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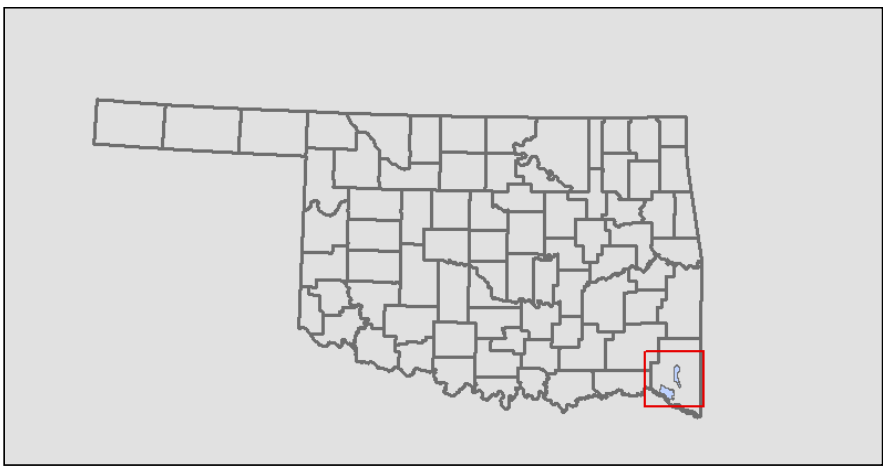
2023 BACTERIAL AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR OKLAHOMA STREAMS IN THE WATERHOLE CREEK AND LUKFATA CREEK STUDY AREA

Oklahoma Waterbody Identification Numbers

Waterhole Creek	OK410100010340_00
Lukfata Creek	OK410210070010_00



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OKLAHOMA Environmental Quality

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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
cfu	colony-forming unit
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
FG	Future Growth
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 (http://www.deq.state.ok.us/rules/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 Waterhole Creek and Lukfata Creek in Oklahoma. 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. The 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 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 Waterhole Creek and Lukfata Creek, as identified in **Table ES – 1**, which 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) and Fish & Wildlife Propagation-Cool Water Aquatic Community (CWAC) beneficial uses.

Elevated levels of bacteria or turbidity above the WQS necessitate 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 and Fish & Wildlife Propagation beneficial uses designated for each waterbody.

Table ES-2 summarizes water quality data collected during the primary contact recreation season from the water quality monitoring (WQM) stations between **2006** and **2017** for each bacterial indicator. The data summary in **Table ES-2** provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. The 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).

ES-2.1 Chapter 730: Criteria for Bacteria

The definitions 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 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.

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 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).

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.

It is worth noting that the Oklahoma Water Quality Standards (OWQS) prior to July 1, 2011 contained three bacterial indicators (fecal coliform, *E. coli* and Enterococci). Since July 1, 2011 the WQS address only *E. coli* and Enterococci bacteria. Therefore, bacterial TMDLs are developed only for *E. coli* and/or Enterococci impaired streams.

ES-2.3 Chapter 730: Criteria for Turbidity

The beneficial use of CWAC 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 NTU; and*

iii. *Other surface waters: 50 NTUs.*

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

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

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

Table ES - 1 Excerpt from the 2022 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*EC*	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Cool Water Aquatic Life
OK410100010340_00	Waterhole Creek	16.61	2025	4	X	X*	N		
OK410210070010_00	Lukfata Creek	17.80	2025	1			F	X	N

Note: ***ENT*** = *Enterococci;* ***EC***= *Escherichia coli;* ***N*** = *Not attaining;* ***X*** = *Criterion exceeded;* ***I*** = *Insufficient information;* ***F*** = *Fully supporting.*
Source: *2022 Integrated Report, DEQ 2022*
*****: TMDL has been completed or under process.

Table ES - 2 Summary of Indicator Bacterial Samples from Primary Body Contact Recreation Subcategory Season May 1 to September 30, 2006-2017

Waterbody ID	Waterbody Name	Indicator	Number of Samples	Geometric Mean Conc. (cfu/100 ml)	Assessment Results/ Recommended Action
OK410100010340_00	Waterhole Creek	ENT	12	129.5	Impaired/TMDL
		EC	10	153	Impaired & 2020 Draft TMDL

Note: *ENT = Enterococci; water quality criterion = Geometric Mean of 33 counts/100 mL; EC= Escherichia coli, water quality criterion = Geometric Mean of 126 counts/100 m; TMDLs will be developed for waterbodies highlighted in green.*

Table ES - 3 Summary of Turbidity Data at Base Flow Samples, 2016-2021

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 10 NTU	% samples exceeding criterion	Average Turbidity (NTU)	Assessment Results / Recommended Actions
OK410210070010_00	Lukfata Creek	OK410210-07-0010G	16	4	25%	7.7	Impaired/TMDL

Table ES - 4 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS
OK410210070010_00	**Lukfata Creek**	0.74	12%	6.9	15%

[a] Calculated using the regression equation and the turbidity standard (10 NTU for CWAC)

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 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-3 summarizes a subset of water quality data collected for turbidity under base flow conditions between 2016 and 2021, 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.

TMDLs for turbidity in streams designated as CWAC must take into account that no more than 10% of the samples may exceed the numeric criterion of turbidity, which is 10 nephelometric turbidity units (NTU). However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate in this TMDL. Since there is no numeric criterion in the Oklahoma WQS for TSS, a regression method to convert the turbidity criterion to TSS, based on a relationship between turbidity and TSS, was used to establish TSS goals as surrogates. **Table ES-4** provides the results of the waterbody specific regression analysis.

ES-2.5 Chapter 740: Minimum number of Samples

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

255:740-15-3. 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 252:740-15-5 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.

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 fecal coliform under the current permits and will be required to monitor *E. coli* when their permits come to renew. These facilities are also required to monitor TSS in accordance with their permits.

Nonpoint sources 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-5 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:

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 primary contact recreation 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 WQgoal 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).

Table ES - 5 Summary of Potential Pollutant Sources by Category

Waterbody ID	Waterbody Name	Municipal OPDES Facility	Industrial OPDES Facility	MS4	OPDES No Discharge Facility	PFO	Mines	Construction Stormwater Permit	Multi-Sector General Permit	Nonpoint Source
OK410100010340_00	Waterhole Creek		Ø			Ø	Ø	Ø	Ø	Bacteria
OK410210070010_00	Lukfata Creek					Ø				Turbidity

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.

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

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

unit conversion factor = 24,465,525

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

Where:

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

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

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 colony forming units (cfu) per day across the full range of flow conditions. For information purpose, percent reductions are also provided. The difference between existing loading and the water quality target is used to calculate the loading reductions required. For bacteria, the PRG is calculated by reducing all samples by the same percentage until the geometric mean of the reduced sample values meets the corresponding bacterial geometric mean standard (126 cfu/100 ml for *E. coli* and 33 cfu/100 ml for Enterococci) with 10% of MOS.

Table ES-6 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area.

Table ES - 6 Bacterial Percent Reductions Required to Meet Water Quality Standards

Waterbody ID	Waterbody Name	Required Reduction Rate (%)
		Enterococci
OK410100010340_00	Waterhole Creek	77.1

ES-5.2 TSS PRG

Similarly, PRGs for TSS are calculated as the required overall reduction so that no more than 10% of the samples exceed the TMDL target for TSS. The PRGs for the waterbodies requiring turbidity TMDLs in this report are summarized in **Table ES-7**.

Table ES - 7 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK410210070010_00	Lukfata Creek	41.4%

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. Similarly, the TSS TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using more than five years of water quality data and by using all available USGS flow records when estimating flows to develop flow exceedance percentiles.

ES-5.4 MOS

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

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.

The TMDL, WLA, LA, and MOS vary with flow condition, and were 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 was then calculated as follows:

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

For turbidity, TMDLs are calculated for TSS instead of turbidity. Thus, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confidence there is in the TMDL targets. As a result, it leads to a smaller MOS. The selection of MOS is based on the normalized root mean square error (NRMSE) for each waterbody (**Table ES-4**).

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

ES – 6 Reasonable Assurance

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.

Reasonable assurance of nonpoint sources will meet their allocated amount in the TMDL which is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. The OCC has responsibilities for the state's NPS program defined in Section 319 of 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://www.deq.ok.gov/water-quality-division/watershed-planning/tmdl/. 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 (http://www.deq.state.ok.us/rules/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 Waterhole Creek and Lukfata Creek in Oklahoma. 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 2005).

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
Waterhole Creek	OK410100010340_00
Lukfata Creek	OK410210070010_00

Figure 1-1 shows these Oklahoma waterbodies and their contributing watersheds. This map also display locations of the water quality monitoring (WQM) stations used as the

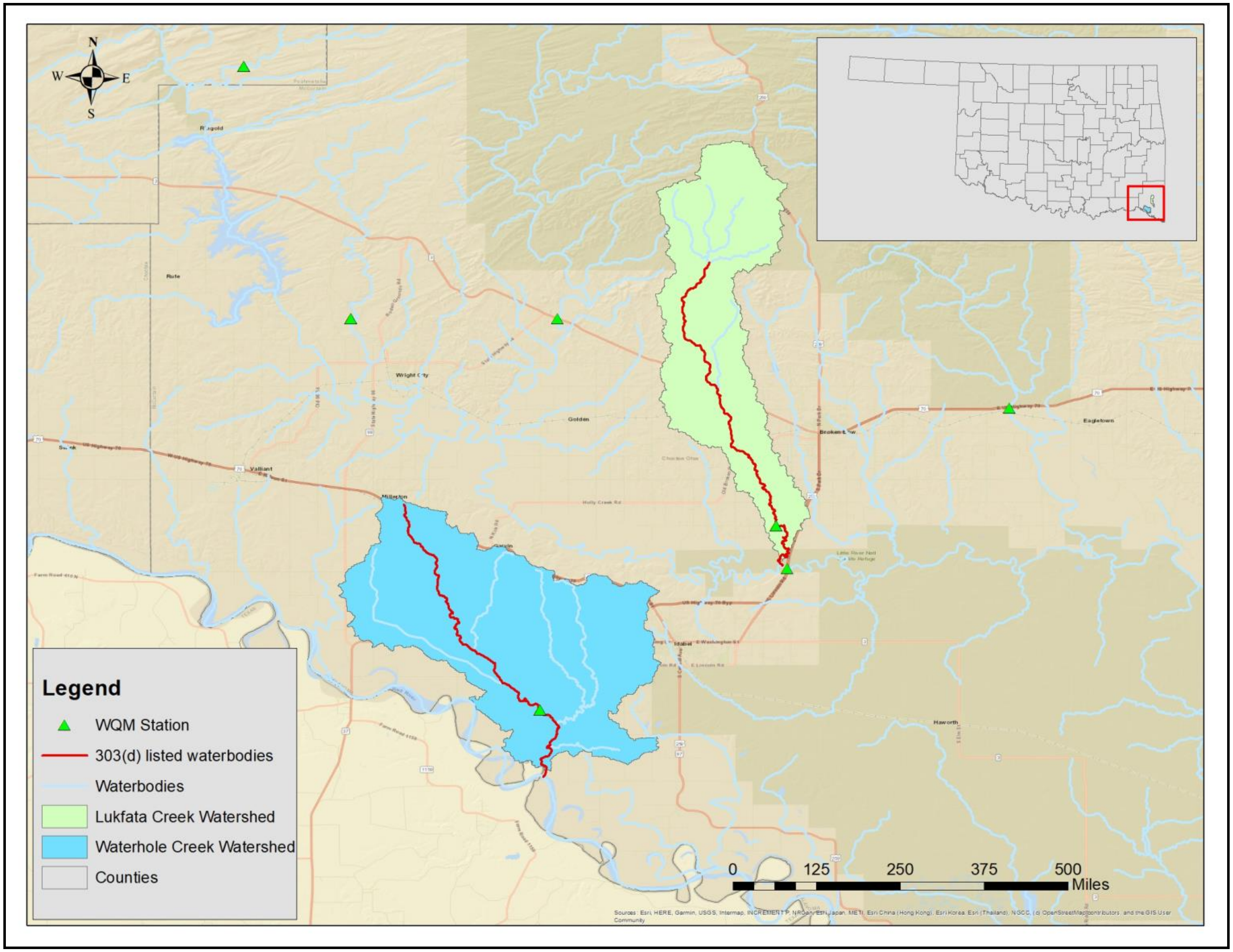
basis for placement of these waterbodies on the Oklahoma 303(d) list. These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

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. **Table 1-2** provides a description of the locations of WQM stations on the selected waterbodies.

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

Waterbody Name	Waterbody ID	WQM Station	Station Location
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	Lat: 33.853, Long: -94.91352
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	Lat: 33.96817, Long: -94.76617

Figure 1-1 Waterhole Creek and Lukfata Creek Study Area Watersheds Not Supporting Primary Body Contact Recreation or Fish & Wildlife Propagation Beneficial Uses



1.2 Watershed Description

1.2.1 General

The Waterhole Creek and Lukfata Creek Study Area is located in the Southeast of Oklahoma. The waterbodies and their watersheds addressed in this report are located in McCurtain County, which is part of the Ouachita Mountains and South Central Plains Level III ecoregions (Woods, A.J, et al 2005). The watersheds in the Study Area are located in the Ouachita Mountain Uplift geological provinces. **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)
McCurtain	30,814	16.6

Table 1-4 Major Municipalities by Watershed

Waterbody Name	Waterbody ID	Municipalities
Waterhole Creek	OK410100010340_00	Acworth, Garvin, Idabel, Millerton, Negley
Lukfata Creek	OK410210070010_00	Broken Bow, Old Glory Mountain, Stephens Gap, Steel Junction, Idabel, Shults

1.2.2 Climate

Table 1-5 summarizes the average annual precipitation at the Mesonet Station near each Oklahoma waterbody derived from the current and past 15 years of daily data. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 52.0 and 59.8 inches (Oklahoma Climatological Survey 2022).

Table 1-5 Average Annual Precipitation by Watershed

Waterbody Name	Waterbody ID	Mesonet Station	Average Annual Precipitation (inches)
Waterhole Creek	OK410100010340_00	Idabel	52.0
Lukfata Creek	OK410210070010_00	Broken Bow	59.8

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 2019). 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 most dominant land use categories throughout the Waterhole Creek and Lukfata Creek Study Area are Pasture/Hay, Evergreen Forest, and Deciduous Forest. The aggregated total of low, medium, and high intensity developed land use percentage ranges from approximately 1.7% in the Waterhole Creek Watershed (OK410100010340_00) to 2.1% in the Lukfata Creek Watershed (OK410210070010_0). The watersheds targeted for TMDL development in this Study Area range in size from 31,257 acres (Lukfata Creek, OK410210070010_00) to 46,236 acres (Waterhole Creek, OK410100010340_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 Table A-2** along with corresponding water chemistry data results. A summary of the method used to project flows for ungaged streams and flow exceedance percentiles from projected flow data are provided in **Appendix B**.

