311510020090_00	OK311510010090_00	OK311510010040_00	OK311800000060_00	OK311600020060_00	OK311600020110_05	OK31121000050_00	OK311200000010_00	OK311100010190_20	OK311100010190_00
USGS Gage Reference	7301420 (adjacent)	7301420 (downstream)	7304500 (adjacent)	7304500 (adjacent)	7301110 (downstream)	7304500 (adjacent)	7327550 (adjacent)	7315500 (downstream)	7316000 (downstream)	7316000 (downstream)
Projected Gage	2552	2552	3027	3027	2936	3027	2873	2950	3128	3128
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
28	6.0	4.1	3.0	1.1	132.0	7.0	54.0	1,390.0	1,990.0	1,970.0
29	5.8	3.9	2.9	1.0	127.0	6.8	53.0	1,320.0	1,880.0	1,860.0
30	5.8	3.9	2.7	1.0	122.0	6.4	52.0	1,250.0	1,800.0	1,780.0
31	5.6	3.8	2.7	1.0	118.0	6.2	51.0	1,200.0	1,700.0	1,700.0
32	5.6	3.8	2.6	0.9	114.0	6.0	50.0	1,140.0	1,630.0	1,620.0
33	5.3	3.6	2.5	0.9	110.0	5.8	49.0	1,090.0	1,560.0	1,550.0
34	5.3	3.6	2.4	0.9	107.0	5.6	48.0	1,050.0	1,490.0	1,480.0
35	5.1	3.5	2.3	0.8	104.0	5.5	48.0	1,000.0	1,420.0	1,410.0
36	5.1	3.5	2.2	0.8	101.0	5.3	46.0	961.0	1,370.0	1,350.0
37	4.9	3.3	2.2	0.8	98.0	5.1	46.0	923.0	1,310.0	1,300.0
38	4.9	3.3	2.1	0.7	95.0	4.9	45.0	889.0	1,260.0	1,250.0
39	4.9	3.3	2.0	0.7	93.0	4.7	43.0	857.0	1,210.0	1,200.0
40	4.7	3.2	1.9	0.7	90.0	4.5	42.0	821.0	1,170.0	1,160.0
41	4.7	3.2	1.8	0.7	88.0	4.3	41.0	789.0	1,120.0	1,110.0
42	4.7	3.2	1.7	0.6	85.0	4.1	41.0	759.0	1,080.0	1,080.0
43	4.5	3.1	1.7	0.6	83.0	3.9	40.0	734.0	1,050.0	1,040.0
44	4.5	3.1	1.7	0.6	81.0	3.9	39.0	710.0	1,010.0	1,000.0
45	4.5	3.1	1.6	0.6	79.0	3.7	38.0	689.0	978.0	970.0
46	4.3	2.9	1.5	0.5	77.0	3.5	36.0	665.0	945.0	940.0
47	4.3	2.9	1.5	0.5	75.0	3.5	35.0	642.0	912.0	906.0
48	4.3	2.9	1.4	0.5	73.0	3.3	34.0	622.0	884.0	880.0
49	4.1	2.8	1.3	0.5	71.0	3.1	33.0	603.0	853.0	847.0
50	4.1	2.8	1.3	0.5	69.0	3.1	32.0	587.0	823.0	818.0
51	3.8	2.6	1.2	0.4	67.0	2.9	31.0	571.0	799.0	794.0
52	3.8	2.6	1.2	0.4	65.0	2.9	30.0	555.0	771.0	769.0
53	3.8	2.6	1.2	0.4	64.0	2.7	29.0	540.0	748.0	744.0
54	3.8	2.6	1.2	0.4	62.0	2.7	28.0	525.0	727.0	724.0
55	3.6	2.5	1.1	0.4	60.0	2.5	28.0	510.0	703.0	700.0
56	3.6	2.5	1.1	0.4	59.0	2.5	27.0	497.0	684.0	681.0

