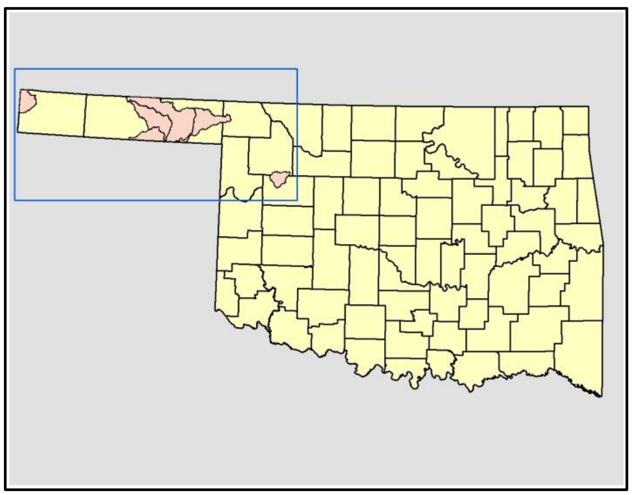
FINAL

2014 MINERAL
TOTAL MAXIMUM DAILY LOADS FOR OKLAHOMA STREAMS IN THE BEAVER RIVER WATERSHED
(OK720500, OK720900)

Oklahoma Waterbody Identification Numbers

Bent Creek	OK720500010070_00
Beaver River	OK720500020140_00
Beaver River	OK720500020290_00
Beaver River	OK720500020450_00
Palo Duro Creek	OK720500020500_00
Cimarron River	OK720900000180_00



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DEQ

OKLAHOMA

DEPARTMENT OF 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
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
CPP	Continuing Planning Process
CWA	Clean Water Act
CWAC	Cool water aquatic community
DEQ	Oklahoma Department of Environmental Quality
DMR	Discharge monitoring report
E. coli	*Escherichia coli*
ENT	Enterococci
EPA	U.S. Environmental Protection Agency
HUC	Hydrologic unit code
IQR	Interquartile range
LA	Load allocation
LDC	Load duration curve
LOC	Line of organic correlation
mg	Million gallons
mgd	Million gallons per day
mg/L	Milligram per liter
mL	Milliliter
MOS	Margin of safety
MS4	Municipal separate storm sewer system

MSGP	Multi-Sector General Permit
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NRCS	Natural Resources Conservation Service
NRMSE	Normalized root mean square error
NTU	Nephelometric turbidity unit
OAC	Oklahoma Administrative Code
OLS	Ordinary least square
O.S.	Oklahoma statute
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
OKWBID	Oklahoma Waterbody Identification Number
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWQS	Oklahoma Water Quality Standards
OWRB	Oklahoma Water Resources Board
PBCR	Primary Body Contact Recreation
PRG	Percent reduction goal
r^2	Correlation coefficient
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow
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 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, was 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 minerals [chlorides, sulfates, and total dissolved solids (TDS)] for selected waterbodies in the Beaver River watershed 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.

Data assessment and TMDL calculations were 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. Then the draft TMDL goes to EPA for review before submitting it 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 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 report was to establish load allocations for minerals (chlorides, sulfates, TDS) 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 established 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 the OPDES. An LA is the fraction of the total pollutant load apportioned to nonpoint sources. The 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 the dissolved mineral concentrations within each watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process.

ES - 2 PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

This TMDL report focused on waterbodies, identified in **Table ES-1** that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2012 Integrated Report* for non-support of the agriculture water supply beneficial use. Elevated levels of chloride, sulfates, and TDS above the WQS numeric criteria resulted in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the agriculture water supply use designated for each waterbody.

In the 2012 §303(d) List, three of the waterbodies within the Study Area were listed as a result of elevated levels of chlorides, five of the waterbodies were listed as a result of elevated levels of sulfate, and three of the waterbodies were listed as a result of elevated levels of TDS.

Table ES-2 summarizes water quality data collected from the water quality monitoring (WQM) stations between 1999 and 2012. The data summary in **Table ES-2** provides an understanding of the amount of water quality data available and an evaluation of the exceedances of the water quality criteria. This data was used to determine if a TMDL was necessary for the specific waterbody/pollutant combinations that were originally identified on the DEQ 2012 §303(d) list (DEQ 2013). Within the Study Area, a total of 11 TMDLs were required: 4 of the waterbodies had elevated levels of chloride, 4 of the waterbodies had elevated levels of sulfates, and 3 of the waterbodies had elevated levels of TDS for which TMDLs were required. Based on the data assessment completed for each of the waterbody/pollutant combinations listed in **Table 2-3**, there was one new pollutant candidate requiring TMDL, and one pollutant as a candidate for delisting from the 303(d) List.

ES-2.1 Chapter 45: Criteria for Minerals

The definition of agriculture is summarized by the following excerpt from Chapter 45 (785:45-5-13) of the Oklahoma WQS.

785:45-5-13. Agriculture

(a) ***General.*** *The surface waters of the State shall be maintained so that toxicity does not inhibit continued ingestion by livestock or irrigation of crops.*

(b) ***Definitions.*** *The following words and terms, when used in this Section, shall have the following meaning unless the context clearly indicates otherwise:*

(1) "Long term average concentration" means the arithmetic mean of at least ten samples taken across at least twelve months.

(2) "Short term average concentration" means the arithmetic mean of all samples taken during any 30-day period.

(c) ***Subcategories of the Agriculture beneficial use.***

(1) The narrative and numerical criteria stated or referenced in this section and in Appendix F of this chapter are designed to maintain and protect the beneficial use classification of "Agriculture". This classification encompasses two subcategories which are capable of sustaining different agricultural applications. These subcategories are Irrigation Agriculture and Livestock Agriculture.

(2) Irrigation Agriculture means a subcategory of the Agriculture beneficial use requiring water quality conditions that are dictated by individual crop tolerances.

(3) Livestock Agriculture is a subcategory of the Agriculture beneficial use requiring much less stringent protection than crop irrigation.

(4) If a waterbody is designated in Appendix A of this Chapter with the Agriculture beneficial use but does not have a designation of a subcategory thereof, the criteria for Irrigation Agriculture shall be applicable.