Figure 1-2 Waterhole Creek and Lukfata Creek Study Area Land Use Map

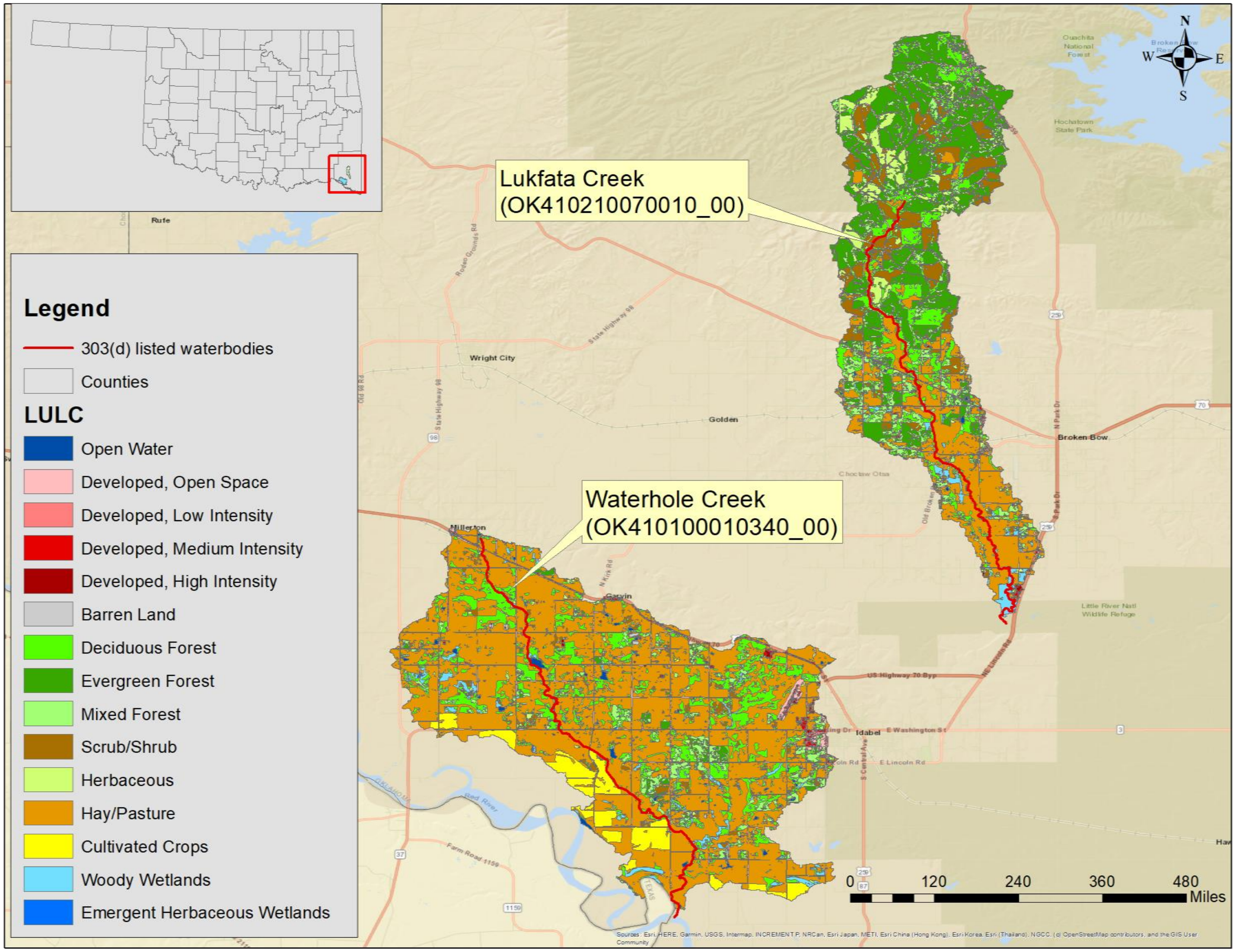


Table 1-6 Land Use Summaries by Watershed

Landuse Category	Watershed	
	Waterhole Creek	Lukfata Creek
Waterbody ID	OK410100010340_00	OK410210070010_00
Open Water (Acres)	331.8	60.0
Developed, Open Space (Acres)	1,434.1	1,047.5
Developed, Low Intensity (Acres)	552.9	379.2
Developed, Medium Intensity (Acres)	319.8	128.1
Developed, High Intensity (Acres)	75.0	39.5
Bare Rock/Sand/Clay (Acres)	59.7	21.0
Deciduous Forest (Acres)	6,940.6	4,603.2
Evergreen Forest (Acres)	519.9	9,507.3
Mixed Forest (Acres)	2,196.1	3,400.0
Shrub/Scrub (Acres)	876.1	3,272.2
Grasslands/Herbaceous(Acres)	330.8	1,817.4
Pasture/Hay (Acres)	29,217.5	6,330.8
Cultivated Crops (Acres)	2,281.1	
Woody Wetlands (Acres)	1,033.8	627.4
Emergent Herbaceous Wetlands (Acres)	66.5	23.0
Total (Acres)	**46,235.7**	**31,256.6**
Open Water (%)	0.7	0.2
Developed, Open Space (%)	3.1	3.4
Developed, Low Intensity (%)	1.2	1.2
Developed, Medium Intensity(%)	0.7	0.4
Developed, High Intensity (%)	0.2	0.1
Bare Rock/Sand/Clay (%)	0.1	0.1
Deciduous Forest (%)	15.01	14.7
Evergreen Forest (%)	1.1	30.4
Mixed Forest (%)	4.7	10.9
Shrub/Scrub (%)	1.9	10.5
Grasslands/Herbaceous (%)	0.7	5.8
Pasture/Hay (%)	63.2	20.3
Cultivated Crops (%)	4.9	
Woody Wetlands (%)	2.2	2.0
Emergent Herbaceous Wetlands(%)	0.1	0.1
Total (%):	**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 (OWQS) 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 DEQ to promulgate rules …w*hich 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
  - CWAC– Cold Water Aquatic Community
  - WWAC – Warm Water Aquatic Community
- FISH – Fish Consumption
- PBCR – Primary Body Contact Recreation
- PPWS – Public & Private Water Supply
- HQW– High Quality Water

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

Waterbody Name	Waterbody ID	AES	AG	CWAC	WWAC	FISH	PBCR	PPWS	HQW
Waterhole Creek	OK410100010340_00	F	F		N	X	N	I	
Lukfata Creek	OK410210070010_00	F	F	N		X	F	I	V

F – Fully supporting information; **N** – Not supporting; **I**-Insufficient data; **X**–Not assessed; **V**- Listed; **Source:** DEQ 2022 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 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 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 excerpt below from 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).*

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.

It is worth noting that the Oklahoma Water Quality Standards (OWQS) prior to July 1, 2011 contained three bacterial indicators (fecal coliform, *E. coli* and Enterococci). Since July 1, 2011 the WQS address only *E. coli* and Enterococci bacteria. Therefore, bacterial TMDLs are developed only for *E. coli* and/or Enterococci impaired streams.

2.1.3 Chapter 730: Criteria for Turbidity

The beneficial use of CWAC 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 NTU; and*
>
> iii. *Other surface waters: 50 NTUs.*
>
> (B) *In waters where background turbidity exceeds these values, turbidity from point sources will be restricted to not exceed ambient levels.*
>
> (C) *Numerical criteria listed in (A) of this paragraph apply only to seasonal base flow conditions.*
>
> (D) *Elevated turbidity levels may be expected during, and for several days after, a runoff event.*

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

252:740-15-3. Data requirements

(e). Minimum number of samples.

(2) Streams. Except when (f) of this Section or any of subsection (e), (h), (i), (j), (k), (l), or (m) of 252:740-15-5 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 CWAC 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 or turbidity impairments that affect the PBCR or CWAC 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 2012 Continuing Planning Process (pp. 139-140). 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 (27 watersheds)

Priority 2 watersheds - 70th to 90th percentile (56 watersheds)

Priority 3 watersheds - 40th to 70th percentile (87 watersheds)

Priority 4 watersheds - below the 40th percentile (124 watersheds)

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	*EC*	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Cool Water Aquatic Life
OK410100010340_00	Waterhole Creek	16.61	2033	4	X	X*	N		
OK410210070010_00	Lukfata Creek	17.80	2024	1				X	N

Note: ENT = Enterococci; ***EC***= *Escherichia coli;* **N** = Not attaining; **X** = Criterion exceeded
* TMDL has been completed or under process.

Table 2-3 Summary of Assessment of Indicator Bacterial Samples from Primary Body Contact Recreation Subcategory Season May 1 to September 30, 2006-2011

Waterbody ID	Waterbody Name	Indicator	Number of Samples	Geometric Mean Conc. (cfu/100 ml)	Assessment Results/ Recommended Action
OK410100010340_00	Waterhole Creek	ENT	12	129.5	Impaired/TMDL
		EC	10	153	Impaired & 2020 Draft TMDL

Note: ENT = Enterococci; water quality criterion = Geometric Mean of 33 counts/100 mL
EC= *Escherichia coli,* water quality criterion = Geometric Mean of 126 counts/100 mL
TMDLs will be developed for waterbodies highlighted in green

Table 2-4 Summary of All Turbidity Samples, 2016-2021

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 10 NTU	% samples exceeding criterion	Average Turbidity (NTU)
OK410210070010_00	Lukfata Creek	OK410210-07-0010G	28	9	32%	15.9

Table 2-5 Summary of Turbidity Data at Base Flow Samples, 2016-2021

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 10 NTU	% samples exceeding criterion	Average Turbidity (NTU)	Assessment Results / Recommended Actions
OK410210070010_00	Lukfata Creek	OK410210-07-0010G	16	4	25%	7.7	Impaired/TMDL

Table 2-6 Summary of TSS Data at Base Flow Samples, 2016-2021

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK410210070010_00	Lukfata Creek	OK410210-07-0010G	13	<10

2.2 Problem Identification

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

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 2011 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 PBCR 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 PBCR season are provided in **Appendix A.** For the data collected between 2006 and 2011, evidence of nonsupport of the PBCR use based on Enterococci exceedances was observed in Waterhole Creek. A TMDL for *E. coli* is already included in a draft report (*2020 Bacterial Total Maximum Daily Loads for Oklahoma Streams in Southeast Oklahoma*).

One bacterial TMDL is needed for the waterbodies in the Study Area. Rows highlighted in green in **Table 2-3** required TMDLs.

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 are used as a surrogate in this TMDL. Therefore, both turbidity and TSS data are presented in this subsection.

According to the DEQ 2022 303(d) list, turbidity is the cause of nonsupport of the Fish and Wildlife Propagation for Lukfata Creek (OK410210070010_00). **Table 2-4** summarizes turbidity data collected from the WQM stations between 2016 and 2021. TSS data collected between 2016 and 2021 resulted in 25 total samples with 21 (84%) being below the detection limit of 10 mg/L. According to WQS 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 25^{th} flow exceedance percentile (i.e., the lower 75% of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2023). Therefore, **Table 2-5** and **Table 2-6** were prepared to represent the subset of these data for samples collected during base flow conditions. Water quality samples collected under flow conditions greater than the 25^{th} flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. Using this qualified data set, 4 of the 19 samples (21%) identified for the Lukfata Creek have turbidity higher than 10, which indicate nonsupport of the Fish and Wildlife Propagation use, and a TMDL was developed for this waterbody. 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 target for Enterococci is geometric mean standard of 33 cfu/100ml. The TMDL for bacteria will incorporate an explicit 10% margin of safety as well as 10% future growth.

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 [252:730-5-12(f)(7)], the turbidity criterion for streams with CWAC beneficial use is 10 NTUs (DEQ 2022). The turbidity numerical criteria apply 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 or CWAC must take into account that no more than 10% of the samples may exceed the numeric criteria for turbidity. 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 waterbody 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. To accommodate the potential for future growth in watersheds with no WLA for TSS, 1% of TSS loading is reserved as part of the WLA.

Future growth accommodates the potential of future loading growth due to population increase, changes in community infrastructure, development of new facilities in the impaired watershed.

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 sources are permitted through the OPDES program. OPDES-permitted facilities that discharge treated wastewater are currently required to monitor for fecal coliform and TSS in accordance with their permits. Currently facilities with bacterial limits monitor for fecal coliform. When their permits are renewed, they will be required to monitor for *E. coli*. 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 corridors of streams and creeks, highway/road/bridge runoff (non-construction related), impacts from abandoned mine lands, non-irrigated crop production, rangeland grazing, silviculture harvesting, as well as other 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 discernible, 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 loading into the watersheds include:

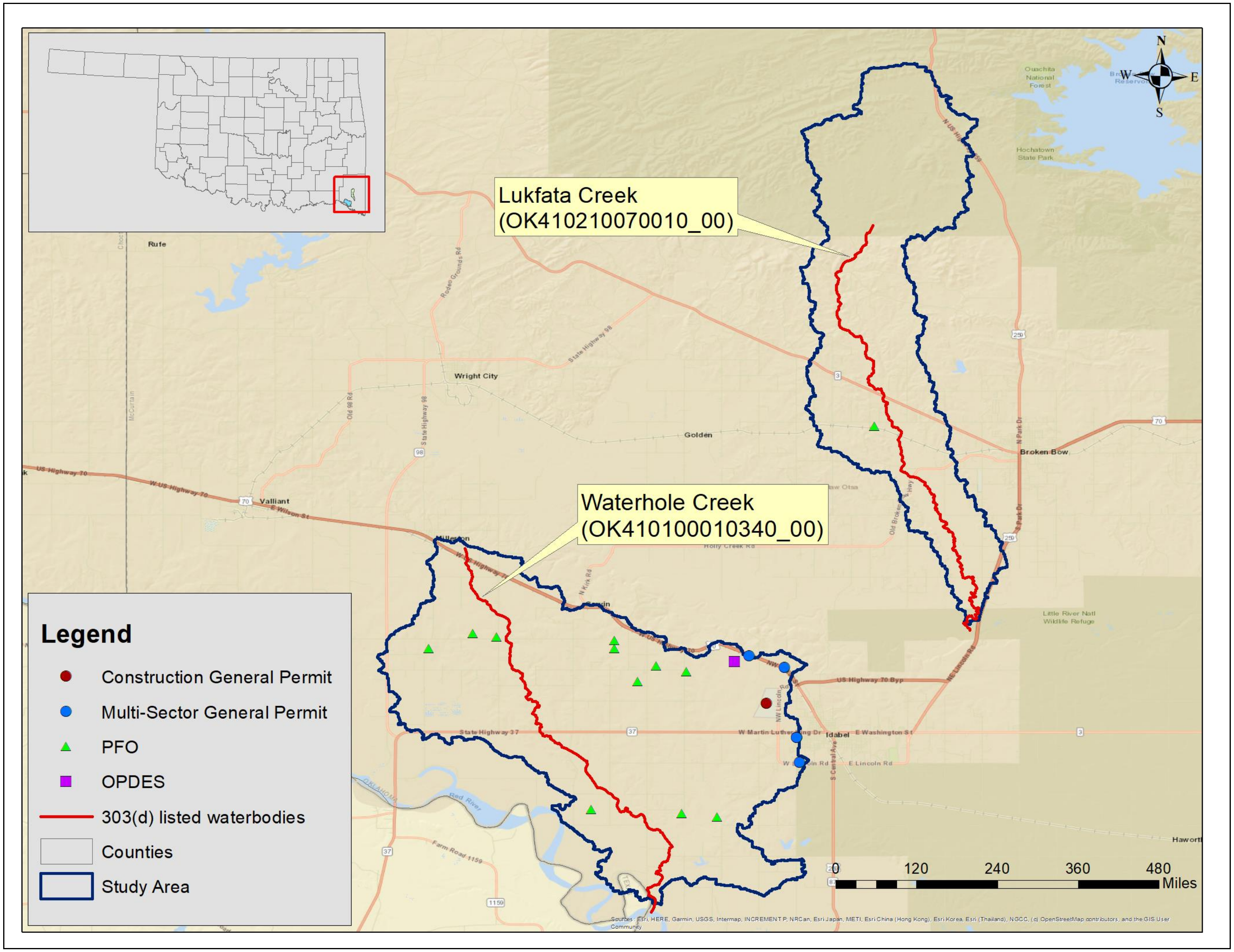
- Continuous Point Source Dischargers
  - OPDES municipal wastewater treatment facilities (WWTF)
  - OPDES Industrial WWTF Discharges
- OPDES-regulated stormwater discharges
  - Municipal separate storm sewer system (MS4) discharges
    - Phase 1 MS4
    - Phase 2 MS4 – OKR04
  - Multi-Sector general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

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. AFOs 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 ten PFOs in the Study Area.

Table 3-1 Stormwater Permits Summary

Watershed	County	Company name	Permit ID	Effective Date	SIC
Construction General Permits (OKR10)					
Waterhole Creek (OK410100010340_00)	McCurtain	D&R Construction & Materials LLC	OKR1029553	10/4/2018	1542
Multi-Sector General Permits (OKR05)					
Waterhole Creek (OK410100010340_00)	McCurtain	Weyerhaeuser NR Company	OKR051670	2/1/2019	2421
		Quality Rock Inc	OKR053237	7/29/2019	1422
		STECO Tire Inc	OKR051069	2/28/2018	3011
		Bone Yard Metal Recycling	OKR053612	12/27/2018	5093

Figure 3-1 Location of OPDES-Permitted Facilities and Registered PFOs 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 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 municipal WWTFs 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 municipal 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. Discharges of TSS will be considered to be organic suspended solids if the discharge permit includes a limit for Biochemical Oxygen Demand (BOD) or Carbonaceous Biochemical Oxygen Demand (CBOD). Only WWTF discharges of inorganic suspended solids will be considered and will receive WLAs.

There is one industrial WWTF within the Waterhole Creek Watershed Area (Weyerhauser Company, OK0043885, SIC 2421). However, this facility primarily discharges stormwater and is not considered to be a source of bacterial loading.

3.2.1.1 Municipal OPDES WWTFs

There are no active permitted municipal point source facilities within the Study Area.

3.2.1.2 Industrial OPDES WWTFs

There is one industrial WWTFs within the Waterhole Creek Watershed Area (Weyerhauser Company, OK0043885, SIC 2421). However, this facility primarily discharges stormwater and is not considered a source of bacterial loading.

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 cfu/100mL for *E.coli* (Pitt et. al. 2004).

EPA regulations [40 CFR. § Part 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 252:730-5-12(f)(7)]. 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.

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 are no Phase I MS4 facilities 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://www.deq.ok.gov/stormwater-permitting/okr04-municipal-stormwater/. There are no Phase II MS4 communities in the Study Area.

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 1-3 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 no facilities within the Lukfata Creek Watershed where the receiving stream is impaired for turbidity.

There are four facilities within the Study Area with multi-sector general permits shown in **Table 3-1**. However, none of the facilities in **Table 3-1** are considered a possible source of bacteria.

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 11 of the MSGP. Specific effluent limitation guidelines for Sector J SIC codes 1411, 1422, 1423, 1429, 1442, 1446, 1455, 1459, 1474, 1475, 1479, 1481, and 1499 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.

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 with SIC codes 1411, 1422, 1423, 1429, 1442, 1446 (excluding hydrofluoric acid (HF) flotation) and 3281 are regulated under DEQ General Permit OKG950000. A rock, sand or gravel facility that does not fall under one of the previously mentioned SIC codes would be required to apply for an individual industrial wastewater permit before they would be allowed to discharge process wastewater or co-mingled stormwater. HF flotation has been excluded from coverage under this Permit due to more stringent effluent limitation guidelines in 40 CFR 436.42. 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 including those with Reuse (SWS and SWSR), Cool Water Aquatic Communities, Trout Fisheries, Appendix B Waters [OAC 252:730-5-25(c)(2)], and within one (1) stream mile of a lake. In addition, for a new facility, no discharge is allowed into waterbodies listed as impaired for turbidity in Oklahoma's 303(d) list. However, a new facility may be allowed to discharge into a receiving stream listed as impaired for pH in Oklahoma's 303(d) list if the facility can certify the discharge will maintain a pH of 6.5-9.0 standard units. For existing facilities, discharges into turbidity-impaired streams are 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. Also, if a facility discharges to a stream segment that is not included in

Oklahoma's 303(d) list, but is within one mile upstream of an impaired segment, then the discharge will be treated as though it were to be to an impaired segment (DEQ 2018).

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 6.5–9.0. Industrial sand and gravel facilities (SIC code 1446) have an additional TSS effluent limit for monthly average of 25 mg/L which apply only to them. 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.

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 possible contributor to turbidity impairment. The permits for construction projects currently active are summarized in **Table 3-1** and shown in **Figure 3-1**. There are no facilities with general permits for construction activities in the Lukfata Creek Watershed where the receiving stream is impaired for turbidity. There is one facility within the Waterhole Creek Watershed with a multi-sector general permit. However, stormwater from construction activities is not considered a possible contributor to bacterial impairment.

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.

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.

There are no SSOs in the Study Area.

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. The location of each AFO is shown in **Figure 3-1** and is listed in **Table 3-2**.

3.2.5.1 CAFO

CAFO is an animal feeding operation that confines and feeds at least 1,000 animal units for 45 days or more in a 12-month period (ODAFF 2021). AWMPs (Section 35:17-4-12), as specified in Oklahoma's CAFO regulations are designed to protect water quality through the use of structures such as dikes, berms, terraces, ditches, to isolate animal waste from outside surface drainage, except for a 25-year, 24–hour rainfall event.[1] AWMPs may include, but are not limited to, a NRCS Geospatial Nutrient Tool or Nutrient Management Plan per EPA guidance.

CAFOs are considered no-discharge facilities for the purpose of the TMDL calculations in this report. They are not considered a source of bacterial or TSS loading, and runoff of animal waste into surface waterbodies or groundwater is prohibited. CAFOs are designated by EPA as significant sources of pollution and may have the potential to cause serious impacts to water quality if not managed properly. Potential problems for CAFOs can include animal waste discharges to waters of the State and failure to properly operate wastewater lagoons.

Oklahoma CAFO Rules require CAFOs to submit a *Documentation of No Hydrologic Connection* (OAC 35:17-4-10[2]) for all retention structures designed to prevent any leakage of wastewater into waterbodies. Thus, the potential for pollutant loading from CAFOs to a receiving stream is almost non-existent.

Per data provided by ODAFF in May 2011, there are no CAFOs in this study area.

1 CAFO Animal Waste Management Plan Requirements [Title 35 (ODAFF), Chapter 17 (Water Quality), Subchapter 4 (Concentrated Animal Feeding Operations)] can be found in 35:17-4-12.

2 USDA NRCS design specifications in the USDA NRCS Agricultural Waste Management Field Handbook Chapter 10 shall satisfy documentation of no hydrologic connection so long as the facility is designed by USDA NRCS and does not exceed one thousand (1,000) animal units.

Table 3-2 Registered PFOs in Study Area

Waterbody Name	Waterbody ID	Company Name	Poultry ID	County	Type	Total Birds
Waterhole Creek	OK410100010340_00	Tyson Foods	547	McCurtain	Broilers	102,000
		Tyson Foods	551	McCurtain	Broilers	26,000
		Tyson Foods	979	McCurtain	Broilers	122,000
		Tyson Foods	1246	McCurtain	Layers	66,000
		Tyson Foods	1652	McCurtain	Broilers	192,000
		Tyson Foods	1653	McCurtain	Broilers	192,000
		Tyson Foods	1661	McCurtain	Broilers	192,000
		Tyson Foods	1666	McCurtain	Broilers	276,000
		Tyson Foods	1750	McCurtain	Broilers	184,000
Lukfata Creek	OK410210070010_00	Tyson Foods	1639	McCurtain	Broilers	50,940

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 "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 groundwater. 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.

For large SFOs with more than 1,000 animal units, monitoring wells or a leakage detection system for waste retention structures must be installed in order to monitor and control seepage/leakage [OAC 35:17-3-11(e)(6)]. Oklahoma Rules requires SFOs to submit a *Documentation of No Hydrologic Connection* (OAC 35:17-3-12) for all retention structures in order to prevent any leaking of wastewater to waterbodies. Thus, the potential for loading from SFOs to the receiving stream is almost non-existent.

There are no SFOs in the 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

[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)

[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.

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 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]

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 April 2014, there are ten PFOs located in the watershed as shown in **Table 3-2**. These PFOs are small animal feeding operations and are not required to get NPDES permits; they are required only to register with ODAFF. They generate dry litter and do not have any significant impact on the watershed.

3.2.6 Section 404 Permits

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

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

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.

4 Nutrient limited watersheds are defined in the Oklahoma Water Quality Standards (Title 252, Chapter 730). Nutrient limited watersheds can be found in Appendix A of the OWQS. They are the ones designated “NLW” in the “Remarks” column.

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 14 watersheds in different areas within the United States was approximately 15,000/100 mL in stormwater runoff (EPA 1983). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal coliform bacteria. Water quality data collected from streams draining many of the non-permitted communities show a high level of fecal coliform bacteria.

Various potential nonpoint sources of TSS as indicated in the 2022 Integrated Report include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff, non-irrigated crop production, rangeland grazing and other sources of sediment loading (DEQ 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/or 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 2018 to 2022 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 3-3** in cfu/day provides a relative magnitude of loading in each of the TMDL watersheds impaired for bacteria.

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

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per Acre	Fecal Production (x 10^9 cfu/day) of Deer Population
OK410100010340_00	Waterhole Creek	46,235.7	542	0.01	271
OK410210070010_00	Lukfata Creek	31,256.6	367	0.01	183

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 bacteria. 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.

Table 3-5 provides estimated numbers of commercially raised farm animals and estimated acreage where manure was applied by watershed. This was calculated using the 2017 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2017) 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 3-5,** 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 3-4** gives the daily fecal coliform production rates by animal species:

Table 3-4 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
Geese*	4.90E+10
Chickens*	1.36E+08
Turkey*	9.30E+07
Deer*	$5x10^8$
Dogs⁑	$3.3x10^9$
Cats⁑	$5.4x10^8$

* According to a livestock study conducted by the ASAE (1999)

⁑ Schueler, TR 1999

Using the estimated animal populations and the fecal coliform production rates from **Table 3-4**, an estimate of fecal coliform production from each group of commercially raised farm animal was calculated in each watershed of the Study Area. These estimates are presented in **Table 3-6**. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into streams by runoff or by direct deposition from wading animals. Because of their numbers, cattle appear to represent the most likely commercially raised farm animal source of fecal bacteria loading.

Table 3-5 Commercially Raised Farm Animals and Manure Application Area Estimated by Watershed

Waterbody ID	Waterbody Name	Cattle	Dairy Cows	Horses	Goats	Sheep	Hogs & Pigs	Ducks & Geese	Acres of Manure Application
OK410100010340_00	Waterhole Creek	2,773	1	90	77	9	15	6	877
OK410210070010_00	Lukfata Creek	1,875	1	61	52	6	10	4	593

Table 3-6 Fecal Coliform Production Estimated for Commercially Raised Farm Animals ($x10^9$ number/day)

Waterbody ID	Waterbody Name	Cattle	Dairy Cows	Horses	Goats	Sheep	Hogs & Pigs	Ducks & Geese	Total
OK410100010340_00	Waterhole Creek	288,376	92	38	930	107	163	290	290,008
OK410210070010_00	Lukfata Creek	195,032	61	26	629	72	110	196	196,135

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 2020, 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 2010), dog and cat populations can be estimated for each watershed. **Table 3-7** summarizes the estimated number of dogs and cats for the watersheds of the Study Area. **Table 3-8** provides an estimate of the fecal coliform production from pets. These estimates are based on estimated fecal coliform production rates from **Table 3-4.**

Table 3-7 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK410100010340_00	Waterhole Creek	388	273
OK410210070010_00	Lukfata Creek	262	185

Table 3-8 Estimated Fecal Coliform Daily Production by Pets (x10^9 counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK410100010340_00	Waterhole Creek	1,280	148	1,427
OK410210070010_00	Lukfata Creek	866	100	966

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 sources 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 et al. (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 1984). **Table 3-9** 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):

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

Table 3-9 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	# of Septic Tanks/Mile^2
OK410100010340_00	Waterhole Creek	205	299	21	525	4.1
OK410210070010_00	Lukfata Creek	139	202	14	355	4.1

The average of number of people per household was calculated to be 2.13 for McCurtain County (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 1984; Cogger and Carlile 1984). Using this information, the estimated load from failing septic systems within the watersheds was summarized below in **Table 3-10.**

Table 3-10 Estimated Fecal Coliform Load from OSWD Systems

Waterbody ID	Waterbody Name	Watershed Area (Acres)	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day
OK410100010340_00	Waterhole Creek	46,235.7	299	36	203
OK410210070010_00	Lukfata Creek	19,783	202	24	137

3.4 Summary of Sources of Impairment

There are no continuous, permitted point sources of bacteria in the Waterhole Creek watershed which require bacterial WLAs. Therefore, the conclusion is that nonsupport of PBCR use in this watershed is caused by nonpoint sources of bacteria. There are nine PFOs which could possibly contribute bacterial loading into the Waterhole Creek. However, PFOs are not allowed to discharge or allow the runoff of animal waste so they are not considered to be major sources of bacteria as long as they are in compliance with their Nutrient Management Plans and Animal Waste Management Plans as outlined in the ODAFF PFOs Rules. Therefore the various nonpoint sources are considered to be the major source of bacterial loading in the Waterhole Creek watershed.

