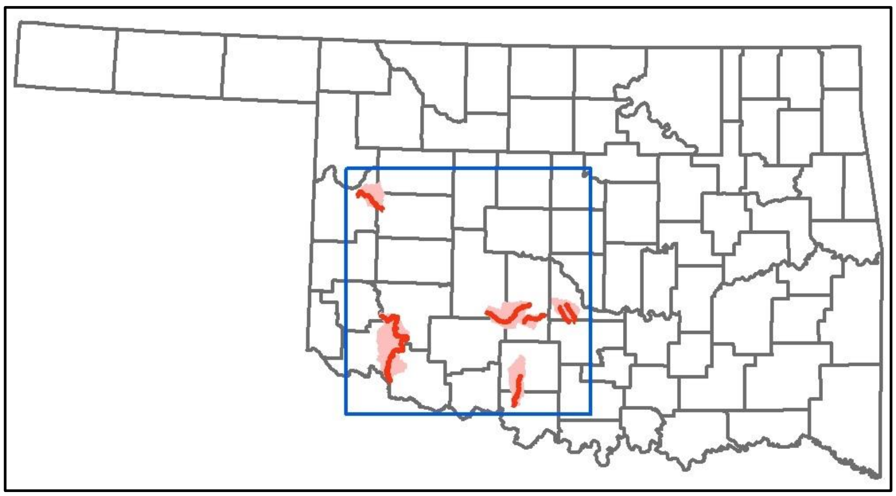
DRAFT

2024 BACTERIAL AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR OKLAHOMA STREAMS IN BASIN 3 AREA

Oklahoma Waterbody Identification Numbers

Finn Creek	OK310810020020_00
Criner Creek	OK310810020050_00
Roaring Creek	OK310810020170_00
Little Washita River	OK310820020010_00
Quartermaster Creek	OK310840010060_00
Cow Creek	OK311200000060_00
Red River, North Fork	OK311500010020_00
Red River, North Fork	OK311500010020_10



Prepared by:

Oklahoma Department of Environmental Quality

FEBRUARY 2025

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ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
AFO	Animal Feeding Operation
AgPDES	Agriculture Pollutant Discharge Elimination System
ASAE	American Society of Agricultural Engineers
AVMA	American Veterinary Medical Association
BMP	Best management practices
BOD	Biochemical Oxygen Demand
BUMP	Beneficial Use Monitoring Program
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	cubic feet per second
CN	Curve number
CPP	Continuing Planning Process
CWA	Clean Water Act
CWAC	Cool water aquatic community
DEM	Digital Elevation Model
DEQ	Oklahoma Department of Environmental Quality
DMR	Discharge monitoring report
E. coli	*Escherichia coli*
ENT	Enterococci
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
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
MSGP	Multi-Sector General Permit
NASS	USDA's National Agricultural Statistics Service
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NRCS	Natural Resources Conservation Service
NRMSE	Normalized root mean square error
NTU	Nephelometric turbidity unit
NWIS	National Water Information System
OAC	Oklahoma Administrative Code
OCC	Oklahoma Conservation Commission
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
r^2	Correlation coefficient
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow
STORET	EPA Storage and Retrieval System
TMDL	Total Maximum Daily Load

TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WWAC	warm water aquatic community
WLA	wasteload allocation
WQ	Water Quality
WQM	Water quality monitoring
WQMP	Water Quality Management Plan
WQS	Water quality standard
WWTF	wastewater treatment facility

EXECUTIVE SUMMARY

ES - 1 Overview

As promulgated by Section 402 of the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) has delegated authority to the Oklahoma Department of Environmental Quality (DEQ) to partially oversee the National Pollutant Discharge Elimination System (NPDES) Program in the State of Oklahoma. Exceptions are agriculture [retained by the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF)], and the oil & gas industry (retained by the Oklahoma Corporation Commission) for which 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 (https://oklahoma.gov/content/dam/ok/en/deq/documents/deqmainresources/606.pdf)].

This total maximum daily load (TMDL) report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli)* and enterococci] and turbidity for selected waterbodies in Oklahoma Basin 3 Area. 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 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 DEQ guidance and procedures. DEQ is required to develop TMDLs for all impaired waterbodies which are on the 303(d) list. The draft TMDL went to EPA for review before it was submitted for public comment. After the public comment period, the TMDL was submitted to EPA for final approval. Once EPA approves the final TMDL, the waterbody is moved to Category 4a of the Integrated Report, where it remains until it reaches compliance with Oklahoma's water quality standards (WQS).

These TMDLs provide a load reduction to meet ambient water quality criterion with a given set of facts. The adoption of these TMDLs into the Water Quality Management Plan (WQMP) provides a mechanism to recalculate acceptable pollutant loads when information changes in the future. Updates to the WQMP demonstrate compliance with the water quality criterion. The updates to the WQMP are also useful when the water quality criterion changes and loading scenarios are reviewed to ensure that the predicted in-stream criterion will be met.

The purpose of this TMDL study was to establish pollutant load allocations for indicator bacteria and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and in-stream water quality conditions. A TMDL consists of wasteload allocations (WLA), load allocations (LA), and a margin of safety (MOS). A WLA is the fraction of the total pollutant load apportioned to point sources and includes stormwater discharges regulated under OPDES as point sources. An 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 and 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 native tribes, and local, State, and federal government agencies.

ES - 2 Problem Identification and Water Quality Target

This TMDL study focused on waterbodies in Oklahoma Basin 3 Study Area, identified in Table ES -1 that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2022 Integrated Report* for nonsupport of primary body contact recreation (PBCR) or the Fish and Wildlife Propagation-Warm Water Aquatic Community (WWAC) beneficial uses.

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 the Fish & Wildlife Propagation beneficial uses designated for each waterbody.

Table ES -2 summarizes bacterial data collected during primary body contact recreation (PBCR) season from the water quality monitoring (WQM) stations between 2006 and 2021. Table ES - 1 summarizes turbidity data collected during base flow from the WQM stations between 2006 and 2022. The data summary in Table ES -2 and Table ES - 1 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 PBCR season includes the data used to support the decision to place specific waterbodies within the study area on the DEQ 2022 303(d) list (DEQ 2022).

ES-2.1 Chapter 730: Criteria for Bacteria

The definition of PBCR and the bacterial WQSs for PBCR are summarized by the following excerpt from Title 252, Chapter 730-5-16 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 the following limits for bacteria set forth in (c) of this section 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 252:730-5-16 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 therefor. 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.

ES-2.2 Chapter 740: Implementation of OWQS for Bacteria

To implement Oklahoma's WQS for PBCR, DEQ promulgated Chapter 740, *Implementation of Oklahoma's Water Quality Standards* (DEQ 2022).

The excerpt below from Chapter 740 (OAC 252:740-15-6), 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 252:740 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 252:740-15-3(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 252:740-15-3(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 252:740-15-3(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 252:740-15-3(c).

Where concurrent data exist for multiple bacterial indicators on the same waterbody, each indicator group must demonstrate compliance with the numeric criteria prescribed (DEQ 2022).

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 are used to develop TMDLs for *E. coli* and enterococci bacterial indicators.

ES-2.3 Chapter 730: Criteria for Turbidity

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 (DEQ 2022). The numeric criteria for turbidity to maintain and protect the use of "Fish and Wildlife Propagation" from Title 252:730-5-12(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 NTUs; 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.

Table ES -1 Excerpt from the 2022 Integrated Report – Oklahoma 303(d) List of Impaired Waters

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
OK310810020020_00	Finn Creek	14.15	2033	4		5a	N		F
OK310810020050_00	Criner Creek	11.76	2033	4		5a	N		F
OK310810020170_00	Roaring Creek	18.27	2033	4			F	5a	N
OK310820020010_00	Little Washita River	36.98	2033	4			F	5a	N
OK310840010060_00	Quartermaster Creek	32.98	2030	3			F	5a	N
OK311200000060_00	Cow Creek	25.73	2027	2		5a	N	4a	N
OK311500010020_00	Red River, North Fork	22.72	2030	3			I	5a	N
OK311500010020_10	Red River, North Fork	61.7	2030	3	4a	5a	N		N*

ENT = Enterococci; N = Not attaining; I = Insufficient information

Source: 2022 Integrated Report, DEQ 2022

4a: TMDL has been completed.

5a: TMDL is underway or will be scheduled.

*: WWAC impaired due to selenium and macroinvertebrate bioassessment

Table ES -2 Summary of Indicator Bacterial Samples from Primary Body Contact Recreation Subcategory Season May 1 to September 30, 2006-2021

Waterbody ID	Waterbody Name	Indicator	Number of Samples	Data Period	Geometric Mean Conc (colonies/100 mL)	Assessment Results / Recommended Actions
OK310810020020_00	Finn Creek	ENT	12	2006 - 2010	333.0	Impaired / 2012 TMDL
		EC	10	2019 - 2021	136.0	Impaired / TMDL
OK310810020050_00	Criner Creek	EC	10	2019 - 2021	202.8	Impaired / TMDL
OK310810020170_00	Roaring Creek	EC	10	2019 - 2020	47.2	Attain WQS / No TMDL
OK310820020010_00	Little Washita River	EC	10	2019 - 2020	34.1	Attain WQS / No TMDL
OK310840010060_00	Quartermaster Creek	ENT	13	2006 - 2010	296.7	Impaired / 2007 TMDL
		EC	10	2019 - 2020	80.9	Attain WQS / No TMDL
OK311200000060_00	Cow Creek	ENT	12	2006 - 2010	386.6	Impaired / 2007 TMDL
		EC	12	2006 - 2010	401.9	Impaired / TMDL
OK311500010020_00	Red River, North Fork	ENT	3	2013	41.1	Impaired / List in 303(d) and TMDL
		EC	4	2013	34.0	Insufficient data / Additional data request
OK311500010020_10	Red River, North Fork	ENT	10	2006 - 2013	159.1	Impaired / 2008TMDL
		EC	11	2006 - 2013	264.9	Impaired / TMDL

Enterococci (ENT) water quality criterion = Geometric Mean of 33 colonies/100 mL
E. coli (EC) water quality criterion = Geometric Mean of 126 colonies/100 mL
TMDLs will be developed for waterbodies highlighted in green.

Table ES - 1 Summary of Turbidity Data Excluding High Flow Samples, 2006-2022

Waterbody ID	Waterbody Name	Data Period	Number of Turbidity Samples	Number of Samples Greater Than 50 NTUs	%Samples Exceeding Criterion	Average Turbidity (NTU)	Assessment Results / Recommended Actions
OK310810020020_00	Finn Creek	2019 - 2021	19	0	0%	5.0	Attain WQS / No TMDL
OK310810020050_00	Criner Creek	2019 - 2021	11	0	0%	3.7	Attain WQS / No TMDL
OK310810020170_00	Roaring Creek	2019 - 2021	19	2	10.5%	15.7	Impaired / TMDL
OK310820020010_00	Little Washita River	2019 - 2021	19	2	10.5%	57.0	Impaired / TMDL
OK310840010060_00	Quartermaster Creek	2019 - 2021	18	3	16.7%	26.7	Impaired / TMDL
OK311200000060_00	Cow Creek	2006 - 2011	19	3	15.8%	31.1	Impaired / 2010 TMDL
OK311500010020_00	Red River, North Fork	2016 -2019	12	5	41.7%	115.9	Impaired / TMDL
OK311500010020_10	Red River, North Fork	2018 - 2022	17	0	0%	8.3	Attain WQS / No TMDL

Table ES - 2 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
OK310810020170_00	Roaring Creek	0.61	24.4%	64.9	25%
OK310820020010_00	Little Washita River	0.68	16.5%	81.2	20%
OK310840010060_00	Quartermaster Creek	0.78	21.1%	56.7	25%
OK311500010020_00	Red River, North Fork	0.997	1.4%	69.6	5%

[a] Calculated using the regression equation and the turbidity standard (50 NTUs)
[b] Based on the goodness-of-fit of the turbidity-TSS regression (NRMSE)

ES-2.4 Chapter 740: Implementation of OWQS for Fish and Wildlife Propagation

Chapter 740, *Implementation of Oklahoma's Water Quality Standards* (DEQ 2022) describes Oklahoma's WQS for Fish and Wildlife Propagation. The excerpt below from Chapter 740 (OAC 252:740-15-5), 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 252:730 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 252:730-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 252:740-15-4(b).

252:740-15-4. Default protocols

(b) Short term average numerical parameters.

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

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

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

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

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 - 1 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 25th flow exceedance percentile (i.e., the lower 75% of flows). Water quality samples collected under flow conditions greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis.

ES-2.5 Chapter 740: Minimum Number of Samples

Chapter 740, *Implementation of Oklahoma's Water Quality Standards* (DEQ 2022). The excerpt below from Chapter 740 [OAC 252:740-15-3(d)], stipulates the minimum number of samples to assess beneficial use.

252:740-15-3. Data requirements

(d) Minimum number of samples.

(1) Streams. Except when (f) of this Section or any of subsection (e), (h), (i), (j), (k), (l), or (m) of 252:740-15-5applies, a minimum of 10 samples shall be required to assess beneficial use support due to field parameters including but not limited to DO, pH and temperature, and due to routine water quality constituents including but not limited to coliform bacteria, dissolved solids and salts. Analyses may be aggregated to meet the 10 sample minimum requirements in non-wadable stream reaches that are 25 miles or less in length, and in wadable stream reaches that are 10 miles or less in length, if water quality conditions are similar at all sites. Provided, a minimum of 10 samples shall not be necessary if the existing samples already assure exceedance of the applicable percentage of a prescribed screening level.

Table ES - 3 shows the bacterial and turbidity TMDLs that will be developed in this report. Table ES -2 and Table ES - 1 show new listing with assessment results.

Table ES - 3 Stream and Pollutants for TMDL Development

Waterbody ID	HUC 8 Codes	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Turbidity
OK310810020020_00	11130303	Finn Creek	14.15	2033	4		X	
OK310810020050_00	11130303	Criner Creek	11.76	2033	4		X	
OK310810020170_00	11130303	Roaring Creek	18.27	2033	4			X
OK310820020010_00	11130302	Little Washita River	36.98	2033	4			X
OK310840010060_00	11130301	Quartermaster Creek	32.98	2030	3			X
OK311200000060_00	11130208	Cow Creek	25.73	2027	2		X	
OK311500010020_00	11120303	Red River, North Fork	22.72	2030	3	X		X
OK311500010020_10	11120303	Red River, North Fork	61.70	2030	3		X	

ES - 3 Pollutant Source Assessment

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

Point sources are permitted through the OPDES program. OPDES-permitted facilities that discharge treated sanitary wastewater are required to monitor *E. coli* under the current permits. These facilities are also required to monitor TSS in accordance with their permits. There are three permitted municipal point source facilities within the study area. However, they won't receive a TSS WLA because municipal wastewater treatment facilities are not considered a potential source of turbidity because they discharge organic TSS with limits for $CBOD_5$.

Nonpoint sources include those sources that cannot be identified as entering a waterbody at a specific 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 OPDES 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 - 4 summarizes the point and nonpoint sources that contribute bacteria or TSS to each respective waterbody.

ES - 4 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 LDC is a simple and efficient method to show the relationship between flow and pollutant load. LDCs graphically display the changing water quality over changing flows that may not be apparent when visualizing 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:

Table ES - 4 Summary of Potential Pollutant Sources by Category

Waterbody ID	Waterbody Name	Municipal OPDES Facility	Industrial OPDES Facility	MS4	OPDES No Discharge Facility	AFO	Mines	Construction Stormwater Permit	Multi-Sector General Permit	Nonpoint Source
OK310810020020_00	**Finn Creek**									Bacteria
OK310810020050_00	**Criner Creek**									Bacteria
OK310810020170_00	**Roaring Creek**									Turbidity
OK310820020010_00	**Little Washita River**	Ø	Ø		Ø		Ø	Ø	Ø	Turbidity
OK310840010060_00	**Quartermaster Creek**								Ø	Turbidity
OK311200000060_00	**Cow Creek**	O	Ø		Ø		Ø	Ø	Ø	Bacteria
OK311500010020_00	**Red River, North Fork**			Ø	Ø	Ø	Ø	Ø	Ø	Turbidity
				O	Ø	Ø	Ø	Ø	Ø	Bacteria
OK311500010020_10	**Red River, North Fork**				Ø	Ø	Ø	Ø	Ø	Bacteria

O : Facility present in watershed and potential as contributing pollutant source

Ø : Facility present in watershed, but not recognized as pollutant source

No facility present in watershed

1. Prepare flow duration curves for gaged and ungaged WQM stations.
2. Estimate existing loading in the waterbody using ambient bacterial water quality data.
3. Estimate loading in the waterbody using measured TSS water quality data and turbidity-converted data.
4. Use 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 facilities (WWTF) 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 following are the basic steps in developing a LDC:

1. Obtain daily flow data for the site of interest from the U.S. Geological Survey (USGS), or if unavailable, obtain projected flow from a nearby USGS site.
2. Sort the flow data and calculate the flow exceedance percentiles.
3. Obtain the water quality data.
4. For bacterial TMDLs, obtain the water quality data from the PBCR season (May 1 through September 30).
5. For turbidity TMDLs, obtain available turbidity and TSS water quality data.
6. Match the water quality observations with the flow data from the same date
7. Display a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacterial indicator.
8. Display a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS.
9. For bacterial TMDLs, display and differentiate another curve derived by plotting the geometric mean of all existing bacterial samples continuously along the full spectrum of flow exceedance percentiles which represents the observed load in the stream.

10. For turbidity TMDLs, match the water quality observations with the flow data from the same date and determine the corresponding exceedance percentile. Plot the flow exceedance percentiles and daily load observations in a load duration plot (Section 5).

ES-4.1 Bacterial LDC

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

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

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

Unit conversion factor = 24,465,525

ES-4.2 TSS LDC

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 (lbs/day) = WQ_{goal} * flow (cfs) * unit conversion factor

Where:

WQ_{goal} = waterbody specific TSS concentration derived from regression analysis results

Unit conversion factor = 5.39377

ES-4.3 LDC Summary

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading and load reductions required to meet the TMDL water quality target can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required.

Historical observations of bacteria were plotted as a separate LDC based on the geometric mean of all samples. 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 bacterial observations to a geometric mean water quality criterion in the LDC; therefore individual bacterial samples are not plotted on the LDCs.

Historical observations of TSS and/or turbidity concentrations are paired with flow data and are plotted on the LDC for a stream.

ES - 5 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. A TMDL is expressed as the sum of three elements (WLA, LA, and MOS) as described in the following mathematical equation:

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

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.

ES-5.1 Bacterial PRG

For each waterbody the TMDLs presented in this report are expressed as colonies per day across the full range of flow conditions. For information purposes, 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 geometric mean of the reduced sample values meets the corresponding bacterial geometric mean standard (126 colonies/100 mL for *E. coli* and 33 colonies/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 base-flow conditions exceed the TMDL.

Table ES - 5 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the study area.

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

Waterbody ID	Waterbody Name	Required Reduction Rate (%)	
		Enterococci	*E. coli*
OK310810020020_00	Finn Creek	-	16.6%
OK310810020050_00	Criner Creek	-	44.1%
OK311200000060_00	Cow Creek	-	71.8%
OK311500010020_00	Red River, North Fork	97.3%	-
OK311500010020_10	Red River, North Fork	-	57.2%

ES-5.2 TSS PRG

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 - 6.

Table ES - 6 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK310810020170_00	Roaring Creek	35.1%
OK310820020010_00	Little Washita River	27.9%
OK310840010060_00	Quartermaster Creek	64.6%
OK311500010020_00	Red River, North Fork	49.4%

ES-5.3 Seasonal Variation

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:

$$LA = TMDL - MOS - \sum WLA$$

Federal regulations (40 CFR § Part 130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading.

The bacterial 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.

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 consecutive period of USGS flow records when estimating flows to develop flow exceedance percentiles.

ES-5.4 MOS

Federal regulations (40 CFR § Part 130.7(c)(1)) also require that TMDLs include an MOS. 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 bacterial 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 - 2).

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

ES - 6 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 assurances" that nonpoint (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.

Reasonable assurance that nonpoint sources will meet their allocated amount in the TMDL is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. Under OAC 155:40-1-4, the OCC is declared the state's technical lead agency for NPS categories defined in Section 319 of the CWA. DEQ will work in conjunction with OCC and other federal, state, and local partners to meet the load reduction goals for NPS. All waterbodies are prioritized as part of the Unified Watershed Assessment (UWA) and that ranking will determine the likelihood of an implementation project in a watershed.

ES - 7 Public Participation

A public notice about the draft TMDL report will be sent to local newspapers, government agencies, stakeholders in the study area affected by these draft TMDLs, and stakeholders who have requested copies of all TMDL public notices. The public notice (which includes the draft 208 TMDL factsheet) and draft TMDL report will be posted at the following DEQ website: https://oklahoma.gov/deq/divisions/water-quality/watershed-planning/tmdl.html. The public will have an opportunity to review the draft TMDL report and make written comments.

The public comment period lasts 45 days. Depending on the interest and responses from the public, a public meeting may be held within the watershed affected by the TMDLs in this report. If a public meeting is held, the public will also have opportunities to ask questions and make formal oral comments at the meeting and/or submit written comments at the public meeting.

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

SECTION 1 INTRODUCTION

1.1 TMDL Program Background

As promulgated by Section 402 (aka Section 1342) of the Clean Water Act (CWA) and 40 CFR § Part 123, the U.S. Environmental Protection Agency (EPA) has delegated authority to the Oklahoma Department of Environmental Quality (DEQ) to partially oversee the National Pollutant Discharge Elimination System (NPDES) Program in the State of Oklahoma. Exceptions are agriculture (retained by State Department of Agriculture, Food, and Forestry), and the oil & gas industry (retained by the Oklahoma Corporation Commission) for which 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 (https://oklahoma.gov/content/dam/ok/en/deq/documents/deqmainresources/606.pdf)].

Section 303(d) [aka Section 1313(d)] of the CWA and 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 in-stream water quality conditions, so states can implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (EPA 1991).

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli)* and enterococci][1] and turbidity for selected waterbodies in Oklahoma Basin 3 Area. 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

[1] All future references to bacteria in this document imply these two fecal pathogen indicator bacterial groups unless specifically stated otherwise

Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (EPA 2003).

These TMDLs provide a load reduction to meet ambient water quality criterion with a given set of facts. The adoption of these TMDLs into the Water Quality Management Plan (WQMP) provides a mechanism to recalculate acceptable pollutant loads when information changes in the future. Updates to the WQMP demonstrate compliance with the water quality criterion. The updates to the WQMP are also useful when the water quality criterion changes and loading scenarios are reviewed to ensure that the predicted in-stream criterion will be met.

The purpose of this TMDL study was to establish pollutant load allocations for indicator bacteria and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and in-stream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under OPDES. 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, 2022 Integrated Report* for nonsupport of primary body contact recreation (PBCR) or Fish & Wildlife Propagation beneficial uses. The waterbodies considered for TMDL development in this report are listed in Table 1-1:

Table 1-1 TMDL Waterbodies

Waterbody Name	Waterbody ID
Finn Creek	OK310810020020_00
Criner Creek	OK310810020050_00
Roaring Creek	OK310810020170_00
Little Washita River	OK310820020010_00
Quartermaster Creek	OK310840010060_00
Cow Creek	OK311200000060_00

Waterbody Name	Waterbody ID
Red River, North Fork	OK311500010020_00
Red River, North Fork	OK311500010020_10

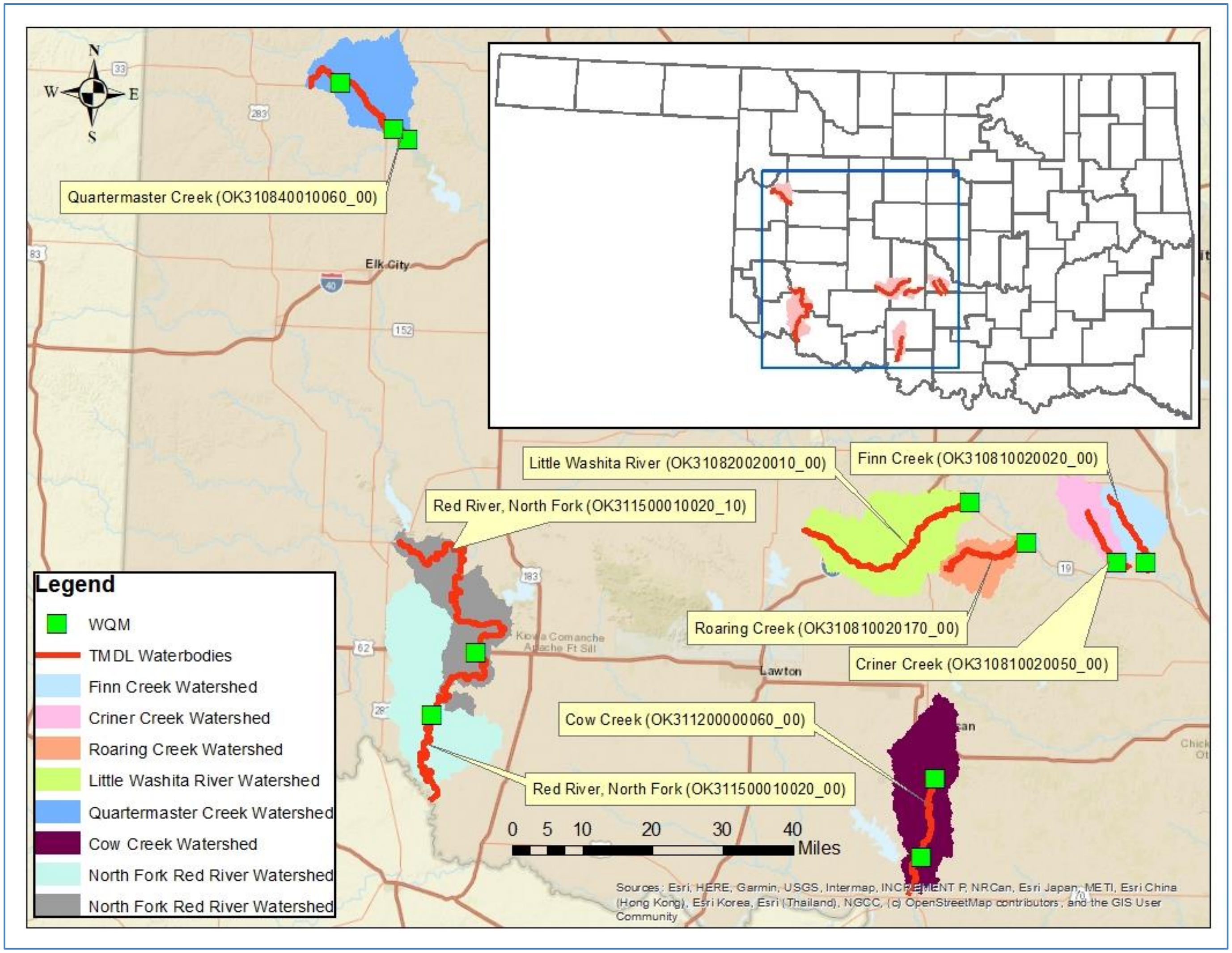
Figure 1-1 shows these Oklahoma waterbodies and their contributing watersheds. These maps also display locations of the water quality monitoring (WQM) stations used as the basis for placement of these waterbodies on the Oklahoma 303(d) list. These waterbodies and their surrounding watersheds are hereinafter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

TMDLs are required to be developed whenever elevated levels of pathogen indicator bacteria or turbidity are above the WQS numeric criterion. 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 & Wildlife Propagation use designated for each waterbody. Error! Reference source not found. provides a description of the locations of WQM stations o n the 303(d)-listed waterbodies.

Table 1-2 Water Quality Monitoring Stations used for Assessment of Streams

WQM Station	Waterbody Name	Station Location	Waterbody ID
OK310810-02-0020D	Finn Creek	Lat.: 34.86; Long.: -97.42	OK310810020020_00
OK310810-02-0050D	Criner Creek	Lat.: 34.86; Long.: -97.50	OK310810020050_00
OK310810-02-0170B	Roaring Creek	Lat.: 34.89; Long.: -97.72	OK310810020170_00
OK310820-02-0010A	Little Washita River	Lat.: 34.97; Long.: -97.87	OK310820020010_00
OK310840-01-0060B	Quartermaster Creek	Lat.: 35.68; Long.: -99.32	OK310840010060_00
OK310840-01-0060L		Lat.: 35.70; Long.: -99.36	
OKR09730-116		Lat.: 35.79; Long.: -99.50	
OK311200-00-0060L	Cow Creek	Lat.: 34.25; Long.: -97.97	OK311200000060_00
OKR09730-098		Lat.: 34.40; Long.: -97.94	
311500010020-002AT	Red River, North Fork	Lat.: 34.51; Long.: -99.21	OK311500010020_00
311500010020-001AT	Red River, North Fork	Lat.: 34.64; Long.: -99.10	OK311500010020_10

Figure 1-1 Watersheds in Oklahoma Basin 3 Study Area Not Supporting Primary Body Contact Recreation, Agriculture, or Fish & Wildlife Propagation Beneficial Uses



1.2 Watershed Description

1.2.1 General

The study area is located in the north-central portion of Oklahoma. The waterbodies and their watersheds addressed in this report are scattered over 14 counties in Table 1-3. These counties are part of the Central Great Plains and Cross Timbers Level III ecoregions (Woods, A.J, et al 2005). Table 1-3, derived from the 2020 U.S. Census, demonstrates that the counties in which these watersheds are located are mostly sparsely populated (U.S. Census Bureau 2020). Table 1-4 lists major towns and cities located in each watershed.

Table 1-3 County Population and Density

County Name	Population (2020 Census)	Population Density (per square mile)
Caddo	26,945	20.9
Comanche	121,125	111.7
Custer	28,516	28.5
Dewey	4,484	4.4
Garvin	25,656	31.5
Grady	54,795	49.6
Greer	5,491	8.5
Jackson	24,785	30.8
Jefferson	5,337	6.9
Kiowa	8,509	8.3
McClain	41,662	71.8
Roger Mills	3,442	3.0
Stephens	42,848	48.1
Tillman	6,968	7.9

Table 1-4 Major Municipalities by Watershed

Waterbody Name	Waterbody ID	Municipalities
Finn Creek	OK310810020020_00	Maysville, Stealy
Criner Creek	OK310810020050_00	Criner, Lindsay, Maysville
Roaring Creek	OK310810020170_00	Bray, East Roaring Creek, Rush Springs
Little Washita River	OK310820020010_00	Cyril, East Minnekah, Fletcher, Laverty, Rocky Ford, Rush Springs
Quartermaster Creek	OK310840010060_00	Hammon, Leedey, McClure, Strong City
Cow Creek	OK311200000060_00	Comanche, Corum, Duncan, Empire City
Red River, North Fork	OK311500010020_00	Altus, Elmer, Frederick, Headrick, Tipton

Waterbody Name	Waterbody ID	Municipalities
Red River, North Fork	OK311500010020_10	Frederick, Headrick, Tipton, Long Mountain, Roosevelt, Warren

1.2.2 Climate

Table 1-5 summarizes the average annual precipitation at Mesonet Station near each Oklahoma waterbody derived from current and past 15 years daily data. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 25.6 and 37.1 inches (Oklahoma Climatological Survey 2019).

Table 1-5 Average Annual Precipitation by Watershed

Waterbody Name	Waterbody ID	Mesonet Station	Average Annual Precipitation (inches)
Finn Creek	OK310810020020_00	Washington	37.1
Criner Creek	OK310810020050_00	Washington	37.1
Roaring Creek	OK310810020170_00	Acme	34.1
Little Washita River	OK310820020010_00	Acme	34.1
Quartermaster Creek	OK310840010060_00	Butler	25.6
Cow Creek	OK311200000060_00	Waurika	34.9
Red River, North Fork	OK311500010020_00	Tipton	25.7
Red River, North Fork	OK311500010020_10	Mangum	26.9

1.2.3 Land Use

Table 1-6 summarizes 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) National Land Cover Dataset (USGS 2021). The percentages provided in Table 1-6 are rounded so in some cases may not total exactly 100%. The land use categories are displayed in Figure 1-2. The two most dominant land use categories throughout the study area are Grassland/Herbaceous and Cultivated Crops. The watersheds targeted for TMDL development in this study area range in size from 42,432.4 acres (Finn Creek, OK310810020020_00) to 163,207.5 acres (Red River, North Fork, OK311500010020_00).

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. Not all of the waterbodies in this study area have historical flow data available. 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. 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 conditions recorded during the time of water quality sampling for turbidity are included in Appendix A along with corresponding water quality 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 Table B-1.