(d) ***Highly saline water****. Highly saline water should be used with best management practices as outlined in "Diagnosis and Reclamation of Saline Soils," United States Department of Agriculture Handbook No. 60 (1958).*

(e) ***General criteria for the protection of Irrigation Agriculture.*** *This subsection prescribes general criteria to protect the Irrigation Agriculture subcategory. For chlorides, sulfates, and total dissolved solids at 180°C (see Standard Methods), the arithmetic mean of the concentration of the samples taken for a year in a particular segment shall not exceed the historical "yearly mean standard" determined from the table in Appendix F of this Chapter. For permitting purposes, the long term average concentration shall not exceed the yearly mean standard. Yearly mean standards shall be implemented by the permitting authority using the greater of 1.47 cfs or long term average flows and complete mixing of effluent and receiving water. For permitting purposes, the short term average concentration shall not exceed the sample standard. Sample standards shall be implemented by the permitting authority using the greater of 1.0 cfs or short term average flows and complete mixing of effluent and receiving water. The data from sampling stations in each segment are averaged, and the mean chloride, sulfate, and total dissolved solids at 180°C are presented in Appendix F of this Chapter. Segment averages shall be used unless more appropriate data are available.*

(f) ***Historic concentrations.*** *The table in Appendix F of this Chapter contains statistical values from historical water quality data of mineral constituents. In cases where mineral content varies within a segment, the most pertinent data available should be used.*

(g) ***Criteria to protect Irrigation Agriculture subcategory.*** *For the purpose of protecting the Irrigation Agriculture subcategory, neither long term average concentrations nor short term average concentrations of minerals shall be required to be less than 700 mg/L for TDS, nor less than 250 mg/L for either chlorides or sulfates.*

ES-2.2 Chapter 46: Implementation of OWQS for Agriculture Support

To implement Oklahoma's WQS for agriculture use, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2013). The excerpt below from Chapter 46: 785:46-15-8, stipulates how water quality data was assessed to determine support of the agriculture use as well as how the water quality target for TMDLs was defined for each mineral.

As stipulated in the WQS, both the arithmetic mean of all samples collected and the percentage of samples exceeding the single sample standard were used to assess the impairment status of the agriculture use for a waterbody. Therefore, both the arithmetic mean and the single sample criterion for each waterbody were used to develop TMDLs for each of the minerals - chlorides, sulfates, and TDS.

785:46-15-8. Assessment of Agriculture support

(a) ***Scope.*** *The provisions of this Section shall be used to determine whether the beneficial use of Agriculture designated in OAC 785:45 for a waterbody is supported.*

(b) ***General support tests for chlorides, sulfates, and TDS.***

(1) The Agriculture beneficial use designated for a waterbody shall be deemed to be fully supported with respect to chloride if the mean of all chloride sample concentrations from that waterbody do not exceed the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45 and no more than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45.

(2) The Agriculture beneficial use designated for a waterbody shall be deemed to be not supported with respect to chloride if the mean of all chloride sample concentrations from that waterbody exceeds the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45, or greater than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45. Provided, if the chloride sample concentrations are each less than 250 mg/L, then the Agriculture beneficial use shall be deemed to be fully supported with respect to chloride.

(3) The Agriculture beneficial use designated for a waterbody shall be deemed to be fully supported with respect to sulfate if the mean of all sulfate sample concentrations from that waterbody do not exceed the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45 and no more than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45.

(4) The Agriculture beneficial use designated for a waterbody shall be deemed to be not supported with respect to sulfate if the mean of all sulfate sample concentrations from that waterbody exceeds the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45, or greater than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45. Provided, if the sulfate sample concentrations are each less than 250 mg/L, then the Agriculture beneficial use shall be deemed to be fully supported with respect to sulfate.

(5) The Agriculture beneficial use designated for a waterbody shall be deemed to be fully supported with respect to TDS if the mean of all TDS sample concentrations from that waterbody do not exceed the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45 and no more than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45.

(6) The Agriculture beneficial use designated for a waterbody shall be deemed to be not supported with respect to TDS if the mean of all TDS sample concentrations from that waterbody exceeds the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45, or greater than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45. Provided, if the TDS sample concentrations are each less than 700 mg/L, then the Agriculture beneficial use shall be deemed to be fully supported with respect to TDS.

785:46-15-3. Data Requirements

(d) Minimum number of samples.

(1) Streams. Except when (f) of this Section or any of subsections (e), (h), (i), (j), (k), (l), or (m) of 785:46-15-5 applies, a minimum of 10 samples shall be required to assess beneficial use support due to field parameters including but not limited to DO, pH and temperature, and due to routine water quality constituents including but not limited to coliform bacteria, dissolved solids, and salts. Analyses may be aggregated to meet the 10 samples minimum requirements in non-wadable stream reaches that are 25 miles or less in length, and in wadable stream reaches that are 10 miles or less in length, if water quality conditions are similar at all sites. Provided, a minimum of 10 samples shall not be necessary if the existing samples already assure exceedance of the applicable percentage of a prescribed screening level.

Table ES-2 shows mineral TMDLs that were developed in this report.

Table ES - 1 Excerpt from the 2012 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	HUC 8	Stream Miles	TMDL Date	Priority	Chloride	Sulfates	TDS	Agriculture Designated Use
OK720500010070_00	**Bent Creek**	11100301	18.1	2023	4		X		N
OK720500020140_00	**Beaver River**	11100201	39	2023	4	X			N
OK720500020290_00	**Beaver River**	11100201 & 11100102	31.4	2023	4	X	X	X	N
OK720500020450_00	**Beaver River**	11100102	28.2	2023	4	X	X	X	N
OK720500020500_00	**Palo Duro Creek**	11100102 & 11100104	15.8	2023	4		X	X	N
OK720900000180_00	**Cimarron River**	11040001 & 11040002	19.24	2017	2		X		N
						X = Criterion exceeded			N = Not attaining

Table ES - 2 Summary of Mineral Samples, 1999-2012

WBID	Waterbody Name	Indicator	Data Period of Record	Number of Samples	Yearly Mean Std	Arithmetic Mean Concentration (mg/L)	Single Sample Std	Number of Samples Exceeding Single Sample Criterion	% Samples Exceeding Single Sample Criterion (NS>10%)	AG Use:	Notes Highlight = TMDL required
OK720500010070_00	Bent Creek	Chlorides	6/4/07 – 12/17/12	26	735	42.0	945	0	0	FS	
		Sulfates	6/4/07 – 12/17/12	26	723	1,090	977	17	65.4	NS	TMDL required
		TDS	6/4/07 – 12/17/12	26	2,442	1,914	3,010	0	0	FS	
OK720500020140_00	Beaver River at US 64, Rosston	Chlorides	5/24/05 – 9/11/07	19	735	1,015	945	7	36.8	NS	TMDL required
		Sulfates	5/24/06 – 9/11/07	19	723	378	977	0	0	FS	
		TDS	7/10/07 – 9/11/07	3	2,442	2,140	3,010	0	0	FS	
OK720500020290_00	Beaver River at US 270, Beaver	Chlorides	5/30/06 – 6/7/12	38	1,455	3,237	1,893	36	94.7	NS	TMDL required
		Sulfates	5/30/06 – 6/7/12	38	890	1,127	1,192	17	44.7	NS	TMDL required
		TDS	7/10/07 – 5/15/12	29	3,847	7,047	4,938	29	100	NS	TMDL required
OK720500020450_00	Beaver River at US 83, near Boyd	Chlorides	5/31/06 – 5/6/08	17	735	2,991	945	17	100	NS	TMDL required
		Sulfates	5/31/06 – 5/6/08	17	723	814	977	3	17.6	NS	TMDL required
		TDS	7/10/07 – 5/6/08	8	2,442	6,020	3,010	8	100	NS	TMDL required
OK720500020500_00	Palo Duro Creek	Chlorides[1]	9/14/99 -7/11/00	10	735	1,328	945	6	60.0	NS	TMDL required
		Sulfates	9/14/99 -7/11/00	10	723	1,654	977	5	50.0	NS	TMDL required
		TDS	9/14/99 -7/11/00	10	2,442	4,894	3,010	7	70.0	NS	TMDL required
OK720900000180_00	Cimarron River	Chlorides	6/4/07 – 4/6/2009	17		80.5					
		Sulfates	6/4/07 – 4/6/2009	17		921					Delist: listed in error
		TDS	6/4/07 – 4/6/2009	17		1,671					