There are also no continuous, permitted point sources of TSS in the Lukfata Creek Watershed. Therefore, nonsupport of the CWAC use in this watershed 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.

Table 3-11 provides a summary of the estimated percentage of fecal coliform loads in cfu/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. The percentage of fecal coliform loads from commercially raised farm animals was 99.35%. Because of their numbers and animal unit production of bacteria, commercially raised farm animals 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.

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

Table 3-11 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
OK410100010340_00	Waterhole Creek	99.35	0.49	0.09	0.07
OK410210070010_00	Lukfata Creek	99.35	0.49	0.09	0.07

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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:

$$TMDL = WLA + LA + MOS$$

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

For *E. coli* or Enterococci bacteria, TMDLs are expressed as colony-forming units per day, and represent the maximum one day load the stream can assimilate while still attaining the WQS. Percent reduction goals are also calculated to aid to characterizing the possible magnitude of the effort to restore the segment to meeting water quality criterion. Turbidity TMDLs will be derived from TSS calculations and expressed in pounds (lbs) per day which will represent the maximum one day load the stream can assimilate while still attaining the WQS, as well as a PRG.

4.2 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 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, 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 5 NTUs (half of turbidity standard for CWAC 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 (*b*1) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). **Figure 4-1** shows an example of the correlation between TSS and turbidity, along with the LOC and the OLS lines.

The NRMSE and R-square (r^2) were used as the primary measures of goodness-of-fit. 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.

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 75^{th} percentile (Q_3) and 25^{th} 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.

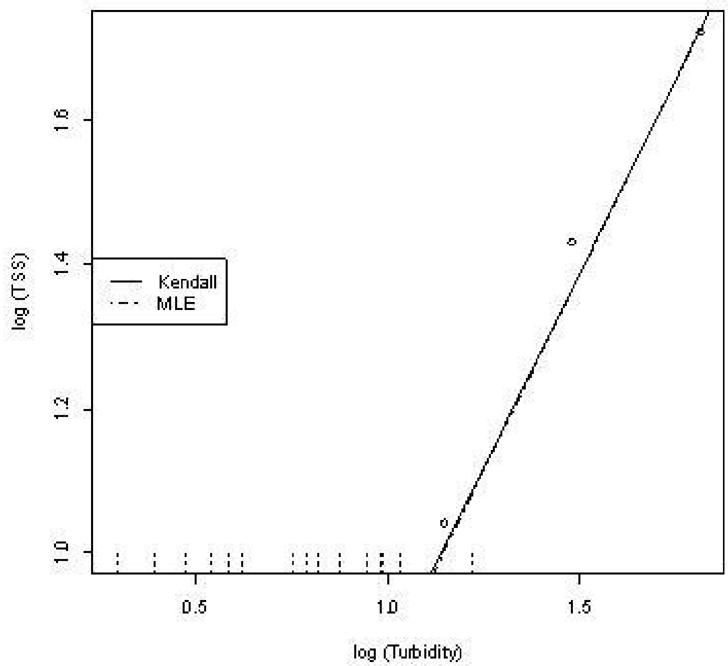
- Log-transform both turbidity and TSS data to minimize effects of their non-linear data distributions.
- Use methods for estimating summary statistics of data which include non-detects: simple substitution, distributional, and robust methods (Helsel and Hirsch, 2002).
- Compare results for the mean 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 the data below detection limits 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 (**Appendix D**). 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 4-1**. If extreme outliers were not present in the sample data and the distributions of points were close to trend line (**Figure 4-1**), parametric method (MLE) performed similar or slightly better than non-parametric method (Kendall's tau).

[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.

Figure 4-1 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:

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

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

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

Where x_i = log(turbidity)i, y_i = log(TSS)i, i = 1…n, $\bar{x}$ = average of x_i, $\bar{y}$ = average of yi, 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 (FDCs) serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. FDCs 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. The 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.

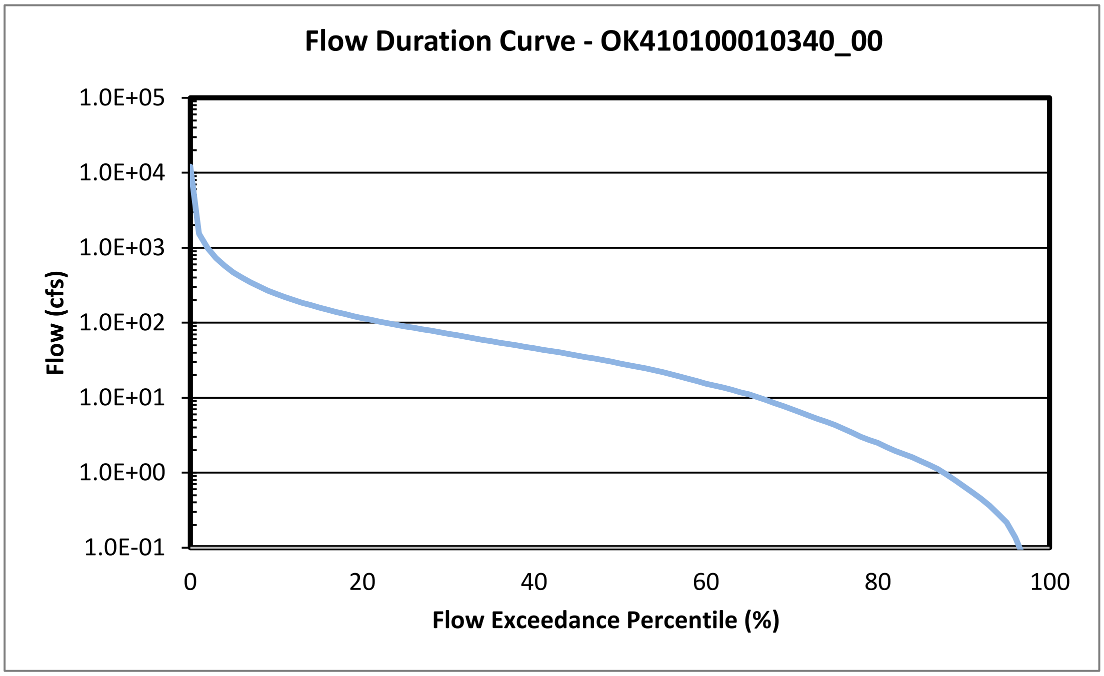
Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations 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-2**.

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0% and downward at a frequency near 100%, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100%.

As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a “stair step” effect due to the USGS flow data rounding conventions near the limits of quantization. An example of a typical flow duration curve is shown in **Figure 4-2**.

Flow duration curves for each impaired waterbody in the Study Area are provided in Section 5.1.

Figure 4-2 Flow Duration Curve for Waterhole Creek (OK410100010340_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 cfu/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 cfu per day. The cfu is a total for the day at a specific flow for bacteria, which is the best equivalent to a mass per day of a pollutant such as sulfate. Expressing bacterial TMDLs as cfu 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.

The following are the basic steps in developing an LDC:

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

Where:

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

Unit conversion factor = 24,465,525

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

Where:

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

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.”

<u>WLA for WWTF</u>

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 (cfu/day)

Where:

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

Flow (mgd) = permitted flow

Unit conversion factor = 37,854,120

4.3.3.3.2 WLA for TSS

WLA = WQ goal * flow * unit conversion factor (lb/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 and turbidity TMDLs, the percentage of the TMDL reserved for future sources were 10% and 1%, respectively.

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. Therefore, MLE was used for Lukfata Creek in **Table 5-1**.

Using the maximum likelihood estimation (MLE) methods described in Section 4, correlations between TSS and turbidity were developed for establishing the statistics of the regressions and the resulting TSS goals provided in **Table 5-2**. The regression analysis for each impaired waterbody in the Study Area using MLE method is displayed in **Figure 5-1**.

An acceptable regression relationship (R^2 value of approximately 0.5) could not be developed for Lukfata Creek (OK410210070010_00). Therefore, the regression statistics for this waterbody were derived from Cloudy Creek (OK410210020300_00, TMDL ID 59169). Cloudy Creek is in the same geographical area as Lukfata Creek and has similar land uses. Cloudy Creek is also located in the Ouachita Mountain Uplift and Ouachita Mountains Level III ecoregion. This approach was superior to one based on a larger geographic area, which presumably would have more diverse hydrologic conditions and watershed characteristics.

Table 5-1 Censored TSS data at base flow

Waterbody ID	Waterbody Name	Total number of 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)
OK410210070010_00	**Lukfata Creek**	44	42	95.5

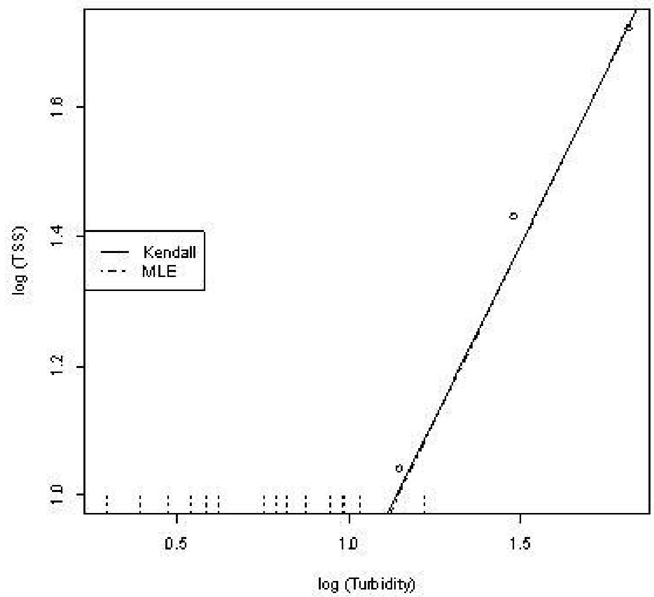
Table 5-2 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square[a]	NRMSE[a]	TSS Goal (mg/L)[b]	MOS
OK410210070010_00	**Lukfata Creek**	0.74	12%	6.9	15%

[a] R-square and NRMSE values are for Cloudy Creek (OK410210020300_00)

[b] Calculated using the regression equation for Cloudy Creek and the turbidity standard (10 NTU for CWAC)

Figure 5-1 Regression Estimation for TSS-Turbidity for Cloudy Creek[1] (OK410210020300_00)



Note: The regression for Cloudy Creek (OK410210020300_00) was used for Lukfata Creek (OK410210070010_00) since they are in a similar geographic area and have similar land uses.

A regression method is not truly appropriate for a data set with a very high rate of censoring (greather than 50%). However, a regression with MLE method was used in this study because there are no alternatives to find a relationship between TSS and turbidity. Even though the regression method was inappropriate for highly censored data, PRGs from the regression method were not much different from those computed by direct calculation with turbidity (**Appendix F**).

5.2 Flow Duration Curve

Following the same procedures described in Section 4.2.1, a flow duration curve for each stream segment requiring a TMDL in the Study Area was developed. These are shown in **Figure 5-2** through **Figure 5-3.**

Waterhole Creek (OK410100010340_00) and Lukfata Creek (OK410210070010_00) did not have USGS flow gages. Therefore, flows for these waterbodies were estimated using the watershed area ratio method based on measured flows at existing adjacent USGS gage stations.

[1] The correlation coefficient for Cloudy Creek is > than 0.5. The correlation coefficient for Lukfata Creek (OK410210070010_00) was < than 0.5. Since Lukfata Creek is in the same geographical area and has similar land uses as Cloudy Creek, the regression for Cloudy Creek was used for Lukfata Creek.

The flow duration curves for Waterhole Creek (OK410100010340_00) and Lukfata Creek (OK410210070010_00) were developed based on the flow data from 1961 to 2022 at USGS gage station 07337900 (Glover River near Glover, OK).