Figure 1-2 Land Use Map

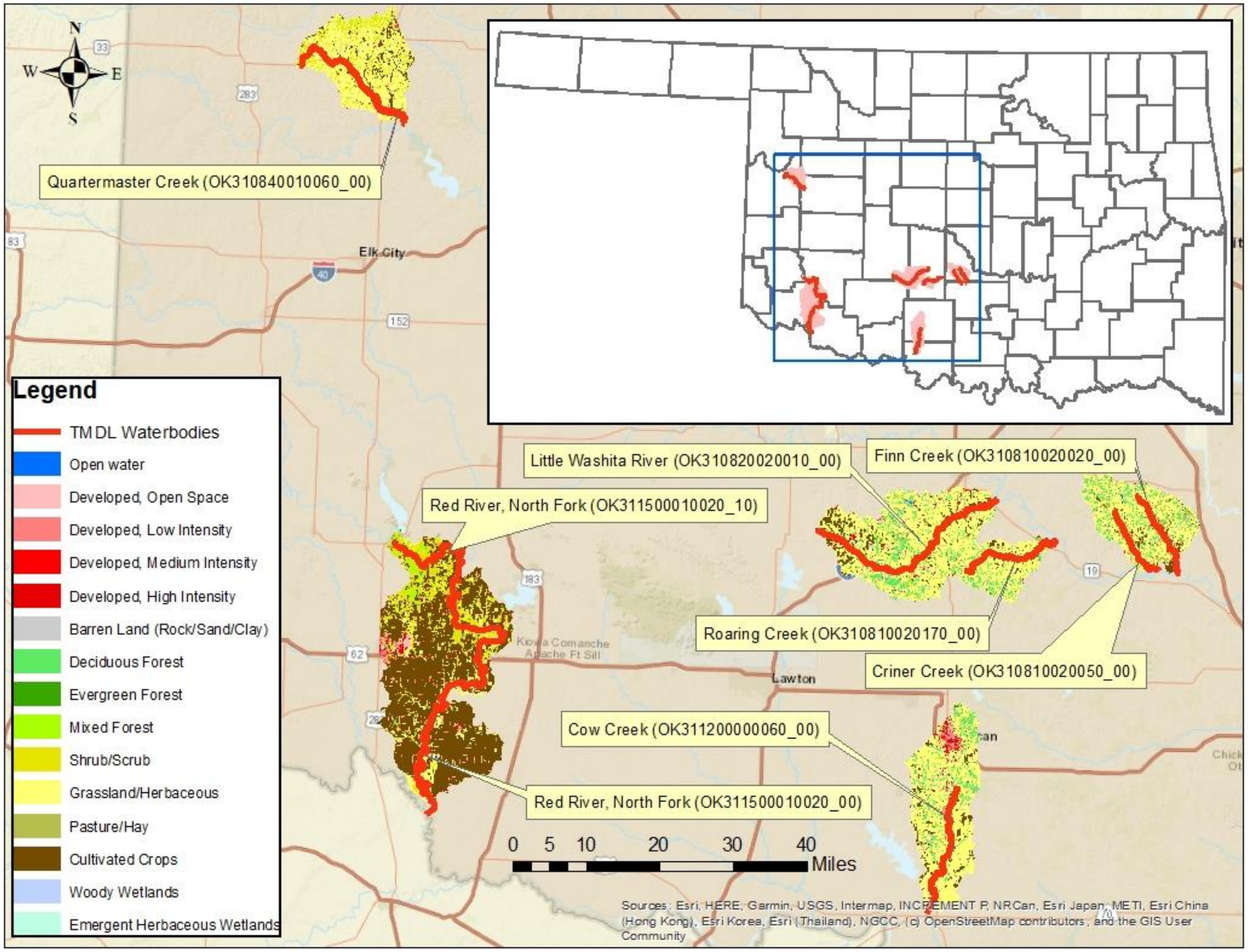


Table 1-6 Land Use Summaries by Watershed

Landuse Category	Watershed			
	Finn Creek	Criner Creek	Roaring Creek	Little Washita River
Waterbody ID	OK310810020020_00	OK310810020050_00	OK310810020170_00	OK310820020010_00
Open Water	525.9	400.1	306.0	822.0
Developed, Open Space	1,129.8	1,117.6	880.1	5,014.6
Developed, Low Intensity	229.5	231.0	219.2	1,611.7
Developed, Medium Intensity	115.7	129.4	217.0	1,434.5
Developed, High Intensity	12.8	14.0	82.8	298.5
Bare Rock/Sand/Clay	16.3	18.0	64.9	294.4
Deciduous Forest	5,611.0	6,865.2	6,419.4	21,609.7
Evergreen Forest				503.3
Mixed Forest	0.8		0.9	92.6
Shrub/Scrub	198.3	290.4	464.5	1,639.4
Grasslands/Herbaceous	24,552.0	26,426.5	30,316.6	103,505.0
Pasture/Hay	5,489.9	3,097.0	219.4	1,045.9
Cultivated Crops	4,511.1	4,115.2	3,410.0	16,687.8
Woody Wetlands	1.5	1.9	2.4	19.9
Emergent Herbaceous Wetlands	37.8	32.4	17.5	89.7
Total (Acres)	**42,432.4**	**42,738.7**	**42,620.7**	**154,669.0**
Open Water	1.2%	0.9%	0.7%	0.5%
Developed, Open Space	2.7%	2.6%	2.1%	3.2%
Developed, Low Intensity	0.5%	0.5%	0.5%	1.0%
Developed, Medium Intensity	0.3%	0.3%	0.5%	0.9%
Developed, High Intensity	0.03%	0.03%	0.2%	0.2%
Bare Rock/Sand/Clay	0.04%	0.04%	0.2%	0.2%
Deciduous Forest	13.2%	16.1%	15.1%	14.0%
Evergreen Forest				0.3%
Mixed Forest	0.002%		0.002%	0.1%
Shrub/Scrub	0.5%	0.7%	1.1%	1.1%
Grasslands/Herbaceous	57.9%	61.8%	71.1%	66.9%
Pasture/Hay	12.9%	7.2%	0.5%	0.7%
Cultivated Crops	10.6%	9.6%	8.0%	10.8%
Woody Wetlands	0.004%	0.004%	0.01%	0.01%
Emergent Herbaceous Wetlands	0.1%	0.1%	0.04%	0.1%
Total (%):	**100.0**	**100.0**	**100.0**	**100.0**

Landuse Category	Watershed			
	Quartermaster Creek	Cow Creek	Red River, North Fork	Red River, North Fork
Waterbody ID	**OK310840010060_00**	**OK311200000060_00**	**OK311500010020_00**	**OK311500010020_10**
Open Water	384.4	790.0	590.4	1,287.7
Developed, Open Space	2,795.0	5,650.0	6,401.4	3,015.7
Developed, Low Intensity	447.8	3,467.2	3,468.1	659.7
Developed, Medium Intensity	242.7	2,509.4	1,651.6	257.6
Developed, High Intensity	43.3	938.5	844.9	12.2
Bare Rock/Sand/Clay	10.8	28.9	308.9	362.1
Deciduous Forest	2.2	17,013.0	223.1	260.2
Evergreen Forest	227.2	6.1	13.2	90.7
Mixed Forest	1,550.6	10.2	1,888.3	7,530.9
Shrub/Scrub	15,682.7	1,306.6	13,412.3	34,449.7
Grasslands/Herbaceous	65,483.8	83,925.8	17,249.1	17,054.5
Pasture/Hay	40.6	407.6	518.5	103.8
Cultivated Crops	11,495.1	8,148.9	114,835.9	55,714.1
Woody Wetlands	9.7	30.8	703.9	999.6
Emergent Herbaceous Wetlands	45.7	72.4	1,097.9	756.5
Total (Acres)	**98,461.6**	**124,305.4**	**163,207.5**	**122,555.0**
Open Water	0.4%	0.6%	0.4%	1.1%
Developed, Open Space	2.8%	4.5%	3.9%	2.5%
Developed, Low Intensity	0.5%	2.8%	2.1%	0.5%
Developed, Medium Intensity	0.2%	2.0%	1.0%	0.2%
Developed, High Intensity	0.04%	0.8%	0.5%	0.010%
Bare Rock/Sand/Clay	0.01%	0.02%	0.2%	0.3%
Deciduous Forest	0.002%	13.7%	0.1%	0.2%
Evergreen Forest	0.2%	0.005%	0.01%	0.07%
Mixed Forest	1.6%	0.01%	1.2%	6.1%
Shrub/Scrub	15.9%	1.1%	8.2%	28.1%
Grasslands/Herbaceous	66.5%	67.5%	10.6%	13.9%
Pasture/Hay	0.0%	0.3%	0.3%	0.1%
Cultivated Crops	11.7%	6.6%	70.4%	45.5%
Woody Wetlands	0.01%	0.02%	0.4%	0.82%
Emergent Herbaceous Wetlands	0.05%	0.1%	0.7%	0.62%
Total (%):	**100.0**	**100.0**	**100.0**	**100.0**

SECTION 2 PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 252 of the Oklahoma Administrative Code contains Oklahoma Water Quality Standards (WQS) and implementation procedures (DEQ 2022). The Oklahoma Department of Environmental Quality (DEQ) has statutory authority and responsibility concerning establishment of State WQS, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the DEQ 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 (DEQ 2022). An excerpt of the Oklahoma WQS (Title 252) summarizing the State of Oklahoma Antidegradation Policy is provided in Appendix C. Table 2-1, an excerpt from the 2022 Integrated Report (DEQ 2022), lists beneficial uses designated for each impaired stream segment in the study area. The beneficial uses include:

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

Table 2-1 Designated Beneficial Uses for Each Stream Segment in the Study Area

Waterbody ID	Waterbody Name	AES	AG	WWAC	FISH	PBCR	PPWS	EWS
OK310810020020_00	**Finn Creek**	F	F	F	X	N	I	
OK310810020050_00	**Criner Creek**	F	F	F	X	N	I	
OK310810020170_00	**Roaring Creek**	F	F	N	X	X	I	
OK310820020010_00	**Little Washita River**	F	N	N	X	F	I	
OK310840010060_00	**Quartermaster Creek**	F	N	N	X	F	I	
OK311200000060_00	**Cow Creek**	I	F	N	F	N		F
OK311500010020_00	**Red River, North Fork**	F	N	N	F	I	F	

Waterbody ID	Waterbody Name	AES	AG	WWAC	FISH	PBCR	PPWS	EWS
OK311500010020_10	**Red River, North Fork**	F	N	N	F	N	I	
F – Fully supporting information		**N** – Not supporting	**I** – Insufficient	**X** – Not assessed	Source: **DEQ 2016 Integrated Report**			

2.1.1 Chapter 730: Definition of PBCR and Bacterial WQSs

The definition of PBCR and the bacterial WQSs for PBCR are summarized by the following excerpt from Title 252, Chapter 730-5-16 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 252:730-5-16 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.

2.1.2 Chapter 740: Implementation of OWQS for PBCR

To implement Oklahoma's WQS for PBCR, DEQ promulgated Chapter 740, *Implementation of Oklahoma's Water Quality Standards* (DEQ 2022). The following excerpt from Chapter 740 (OAC 252:740-15-6), 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 252:730 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 252:740-15-3(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 252:740-15-3(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 252:740-15-3(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 252:740-15-3(c).*

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 (DEQ 2022).

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.

2.1.3 Chapter 730: Criteria for Turbidity

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 (DEQ 2022). The numeric criteria for turbidity to maintain and protect the use of “Fish and Wildlife Propagation” from Title 252:730-5-12(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 NTUs; 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.*

2.1.4 Chapter 740: Implementation of OWQS for Fish and Wildlife Propagation

Chapter 740, *Implementation of Oklahoma’s Water Quality Standards* (DEQ 2022) describes Oklahoma’s WQS for Fish and Wildlife Propagation. The following excerpt (OAC 252:740-15-5) 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 252:730 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 252:730-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 252:740-15-4(b).

252:740-15-4. Default protocols

(b) Short term average numerical parameters.

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

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

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

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

2.1.5 Chapter 740: Minimum Number of Samples

Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (DEQ 2022). The excerpt below from Chapter 740 (OAC 252:740-15-3(d)), stipulates the minimum number of samples to assess beneficial use.

252:740-15-3. Data requirements

(d) Minimum number of samples.

(1) Streams. Except when (f) of this Section or any of subsection (e), (h), (i), (j), (k), (l), or (m) of 785:46-15-5 applies, a minimum of 10 samples shall be required to assess beneficial use support due to field parameters including but not limited to DO, pH and temperature, and due to routine water quality constituents including but not limited to coliform bacteria, dissolved solids and salts. Analyses may be aggregated to meet the 10 sample minimum requirements in non-

wadable stream reaches that are 25 miles or less in length, and in wadable stream reaches that are 10 miles or less in length, if water quality conditions are similar at all sites. Provided, a minimum of 10 samples shall not be necessary if the existing samples already assure exceedance of the applicable percentage of a prescribed screening level.

2.1.6 Prioritization of TMDL Development

Table 2-2 summarizes the PBCR and WWAC use attainment status and the bacterial 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 bacterial and/or turbidity impairments that affect the PBCR and WWAC beneficial uses.

After the 303(d) list is compiled, DEQ assigns a four-level rank to each of the Category 5a waterbodies. This rank helps in determining the priority for TMDL development. The rank is based on criteria developed using the procedure outlined in the 2022 Integrate Report (pp. 63-64). The TMDL prioritization point totals calculated for each watershed were broken down into the following four priority levels:[1]

Priority 1 watersheds - above the 90th percentile

Priority 2 watersheds - 70th to 90th percentile

Priority 3 watersheds - 40th to 70th percentile

Priority 4 watersheds - below the 40th percentile

Each waterbody on the 2022 303(d) list has been assigned a potential date of TMDL development based on the priority level for the corresponding HUC 11 watershed.

Priority 1 watersheds are targeted for TMDL development within the next two years.

Other priority watersheds are established for TMDL development within the next five years for Priority 2, eight years for Priority 3, and eleven years for Priority 4.

[1] Appendix C, 2022 Integrated Report

Table 2-2 Excerpt from the 2022 Integrated Report – Oklahoma 303(d) List of Impaired Waters

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
OK310810020020_00	Finn Creek	14.15	2033	4		5a	N		F
OK310810020050_00	Criner Creek	11.76	2033	4		5a	N		F
OK310810020170_00	Roaring Creek	18.27	2033	4			F	5a	N
OK310820020010_00	Little Washita River	36.98	2033	4			F	5a	N
OK310840010060_00	Quartermaster Creek	32.98	2030	3			F	5a	N
OK311200000060_00	Cow Creek	25.73	2027	2		5a	N	4a	N
OK311500010020_00	Red River, North Fork	22.72	2030	3			I	5a	N
OK311500010020_10	Red River, North Fork	61.7	2030	3	4a	5a	N		N*

ENT = Enterococci; N = Not attaining; I = Insufficient information

Source: 2022 Integrated Report, DEQ 2022

4a: TMDL has been completed.
5a: TMDL is underway or will be scheduled.
*: WWAC impaired due to selenium and macroinvertebrate bioassessment

2.2 Problem Identification

This subsection summarizes water quality data caused by elevated levels of impairment.

2.2.1 Bacterial Data Summary

Table 2-3 summarizes water quality data collected during primary contact recreation season from the WQM stations between 2006 and 2021 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 2022 303(d) list (DEQ 2022). Water quality data from the primary contact recreation season are provided in Appendix A. For the data collected between 2006 and 2021, evidence of nonsupport of the PBCR use based on *E. coli* or enterococci exceedances was observed in six waterbodies: Finn Creek (OK310810020020_00), Cow Creek (OK311200000060_00), and Red River, North Fork (OK311500010020_10) for *E. coli* and enterococci impairments, and Quartermaster Creek (OK310840010060_00) and Red River, North Fork (OK311500010020_00) for enterococci impairment, and Criner Creek (OK310810020050_00) for *E. coli* impairment. Rows highlighted in green in Table 2-3 required TMDLs.

Enterococci impairment in Finn Creek (OK310810020020_00), Quartermaster Creek (OK310840010060_00), Cow Creek (OK311200000060_00), and Red River, North Fork (OK311500010020_10) within the study area will be removed from further consideration for bacterial TMDL development in this report because those impairments were handled in previous TMDLs (2007 Bacteria TMDL for the Lower Red River Area, 2007 Bacteria TMDL for the Washita River, and 2008 Bacteria TMDL for the Upper Red River Area). In addition, detailed review of the data collected in 2013 for Red River, North Fork (OK311500010020_00) indicated an impairment of enterococci.

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 2006 and 2022 for turbidity. However, as stipulated in Title *252:730-5-12 (f)(7)(C),* numeric criteria for turbidity only apply under base flow conditions. While the base flow condition is not specifically defined in the Oklahoma WQS, DEQ considers base flow conditions to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75% 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 greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. Using this qualified data set, five of the eight waterbodies identified in Table 2-1 indicate nonsupport of the Fish and Wildlife Propagation use based on turbidity levels observed in the waterbody so TMDLs were developed for them, except Cow Creek (OK311200000060_00). Cow Creek's turbidity TMDL was developed in 2010 Bacteria and Turbidity TMDLs for the Red River. Therefore, turbidity TMDL will be developed for Roaring Creek (OK310810020170_00), Little Washita River (OK310820020010_00), Quartermaster Creek (OK310840010060_00), and Red River, North Fork (OK311500010020_00).

Table 2-6 summarizes water quality data collected from the WQM stations between 2015 and 2018 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. The water quality data analyzed for turbidity and TSS are provided in Appendix A.

2.3 Water Quality Targets

The Code of Federal Regulations (40 CFR § Part 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 colonies/100 mL and 33 colonies/100 mL, respectively. The TMDL for bacteria will incorporate an explicit 10% margin of safety.

An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (DEQ 2022). According to the Oklahoma WQS (OAC 252:730), the turbidity criterion for streams with WWAC beneficial use is 50 NTUs (DEQ 2022). 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 NTUs. 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.

Table 2-3 Summary of Assessment of Indicator Bacterial Samples from Primary Body Contact Recreation Subcategory Season May 1 to September 30, 2006 - 2021

Waterbody ID	Waterbody Name	Indicator	Number of Samples	Data Period	Geometric Mean Conc (colonies/100 mL)	Assessment Results / Recommended Actions
OK310810020020_00	Finn Creek	ENT	12	2006 - 2010	333.0	Impaired / 2012 TMDL
		EC	10	2019 - 2021	136.0	Impaired / TMDL
OK310810020050_00	Criner Creek	EC	10	2019 - 2021	202.8	Impaired / TMDL
OK310810020170_00	Roaring Creek	EC	10	2019 - 2020	47.2	Attain WQS / No TMDL
OK310820020010_00	Little Washita River	EC	10	2019 - 2020	34.1	Attain WQS / No TMDL
OK310840010060_00	Quartermaster Creek	ENT	13	2006 - 2010	296.7	Impaired / 2007 TMDL
		EC	10	2019 - 2020	80.9	Attain WQS / No TMDL
OK311200000060_00	Cow Creek	ENT	12	2006 - 2010	386.6	Impaired / 2007 TMDL
		EC	12	2006 - 2010	401.9	Impaired / TMDL
OK311500010020_00	Red River, North Fork	ENT	3	2013	41.1	Impaired / List in 303(d) and TMDL
		EC	4	2013	34.0	Insufficient data / Additional data request
OK311500010020_10	Red River, North Fork	ENT	10	2006 - 2013	159.1	Impaired / 2008 TMDL
		EC	11	2006 - 2013	264.9	Impaired / TMDL

Enterococci (ENT) water quality criterion = Geometric Mean of 33 colonies/100 mL
E. coli (EC) water quality criterion = Geometric Mean of 126 colonies/100 mL
TMDLs will be developed for waterbodies that are highlighted

Table 2-4 Summary of All Turbidity Samples, 2006 - 2022

Waterbody ID	Waterbody Name	WQM Stations	Number of Turbidity Samples	Number of Samples Greater than 50 NTUs	% Samples Exceeding Criterion	Average Turbidity (NTUs)
OK310810020020_00	Finn Creek	OK310810-02-0020D	22	4	18.2%	24.8
OK310810020050_00	Criner Creek	OK310810-02-0050D	22	3	13.6%	27.3
OK310810020170_00	Roaring Creek	OK310810-02-0170B	20	3	15.0%	39.0
OK310820020010_00	Little Washita River	OK310820-02-0010A	20	3	15.0%	59.6
OK310840010060_00	Quartermaster Creek	OK310840-01-0060B	20	4	20.0%	41.5
OK311200000060_00	Cow Creek	OK311200-00-0060L	23	7	30.4%	54.0
OK311500010020_00	Red River, North Fork	311500010020-002AT	18	10	55.6%	164.6
OK311500010020_10	Red River, North Fork	311500010020-001AT	26	7	26.9%	125.6

Table 2-5 Summary of Turbidity Samples Excluding High Flow Samples, 2006 - 2022

Waterbody ID	Waterbody Name	Data Period	Number of Turbidity Samples	Number of Samples Greater than 50 NTUs	% Samples Exceeding Criterion	Average Turbidity (NTUs)	Assessment Results / Recommended Actions
OK310810020020_00	Finn Creek	2019 - 2021	19	0	0%	5.0	Attain WQS / No TMDL
OK310810020050_00	Criner Creek	2019 - 2021	11	0	0%	3.7	Attain WQS / No TMDL
OK310810020170_00	Roaring Creek	2019 - 2021	19	2	10.5%	15.7	Impaired / TMDL
OK310820020010_00	Little Washita River	2019 - 2021	19	2	10.5%	57.0	Impaired / TMDL
OK310840010060_00	Quartermaster Creek	2019 - 2021	18	3	16.7%	26.7	Impaired / TMDL
OK311200000060_00	Cow Creek	2006 - 2011	19	3	15.8%	31.1	Impaired / 2010 TMDL
OK311500010020_00	Red River, North Fork	2016 -2019	12	5	41.7%	115.9	Impaired / TMDL
OK311500010020_10	Red River, North Fork	2018 - 2022	17	0	0%	8.3	Attain WQS / No TMDL

Table 2-6 Summary of All TSS Samples, 2006 - 2022

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK310810020020_00	Finn Creek	OK310810-02-0020D	19	36.5
OK310810020050_00	Criner Creek	OK310810-02-0050D	19	48.2
OK310810020170_00	Roaring Creek	OK310810-02-0170B	18	64.6
OK310820020010_00	Little Washita River	OK310820-02-0010A	18	95.3
OK310840010060_00	Quartermaster Creek	OK310840-01-0060B	18	53.7
OK311200000060_00	Cow Creek	OK311200-00-0060L	23	61.9
OK311500010020_00	Red River, North Fork	311500010020-002AT	17	165.7
OK311500010020_10	Red River, North Fork	311500010020-001AT	23	128.5

Table 2-7 Summary of TSS Samples Excluding High Flow Samples, 2006 - 2022

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK310810020020_00	Finn Creek	OK310810-02-0020D	9	11.3
OK310810020050_00	Criner Creek	OK310810-02-0050D	9	10.0
OK310810020170_00	Roaring Creek	OK310810-02-0170B	17	19.0
OK310820020010_00	Little Washita River	OK310820-02-0010A	17	95.4
OK310840010060_00	Quartermaster Creek	OK310840-01-0060B	16	36.4
OK311200000060_00	Cow Creek	OK311200-00-0060L	18	17.6
OK311500010020_00	Red River, North Fork	311500010020-002AT	11	94.8
OK311500010020_10	Red River, North Fork	311500010020-001AT	16	32.9

SECTION 3 POLLUTANT SOURCE ASSESSMENT

3.1 Overview

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 OPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point source dischargers are permitted through the OPDES program. OPDES-permitted facilities that discharge treated wastewater are currently required to monitor for *E. coli* 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 natural sources or 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 OPDES 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 bacterial 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 of bacteria were considered in this report:

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

The 2022 Integrated Water Quality Assessment Report (DEQ 2022) listed potential sources of turbidity as:

- Grazing in Riparian or Shoreline Zones
- Non-irrigated Crop Production
- Rangeland Grazing
- Unknown sources

The following discussion describes what is known regarding point and nonpoint sources of bacteria and/or TSS in the impaired watersheds. Where information was available on point and nonpoint sources of indicator bacteria and/or TSS, data were provided and summarized as part of each category.

3.2 OPDES-Permitted Facilities

Under 40 CFR § Part 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. OPDES-permitted facilities classified as point sources that may contribute bacterial or TSS loading into the watersheds include:

- Continuous Point Source Dischargers
  - OPDES municipal wastewater treatment facilities (WWTF)
  - OPDES Industrial WWTF Discharges
- OPDES-regulated stormwater discharges
  - Municipal separate storm sewer system (MS4) discharges
    - Phase 1 MS4
    - Phase 2 MS4 – OKR04
  - Multi-sector general permits (OKR05)
    - Regulated Sector J Discharges
    - Rock, Sand and Gravel Quarries
  - Construction stormwater discharges (OKR10)
- No-discharge WWTF
- Sanitary sewer overflow (SSO)
- AgPDES Animal Feeding Operations (AFO)
  - Concentrated Animal Feeding Operations (CAFO)
  - Swine Feeding Operation (SFO)
  - Poultry Feeding Operation (PFO)

No OPDES-permitted facilities were in Finn Creek (OK310810020020_00), Criner Creek (OK310810020050_00), and Roaring Creek (OK310810020170_00) watersheds. There are a few OPDES-permitted facilities in each of the remaining five watersheds in the study area.

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 bacterial 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. There are two CAFOs in the study area.

Table 3-1 Point Source Discharges in the Study Area

TMDL WB	OPDES Permit No.	Facility	SIC code	Facility Type	Design Flow (mgd)	Monthly / Daily E. coli colonies /100 mL	Monthly / Weekly TSS mg/L	Expiration Date	Notes
Little Washita River OK310820020010_00	WD19-002	Georgia-Pacific Gypsum LLC-Fletcher Operations	3275	Surface Impoundments	-	N/A	N/A	9/30/2024	No discharge from 10/1/2019
	OK0041467	Town of Cyril	4952	Lagoon	0.135	May: 126/406 *E. coli*	30/90	1/31/2027	
Cow Creek OK311200000060_00	OK0031763	Comanche WWT	4952	Lagoon	0.21	May – Sep: 126/406 *E. coli*	30/90	7/31/2026	
	OK0100498	Halliburton Energy Services, Inc.	4959	Ion Exchange	0.015	N/A	N/A	11/30/2026	
	OK0100722	Phillips 66 Company	1311	Multi-stage filter	0.72	N/A	-/41	6/30/2024	
	OKG110071	Dolese Bros. Co.- Duncan							Termination on 12/31/2021
Red River, North Fork OK311500010020_00	OK0028037	The City of Altus (SE WDS)	4952	Activated Sludge	3.5	May – Sep: 126/406 *E. coli*	15/22.5	6/30/2024	

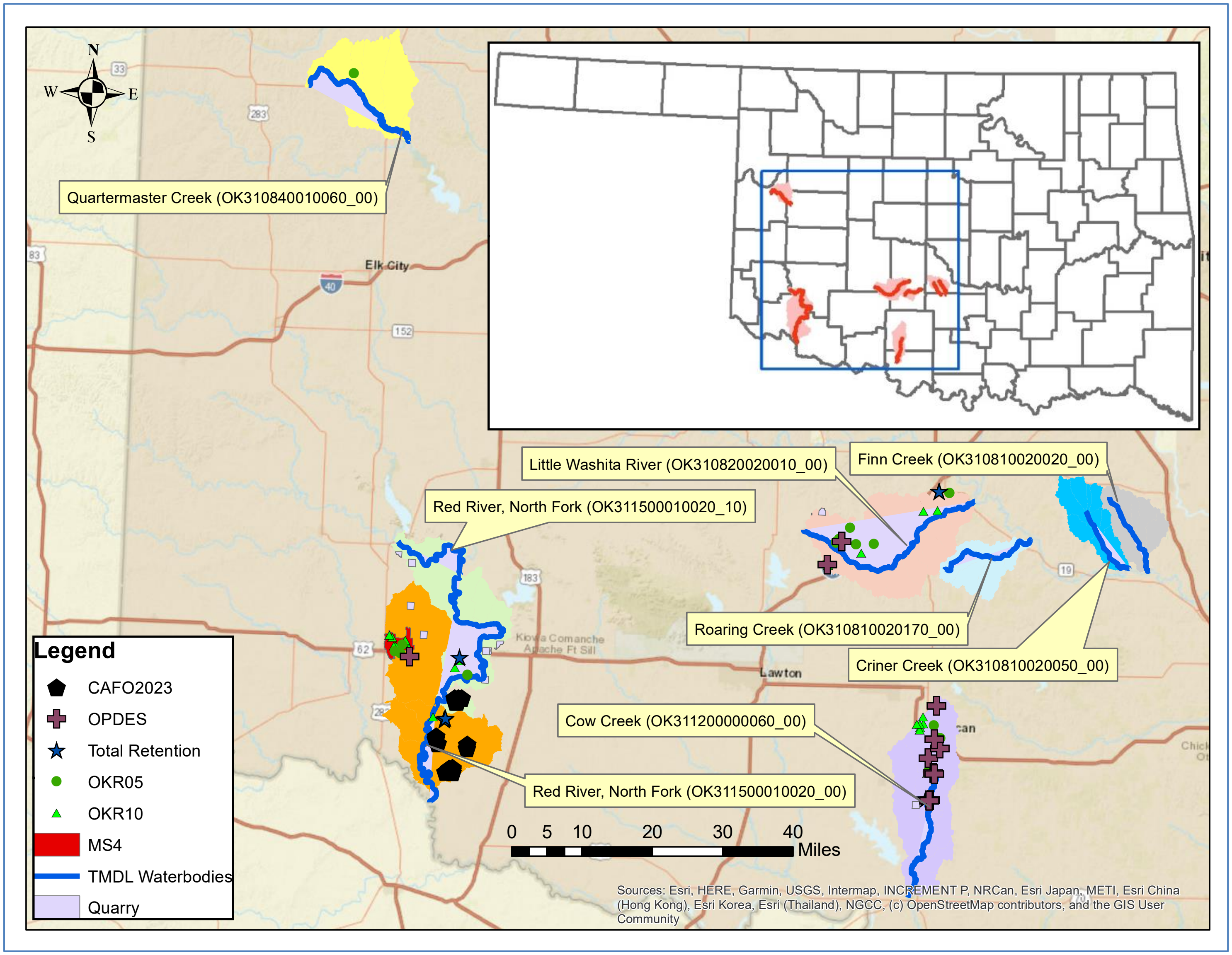
Table 3-2 Construction Permits Summary

Watershed	Company Name	County	Permit ID	NOI Date	Receiving Water
Little Washita River OK310820020010_00	OBC Inc	Caddo	OKR1027032	4/25/2018	Little Washita River OK310820020010_00
	Sewell Bros Inc	Grady	OKR1031565	10/26/2020	
	Georgia-Pacific Gypsum LLC	Comanche	OKR1031639	11/18/2020	
	Southwestern Bell Telephone Company AT&T Oklahoma	Grady	OKR1031858	2/10/2021	
Cow Creek OK311200000060_00	MJ Lewis & Associates Inc	Stephens	OKR1021600	4/4/2018	Claridy Creek OK311200000110_00
	GHD Services Inc		OKR1027850	6/6/2018	
	WW Builders Inc		OKR1028300	12/17/2018	
	GDN LLC		OKR1028754	1/29/2018	
	GE Johnson Construction		OKR1029681	11/19/2018	
	Southwestern Bell Telephone Company ATT Oklahoma co Apex Companies		OKR1030494	10/7/2019	
	Schiralli Construction Corp		OKR1031401	9/8/2020	
	4D Construction LLC		OKR1031672	11/30/2020	
Red River, North Fork OK311500010020_00	Bridge Co Contractors Inc	Jackson	OKR1031073	4/28/2020	Red River, North Fork OK311500010020_00
	Nassaney Land Company		OKR1026359	4/17/2018	Unnamed Tributary (OK311500010055_00) of Stinking Creek
	SGS LLC		OKR1028433	12/15/2017	
	Braddock Development Company LLC		OKR1029147	6/14/2018	
	Terra Construction Inc		OKR1029798	1/23/2019	
	Hutchinson Oil Co		OKR1030224	7/12/2019	
	Korte Construction Company		OKR1030842	2/25/2020	
	SGS LLC		OKR1031906	3/2/2021	
	Will Properties LLC		OKR109502	7/27/2018	
Red River, North Fork OK311500010020_10	Oklahoma Transmission Company	Jackson	OKR1031374	8/20/2020	OK311500010023_00 Maxwell's Creek
	Public Service Company of Oklahoma		OKR1031175	6/17/2020	
	Sewell Bros Inc		OKR1031661	11/23/2020	

Table 3-3 Multi-Sector General Permits Summary

Watershed	Company Name	County	Permit ID	NOI Date	SIC	Receiving Water
Little Washita River OK310820020010_00	ACG Materials	Caddo	OKR052517	10/1/2019	1499	McCarty Creek (OK310820020110_00)
Little Washita River OK310820020010_00	ACG Materials	Caddo	OKR052519	10/1/2019	1481	Little Washita River (OK310820020010_00)
Little Washita River OK310820020010_00	ACG Materials	Caddo	OKR052522	11/14/2017	4013	Gladys Creek (OK310820020150_00)
Little Washita River OK310820020010_00	Midwest Cooling Towers Inc	Grady	OKR052689	11/28/2017	2491	Patrick's Trib (OK310820020012_00)
Little Washita River OK310820020010_00	Cogburn Metals LLC	Caddo	OKR053571	11/8/2018	5093	Chetonia Creek (OK310820020120_00)
Little Washita River OK310820020010_00	Valence Drilling Fluids LLC	Caddo	OKR053635	2/4/2019	1389	Little Washita River (OK310820020010_00)
Little Washita River OK310820020010_00	Georgia-Pacific Gypsum LLC	Comanche	OKR053640	3/19/2019	3275	Little Washita River (OK310820020010_00)
Little Washita River OK310820020010_00	Stellar Drilling Fluids LLC	Caddo	OKR053808	6/8/2020	1389	Little Washita River (OK310820020010_00)
Quartermaster Creek OK310840010060_00	OneOK Field Services LLC	Roger Mills	OKR053267	9/26/2017	1389	Quartermaster Creek (OK310840010060_00)
Cow Creek OK311200000060_00	Halliburton Energy Services Inc	Stephens	OKR050027	10/17/2017	3533	Willow Creek (OK311200000120_00)
Cow Creek OK311200000060_00	National Oil Well Varco LP	Stephens	OKR050821	12/5/2017	3533	Unnamed Tributary (OK311200000160_00) of East Cow Creek
Cow Creek OK311200000060_00	Halliburton Energy Services Inc	Stephens	OKR050845	1/2/2018	1389	Unnamed Tributary (OK311200000160_00) of East Cow Creek
Cow Creek OK311200000060_00	BELL PROCESSING, INC.	Stephens	OKR051103	2/2/2018	5093	Willow Creek (OK311200000120_00)
Cow Creek OK311200000060_00	Sellers Auto & Truck Sales	Stephens	OKR051106	12/8/2017	5015	Claridy Creek (OK311200000110_00)
Cow Creek OK311200000060_00	Halliburton Energy Services Inc	Stephens	OKR053283	10/4/2017	1389	Unnamed Tributary (OK311200000160_00) of East Cow Creek
Red River, North Fork OK311500010020_00	Bar-S Foods Company	Jackson	OKR050525	1/22/2018	2011	Unnamed Tributary (OK311500010055_00) of Stinking Creek
Red River, North Fork OK311500010020_00	United States Air Force	Jackson	OKR050947	1/9/2018	4581	Unnamed Tributary (OK311500010055_00) of Stinking Creek
Red River, North Fork OK311500010020_00	United Parcel Service, Inc	Jackson	OKR051093	11/29/2017	4512	Unnamed Tributary (OK311500010055_00) of Stinking Creek
Red River, North Fork OK311500010020_10	T&G Construction Inc	Jackson	OKR053575	4/1/2019	1442	Red River, North Fork (OK311500010020_10)

Figure 3-1 Location of OPDES-Permitted Facilities and AgPDES-Permitted AFOs in the Study Area



3.2.1 Continuous Point Source Dischargers

Continuous point source discharges, such as WWTFs, 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 WWTFs could result in discharge of elevated concentrations of bacteria or 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 WWTFs receiving primarily domestic sewage 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 such WWTFs 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. Therefore, TSS in domestic wastewater will be considered to be organic suspended solids and their limit will be determined based on the presence of Biochemical Oxygen Demand (BOD) or Carbonaceous Biochemical Oxygen Demand (CBOD) limits in the discharge permit. Industrial WWTFs discharging primarily inorganic suspended solids will be considered as a TSS source and will receive TSS WLAs unless they provide effluent information verifying that the organic TSS fraction is greater than 70%, similar to that found in treated domestic wastewater.

The locations of the OPDES-permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed in Figure 3-1.

3.2.1.1 Municipal OPDES WWTFs

There are three permitted municipal point sources within the study area. Municipal WWTFs are designated with a Standard Industrial Code (SIC) number 4952. They are considered as a potential source of bacteria. However, they are not considered as a potential source of turbidity because they discharge organic TSS with limits for $CBOD_5$. Therefore, the Town of Cyril will not receive a TSS WLA, and Comanche WWT and the City of Altus will receive a bacteria WLA only in the study area.

3.2.1.2 Industrial OPDES WWTFs

There are four OPDES industrial point sources (three active and one inactive) dischargers in this study area. Those three active facilities are considered as a TSS contributor. However, turbidity TMDL will not be addressed for Cow Creek because it was developed in 2010. Also, Georgia-Pacific Gypsum LLC in the Little Washita River watershed will not get TSS WLA because of no wastewater discharge.

3.2.2 Stormwater Permits

Stormwater runoff from OPDES-permitted facilities (MS4s, facilities with multi-sector general permits, and construction sites) can contain impairments. The National Stormwater Quality Database (NSQD) summarizes concentrations for a number of pollutants of concern in stormwater runoff from around the country (Pitt et. al. 2004). Based on data summarized in the NSQD, median concentration in stormwater ranged from 700 to 1,900 counts/100 mL for *E. coli* and from 17 to 99 mg/L for TSS (Pitt et. al. 2004).

EPA regulations [40 C.F.R. §130.2(h)] require 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 252:730). In other words, the turbidity impairment status is limited to base flow conditions so permitted stormwater discharges do not impair streams with TSS. Therefore, TSS WLAs for NPDES-regulated stormwater discharges are considered unnecessary in this TMDL report and will not be included in the TMDL calculations. Stormwater runoff from permitted areas can contain high fecal coliform concentrations.

3.2.2.1 Municipal Separate Storm Sewer System Permit

3.2.2.1.1 Phase I MS4

In 1990, EPA developed Phase I of the NPDES Stormwater Program. This program was designed to prevent harmful pollutants in MS4s from being washed by stormwater runoff into local waterbodies (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 isn't any Phase I MS4 in the study area.