Agricultural Use: FS = Fully Supporting NS = Not Supporting [1] = Pollutant not identified on the 2012 303(d) list

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. Minerals (chlorides, sulfates, and TDS) may originate from point sources such as industrial and municipal continuous dischargers, mines, or CAFOs. Point sources discharge treated wastewater and are permitted through the OPDES program. There are no active permitted municipal or industrial point source facilities within the Study Area.

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 currently contribute or have historically contributed minerals to surface water as a result of rainfall runoff or to groundwater that later flows into surface water. Sources of minerals can originate upstream at great distances or nearby the surface-water sampling sites (Mashburn and Sughru 2003). Minerals may originate from natural background loads from soils, local geological formations (e.g. carbonate deposits, salt deposits, sandstone and gypsum), and groundwater (e.g. mineral springs). Possible anthropogenic (man-made) sources of minerals in urban and agricultural runoff include agricultural irrigation, road salting from deicing of roadways, land application of produced water and drilling muds from oilfield operations, and abandoned or improperly capped oil and gas wells.

Unfortunately, lax rules before 1980 allowed produced water to be held in unlined or poorly lined open pits prior to re-injection into the subsurface. Even earlier it was common to have evaporation in brine disposal pits (which seemingly made the high volumes of saline water go away) and discharged to streams. These practices have not been allowed for more than 30 years. A sodium/chloride (Na/Cl) ratio below 0.6 can be indicative of a produced water/oilfield brine source (Morton, 1986).

The potential nonpoint sources of minerals considered in this report were:

- Background loads from local geological formations - Background concentrations of sulfate originate from drainage of geological formations and their high gypsum content.
- Agricultural irrigation
- Salts from roadway deicing
- Groundwater flow which could contribute minerals to receiving streams even under low flow conditions.
- Commercial soil farming sites - Land application activities such as commercial soil farming or one-time land application sites could result in the buildup of mineral concentrations on the land surface which could be transported to receiving waters under some rainfall runoff conditions.
- Underground injection well activities
- Abandoned or improperly capped oil and gas wells
- Historic oil and gas well related spill sites and drilling mud pits

- Historic oilfield produced water/brine “evaporation pits” and holding pits
- Damaged and poorly maintained well casing and lines for underground injection wells

For the TMDLs in this report, all sources of pollutant loading not regulated by OPDES permits were considered nonpoint sources. No critical conditions were identified for mineral TMDLs and therefore, mean annual conditions will need to be used to guide implementation. Despite limited data, the following general deductions can be made regarding sources of minerals that can affect surface water quality in the impaired watersheds of the Study Area:

- Permitted facilities (WWTF, CAFOs) in the impaired watersheds contribute insignificant pollutant loading of chlorides, sulfates, and TDS.
- During high flow conditions, in-stream concentrations of minerals are lower because stormwater runoff provides dilution.
- The persistent availability of minerals may be attributed to historical oil and gas field development, underground injection well activities, natural geology, and high concentrations in groundwater, despite various remediation efforts within the Study Area.
- Given the limited number of roadways and developed land within the impaired watersheds of the Study Area, roadway salts and urban runoff contribute insignificant pollutant loading of chlorides, sulfates, and TDS.
- The majority of mineral loadings in the Study Area originate from a variety of nonpoint sources, both background and anthropogenic sources.

ES - 4 USING LOAD DURATION CURVES TO DEVELOP TMDLS

The TMDL calculations presented in this report were derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs. As a TMDL development tool, LDCs can help identify 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 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 three following steps:

1. Prepare flow duration curves for gaged and ungaged WQM stations.
2. Estimate existing loading in the waterbody using measured water quality data.
3. Use LDCs to identify if there is a critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

Use of LDCs obviated 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 was 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.

The following are the basic steps in developing an LDC:

1. Obtain daily flow data for the site of interest from the U.S. Geological Survey (USGS), or if unavailable, projected from a nearby USGS site.
2. Sort the flow data and calculate flow exceedance percentiles.
3. Obtain the water quality data
4. Display a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS numeric criterion for each parameter
5. Match the water quality observations with the flow data from the same date
6. Determine the corresponding exceedance percentile.

ES-4.1 Mineral LDC

The culmination of above steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

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

Where:

WQS *is single sample criteria as indicated in* **Table 2-5.** *Values vary from* ***945 to 1,893*** *mg/L for* ***chloride;*** *from* ***977 to 1,192*** *for* ***sulfate,*** *and from* ***3,010 to 4,938*** *for* ***TDS***

Unit Conversion factor = 5.39377

Historical observations of chloride, sulfate, or TDS concentrations were paired with flow data and were plotted on the LDC for a stream.

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

ES-4.2 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.

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. This definition can be expressed by the following equation:

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

The WLA is the portion of the TMDL allocated to existing and future point sources. The LA is the portion of the TMDL allocated to nonpoint sources, including natural background sources. The MOS is intended to ensure that WQSs will be met. For chloride, sulfate, and TDS, TMDLs are expressed in pounds (lbs) per day which will represent the maximum one day load the stream can assimilate while still attaining the WQS.

ES-5.1 Mineral PRG

Percent reduction goals (PRGs) for minerals were calculated using two criteria:

1. Through an iterative process of taking a series of percent reduction values, applying each value uniformly to the concentrations of samples and verifying than no more than 10% of the samples exceed the sample WQS.
2. Calculating the required reduction for the average of all the data to be at or below the yearly mean standard. The PRG was derived by selecting the greater of the two reductions. **Table ES-3** summarizes the PRGs for each waterbody/pollutant combination.

ES-5.2 Seasonal Variation

Federal regulations [40 CFR §130.7(c)(1)] require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation for the mineral TMDLs established in this report was accounted for by using more than five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

ES-5.3 MOS

Federal regulations [40 CFR §130.7(c)(1)] also require that TMDLs include an MOS. The MOS, which can be implicit or explicit, is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained. For mineral TMDLs, an explicit MOS was set at 10%.