Figure 5-2 Flow Duration Curve for Waterhole Creek (OK410100010340_00)

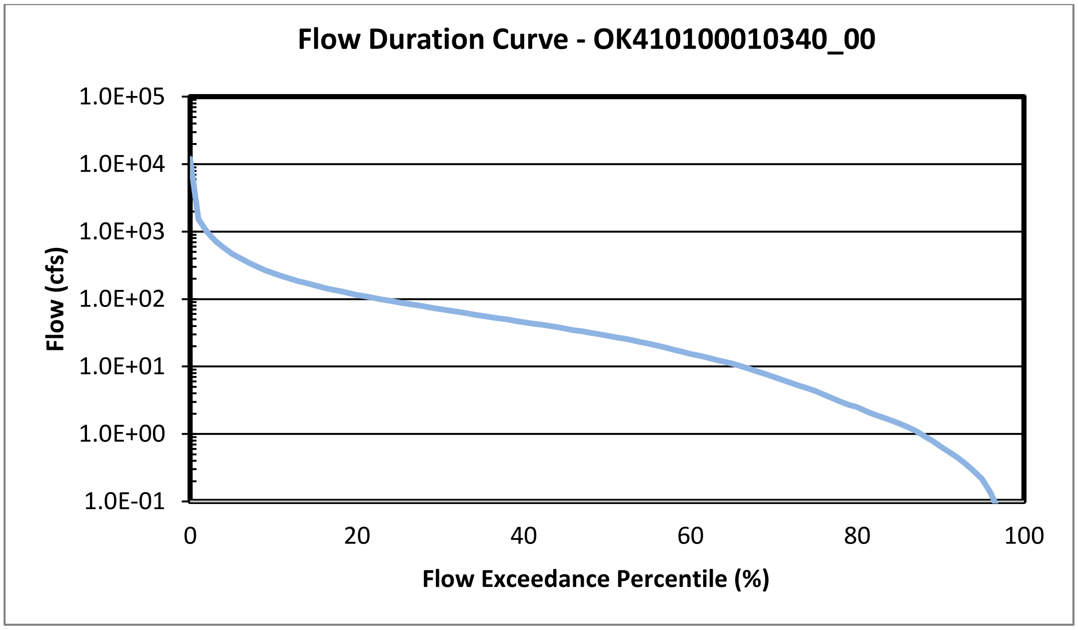
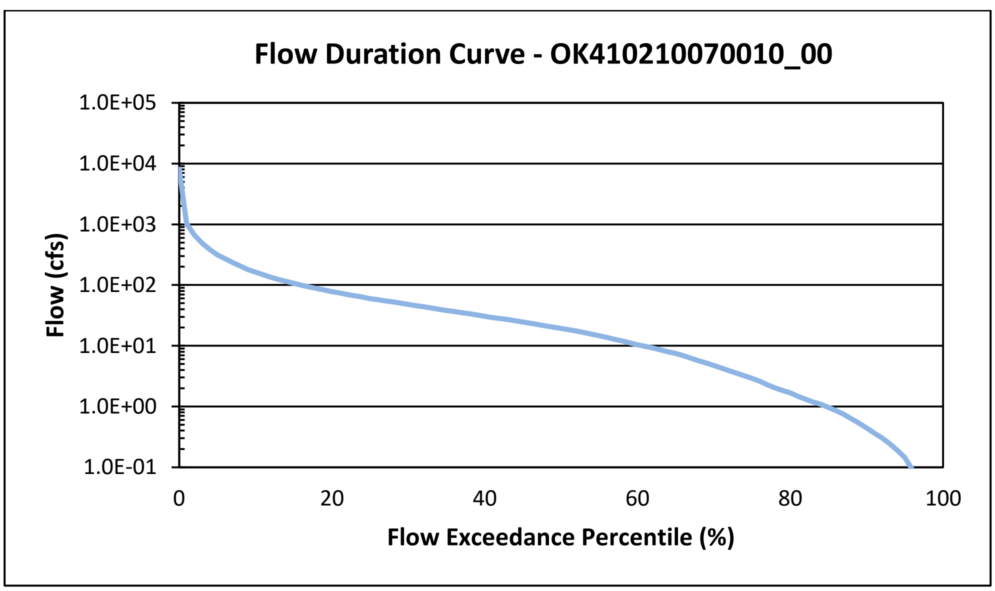


Figure 5-3 Flow Duration Curve for Lukfata Creek (OK410210070010_00)



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.

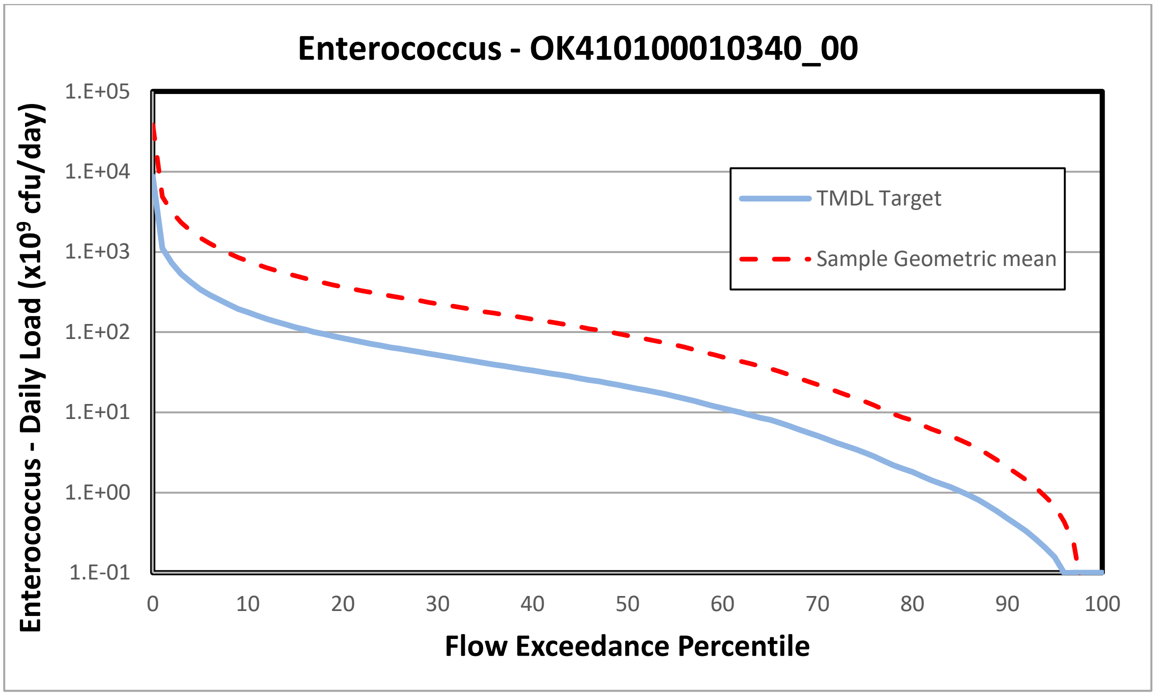
5.3.1 Bacterial LDCs

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 **2011** 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*. The bacterial LDCs developed for the impaired waterbody is shown in **Figure 5-4**.

The LDC for Waterhole Creek (**Figure 5-4**) is based on Enterococci measurements during primary contact recreation season at WQM station OK410100-01-0340D.

Figure 5-4 Load Duration Curve for Enterococci in Waterhole Creek (OK410100010340_00)



5.3.2 TSS LDCs

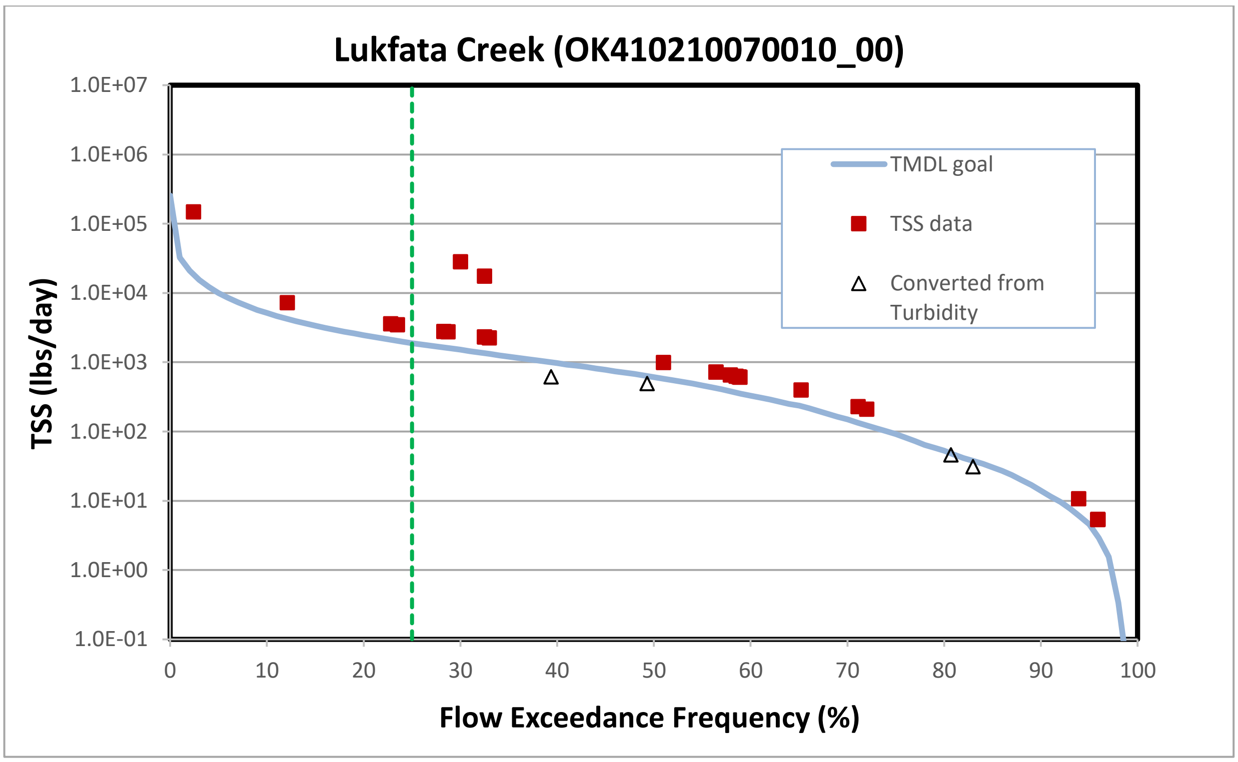
To calculate the TSS load at the WQ target, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*5.39377*) and the TSS goal for each waterbody. This calculation produces the maximum TSS load in the waterbody that will result in attainment of the WQ target (50 NTU for WWAC and 10 NTU for CWAC) 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 and estimated TSS value is used. Pollutant loads are then calculated by multiplying the TSS concentration by the flow rate and the unit conversion factor. The associated flow exceedance percentile is then matched with the flow from the tables provided in **Appendix B**. The observed/estimated 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 5-5 shows the TSS LDC developed for Lukfata Creek (OK410210070010_00). TSS levels exceed the water quality target during all flow conditions, indicating water quality impairments due to nonpoint sources. Wet weather influenced samples found during low flow conditions can be caused by an isolated rainfall event during dry weather conditions. It is noted that the LDC plots include data under all flow conditions to show the overall condition of the waterbody. However, the turbidity standard only applies for base-flow conditions. Thus, when interpreting the LDC to derive TMDLs for TSS, only the portion of the graph corresponding to flows above the 25th flow exceedance percentile should be used.

In the LDC curve, TSS data were plotted based on an instant flow sample 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 uncertainty with using estimated flows from an adjacent waterbody.

Figure 5-5 Load Duration Curve for Total Suspended Solids in Lukfata Creek (OK410210070010_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.

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 reduction necessary to meet the TMDL water quality target for each bacterial indicator in each of the impaired waterbodies in the Study Area.

PRGs for TSS are calculated as the required overall reduction so that no more than 10% of the samples exceed the TMDL target for TSS. The PRGs for the waterbodies requiring turbidity TMDLs in this report are summarized in **Table 5-4**.

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

Waterbody ID	Waterbody Name	Required Reduction Rate (%)
		Enterococci
OK410100010340_00	Waterhole Creek	77.1

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK410210070010_00	Lukfata Creek	41.4%

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 (cfu/day)

Where:

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

Flow (mgd) = permitted flow

Unit conversion factor = 37,854,120

When multiple 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 fecal coliform or *E. coli* limits and disinfection requirements of OPDES permits.

Only municipal sewerage facilities (i.e. SIC code 4952) are expected to be sources of bacteria in this study. Hence, WLA allocations are not calculated for industrial NPDES permittees. Certain facilities that utilize lagoons for treatment have not been required to provide disinfection since storage time and exposure to ultraviolet radiation from sunlight should reduce bacterial levels. In the future, all point source dischargers which are assigned a wasteload allocation but do not currently have a bacterial limit in their permit will receive a permit limit consistent with the wasteload allocation as their permits are reissued. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacterial load from existing discharges will be considered consistent with the TMDL provided that the NPDES permit requires in-stream criteria to be met.

Permitted stormwater discharges are considered point sources. However, there are no designated MS4s within the watersheds of the Study Area impaired for contact recreation, so there are no WLAs for MS4s.

5.4.2 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. For bacterial and turbidity TMDLs, the percentage of the TMDL reserved for future sources were 10% and 1%, respectively.

5.4.3 Total Suspended Solids WLA

OPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated by using the average of self-reported monthly flow multiplied by the water quality target. In other words, the facilities are required to meet instream criteria in their discharge. If the current monthly TSS limits of a facility are greater than instream TSS criteria, the new limits equal to instream criteria will be applied to the facility as their permit is renewed. The WLA is derived as follows:

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

Where:

WQ goal = waterbody-specific water quality goal as summarized in* Table 5-2, *or monthly TSS limit in the current permit, whichever is smaller

Flow (mgd) = average monthly flow

Unit conversion factor = 8.3445

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.

5.4.4 Permit Implication

5.4.4.1 Bacterial Permit Limitations

All point source dischargers assigned a wasteload allocation will receive a permit limit equal to the water quality standard as their permits are reissued and are required to meet water quality standards 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.

5.4.4.2 TSS Permit Limitations

Stormwater discharges from MS4s, industrial facilities, and construction sites 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 plant 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** was equal to or greater than the daily maximum limit in the current permit, the permit TSS limits stay the same and the TMDL has no impact on the permit limits when a permit is renewed.

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

The TMDLs do not place specific requirements for monthly average limit. The permitting 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 that proposed discharges under Section 404 Permits comply with Oklahoma WQS. The proposed discharge must also comply with the TSS TMDLs in this report. Section 401 Certification will be conditioned to meet one of the following two conditions to be certified by the State:

- Include TSS limits in the permit and establish a monitoring requirement to ensure compliance with turbidity standards and TSS TMDLs; or
- Submit to 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 waterbody not supporting the PBCR or WWAC uses are calculated as the difference between the TMDL, MOS, and WLA, as follows:

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 1^{st} through September 30^{th}. Seasonal variation was also accounted for in these TMDLs by using five years of water quality data and by using the all available 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 an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained. EPA guidance allows for use of implicit or explicit expressions of the MOS, or both.

For 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. **Table 5-5** shows the MOS for Lukfata Creek.

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

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK410210070010_00	Lukfata Creek	12%	15%

5.8 TMDL Calculations

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

This definition can be expressed by the following equation:

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

The TMDL represents a continuum of desired load over all flow conditions, rather than fixed at a single value, because loading capacity varies as a function of the flow present in the stream. The higher the flow is, the more wasteload the stream can handle without violating WQS. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges or increased load from existing discharges will be considered consistent with the TMDL provided the 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 bacterial and TSS TMDL, WLA, LA and MOS loadings at the 50% flow percentile. **Table 5-8** 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 5-9** presents the allocations for total suspended solids.