3.2.2.1.2 Phase II MS4 (OKR04)

In 1999, Phase II began requiring certain small MS4s to comply with the NPDES stormwater program. 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," to protect water quality, and to satisfy appropriate water quality requirements of the CWA. Phase II MS4 stormwater programs must address the following six minimum control measures:

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

In Oklahoma, Phase II General Permit (OKR04) for small MS4 communities has been in effect since 2005. Information about DEQ's MS4 program can be found on-line at the following DEQ website: https://oklahoma.gov/deq/permits/water-permits/stormwater-permitting/municipal-stormwater.html.

There is one Phase II MS4 (the City of Altus) in the study area. The City of Altus is located in Red River, North Fork (OK311500010020_00) watersheds which are impaired for turbidity and enterococci. However, Oklahoma Water Quality Standard for turbidity does not apply to stormwater runoff from the watershed including MS4. Therefore, the City of Altus will receive enterococci WLA only.

3.2.2.2 Multi-Sector General Permits (OKR05)

A DEQ multi-sector industrial general permit (MSGP) is required for stormwater discharges from all industrial facilities (DEQ 2022) whose Standard Industrial Classification (SIC) code is listed on Table 1-2 of the MSGP. Stormwater discharges from all industrial facilities occur only during or immediately following periods of rainfall and elevated flow conditions. Since turbidity criteria do not apply during these periods, stormwater is not considered a potential source of turbidity impairment.

There are 19 facilities within the study area with multi-sector general permits shown in Table 3-3.

3.2.2.2.1 Regulated Sector J Discharges

Sector J facilities include crushed stone, construction sand & gravel, and industrial sand mines. The activities in these facilities include the exploration and mining of minerals (e.g., stone, sand, clay, chemical and fertilizer minerals, non-metallic minerals, etc.). A "*mine*" refers to an area of land actively excavated for the production of sand and gravel from natural deposits. Under the MSGP (OKR05), effluent from Sector J facilities include stormwater discharges associated with industrial activity from active and inactive mineral mining and mine dewatering. "*Mine dewatering*" is any water that is impounded or that collects in the mine and is pumped, drained, or otherwise removed from the mine through the efforts of the mine operator. This term also includes wet pit overflows caused solely by direct rainfall and uncontaminated ground water seepage. Specific requirements for Sector J stormwater discharges can be found in Part 10 of the MSGP. Specific effluent limitation guidelines for Sector J SIC codes (1422 - 1429, 1442, 1446) are referenced in Table 1-3 of the MSGP. The effluent guidelines [40 CFR § Part 436, Subpart B, C and D] are adopted by reference in the OPDES under OAC 252:606-1-3(b)(8).

Mine dewatering discharges can happen at any time and have the following specific effluent limitations:

- pH 6.5 to 9.0
- TSS Daily Maximum: 45 mg/L
- TSS 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 MSGP. None of the facilities in Table 3-3 are Sector J facilities.

3.2.2.2.2 Rock, Sand and Gravel Quarries

Stormwater from rock, sand and gravel quarries in Oklahoma fall under the MSGP. But wastewater generated at quarries is regulated under DEQ General Permit OKG950000. Wastewater discharges regulated by this Permit are process wastewater and stormwater runoff that comes in direct contact with active process areas associated with the mining of stone, sand, and gravel; cutting stone; crushing stone to size; washing and stockpiling of processed stone and sand; and washing and maintenance areas of vehicles and equipment. Permitted activities include discharge of industrial wastewater, construction or operation of industrial surface water impoundments, land application of industrial wastewater for dust suppression, and recycling of wastewater as wash water or cooling water.

Wastewater and stormwater runoff from mining activities have the potential to contain elevated suspended solids and elevated pH due to contact with minerals. Suspended solids, as well as fugitive dust from operations, are a potential source of metals. Oil and grease may be generated due to equipment washing activities.

General Permit OKG950000 does not allow discharge of wastewater into Outstanding Resource Waters, High Quality Waters, Sensitive

Public & Private Water Supplies, and Appendix B Waters (OAC 282:730). In addition, no discharge is allowed into waterbodies listed as impaired for turbidity in Oklahoma's 303(d) list for which a TMDL has not been performed. Discharges into turbidity-impaired streams are also not allowed if their TMDL indicated that discharge limits more stringent than 45 mg/l for TSS or 6.5-9.0 standard units for pH are required (DEQ 2022).

The General Permit contains technology-based effluent limits of 45 mg/L for TSS, 15 mg/L for oil and grease, and pH range of 6.0–9.0. However, the Permit includes a provision that when exceedances of water quality criteria are determined to be the result of a facility's discharge to receiving waters, DEQ may determine that the facility is no longer eligible for coverage under the General Permit. DEQ will then require the facility to apply for an individual discharge permit with additional chemical-specific limits or toxicity testing requirements as necessary to protect the beneficial uses of the receiving stream.

The locations of quarries in the study area are shown in Figure 3-1. Table 3-4 summarizes a list of quarries from the Oklahoma Department of Mines located within the study area. However, there are no OKG950000 permits.

Table 3-4 Rock, Sand and Gravel Quarries

<table>
<tr><th>Company Name</th><th>County</th><th>Permit ID</th><th>Permitted Acres</th><th>Watershed</th></tr>
<tr><td>Harrison Gypsum Co. (Mine #2)</td><td rowspan="2">Caddo</td><td>L.E.-1606-C</td><td>363</td><td rowspan="2">Little Washita River (OK310820020010_00)</td></tr>
<tr><td>Harrison Gypsum Co. (Mine #4)</td><td>L.E.-2009-A</td><td>54</td></tr>
<tr><td>Miller Construction & Sons, Inc.</td><td rowspan="2">Stephens</td><td>L.E.-1847</td><td>3</td><td rowspan="2">Cow Creek (OK311200000060_00)</td></tr>
<tr><td>Miller Construction</td><td>X08-1185</td><td>-</td></tr>
<tr><td>Altus Sand and Gravel (Fowler Pit)</td><td rowspan="2">Jackson</td><td>L.E.-1285</td><td>5</td><td rowspan="2">Red River, North Fork (OK311500010020_00)</td></tr>
<tr><td>Hokett Construction</td><td>L.E.-1677</td><td>10</td></tr>
<tr><td>Southwestern State Sand (#1 & #1A)</td><td>Tillman</td><td>L.E.-1499-A</td><td>139</td><td rowspan="5">Red River, North Fork (OK311500010020_10)</td></tr>
<tr><td>T & G Construction, Inc.</td><td>Kiowa</td><td>L.E.-1649</td><td>5</td></tr>
<tr><td>Meridian Aggregates Company, a Limited Partnership (Snyder Quarry)</td><td>Kiowa</td><td>L.E.-1714-B</td><td>-</td></tr>
<tr><td>Shoestring Enterprises, LLC</td><td>Jackson</td><td>X09-1285</td><td>-</td></tr>
<tr><td>Jack Owen</td><td>Greer</td><td>X08-1188</td><td>-</td></tr>
</table>

3.2.2.3 General Permit for Construction Activities (OKR10)

A DEQ stormwater general permit for construction activities is required for any stormwater discharges in the State of Oklahoma associated with construction activities that result in land disturbance equal to or greater than one acre or less than one acre if they are part of a larger common plan of development or sale that totals at least one 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 2022). Stormwater discharges occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply. Therefore, stormwater is not considered a possible contributor to turbidity impairment. The permits for construction projects that were active during the time period that samples were taken are summarized in Table 3-2 and shown in Figure 3-1.

3.2.3 No-Discharge Facilities

Some facilities are classified as no-discharge. These facilities are required to sign an affidavit of no discharge. For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute indicator bacterial or TSS loading. While 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 bacterial loading to surface waters. For example, discharges from the wastewater facility may occur during large rainfall events that exceed the systems' storage capacities.

There are four no-discharge facilities in the study area (see Table 3-5) and three out of four are the municipal no-discharge facilities. They could be contributing to the elevated levels of in-stream indicator bacterial loading if they are not maintained properly.

Table 3-5 OPDES No-Discharge Facilities in the Study Area

Facility	Facility ID	County	Facility Type	Type	Watershed
Grady County RWD # 7 (Ninnekah) WWT	S-10868	Grady	Total Retention	Municipal	Little Washita River (OK310820020010_00)
Edgewood Kwik Mart & Car Wash	I- 69000350	Stephens	Total Retention	Industrial	Cow Creek (OK311200000060_00)
Tipton	S-11516	Tillman	Total Retention	Municipal	Red River, North Fork (OK311500010020_00)
Headrick WWT	S-11527	Jackson	Total Retention	Municipal	Red River, North Fork (OK311500010020_10)

3.2.4 Sanitary Sewer Overflows

Sanitary sewer overflow (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacterial 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 reported between 1993 and 2022. During that period 151 overflows were reported ranging from a minimal quantity to eight million gallons. Table 3-6 summarizes the SSO occurrences by NPDES facilities. Historical data of reported SSOs are provided in Appendix F.

Table 3-6 Sanitary Sewer Overflow Summary (1993 - 2022)

Facility Name	Permit No.	Receiving Water	Facility ID	Number of Occurrences	Date Range		Amount (Gallons)	
					From	To	Min	Max
Altus - E	OK0028037	Unnamed tributary to Stinking Creek	S11514	64	1993	2019	NA	8,000,000
Cyril	OK0041467	Gladys Creek	S10824	84	1993	2022	NA	1,000,000
Grady Co. RWD #7	TRL000081	Erica's trib	S10868	1	-	1995	-	10,000
Tipton	TRL000296	Red River, North Fork	S11516	2	NA	2010	NA	2,000

NA = not available

3.2.5 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. ODAFF is the NPDES-permitting authority for animal feeding operations in Oklahoma under what ODAFF calls the Agriculture Pollutant Discharge Elimination System (AgPDES). Through regulations (rules) established by the Oklahoma Concentrated Animal Feeding Operation (CAFO) Act (Title 2, Chapter 1, Article 20 – 40 to Article 20 – 64 of the State Statutes), Swine Feeding Operation (SFO) Act (Title 2, Chapter 1, Article 20 – 1 to Article 20 – 29 of the State Statutes), and Poultry Feeding Operation (PFO) Registration Act (Title 2, Chapter 10-9.1 to 10-9.25 of the State Statutes), AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the State.

All of these animal feeding operations (AFO) require an Animal Waste Management Plan (AWMP) to prevent animal waste from entering any Oklahoma waterbody. These plans outline how the animal feeding operator will prevent direct discharges of animal waste into waterbodies as well as any runoff of waste into waterbodies. The rules for all of these AFOs recommend using the USDA NRCS' Agricultural Waste Management Field Handbook to develop their Plan. NRCS has developed Animal Waste Management software to develop this Plan.

3.2.5.1 CAFO

A concentrated animal feeding operation is an animal feeding operation that exceeds the statutory animal-number thresholds and discharges pollutants to waters of the state, or meets lower thresholds and discharges through an artificially constructed conveyance or directly into navigable waters. As the Oklahoma Concentrated Animal Feeding Operation Act (QDAFF 2024) states, CAFOs are operations where "more than the number of animals specified… are confined… and pollutants are discharged into waters of the state" and where pollutants may be discharged "through an artificially constructed ditch, flushing system or other similar artificially constructed device". CAFOs must operate under an approved Pollution Prevention Plan and an Animal Waste Management Plan designed to prevent discharges except during a properly designed retention structure overflow caused by a 25-year, 24-hour rainfall event. For TMDL purposes, CAFOs are treated as no-discharge facilities, and runoff of animal waste to surface waters or groundwater is prohibited. Although CAFOs are regulated to prevent releases, improper management can result in significant water-quality impacts, including unauthorized discharges of animal waste or failure to properly operate retention structures. Per data provided by ODAFF in September 2023, there is one CAFOs located in this study area.

Table 3-7 NPDES-Permitted CAFO in Study Area

ODAFF Owner ID	EPA Facility	Company Name	Max # of Swine units at Facility	Max # of Cattle units at Facility	Total # of Animal Units at Facility	County	Watershed
201102	OKG010406	Van der Lann Dairy	0	12,160	12,160	Tillman	Red River, North Fork (OK311500010020_00 and _10)

3.2.5.2 SFO

The purpose of the SFO Act is to provide for environmentally responsible construction and expansion of swine feeding operations and to protect the safety, welfare and quality of life of persons who live in the vicinity of a swine feeding operation.[1] According to the SFO Act, a

1 A concentrated swine feeding operation has at least 750 swine that each weighs over 25 kilograms (about 55 pounds), 3,000 weaned swine weighing under 25 kilograms, or 300 swine animal units. A swine animal unit is a unit of measurement for any swine feeding operation calculated by adding the following numbers: The number of swine weighing over twenty-five (25) kilograms, multiplied by four-tenths (0.4), plus the number of weaned swine weighing under twenty-five (25) kilograms multiplied by one-tenth (0.1)

"Concentrated swine feeding operation" is a lot or facility where swine kept for at least ninety (90) consecutive days or more in any twelve-month period and where crops, vegetation, forage growth or post-harvest residues are not grown during the normal growing season on any part of the lot.

SFOs are required to develop a Swine Waste Management Plan[2], to prevent swine waste from being discharged into surface or groundwaters. This Plan includes the BMPs being used to prevent runoff & erosion. The Swine Waste Management Plan may include, but is not limited to, a Comprehensive Nutrient Management Plan (CNMP) per NRCS guidance or Nutrient Management Plan (NMP) per EPA guidance. SFOs are required to store wastewater in Waste Retention Structures (WRS) and either to land apply wastewater or make the WRS large enough to be total retention lagoons. SFOs are not allowed to discharge to State waterbodies. Per data provided by ODAFF in September 2023, there are no SFOs in this study area.

3.2.5.3 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. According to PFO regulations, PFOs are required to develop an AWMP or an equivalent nutrient management plan (NMP) such as the ODAFF Nutrient Management Plan or EPA Nutrient Management Plan. 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. A PFO AWMP must address both nitrogen and phosphorus. 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 bacterial loads and achieve progress toward meeting the specified reduction goals must be implemented.

According to the PFO rules, runoff of poultry waste from the application site is prohibited. BMPs and practices must be used to minimize movement of poultry waste to waterbodies. Grassed strips at the edge of the field must be used to prevent runoff from carrying eroded soil and poultry waste into the waterbodies. Poultry waste is not allowed to be applied to land when the ground is saturated or while it is raining; and poultry waste application is prohibited on land with excessive erosion.[3]

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[2] Swine Animal Waste Management Plan Requirements [Title 35 (ODAFF), Chapter 17 (Water Quality), Subchapter 3 (Swine Feeding Operations)] can be found in 35:17-3-14.

[3] PFO Animal Waste Management Plan Requirements [Title 35 (ODAFF), Chapter 17 (Water Quality), Subchapter 5 (Registered Poultry Feeding Operations)] can be found in 35:17-5-5.

PFOs located in nutrient limited watersheds should have a nutrient sample analysis from that year to make available.[4] PFOs in non-nutrient limited watersheds perform nutrient sample analysis at least once every three years and must have available the most recent record of the analysis. Per data provided by ODAFF in September 2023, there are no PFOs in the study area.

3.2.6 Section 404 Permits

Section 404 (aka Section 1344) 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 protect Oklahoma WQS.

3.3 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 11 sites in different areas within the United States was approximately 21,000 counts/100 mL in warm weather runoff (EPA 1983). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal

[4] Nutrient limited watersheds are defined in the Oklahoma Water Quality Standards (Title 785, Chapter 45). Nutrient limited watersheds can be found in Appendix A of the OWQS. They are the ones designated "NLW" in the "Remarks" column.

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 2022 Integrated Report include sediments originating from grazing in riparian or shoreline zones, non-irrigated crop production, rangeland grazing and other sources of sediment loading (DEQ 2022). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances.

The following sections provide general information on nonpoint sources contributing bacterial and TSS loading within the study area.

3.3.1 Wildlife

Fecal coliform bacteria are produced by all warm-blooded animals, including wildlife such as mammals and birds. In developing bacterial TMDLs it is important to identify the potential for bacterial 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 bacterial 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 bacterial 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 (ODWC) 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 2019 to 2023 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 5×10^8 fecal coliform units per animal per day (ASAE 1999). Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production based on the estimated deer population provided in Table 3-8 in counts/day provides a relative magnitude of loading in each of the TMDL watersheds impaired for bacteria.

Table 3-8 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 counts/day) of Deer Population
OK310810020020_00	Finn Creek	42,432.4	509	0.012	254.5
OK310810020050_00	Criner Creek	42,738.7	513	0.012	256.5
OK310810020170_00	Roaring Creek	42,620.7	506	0.012	253.0
OK310820020010_00	Little Washita River	154,669.0	1,717	0.011	858.5
OK310840010060_00	Quartermaster Creek	98,461.6	998	0.010	499.0
OK311200000060_00	Cow Creek	124,305.4	1,519	0.012	759.5
OK311500010020_00	Red River, North Fork	163,207.5	1,162	0.007	581.0
OK311500010020_10	Red River, North Fork	122,555.0	814	0.007	407.0

3.3.2 Non-Permitted Agricultural Activities and Domesticated Animals

There are a number of non-permitted agricultural activities that can also be sources of bacterial 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 stream pollutants include:

- Processed commercially raised farm animal manure is often applied to fields as fertilizer, and can contribute to fecal bacterial 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 bacterial loading directly into streams or can cause unstable stream banks which can contribute TSS.

Table 3-12 provides estimated numbers of commercially raised farm animals and estimated acreage where manure was applied by watershed. This was calculated using the 2022 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2024) and 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. According to Table 3-12, 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 in-stream concentrations of bacteria and land application or direct deposition of manure from commercially raised farm animals. There is also not sufficient information available to describe or quantify the contributions of sediment loading caused by commercially raised farm animals responsible for destabilizing stream banks or erosion in pasture fields. 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 bacterial loading to the watersheds in the study area. Table 3-9 gives the daily fecal coliform production rates by animal species:

Table 3-9 Daily Fecal Coliform Production Rates by Animal Species

Animal	Daily fecal coliform production rate counts per animal per day
Beef cattle*	1.04E+11
Dairy cattle*	1.01E+11
Horses*	4.20E+08
Goats	1.20E+10
Sheep*	1.20E+10
Swine*	1.08E+10
Ducks*	2.43E+09
Deer*	$5x10^8$
Dogs⋇	$3.3x10^9$
Cats⋇	$5.4x10^8$
* According to a livestock study conducted by the ASAE (1999)	
⋇ Schueler 2000	

Using the estimated animal populations and the fecal coliform production rates from Table 3-9, 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 **n/a = not available**

Table 3-13. 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.

3.3.3 Domestic Pets

Fecal matter from dogs and cats, which can be transported to streams by runoff from urban and suburban areas, is a potential source of bacterial loading. On average 45% of the nation's households own dogs and 26% own cats. In 2022, the average number of pets per household was 1.46 dogs and 1.78 cats (American Veterinary Medical Association 2022). Using the U.S. Census data at the block level (U.S. Census Bureau 2020), dog and cat populations can be estimated for each watershed. Table 3-10 summarizes the estimated number of dogs and cats for the watersheds of the study area.

Table 3-10 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK310810020020_00	Finn Creek	1,213	854
OK310810020050_00	Criner Creek	1,215	856
OK310810020170_00	Roaring Creek	911	641
OK310820020010_00	Little Washita River	3,284	2,313
OK310840010060_00	Quartermaster Creek	401	283
OK311200000060_00	Cow Creek	2,321	1,635
OK311500010020_00	Red River, North Fork	1,889	1,331
OK311500010020_10	Red River, North Fork	1,156	815

Table 3-11 provides an estimate of the fecal coliform production from pets. These estimates are based on estimated fecal coliform production rates from Table 3-9.

Table 3-11 Estimated Fecal Coliform Daily Production by Pets ($x10^9$ counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK310810020020_00	Finn Creek	4,003	461	4,464
OK310810020050_00	Criner Creek	4,003	461	4,464
OK310810020170_00	Roaring Creek	3,006	346	3,352
OK310820020010_00	Little Washita River	10,837	1,249	12,086
OK310840010060_00	Quartermaster Creek	1,323	153	1,476
OK311200000060_00	Cow Creek	7,659	883	8,542
OK311500010020_00	Red River, North Fork	6,234	719	6,952
OK311500010020_10	Red River, North Fork	3,815	440	4,255

Table 3-12 Commercially Raised Farm Animals and Manure Application Area Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle	Dairy Cows	Horses	Goats	Sheep	Hogs & Pigs	Ducks	Acres of Manure Application
OK310810020020_00	Finn Creek	4,541	5	405	96	88	58	33	4,752
OK310810020050_00	Criner Creek	4,591	5	407	97	89	58	33	4,788
OK310810020170_00	Roaring Creek	8,533	100	104	118	46	1,257	24	9,070
OK310820020010_00	Little Washita River	25,788	238	325	385	169	8,252	62	32,458
OK310840010060_00	Quartermaster Creek	8,380	3	86	81	62	253	7	12,717
OK311200000060_00	Cow Creek	14,513	8	510	279	223	65	37	10,665
OK311500010020_00	Red River, North Fork	8,785	693	109	124	411	81	34	73,442
OK311500010020_10	Red River, North Fork	7,498	197	85	172	311	41	13	46,099

n/a = not available

Table 3-13 Fecal Coliform Production Estimates for Commercially Raised Farm Animals ($x10^9$ counts/day)

Waterbody ID	Waterbody Name	Cattle	Dairy Cows	Horses	Goats	Sheep	Hogs & Pigs	Ducks	Total
OK310810020020_00	Finn Creek	472,264	505	170	1,152	1,056	626	80	475,853
OK310810020050_00	Criner Creek	477,464	505	171	1,164	1,068	626	80	481,078
OK310810020170_00	Roaring Creek	887,432	10,100	44	1,416	552	13,576	58	913,178
OK310820020010_00	Little Washita River	2,681,952	24,038	137	4,620	2,028	89,122	151	2,802,048
OK310840010060_00	Quartermaster Creek	871,520	303	36	972	744	2,732	17	876,324
OK311200000060_00	Cow Creek	1,509,352	808	214	3,348	2,676	702	90	1,517,190
OK311500010020_00	Red River, North Fork	913,640	69,993	46	1,488	4,932	875	83	991,057
OK311500010020_10	Red River, North Fork	779,792	19,897	36	2,064	3,732	443	32	805,996

3.3.4 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 2021). OSWD systems and illicit discharges can be a source of bacterial loading to streams and rivers. Bacterial 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 bacterial 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 3-14 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 12% 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 3-14 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	# of Septic Tanks / Mile^2
OK310810020020_00	Finn Creek	431	605	22	1,058	9.1
OK310810020050_00	Criner Creek	436	606	22	1,064	9.1
OK310810020170_00	Roaring Creek	567	492	11	1,070	7.4
OK310820020010_00	Little Washita River	2,620	1,505	35	4,160	6.2
OK310840010060_00	Quartermaster Creek	392	198	7	597	1.3
OK311200000060_00	Cow Creek	2,392	1,057	23	3,472	5.4
OK311500010020_00	Red River, North Fork	2,575	403	8	2,986	1.6
OK311500010020_10	Red River, North Fork	1,582	278	11	1,871	1.5

The average of number of people per household was calculated to be from 1.8 to 2.5 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 in Table 3-15.

Table 3-15 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)
OK310810020020_00	Finn Creek	42,432.4	605	73	484
OK310810020050_00	Criner Creek	42,738.7	606	73	484
OK310810020170_00	Roaring Creek	42,620.7	492	59	375
OK310820020010_00	Little Washita River	154,669.0	1,505	181	1,151
OK310840010060_00	Quartermaster Creek	98,461.6	198	24	121
OK311200000060_00	Cow Creek	124,305.4	1,057	127	707

Waterbody ID	Waterbody Name	Acres	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day)
OK311500010020_00	Red River, North Fork	163,207.5	403	48	254
OK311500010020_10	Red River, North Fork	122,555.0	278	33	166

3.4 Summary of Sources of Impairment

3.4.1 Bacteria

In the study area, bacterial TMDLs are required for Finn Creek (OK310810020020_00), Criner Creek (OK310810020050_00), Cow Creek (OK311200000060_00), Red River, North Fork (OK311500010020_00), and Red River, North Fork (OK311500010020_10). There are no continuous, permitted point sources of bacteria in the Finn Creek (OK310810020020_00), Criner Creek (OK310810020050_00), and Red River, North Fork (OK311500010020_10) watersheds. Therefore, the conclusion is that nonsupport of PBCR use in those watersheds is caused by nonpoint sources of bacteria. For Cow Creek (OK311200000060_00) and Red River, North Fork (OK311500010020_00), contribution from the continuous permitted point sources is not significant when it is compared to TMDL. Therefore the various nonpoint sources are considered to be the major source of bacterial loading in each watershed that requires a bacterial TMDL.

Table 3-16 provides a summary of the estimated percentage of fecal coliform loads in counts/day from the four major nonpoint source categories (commercially raised farm animals, pets, deer, and septic tanks) that contribute to the elevated bacterial 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 bacterial source tracking studies around the nation demonstrate that wild birds and mammals represent a major source of the fecal bacteria found in streams.

Table 3-16 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
OK310810020020_00	Finn Creek	98.9%	0.9%	0.1%	0.1%
OK310810020050_00	Criner Creek	98.9%	0.9%	0.1%	0.1%
OK310810020170_00	Roaring Creek	99.6%	0.4%	0.03%	0.04%
OK310820020010_00	Little Washita River	99.5%	0.4%	0.03%	0.04%
OK310840010060_00	Quartermaster Creek	99.8%	0.2%	0.1%	0.01%

Waterbody ID	Waterbody Name	Commercially Raised Farm Animals	Pets	Deer	Estimated Loads from Septic Tanks
OK311200000060_00	Cow Creek	99.3%	0.6%	0.05%	0.05%
OK311500010020_00	Red River, North Fork	99.2%	0.7%	0.1%	0.03%
OK311500010020_10	Red River, North Fork	99.4%	0.5%	0.1%	0.02%

The magnitude of loading to land surfaces may not reflect the magnitude of loading to a stream. 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.

3.4.2 Turbidity

Of the four watersheds in the study area that require turbidity TMDLs, there are no facilities given TSS WLA. Therefore, nonsupport of WWAC use in the study area is likely 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

4.1 Pollutant Loads and TMDLs

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 (WLA, LA, and MOS) as described in the following mathematical equation:

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

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 in 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.

4.2 Determine 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 2016 to 2021 at stations within the study area.

4.2.1 Steps Prior to Regression

Prior to developing the regression, the following steps are taken to refine the dataset:

- Remove data collected under high flow conditions exceeding the base-flow criterion. This means that measurements corresponding to flow exceedance percentiles lower than 25^{th} are not to be 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 or total rainfall during these days greater than 1.0 inch, the sample is 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,

- Check the non-detect rate. Non-detects (censored data) are TSS sample observations less than the detection limit (10 mg/L). If the percent of non-detects is ≤ 15%, follow the steps outlined in Section 4.2.2. If the percent of non-detects is > 15%, follow the steps outlined in Section 4.2.3.

4.2.2 Non-Detect Rate Less Than or Equal to (≤) 15%

For observed data where the non-detect rate is less than or equal to (≤) 15%, EPA (2006) recommends using substitution. 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 in-stream turbidity values. For this purpose, an alternate regression fitting procedure known as the line of organic correlation (LOC) was applied. To apply LOC, TSS samples of less than 10 were replaced with 9.99 and then both turbidity and TSS data were log-transformed to minimize effects of their non-linear data distribution. 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
- 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:

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

$m1$ 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

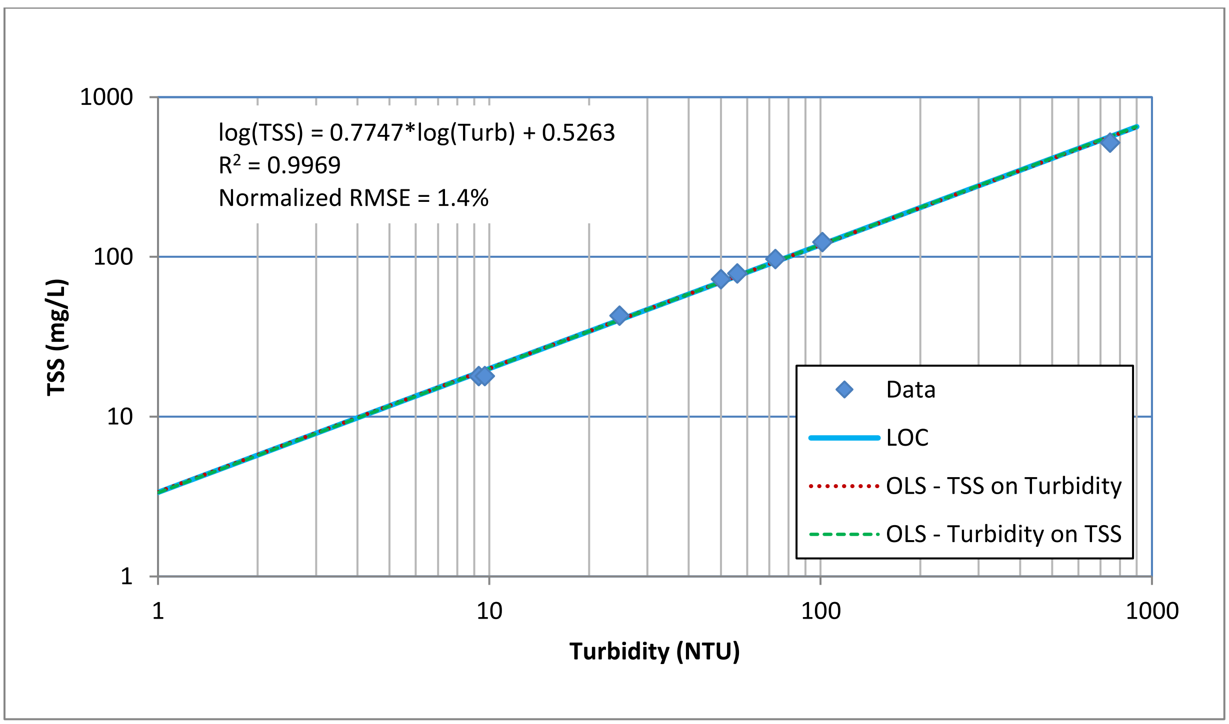
s_x is the standard deviation of the turbidity measurements

The r can range from -1 to 1 with 0 indicating no correlation, and negative r indicating an inverse correlation. Correlation values of 0 to 0.5 indicate a weaker correlation whereas values greater than 0.5 indicate a strong correlation. As a result, correlations of approximately 0.5 or greater are commonly used in TMDL studies (Christensen, Jian, and Ziegler; 2000). This Study considered an R-square (R^2 or coefficient of determination) value of approximately 0.5 or greater to represent a satisfactory relationship between turbidity and TSS, if based on at least 10 observations.

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 3.6% which means the root mean square error (RMSE) is 3.6% 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, North Fork (OK311500010020_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.

4.2.3 Non-Detect Rate is Greater Than 15%

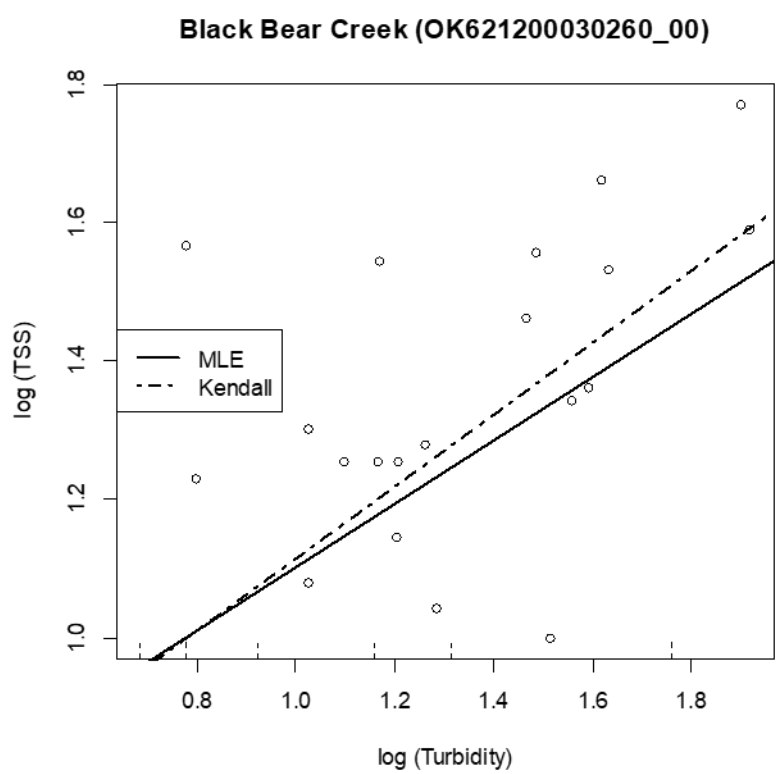
For observed data where the non-detect rate is greater than 15%, follow these steps:

- If the number of samples is less than 25 (Helsel, 2002; p. 360), combine sample data based on their ecoregion, geological area, and beneficial use to reduce NRMSE.
- Log-transform both turbidity and TSS data to minimize effects of their non-linear data distributions.
- Use methods for estimating summary statistics of data which include non-detects: simple substitution, distributional, and robust methods (Helsel and Hirsch, 2002).
- Compare results for the mean and the variance for desirable methods. Extrapolated values are not considered as estimates for specific samples, but only used collectively to estimate summary statistics.
- Choose regression methods for data-sets containing non-detects depend on distribution of data. If the data are linear and normally distributed without outliers, parametric methods may be used. Non-parametric methods may be used regardless of whether or not they are linear (Huston and Juarez-Colunga, 2009).
- Use statistical software (such as Excel, JMP, R, Minitab, or SAS) to calculate the turbidity-TSS relationship. Then, the TSS goal is computed based on regression coefficients.
- Replace less-thans with their detection limits for percentage reduction goal (PRG) calculation. Detection limit substitution may not be the best estimation method, but it is the best conservative method for calculating PRG.

If a small proportion of the observations are not detected, these may be substituted with a value (EPA 2006), the detection limit (dl) in this study. However, substituting for non-detects may incorrectly alter the mean and the variance. Therefore, censored data regression was issued for the data set of censoring greater than 15%. Before determining the relationship between turbidity and TSS, censored data were set as a range from one (TSS=1[1] mg/L) to detection limit (TSS=10 mg/L). Then, turbidity and TSS data were log-transformed and statistical software R determined regression relationships.

With statistical software R, maximum likelihood estimation (MLE) or non-parametric approaches can estimate correlation and regression coefficients as shown in Figure 4-2. If extreme outliers were not present in the sample data and the distributions of points were close to trend line, parametric method (MLE) performed similar or slightly better than non-parametric method (Kendall's tau).

Figure 4-2 Regression estimates by parametric and non-parametric method



After computing TSS goal with estimated regression, censored data were replaced with their detection limit (dl). This simple substitution is the most conservative to calculate PRG among estimation methods for censored data. Then, NRMSE and R-square (R^2) were computed as:

1 Having a TSS of "0" would be almost impossible because there is always some sediment in the background. Consequently, "1" is used as the lowest amount of TSS.

$$RMSE = (Standard\ Error\ of\ Slope) \cdot \sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$NRMSE = \frac{RMSE}{\bar{y}}$$

$$R^2 = 1 - \left[\frac{exp\left(loglik_{intercept}\right)}{exp(loglik_{model})}\right]^{\frac{2}{n}}$$

Where x_i = log(turbidity)$_i$, y_i = log(TSS)$_i$, i = 1…n, $\bar{x}$= average of x_i, y¯ = average of y_i, and n = number of observations.

The regression between TSS and turbidity and statistics for each turbidity impaired stream segment is provided in Section 5-1.

4.3 Steps to Calculating 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 identify whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the following steps that are described in Subsections 4.3.1 through 4.3.3:

1. Prepare flow duration curves for gaged and ungaged WQM stations.
2. Estimate existing loading in the waterbody using ambient bacterial water quality data.
3. Estimate loading in the waterbody using measured TSS water quality data and turbidity-converted data.
4. Use 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 WWTF 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.