WBID	OK311510020090_00	OK311510010090_00	OK311510010040_00	OK311800000060_00	OK311600020060_00	OK311600020110_05	OK31121000050_00	OK311200000010_00	OK311100010190_20	OK311100010190_00
USGS Gage Reference	7301420 (adjacent)	7301420 (downstream)	7304500 (adjacent)	7304500 (adjacent)	7301110 (downstream)	7304500 (adjacent)	7327550 (adjacent)	7315500 (downstream)	7316000 (downstream)	7316000 (downstream)
Projected Gage	2552	2552	3027	3027	2936	3027	2873	2950	3128	3128
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
57	3.6	2.5	1.0	0.4	57.0	2.3	26.0	483.0	660.0	658.0
58	3.4	2.3	1.0	0.4	56.0	2.3	25.0	470.0	642.0	639.0
59	3.4	2.3	0.9	0.3	54.0	2.1	24.0	458.0	622.0	620.0
60	3.2	2.2	0.9	0.3	53.0	2.1	23.0	447.0	604.0	602.0
61	3.2	2.2	0.8	0.3	52.0	1.9	23.0	436.0	587.0	585.0
62	3.0	2.0	0.8	0.3	50.0	1.9	22.0	427.0	570.0	568.0
63	3.0	2.0	0.8	0.3	49.0	1.9	22.0	417.0	554.0	552.0
64	3.0	2.0	0.8	0.3	48.0	1.8	21.0	406.0	540.0	538.0
65	2.8	1.9	0.7	0.3	47.0	1.7	20.0	398.0	525.0	522.0
66	2.8	1.9	0.7	0.3	45.0	1.6	20.0	388.0	511.0	508.0
67	2.6	1.7	0.7	0.2	44.0	1.5	19.0	378.0	498.0	494.0
68	2.6	1.7	0.6	0.2	43.0	1.5	18.0	369.0	485.0	483.0
69	2.3	1.6	0.6	0.2	41.0	1.4	18.0	359.0	473.0	470.0
70	2.3	1.6	0.6	0.2	40.0	1.3	17.0	350.0	460.0	456.0
71	2.1	1.5	0.5	0.2	39.0	1.2	17.0	340.0	445.0	442.0
72	2.1	1.5	0.5	0.2	38.0	1.2	16.0	331.0	431.0	430.0
73	2.1	1.4	0.5	0.2	37.0	1.1	16.0	320.0	418.0	416.0
74	1.9	1.3	0.4	0.2	35.0	1.1	15.0	312.0	405.0	402.0
75	1.8	1.3	0.4	0.2	34.0	1.0	14.0	303.0	392.0	390.0
76	1.7	1.2	0.4	0.1	33.0	0.9	14.0	295.0	380.0	378.0
77	1.6	1.1	0.4	0.1	31.0	0.9	13.0	287.0	367.0	367.0
78	1.5	1.0	0.3	0.1	30.0	0.8	12.0	278.0	355.0	355.0
79	1.3	0.9	0.3	0.1	28.0	0.7	12.0	270.0	344.0	345.0
80	1.2	0.8	0.3	0.1	27.0	0.7	11.0	259.0	332.0	333.0
81	1.2	0.8	0.3	0.1	25.0	0.6	11.0	250.0	321.0	323.0
82	1.0	0.7	0.2	0.1	24.0	0.6	10.0	241.0	309.0	310.0
83	0.9	0.6	0.2	0.1	22.0	0.5	10.0	234.0	297.0	299.0
84	0.9	0.6	0.2	0.1	21.0	0.4	9.6	226.0	285.0	287.0
85	0.8	0.5	0.2	0.1	20.0	0.4	9.3	218.0	273.0	275.0