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.

Table ES - 3 TMDL Percent Reductions Required to Meet Water Quality Standards for Minerals

Waterbody ID	Waterbody Name	Required Reduction Rate					
		Chloride – Single Sample	Chloride – Average	Sulfate – Single Sample	Sulfate - Average	TDS – Single Sample	TDS – Average
OK720500010070_00	Bent Creek			38.5%	**40.3%**		
OK720500020140_00	Beaver River	**43.4%**	34.9%				
OK720500020290_00	Beaver River	**66.0%**	59.6%	**39.4%**	29.0%	**54.4%**	50.9%
OK720500020450_00	Beaver River	**77.9%**	77.9%	**40.2%**	20.1%	58.9%	**64.5%**
OK720500020500_00	Palo Duro Creek	**59.4%**	50.2%	**68.9%**	60.7%	**63.6%**	55.1%

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. The impairments to the waterbodies in this report were not caused by point sources. Since point source dischargers in this TMDL report were not dependent on NPS load reductions, reasonable assurance does not apply.

ES - 7 PUBLIC PARTICIPATION

A public notice was sent to local newspapers, to stakeholders in the Study Area affected by these draft TMDLs, and to stakeholders who requested copies of all TMDL public notices. The public notice, draft TMDL report, and draft 208 Factsheet were posted at the following DEQ website: www.deq.state.ok.us/wqdnew/index.htm.

The public had 45 days (July 21, 2014 to September 4, 2014) to review the draft TMDL report and make written comments. One set of written comments was received during the public notice period. These comments, along with DEQ's response, are now part of the public record of this TMDL report in **Appendix E**. These comments were considered, and revisions were made to the final TMDL report.

There were no requests for a public meeting.

The *Beaver River Watershed Minerals TMDL Report* was finalized and submitted to EPA for final approval.

SECTION 1 INTRODUCTION

1.1 TMDL PROGRAM BACKGROUND

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 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, was 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) of the Clean Water Act (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. TMDLs are based on the relationship between pollution sources and in-stream water quality conditions so that states can implement water quality-based controls to reduce pollution from point and nonpoint sources (including pre-existing historic sources not regulated) and restore and maintain water quality (EPA 1991).

This report documents the data and assessment used to establish TMDLs for chlorides, sulfates, and total dissolved solids (TDS) for selected waterbodies in the Beaver River watershed. Data assessment and TMDL calculations were 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. Once EPA approves a TMDL, then the waterbody may be moved to Category 4a of a state’s Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (EPA 2003).

These TMDLs provide 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 minerals 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. An LA is the fraction of the total pollutant load apportioned to nonpoint sources. The 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 the dissolved mineral concentrations 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 focused on waterbodies that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2012 Integrated Report* for nonsupport of the agriculture water supply beneficial use. The waterbodies considered for TMDL development in this report, which are presented generally upstream to downstream, are listed in **Table 1-1**.

Table 1-1 TMDL Waterbodies

Waterbody Name	Oklahoma Waterbody Identification Number (OK WBID)
Bent Creek	OK720500010070_00
Beaver River at US 64, Rosston	OK720500020140_00
Beaver River at US 270, Beaver	OK720500020290_00
Beaver River at US 83, near Boyd	OK720500020450_00
Palo Duro Creek	OK720500020500_00
Cimarron River	OK720900000180_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 minerals (chloride, sulfates, and TDS), 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 agriculture water supply use designated for each waterbody. **Table 1-2** provides a list and description of the locations of WQM stations from which water quality data was obtained to conduct beneficial use assessments.

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

WQM Station	Waterbody Name	Station Location	Waterbody ID
OK720500-01-0070D	**Bent Creek**	Long.: -99.009083, Lat.: 36.192028	OK720500010070_00
720500020140-001AT	**Beaver River**	Long.: -100.057483, Lat.: 36.789986	OK720500020140_00
720500020290-001AT	**Beaver River**	Long.: -100.51937, Lat.: 36.822801	OK720500020290_00
720500020450-001AT	**Beaver River**	Long.: -100.84393, Lat.: 36.759413	OK720500020450_00
720500020500-001AT	**Palo Duro Creek**	Long.: -101.023499, Lat.: 36.616408	OK720500020500_00
OK720900-00-0180C	**Cimarron River**	Long.: -102.820167, Lat.: 36.912389	OK720900000180_00

1.2 WATERSHED DESCRIPTION

1.2.1 General

The watersheds addressed in the Study Area are located in the northwestern portion of Oklahoma. The waterbodies addressed in this report flow through portions of Beaver, Cimarron, Dewey, Harper, Texas, and Woodward counties in Oklahoma. In addition, some of the waterbodies in the Study Area flow originate in New Mexico and Texas and flow through counties in **Table 1-3**. These counties are part of the Central Great Plains, High Plains, and Southwestern Tablelands Level III ecoregions (Woods, A.J, Omerik, J.M., et al 2005). The watersheds in the Study Area are located in the Dalhart Basin, Anadarko Shelf, and the Anadarko Basin geological provinces (Oklahoma Geological Survey, 2008). Within the Anadarko Shelf and the Anadarko Basin geological province, the targeted watersheds in the Study Area are part of the Cimarron River Valley, High Plains, and Western Sandstone Hills geomorphic provinces (Goins and Goble 2006). **Table 1-3**, derived from the 2010 U.S. Census, demonstrates that the counties in which these watersheds are located vary in population (U.S. Census Bureau 2010). **Table 1-4** lists the Oklahoma towns and cities located in each watershed.

About 90% of the Cimarron River (OK720900000180_00) watershed acreage is located in New Mexico and Colorado, spread across parts of Union County, New Mexico, and Las Animas County, Colorado. Palo Duro Creek (OK720500020500_00), a major tributary of the Beaver River (OK720500020450_00), has its headwaters in Hartley County, Texas and run through Moore and Hansford counties, Texas. This tributary has about 90% of its total watershed area spread across Hansford, Hartley, and Moore Counties in Texas. The impaired portion of the Beaver River starts at Texas County and ends in Harper County, Oklahoma. Bent Creek (OK720500010070_00) is the tributary of the North Canadian River and run through Dewey and Woodward counties, Oklahoma.