4.3.1 Development of Flow Duration Curves

Flow duration curves (FDC) 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. Five of the six 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.

To estimate flows at an ungaged site:

- Identify an upstream or downstream flow gage.
- Calculate the contributing drainage areas of the ungaged sites and the flow gage.
- Calculate daily flows at the ungaged site by using the flow at the gaged site multiplied by the drainage area ratio.

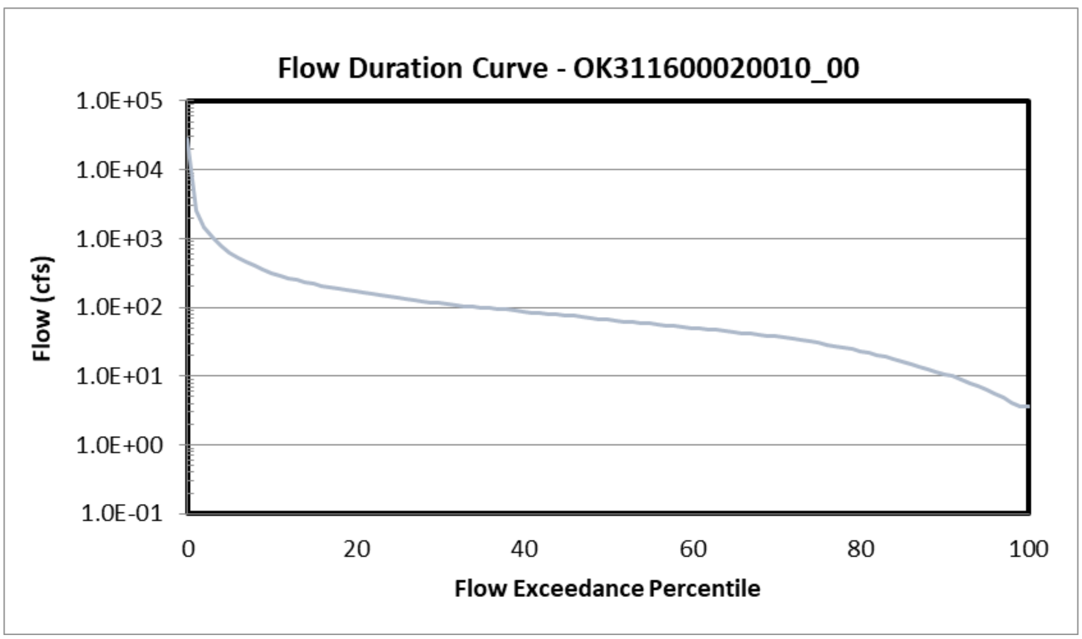
Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations 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 Table B-1.

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 to develop a flow duration curve.

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 4-3.

Flow duration curves for each impaired waterbody in the study area are provided in Section 5.2.

Figure 4-3 Flow Duration Curve for Red River, Salt Fork (OK311600020010_00)



4.3.2 Using Flow Duration Curves to Calculate Load Duration Curves

4.3.2.1 Bacteria

Existing in-stream loads can be calculated using FDCs. For bacteria:

- Calculate the geometric mean of all water quality observations from the period of record selected for the waterbody.
- Convert 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 bacterial indicator.

4.3.2.2 TSS

- Match the water quality observations with the flow data from the same date.
- Convert 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).

4.3.3 Using Load Duration Curves to Develop TMDLs

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).

4.3.3.1 Step 1 - Generate LDCs

LDCs are similar in appearance to flow duration curves.

For bacteria, the ordinate is expressed in terms of a bacterial load in colonies/day. The bacterial 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. Bacterial TMDLs are not easily expressed in mass per day. The equation in Section 4.3.3.1.1 calculates a load in the units of colonies per day. The colonies are 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 bacterial TMDLs as colonies per day is consistent with EPA's *Protocol for Developing Pathogen TMDLs* (EPA 2001).

For TSS, the ordinate is expressed in terms of a load in lbs/day. The curve represents the water quality target for TSS from Table 5-2 expressed in terms of a load obtained through multiplication of the TSS goal by the continuum of flows historically observed at the site.

<u>The following are the basic steps in developing an LDC:</u>

1. Obtain daily flow data for the site of interest from the USGS.
2. Sort the flow data and calculate flow exceedance percentiles.
3. For bacteria, obtain water quality data for the primary contact recreation season (May 1 through September 30).
4. Obtain available turbidity and TSS water quality data.

5. Display 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).

6. For bacterial TMDLs, display another curve derived by plotting the geometric mean of all existing bacterial samples continuously along the full spectrum of flow exceedance percentiles which represents the LDC (See Section 5).

7. For turbidity TMDLs, match the water quality observations with the flow data from the same date and determine the corresponding exceedance percentile (See Section 5).

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.

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. 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).

4.3.3.1.1 Bacterial LDC

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

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

Where:

WQS = 126 colonies/100 mL (E. coli); or 33 colonies/100 mL (enterococci)

Unit conversion factor = 24,465,525

Historical observations of bacteria were plotted as a separate LDC based on the geometric mean of all samples. 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 bacterial observations to a geometric mean water quality criterion in the LDC; therefore individual bacterial samples are not plotted on the LDCs.

4.3.3.1.2 Turbidity LDC

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 (lbs/day) = WQ_{goal} * flow (cfs) * unit conversion factor

Where:

WQ_{goal} = waterbody specific TSS concentration derived from regression analysis results presented in Table 5-2

Unit conversion factor = 5.39377

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.

4.3.3.2 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 bacterial TMDLs in this report, an explicit MOS of 10% was selected. The 10% MOS has been used in other approved bacterial 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. MOS is set to be the next percentile (count by 5%) greater than the NRMSE. For example, for any NRMSE greater than 10% but less than 15%, MOS will be 15%.

4.3.3.3 Step 3 - Calculate WLA

As previously stated, the pollutant load allocation for point sources is defined by the WLA. For bacterial 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. Recent EPA guidance includes OPDES-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 § Part 130.2(i) for expressing TMDLs "in terms of mass per time, toxicity, or other appropriate measures."

WLA for WWTF

For watersheds with permitted point sources discharging the pollutant of concern, OPDES 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 WWTF, then the average of monthly flow rates derived from DMRs can be used. WLA values for each OPDES wastewater discharger are then summed to represent the total WLA for a given segment. Using this information, WLAs can be calculated using the approach as shown in the equations below.

4.3.3.3.1 WLA for Bacteria

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

Where:

WQS = 126 colonies/100 mL (E. coli); or 33 colonies/100 mL (enterococci)

Flow (mgd) = permitted flow

Unit conversion factor = 37,854,120

4.3.3.3.2 WLA for TSS

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

Where:

WQ goal= Waterbody specific water quality goal provided in Table 5-2, or monthly TSS limit in the current permit, whichever is smaller

Flow (mgd) = permitted flow or average monthly flow

Unit conversion factor = 8.3445

4.3.3.3.3 WLA for Future Growth

Future growth allowances in TMDLs account for increased pollutant loadings and can be included as an allocation of pollutant loads from new sources expected in the future. For bacterial TMDLs, 10% of TMDL was reserved for future sources. For turbidity TMDLs, 1% of TMDL was reserved for future point sources because the turbidity criteria are not applied for high flow conditions including stormwater.

4.3.3.4 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 OPDES 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.

$$\mathbf{LA = TMDL - WLA\_{_{WWTF}} - WLA\_{_{MS4}} - WLA\_{_{Growth}} - MOS}$$

4.3.3.4.1 Bacterial WLAs for MS4s

For bacterial 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.

4.3.3.4.2 Turbidity WLA for MS4s

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

4.3.3.5 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 (PRG) 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:

1. If the geometric mean of the reduced values of all samples is less than the geometric mean standards (for bacteria) or

2. If no more than 10% of the reduced values of the samples under flow-base conditions exceed the TMDL (for turbidity).

4.3.3.5.1 WLA Load Reduction

The WLA load reduction for bacteria was not calculated as it was assumed that continuous dischargers (OPDES-permitted WWTFs) are adequately regulated under existing permits to achieve WQS at the end-of-pipe and, therefore, no WLA reduction would be required. Currently, bacterial limits are not required for lagoon systems. Lagoon systems located within a sub-watershed of bacterially-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 bacterially-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.

4.3.3.5.2 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.

E. coli and enterococci: WQSs are considered to be met if the geometric mean of all future data is maintained below the geometric mean criteria (TMDL).

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

Regression methods used in this report depend on the percentage of censored data. When censored data are less than or equal to 15%, the line of organic correlation (LOC) is applied with simple substitution of detection limit for censored data. When censored data are greater than 15%, maximum likelihood estimation (MLE) is applied for the data set without extreme outliers. There are censored data more than 15% in all turbidity impaired waterbodies in Table 5-1, except North Fork Red River (OK311500010020_00). Therefore, MLE was used for three waterbodies and LOC was used for the North Fork Red River in Table 5-1.

Table 5-1 Censored TSS data in base flow

Waterbody ID	Waterbody Name	Total number of paired TSS data	Number of censored data (# of samples falling below the 10 mg/L detection limit)	Percent of censored data (% of samples falling below the 10 mg/L detection limit)
OK310810020170_00	Roaring Creek	16	9	56.3
OK310820020010_00	Little Washita River	16	3	18.8
OK310840010060_00	Quartermaster Creek	15	5	33.3
OK311500010020_00	Red River, North Fork	11	0	0

Using the LOC and MLE methods 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 5-2. The regression analysis for each impaired waterbody in the study area using the LOC or MLE method is displayed in Figure 5-1 through Figure 5-4.

Table 5-2 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
OK310810020170_00	Roaring Creek	0.61	24.4%	64.9	25%
OK310820020010_00	Little Washita River	0.68	16.5%	81.2	20%
OK310840010060_00	Quartermaster Creek	0.78	21.1%	56.7	25%
OK311500010020_00	Red River, North Fork	0.997	1.4%	69.6	5%

[a] Calculated using the regression equation and the turbidity standard (50 NTUs)

[b] Based on the goodness-of-fit of the turbidity-TSS regression (NRMSE)

Figure 5-1 TSS-Turbidity Regression Estimates for Roaring Creek (OK310810020170_00)

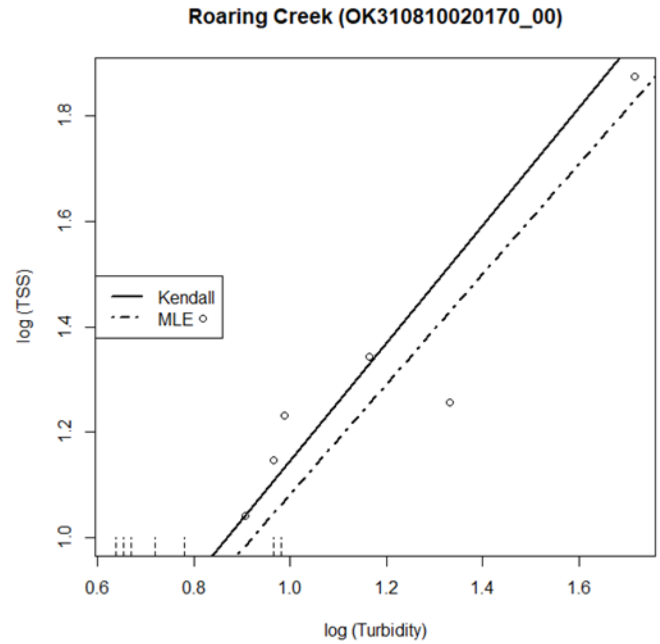


Figure 5-2 TSS-Turbidity Regression Estimates for the Little Washita River (OK310820020010_00)

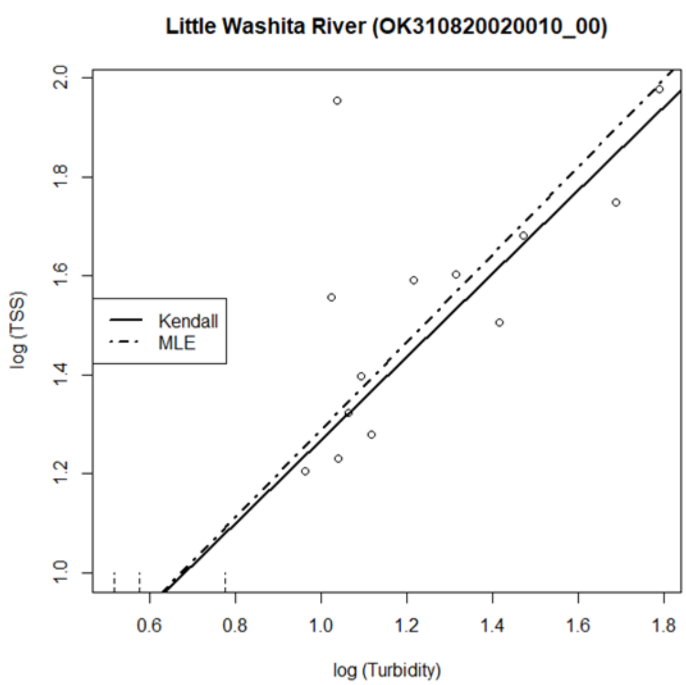


Figure 5-3 TSS-Turbidity Regression Estimates for Quartermaster Creek (OK310840010060_00)

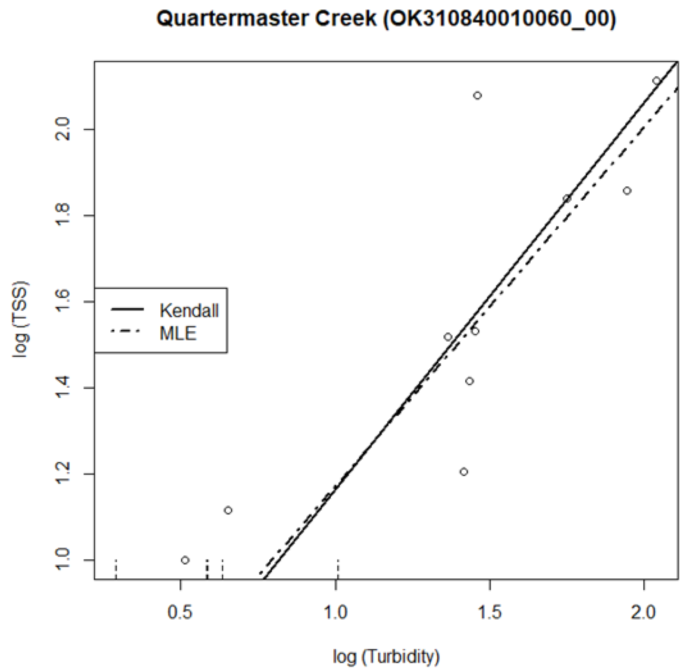
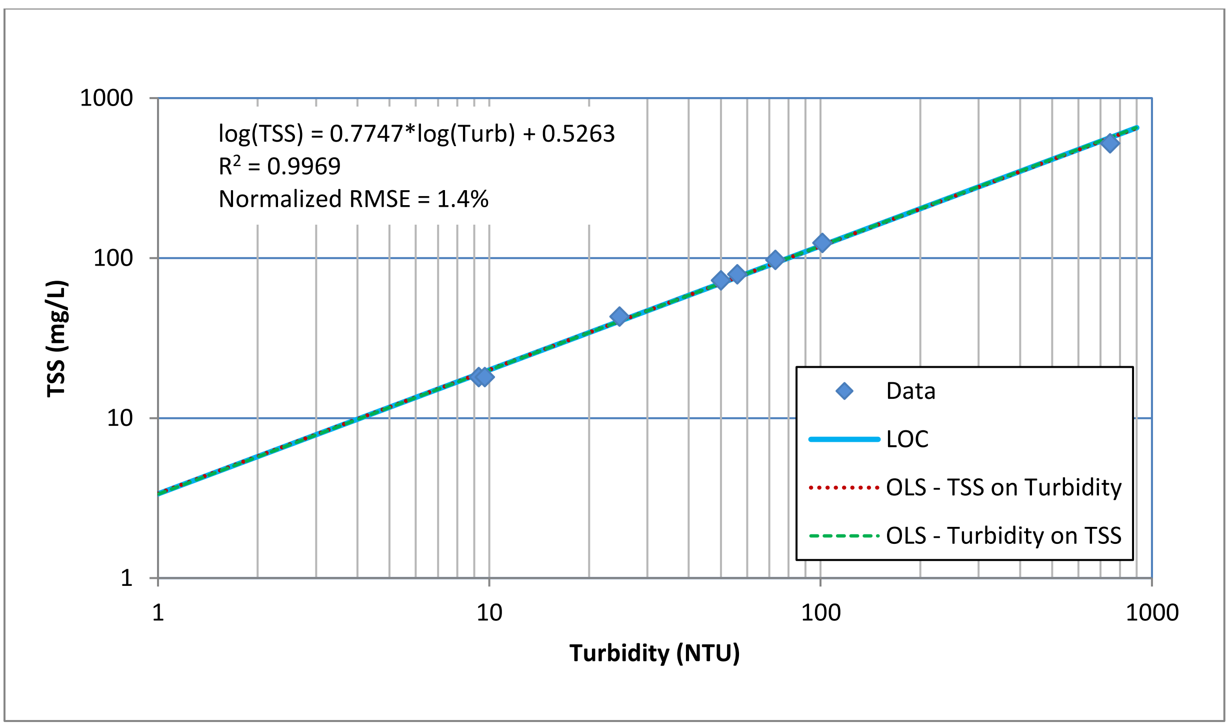


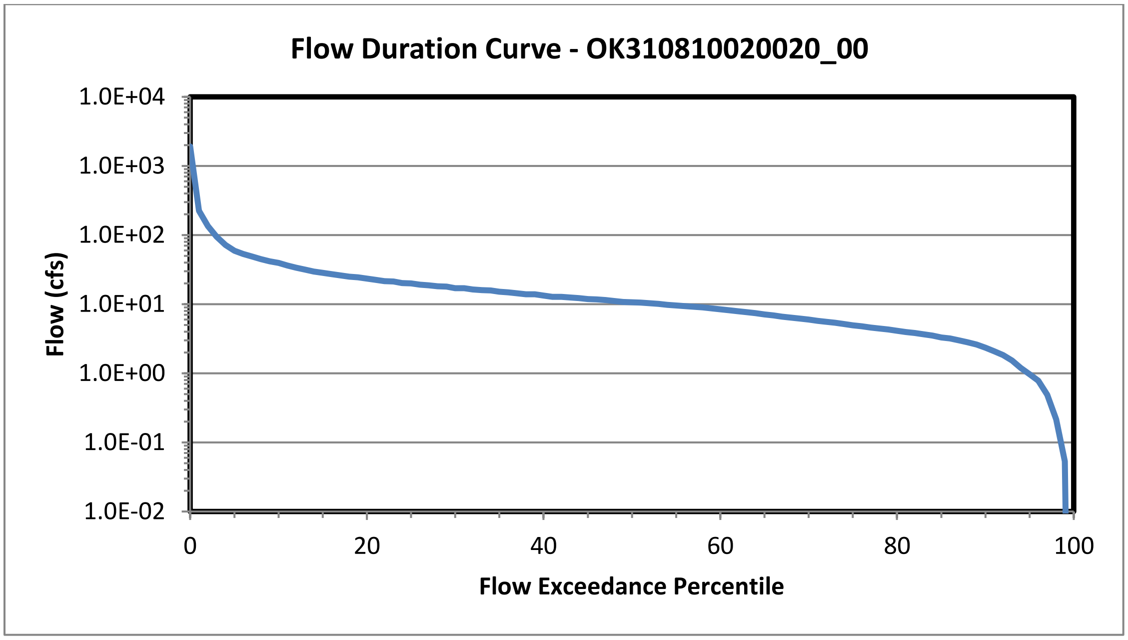
Figure 5-4 Linear Regression for TSS-Turbidity for Red River, North Fork (OK311500010020_00)



5.2 Flow Duration Curve

Following the same procedures described in Section 4.3.1, a flow duration curve for each stream segment requiring a TMDL in the study area was developed. These are shown in Figure 5-5 through Figure 5-12.

Figure 5-5 Flow Duration Curve for Finn Creek (OK310810020020_00)



The flow duration curves for Finn Creek (OK310810020020_00) and Roaring Creek (OK310810020170_00) were developed based on the flow data from 1992 to 2024 at USGS gage station 07327447 on Little Washita River near Cement, OK.

The flow duration curve for Criner Creek (OK310810020050_00) was developed based on the flow data from 1989 to 2024 at USGS gage station 07328180 on North Criner Creek near Criner, OK.

The flow duration curves for the Little Washita River (OK310820020010_00) and Quartermaster Creek (OK310840010060_00) were developed based on the flow data from 1992 to 2024 at USGS gage station 07327550 on Little Washita River East of Ninnekah, OK.

The flow duration curves for Cow Creek (OK311200000060_00) was developed based on the flow data from 1960 to 2024 at USGS gage station 07315700 on Mud Creek near Courtney, OK.

The flow duration curves for the Red River, North Fork (OK311500010020_00) was developed based on the flow data from 1998 to 2024 at USGS gage station 0 7307028 on North Fork Red River near Tipton, OK.

The flow duration curves for the Red River, North Fork (OK311500010020_10) was developed based on the flow data from 1990 to 2024 at USGS gage station 07305000 on North Fork Red River near Headrick, OK.

Figure 5-5 Flow Duration Curve for Finn Creek (OK310810020020_00)

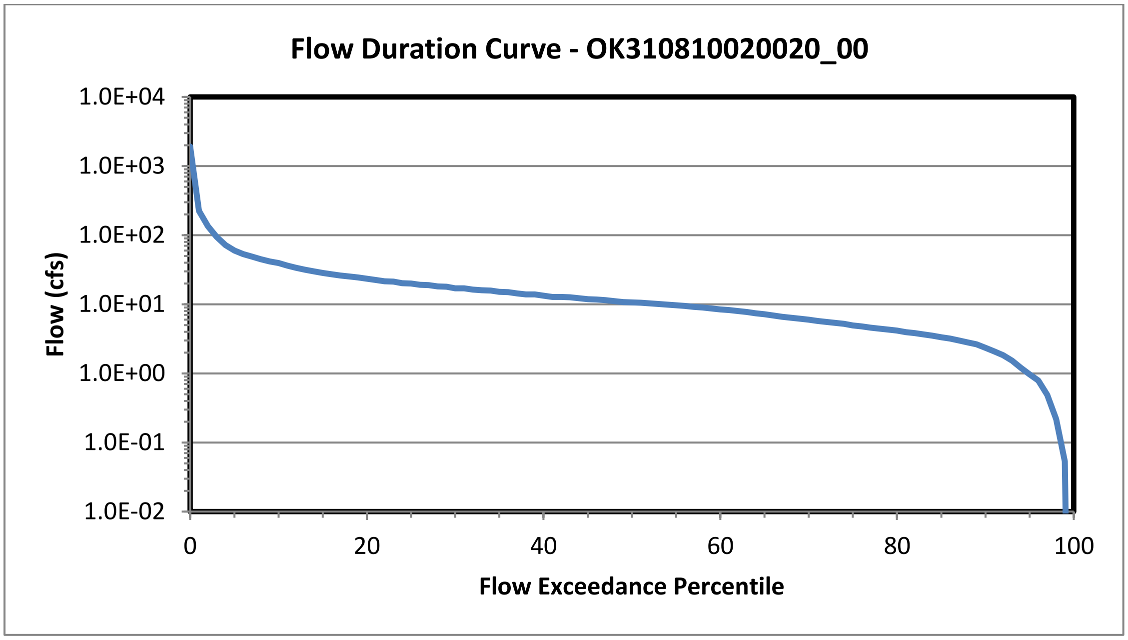


Figure 5-6 Flow Duration Curve for Criner Creek (OK310810020050_00)

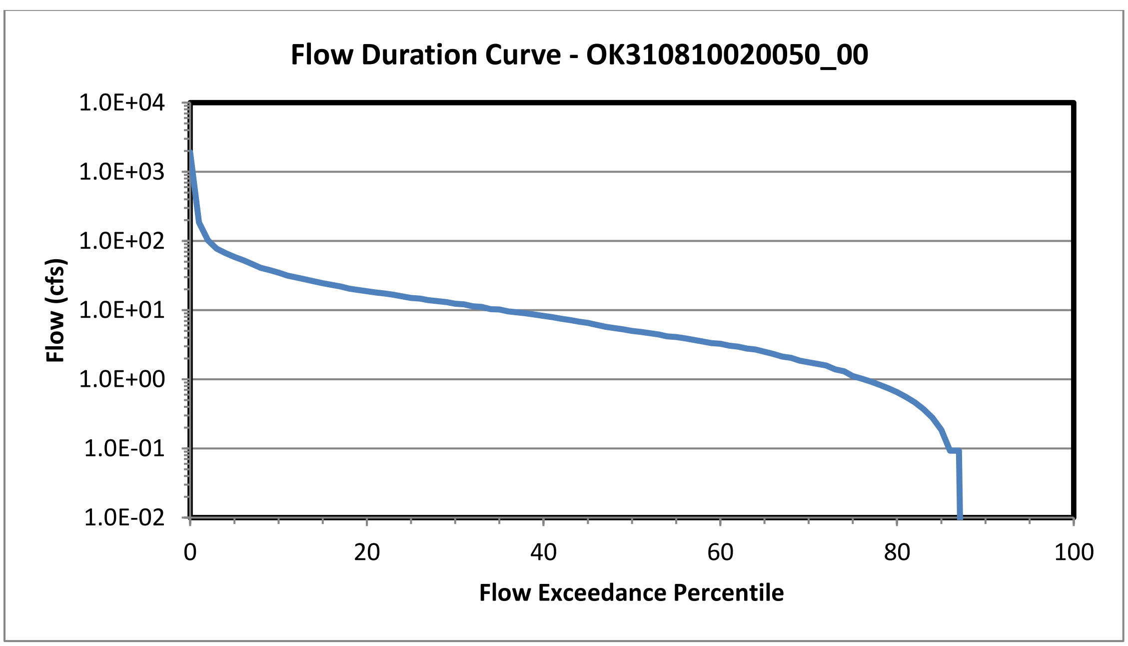


Figure 5-7 Flow Duration Curve for Roaring Creek (OK310810020170_00)

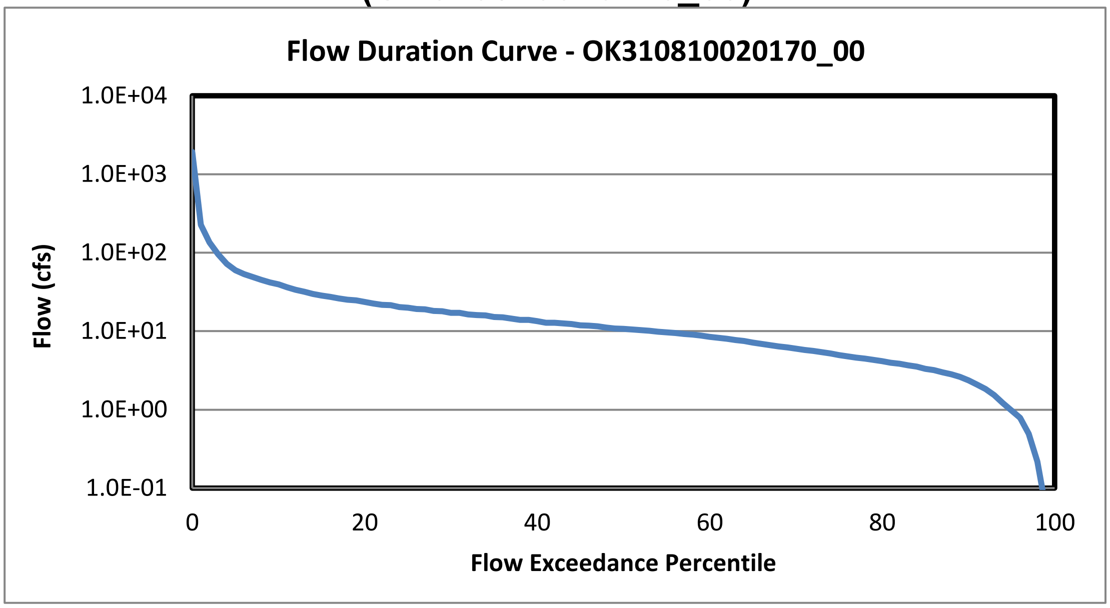


Figure 5-8 Flow Duration Curve for the Little Washita River (OK310820020010_00)

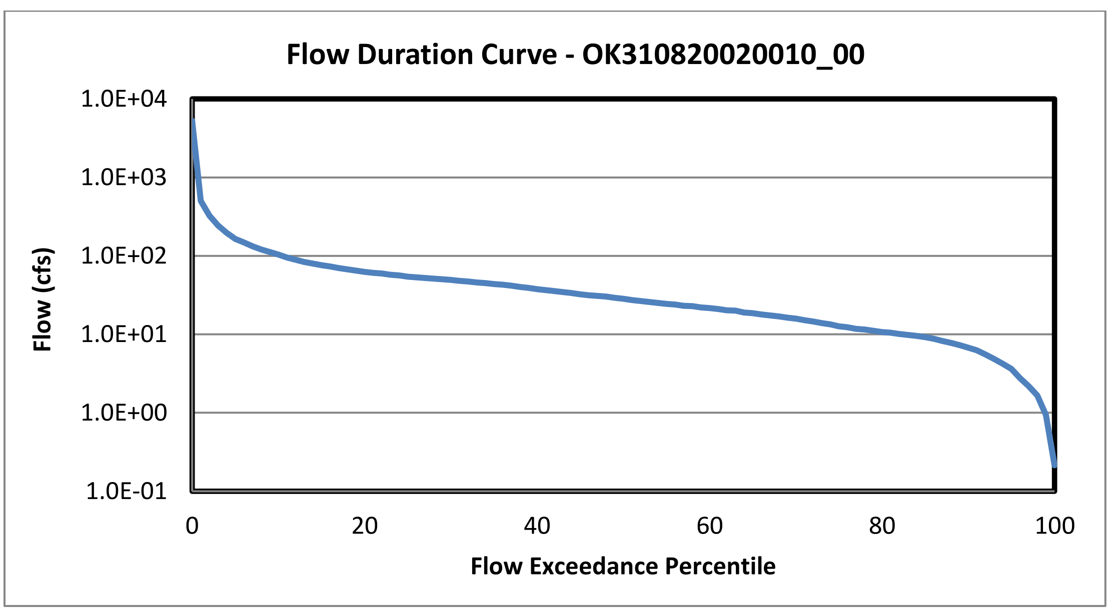


Figure 5-9 Flow Duration Curve for Quartermaster Creek (OK310840010060_00)

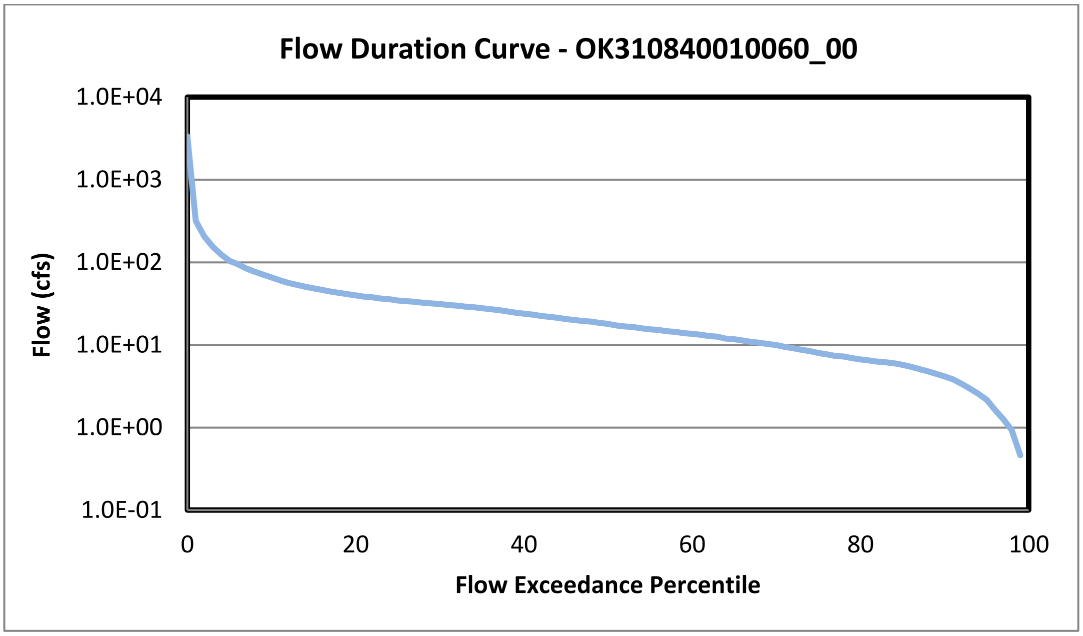


Figure 5-10 Flow Duration Curve for Cow Creek (OK311200000060_00)

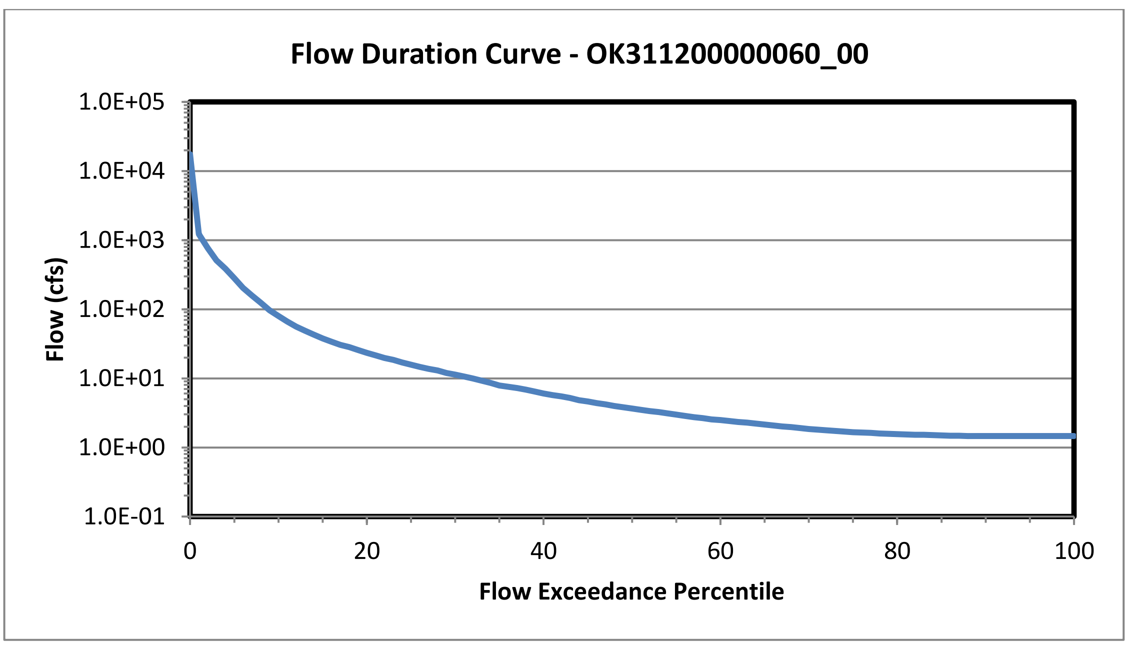


Figure 5-11 Flow Duration Curve for the Red River, North Fork (OK311500010020_00)