Table 5-6 Summaries of Bacterial TMDLs

Stream Name	Waterbody ID	Pollutant	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	Future Growth (cfu/day)	LA (cfu/day)	MOS (cfu/day)
Waterhole Creek	OK410100010340_00	ENT	2.31E+10	0	2.31E+09	1.85E+10	2.31E+09

Table 5-7 Summaries of TSS TMDLs

Stream Name	Waterbody ID	Pollutant	TMDL (lbs/day)	WLA (lbs/day)	WLA_{MS4} (cfu/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
Lukfata Creek	OK410210070010_00	TSS	715	0.0	0.0	7	601	107

Table 5-8 TMDL Calculations for Enterococci in Waterhole Creek (OK410100010340_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	$WLA_{\_WWTF}$ (cfu/day)	$WLA_{\_MS4}$ (cfu/day)	LA (cfu/day)	Future Growth (cfu/day)	MOS (cfu/day)
0	12050	9.73E+12	0	0	7.78E+12	9.73E+11	9.73E+11
5	470	3.79E+11	0	0	3.03E+11	3.79E+10	3.79E+10
10	243	1.96E+11	0	0	1.57E+11	1.96E+10	1.96E+10
15	159	1.28E+11	0	0	1.03E+11	1.28E+10	1.28E+10
20	116	9.33E+10	0	0	7.46E+10	9.33E+09	9.33E+09
25	89	7.18E+10	0	0	5.75E+10	7.18E+09	7.18E+09
30	71.3	5.75E+10	0	0	4.60E+10	5.75E+09	5.75E+09
35	56.5	4.56E+10	0	0	3.65E+10	4.56E+09	4.56E+09
40	45.6	3.68E+10	0	0	2.95E+10	3.68E+09	3.68E+09
45	36.5	2.95E+10	0	0	2.36E+10	2.95E+09	2.95E+09
50	28.6	2.31E+10	0	0	1.85E+10	2.31E+09	2.31E+09
55	21.8	1.76E+10	0	0	1.41E+10	1.76E+09	1.76E+09
60	15.4	1.25E+10	0	0	9.97E+09	1.25E+09	1.25E+09
65	11.1	8.98E+09	0	0	7.18E+09	8.98E+08	8.98E+08
70	7.0	5.68E+09	0	0	4.54E+09	5.68E+08	5.68E+08
75	4.3	3.48E+09	0	0	2.78E+09	3.48E+08	3.48E+08
80	2.5	2.02E+09	0	0	1.61E+09	2.02E+08	2.02E+08
85	1.4	1.15E+09	0	0	9.23E+08	1.15E+08	1.15E+08
90	0.7	5.31E+08	0	0	4.25E+08	5.31E+07	5.31E+07
95	0.2	1.74E+08	0	0	1.39E+08	1.74E+07	1.74E+07
100	0.0	8.07E-11	0	0	6.46E-11	8.07E-12	8.07E-12

Table 5-9 TMDL Calculations for Turbidity in Lukfata Creek (OK410210070010_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	$WLA_{\_WWTF}$ (cfu/day)	$WLA_{\_MS4}$ (cfu/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	8104.4	N/A	0	0	N/A	N/A	N/A
5	315.9	N/A	0	0	N/A	N/A	N/A
10	163.3	N/A	0	0	N/A	N/A	N/A
15	106.8	N/A	0	0	N/A	N/A	N/A
20	77.7	N/A	0	0	N/A	N/A	N/A
25	59.8	2224	0	0	22	1868	334
30	47.9	1782	0	0	18	1497	267
35	38.0	1414	0	0	14	1187	212
40	30.7	1140	0	0	11	958	171
45	24.6	913	0	0	9	767	137
50	19.2	715	0	0	7	601	107
55	14.7	545	0	0	5.5	458	82
60	10.4	386	0	0	3.9	324	58
65	7.5	278	0	0	2.8	234	42
70	4.7	176	0	0	1.8	148	26
75	2.9	108	0	0	1.1	91	16
80	1.7	62	0	0	0.6	52	9
85	1.0	36	0	0	0.4	30	5
90	0.4	16	0	0	0.2	14	2.5
95	0.1	5	0	0	0.1	4.5	0.8
100	0.0	0	0	0	0.0	0.0	0.0

5.9 Strengths and Weaknesses

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 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/water-quality-division/watershed-planning/integrated-report/. **Table 5-10** 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 5-10 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	www.wildlifedepartment.com/wildlifemgmt/endangeredspecies.htm
Oklahoma Department of Agriculture, Food, and Forestry	https://ag.ok.gov/divisions/agricultural-environmental-management/
Oklahoma Water Resources Board	https://www.owrb.ok.gov/quality/monitoring/monitoring.php

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 77.1% for bacteria and 41.4% 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 pathogen or TSS-impaired waters. Similar reduction rates are often found in other pathogen 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.

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

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

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

- **Revise the existing numeric criteria**: Oklahoma's current pathogen criteria, revised in 2011, are based on EPA guidelines (See the *2012 Draft Recreational Water Quality Criteria*, December 2011; Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft; and Ambient

Water Quality Criteria for Bacteria-1986, January 1986). However, those guidelines have received much criticism and EPA studies that could result in revisions to their recommendations are ongoing. The numeric criteria values should also be evaluated using a risk-based method such as that found in EPA guidance.

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

5.11 Reasonable Assurance

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.

Reasonable assurance of nonpoint sources will meet their allocated amount in the TMDL which dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. The OCC has responsibilities for the state's NPS program defined in Section 319 of 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: https://www.deq.ok.gov/water-quality-division/watershed-planning/tmdl/.

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 2011

Waterbody Name	OKWBID	WQM Station (s)	Date*	ENT[1]
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	5/16/2006	190
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	6/13/2006	125
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	7/25/2006	70
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	8/29/2006	270
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	7/13/2010	310
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	8/17/2010	125
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	9/21/2010	60
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	05/09/2011	190
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	05/24/2011	460
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	06/20/2011	70
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	08/02/2011	50
Waterhole Creek	OK410100010340_00	OK410100-01-0340D	08/30/2011	70
			# Samples	**12**
			Geometric Mean[2]	**129.5**
			Geometric Mean Criterion	**33**

Note: [1] ENT = Enterococci; units = counts/100 mL.
[2] Geometric Mean highlighted in Red means exceed WQS and TMDL is needed
* Samples outside the primary body contact recreation season were excluded

Appendix Table A-2 Turbidity and Total Suspended Solids Data (2005-2021)

Waterbody Name	Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition	Rainfall
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/14/2005	7.69	–	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/28/2005	7.35	–	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/1/2005	9.07	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/30/2005	4.51	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	10/4/2005	3.78	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	11/15/2005	2.07	11	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	12/21/2005	2.94	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	1/31/2006	14.5	11	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	3/7/2006	6.37	<10	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	4/11/2006	3.55	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/16/2006	7.56	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/13/2006	6.71	<10	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	7/25/2006	5.81	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/29/2006	6.78	<10	No flow	> 1 inch
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	9/26/2006	3.47	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	10/31/2006	7.04	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	12/5/2006	5.36	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	1/9/2007	5.23	<10	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	2/21/2007	4.81	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	3/27/2007	4.91	<10	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	4/17/2007	4.09	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/25/2010	11.6	–	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/8/2010	6.42	<10	Slightly elevated	

Waterbody Name	Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition	Rainfall
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	7/13/2010	15	13	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/17/2010	4.85	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	9/21/2010	5.73	<10	Trace	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	10/26/2010	4.49	<10	Trace	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	12/8/2010	5.59	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	1/19/2011	6.44	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	2/23/2011	11.5	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	4/5/2011	10.4	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/9/2011	12.6	–	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/24/2011	10.7	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/20/2011	3.91	<10	Low flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/2/2011	3.72	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/30/2011	5.16	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	10/11/2011	7.15	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	11/15/2011	14.9	<10	Base flow	> 1 inch
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	12/20/2011	30	21	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	1/24/2012	2.88	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	3/6/2012	4.29	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	4/3/2012	11	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/8/2012	9.79	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/15/2015	5.25	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	7/1/2015	7.86	–	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	7/20/2015	5.07	<10	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/24/2015	12.6	<10	No flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	9/28/2015	3.82	<10	No flow	

Waterbody Name	Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition	Rainfall
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	11/2/2015	12.4	<10	Slightly elevated	> 1 inch
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	12/7/2015	4.48	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	1/11/2016	6.62	<10	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	2/1/2016	6.79	–	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	2/16/2016	–	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	3/21/2016	5.54	<10	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	4/25/2016	14.7	<10	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/17/2016	5.49	–	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/31/2016	10.2	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	7/5/2016	5.31	<10	Low flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/8/2016	6.22	<10	Trace	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	9/6/2016	6.75	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	10/17/2016	5.17	<10	Trace	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	11/21/2016	13.9	<10	Trace	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	12/19/2016	3.62	<10	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	1/30/2017	7.97	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	3/13/2017	16.5	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	4/11/2017	100	110	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/15/2020	7.13	–	Slightly elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/11/2020	11.5	<10	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/25/2020	8.13	–	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	9/15/2020	6.78	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	10/20/2020	6.52	<10	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	11/30/2020	4.38	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	1/4/2021	12.5	<10	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	3/9/2021	–	<10	Elevated	

Waterbody Name	Waterbody ID	WQM Station	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition	Rainfall
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	3/23/2021	101	76	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	4/20/2021	5.2	<10	Elevated	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	5/25/2021	39.9	45	High flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	6/28/2021	13.6	10	Base flow	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	8/9/2021	7.22	<10	Trace	
Lukfata Creek	OK410210070010_00	OK410210-07-0010G	9/13/2021	6.43	<10	Trace	
Gates Creek	OK410300010020_00	OK410300-01-0020F	6/21/2005	18.7	20	Base flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	7/21/2005	10.1	–	Base flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	7/26/2005	7.46	<10	Base flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	8/30/2005	16.1	19	Base flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	10/4/2005	25.1	11	Slightly elevated	
Gates Creek	OK410300010020_00	OK410300-01-0020F	11/8/2005	10.8	<10	Base flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	2/28/2006	32.9	20	No flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	4/4/2006	17	<10	Slightly elevated	
Gates Creek	OK410300010020_00	OK410300-01-0020F	6/13/2006	21	15	Low flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	7/18/2006	11.6	11	Low flow	
Gates Creek	OK410300010020_00	OK410300-01-0020F	8/22/2006	66.8	30	Trace	
Gates Creek	OK410300010020_00	OK410300-01-0020F	9/26/2006	28.6	22	Slightly elevated	
Gates Creek	OK410300010020_00	OK410300-01-0020F	10/31/2006	9.87	10	Slightly elevated	
Gates Creek	OK410300010020_00	OK410300-01-0020F	4/17/2007	19.6	<10	Slightly elevated	

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. All gages within 150 km radius were identified. For each of the identified gage with a minimum of 99 flow measurements on matching dates, four different regressions were calculated including linear, log linear, logarithmic and exponential regressions. The regression with the lowest root mean square error (RMSE) was chosen for each gage. The potential filling gages were ranked by RMSE from lowest to highest. The record was filled from the first gage (lowest RMSE) for those dates that existed in both records. If dates remained unfilled in the desired timespan of the timeseries, the filling process was repeated with the next gage with the next lowest RMSE and proceeded in this fashion until all missing values in the desired timespan were filled.

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

1. Watershed delineations are performed 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. The watershed average curve number was calculated from soil properties and land cover as described in the U.S. Department of Agriculture (USDA) Publication *TR-55: Urban Hydrology for Small Watersheds*. The soil hydrologic group was extracted from NRCS soil data, and land use category from the National Land Cover Dataset (NLCD). Based on land use and the hydrologic soil group, SCS curve numbers were estimated at the 30-meter resolution of the NLCD grid as shown in **Appendix Table B-1**. The average curve number was then calculated from all the grid cells within the delineated watershed.

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

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

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

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

Furness Method

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

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

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

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

Wurbs Modified NRCS Method

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

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

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

Where:

Q = runoff depth (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

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

$$I_a = 0.2 * S \qquad \textbf{(2)}$$

Thus, the runoff curve number equation can be rewritten:

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

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

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

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

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

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

Where:

M = the mean annual precipitation of the watershed in inches.

The daily precipitation depth for the ungaged watershed, along with the average curve number of the ungaged watershed, was then used to calculate the depth equivalent daily flow (Q) of the ungaged site. Finally, the volumetric flow rate at the ungaged site was calculated by multiplying by the area of the watershed of the ungaged site and converted to cubic feet.

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

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

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

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

Generalized Flow Projection Methodology

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

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

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

C. In the rare case where no coincident flow data was available for a WQM station and no gage was 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.

References

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

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

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

Appendix Table B-2 Estimated Flow Exceedance Percentiles

Stream Name	Waterhole Creek	Lukfata Creek
WBID Segment	OK410100010340_00	OK410210070010_00
USGS Gage Reference	7337900	7337900
USGS Gage Drainage Area (mi^2)	320	320
Drainage Area (mi^2)	72.6	48.8
Percentile	**Q (cfs)**	**Q (cfs)**
0	12050.4	8104.4
1	1534.1	1031.7
2	991.7	667.0
3	729.5	490.6
4	576.3	387.6
5	469.8	315.9
6	401.7	270.1
7	347.2	233.5
8	304.1	204.5
9	267.8	180.1
10	242.8	163.3
11	219.7	147.7
12	200.8	135.1
13	184.4	124.0
14	171.6	115.4
15	158.9	106.8
16	147.9	99.5
17	138.2	92.9
18	130.5	87.8
19	122.5	82.4

Stream Name	Waterhole Creek	Lukfata Creek
WBID Segment	**OK410100010340_00**	**OK410210070010_00**
USGS Gage Reference	**7337900**	**7337900**
USGS Gage Drainage Area (mi^2)	**320**	**320**
Drainage Area (mi^2)	**72.6**	**48.8**
Percentile	**Q (cfs)**	**Q (cfs)**
20	115.5	77.7
21	109.6	73.7
22	103.7	69.7
23	98.5	66.2
24	93.9	63.2
25	89.0	59.8
26	85.3	57.4
27	81.5	54.8
28	78.3	52.7
29	74.4	50.1
30	71.3	47.9
31	68.1	45.8
32	65.1	43.8
33	62.2	41.8
34	59.2	39.8
35	56.5	38.0
36	54.2	36.5
37	52.0	35.0
38	49.9	33.6
39	47.7	32.1
40	45.6	30.7
41	43.6	29.3
42	41.9	28.2
43	40.2	27.0
44	38.4	25.8
45	36.5	24.6
46	34.7	23.4
47	33.4	22.4
48	31.8	21.4
49	30.2	20.3
50	28.6	19.2
51	27.2	18.3
52	25.9	17.4
53	24.5	16.5

Stream Name	Waterhole Creek	Lukfata Creek
WBID Segment	**OK410100010340_00**	**OK410210070010_00**
USGS Gage Reference	**7337900**	**7337900**
USGS Gage Drainage Area (mi^2)	**320**	**320**
Drainage Area (mi^2)	**72.6**	**48.8**
Percentile	**Q (cfs)**	**Q (cfs)**
54	23.1	15.6
55	21.8	14.7
56	20.4	13.8
57	19.1	12.8
58	17.8	12.0
59	16.6	11.1
60	15.4	10.4
61	14.5	9.8
62	13.6	9.2
63	12.7	8.5
64	11.8	7.9
65	11.1	7.5
66	10.2	6.9
67	9.3	6.3
68	8.4	5.7
69	7.7	5.2
70	7.0	4.7
71	6.4	4.3
72	5.8	3.9
73	5.2	3.5
74	4.8	3.2
75	4.3	2.9
76	3.9	2.6
77	3.4	2.3
78	3.0	2.0
79	2.7	1.8
80	2.5	1.7
81	2.2	1.5
82	2.0	1.3
83	1.8	1.2

Stream Name	Waterhole Creek	Lukfata Creek
WBID Segment	**OK410100010340_00**	**OK410210070010_00**
USGS Gage Reference	**7337900**	**7337900**
USGS Gage Drainage Area (mi^2)	**320**	**320**
Drainage Area (mi^2)	**72.6**	**48.8**
Percentile	**Q (cfs)**	**Q (cfs)**
84	1.6	1.1
85	1.4	1.0
86	1.3	0.9
87	1.1	0.7
88	0.9	0.6
89	0.8	0.5
90	0.7	0.4
91	0.5	0.4
92	0.5	0.3
93	0.4	0.2
94	0.3	0.2
95	0.2	0.1
96	0.1	0.1
97	0.1	0.0
98	0.0	0.0
99	0.0	0.0
100	0.0	0.0

Appendix C: State of Oklahoma Antidegradation Policy

Appendix C

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 Sensitive Public and Private Water Supplies (SWS) and SWS-R. It is recognized that certain public and private water supplies possess conditions that make them more susceptible to pollution events and require additional protection. These sensitive water supplies shall be maintained and protected.