WBID	OK311510020090_00	OK311510010090_00	OK311510010040_00	OK311800000060_00	OK311600020060_00	OK311600020110_05	OK31121000050_00	OK311200000010_00	OK311100010190_20	OK311100010190_00
USGS Gage Reference	7301420 (adjacent)	7301420 (downstream)	7304500 (adjacent)	7304500 (adjacent)	7301110 (downstream)	7304500 (adjacent)	7327550 (adjacent)	7315500 (downstream)	7316000 (downstream)	7316000 (downstream)
Projected Gage	2552	2552	3027	3027	2936	3027	2873	2950	3128	3128
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
86	0.7	0.5	0.1	0.0	19.0	0.3	9.0	210.0	260.0	263.0
87	0.6	0.4	0.1	0.0	18.0	0.3	8.5	201.0	248.0	250.0
88	0.6	0.4	0.1	0.0	17.0	0.2	8.1	193.0	238.0	240.0
89	0.5	0.3	0.1	0.0	15.0	0.2	7.5	184.0	227.0	229.0
90	0.4	0.3	0.1	0.0	14.0	0.2	7.0	177.0	216.0	217.0
91	0.4	0.2	0.0	0.0	13.0	0.1	6.4	168.0	208.0	210.0
92	0.3	0.2	0.0	0.0	11.0	0.1	5.8	158.0	195.0	198.0
93	0.2	0.2	0.0	0.0	10.0	0.1	5.2	148.0	185.0	186.0
94	0.2	0.1	0.0	0.0	9.1	0.0	4.5	139.0	175.0	176.0
95	0.2	0.1	0.0	0.0	8.2	0.0	3.9	128.0	164.0	165.0
96	0.1	0.1	0.0	0.0	7.4	0.0	3.2	118.0	153.0	154.0
97	0.1	0.1	0.0	0.0	6.6	0.0	2.2	108.0	140.0	141.0
98	0.1	0.0	0.0	0.0	5.5	0.0	1.7	98.0	122.0	124.0
99	0.0	0.0	0.0	0.0	3.3	0.0	1.0	84.0	106.0	106.0
100	0.0	0.0	0.0	0.0	0.1	0.0	0.0	44.0	39.0	39.0

APPENDIX C

STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix C

State of Oklahoma Antidegradation Policy

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

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

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

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

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

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

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

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

785:46-13-1. Applicability and scope

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

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

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

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

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

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

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

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

785:46-13-2. Definitions

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

"Specified pollutants" means

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

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

(C) Phosphorus;

(D) Total Suspended Solids (TSS); and

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

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

(a) General.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX D

NPDES DISCHARGE MONITORING REPORT DATA

Table D-1 NPDES Discharge Monitoring Report Data

NPDES No.	Outfall	Monitoring Date	Max Flow (MGD)	Average Flow (MGD)	Max TSS (MGD)	Average TSS (MGD)
OK0032514	001	1/31/2007	1.131	0.204	104	**103***
OK0032514	001	2/28/2007	0.108	0.065	109	**107***
OK0032514	001	3/31/2007	0.431	0.147	**149***	**149***
OK0032514	001	6/30/2007	1.1	0.096		
OK0032514	001	7/31/2007	0.144	0.072		
OK0032514	001	10/31/2007				
OK0032514	001	11/30/2007				
OK0032514	001	2/29/2008	0.294	0.247	94	**93***
OK0032514	001	3/31/2008	0.294	0.108	130	**123.5***
OK0032514	001	4/30/2009				
OK0032514	001	10/31/2009				
OK0032514	001	11/30/2009	0.108	0.108	114	**113***
OK0032514	001	12/31/2009	0.108	0.053	102	**97***
OK0032514	001	1/31/2010	0.238	0.108	71	70
OK0032514	001	2/28/2010	0.187	0.078	113	**91.5***
OK0032514	001	3/31/2010	0.238	0.187	115	**105***
OK0032514	001	4/30/2010				
OK0032514	001	5/31/2010				
OK0032514	001	6/30/2010				
OK0032514	001	7/31/2010				
OK0032514	001	8/31/2010				
OK0032514	001	9/30/2010				
OK0032514	001	10/31/2010				
OK0032514	001	12/31/2010	0.108	0.108	**137***	**118.5***
OK0032514	001	1/31/2011	0.108	0.092	95	**93.5***
OK0032514	001	2/28/2011	0.053	0.034	126	**126***
OK0032514	001	3/31/2011	0.053	0.01	**164***	**158***
OK0032514	001	4/30/2011				
OK0032514	001	5/31/2011				
OK0032514	001	6/30/2011				