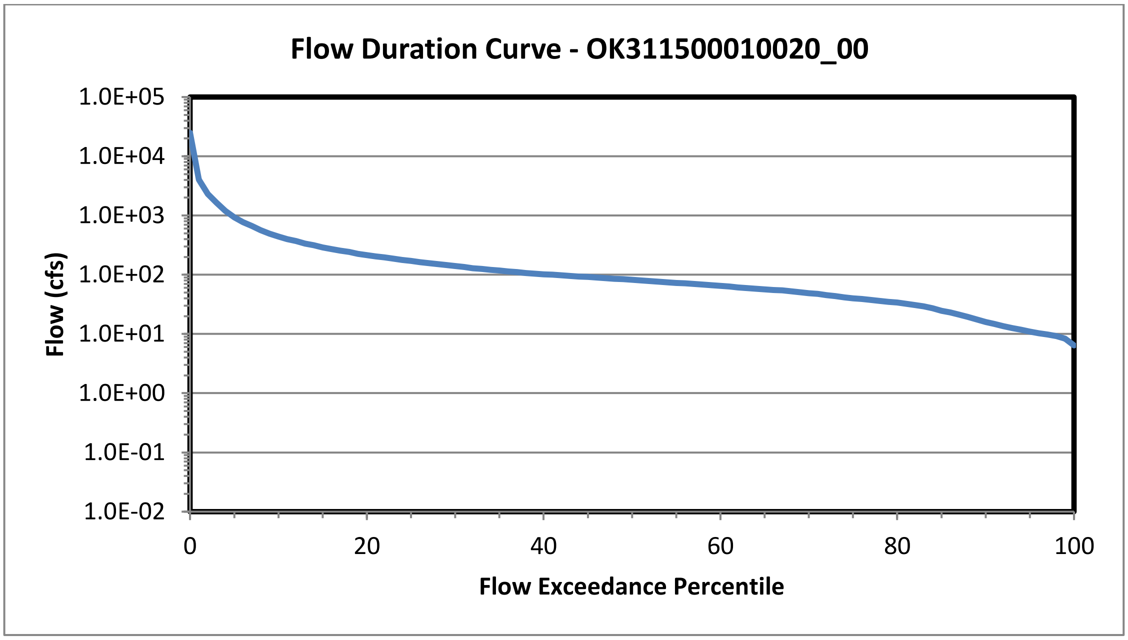
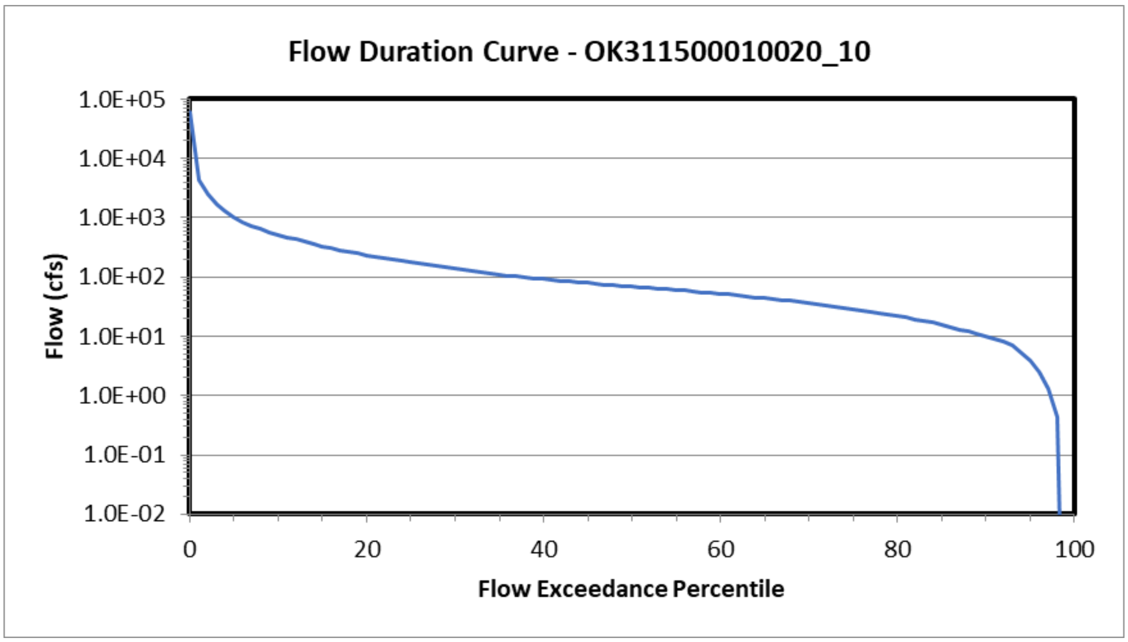


Figure 5-12 Flow Duration Curve for the Red River, North Fork (OK311500010020_10)



5.3 Estimated Loading and Critical Conditions

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

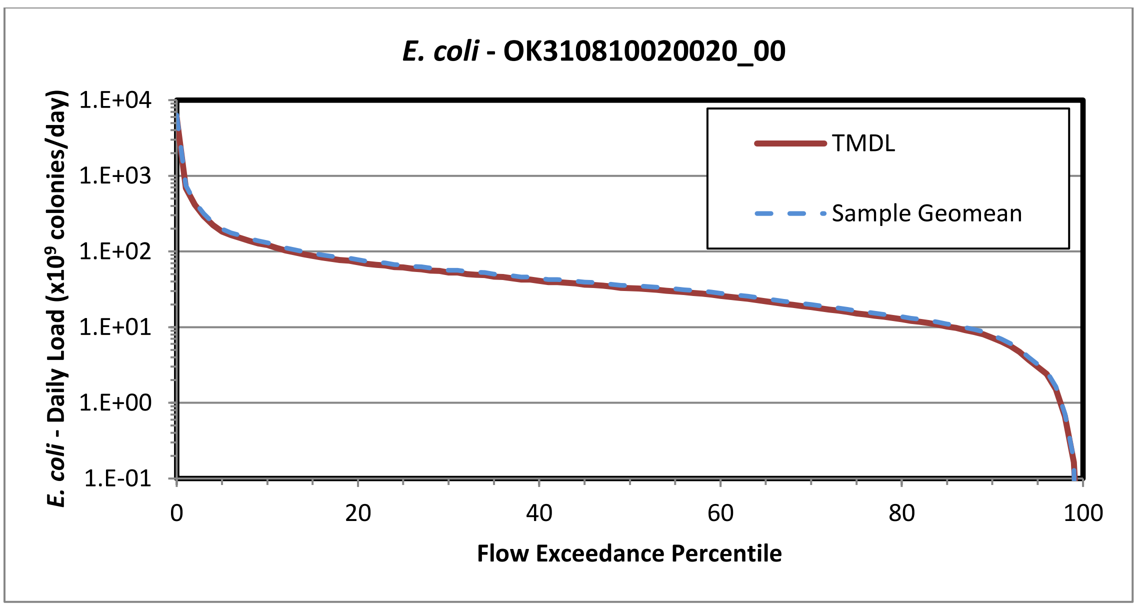
5.3.1 Bacterial LDCs

To calculate the allowable bacterial 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 bacterial load in the stream over the range of flow conditions. The allowable bacterial (*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 bacterial load.

To estimate existing loading, the geometric mean of all bacterial observations (concentrations) for the primary contact recreation season (May 1st through September 30th) from 2006 to 2021 are paired with the flows measured or estimated in that waterbody. Pollutant loads are then calculated by multiplying the measured bacterial concentration by the flow rate and the unit conversion factor of *24,465,525*. Bacterial LDCs are shown in Figure 5-13 through Figure 5-17.

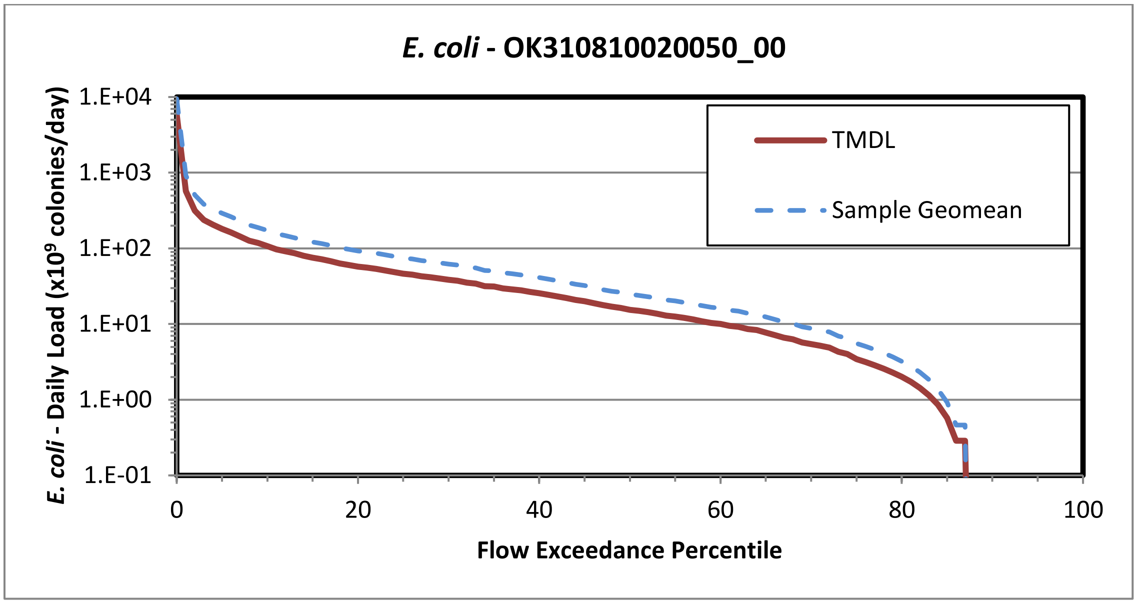
The LDC for Finn Creek (Figure 5-13) is based on *E. coli* measurements during primary contact recreation season at WQM station OK310810-02-0020D.

Figure 5-13 Load Duration Curve for *E. coli* in Finn Creek (OK310810020020_00)



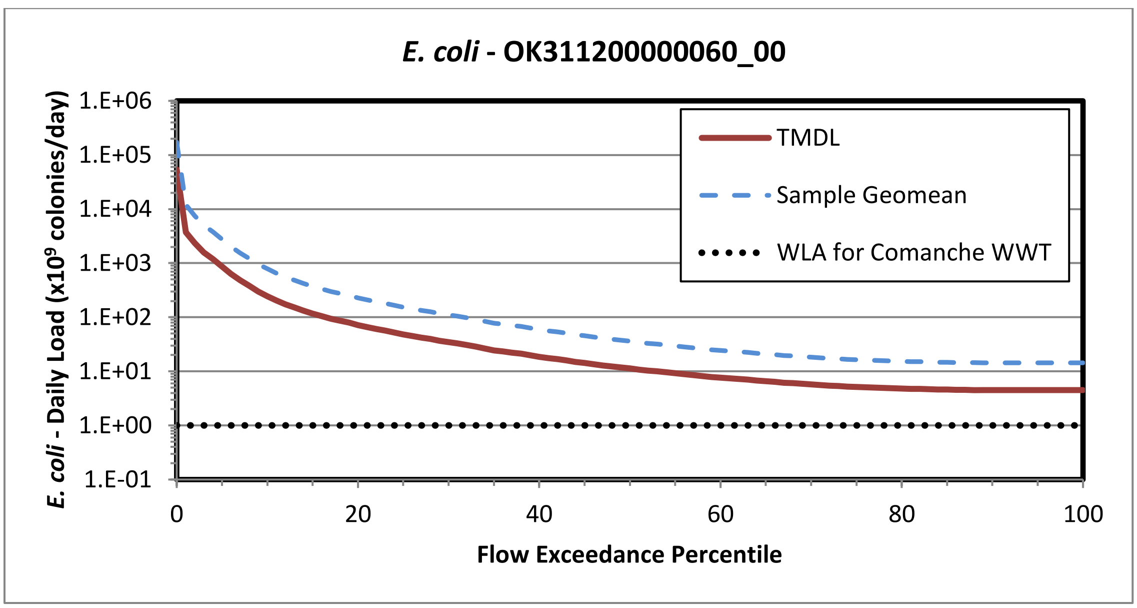
The LDC for Criner Creek (Figure 5-14) is based on *E. coli* measurements during primary contact recreation season at WQM station OK310810-02-0050D.

Figure 5-14 Load Duration Curve for *E. coli* in Criner Creek (OK310810020050_00)



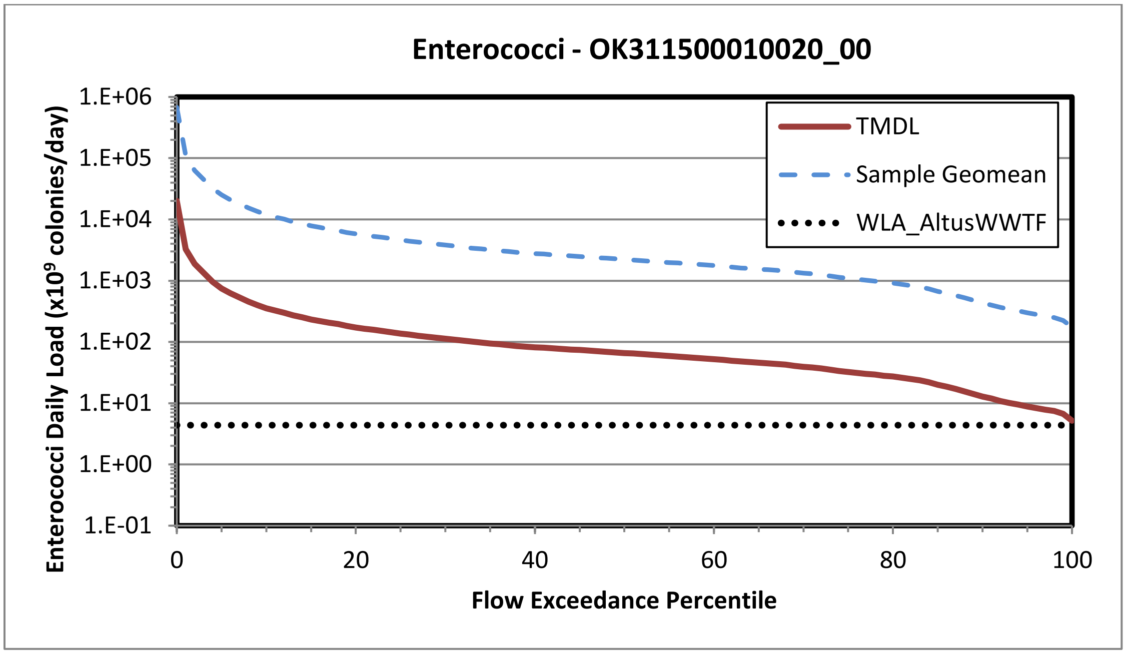
The LDC for Cow Creek (Figure 5-15) is based on *E. coli* measurements during primary contact recreation season at WQM station OK311200-00-0060L.

Figure 5-15 Load Duration Curve for *E. coli* in Cow Creek (OK311200000060_00)



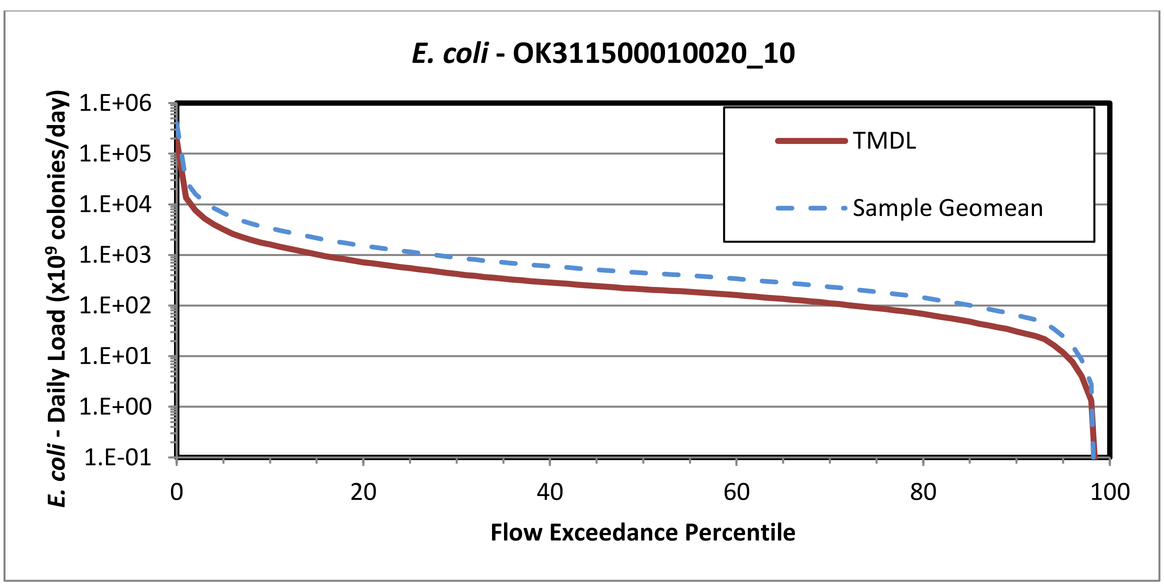
The LDC for Red River, North Fork (Figure 5-16) is based on enterococci measurements during primary contact recreation season at WQM station 311500010020-002AT.

Figure 5-16 Load Duration Curve for Enterococci in Red River, North Fork (OK311500010020_00)



The LDC for Red River, North Fork (Figure 5-17) is based on *E. coli* measurements during primary contact recreation season at WQM station 311500010020-001AT.

Figure 5-17 Load Duration Curve for *E. coli* in Red River, North Fork (OK311500010020_10)



5.3.2 TSS LDCs

To calculate the TSS load at the WQ target, the flow rate (cfs) at each flow exceedance percentile is multiplied by a unit conversion factor (*5.39377*) and the TSS goal (mg/L) 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 2016 to 2021 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 Table B-1**.** 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.

Figure 5-18 through Figure 5-21 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 to 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.

In LDC, TSS data were plotted based on instant flow samples when samples were collected. Therefore, it is possible that measured instance flows can be greater than 25th flow exceedance percentile of daily average flow. In addition, there is an uncertainty of using estimated flows from adjacent waterbody.

Figure 5-18 Load Duration Curve for Total Suspended Solids in Roaring Creek (OK310810020170_00)

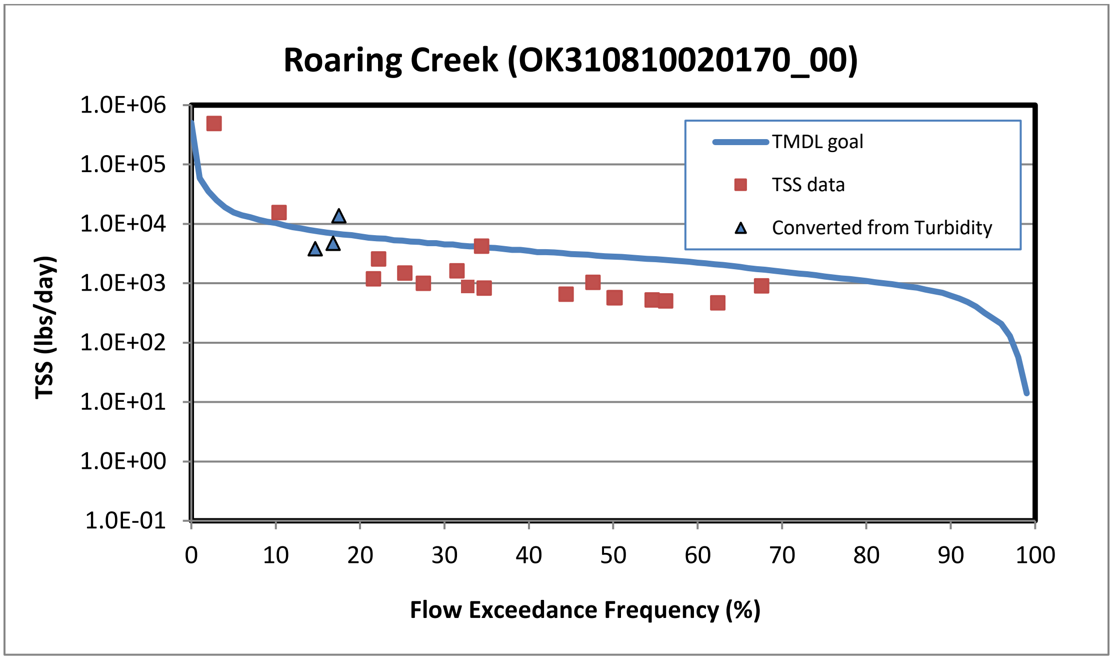


Figure 5-19 Load Duration Curve for Total Suspended Solids in the Little Washita River (OK310820020010_00)

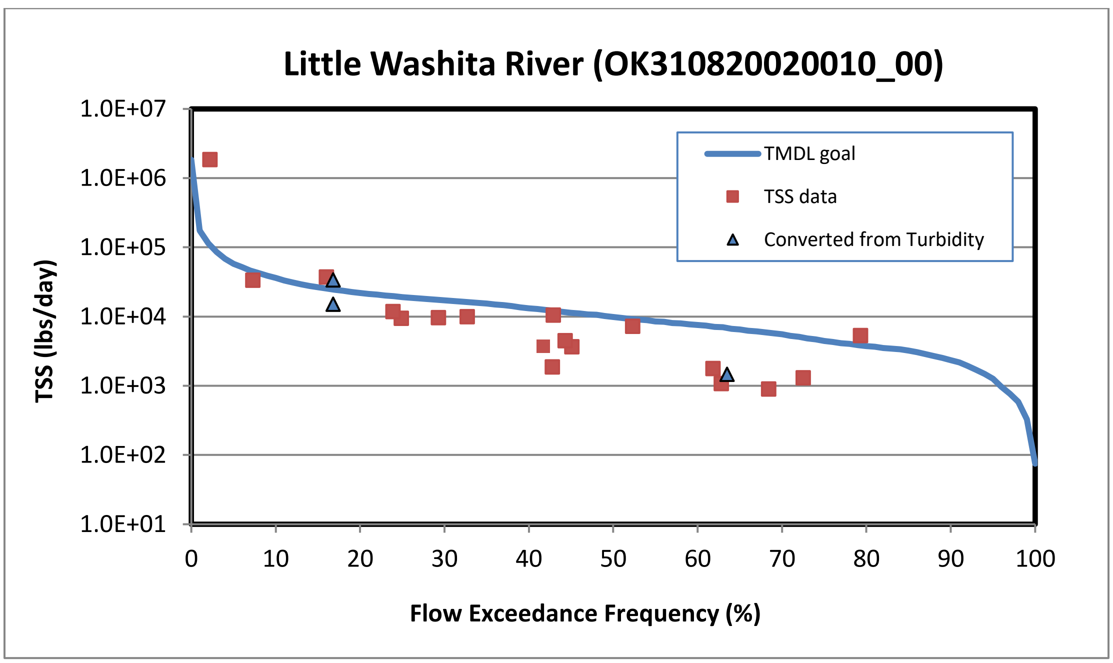


Figure 5-20 Load Duration Curve for Total Suspended Solids in Quartermaster Creek (OK310840010060_00)

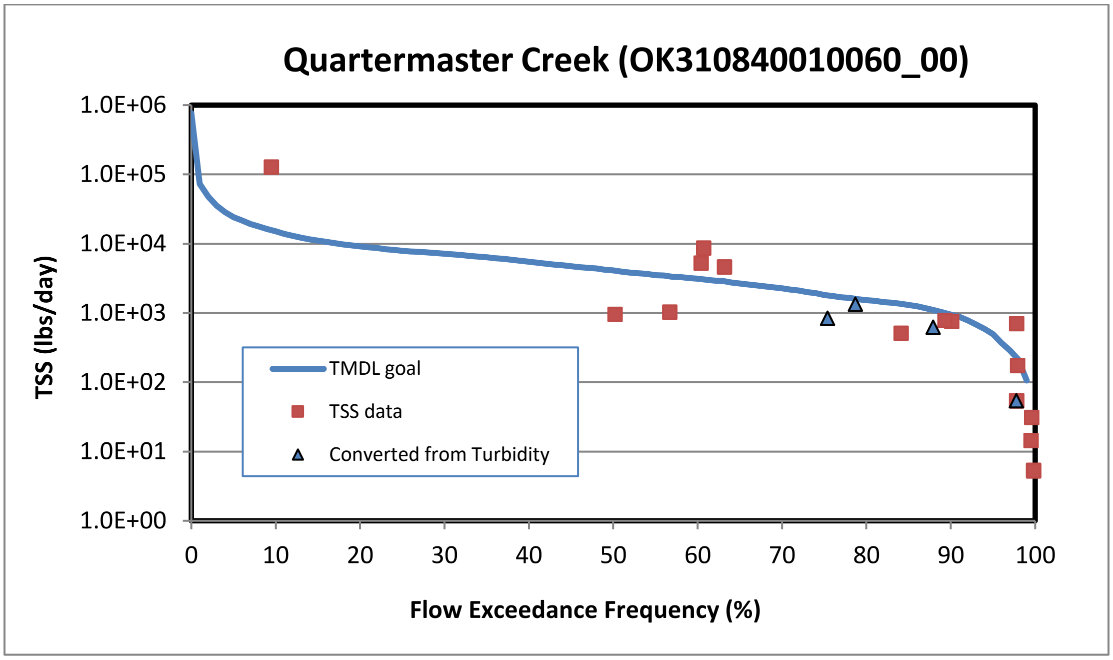
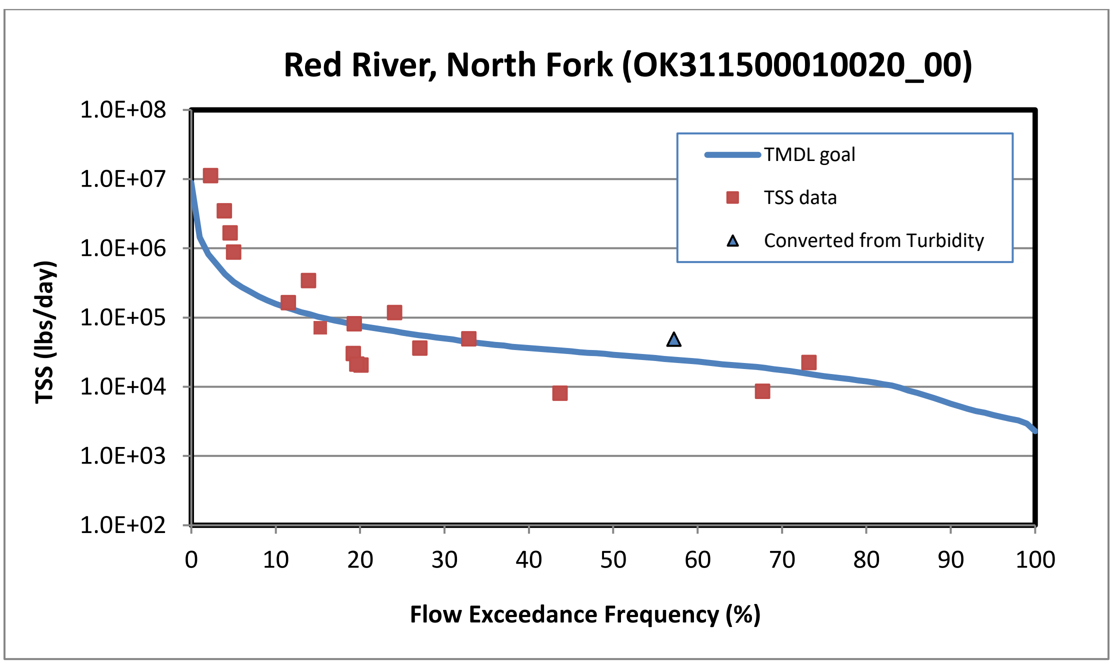


Figure 5-21 Load Duration Curve for Total Suspended Solids in Red River, North Fork (OK311500010020_00)



5.3.3 Establish 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.

5.3.3.1 Bacterial PRGs

PRGs for bacteria 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 5-3 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 ranged from 16.6% to 97.3%.

Table 5-3 TMDL Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate (%)	
		Enterococci	*E. coli*
OK310810020020_00	Finn Creek	-	16.6%
OK310810020050_00	Criner Creek	-	44.1%
OK311200000060_00	Cow Creek	-	71.8%
OK311500010020_00	Red River, North Fork	97.3%	-
OK311500010020_10	Red River, North Fork	-	57.2%

5.3.3.2 TSS PRGs

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 5-4 and range from 27.9% to 64.6%.

Table 5-4 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK310810020170_00	Roaring Creek	35.1%
OK310820020010_00	Little Washita River	27.9%
OK310840010060_00	Quartermaster Creek	64.6%
OK311500010020_00	Red River, North Fork	49.4%

5.4 Wasteload Allocation

5.4.1 Bacterial WLA

For bacterial TMDLs, OPDES-permitted facilities are allocated a daily wasteload calculated as their permitted flow rate multiplied by the in-stream geometric mean water quality criterion. In other words, the facilities are required to meet in-stream criteria in their discharge. The WLA for each facility discharging to a bacterially-impaired waterbody is derived from the following equation:

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

Where:

WQS = 33 and 126 colonies/100 mL for enterococci and E. coli respectively

Flow (mgd) = permitted flow

Unit conversion factor = 37,854,120

When multiple OPDES 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 OPDES WWTFs 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 *E. coli* limits and disinfection requirements of OPDES permits.

Table 5-5 shows WLAs within the study area. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacterial load from existing discharges will be considered consistent with the TMDL provided that the OPDES permit requires in-stream criteria to be met.

Table 5-5 Bacterial WLA for OPDES-Permitted Facilities

Waterbody ID	Stream Name	Name	OPDES Permit No.	Design Flow (mg/d)	Wasteload Allocation ($x10^8$ colonies/day)	
					E. coli	ENT
OK311200000060_00	Cow Creek	**Comanche WWT**	OK0031763	0.21	1.00E+09	-
OK311500010020_00	Red River, North Fork	**City of Altus**	OK0028037	3.5	-	4.37E+09

Permitted stormwater discharges are considered point sources. Therefore, the City of Altus will be given WLAs for MS4s (Table 5-11).

5.4.2 Total Suspended Solids WLA

As discussed in Section 3.2.1, OPDES-permitted facilities discharging primarily inorganic TSS are allocated a daily wasteload calculated by using the average of self-reported monthly flow[1] multiplied by the water quality target. In other words, the facilities are required to meet in-stream criteria in their discharge. If the current monthly TSS limits of a facility are greater than in-stream TSS criteria, the new limits equal to in-stream criteria will be applied to the facility as their permit is renewed.

By definition, any stormwater discharge occurs during periods of rainfall and elevated flow conditions. Elevated turbidity levels may be expected during, and for several days after, a runoff event. However, Oklahoma's Water Quality Standards specify that the criteria for turbidity "apply only to seasonal base flow conditions" [OAC 252:730-5-12(f)(7)]. Therefore, Oklahoma Water Quality Standard for turbidity does not apply to stormwater runoff from the watershed, including MS4. As mentioned above, development for future growth will affect turbidity levels in the watershed, but stormwater runoff from development sites are not covered by the WQSs. To accommodate the potential for future growth in the watersheds of turbidity impaired stream segments, 1% of TSS loading is reserved as part of the WLA. There are no facilities required for TSS WLA in the study area.

5.4.3 WLA for Future Growth

Future growth allowances account for increased pollutant loadings and can be included as an allocation of pollutant loads from new sources expected in the future. In this report, 10% of bacteria loading and 1% of TSS loading were reserved for future growth.

5.4.4 Permit Implication

5.4.4.1 Bacterial Permit Limitations

All point source dischargers except MS4s which are assigned a wasteload allocation in Table 5-6 will receive a permit limit equal to the water quality standard as their permits are reissued and are required to meet water quality standard at the end of pipe. MS4s are considered as point sources and will be assigned a wasteload allocation. However, due the nature of storm water discharges and the typical lack of information on which to base numeric water quality-based effluent limitations, the TMDL requirements are implemented through establishing a comprehensive stormwater management program (SWMP) or storm water pollution prevention plan (SWPPP).

Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacterial load from existing discharges will be considered consistent with the TMDL provided that the OPDES permit requires in-stream criteria to be met.

[1] OAC 252:740-5-2. Regulatory flow determination.

5.4.4.2 TSS Permit Limitations

Stormwater discharges from MS4, industrial facilities, constructions 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 in this TMDL report.

The general permit for rock, sand and gravel quarries (OKG950000) does not allow discharge of wastewater to waterbodies included in Oklahoma's 303(d) List of impaired waterbodies 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.

The TSS limits for water treatment plants with backwash discharge, mines with dewatering operations or any other facilities with TSS limits but without BOD or CBOD limitations can be determined as follows:

- If the corresponding TSS target in Table 5-2 is equal to or greater than the daily maximum limit in the current permit when a permit comes for renewal, the permit TSS limits will stay the same and the TMDL will have no impact on the permit limits.

- If the corresponding TSS target in Table 5-2 is less than the daily maximum limit in the current permit when a permit comes for renewal, the corresponding TSS target in Table 5-2 will become the daily maximum limit in the renewed permit.

- The TMDLs do not place specific requirements for monthly average limit. Permit authority will determine the proper monthly average limit.

- However, under no circumstances, will the monthly average limit in the renewed permit be greater than the monthly average limit in the current permit (anti-backsliding rule).

5.4.5 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 certificate and establish a monitoring requirement to ensure compliance with turbidity standards and TSS TMDLs, or

- Submit to 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 3.3, nonpoint source loading to each waterbody emanates 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 or for TSS are calculated as the difference between the TMDL, MOS, and WLA, as follows:

$$\mathbf{LA = TMDL - WLA\_{_{WWTF}} - WLA\_{_{MS4}} - WLA\_{_{growth}} - MOS}$$

5.6 Seasonal Variability

Federal regulations [40 CFR § Part 130.7(c)(1)] require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The bacterial 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. 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 consecutive period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.7 Margin of Safety

Federal regulations [40 CFR § Part 130.7(c)(1)]require that TMDLs include a MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the 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 bacterial, 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 ranged from 5% to 25%. Table 5-2 shows the MOS for each waterbody.

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:

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

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 OPDES permit requires in-stream criteria to be met.

The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5th flow interval percentile. Table 5-6 and Table 5-7 summarize the TMDL, WLA, LA and MOS loadings at the 50% flow percentile. Table 5-8 to Table 5-12 summarizes the allocations for indicator bacteria. The bacterial TMDLs calculated in these tables apply to the recreation season (May 1 through September 30) only. Table 5-13 to Table 5-16 present the allocations for total suspended solids.