Figure 1-1 Beaver River Watersheds Not Supporting Agriculture Beneficial Use

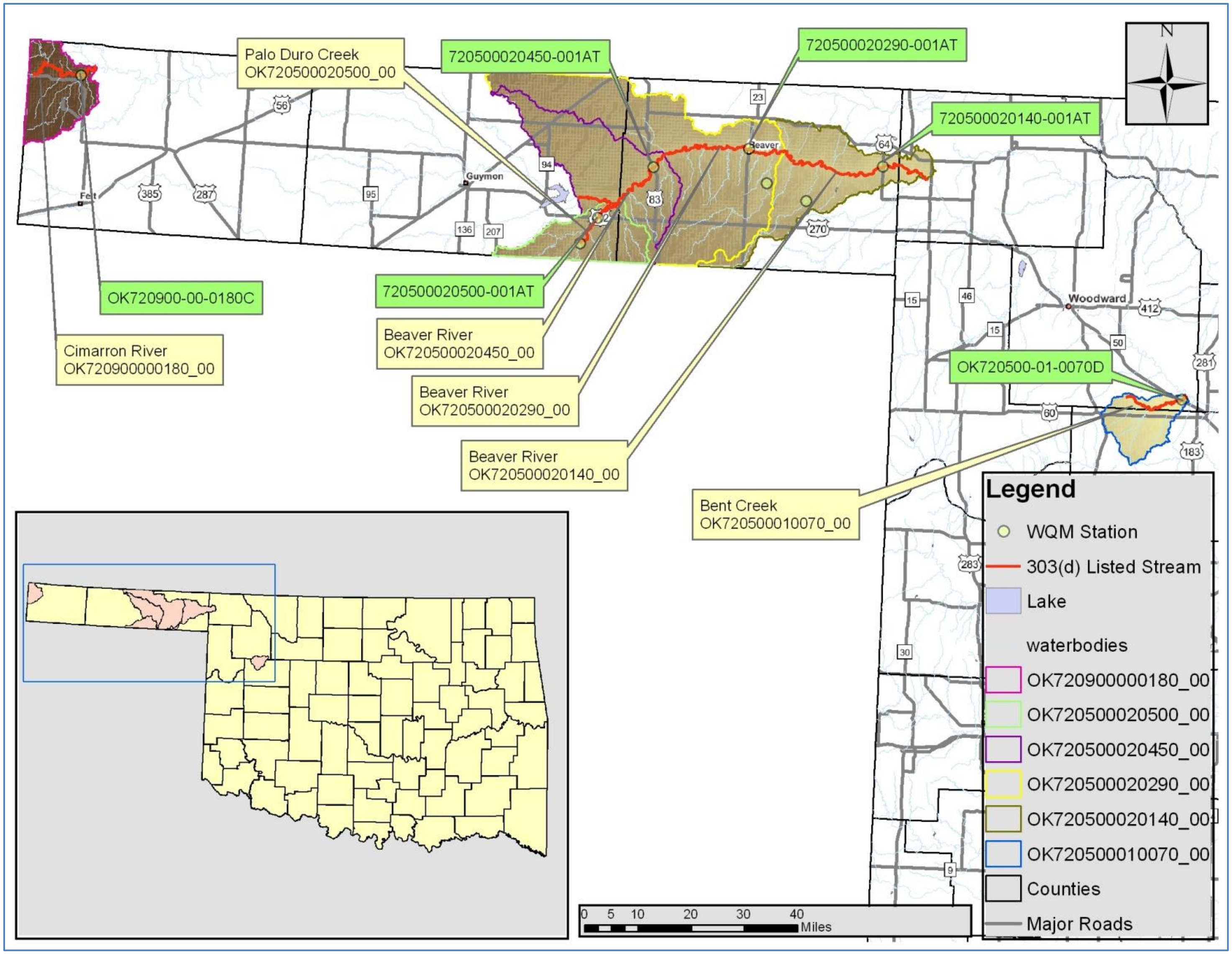


Table 1-3 County Population and Density

County Name	Population (2010 Census)	Population Density (per square mile)
Beaver	5,636	3.1
Cimarron	2,475	1.3
Dewey	4,810	4.8
Harper	3,685	3.5
Texas	20,640	10.1
Woodward	20,081	16.1
Las Animas, Colorado	15,507	3.2
Union, New Mexico	4.549	1.2
Stevens, Kansas	5,724	7.9
Hansford, Texas	5,613	6.1
Hartley, Texas	6,062	4.1
Hutchinson, Texas	22,150	24.7
Moore , Texas	21,904	24.1
Sherman, Texas	3,034	3.3

Table 1-4 Major Municipalities by Watershed

Waterbody Name	Waterbody ID	Municipalities
Bent Creek	OK720500010070_00	Aledo, Camargo, Lenora, Mutual, Seiling, Webb
Beaver River	OK720500020140_00	Booker, Clear Lake, Gaylord, Gate, Knowles, Laverne, Logan, Mocane, Rosston
Beaver River	OK720500020290_00	Balko, Beaver, Elmwood, Floris, Huntoon, Straight, Turpin, Tyrone
Beaver River	OK720500020450_00	Adams, Boyd, Hardesty, Hooker, Optima, Red Horse Creek
Palo Duro Creek	OK720500020500_00	Bryans Corner, Hansford Camp, Horseshoe Hill, Perryton
Cimarron River	OK720900000180_00	Felt, Goodson School, Greendailey Canyon, Kenton, Moses, Wheeless

1.2.2 Climate

Table 1-5 summarizes the average annual precipitation for each Oklahoma waterbody derived from a geospatial layer developed to display annual precipitation using data collected from Oklahoma weather stations between 1971 through 2000. Average annual precipitation values among the watersheds in this portion of Oklahoma ranged between 16.9 and 27.4 inches (Oklahoma Climatological Survey 2005).

Table 1-5 Average Annual Precipitation by Watershed

Waterbody Name	Waterbody ID	Average Annual Precipitation (inches)
Bent Creek	OK720500010070_00	27.4
Beaver River	OK720500020140_00	22.3
Beaver River	OK720500020290_00	20.3
Beaver River	OK720500020450_00	19.1
Palo Duro Creek	OK720500020500_00	19.8
Cimarron River	OK720900000180_00	16.9

1.2.3 Land Use

Table 1-6 summarizes the percentages and acreages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody addressed in the Study Area. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2006 National Land Cover Dataset (USGS 2012). The percentages provided in **Table 1-6** were rounded so in some cases may not total exactly 100%. The land use categories are displayed in **Figures 1-2** below. The most dominant land use category of the watersheds within the Study Area is grasslands/herbaceous. Cultivated Crops is the second most dominant category for all watersheds, except the Cimarron River (OK720900000180_00) which has a very low percentage of cultivated crops. The aggregated total developed land accounts for less than 6% of the land use in each watershed. The watersheds targeted for TMDL development in this Study Area range in size from 83,820 acres (Bent Creek, OK720500010070_00) to 487,688 acres (Beaver River, OK720500020290_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 were obtained. Not all of the waterbodies in this Study Area had historical flow data available. Flow data from the surrounding USGS gage stations and the instantaneous flow measurement data taken with water quality samples were used to estimate flows for ungaged streams. The water chemistry data results available for each waterbody are provided in **Appendix A**. A summary of the methods used to project flows for ungaged streams and flow exceedance percentiles from projected flow data are provided in **Appendix C**.