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

APPENDIX E

DEQ SANITARY SEWER OVERFLOW DATA – 1991-2005

Table E-1 DEQ Sanitary Sewer Overflow Data

Facility Name	Facility ID	Date	Duration (hrs)	Location	Amount (gallons)	Raw	Treated	Cause
WILLOW	S11802	4/5/1997		LAGOON		X		RAIN
MARLOW	S11220	12/23/1991		MARLOW WEST FIRST MANHOLE BEFORE LAGOON		X		HEAVY RAINFALL
MARLOW	S11220	5/24/1995	16.00	9TH ST LIFT STATION	9,600	X		RAIN I/I
MARLOW	S11220	5/24/1995	16.00	CLEVELAND AND APACHE	4,300	X		RAIN I/I
MARLOW	S11220	5/24/1995	16.00	CADDO LIFT STATION	9,600	X		RAIN I/I
MARLOW	S11220	6/26/1995	3.00	1/2 MILE EAST OF LAGOONS	10,000	X		LINE EXPOSED AND BROKEN
MARLOW	S11220	8/3/1995	7.00	WEST LIFT STATION	10,000	X		HYDROLIC OVERLOAD FROM RAIN I/I
MARLOW	S11220	9/21/1997	21.00	BLANTON L.S.	<10,000			LINE LEAKING
MARLOW	S11220	3/22/1998	48.00	S.W. INTERSECTION OF HWY 81 & BLACKBURN	500,000	X		OVERFLOW
MARLOW	S11220	6/21/2000		S.W. OF MARLOW IN FIELD		X		LINE PLUGGED
MARLOW	S11220	7/18/2003	0.00	1/2 MILE S. OF W. CADDO & 10TH	10,000	X		DEBRIS
MARLOW WEST	S11220	5/1/1995	12.00	MH 431	50,000	X		LINE STOPPAGE AT LAGOONS
MARLOW WEST	S11220	6/8/1995	10.00	CADDO LIFT STATION	0	X		POWER FAILURE
MARLOW WEST	S11220	3/27/1995	168.00	AT PLANT (MANHOLE INTO HELL CREEK)	0	X		RAIN I/I
TEMPLE	S11317	5/4/1992	720.00	LAGOON	500	X		HYDRUALIC OVERLOAD OF HOLDING BASIN
TEMPLE	S11317	6/3/1992	0.00	at lagoon	0		X	EXCESSIVE RAIN
TEMPLE	S11317	1/18/1993	288.00	LAGOONS SOUTH OF TOWN	500		X	I/I FROM SYSTEM
TEMPLE	S11317	5/1/1993	168.00	LAGOONS ON SE SIDE OF TEMPLE	140,000	X	X	EXCESSIVE RAINS ALL WINTER
TEMPLE	S11317	9/20/1993	48.00	LIFT STATION AT LAGOONS	0	X		RAINFALL, PUMPS BURNED OUT
TEMPLE	S11317	5/13/1994	0.00	LAGOONS	0	X		HYDROLIC OVERLOAD FROM I/I
TEMPLE	S11317	4/24/1995	72.00	LAGOONS Last cell	0	X		RAIN I/I
TEMPLE	S11317	5/8/1995	24.00	AT LAGOONM POND	0	X		RAIN I/I
TEMPLE	S11317	5/31/1995	100.00	#2 CELL AT LAGOON	50,000	X		RAIN I/I
TEMPLE	S11317	4/11/1996		1/2 MILE S. OF TEMPLE ON HWY. 5			X	SEEPAGE IN BETWEEN BUIDING BOARDS
TEMPLE	S11317	5/3/1996	519.00	1/2 MILE S.E. OF TEMPLE, OK.	100	X		LAGOONS FULL
TEMPLE	S11317	9/3/1996						