(d) Application to beneficial uses. Except as provided by 27 O.S. § 1-3-101(B), and subject to the provisions of 85 O.S. § 1085.30, no water quality degradation which will interfere with the attainment or maintenance of an existing or designated beneficial use shall be allowed.

(e) 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, 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.

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 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 "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 area, 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 D: Censored Data Estimation for the Waterhole Creek and Lukfata Creek Study Area

1. Background

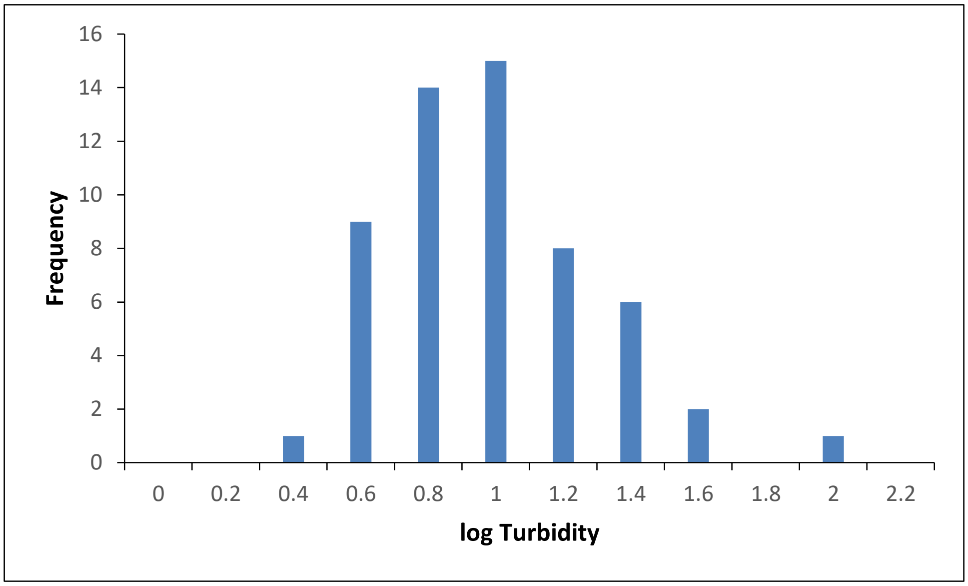
Sample size is an important feature of any empirical study. In this Study, the total number of TSS data is 44. The sample size (more than 25) is adequate for producing statistical estimates, but the censored data percentage is high (95.5%). An MLE or K regression is not recommended for waterbodies with a large percentage of censored data; therefore, the turbidity and TSS data for Lukfata Creek are combined with data from Gates Creek (OK410300010020_00). The impaired beneficial use of Gates Creek is CWAC, and its Turbidity TMDL ID (59174) was completed in 2014. The combination is under assumption of similar distribution and uniform characteristics. It is assumed as log-normal distribution with equivalent mean (μ) and standard deviation (σ). This assumption can hold because sampling locations are geologically close and sampling areas are located in same geological province as the Ouachita Mountain Uplift. Gates Creek is also part of the South Central Plains Level III ecoregion.

Appendix Table D-1 Censored TSS Data in Base Flow for CWAC Waterbodies

WBID	Waterbody name	Total number of TSS data	Number of censored data	% of censored data
OK410210070010_00	Lukfata Creek	44	42	95.5%
OK410300010020_00	Gates Creek	13	4	30.8%

Among combined data for TSS, about 80.4% of TSS data are censored-data, recorded as 10 mg/L of detection limits (dl). Methods for estimating these non-detects (censored data) can be divided into the three classes: simple substitution, distributional, and robust methods.

Figure Appendix D-1 Histogram of Turbidity Data

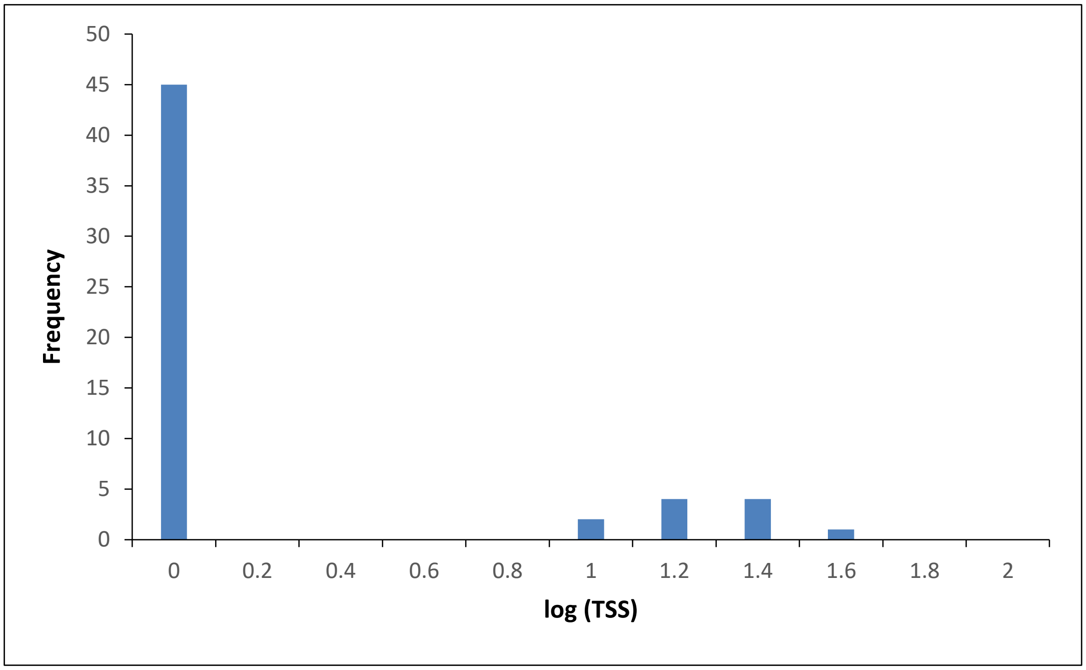


2. Simple Substitution Methods

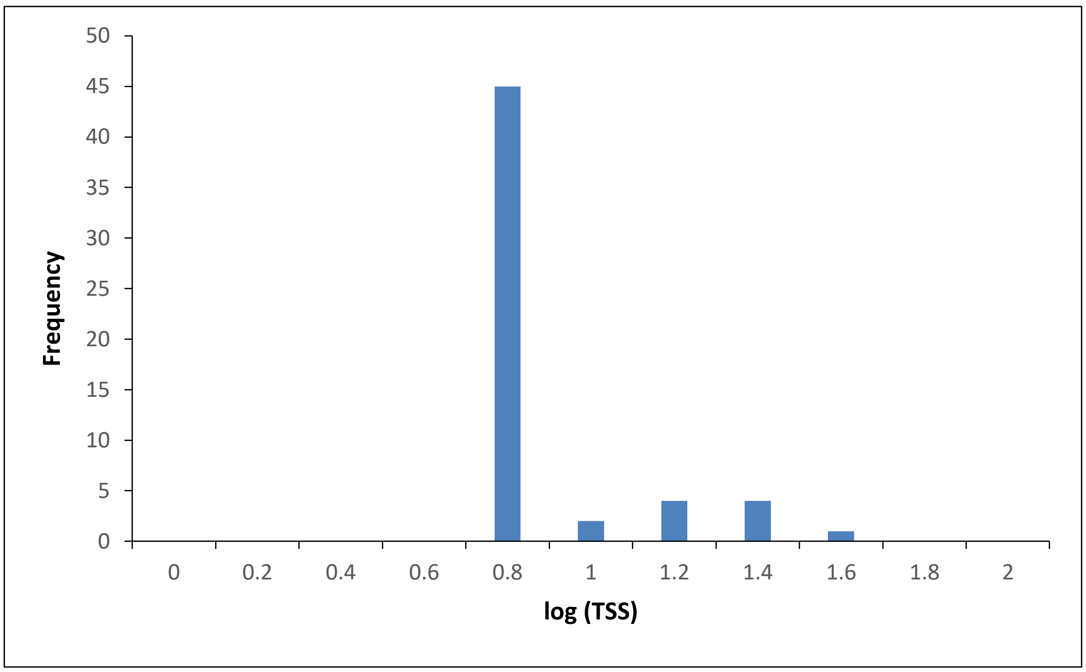
Simple substitution methods substitute a single value such as one-half the reporting limit for each less-than values (censored data). Summary statistics are calculated and shown in **Appendix Table D-1** and **Appendix Figure D-1**.

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.

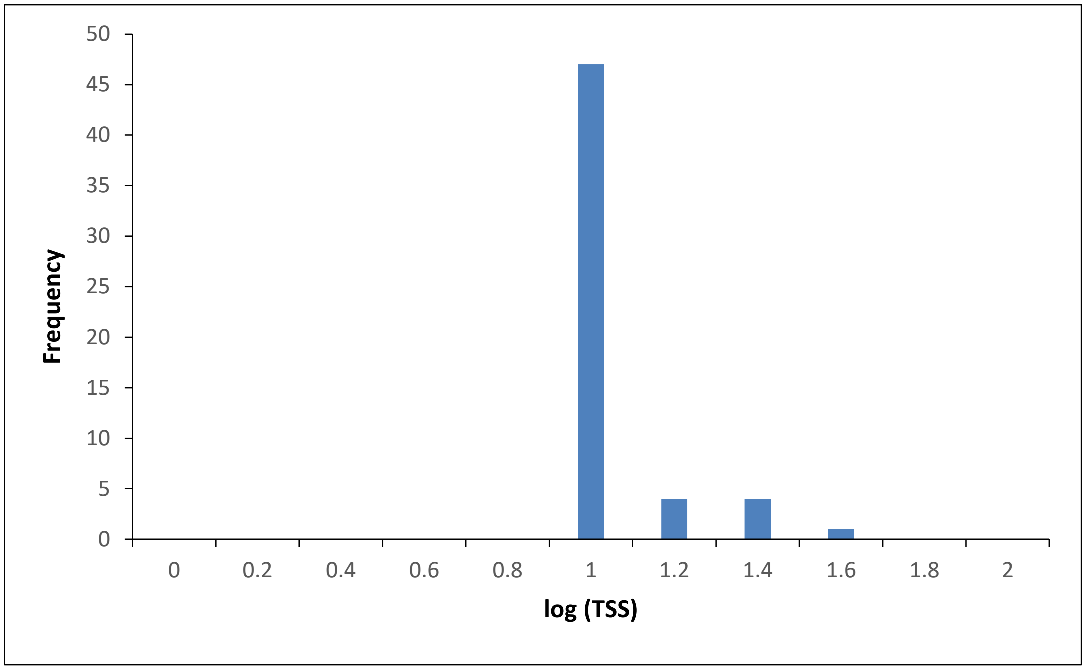
Figure Appendix D-2 Histograms for Simple Substitution Methods



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



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



(c) 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 D-2**). Cohen's procedure is followed below:

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

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

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

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

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

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

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

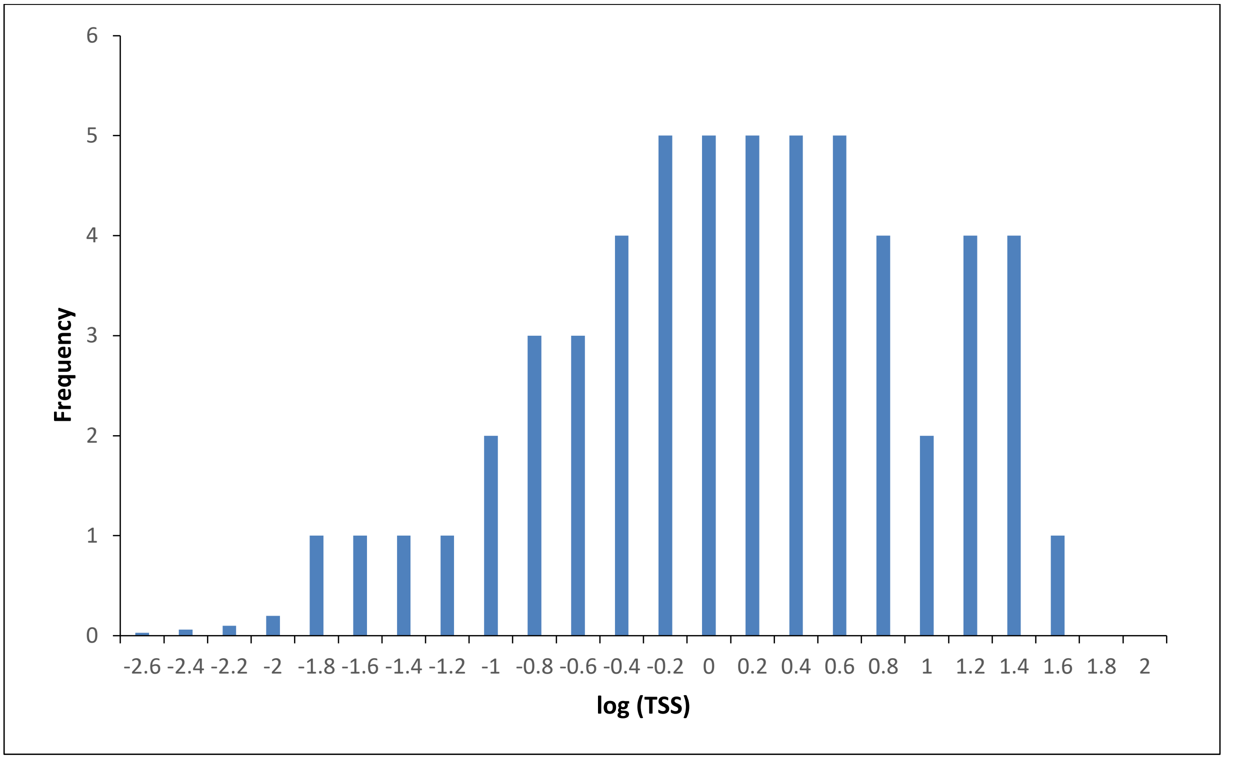
$$\hat{\sigma}^2 = \hat{\mu}^2\left[exp\left(\hat{\sigma}_y{}^2\right) - 1\right]$$

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), $\hat{\lambda}$ = 2.7 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.