Table 5-6 Summaries of Bacterial TMDLs

Stream Name	Waterbody ID	Pollutant	TMDL (colonies /day)	WLA$_{_WWTF}$ (colonies /day)	WLA$_{_MS4}$ (colonies /day)	WLA$_{_growth}$ (colonies /day)	LA (colonies /day)	MOS (colonies /day)
Finn Creek	OK310810020020_00	EC	3.28E+10	0.00E+00	0.00E+00	3.28E+09	2.62E+10	3.28E+09
Criner Creek	OK310810020050_00	EC	1.55E+10	0.00E+00	0.00E+00	1.55E+09	1.24E+10	1.55E+09
Cow Creek	OK311200000060_00	EC	1.13E+10	1.00E+09	0.00E+00	1.13E+09	8.03E+09	1.13E+09
Red River, North Fork	OK311500010020_00	ENT	6.60E+10	4.37E+09	2.77E+09	6.60E+09	4.57E+10	6.60E+09
Red River, North Fork	OK311500010020_10	EC	2.10E+11	0.00E+00	0.00E+00	2.10E+10	1.68E+11	2.10E+10

Table 5-7 Summaries of TSS TMDLs

Stream Name	Waterbody ID	Pollutant	TMDL (lbs/day)	WLA (lbs/day)	WLA$_{_MS4}$ (lbs/day)	WLA$_{_Growth}$ (lbs/day)	LA (lbs/day)	MOS (lbs/day)
Roaring Creek	OK310810020170_00	TSS	3,738	0	0	37.4	2,766	935
Little Washita River	OK310820020010_00	TSS	12,403	0	0	124.0	9,798	2,481
Quartermaster Creek	OK310840010060_00	TSS	5,469	0	0	54.7	4,047	1,367
Red River, North Fork	OK311500010020_00	TSS	30,652	0	0	306.5	28,813	1,533

Table 5-8 *E. coli* TMDL Calculations for Finn Creek (OK310810020020_00)

Percentile	Flow (cfs)	TMDL (colonies/day)	WLA_{WWTF} (colonies/day)	WLA_{MS4} (colonies/day)	WLA_{growth}(colonies/day)	LA (colonies/day)	MOS (colonies/day)
0	1,915.6	5.91E+12	0	0	5.91E+11	4.72E+12	5.91E+11
5	59.6	1.84E+11	0	0	1.84E+10	1.47E+11	1.84E+10
10	39.4	1.21E+11	0	0	1.21E+10	9.71E+10	1.21E+10
15	28.4	8.76E+10	0	0	8.76E+09	7.01E+10	8.76E+09
20	23.4	7.22E+10	0	0	7.22E+09	5.77E+10	7.22E+09
25	19.9	6.13E+10	0	0	6.13E+09	4.91E+10	6.13E+09
30	17.0	5.25E+10	0	0	5.25E+09	4.20E+10	5.25E+09
35	15.1	4.66E+10	0	0	4.66E+09	3.73E+10	4.66E+09
40	13.3	4.10E+10	0	0	4.10E+09	3.28E+10	4.10E+09
45	11.8	3.64E+10	0	0	3.64E+09	2.91E+10	3.64E+09
50	10.6	3.28E+10	0	0	3.28E+09	2.62E+10	3.28E+09
55	9.6	2.96E+10	0	0	2.96E+09	2.37E+10	2.96E+09
60	8.4	2.60E+10	0	0	2.60E+09	2.08E+10	2.60E+09
65	7.1	2.20E+10	0	0	2.20E+09	1.76E+10	2.20E+09
70	6.0	1.84E+10	0	0	1.84E+09	1.47E+10	1.84E+09
75	4.9	1.52E+10	0	0	1.52E+09	1.22E+10	1.52E+09
80	4.1	1.28E+10	0	0	1.28E+09	1.02E+10	1.28E+09
85	3.3	1.02E+10	0	0	1.02E+09	8.16E+09	1.02E+09
90	2.3	7.22E+09	0	0	7.22E+08	5.77E+09	7.22E+08
95	1.0	2.99E+09	0	0	2.99E+08	2.39E+09	2.99E+08
100	0	0	0	0	0	0	0

Table 5-9 *E. coli* TMDL Calculations for Cow Creek (OK311200000060_00)

Percentile	Flow (cfs)	TMDL (colonies/day)	WLA_{WWTF} (colonies/day)	WLA_{MS4} (colonies/day)	WLA_{growth} (colonies/day)	LA (colonies/day)	MOS (colonies/day)
0	1,913.9	5.90E+12	0	0	5.90E+11	4.72E+12	5.90E+11
5	58.7	1.81E+11	0	0	1.81E+10	1.45E+11	1.81E+10
10	34.8	1.07E+11	0	0	1.07E+10	8.59E+10	1.07E+10
15	24.5	7.55E+10	0	0	7.55E+09	6.04E+10	7.55E+09
20	18.7	5.76E+10	0	0	5.76E+09	4.61E+10	5.76E+09
25	15.1	4.64E+10	0	0	4.64E+09	3.71E+10	4.64E+09
30	12.4	3.84E+10	0	0	3.84E+09	3.07E+10	3.84E+09
35	10.2	3.15E+10	0	0	3.15E+09	2.52E+10	3.15E+09
40	8.3	2.55E+10	0	0	2.55E+09	2.04E+10	2.55E+09
45	6.5	2.00E+10	0	0	2.00E+09	1.60E+10	2.00E+09
50	5.0	1.55E+10	0	0	1.55E+09	1.24E+10	1.55E+09
55	4.1	1.26E+10	0	0	1.26E+09	1.01E+10	1.26E+09
60	3.3	1.00E+10	0	0	1.00E+09	8.02E+09	1.00E+09
65	2.5	7.73E+09	0	0	7.73E+08	6.19E+09	7.73E+08
70	1.8	5.44E+09	0	0	5.44E+08	4.35E+09	5.44E+08
75	1.1	3.44E+09	0	0	3.44E+08	2.75E+09	3.44E+08
80	0.7	2.00E+09	0	0	2.00E+08	1.60E+09	2.00E+08
85	0.2	5.73E+08	0	0	5.73E+07	4.58E+08	5.73E+07
90	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0

Table 5-10 *E. coli* TMDL Calculations for Cow Creek (OK311200000060_00)

Percentile	Flow (cfs)	TMDL (colonies/day)	WLA_{WWTF} (colonies/day)	WLA_{MS4} (colonies/day)	WLA_{growth} (colonies/day)	LA (colonies/day)	MOS (colonies/day)
0	17,493.0	5.39E+13	1.00E+09	0	5.39E+12	4.31E+13	5.39E+12
5	279.2	8.61E+11	1.00E+09	0	8.61E+10	6.88E+11	8.61E+10
10	79.6	2.45E+11	1.00E+09	0	2.45E+10	1.95E+11	2.45E+10
15	37.7	1.16E+11	1.00E+09	0	1.16E+10	9.19E+10	1.16E+10
20	23.3	7.18E+10	1.00E+09	0	7.18E+09	5.64E+10	7.18E+09
25	15.7	4.83E+10	1.00E+09	0	4.83E+09	3.76E+10	4.83E+09
30	11.3	3.48E+10	1.00E+09	0	3.48E+09	2.68E+10	3.48E+09
35	7.9	2.43E+10	1.00E+09	0	2.43E+09	1.85E+10	2.43E+09
40	6.0	1.86E+10	1.00E+09	0	1.86E+09	1.39E+10	1.86E+09
45	4.6	1.42E+10	1.00E+09	0	1.42E+09	1.04E+10	1.42E+09
50	3.7	1.13E+10	1.00E+09	0	1.13E+09	8.03E+09	1.13E+09
55	3.0	9.20E+09	1.00E+09	0	9.20E+08	6.36E+09	9.20E+08
60	2.5	7.64E+09	1.00E+09	0	7.64E+08	5.11E+09	7.64E+08
65	2.1	6.59E+09	1.00E+09	0	6.59E+08	4.27E+09	6.59E+08
70	1.9	5.71E+09	1.00E+09	0	5.71E+08	3.56E+09	5.71E+08
75	1.7	5.14E+09	1.00E+09	0	5.14E+08	3.11E+09	5.14E+08
80	1.6	4.82E+09	1.00E+09	0	4.82E+08	2.85E+09	4.82E+08
85	1.5	4.61E+09	1.00E+09	0	4.61E+08	2.69E+09	4.61E+08
90	1.5	4.51E+09	1.00E+09	0	4.51E+08	2.60E+09	4.51E+08
95	1.5	4.51E+09	1.00E+09	0	4.51E+08	2.60E+09	4.51E+08
100	1.5	4.51E+09	1.00E+09	0	4.51E+08	2.60E+09	4.51E+08

Table 5-11 Enterococcus TMDL Calculations for the Red River, North Fork (OK311500010020_00)

Percentile	Flow (cfs)	TMDL (colonies/day)	WLA_{WWTF} (colonies/day)	WLA_{MS4} (colonies/day)	WLA_{growth} (colonies/day)	LA (colonies/day)	MOS (colonies/day)
0	24,905.4	2.01E+13	4.37E+09	8.45E+11	2.01E+12	1.52E+13	2.01E+12
5	927.0	7.48E+11	4.37E+09	3.14E+10	7.48E+10	5.63E+11	7.48E+10
10	440.4	3.56E+11	4.37E+09	1.49E+10	3.56E+10	2.65E+11	3.56E+10
15	288.4	2.33E+11	4.37E+09	9.78E+09	2.33E+10	1.72E+11	2.33E+10
20	213.4	1.72E+11	4.37E+09	7.24E+09	1.72E+10	1.26E+11	1.72E+10
25	170.4	1.38E+11	4.37E+09	5.78E+09	1.38E+10	9.99E+10	1.38E+10
30	140.4	1.13E+11	4.37E+09	4.76E+09	1.13E+10	8.16E+10	1.13E+10
35	117.4	9.48E+10	4.37E+09	3.98E+09	9.48E+09	6.75E+10	9.48E+09
40	101.6	8.20E+10	4.37E+09	3.45E+09	8.20E+09	5.78E+10	8.20E+09
45	91.4	7.38E+10	4.37E+09	3.10E+09	7.38E+09	5.16E+10	7.38E+09
50	81.8	6.60E+10	4.37E+09	2.77E+09	6.60E+09	4.57E+10	6.60E+09
55	73.0	5.89E+10	4.37E+09	2.48E+09	5.89E+09	4.03E+10	5.89E+09
60	64.9	5.24E+10	4.37E+09	2.20E+09	5.24E+09	3.54E+10	5.24E+09
65	56.5	4.56E+10	4.37E+09	1.92E+09	4.56E+09	3.02E+10	4.56E+09
70	48.8	3.94E+10	4.37E+09	1.66E+09	3.94E+09	2.55E+10	3.94E+09
75	40.1	3.24E+10	4.37E+09	1.36E+09	3.24E+09	2.02E+10	3.24E+09
80	33.8	2.73E+10	4.37E+09	1.15E+09	2.73E+09	1.63E+10	2.73E+09
85	24.7	2.00E+10	4.37E+09	8.38E+08	2.00E+09	1.08E+10	2.00E+09
90	15.9	1.28E+10	4.37E+09	5.40E+08	1.28E+09	5.37E+09	1.28E+09
95	11.0	8.87E+09	4.37E+09	3.72E+08	8.87E+08	2.35E+09	8.87E+08
100	6.4	5.18E+09	4.37E+09	2.18E+08	6.91E+07	0.00E+00	5.18E+08

Table 5-12 *E. coli* TMDL Calculations for the Red River, North Fork (OK311500010020_10)

Percentile	Flow (cfs)	TMDL (colonies/day)	WLA_{WWTF} (colonies/day)	WLA_{MS4} (colonies/day)	WLA_{growth} (colonies/day)	LA (colonies/day)	MOS (colonies/day)
0	61,700.0	1.90E+14	0	0	1.90E+13	1.52E+14	1.90E+13
5	1,030.0	3.18E+12	0	0	3.18E+11	2.54E+12	3.18E+11
10	519.5	1.60E+12	0	0	1.60E+11	1.28E+12	1.60E+11
15	332.5	1.02E+12	0	0	1.02E+11	8.20E+11	1.02E+11
20	233.0	7.18E+11	0	0	7.18E+10	5.75E+11	7.18E+10
25	178.0	5.49E+11	0	0	5.49E+10	4.39E+11	5.49E+10
30	137.0	4.22E+11	0	0	4.22E+10	3.38E+11	4.22E+10
35	110.0	3.39E+11	0	0	3.39E+10	2.71E+11	3.39E+10
40	92.0	2.84E+11	0	0	2.84E+10	2.27E+11	2.84E+10
45	79.0	2.44E+11	0	0	2.44E+10	1.95E+11	2.44E+10
50	68.0	2.10E+11	0	0	2.10E+10	1.68E+11	2.10E+10
55	60.5	1.87E+11	0	0	1.87E+10	1.49E+11	1.87E+10
60	52.1	1.61E+11	0	0	1.61E+10	1.28E+11	1.61E+10
65	43.8	1.35E+11	0	0	1.35E+10	1.08E+11	1.35E+10
70	36.2	1.11E+11	0	0	1.11E+10	8.92E+10	1.11E+10
75	28.7	8.85E+10	0	0	8.85E+09	7.08E+10	8.85E+09
80	22.2	6.84E+10	0	0	6.84E+09	5.47E+10	6.84E+09
85	15.6	4.81E+10	0	0	4.81E+09	3.85E+10	4.81E+09
90	10.0	3.08E+10	0	0	3.08E+09	2.47E+10	3.08E+09
95	3.8	1.17E+10	0	0	1.17E+09	9.40E+09	1.17E+09
100	0	0	0	0	0	0	0

Table 5-13 Total Suspended Solids TMDL Calculations for Roaring Creek (OK310810020170_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA (lbs/day)			LA (lbs/day)	MOS (lbs/day)
			WWTF	MS4	Future Growth		
0	1,924.2	N/A	0.0	0.0	N/A	N/A	N/A
5	59.9	N/A	0.0	0.0	N/A	N/A	N/A
10	39.6	N/A	0.0	0.0	N/A	N/A	N/A
15	28.5	N/A	0.0	0.0	N/A	N/A	N/A
20	23.5	N/A	0.0	0.0	N/A	N/A	N/A
25	20.0	6,990	0.0	0.0	69.9	5,173	1,748
30	17.1	5,981	0.0	0.0	59.8	4,426	1,495
35	15.2	5,308	0.0	0.0	53.1	3,928	1,327
40	13.4	4,673	0.0	0.0	46.7	3,458	1,168
45	11.9	4,149	0.0	0.0	41.5	3,070	1,037
50	10.7	3,738	0.0	0.0	37.4	2,766	935
55	9.7	3,375	0.0	0.0	33.8	2,498	844
60	8.5	2,961	0.0	0.0	29.6	2,191	740
65	7.2	2,504	0.0	0.0	25.0	1,853	626
70	6.0	2,093	0.0	0.0	20.9	1,549	523
75	5.0	1,735	0.0	0.0	17.4	1,284	434
80	4.2	1,454	0.0	0.0	14.5	1,076	364
85	3.3	1,163	0.0	0.0	11.6	860	291
90	2.4	822	0.0	0.0	8.2	609	206
95	1.0	340	0.0	0.0	3.4	252	85
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NA = Not Applicable

Table 5-14 Total Suspended Solids TMDL Calculations for the Little Washita River (OK310820020010_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA (lbs/day)			LA (lbs/day)	MOS (lbs/day)
			WWTF	MS4	Future Growth		
0	5,261.4	N/A	0.0	0.0	N/A	N/A	N/A
5	164.8	N/A	0.0	0.0	N/A	N/A	N/A
10	103.4	N/A	0.0	0.0	N/A	N/A	N/A
15	76.3	N/A	0.0	0.0	N/A	N/A	N/A
20	62.7	N/A	0.0	0.0	N/A	N/A	N/A
25	54.5	23,846	0.0	0.0	238.5	18,838	4,769
30	49.2	21,521	0.0	0.0	215.2	17,002	4,304
35	43.9	19,196	0.0	0.0	192.0	15,165	3,839
40	37.7	16,506	0.0	0.0	165.1	13,040	3,301
45	32.5	14,227	0.0	0.0	142.3	11,239	2,845
50	28.3	12,403	0.0	0.0	124.0	9,798	2,481
55	24.4	10,671	0.0	0.0	106.7	8,430	2,134
60	21.6	9,458	0.0	0.0	94.6	7,472	1,892
65	18.5	8,118	0.0	0.0	81.2	6,413	1,624
70	15.8	6,932	0.0	0.0	69.3	5,476	1,386
75	12.7	5,564	0.0	0.0	55.6	4,396	1,113
80	10.7	4,698	0.0	0.0	47.0	3,712	940
85	9.2	4,021	0.0	0.0	40.2	3,176	804
90	6.7	2,948	0.0	0.0	29.5	2,329	590
95	3.6	1,586	0.0	0.0	15.9	1,253	317
100	0.2	94	0.0	0.0	0.9	83	9

NA = Not Applicable

Table 5-15 Total Suspended Solids TMDL Calculations for Quartermaster Creek (OK310840010060_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA (lbs/day)			LA (lbs/day)	MOS (lbs/day)
			WWTF	MS4	Future growth		
0	3,347.8	N/A	0.0	0.0	N/A	N/A	N/A
5	104.7	N/A	0.0	0.0	N/A	N/A	N/A
10	65.6	N/A	0.0	0.0	N/A	N/A	N/A
15	48.4	N/A	0.0	0.0	N/A	N/A	N/A
20	39.8	N/A	0.0	0.0	N/A	N/A	N/A
25	34.5	10,552	0.0	0.0	105.5	7,809	2,638
30	31.2	9,519	0.0	0.0	95.2	7,044	2,380
35	27.8	8,486	0.0	0.0	84.9	6,280	2,122
40	23.9	7,291	0.0	0.0	72.9	5,396	1,823
45	20.6	6,279	0.0	0.0	62.8	4,646	1,570
50	17.9	5,469	0.0	0.0	54.7	4,047	1,367
55	15.4	4,699	0.0	0.0	47.0	3,477	1,175
60	13.6	4,160	0.0	0.0	41.6	3,078	1,040
65	11.7	3,565	0.0	0.0	35.6	2,638	891
70	9.9	3,038	0.0	0.0	30.4	2,248	760
75	8.0	2,430	0.0	0.0	24.3	1,799	608
80	6.7	2,046	0.0	0.0	20.5	1,514	511
85	5.7	1,745	0.0	0.0	17.4	1,291	436
90	4.1	1,268	0.0	0.0	12.7	938	317
95	2.2	663	0.0	0.0	6.6	491	166
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NA = Not Applicable

Table 5-16 Total Suspended Solids TMDL Calculations for the Red River, North Fork (OK311500010020_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA (lbs/day)			LA (lbs/day)	MOS (lbs/day)
			WWTF	MS4	Future Growth		
0	24,905.4	N/A	0.0	0.0	N/A	N/A	N/A
5	927.0	N/A	0.0	0.0	N/A	N/A	N/A
10	440.4	N/A	0.0	0.0	N/A	N/A	N/A
15	288.4	N/A	0.0	0.0	N/A	N/A	N/A
20	213.4	N/A	0.0	0.0	N/A	N/A	N/A
25	170.4	63,885	0.0	0.0	638.8	60,052	3,194
30	140.4	52,638	0.0	0.0	526.4	49,480	2,632
35	117.4	44,016	0.0	0.0	440.2	41,375	2,201
40	101.6	38,093	0.0	0.0	380.9	35,808	1,905
45	91.4	34,269	0.0	0.0	342.7	32,213	1,713
50	81.8	30,652	0.0	0.0	306.5	28,813	1,533
55	73.0	27,372	0.0	0.0	273.7	25,729	1,369
60	64.9	24,335	0.0	0.0	243.4	22,875	1,217
65	56.5	21,186	0.0	0.0	211.9	19,915	1,059
70	48.8	18,300	0.0	0.0	183.0	17,202	915
75	40.1	15,038	0.0	0.0	150.4	14,136	752
80	33.8	12,676	0.0	0.0	126.8	11,916	634
85	24.7	9,265	0.0	0.0	92.6	8,709	463
90	15.9	5,966	0.0	0.0	59.7	5,608	298
95	11.0	4,117	0.0	0.0	41.2	3,870	206
100	6.4	2,405	0.0	0.0	24.0	2,140	240

NA = Not Applicable

5.9 Strength and Weakness

Strength: The LDC is a simple and efficient method to show the relationship between flow and pollutant load. Therefore, it facilitates rapid development of TMDLs and provides some information for identifying whether impairments are associated with point or nonpoint sources. 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.

Weakness: LDCs graphically display the changing water quality over changing flows that may not be apparent when visualizing raw data. Flow range is only a general indicator of the relative proportion of point/nonpoint contributions. LDCs cannot identify nonpoint sources as entering a waterbody at a specific location. Therefore, the specific control actions cannot be stipulated.

5.10 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 § Part 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (DEQ 2012). The CPP can be viewed at DEQ's website: https://www.deq.ok.gov/wp-content/uploads/water-division/2012-OK-CPP.pdf. Table 5-17 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 5-17 Partial List of Oklahoma Water Quality Management Agencies

Agency	Web Link
Oklahoma Conservation Commission	https://conservation.ok.gov/water-quality-division/
Oklahoma Department of Wildlife Conservation	https://www.wildlifedepartment.com/hunting/research
Oklahoma Department of Agriculture, Food, and Forestry	https://ag.ok.gov/divisions/agricultural-environmental-management/
Oklahoma Water Resources Board	https://oklahoma.gov/owrb/data-and-maps/water-monitoring-and-data.html

5.10.1 Point Sources

Point source WLAs are outlined in the Oklahoma Water Quality Management Plan (aka the 208 Plan) under the OPDES program.

5.10.2 Nonpoint Sources

Nonpoint source pollution in Oklahoma is managed by the Oklahoma Conservation Commission. The Oklahoma Conservation Commission works with other agencies that collect water monitoring information and/or address water quality problems associated with nonpoint source pollution. These agencies at the State level are DEQ, OWRB, Corporation Commission (for oil & gas activities), and ODAFF [they are the NPDES-permitting authority for CAFOs and SFOs in Oklahoma under what ODAFF calls the Agriculture Pollutant Discharge Elimination System (AgPDES)]. The agencies at the Federal level are EPA, USGS, U.S. Army Corps of Engineers (USACE) & the National Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA). 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.

The reduction rates called for in this TMDL report are as high as 97.3% for bacteria and 64.6% for TSS. DEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of bacterial and TSS loading. The high reduction rates are not uncommon for bacteria- or TSS-impaired waters. Similar reduction rates are often found in other bacteria 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 Health and Environment proposed to exclude certain high flow conditions during which pathogen standards will not apply though 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 future.

5.11 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 discharge limitations less than or equal to the water quality standards numerical criteria. Therefore, reasonable assurance is derived from Oklahoma Pollutant Discharge Elimination System (OPDES). The wasteload allocations for MS4s will be implemented through the OPDES MS4 permits. MS4 permits contain specific requirements for the regulated communities/facilities to establish a comprehensive stormwater management program (SWMP) or stormwater pollution prevention plan (SWP3) to implement best management practices (BMPs), public education and outreach, and illicit discharge elimination.

Reasonable assurance that nonpoint sources will meet their allocated amount in the TMDL is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. Under OAC 155:40-1-4, the OCC is declared the state's technical lead agency for NPS categories defined in Section 319 of the CWA. DEQ will work in conjunction with OCC and other federal, state, and local partners to meet the load reduction goals for NPS. All waterbodies are prioritized as part of the Unified Watershed Assessment (UWA) and that ranking will determine the likelihood of an implementation project in a watershed.

SECTION 6 PUBLIC PARTICIPATION

This TMDL report has been preliminary reviewed by EPA. After EPA reviewed this draft TMDL report, DEQ was given approval to submit this report for public notice. A public notice will be sent to local newspapers, to stakeholders in the study area affected by these draft TMDLs, and to stakeholders who have requested all copies of TMDL public notices. The public notice will also be posted at the DEQ website: http://www.deq.state.ok.us/wqdnew/index.htm.

The public comment period lasts 45 days. During that time, the public has the opportunity to review the TMDL report and make written comments. Depending on the interest and responses from the public, a public meeting may be held within the watershed affected by the TMDLs in this report. If a public meeting is held, the public will also have opportunities to ask questions and make formal oral comments at the meeting and/or to submit written comments at the public meeting.

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

After EPA's final approval, the TMDLs and 208 Factsheet will be adopted into the Water Quality Management Plan (WQMP).

SECTION 7 REFERENCES

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Appendix A Ambient Water Quality Data

Appendix Table A-1 Bacterial Data: 2006 to 2021

Waterbody Name	WQM Station	Date	EC[1]	ENT[1,2]
Finn Creek	OK310810-02-0020D	5/30/2006		85
Finn Creek	OK310810-02-0020D	6/26/2006		145
Finn Creek	OK310810-02-0020D	5/18/2009		100
Finn Creek	OK310810-02-0020D	6/22/2009		670
Finn Creek	OK310810-02-0020D	8/31/2009		175
Finn Creek	OK310810-02-0020D	5/4/2010		280
Finn Creek	OK310810-02-0020D	5/18/2010		2,200
Finn Creek	OK310810-02-0020D	6/22/2010		1,220
Finn Creek	OK310810-02-0020D	7/27/2010		850
Finn Creek	OK310810-02-0020D	9/7/2010		310
Finn Creek	OK310810-02-0020D	9/21/2010		520
Finn Creek	OK310810-02-0020D	6/18/2019	20	
Finn Creek	OK310810-02-0020D	7/30/2019	1	
Finn Creek	OK310810-02-0020D	8/27/2019	70	
Finn Creek	OK310810-02-0020D	5/19/2020	520	
Finn Creek	OK310810-02-0020D	6/23/2020	580	
Finn Creek	OK310810-02-0020D	7/14/2020	310	
Finn Creek	OK310810-02-0020D	7/27/2020	90	
Finn Creek	OK310810-02-0020D	8/31/2020	90	
Finn Creek	OK310810-02-0020D	5/3/2021	1,700	
Finn Creek	OK310810-02-0020D	5/11/2021	1,200	
Criner Creek	OK310810-02-0050D	6/18/2019	1	
Criner Creek	OK310810-02-0050D	7/30/2019	1	
Criner Creek	OK310810-02-0050D	8/24/2019	1,270	
Criner Creek	OK310810-02-0050D	5/19/2020	470	
Criner Creek	OK310810-02-0050D	6/23/2020	1,950	
Criner Creek	OK310810-02-0050D	7/14/2020	250	

Waterbody Name	WQM Station	Date	EC[1]	ENT[1,2]
Criner Creek	OK310810-02-0050D	7/27/2020	50	
Criner Creek	OK310810-02-0050D	8/31/2020	1,980	
Criner Creek	OK310810-02-0050D	5/3/2021	2,400	
Criner Creek	OK310810-02-0050D	5/11/2021	1,700	
Cow Creek	OK311200-00-0060L	6/5/2006	770	260
Cow Creek	OK311200-00-0060L	7/10/2006	600	370
Cow Creek	OK311200-00-0060L	5/26/2009	580	450
Cow Creek	OK311200-00-0060L	8/3/2009	10	30
Cow Creek	OK311200-00-0060L	9/8/2009	85	110
Cow Creek	OK311200-00-0060L	9/14/2009	1,800	1,140
Cow Creek	OK311200-00-0060L	5/24/2010	210	300
Cow Creek	OK311200-00-0060L	6/28/2010	5,200	10,000
Cow Creek	OK311200-00-0060L	8/2/2010	100	50
Cow Creek	OK311200-00-0060L	8/24/2010	1,360	1,660
Cow Creek	OK311200-00-0060L	9/13/2010	5,300	5,500
Cow Creek	OK311200-00-0060L	6/30/2009	55	50
Red River, North Fork	311500010020-002AT	6/3/2013	641	
Red River, North Fork	311500010020-002AT	6/18/2013	98	488
Red River, North Fork	311500010020-002AT	7/10/2013	330	1,414
Red River, North Fork	311500010020-002AT	7/24/2013	99	1,986
Red River, North Fork	311500010020-001AT	5/2/2006	63	20
Red River, North Fork	311500010020-001AT	5/31/2006	8,164	19,863
Red River, North Fork	311500010020-001AT	6/6/2006	41	109
Red River, North Fork	311500010020-001AT	6/13/2006	86	10
Red River, North Fork	311500010020-001AT	7/18/2006	173	52
Red River, North Fork	311500010020-001AT	8/15/2006	565	41
Red River, North Fork	311500010020-001AT	5/22/2013	210	203
Red River, North Fork	311500010020-001AT	6/4/2013	534	2,420
Red River, North Fork	311500010020-001AT	6/18/2013	479	75

Waterbody Name	WQM Station	Date	EC[1]	ENT[1,2]
Red River, North Fork	311500010020-001AT	7/23/2013	86	272
Red River, North Fork	311500010020-001AT	8/13/2013	517	2,420

[1] EC = *E. coli*; units = counts/100 mL

[2] ENT = Enterococci; units = counts/100 mL.

Appendix Table A-2 Turbidity and Total Suspended Solids Data (2013-2018)

Waterbody Name	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
Roaring Creek	OK310810-02-0170B	06/25/19	52	75.0	Slightly elevated
Roaring Creek	OK310810-02-0170B	07/09/19	26.3		Base flow
Roaring Creek	OK310810-02-0170B	08/06/19	6.04	<10.0	Base flow
Roaring Creek	OK310810-02-0170B	09/10/19	6.58	26.0	Base flow
Roaring Creek	OK310810-02-0170B	10/15/19	4.68	<10.0	Base flow
Roaring Creek	OK310810-02-0170B	11/19/19	9.6	<10.0	Base flow
Roaring Creek	OK310810-02-0170B	01/07/20	4.35	<10.0	Base flow
Roaring Creek	OK310810-02-0170B	02/11/20	14.6	22.0	Slightly elevated
Roaring Creek	OK310810-02-0170B	03/17/20	6.03	<10.0	Slightly elevated
Roaring Creek	OK310810-02-0170B	04/21/20	19.6		Base flow
Roaring Creek	OK310810-02-0170B	05/27/20	74.8		Slightly elevated
Roaring Creek	OK310810-02-0170B	07/07/20	21.5	18.0	Base flow
Roaring Creek	OK310810-02-0170B	08/04/20	8.07	11.0	Base flow
Roaring Creek	OK310810-02-0170B	09/15/20		50.0	Slightly elevated
Roaring Creek	OK310810-02-0170B	10/13/20	4.5	<10.0	Base flow
Roaring Creek	OK310810-02-0170B	11/24/20	9.24	<10.0	Base flow
Roaring Creek	OK310810-02-0170B	12/29/20	6.03	<10.0	Base flow
Roaring Creek	OK310810-02-0170B	02/02/21	9.25	14.0	Base flow
Roaring Creek	OK310810-02-0170B	03/10/21	9.72	17.0	Base flow
Roaring Creek	OK310810-02-0170B	04/12/21	5.23	<10.0	Slightly elevated
Roaring Creek	OK310810-02-0170B	05/17/21	482	840.0	Elevated
Little Washita River	OK310820-02-0010A	06/25/19	61.6	95.0	Slightly elevated

Waterbody Name	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
Little Washita River	OK310820-02-0010A	08/01/19	6.84		Base flow
Little Washita River	OK310820-02-0010A	08/06/19	9.18	16.0	Base flow
Little Washita River	OK310820-02-0010A	09/10/19	10.9	90.0	Base flow
Little Washita River	OK310820-02-0010A	10/15/19	3.77	<10.0	Base flow
Little Washita River	OK310820-02-0010A	11/19/19	11.6	21.0	Base flow
Little Washita River	OK310820-02-0010A	01/07/20	12.4	25.0	Base flow
Little Washita River	OK310820-02-0010A	02/11/20	20.6	40.0	Slightly elevated
Little Washita River	OK310820-02-0010A	03/17/20	29.6	48.0	Slightly elevated
Little Washita River	OK310820-02-0010A	04/21/20	22.3		Slightly elevated
Little Washita River	OK310820-02-0010A	05/27/20	55.6		Slightly elevated
Little Washita River	OK310820-02-0010A	07/07/20	48.8	56.0	Base flow
Little Washita River	OK310820-02-0010A	08/04/20	11	17.0	Base flow
Little Washita River	OK310820-02-0010A	09/15/20		51.0	Base flow
Little Washita River	OK310820-02-0010A	10/13/20	3.3	<10.0	Low flow
Little Washita River	OK310820-02-0010A	11/24/20	26.1	32.0	Base flow
Little Washita River	OK310820-02-0010A	12/29/20	13.1	19.0	Base flow
Little Washita River	OK310820-02-0010A	02/02/21	16.5	39.0	Slightly elevated
Little Washita River	OK310820-02-0010A	03/10/21	10.6	36.0	Base flow
Little Washita River	OK310820-02-0010A	04/12/21	5.97	<10.0	Base flow
Little Washita River	OK310820-02-0010A	05/17/21	813	1,100.0	Elevated
Quartermaster Creek	OK310840-01-0060B	06/11/19	325	350.0	Elevated
Quartermaster Creek	OK310840-01-0060B	07/24/19	4.51	13.0	Base flow
Quartermaster Creek	OK310840-01-0060B	08/01/19	17.9		Low flow
Quartermaster Creek	OK310840-01-0060B	08/09/19	87.9	72.0	Low flow
Quartermaster Creek	OK310840-01-0060B	09/30/19	28.5	34.0	Base flow

Waterbody Name	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
Quartermaster Creek	OK310840-01-0060B	11/04/19	26.1	16.0	Base flow
Quartermaster Creek	OK310840-01-0060B	12/09/19	4.31	<10.0	Base flow
Quartermaster Creek	OK310840-01-0060B	01/27/20	28.8	120.0	Slightly elevated
Quartermaster Creek	OK310840-01-0060B	03/02/20	56.5	69.0	Slightly elevated
Quartermaster Creek	OK310840-01-0060B	04/06/20	28.6		Base flow
Quartermaster Creek	OK310840-01-0060B	05/11/20	14.2		Base flow
Quartermaster Creek	OK310840-01-0060B	06/15/20	23.1	33.0	Low flow
Quartermaster Creek	OK310840-01-0060B	07/20/20	27.2	26.0	Low flow
Quartermaster Creek	OK310840-01-0060B	08/24/20	10.2	<10.0	Trace
Quartermaster Creek	OK310840-01-0060B	10/05/20		<10.0	Low flow
Quartermaster Creek	OK310840-01-0060B	11/03/20	3.27	<10.0	Base flow
Quartermaster Creek	OK310840-01-0060B	12/14/20	1.95	<10.0	Slightly elevated
Quartermaster Creek	OK310840-01-0060B	01/25/21	25.1	33.0	Elevated
Quartermaster Creek	OK310840-01-0060B	03/01/21	110	130.0	Base flow
Quartermaster Creek	OK310840-01-0060B	04/05/21	3.84	<10.0	Low flow
Quartermaster Creek	OK310840-01-0060B	05/10/21	3.86	<10.0	Low flow
Red River, North Fork	311500010020-002AT	08/15/16	101.3	124.0	
Red River, North Fork	311500010020-002AT	09/26/16	1,000	990.0	Interstitial
Red River, North Fork	311500010020-002AT	11/08/16	50	72.5	Above Normal
Red River, North Fork	311500010020-002AT	01/23/17	24.7	43.0	Normal
Red River, North Fork	311500010020-002AT	03/21/17	9.3	18.0	Normal
Red River, North Fork	311500010020-002AT	04/19/17	56	79.0	Low
Red River, North Fork	311500010020-002AT	09/13/17	8.7	25.0	Normal
Red River, North Fork	311500010020-002AT	10/10/17	748	520.0	Normal
Red River, North Fork	311500010020-002AT	01/23/18	4	16.0	Normal

Waterbody Name	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
Red River, North Fork	311500010020-002AT	04/17/18	8	30.0	Normal
Red River, North Fork	311500010020-002AT	08/06/18	73	97.1	Normal
Red River, North Fork	311500010020-002AT	08/14/18	112.7		Normal
Red River, North Fork	311500010020-002AT	10/16/18	324.7	296.0	Normal
Red River, North Fork	311500010020-002AT	11/27/18	9.7	18.0	Above Normal
Red River, North Fork	311500010020-002AT	03/19/19	34.3	46.0	Normal
Red River, North Fork	311500010020-002AT	04/30/19	162	174.0	Above Normal
Red River, North Fork	311500010020-002AT	08/20/19	66.3	68.0	Above Normal
Red River, North Fork	311500010020-002AT	09/25/19	170.3	200.0	Above Normal

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 were developed using existing USGS measured flow where the data existed 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 were derived for each Oklahoma stream segment in the following priority:

A. In cases where a USGS flow gage occurred on, or within one-half mile upstream or downstream of the Oklahoma stream segment:

1. If simultaneously collected flow data matching the water quality sample collection date were available, those flow measurements were used.

2. If flow measurements at the coincident gage were missing for some dates on which water quality samples were collected, the gaps in the flow record were filled, or the record was extended by estimating flow based on measured streamflows at a nearby gages. Based on Land Use and watershed size, an adjacent flow gage was identified and missing flow was estimated by the drainage area ratio.

3. The flow frequency for the flow duration curves were based on measured flows only. The filled timeseries described above was used to match flows to sampling dates to calculate loads.

4. On streams impounded by dams to form reservoirs of sufficient size to impact stream flow, only flows measured after the date of the most recent impoundment were used to develop the flow duration curve. This also applied to reservoirs on major tributaries to the streams.

B. In case no coincident flow data was available for a stream segment, but flow gage(s) were present upstream and/or downstream without a major reservoir between, flows were estimated for the stream segment from an upstream or downstream gage using a watershed area ratio method derived by delineating subwatersheds.