Figure 1-2 Land Use Map

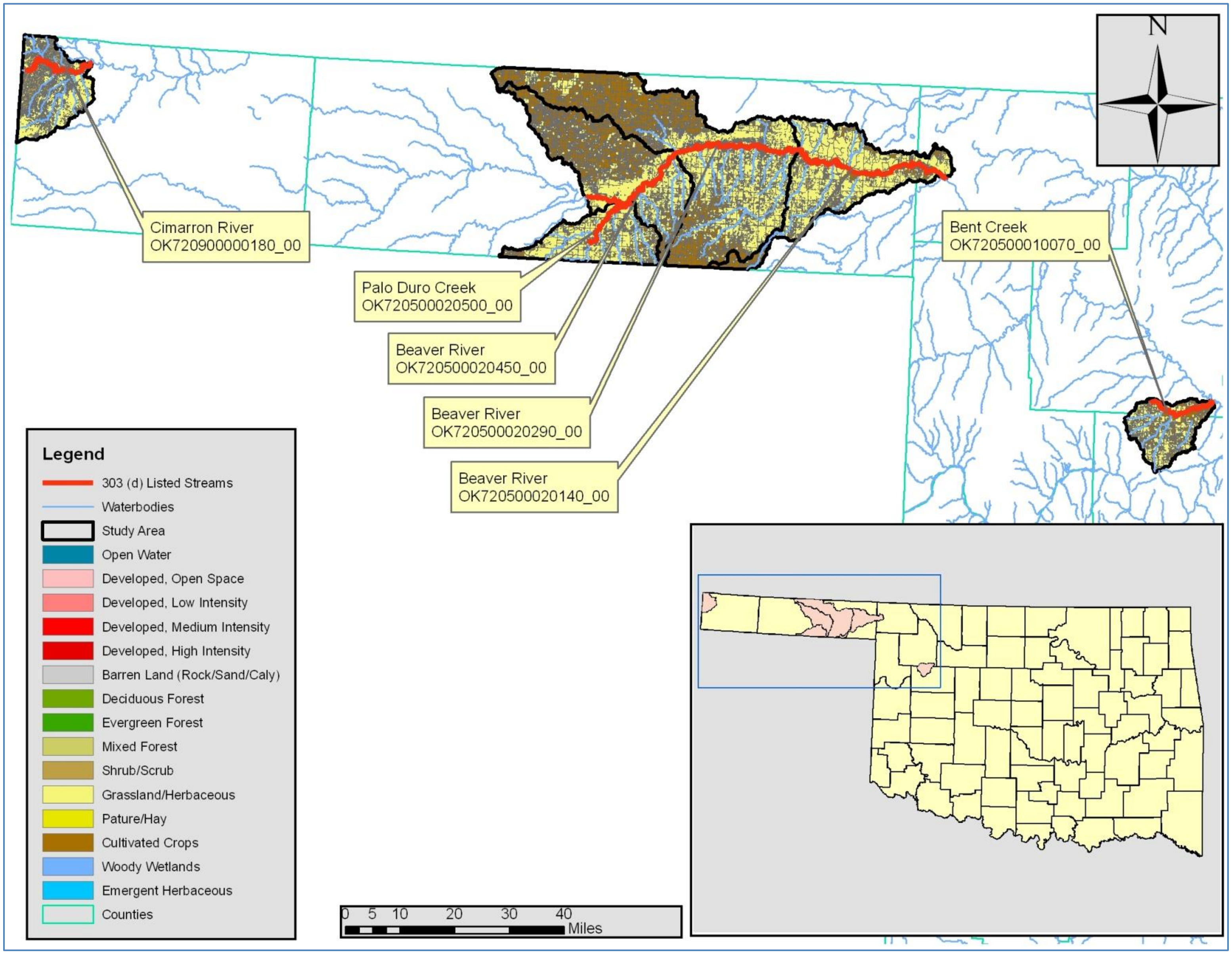


Table 1-6 Land Use Summaries by Watershed

Landuse Category	Watershed					
	Bent Creek	Beaver River	Beaver River	Beaver River	Palo Duro Creek	Cimarron River
Waterbody ID	**OK720500010070_00**	**OK720500020140_00**	**OK720500020290_00**	**OK720500020450_00**	**OK720500020500_00**	**OK720900000180_00**
Open Water	51	1,961	237	159	28	97
Developed, Open Space	4,223	7,925	19,599	10,428	4,049	565
Developed, Low Intensity	87	160	778	781	22	5
Developed, Medium Intensity	7	14	43	67	1	
Developed, High Intensity	10	2	7	19		
Bare Rock/Sand/Clay		263	332	92	52	5
Deciduous Forest	2	90	242	28		92
Evergreen Forest	5,255	1	5			732
Mixed Forest			1			
Shrub/Scrub	1,016	10,816	30,992	21,629	7,675	37,832
Grasslands/Herbaceous	51,898	181,138	257,120	118,259	96,508	80,195
Pasture/Hay		909				
Cultivated Crops	21,271	26,399	176,889	97,487	12,415	412
Woody Wetlands		1,039	1,354	228	244	579
Emergent Herbaceous Wetlands		34	89	79		649
Total (Acres)	**83,820**	**230,751**	**487,688**	**249,256**	**120,994**	**121,163**
Open Water	0.1	0.8	0.05	0.06	0.02	0.08
Developed, Open Space	5.0	3.4	4.0	4.2	3.3	0.5
Developed, Low Intensity	0.1	0.1	0.2	0.3	0.02	0.004
Developed, Medium Intensity	0.01	0.01	0.01	0.03	0.001	0
Developed, High Intensity	0.01	0.001	0.001	0.01	0	0
Bare Rock/Sand/Clay	0	0.1	0.1	0.04	0.04	0.004
Deciduous Forest	0.002	0.04	0.05	0.01	0	0.1
Evergreen Forest	6.3	0.0004	0.01	0	0	0.6
Mixed Forest	0	0	0.0002	0	0	0
Shrub/Scrub	1.2	4.7	6.4	8.7	6.3	31.3
Grasslands/Herbaceous	61.9	78.5	52.7	47.4	79.8	66.3
Pasture/Hay	0	0.4	0	0	0	0
Cultivated Crops	25.4	11.4	36.3	39.1	10.3	0.3
Woody Wetlands	0	0.5	0.3	0.1	0.2	0.5
Emergent Herbaceous Wetlands	0	0.01	0.02	0.03	0	0.5
Total (%):	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

SECTION 2 PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 OKLAHOMA WATER QUALITY STANDARDS

Title 785 of the Oklahoma Administrative Code contains Oklahoma's Water Quality Standards in Chapter 45 (OWRB 2013) and implementation procedures in Chapter 46 (OWRB 2013). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of State water quality standards, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …which establish classifications of uses of waters of the State, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters. [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the State. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2013). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegradation Policy is provided in **Appendix D**. **Table 2-1**, an excerpt from the 2012 Integrated Report (DEQ 2013), lists beneficial uses designated for each impaired stream in the Study Area. The beneficial uses included:

- AES – Aesthetics
- AG – Agriculture Water Supply
- Fish and Wildlife Propagation-WWAC (Warm Water Aquatic Community)
- FISH-Fish Consumption
- PBCR – Primary Body Contact Recreation
- PPWS – Public & Private Water Supply
- High Quality Water (HQW)

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

Waterbody Name	WBID	HUC	AES	AG	WWAC	FISH	PBCR	PPWS	HQW
Bent Creek	OK72050001007_00	11100301	F	N	F	X	N	I	
Beaver River	OK720500020140_00	11100201	F	N	N	N	N		
Beaver River	OK720500020290_00	11100201 & 11100102	F	N	N	N	N		
Beaver River	OK720500020450_00	11100102	F	N	N	F	N		
Palo Duro Creek	OK720500020500_00	11100102 & 11100104	I	N	N	I	N	I	
Cimarron River	OK720900000180_00	11040001 & 11040002	I	N	N	X	N	I	√

F – Fully supporting that designated use; N – Not supporting that use; I – Insufficient information; X – Not assessed

2.1.1 Chapter 45: Criteria for Agriculture

The definition of agriculture is summarized by the following excerpt from Chapter 45 (785:45-5-13) of the Oklahoma WQS.

785:45-5-13. Agriculture

(a) ***General.*** *The surface waters of the State shall be maintained so that toxicity does not inhibit continued ingestion by livestock or irrigation of crops.*

(b) ***Definitions.*** *The following words and terms, when used in this Section, shall have the following meaning unless the context clearly indicates otherwise:*

(1) "Long term average concentration" means the arithmetic mean of at least ten samples taken across at least twelve months.

(2) "Short term average concentration" means the arithmetic mean of all samples taken during any 30-day period.

(c) ***Subcategories of the Agriculture beneficial use.***

(1) The narrative and numerical criteria stated or referenced in this section and in Appendix F of this chapter are designed to maintain and protect the beneficial use classification of "Agriculture". This classification encompasses two subcategories which are capable of sustaining different agricultural applications. These subcategories are Irrigation Agriculture and Livestock Agriculture.

(2) Irrigation Agriculture means a subcategory of the Agriculture beneficial use requiring water quality conditions that are dictated by individual crop tolerances.

(3) Livestock Agriculture is a subcategory of the Agriculture beneficial use requiring much less stringent protection than crop irrigation.

(4) If a waterbody is designated in Appendix A of this Chapter with the Agriculture beneficial use but does not have a designation of a subcategory thereof, the criteria for Irrigation Agriculture shall be applicable.

(d) ***Highly saline water****. Highly saline water should be used with best management practices as outlined in "Diagnosis and Reclamation of Saline Soils," United States Department of Agriculture Handbook No. 60 (1958).*

(e) ***General criteria for the protection of Irrigation Agriculture.*** *This subsection prescribes general criteria to protect the Irrigation Agriculture subcategory. For chlorides, sulfates, and total dissolved solids at 180°C (see Standard Methods), the arithmetic mean of the concentration of the samples taken for a year in a particular segment shall not exceed the historical "yearly mean standard" determined from the table in Appendix F of this Chapter. For permitting purposes, the long term average concentration shall not exceed the yearly mean standard. Yearly mean standards shall be implemented by the permitting authority using the greater of*

1.47 cfs or long term average flows and complete mixing of effluent and receiving water. For permitting purposes, the short term average concentration shall not exceed the sample standard. Sample standards shall be implemented by the permitting authority using the greater of 1.0 cfs or short term average flows and complete mixing of effluent and receiving water. The data from sampling stations in each segment are averaged, and the mean chloride, sulfate, and total dissolved solids at 180°C are presented in Appendix F of this Chapter. Segment averages shall be used unless more appropriate data are available.

(f) ***Historic concentrations.*** *The table in Appendix F of this Chapter contains statistical values from historical water quality data of mineral constituents. In cases where mineral content varies within a segment, the most pertinent data available should be used.*

(g) ***Criteria to protect Irrigation Agriculture subcategory.*** *For the purpose of protecting the Irrigation Agriculture subcategory, neither long term average concentrations nor short term average concentrations of minerals shall be required to be less than 700 mg/L for TDS, nor less than 250 mg/L for either chlorides or sulfates.*

2.1.2 Chapter 46: Implementation of OWQS for Agriculture

To implement Oklahoma's WQS for agriculture use, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2013). The following excerpt from Chapter 46: 785:46-15-8, stipulates how water quality data was assessed to determine support of the agriculture use as well as how the water quality target for TMDLs was defined for each mineral.

785:46-15-8. Assessment of Agriculture support

(a) ***Scope.*** *The provisions of this Section shall be used to determine whether the beneficial use of Agriculture designated in OAC 785:45 for a waterbody is supported.*

(b) ***General support tests for chlorides, sulfates, and TDS.***

(1) The Agriculture beneficial use designated for a waterbody shall be deemed to be fully supported with respect to chloride if the mean of all chloride sample concentrations from that waterbody do not exceed the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45 and no more than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45.

(2) The Agriculture beneficial use designated for a waterbody shall be deemed to be not supported with respect to chloride if the mean of all chloride sample concentrations from that waterbody exceeds the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45, or greater than 10% of the

sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45. Provided, if the chloride sample concentrations are each less than 250 mg/L, then the Agriculture beneficial use shall be deemed to be fully supported with respect to chloride.

(3) The Agriculture beneficial use designated for a waterbody shall be deemed to be fully supported with respect to sulfate if the mean of all sulfate sample concentrations from that waterbody do not exceed the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45 and no more than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45.

(4) The Agriculture beneficial use designated for a waterbody shall be deemed to be not supported with respect to sulfate if the mean of all sulfate sample concentrations from that waterbody exceeds the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45, or greater than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45. Provided, if the sulfate sample concentrations are each less than 250 mg/L, then the Agriculture beneficial use shall be deemed to be fully supported with respect to sulfate.

(5) The Agriculture beneficial use designated for a waterbody shall be deemed to be fully supported with respect to TDS if the mean of all TDS sample concentrations from that waterbody do not exceed the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45 and no more than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45.

(6) The Agriculture beneficial use designated for a waterbody shall be deemed to be not supported with respect to TDS if the mean of all TDS sample concentrations from that waterbody exceeds the yearly mean standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45, or greater than 10% of the sample concentrations from that waterbody exceed the sample standard prescribed in Appendix F or site specific criteria promulgated in Appendix E of OAC 785:45. Provided, if the TDS sample concentrations are each less than 700 mg/L, then the Agriculture beneficial use shall be deemed to be fully supported with respect to TDS.