Facility Name	Facility ID	Date	Duration (hrs)	Location	Amount (gallons)	Raw	Treated	Cause
TEMPLE	S11317	12/1/1996			160		X	RAINS
TEMPLE	S11317	10/28/1998		N. HWY 65 & BOUNDRY	1,000	X		BLOCKAGE
TEMPLE	S11317	6/24/1999		LAGOONS				
TEMPLE	S11317	7/2/1999		1/2 MILE S. ON HWY 5	774,864		X	SEEPAGE
TEMPLE	S11317	10/18/1999		1/2 MILE S. ON HWY 5			X	SEEPAGE THROUGH DAM
TEMPLE	S11317	10/22/1999		1/2 MILE S. OF TEMPLE ON HWY 5	>2 MILLN		X	DAMAGED LINE TO DAM
TEMPLE	S11317	11/4/2000	103.00	1/2 MILE MS. ON HWY 5	>3 MILLN		X	RAINS
TEMPLE	S11317	11/9/2000		1/2 MILE S. ON HWY 5	75,600		X	RAINS
TEMPLE	S11317	5/8/2001		217 E. TEXAS /S. CHERRY & E. TEXAS	100	X		LINE STOPPAGE
TEMPLE	S11317	9/6/2001		1/2 MILE S. OF CITY & 1/4 MILE EAST AT WHISKEY CREEK	2,000		X	SEEPAGE
TEMPLE	S11317	5/21/2003	0.00	1/2 MILE S. OF TOWN	>3 MILLN		X	DISCHARGING LAGOON
TEMPLE	S11317	11/2/2003	4.50	GREEN DR. - RESIDENT ROBERT HALE	1,100	X		DEBRIS
TEMPLE	S11317	1/15/2004	3.30	HWY 5, S. ON S. ASH	300	X		DEBRIS
TEMPLE	S11317	3/5/2004	122.00	1/2 MILE S.E. OF TOWN ON HWY 5	47,872		X	CLEANED CLARIFIER
TEMPLE	S11317	3/30/2004	0.00					
TEMPLE	S11317	5/5/2004	0.00	632 W. OREGON E. OF SANDS MOTEL	500	X		MALFUNCTION
TEMPLE	S11317	12/1/2004	0.00	WWTP			X	RAIN
TEMPLE	S11317	7/25/2005	102.00	PLANT			X	OVERFLOWING
TEMPLE	S11317	10/18/2005	0.00	WEST OF TOWN	46,750		X	DRAIN CLARIFIER
MARIETTA	S10901	1/13/1992	0.00	SW Seminole, South outfall line to sewage treatment plant.	0	X		?
MARIETTA	S10901	1/13/1992	11.00	700 W SEMINOLE BEHIND AND WEST OF LIVESTOCK AUCTION		X		RAIN OVERLOAD DUE TO I/I
MARIETTA	S10901	9/3/1992		WWTP		X	X	PLANT BROKEN DOWN
MARIETTA	S10901	12/13/1992	14.00	SW PART OF MARIETTA INTO DALES CREEK	2,000	X		RAINFALL I/I
MARIETTA	S10901	2/28/1993	48.00	700 WEST SEMINOLE	0	X		EXCESSIVE RAINFALL
MARIETTA	S10901	2/28/1993	48.00	BEHIND LIVESTOCK BARN	0	X		EXCESSIVE RAIN
MARIETTA	S10901	1/19/1995	1.00	AT PLANT	1,000	R		CLARIFIER STOPPDE UP
MARIETTA	S10901	6/13/1999	10.00	TREATMENT PLANT	60,000		X	SLUDGE RETURN TUBE PLUGGED