1. Watershed delineations are performed with predetermined watershed shapefile using ESRI Arc Hydro with a 30-meter resolution National Elevation Dataset digital elevation model and National Hydrography Dataset (NHD) streams. The area of each watershed was calculated following watershed delineation.

2. Drainage area of the ungagged site was calculated based on watershed delineation. To calculate the contributing drainage area for the ungagged sites, the areas of delineated subwatersheds between the ungagged site and the USGS gaging station were subtracted from or added to the available drainage area of the USGS gaging station.

3. The average flow was by using using the flow at the gaged site multiplied by the drainage area ratio.

C. In the rare case where no coincident flow data was available for a WQM station and no gages were present upstream or downstream, flows were estimated for the WQM station from a gage on an adjacent watershed of similar size and properties, via the same procedure described previously for upstream or downstream gages.

Appendix Table B-1 Estimated Flow Exceedance Percentiles

Stream Name	Finn Creek	Criner Creek	Roaring Creek	Little Washita River
WBID Segment	OK310810020020_00	OK310810020050_00	OK310810020170_00	OK310820020010_00
USGS Gage Reference	07327447	07328180	07327447	07327550
USGS Gage Drainage Area (mi^2)	62.3	7.2	62.3	232.0
Drainage Area (mi^2)	66.3	66.8	66.6	241.7
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
0	1,915.6	1,913.9	1,924.2	5,261.4
1	224.5	185.8	225.6	501.1
2	135.2	102.2	135.8	327.0
3	94.7	77.1	95.1	244.0
4	72.0	66.6	72.3	196.1
5	59.6	58.7	59.9	164.8
6	53.2	53.0	53.5	148.2
7	49.0	46.5	49.2	132.5
8	44.7	40.9	44.9	121.1
9	41.5	38.1	41.7	111.7
10	39.4	34.8	39.6	103.4
11	36.2	31.6	36.3	95.0
12	33.5	29.7	33.7	89.1
13	31.6	27.9	31.8	83.8
14	29.8	26.0	29.9	79.4
15	28.4	24.5	28.5	76.3
16	27.1	23.2	27.3	73.0
17	26.1	22.0	26.2	70.0
18	25.1	20.5	25.2	67.2
19	24.5	19.5	24.6	64.8

Stream Name	Finn Creek	Criner Creek	Roaring Creek	Little Washita River
WBID Segment	OK310810020020_00	OK310810020050_00	OK310810020170_00	OK310820020010_00
USGS Gage Reference	07327447	07328180	07327447	07327550
USGS Gage Drainage Area (mi^2)	62.3	7.2	62.3	232.0
Drainage Area (mi^2)	66.3	66.8	66.6	241.7
Percentile	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
20	23.4	18.7	23.5	62.7
21	22.3	18.0	22.4	60.7
22	21.6	17.4	21.7	59.5
23	21.3	16.6	21.4	57.5
24	20.2	15.8	20.3	56.3
25	19.9	15.1	20.0	54.5
26	19.2	14.6	19.2	53.3
27	18.8	13.9	18.9	52.3
28	18.1	13.5	18.2	51.3
29	17.9	13.0	18.0	50.2
30	17.0	12.4	17.1	49.2
31	17.0	12.1	17.1	48.1
32	16.3	11.4	16.4	47.1
33	16.0	11.1	16.0	45.9
34	15.9	10.3	15.9	45.0
35	15.1	10.2	15.2	43.9
36	14.9	9.6	15.0	42.7
37	14.4	9.3	14.4	41.7
38	13.8	9.0	13.9	40.3
39	13.8	8.6	13.9	38.9
40	13.3	8.3	13.4	37.7
41	12.8	7.9	12.8	36.7

Stream Name	Finn Creek	Criner Creek	Roaring Creek	Little Washita River
WBID Segment	OK310810020020_00	OK310810020050_00	OK310810020170_00	OK310820020010_00
USGS Gage Reference	07327447	07328180	07327447	07327550
USGS Gage Drainage Area (mi^2)	62.3	7.2	62.3	232.0
Drainage Area (mi^2)	66.3	66.8	66.6	241.7
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
42	12.8	7.5	12.8	35.6
43	12.6	7.2	12.6	34.6
44	12.2	6.8	12.3	33.6
45	11.8	6.5	11.9	32.5
46	11.7	6.1	11.8	31.6
47	11.5	5.8	11.5	30.8
48	11.1	5.5	11.2	30.2
49	10.7	5.3	10.8	29.2
50	10.6	5.0	10.7	28.3
51	10.5	4.8	10.5	27.3
52	10.3	4.6	10.3	26.5
53	10.1	4.5	10.1	25.9
54	9.8	4.2	9.9	25.2
55	9.6	4.1	9.7	24.4
56	9.4	3.9	9.5	24.1
57	9.2	3.7	9.2	23.1
58	9.0	3.5	9.0	22.8
59	8.7	3.3	8.8	22.1
60	8.4	3.3	8.5	21.6
61	8.2	3.1	8.2	21.1
62	7.9	3.0	8.0	20.3
63	7.7	2.8	7.7	20.0

Stream Name	Finn Creek	Criner Creek	Roaring Creek	Little Washita River
WBID Segment	OK310810020020_00	OK310810020050_00	OK310810020170_00	OK310820020010_00
USGS Gage Reference	07327447	07328180	07327447	07327550
USGS Gage Drainage Area (mi^2)	62.3	7.2	62.3	232.0
Drainage Area (mi^2)	66.3	66.8	66.6	241.7
Percentile	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
64	7.4	2.7	7.5	19.0
65	7.1	2.5	7.2	18.5
66	6.9	2.3	6.9	17.9
67	6.6	2.1	6.6	17.4
68	6.4	2.0	6.4	16.9
69	6.2	1.9	6.2	16.3
70	6.0	1.8	6.0	15.8
71	5.7	1.7	5.8	15.1
72	5.6	1.6	5.6	14.6
73	5.4	1.4	5.4	13.9
74	5.2	1.3	5.2	13.4
75	4.9	1.1	5.0	12.7
76	4.8	1.0	4.8	12.3
77	4.6	0.9	4.6	11.8
78	4.4	0.8	4.5	11.6
79	4.3	0.7	4.3	11.0
80	4.1	0.7	4.2	10.7
81	3.9	0.6	4.0	10.5
82	3.8	0.5	3.8	10.1
83	3.7	0.4	3.7	9.9
84	3.5	0.3	3.5	9.6
85	3.3	0.2	3.3	9.2

Stream Name	Finn Creek	Criner Creek	Roaring Creek	Little Washita River
WBID Segment	OK310810020020_00	OK310810020050_00	OK310810020170_00	OK310820020010_00
USGS Gage Reference	07327447	07328180	07327447	07327550
USGS Gage Drainage Area (mi^2)	62.3	7.2	62.3	232.0
Drainage Area (mi^2)	66.3	66.8	66.6	241.7
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
86	3.2	0.1	3.2	8.8
87	3.0	0.1	3.0	8.2
88	2.8	0.0	2.8	7.7
89	2.6	0.0	2.6	7.2
90	2.3	0.0	2.4	6.7
91	2.1	0.0	2.1	6.2
92	1.8	0.0	1.8	5.6
93	1.5	0.0	1.5	4.9
94	1.2	0.0	1.2	4.2
95	1.0	0.0	1.0	3.6
96	0.8	0.0	0.8	2.8
97	0.5	0.0	0.5	2.2
98	0.2	0.0	0.2	1.7
99	0.1	0.0	0.1	0.9
100	0.0	0.0	0.0	0.2

Stream Name	Quartermaster Creek	Cow Creek	Red River, North Fork	Red River, North Fork
WBID Segment	OK310840010060_00	OK311200000060_00	OK311500010020_00	OK311500010020_10
USGS Gage Reference	07327550	07315700	07307028	07305000
USGS Gage Drainage Area (mi^2)	232.0	574.0	5,010	4,560
Drainage Area (mi^2)	153.8	194.2	5,010	4,560
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
0	3,347.8	17,493.0	24,905.4	61,700.0
1	318.7	1,216.1	4,058.6	4,353.2
2	207.9	759.3	2,315.4	2,480.0
3	155.1	509.0	1,655.4	1,710.0
4	124.6	385.5	1,185.4	1,280.0
5	104.7	279.2	927.0	1,030.0
6	94.1	204.5	768.5	846.9
7	84.2	157.0	660.9	731.7
8	76.9	124.4	566.4	638.6
9	70.9	96.5	495.6	571.6
10	65.6	79.6	440.4	519.5
11	60.3	66.1	400.4	470.0
12	56.6	56.3	370.4	431.0
13	53.2	48.8	335.4	394.4
14	50.4	42.7	314.4	364.0
15	48.4	37.7	288.4	332.5
16	46.3	33.9	271.4	307.0
17	44.4	30.6	254.4	285.0
18	42.6	28.2	242.4	268.0
19	41.1	25.8	225.5	248.9
20	39.8	23.3	213.4	233.0
21	38.5	21.4	203.4	221.0

Stream Name	Quartermaster Creek	Cow Creek	Red River, North Fork	Red River, North Fork
WBID Segment	OK310840010060_00	OK311200000060_00	OK311500010020_00	OK311500010020_10
USGS Gage Reference	07327550	07315700	07307028	07305000
USGS Gage Drainage Area (mi²)	232.0	574.0	5,010	4,560
Drainage Area (mi²)	153.8	194.2	5,010	4,560
Percentile	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
22	37.7	19.7	195.4	208.0
23	36.5	18.4	187.4	197.0
24	35.7	17.0	178.4	187.0
25	34.5	15.7	170.4	178.0
26	33.8	14.7	163.4	168.0
27	33.1	13.6	156.4	160.0
28	32.5	13.0	150.4	151.0
29	31.8	12.0	145.4	144.0
30	31.2	11.3	140.4	137.0
31	30.5	10.6	135.4	130.0
32	29.8	9.9	129.4	125.0
33	29.1	9.2	125.4	119.0
34	28.5	8.6	121.4	115.0
35	27.8	7.9	117.4	110.0
36	27.0	7.6	113.4	105.0
37	26.4	7.2	110.4	102.0
38	25.5	6.9	106.4	98.0
39	24.6	6.4	104.0	95.0
40	23.9	6.0	101.6	92.0
41	23.2	5.7	99.9	90.0
42	22.5	5.5	97.5	86.7
43	21.9	5.2	95.4	84.0

Stream Name	Quartermaster Creek	Cow Creek	Red River, North Fork	Red River, North Fork
WBID Segment	OK310840010060_00	OK311200000060_00	OK311500010020_00	OK311500010020_10
USGS Gage Reference	07327550	07315700	07307028	07305000
USGS Gage Drainage Area (mi²)	232.0	574.0	5,010	4,560
Drainage Area (mi²)	153.8	194.2	5,010	4,560
Percentile	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
44	21.2	4.8	93.2	81.6
45	20.6	4.6	91.4	79.0
46	20.0	4.4	89.2	76.4
47	19.5	4.2	87.1	74.0
48	19.1	4.0	85.5	71.6
49	18.4	3.8	83.8	69.9
50	17.9	3.7	81.8	68.0
51	17.2	3.5	80.0	66.3
52	16.7	3.4	78.2	65.0
53	16.4	3.2	76.5	63.3
54	15.9	3.1	74.7	62.0
55	15.4	3.0	73.0	60.5
56	15.2	2.9	71.3	59.0
57	14.6	2.7	69.5	57.1
58	14.4	2.6	68.2	55.5
59	13.9	2.5	66.4	54.0
60	13.6	2.5	64.9	52.1
61	13.3	2.4	63.0	50.5
62	12.8	2.3	61.3	48.9
63	12.6	2.3	59.4	47.0
64	11.9	2.2	58.2	45.1
65	11.7	2.1	56.5	43.8

Stream Name	Quartermaster Creek	Cow Creek	Red River, North Fork	Red River, North Fork
WBID Segment	OK310840010060_00	OK311200000060_00	OK311500010020_00	OK311500010020_10
USGS Gage Reference	07327550	07315700	07307028	07305000
USGS Gage Drainage Area (mi^2)	232.0	574.0	5,010	4,560
Drainage Area (mi^2)	153.8	194.2	5,010	4,560
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
66	11.3	2.1	55.4	42.1
67	10.9	2.0	54.3	40.9
68	10.6	2.0	52.5	39.4
69	10.2	1.9	50.6	38.0
70	9.9	1.9	48.8	36.2
71	9.5	1.8	47.4	34.7
72	9.1	1.8	45.5	33.0
73	8.7	1.7	43.6	31.4
74	8.4	1.7	41.5	30.0
75	8.0	1.7	40.1	28.7
76	7.7	1.6	38.8	27.5
77	7.4	1.6	37.4	26.1
78	7.2	1.6	36.2	25.0
79	6.9	1.6	34.8	23.6
80	6.7	1.6	33.8	22.2
81	6.5	1.5	32.2	20.8
82	6.3	1.5	30.6	19.3
83	6.1	1.5	29.2	18.2
84	6.0	1.5	27.2	16.9
85	5.7	1.5	24.7	15.6
86	5.4	1.5	23.0	14.2
87	5.1	1.5	21.1	13.1

Stream Name	Quartermaster Creek	Cow Creek	Red River, North Fork	Red River, North Fork
WBID Segment	OK310840010060_00	OK311200000060_00	OK311500010020_00	OK311500010020_10
USGS Gage Reference	07327550	07315700	07307028	07305000
USGS Gage Drainage Area (mi^2)	232.0	574.0	5,010	4,560
Drainage Area (mi^2)	153.8	194.2	5,010	4,560
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
88	4.8	1.5	19.3	12.1
89	4.5	1.5	17.6	11.2
90	4.1	1.5	15.9	10.0
91	3.8	1.5	14.7	9.0
92	3.4	1.5	13.5	8.2
93	3.0	1.5	12.5	7.0
94	2.6	1.5	11.8	5.3
95	2.2	1.5	11.0	3.8
96	1.6	1.5	10.3	2.5
97	1.3	1.5	9.7	1.3
98	0.9	1.5	9.2	0.4
99	0.5	1.5	8.3	0.0
100	0.0	1.5	6.4	0.0

Appendix C Censored Data Estimation

(A) Censored Data Estimation

1. Background

Sample size is an important feature of any empirical study. The small sample size (less than 25) has been shown to produce estimates with large bias and poor statistical representation. To lessen these problems, assessment data for Roaring Creek, Little Washita River and Quartermaster Creek were combined for turbidity and TSS data.

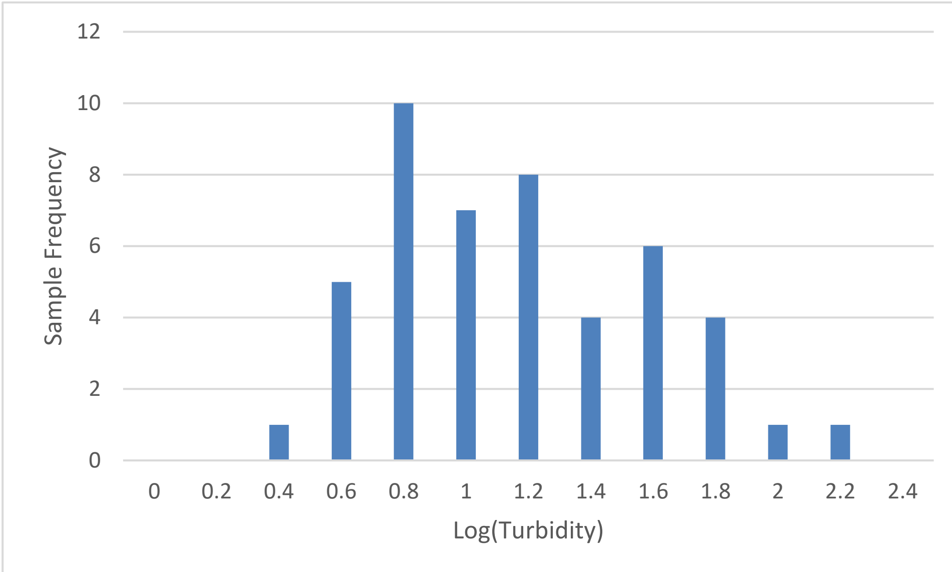
All combined turbidity data of waterbodies are illustrated in **Appendix Figure C-1** and demonstrated log-normal distribution. The difference in log-mean between combined data and each stream data ranged approximately 6% to 13%.

Appendix Table C-1 Censored TSS Data in Black Bear Creek

WBID	Waterbody Name	Total Number of Paired TSS Data	Number of Censored Data	% of Censored Data
OK310810020170_00	Roaring Creek	16	9	56.3%
OK310820020010_00	Little Washita River	16	3	18.8%
OK310840010060_00	Quartermaster Creek	15	5	33.3%
Total		47	17	36.2%

Among combined data for TSS (**Appendix Table C-1**), about 36% of TSS data are censored-data, recorded as 10 mg/L of detection limits (dl) (Appendix Table C-1). Methods for estimating these non-detects (censored data) can be divided into the three classes: simple substitution, distributional, and robust methods.

Appendix Figure C-1 Histogram of Combined Turbidity Data

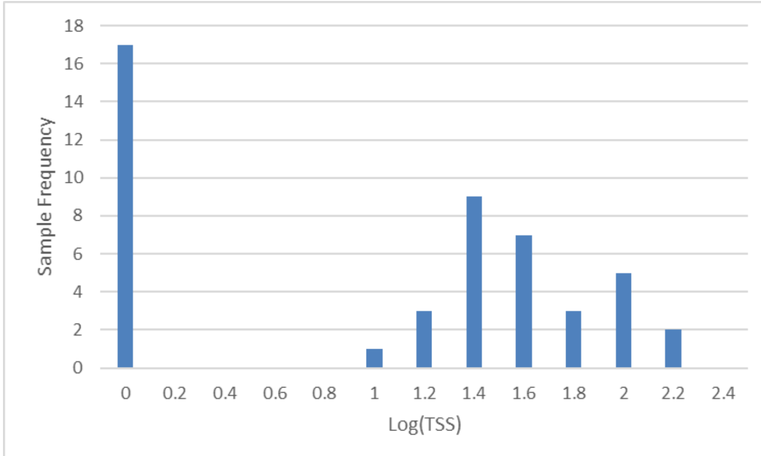


2. Simple Substitution Methods

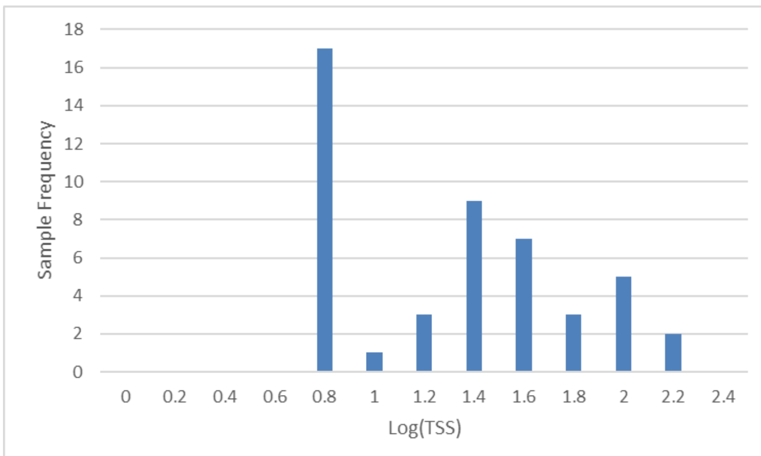
Simple substitution methods substitute a single value such as one-half the reporting limit for each less-than values (censored data). Summary statistics are calculated and shown in Appendix Table C-2 and Appendix Figure C-2.

The distribution resulting from simple substitution methods have large gaps and do not appear realistic. Substitution of one produced estimates of mean and median which were biased low, while substituting the reporting limit resulted in estimates above the true value. Results for the standard deviation and interquartile range (IQR), and for substituting one-half the reporting limit, were also far less desirable than alternative methods discussed below.

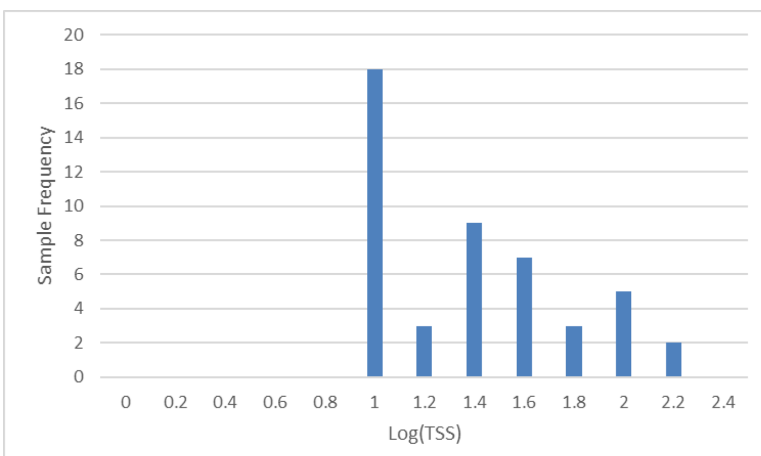
Appendix Figure C-2 Histograms for Simple Substitution Methods



(b) Substitute one [(log(TSS) = 0] for all less-thans



(c) Substitute one-half the reporting limit for all less-thans



(d) Substitute the reporting limit for all less-thans

3. Distributional Methods

Distributional methods use the characteristics of an assumed distribution to estimate summary statistics. Data both below (non-detects) and above (detects) the reporting limit are assumed follow a log-normal distribution. Given a distribution, estimates of summary statistics are computed which best match the observed concentrations above the reporting limit and the percentage of data below the limit. Maximum-likelihood estimation (MLE) is used to estimate summary statistics in this study.

Cohen's procedure can be used for left-censored lognormal distribution (Gilbert, 1987). This hand calculated estimation is compared with estimation results from EXCEL and R (Appendix Table C-2). Cohen's procedure is followed below:

$$h = \frac{(n-k)}{n}$$

$$\bar{y}_u = \frac{\sum_{i=1}^{k} y_i}{k}$$

$$s_u{}^2 = \frac{\sum_{i=1}^{k}(y_i - \bar{y}_u)^2}{k}$$

$$\hat{\gamma} = \frac{s_u{}^2}{(\bar{y}_u - y_0)^2}$$

$$\hat{\mu}_y = \bar{y}_u - \hat{\lambda}(\bar{y}_u - y_0)$$

$$\hat{\sigma}_y{}^2 = s_u{}^2 + \hat{\lambda}(\bar{y}_u - y_0)^2$$

$$\hat{\mu} = exp\left(\hat{\mu}_y + \frac{\hat{\sigma}_y{}^2}{2}\right)$$

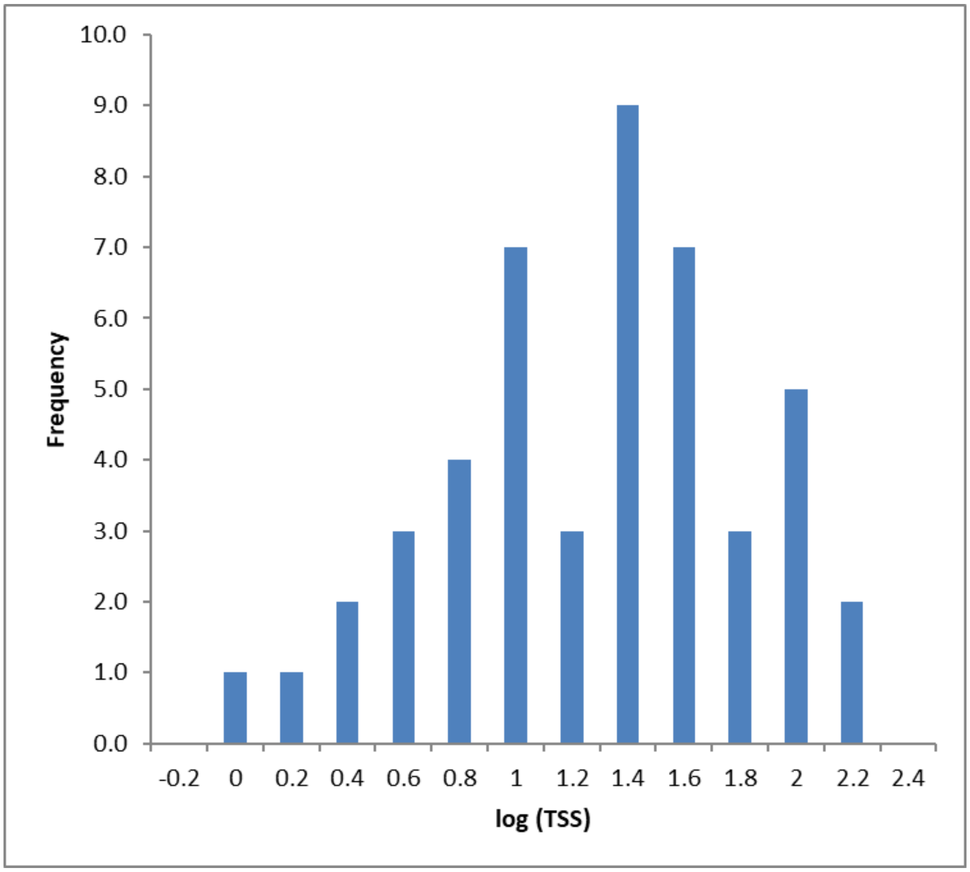
$$\hat{\sigma}^2 = \hat{\mu}^2\left[exp\left(\hat{\sigma}_y{}^2\right) - 1\right]$$

Where n = total number of observed TSS, k = number out of n that are above dl, y_i = ln $(TSS)_i$, y_0 = ln (dl), $\hat{\lambda}$ = 0.39 based on h and $\hat{\gamma}$ from Table A15 (Gilbert, 1987), $\hat{\mu}$ = the mean of the lognormal distribution, and $\hat{\sigma}^2$ = the variance of the lognormal distribution.

For EXCEL, calculation includes following steps that are described below:

- Build normal distribution curve for log-transformed TSS data with guessed μ and σ.
- Draw probability density function (PDF) for detects.
- Minimize area difference under the curve for above two distribution curves in the same range of x-axis with solver in EXCEL by changing μ and σ (Appendix Figure C-3).

Appendix Figure C-3 EXCEL Histograms for Distributional Methods (MLE)



For R, the R code shown below can be used.

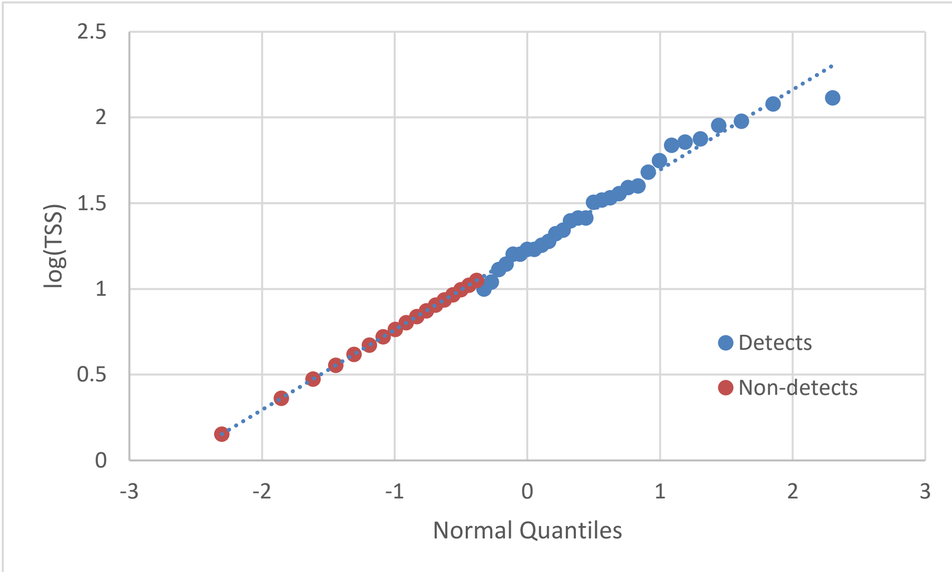
```
read.csv("C:/D Drive/Data/Basin3.csv", header=T)
data=read.csv("C:/D Drive/Data/Basin3.csv", header=T)
data_mle=with(data,cenmle(TSS,TSSCen), dis='lognormal')
data_mle
```

4. Robust Methods

Robust methods combine observed data above the reporting limit with below-limit values extrapolated assuming a distributional shape, in order to compute estimates of summary statistics. A distribution is fit to the data above the reporting limit by either MLE or probability plot procedures, but the fitted distribution is used only to extrapolate a collection of values below the reporting limit.

First, Regression of log of concentration (TSS) verse normal score is used to extrapolate “fill-in” values below the reporting limit. Then, these “fill-ins” are retransformed back to original units, and combined with data above the reporting limit to compute estimates of summary statistics (Appendix Figure C-4).

Appendix Figure C-4 Robust Method of Estimating Summary Statistics



For R, the R code shown below can be used.

```
read.csv("C:/D Drive/Data/Basin3.csv", header=T)
data=read.csv("C:/D Drive/Data/Basin3.csv", header=T)
data_ROS=with(data,ros(TSS,TSSCen))
with(data,ros(TSS,TSSCen))
mean(data_ROS)
sd(data_ROS)
```

5. Results

Robust ROS has shown to perform well for estimating the median and IQR in this study. Estimations can be compared for their 25th percentile. Number of non-detect values are 17 out of 47 samples. Therefore, 25th percentile value falls under these non-detect values which are less than 10 mg/L. In Appendix Table C-2, Robust ROS method estimates 25th percentile value as less than 10, while MLE method estimates 10 as 25th percentile.

Among substitution methods, "dl/2 subbed" showed close estimation with Robust ROS method. Based on summary statistics, censored data were speculated to be little less than 10 mg/L at 25th percentile.

Use of these methods rather than simple substitution methods for censored data should substantially lower estimation errors for summary statistics. However, extrapolating censored data obtained using one of the estimation methods listed may produce coefficients strongly dependent on the values extrapolated in the regression analysis. Therefore, alternative methods capable of incorporating censored observations are described in Appendix D. In this study, dl substitution was used for conservative PRG calculation because dl is believed to be greater than actual concentration of censored data.

Appendix Table C-2 Summary Statistics

Category	Censored data estimation		Mean	Standard Deviation	25th Percentile	Median	75th Percentile	IQR
TSS	dl subbed		30.0	30.1	10.0	17.0	35.0	25.0
	dl/2 subbed		28.2	31.4	5.0	17.0	35.0	30.0
	One [log(TSS)=0]subbed		26.7	32.6	1.0	17.0	35.0	34.0
	MLE	Cohen's	30.4	50.3	n/a	n/a	n/a	n/a
		EXCEL	28.6	31.2	10.0	17.0	35.0	25.0
		R	30.5	50.2	n/a	n/a	n/a	n/a
	Robust ROS	EXCEL	28.7	31.1	8.3	17.0	35.0	26.7
		R	28.5	31.3	n/a	n/a	n/a	n/a

n/a = not available

References

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Wiley.

Appendix D Censored Data Regression

Censored Data Regression

1. Background

With censored data, the use of ordinary least squares (OLS) for regression can result in wrong relationship between dependent and independent variables (See Appendix Table C-1; Helsel and Hirsch, 2002). Coefficients for slopes and intercepts cannot be computed without values for the censored observations, and substituting fabricated values may produce coefficients strongly dependent on the values substituted. Two alternative methods capable of incorporating censored observations are described below. All data were log-tranformed and censored data were set as a range from one (TSS=1 mg/L; log (TSS) = 0) to detection limit (TSS=10 mg/L; log (TSS) = 1).

2. Maximum Likelihood Estimation (MLE)

Maximum likelihood estimation (MLE) in the presence of censored data is very similar to the estimation that occurs when conducting a standard linear regression. The difference is that the likelihood that is computed when censored values are present explicitly accounts for the values below the detection limit (dl).

Assumptions for correlation and regression type maximum likelihood estimators include:

- The presence of a linear trend in the data;
- Observations are approximately normally distributed about the estimated trend line;
- Variances are approximately equal in magnitude at all points along the trend line; and
- Independent observations.

The relationship between two variables is presented with the correlation coefficient (Loglik-r) and p-value in Appendix Table D-1.

3. Non-Parametric Approaches

Non-parametric measures of association tend to evaluate the monotonic association between two variables. This means that such methods are evaluating whether values of the response tend to increase as values of the explanatory variable increase (or vice versa). These non-parametric measures do not quantify how big the increase or decrease is, merely whether there is an increase or decrease. This means that non-parametric methods should be useful at evaluating whether there is an increasing or decreasing trend in the data, regardless of whether or not it is linear.

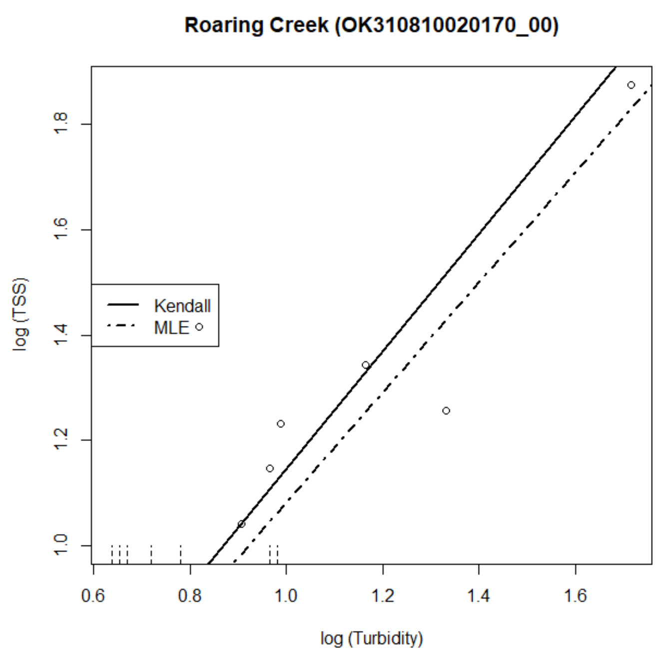
One of the most popular non-parametric measures of association between variables in water quality is Kendall's tau (Huston & Juarez-Colunga, 2009). Like other measures of correlation, Kendall's tau falls between -1 and 1, where values close to 1 indicate a strong positive association and values close to -1 indicate a strong negative association. Values of tau near 0 indicate little or no association. Kendall’s tau was used in this study because of the high number of non-detects (censored data). Because tau depends only on the ranks of the data and not the values themselves, it can be used in cases where some of the data are censored (Helsel and Hirsch, 2002).