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



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

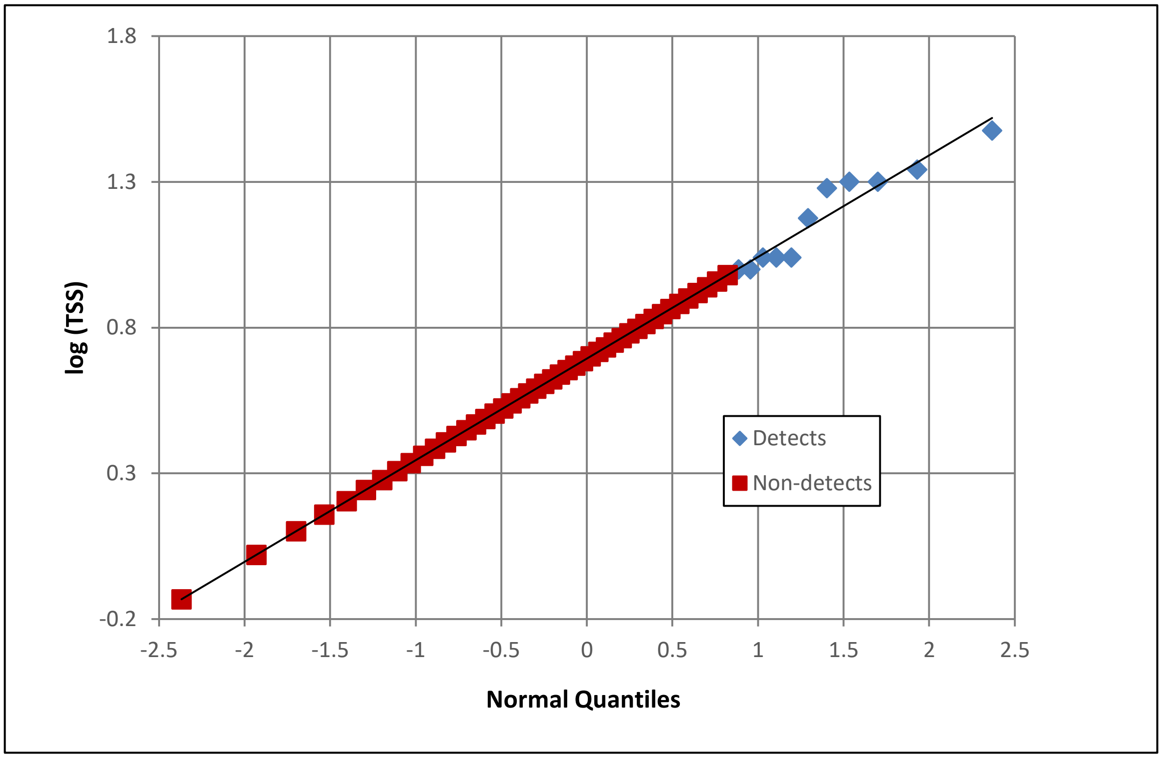
```
read.csv("d:/CWAC.csv", header=T)
data=read.csv("d:/CWAC.csv", header=T)
data_mle=with(data,cenmle(TSS,TSSCen), dis='lognormal')
data_mle
```

4. Robust Methods

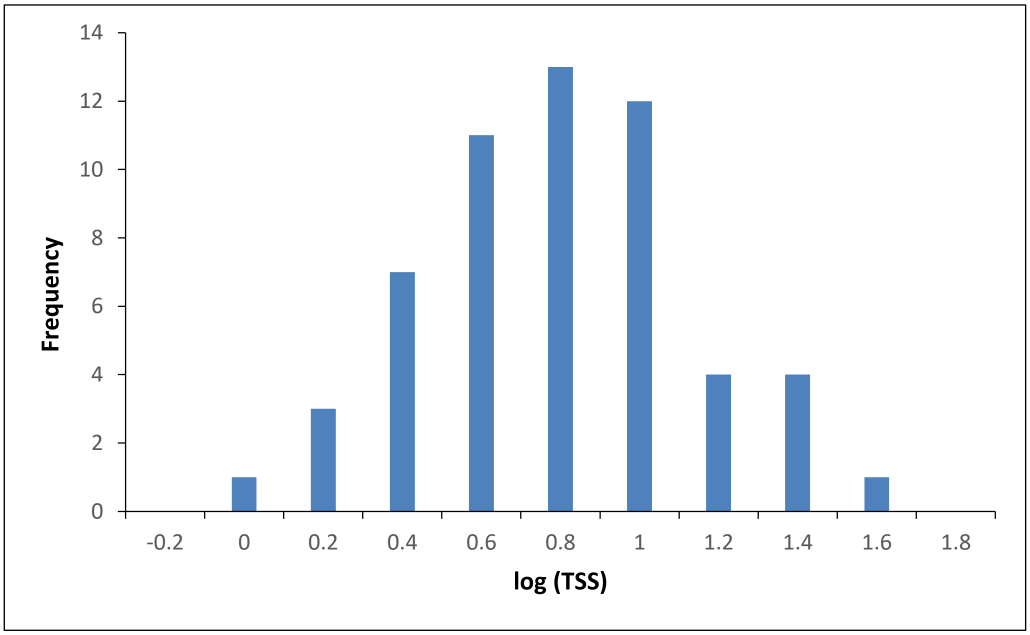
Robust methods combine observed data above the reporting limit with below-limit values extrapolated assuming a distributional shape, in order to compute estimates of summary statistics. A distribution is fit to the data above the reporting limit by either MLE or probability plot procedures, but the fitted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

Figure Appendix D-4 Robust Method of Estimating Summary Statistics



(a) Normal Quantiles



(b) Histogram for Robust Regression on Order Statistics (ROS)

5. Results

Robust ROS and MLE have shown to perform better than simple substitution methods for estimating the median and IQR of TSS in this Study when comparing to the turbidity distribution. In addition to this, estimations can be compared for their 75th percentile. For Robust ROS, upper one-sided 95% confidence limit (8.3 mg/L) of the mean is less than 75th percentile of the estimations whereas that (6.3 mg/L) of the mean for MLE is equal to the 75th percentile. This tells that Robust ROS will estimate 95% of estimated mean intervals will not contain 75th percentile and mean estimation is slightly more centered at sample mean than that of MLE.

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 in **Table Appendix D-2** 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 E**. 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 D-2 Summary Statistics

Category	Censored data estimation		Mean	Standard deviation	25th percentile	Median	75th percentile	IQR	95% Confidence Limit
Turbidity	All detects		9.9	10.1	4.8	6.5	11.0	6.2	n/a
TSS	dl subbed		11.2	3.7	10.0	10.0	10.0	0	n/a
	dl/2 subbed		7.2	5.3	5.0	5.0	5.0	0	n/a
	One		4.0	6.7	1.0	1.0	1.0	0	n/a
	MLE	Cohen's	7.0	6.2	n/a	n/a	n/a	n/a	n/a
		EXCEL	4.6	6.7	0.4	1.6	6.3	n/a	6.3
		R	7.0	6.2	n/a	5.2	n/a	n/a	n/a
	Robust ROS	EXCEL	6.7	5.9	2.9	4.9	8.4	n/a	8.3
		R	6.1	6.1	n/a	4.0	n/a	n/a	n/a

n/a = not available

References

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

Appendix E: Censored Data Regression for the Waterhole Creek and Lukfata Creek Study Area

Censored Data Regression for the Waterhole Creek and Lukfata Creek Study Area

1. Background

With censored data the use of ordinary least squares (OLS) for regression is prohibited (See **Appendix Table D-1**; Helsel and Hirsch, 2002). Coefficients for slopes and intercept 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 E-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[1] code shown:

```
read.csv("c:/temp/lukfatagates.csv", header=T)
data=read.csv("c:/temp/lukfatagates.csv", header=T)
with(data,cenxyplot(x=Turbidity,xcen=0,y=TSS,ycen=TSSCen,log="",
main="Lukfata Creek",
xlab="log (Turbidity)",
ylab="log (TSS)",
)
)
mle.reg=cenreg(Cen(obs=data$TSS,censored=data$TSSCen)~data$Turbidity,dist="gaussian")
data.Kendall=cenken(y=data$TSS, ycen=data$TSSCen,x=data$Turbidity,xcen=data$TurCen)
abline(mle.reg,lty=4,lwd=2)
lines(data.Kendall,lwd=2)
legend(x="left",legend=c("Kendall","MLE"),lty=c(1,4),lwd=2)
```

4. Results

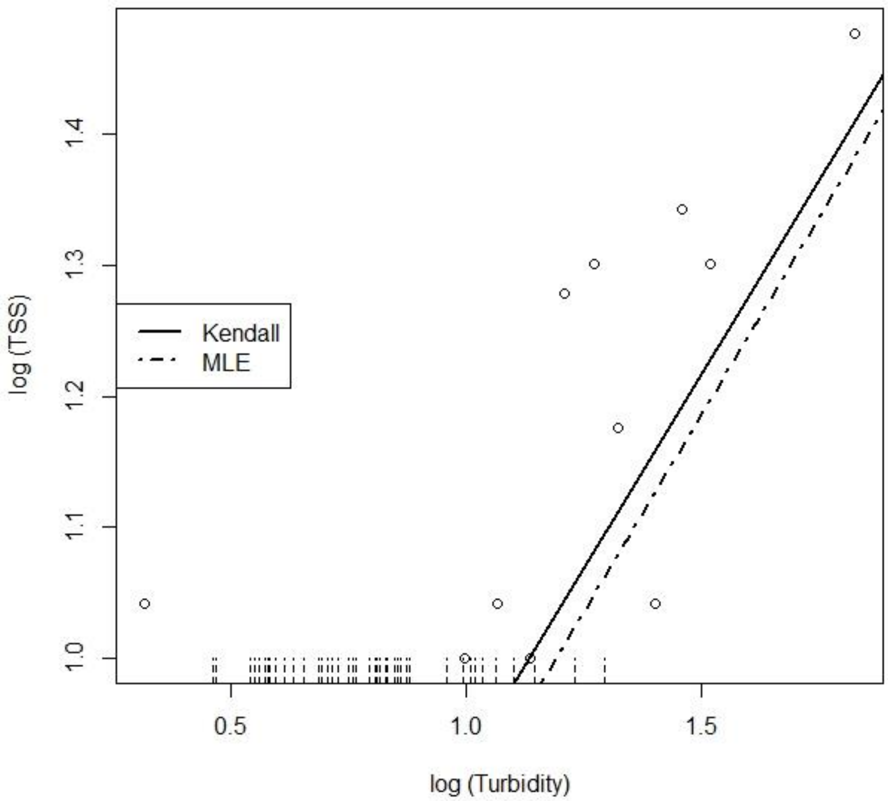
Appendix Table E-1 Regression Statistics with Censored Data

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
OK4102100070010_00	**Lukfata Creek**	7.64	0.603	0.28	0.61 (**0.38**)	2.7E-07	8.32	0.59	0.33	0.26	1.6E-05
OK410210020300_00[a]	**Cloudy Creek**	6.93	1.09	-0.25	0.86 (**0.74**)	7.3E-07	7.04	1.08	-0.23	0.30	0.0014

[a] Data is from the TMDL report for Cloudy Creek (OK410210020300_00, TMDL ID 59169).

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

Figure Appendix E-1 Trend lines estimated for Lukfata Creek and Gates Creek combined data using 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, the tau value of Non-parametric method is 0.26 (**Appendix Table E-1**), which is close to 0 and indicates a poor correlation. The MLE method using the combined data from Lukfata Creek and Gates Creek did not produce an acceptable R-square value (0.38). Therefore, the regression for Cloudy Creek (OK410210020300_00, TMDL ID 59169) was used in this study to calculate the TMDL and percent reduction goal. Cloudy Creek is also geographically close to Lukfata Creek and located in the Ouachita Mountain Uplift and Ouachita Mountains Level III ecoregion.

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 F: Direct Calculation of Percent Reduction Goals from Turbidity Data

Direct Calculation of Percent Reduction Goals from Turbidity Data

1. Background

Regression of censoring greater than 50% is not truly appropriate. However, there is no alternative to find relationship between TSS and turbidity for this study.

Percent reduction goals (PRGs) were computed directly from turbidity data and compared with regression method. PRG agreement between methods can be used as verification of regression method. For this purpose, 10% explicit MOS was applied in direct calculation to meet no more than 10% of the samples exceed the standards. Then, these PRGs were compared with PRGs from regression in this study.

2. Regression Methods

Censored data MLE regression was applied to all turbidity impaired waterbodies in this study. Regression methods were explained in Section 4 and results from this method were summarized in **Table Appendix F-1**. The MOS for MLE regression was 15% and was calculated based on NRMSE.

3. Results

PRG difference between MLE method and direct calculation was less than 15%. PRG from MLE method was greater than the direct calculation. PRGs were not underestimated in the regression method. Therefore, MLE method was more conservative than direct calculation. Even though MLE method was not appropriate for this data set, it did not underestimate the pollutant.

Table Appendix F-1: Percent Reduction Goal

WBID	Waterbody name	MLE Method			Direct Calculation		
		TSS target (mg/L)	MOS (%)	PRG (%)	Turbidity target (NTU)	MOS (%)	PRG (%)
OK4102100070010_00	**Lukfata Creek**	6.9	15	41.4	10	10	33.9