Facility Name	Facility ID	Date	Duration (hrs)	Location	Amount (gallons)	Raw	Treated	Cause
MARIETTA	S10901	6/23/2001	0.50		500	X		LINE STOPPAGE
MARIETTA	S10901	12/19/2001	1.00	N. CENTRAL PORTION OF TOWN	>500	X		LINE STOPPAGE
MARIETTA	S10901	2/11/2002	1.00	2ND ST N.W. & MILL ST	100	X		LINE COLLAPSED
MARIETTA	S10901	3/4/2002	0.50	NEAR BIG FIVE DAYCARE	200	X		HAND TOWELS
MARIETTA	S10901	3/18/2002	0.00	S.W. PART OF MARIETTA			X	I&I
MARIETTA	S10901	4/30/2002	0.50	CITY PARK N.W. OF TOWN	300	X		RAGS
MARIETTA	S10901	11/20/2002	0.20	CITY PARK	100	X		TOWELS
MARIETTA	S10901	11/20/2002	6.00	S. OF HARPER'S WESTERN WEAR	2,000	X		GREASE

APPENDIX F

RESPONSE TO COMMENTS

Steve A. Thompson
Executive Director

Mary Fallin
Governor

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Response to Public Comment

Draft Bacteria and Turbidity TMDLs for the Red River Area Watershed

August 30, 2012

Comment sent by via email from Edward J. Phillips, Representing the Citizens for Lake Texoma:

Thank you for the opportunity to provide comments and recommendation regarding the draft report describing reductions needed to improve water quality in the Red River Study Area.

We understand the focus of the draft report and TMDLs was on bacteria and turbidity for the Red River Area Watershed. We appreciate the study and recommended actions to protect the public including swimming and fish communities for these areas.

We are also concerned about the "cumulative effects" of excessive nutrients and pollution such as but not limited to phosphorous and nitrogen that are being generated throughout the total Red River Basin and watershed by point and non-point sources of pollution. As you are aware, Lake Texoma receives a significant amount of the "cumulative pollution" flowing from the 48,000 square mile watershed consisting of the Upper Red River, Washita River and the Lake Texoma watersheds. The TMDLs may be evaluated and set to meet segment standards but when multiple segments and sources are added it often results in significantly impaired main bodies of lakes and streams. Most professionals and several studies have documented excessive nutrients in Lake Texoma and its inflows which are causing Harmful Alga Blooms (HAB's) such as blue-green and golden algae and resultant critical public health, environmental and economic problems. Some of the Lake Texoma waters can be increasingly impaired for recreation, fishing, and swimming during certain conditions.

We understand and appreciate the reasons for monitoring and testing of watershed segments. But the cumulative effects should be evaluated and considered also in developing a systems approach to overall and segment TMDLs in Oklahoma and Texas areas of the Red River watershed. Point sources are often evaluated at the end of the discharge pipe instead of the receiving water body *and watershed*. Non-point source TMDLs are also focused on segments.

The current draft report describing reductions needed to improve water quality in the Red River Study Area including part of Lake Texoma does not include measurement and evaluation of phosphorous which is one of the major underlying causes of Harmful Alga Blooms such as blue green algae. TMDLs have not been established for phosphorous from major point-source discharge facilities.

(comment continues on next page)

Other studies have indicated excessive phosphorous entering the Red and Washita River and Lake Texoma watersheds. Excessive phosphorous levels certainly cause impairment of water quality and public use for recreation, swimming and fishing as experienced at Lake Texoma and other lakes in 2011.

It would be very helpful to conduct additional studies such as identified in the excerpts from the public notice to determine the factual scope of the problem, possible sources and recommended remedial actions. "A TMDL document uses scientific data collection and analysis to determine the amount and source of each pollutant entering the system, and allocates pollutant loads to each source at levels that would ultimately restore water quality to meet clean water standards. A TMDL is the amount of each pollutant a waterway can receive and not violate water quality standards. A TMDL takes into account the pollution from all sources."