To estimate regression coefficient and correlation when censored observations are present, the following R[9] code shown as an example for Roaring Creek:

```
read.csv("C:/Users/257691/OneDrive - State of Oklahoma/My Documents/Data/Roar.csv", header=T)
data=read.csv("C:/Users/257691/OneDrive-State of Oklahoma/My Documents/Data/Roar.csv", header=T)
with (data,cenxyplot(x=Turbidity,xcen=0,y=TSS,ycen=TSSCen,log="",
main=" Roaring Creek (OK310810020170_00)",
xlab="log (Turbidity)",
ylab="log (TSS)",
)
)
mle.reg=cenreg(Cen(obs=data$TSS,censored=data$TSSCen)~data$Turbidity,dist="gaussian")
mle.reg
data.Kendall=cenken(y=data$TSS, ycen=data$TSSCen,x=data$Turbidity,xcen=data$TurCen)
data.Kendall
abline(mle.reg,lwd=2)
lines(data.Kendall,lty=4,lwd=2)
legend(x="left",legend=c("MLE","Kendall"),lty=c(1,4),lwd=2)
```

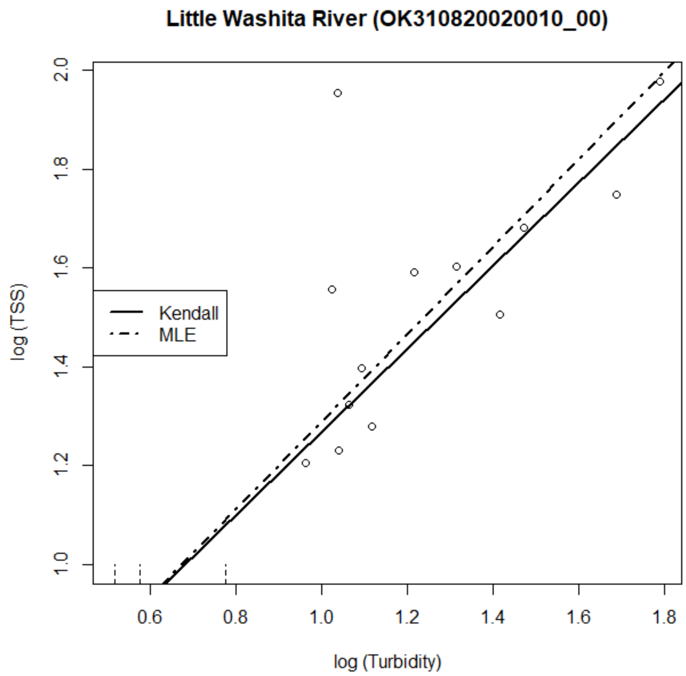
4. Results

Appendix Figure D-1 Trend lines estimated for Roaring Creek by MLE and non-parametric methods

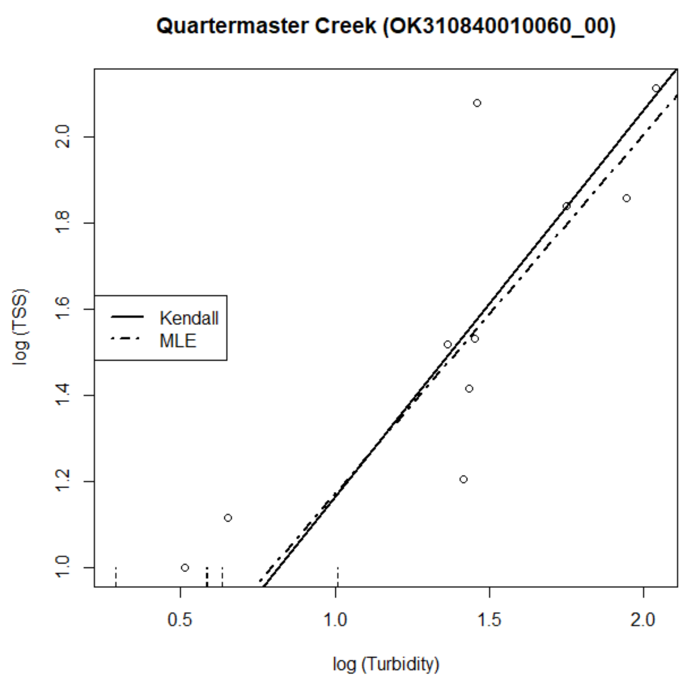


9 R is a computer language and environment for statistical computing and graphics. http://www.r-project.org/

Appendix Figure D-2 Trend lines estimated for the Little Washita River by MLE and non-parametric methods



Appendix Figure D-3 Trend lines estimated for the Quartermaster Creek by MLE and non-parametric methods



Non-parametric methods have been described as robust compared to parametric ones. This means that when extreme outliers are present, or the distribution of points is highly unusual, non-parametric methods are recommended. In less extreme situations, non-parametric methods performed similarly or slightly worse than MLE methods (Huston & Juarez-Colunga, 2009). In this study, MLE method estimated correlation better than Kendall's tau method (see Appendix Table D-1). Both method meet regression criteria ($R^2 > 0.5$).

Appendix Table D-1 Regression Statistics with Censored Data

WBID	Waterbody Name	MLE Method					Non-parametric Method				
		TSS Target (mg/L)	Slope	Intercept	Loglik-r (R^2)	p-value	TSS Target (mg/L)	Slope	Intercept	tau	p-value
OK310810020170_00	**Roaring Creek**	64.9	1.05	0.03	0.78 (**0.61**)	0.0001	84.2	1.12	0.03	0.52	0.0016
OK310820020010_00	**Little Washita River**	81.2	0.89	0.40	0.82 (**0.68**)	0.00002	71.8	0.84	0.43	0.68	0.0003
OK310840010060_00	**Quartermaster Creek**	56.7	0.84	0.34	0.88 (**0.78**)	0.000002	61.8	0.90	0.26	0.73	0.0001

References

Helsel, D.R., and Hirsch R.M., 2002. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations, Book 4, Chapter. A3, U.S. Geological Survey, 522 p., http://pubs.usgs.gov/twri/twri4a3/

Huston, C and E Juarez-Colunga 2009. Guidelines for computing summary statistics for data-sets containing non-detects. Department of Statistics and Actuarial Science, Simon Fraser University.

Appendix E State of Oklahoma Antidegradation Policy

State of Oklahoma Antidegradation Policy

252:730-3-1. 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 252:730-3-2 and Subchapter 13 of OAC 252:740.

252:730-3-2. 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 252:730-5-25(c)(2)(A) and 252:740-13-6(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.

252:740-13-1. Applicability and scope

(a) The rules in this Subchapter provide a framework for implementing the antidegradation policy stated in OAC 252:730-3-2 and OAC 252:730-5-25 for all waters of the state. This policy and framework includes four tiers, or levels, of protection.

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

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

(2) Tier 2. Maintenance and protection Sensitive Water Supply-Reuse waterbodies.

(3) Tier 2.5 Maintenance and protection of High Quality Waters, Sensitive Public and Private Water Supply waters.

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

(c) In addition to the four tiers of protection, this Subchapter provides rules to implement the protection of waters in areas listed in Appendix B of OAC 252:730. Although Appendix B areas are not mentioned in OAC 252:730-3-2, 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, Tier 2.5 and Tier 3 waterbodies or areas, and implementation rules applicable to Tier 2 waterbodies shall be applicable also to Tier 2.5 and 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, SWS, or SWS-R limitation.

252:740-13-2. 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 DEQ or the permitting authority.

252:740-13-3. 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.

252:740-13-4. Tier 2 protection; maintenance and protection of sensitive water supply-reuse and other tier 2 waterbodies

(a) General rules for Sensitive Water Supply – Reuse (SWS-R) Waters.

(1) Classification of SWS-R Waters. DEQ may consider classification of a waterbody as an SWS-R waterbody based upon required documentation submitted by any interested party. The interested party shall submit documentation presenting background information and justification to support the classification of a waterbody as SWS-R including, but not limited to, the following:

(A) Determination of the waterbody's assimilative capacity pursuant to 252:740-13-8, including all supporting information and calculations.

(B) Documentation demonstrating that municipal wastewater discharge for the purpose of water supply augmentation has been considered as part of a local water supply plan or other local planning document.

(C) Any additional information or documentation necessary for DEQ's consideration of a request for the classification of a waterbody as SWS-R.

(D) Prior to consideration by DEQ, any interested party seeking the classification of a waterbody as SWS-R shall submit documentation to DEQ staff demonstrating that local stakeholders, including those that use the waterbody for any designated or existing beneficial uses, have been afforded notice and an opportunity for an informal public meeting, if requested, regarding the proposed classification of the waterbody as SWS-R at least one hundred eighty (180) days prior to DEQ consideration. In addition, all information or documentation submitted pursuant to this subsection shall be available for public review.

(2) The drought of record waterbody level shall be considered the receiving water critical condition for SWS-R waterbodies.

(A) All beneficial uses shall be maintained and protected during drought of record conditions.

(B) Drought of record shall be determined with the permitting authority approved monthly time step model using hydrologic data with a minimum period of record from 1950 to the present. If empirical data are not available over the minimum period of record, modeled data shall be included in the analysis, if available.

(3) In accordance with OAC 252:730-5-25(c)(8)(D), SWS-R waterbodies with a permitted discharge shall be monitored and water quality technically evaluated to ensure that beneficial uses are protected and maintained and use of assimilative capacity does not exceed that prescribed by permit. Prior to any monitoring and/or technical analysis, the permittee shall submit a Receiving Water Monitoring and Evaluation Plan to the permitting authority for review and approval.

(A) The Receiving Water Monitoring and Evaluation Plan shall include, at a minimum, 17 the following sections:

(i) Monitoring section that meets the required spatial, temporal, and parametric coverage of this subchapter, OAC 252:740-15, and OAC 252:628-11.

(ii) Analysis and reporting section that meets the requirements of this subchapter, OAC 252:740-15, and OAC 252:628-11.

(iii) Quality Assurance Project Plan that meets the most recent requirements for United States Environmental Protection Agency Quality Assurance Project Plans.

(B) The monitoring section of the Receiving Water Monitoring and Evaluation Plan, at a minimum shall:

(i) Include parametric, temporal (including frequency of sampling events), and spatial sampling design adequate to characterize water quality related to limnological, hydrologic, seasonal, and diurnal influences and variation.

(ii) Include nutrient monitoring adequate to characterize both external and internal loading and nutrient cycling.

(iii) Include algal biomass monitoring consistent with this sub-paragraph (B) and phytoplankton monitoring sufficient to evaluate general shifts and/or trends in phytoplankton community dynamics over time.

(iv) Include in-situ monitoring of dissolved oxygen, temperature, and pH adequate to characterize diurnal changes and fluctuations during periods of thermal stratification and complete mix.

(v) Include monitoring of pollutants with a permit effluent limit and/or permit monitoring requirements.

(C) The Receiving Water Monitoring and Evaluation Plan may include special studies, as necessary.

(D) At least biennially and prior to permit renewal, the permittee shall submit a Receiving Water Monitoring and Evaluation Report to the permitting authority that includes, at a minimum:

(i) Summarized review of monitoring objectives and approach.

(ii) Presentation and evaluation of monitoring results, including an analysis of both short-term and long-term trends.

(iii) An assessment of beneficial use attainment that is at a minimum in accordance with OAC 252:740-15.

(iv) Summarized assessment of data quality objectives, including an explanation of any data quality issues.

(v) All monitoring data shall be submitted electronically.

(E) If the report documents nonattainment of a beneficial use(s) resulting from the discharge, the permitting authority shall consider actions including, but not limited to, additional permit requirements, cessation of the discharge, and/or a recommendation to DEQ to revoke the SWS-R waterbody classification.

(b) General rules for other Tier 2 Waterbodies.

(1) General rules for other Tier 2 waterbodies shall be developed as waters are identified.

(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 252:730.

252:740-13-5. Tier 2.5 protection; maintenance and protection of high quality waters, sensitive water supplies, and other tier 2.5 waterbodies

(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 252:730 with the limitation "HQW". Any 18 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 252:730 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", "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 252:730.

252:740-13-6. 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 252:730

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 252:740-13-6(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 252:740-13-6(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 252:730, 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 19 "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 252:730 as "ORW".

252:740-13-7. Protection for Appendix B areas

(a) General. Appendix B of OAC 252:730 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 252:730 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 252:730 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 252:730.

252:740-13-8. Antidegradation review in surface waters

(a) General. The antidegradation review process below presents the framework to be used when making decisions regarding the intentional lowering of water quality, where water quality is better than the minimum necessary to protect beneficial uses. OWRB technical guidance TRWQ2017-01 provides additional information.

(b) Determination of Assimilative Capacity in Tier 2, Tier 2.5, and Tier 3 Waters.

(1) All water quality monitoring and technical analyses necessary to determine receiving waterbody assimilative capacity for all applicable numeric and narrative criteria and associated parameters protective of waterbody beneficial uses shall be conducted by the interested party.

(2) Prior to initiating any monitoring or technical analysis to support determination of waterbody assimilative capacity, the interested party shall submit a workplan consistent with the requirements of OWRB technical guidance TRWQ2017-01 for review and approval by DEQ staff.

(3) As part of an approved workplan, the interested party shall characterize existing water quality of the receiving waterbody for each applicable criteria and associated parameters and evaluate if there is available assimilative capacity. Consistent with OWRB technical guidance TRWQ2017-01, characterization of existing water quality shall address, at a minimum:

(A) Measurement of load and or concentration for all applicable criteria and associated parameter(s) in the receiving water; and

(B) The measurement of both existing and proposed point and nonpoint source discharge concentrations and or loadings, including the measurement of external and internal nutrient loading, where required by OWRB technical guidance TRWQ2017-01; and

(C) The critical low flow or critical lake level of the receiving waterbody, including drought of record in waterbodies receiving IPR discharges; and

(D) The limnological, hydrologic, seasonal, spatial and temporal variability and critical conditions of the waterbody; and

(E) Volumetric determination of anoxic dissolved oxygen condition consistent with OAC 252:730 and 252:740; and

(F) The bioaccumulative nature of a pollutant shall be considered when determining assimilative capacity; and

(G) The 303(d) list as contained in the most recently approved Integrated Water Quality Assessment Report shall be reviewed and any difference between the water quality assessment information and the characterization of existing water quality shall be reconciled.

(4) Assimilative capacity shall be determined by comparing existing water quality, as determined consistent with subsection (a)(3) above to the applicable narrative and numeric criteria. In Tier 2 waters, assimilative capacity shall be determined and used with a margin(s) of safety (252:740-13-8(d)(1)(D)), which takes into account any uncertainty between existing or proposed discharges and impacts on receiving water quality.

(5) When existing water quality does not meet the criterion or associated parameter necessary to support beneficial use(s) or is identified as impaired on Oklahoma's

303(d) list as contained in the most recently approved Integrated Water Quality Assessment Report, no assimilative capacity shall exist for the given criterion.

(c) Use of Assimilative Capacity in Tier 1 Waters. Available assimilative capacity may be used in Tier 1 waters such that, water quality is maintained to fully protect all designated and existing beneficial uses.

(d) Use of Assimilative Capacity in Tier 2 Waters.

(1) If it is determined that assimilative capacity is available, the consumption of assimilative capacity may be allowed in a manner consistent with the requirements in 40 CFR 131.12(a)(2) and this subchapter. In allowing the use of assimilative capacity, the state shall assure that:

(A) Water quality shall be maintained to fully protect designated and existing beneficial uses.

(B) Assimilative capacity shall be reserved such that all applicable narrative criteria in OAC 252:730 are attained and beneficial uses are protected.

(C) Fifty percent (50%) of assimilative capacity shall be reserved for all applicable water quality criteria listed in OAC 252:730, Appendix G, Table 2.

(D) In order to preserve a margin of safety; in no case shall any activity be authorized without the application of margin(s) of safety specified below:

(i) A twenty percent (20%) margin of safety shall be applied to an applicable numeric criterion for chlorophyll-a, total phosphorus, and total nitrogen. If numeric criteria are not available, the narrative nutrient criterion (252:730-5-9(d)) shall be applied and a twenty percent (20%) margin of safety shall be applied to the parameters listed in the criterion.

(ii) No more than forty-five percent (45%) of the lake volume shall be less than the dissolved oxygen criterion magnitude in OAC 252:730-5-12(f)(1)(C)(ii).

(iii) If the existing value of a criterion is within the margin of safety, no assimilative capacity is available and existing water quality shall be maintained or improved.

(E) When existing water quality does not satisfy the applicable criterion and support beneficial use(s) or has been designated as impaired in Oklahoma's 303(d) list as contained in the most recently approved Integrated Water Quality Assessment Report, the applicable criterion shall be met at the point of discharge. If a TMDL has been approved for the impairment, loading capacity for the parameter may be available if TMDL load allocations include the proposed load from the discharge.

(2) An analysis of alternatives shall evaluate a range of practicable alternatives that would prevent or lessen the water quality degradation associated with the proposed activity. When the analysis of alternatives identifies one or more practicable alternatives, the State shall only find that a lowering is necessary if one such alternative is selected for implementation.

(3) After an analysis of alternatives and an option that utilizes any or all of the assimilative capacity is selected, the discharger must demonstrate that the lowering of water quality is necessary to accommodate important economic or social development in the area in which the waters are located.

(e) Use of Assimilative Capacity in Tier 2.5 or 3.0 Waters. Consistent with 252:730-3-2(a) - (c), 252:730-5-25(a), 252:730-5-25(b), and 252:730-5-25(c)(1) – (c)(6) all available assimilative capacity shall be reserved in waterbodies classified as Tier 2.5 or 3.0 waters.

(f) Public Participation. Agencies implementing subsection 8(d), shall conduct all activities with intergovernmental coordination and according to each agency's public participation procedures, including those specified in Oklahoma's continuing planning process.

Appendix F DEQ Sanitary Sewer Overflow Data (1993-2022)

Table Appendix F-1 DEQ Sanitary Sewer Overflow Data (1990-2019)

sso_report_id	permit_no	date_sso_began	date_sso_stopped	bypass_amount
9345	OK0028037	11/29/1993 0:00	11/29/1993 0:00	500
10468	OK0028037	8/7/1994 0:00	8/10/1994 0:00	500
10719	OK0028037	10/31/1994 0:00	10/31/1994 0:00	15
11154	OK0028037	12/13/1994 0:00	12/13/1994 0:00	500000
11242	OK0028037	1/9/1995 0:00	1/9/1995 0:00	500
11663	OK0028037	3/23/1995 0:00	3/23/1995 0:00	9000
12024	OK0028037	5/3/1995 0:00	5/6/1995 0:00	3000000
12667	OK0028037	6/3/1995 0:00	6/4/1995 0:00	2600000
12678	OK0028037	6/3/1995 0:00	6/5/1995 0:00	0
13074	OK0028037	6/15/1995 0:00	7/15/1995 0:00	8000000
13273	OK0028037	8/2/1995 0:00	8/2/1995 0:00	0
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13938	OK0028037	1/27/1996 0:00		
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16946	OK0028037	5/14/1997 0:00		100
17013	OK0028037	6/2/1997 0:00		100
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17581	OK0028037	11/18/1997 0:00		
18335	OK0028037	3/3/1998 0:00		
19790	OK0028037	9/28/1998 0:00		75
20968	OK0028037	3/29/1999 0:00		
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46508	OK0028037	4/29/2009 0:00	4/29/2009 0:00	1000
49818	OK0028037	7/12/2010 0:00	7/12/2010 0:00	500

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58128	OK0028037	2/8/2015 0:00	2/22/2015 0:00	15
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60498	OK0028037	12/8/2015 0:00	12/8/2015 0:00	
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17466	OK0041467	10/12/1997 0:00		
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25213	OK0041467	10/28/2000 0:00		
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41626	OK0041467	8/19/2007 0:00	8/19/2007 0:00	
41630	OK0041467	8/19/2007 0:00	8/19/2007 0:00	
41963	OK0041467	10/15/2007 0:00	10/16/2007 0:00	
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43228	OK0041467	3/18/2008 0:00	3/27/2008 0:00	1000
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66511	OK0041467	4/15/2019 0:00		
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67067	OK0041467	5/22/2019 0:00		
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71218	OK0041467	7/20/2021 0:00	7/25/2021 0:00	24000
71287	OK0041467	8/16/2021 0:00	8/17/2021 0:00	926000
71308	OK0041467	8/23/2021 0:00	8/24/2021 0:00	358600
71332	OK0041467	9/6/2021 0:00	9/7/2021 0:00	500000
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Appendix G Stormwater Permitting Requirements and Presumptive Best Management Practices (BMP) Approach

Stormwater Permitting Requirements and Presumptive Best Management Practices (BMPs) Approach

A. Background

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

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

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

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

This approach was further elaborated in a guidance memo issued in 2002. [See Memorandum from Robert Wayland, Director of OWOW and James Hanlon, Director of OWM to Regional Water Division Directors: "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit requirements Based on Those WLAs " (Date published: 11/22/2002)] "The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address stormwater discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. …… If it is determined that a BMP approach (including an iterative BMP approach) is appropriate to meet the stormwater component of the TMDL, EPA recommends that the TMDL reflect this." This BMP-based approach to stormwater sources in TMDLs is also recognized and described in the most recent EPA guidance. [See "TMDLs to Stormwater Permits Handbook" (DRAFT), EPA, November 2008] This TMDL adopts the EPA recommended approach and relies on appropriate BMPs for implementation. No numeric effluent limitations are required or anticipated for municipal stormwater discharge permits.

B. Specific SWMP/SWPPP Requirements

As noted in SECTION 3 of this report, Oklahoma Pollutant Discharge Elimination System (OPDES)-permitted facilities and non-point sources (e.g., wildlife, agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal system, and domestic pets) could contribute to exceedances of the water quality criteria. In particular, stormwater runoff from the Phase I and II Municipal Separate Storm Sewer Systems (MS4s) is likely to contain elevated bacterial concentrations. Permits for these discharges must comply with the provisions of this TMDL. **Appendix Table G-1** provides a list of Phase I and II MS4s that are affected by this bacterial TMDL report.

Agricultural activities and other nonpoint sources of bacteria are unregulated. Voluntary measures and incentives should be used and encouraged wherever possible and such sources should strive to attain the reduction goals established in this TMDL.

Appendix Table G-1 MS4 Permit affected by this TMDL Report

Entity	Permit No.	MS4 Phase	Date Issued
City of Altus	OKR040043	Phase 2 MS4	03/1/2016

The provisions of this appendix apply only to OPDES/NPDES regulated stormwater discharges. Regulated CAFOs within the watershed operate under NPDES permits issued and overseen 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 bacterial loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA, as the responsible permitting agency, for follow up.

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

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

As noted above, when a BMP approach is selected a coordinated monitoring program is necessary to establish the effectiveness of the selected BMPs and demonstrate progress toward attaining water quality standards. The monitoring results should be used to refine bacterial controls in the future. With nine permitted entities in the watershed, it is likely that a cooperative monitoring program would be more cost effective than nine individual programs. Individual permittees are not required to participate in a coordinated program and are free to develop their own program if desired.

After EPA approval of the final TMDL, existing MS4 permittees will be notified of the TMDL provisions and schedule. Industrial stormwater permittees are not expected to be a significant source of bacteria. But if any are identified, similar actions will be required.

Compliance with the following provisions will constitute compliance with the requirements of this TMDL.

1. Develop a Bacterial Reduction Plan

Permittees shall submit an approvable Bacterial Reduction Plan to the DEQ within 24 months of EPA approval of this TMDL. Unless disapproved by the Director within 60 days of submission, the plan shall be approved and then implemented by the permittee. This plan shall, at a minimum, include the following:

a. Consideration of ordinances or other regulatory mechanisms to require bacterial pollution control, as well enforcement procedures for noncompliance.

b. Evaluation of the existing SWMP in relation to TMDL reduction goals

c. Develop an evaluation to identify potential significant sources of bacteria entering your MS4. Develop (or modify an existing program as necessary) and implement a program to reduce the discharge of bacteria in municipal stormwater contributed by any other significant source identified in the source identification evaluation.

d. Educational programs directed at reducing bacterial pollution. Implement a public education program to reduce the discharge of bacteria in municipal stormwater contributed (if applicable) by pets, recreational and exhibition livestock, and zoos.

e. Investigation and implementation of BMPs associated with development. These BMPs should prevent additional stormwater bacterial pollution associated with new development and re-development.

f. Develop (or modify an existing program as necessary) and implement a program to reduce the discharge of bacteria in municipal stormwater contributed by areas within your MS4 served by on-site wastewater treatment systems.

g. Implementation of BMPs applicable to bacteria - **Appendix Table G-2** presents summary information on some BMPs that may be considered. Permittees are not limited to BMPs on this list and should select BMPs appropriate to the local community that are expected to result in progress toward meeting the reduction goals established in the TMDL.

h. Modifications to the dry weather field screening and illicit discharge detection and elimination provisions of the SWMP to consider stormwater sampling and other measures intended to specifically identify bacterial pollution sources and high priority areas for bacterial reductions.

i. Periodic evaluation of the effectiveness of the bacterial reduction plan to ensure progress toward attainment of water quality standards.

j. An implementation schedule leading to modification of the SWMP and full implementation of the plan within three years of notification.

2. Develop or Participate in a Bacterial Monitoring Program

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

a. Within 24 months of EPA approval of this TMDL, the permittee shall prepare and submit to the DEQ either a TMDL monitoring plan or a commitment to participate in a coordinated regional monitoring program. Unless disapproved by the Director within 60 days of submission, the plan shall be approved and then implemented by the permittee. The plan or program shall include:

   (1). A detailed description of the goals, monitoring, and sampling and analytical methods

   (2). A list and map of the selected TMDL monitoring sites

   (3). The frequency of data collection to occur at each station or site

   (4). The parameters to be measured, as appropriate for and relevant to the TMDL

   (5). A Quality Assurance Project Plan that complies with EPA requirements [EPA Requirements for QA Project Plans (QA/R-5)]

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

3. Annual Reporting

The permittee shall include a TMDL implementation report as part of their annual report. The TMDL implementation report shall include the status and actions taken by the permittee to implement the Bacterial Reduction Plan and monitoring program. The TMDL implementation report shall document relevant actions taken by the permittee that affect MS4 stormwater discharges to the waterbody segments that are the subject of the TMDL. This TMDL implementation report also shall identify the status of any applicable TMDL implementation schedule milestones.

Appendix Table G-2 Some BMPs Applicable to Bacteria

BEST MANAGEMENT PRACTICE	Impairment Source		Reported Efficiency	Note
	Agriculture	Urban		
Animal waste management: A planned system designed to manage liquid and solid waste from livestock and poultry. It improves water quality by storing and spreading waste at the proper time, rate and location.	X		75%[1]	
Artificial wetland/rock reed microbial filter: A long shallow hydroponic plant/rock filter system that treats polluted waste and wastewater. It combines horizontal and vertical flow of water through the filter, which is filled with aquatic and semi-aquatic plants and microorganisms and provides a high surface area of support media, such as rocks or crushed stone.	X	X		
Compost facility: Treating organic agricultural wastes in order to reduce the pollution potential to surface and ground water. The composting facility must be constructed, operated and maintained without polluting air and/or water resources.	X	X		Permit may be needed
Conservation landscaping: The placement of vegetation in and around stormwater management BMPs. Its purpose is to help stabilize disturbed areas, enhance the pollutant removal capabilities of stormwater BMP, and improve the overall aesthetics of a stormwater BMP.		X		
Diversions: Establishing a channel with a supporting ridge on the lower side constructed along the general land slope which improves water quality by directing nutrient and sediment laden water to sites where it can be used or disposed of safely.	X	X		
Drain Inlet Inserts: A proprietary BMP that is generally easily installed in a drain inlet or catch basin to treat stormwater runoff. Three basic types of inlet insert are available, the tray type, bag type and basket type. The tray type allows flow to pass through filter media residing in a tray located around the perimeter of the inlet.	X	X	5%[2]	
Dry detention pond/basin: Detention ponds/basins that have been designed to temporarily detain stormwater runoff. These ponds fill with stormwater and release it over a period of a few days. They can also be used to provide flood control by including additional flood detention storage.	X	X	40%[2] 51%[3] 88% [4]	
Earthen embankments: A raised impounding structure made from compacted soil. It is appropriate for use with infiltration, detention, extended-detention or retention facilities.	X	X		
Drip irrigation: An irrigation method that supplies a slow, even application of low-pressure water through polyethylene tubing running from supply line directly to a plant's base. Water soaks into the soil gradually, reducing runoff and evaporation (i.e., salinity). Transmission of nutrients and pathogens spread by splashing water and wet foliage created by overhead sprinkler irrigation is greatly reduced. Weed growth is minimized, thereby reducing herbicide applications. Vegetable farming and virtually every type of landscape situation can benefit from the use of drip irrigation.	X	X		
Fencing: A constructed barrier to livestock, wildlife or people. Standard or conventional (barbed or smooth wire), suspension, woven wire, or electric fences consist of acceptable fencing designs to control the animal(s) or people of concern and meet the intended life of the practice.	X		75%[1]	

BEST MANAGEMENT PRACTICE	Impairment Source		Reported Efficiency	Note
	Agriculture	Urban		
Filtration (e.g., sand filters): Intermittent sand filters capture, pre-treat to remove sediments, store while awaiting treatment, and treat to remove pollutants (by percolation through sand media) the most polluted stormwater from a site. Intermittent sand filter BMPs may be constructed in underground vaults, in paved trenches within or at the perimeter of impervious surfaces, or in either earthen or concrete open basins.	X	X	30%[1] 55%[2] 37%[4]	
Infiltration Basin: A vegetated open impoundment where incoming stormwater runoff is stored until it gradually infiltrates into the soil strata. While flooding and channel erosion control may be achieved within an infiltration basin, they are primarily used for water quality enhancement.		X	50%[1]	
Infiltration Trench: A shallow, excavated trench backfilled with a coarse stone aggregate to create an underground reservoir. Stormwater runoff diverted into the trench gradually infiltrates into the surrounding soils from the bottom and sides of the trench. The trench can be either an open surface trench or an underground facility.		X	50%[1]	
Irrigation water management: The process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner. An irrigation system adapted for site conditions (soil, slope, crop grown, climate, water quantity and quality, etc.) must be available and capable of applying water to meet the intended purpose(s).	X	X		
Lagoon pump out: A waste treatment impoundment made by constructing an embankment and/or excavating a pit or dugout in order to biologically treat waste (such as manure and wastewater) and thereby reduce pollution potential by serving as a treatment component of a waste management system.	X	X		
Land-use conversion: BMPs that involve a change in land use in order to retire land contributing detrimentally to the environment. Some examples of BMPs with associated land use changes are: Conservation Reserve Program (CRP) - cropland to pasture; Forest conservation - pervious urban to forest; Forest/grass buffers - cropland to forest/pasture; Tree planting - cropland/pasture to forest; and Conservation tillage – conventional tillage to conservation tillage.	X	X		
Limit livestock access: Excluding livestock from areas where grazing or trampling will cause erosion of stream banks and lowering of water quality by livestock activity in or adjacent to the water. Limitation is generally accomplished by permanent or temporary fencing. In addition, installation of an alternative water source away from the stream has been shown to reduce livestock access.	X			
Litter control: Litter includes larger items and particulates deposited on street surfaces, such as paper, vegetation residues, animal feces, bottles and broken glass, plastics and fallen leaves. Litter-control programs can reduce the amount of deposition of pollutants by as much as 50%, and may be an effective measure of controlling pollution by storm runoff.		X		
Livestock water crossing facility: Providing a controlled crossing for livestock and/or farm machinery in order to prevent streambed erosion and reduce sediment.	X		100%[1]	

BEST MANAGEMENT PRACTICE	Impairment Source		Reported Efficiency	Note
	Agriculture	Urban		
Manufactured BMP systems: Structural measures which are specifically designed and sized by the manufacturer to intercept stormwater runoff and prevent the transfer of pollutants downstream. They are used solely for water quality enhancement in urban and ultra-urban areas where surface BMPs are not feasible.	X	X		
Onsite treatment system installation: Conventional onsite wastewater treatment and disposal system (onsite system) consists of three major components: a septic tank, a distribution box, and a subsurface soil absorption field (consisting of individual trenches). This system relies on gravity to carry household waste to the septic tank, move effluent from the septic tank to the distribution box, and distribute effluent from the distribution box throughout the subsurface soil absorption field. All of these components are essential for a conventional onsite system to function in an acceptable manner.		X		
Porous pavement: An alternative to conventional pavement, it is made from asphalt (in which fine filler fractions are missing) or modular or poured-in concrete pavements. Its use allows rainfall to percolate through it to the sub-base, providing storage and enhancing soil infiltration that can be used to reduce runoff and combined sewer overflows. The water stored in the sub-base then gradually infiltrates the subsoil.		X	50%[1]	
Proper site selection for animal feeding facility: Establishing or relocating confined feeding facilities away from environmentally vulnerable areas such as sinkholes, streams, and rivers in order to reduce or eliminate the amount of pollutant runoff reaching these areas.	X			
Raingarden/bio-retention basin: Rain gardens are landscaped gardens of trees, shrubs, and plants located in commercial or residential areas in order to treat stormwater runoff through temporary collection of the water before infiltration. They are slightly depressed areas into which stormwater runoff is channeled by pipes, curb openings, or gravity.		X	40%[1]	
Range and pasture management: Systems of practices to protect the vegetative cover on improved pasture and native rangelands. It includes practices such as seeding or reseeding, brush management (mechanical, chemical, physical, or biological), proper stocking rates and proper grazing use, and deferred rotational systems.	X		50%[1]	
Wet retention ponds/basins: A stormwater facility that includes a permanent pool of water and, therefore, is normally wet even during non-rainfall periods. Inflows from stormwater runoff may be temporarily stored above this permanent pool.	X	X	32%[1] 70%[4]	
Riparian buffer zones: A protection method used along streams to reduce erosion, sedimentation, and the pollution of water from agricultural non-point sources.	X	X	43–57%[1]	Forested buffer w/o incentive payment

BEST MANAGEMENT PRACTICE	Impairment Source		Reported Efficiency	Note
	Agriculture	Urban		
Septic system pump-out: A typical septic system consists of a tank that receives waste from a residence or business, and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.		X	5%[1]	
Sewer line maintenance (e.g., sewer flushing): Sewer flushing during dry weather is designed to periodically remove solids that have deposited on the bottom of the sewer and the biological slime that grows on the walls of combined sewers during periods of low-flow. Flushing is especially necessary in sewer systems that have low grades which has resulted in velocities during low-flow periods that fall below those needed for self-cleaning.		X		
Stream bank protection and stabilization (e.g., riprap, gabions): Stabilizing shoreline areas that are being eroded by landscaping, constructing bulkheads, riprap revetments, gabion systems, or establishing vegetation.	X	X	40-75%[1]	40 % w/o fencing; 75 % w/fencing
Street sweeping: The practice of passing over an impervious surface, usually a street or a parking lot, with a vacuum or a rotating brush for the purpose of collecting and disposing of accumulated debris, litter, sand and sediments. In areas with defined wet and dry seasons, sweeping prior to the wet season is likely to be beneficial; following snowmelt and heavy leaf fall are also opportune times.		X		
Terrace: An earth embankment, or a combination ridge and channel, constructed across the field slope. Terraces can be used when there is a need to conserve water, excessive runoff is a problem, and the soils and topography are such that terraces can be constructed and farmed with reasonable effort.	X	X		
Vegetated filter strip: A densely vegetated strip of land engineered to accept runoff from upstream development as overland sheet flow. It may adopt any naturally vegetated form, from grassy meadow to small forest. The purpose of a vegetated filter strip is to enhance the quality of stormwater runoff through filtration, sediment deposition, infiltration and absorption.	X	X	<30% [3]	
Waste system/storage (e.g., lagoons, litter shed): Waste treatment lagoons biologically treat liquid waste to reduce the nutrient and BOD content. Lagoons must be emptied and their contents disposed of properly.	X	X	80–100%[1]	
Water treatment (e.g., disinfection, flocculation, carbon filter system): Physical, chemical and/or biological processes used to treat concentrated discharges. Physical-chemical processes that have been demonstrated to effectively treat discharge include sedimentation, vortex separation, screening (e.g., fine-mesh screening), and sand-peat filters. Chemical additives used to enhance separation of particles from liquid include chemical coagulants such as lime, alum, ferric chloride, and various polyelectrolytes. Biological processes that have been demonstrated to effectively treat discharges include contact stabilization, biodiscs, oxidation ponds, aerated lagoons, and facultative lagoons.	X	X		

BEST MANAGEMENT PRACTICE	Impairment Source		Reported Efficiency	Note
	Agriculture	Urban		
Wetland development/enhancement: The construction of a wetland for the treatment of animal waste runoff or stormwater runoff. Wetlands improve water quality by removing nutrients from animal waste or sediments and nutrients from stormwater runoff.	X	X	30%[1] 78%[4]	Including creation and restora-tion

Sources

1 BMP Efficiencies Chesapeake Bay Watershed Model (PhaseIV) August 1999; Draft FC and Nitrate TMDL IP for Dry River (2001); EPA (1998); EPA (1999b); Novotny (1994); Storm Water Best Management Practice Categories and Pollutant Removal Efficiencies (2003); USDA (2003); DCR (1999); DEQ/DCR (2001).

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

3 The Expected Pollutant Removal (Percent) Data Adapted from US EPA, 1993C.

4 National Pollutant Removal Performance Database, Version 3, September, 2007