We also note that caution is required when measuring, evaluating, establishing TMDL limits and controlling phosphorous and other nutrients entering the Lake Texoma watershed. Phosphorous and nutrient abatement and reduction programs must be time phased to balance water quality improvements and positive/negative economic impacts. Some of the necessary improvements will take significant time and federal, state and local funds.

Fishery biologists advise that the end objective should be to reduce the Lake Texoma nutrients to acceptable levels. Elimination of all or most nutrients can harm the productivity of the overall aquatic community and food chain in Lake Texoma since it is an older lake established in the 1940's.

Response:

Thank you for your comment regarding the "Draft Bacteria and Turbidity TMDL Report for the Red River Area Watershed". Lake Texoma was not addressed in this TMDL report because, as you noted, the foci of this report were streams and rivers impaired with bacteria or turbidity.

DEQ appreciates your concern regarding excessive nutrients, and we have been developing TMDLs for those lakes that are impaired with nutrients. Because of all the lakes we have here in Oklahoma, we have begun by evaluating those lakes with the beneficial use of Public and Private Water Supplies (aka drinking water) which are considered to be Sensitive Water Supplies (see Appendix A of Oklahoma's Water Quality Standards to see which ones are SWS lakes). By looking up Lake Texoma on page 50 of Appendix A of the Water Quality Standards, one can see that Lake Texoma is not an SWS lake.

TMDLs are developed only for those impaired waterbodies on the 303(d) List. If lakes have nutrient levels exceeding Oklahoma's Water Quality Standards, they will appear on the 303(d) list (which is Appendix C of Oklahoma's Integrated Report) as being impaired by nitrogen, phosphorus, or chlorophyll-a. Elevated levels of chlorophyll-a [defined in the Water Quality Standards in 785:45-5-10(7)] mean that too much algae is growing in the lake. As you noted in your comment, too much algae means there is too much nitrogen and phosphorus in the lake.

If one looks up Lake Texoma on the 303(d) List, one can see that it is not listed as being impaired for nutrients. However, monitoring is on-going by the Oklahoma Water Resources Board (DEQ *doesn't do lake monitoring). Information about OWRB sampling at Lake Texoma can be found by going to: http://www.owrb.ok.gov/quality/monitoring/bump/pdf_bump/Current/Lakes/Texoma.pdf.*

Since you have observed a problem and represent a local group in the area, the Citizens for Lake Texoma may want to consider organizing people in the Lake Texoma area to take steps towards preventing nutrient pollution. Some ideas about things that can be done can be found at the following EPA website: http://www.epa.gov/nutrientpollution/whatyoucando/index.html.

EPA Nutrient Pollution Outreach and Education Materials can be found at: http://water.epa.gov//polwaste/nutrientoutreach.cfm. This includes a Nutrient Pollutant Community Outreach Toolkit designed to assist citizen groups, like yours, in reaching out to communities to share information about the growing threats to our nation's water resources from nutrient pollution. Given what you wrote in your letter, you seem to have a good idea about the problem. The Toolkit gives many ideas you can share with the Lake Texoma community on what everybody can do to make a difference in reducing nutrients.

EPA's Nonpoint Source Outreach Toolbox also has many other items you can modify in reaching out to your community such as fact sheets, brochures, public service announcements, billboard messages, newspaper ads, bus boards, and movie slides.

EPA also has free materials you can order from the National Service Center for Environmental Publications, including a DVD entitled "Reduce Runoff: Slow it Down, Spread it Out, Soak it In!" It includes a video done in conjunction with The Weather Channel called, "After the Storm". You can either request it over the internet (click on title link above) or call them (800-490-9198). The publication number is 84211001. If you have further questions about establishing a nutrient pollution reduction community program, contact Dr. Karen Miles at DEQ, Watershed Outreach Coordinator, at 405-702-8192.