785:46-15-3. Data Requirements

(d) Minimum number of samples.

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

As stipulated in the WQS, both the arithmetic mean of all samples collected and the percentage of samples exceeding the single sample standard was used to assess the impairment status of the agriculture use for a waterbody. Therefore, both the arithmetic mean and the single sample criterion for each waterbody was used to develop TMDLs for each of the minerals - chlorides, sulfates, and TDS.

2.1.3 Prioritization of TMDL Development

Table 2-2 summarizes the Agricultural, use attainment status and the mineral, 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 mineral, impairments that affect the Agricultural 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 (32 watersheds)

Priority 2 watersheds - 70th to 90th percentile (64 watersheds)

Priority 3 watersheds - 40th to 70th percentile (81 watersheds)

Priority 4 watersheds - below the 40th percentile (141 watersheds)

Each waterbody on the 2012 303(d) list has been assigned a potential date of TMDL development based on the priority level for the corresponding HUC 11 watershed.

[1] Appendix C, 2012 Integrated Report

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

Table 2-2 Excerpt from the 2012 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Name	Stream Miles	TMDL Date	Priority	Chloride	Sulfates	TDS	Designated Use Agriculture Water Supply
				X = Criterion Exceeded **N** = Not Supporting Source: DEQ 2012 Integrated Report				
OK720500010070_00	Bent Creek	18.1	2023	4		X		N
OK720500020140_00	Beaver River	39	2023	4	X			N
OK720500020290_00	Beaver River	31.4	2023	4	X	X	X	N
OK720500020450_00	Beaver River	28.2	2023	4	X	X	X	N
OK720500020500_00	Palo Duro Creek	15.8	2023	4		X	X	N
OK720900000180_00	Cimarron River	19.24	2017	2		X		N

2.2 PROBLEM IDENTIFICATION

This section summarizes waterbody impairments caused by elevated levels of minerals (chlorides, sulfates, and TDS). **Table 2-3** summarizes all available water quality data collected from the WQM stations identified in **Table 1-2** between 1999 and 2012. The data summary in **Table 2-3** provides an understanding of the limited amount of water quality data available and an evaluation of the exceedances of the water quality criteria. This data was used to determine if a TMDL was necessary for the specific waterbody/pollutant combinations that were originally identified on the DEQ 2012 §303(d) list (DEQ 2012) within the Study Area. Based on the analysis of the water quality data results within the Study Area, it was found that a total of 11 TMDLs were required: 4 of the waterbodies had elevated levels of chloride, 4 of the waterbodies had elevated levels of sulfate, and 3 of the waterbodies had elevated levels of TDS. There was one new pollutant requiring a TMDL that had not been identified in the 2012 303(d) list and one pollutant as a candidate for delisting from the 303(d) List. The water quality data used to prepare **Table 2-3** is in **Appendix A**.

Table 2-3 Summary of Mineral Samples, 1999-2012

Waterbody ID	Waterbody Name	Indicator	Data Period of Record	Number of Samples	Yearly Mean Std	Arithmetic Mean Concentration (mg/L)	Single Sample Std	Number of Samples Exceeding Single Sample Criterion	% Samples Exceeding Single Sample Criterion (NS>10%)	AG Use **NS** = Not Supporting: **FS** = Fully Supporting	Notes **Highlight = TMDL required**
OK720500010070_00	Bent Creek	Chlorides	6/4/07 – 12/17/12	26	735	42.0	945	0	0	FS	
		Sulfates	6/4/07 – 12/17/12	26	723	1,090	977	17	65.4	NS	**TMDL required**
		TDS	6/4/07 – 12/17/12	26	2,442	1,914	3,010	0	0	FS	
OK720500020140_00	Beaver River at US 64, Rosston	Chlorides	5/24/05 – 9/11/07	19	735	1,015	945	7	36.8	NS	**TMDL required**
		Sulfates	5/24/05 – 9/11/07	19	723	378	977	0	0	FS	
		TDS	7/10/07 – 9/11/07	3	2,442	2,140	3,010	0	0	FS	
OK720500020290_00	Beaver River at US 270, Beaver	Chlorides	5/30/06 – 6/7/12	38	1,455	3,237	1,893	36	94.7	NS	**TMDL required**
		Sulfates	5/30/06 – 6/7/12	38	890	1,127	1,192	17	44.7	NS	**TMDL required**
		TDS	7/10/07 – 5/15/12	29	3,847	7,047	4,938	29	100	NS	**TMDL required**
OK720500020450_00	Beaver River at US 83, near Boyd	Chlorides	5/31/06 – 5/6/08	17	735	2,991	945	17	100	NS	**TMDL required**
		Sulfates	5/31/06 – 5/6/08	17	723	814	977	3	17.6	FS	**TMDL required**
		TDS	7/10/07 – 5/6/08	8	2,442	6,020	3,010	8	100	NS	**TMDL required**
OK720500020500_00	Palo Duro Creek	Chlorides[1]	9/14/99 -7/11/00	10	735	1,328	945	6	60.0	NS	**TMDL required**
		Sulfates	9/14/99 -7/11/00	10	723	1,654	977	5	50.0	NS	**TMDL required**
		TDS	9/14/99 -7/11/00	10	2,442	4,894	3,010	7	70.0	NS	**TMDL required**
OK720900000180_00	Cimarron River	Chlorides	6/4/07 – 4/6/2009	17		80.5					
		Sulfates	6/4/07 – 4/6/2009	17		921					Delist: listed by error
		TDS	6/4/07 – 4/6/2009	17		1,671					

[1] = Pollutant not identified on the 2012 303(d) list

2.2.1 Seasonality

Seasonal arithmetic mean concentration can be calculated by averaging seasonal observation between 1999 and 2012. Sampling was conducted at the WQM stations identified in **Table 1-2**. Data were analyzed seasonally including winter (November through March), spring (April and May), and summer (June through October). These periods reflect differences in the mass of chloride available since road salt is applied only during the snow and ice season. However, the available water quality data did not show any significant patterns related to seasonal variation as shown in **Table 2-4**.

None of the waterbodies in the Study Area has the highest average chloride concentration during winter. The average chloride concentration was the highest during spring for Bent Creek (OK720500010070_00), Beaver River (OK720500020140_00), and Cimarron River (OK720900000180_00). The average chloride concentration was the highest during summer for Beaver River (OK720500020290_00 and OK720500020450_00) and Palo Duro Creek (OK720500020500_00). Road salt did not appear to have a major impact on the in-stream concentration of chloride in the Study Area. This indicated that the chloride source may be groundwater, oil and gas production facilities, and/or irrigation flows. Also, sulfate and TDS data did not show any significant seasonal pattern as well.

Table 2-4 Seasonal Arithmetic Concentration of Mineral Samples, 1999-2012

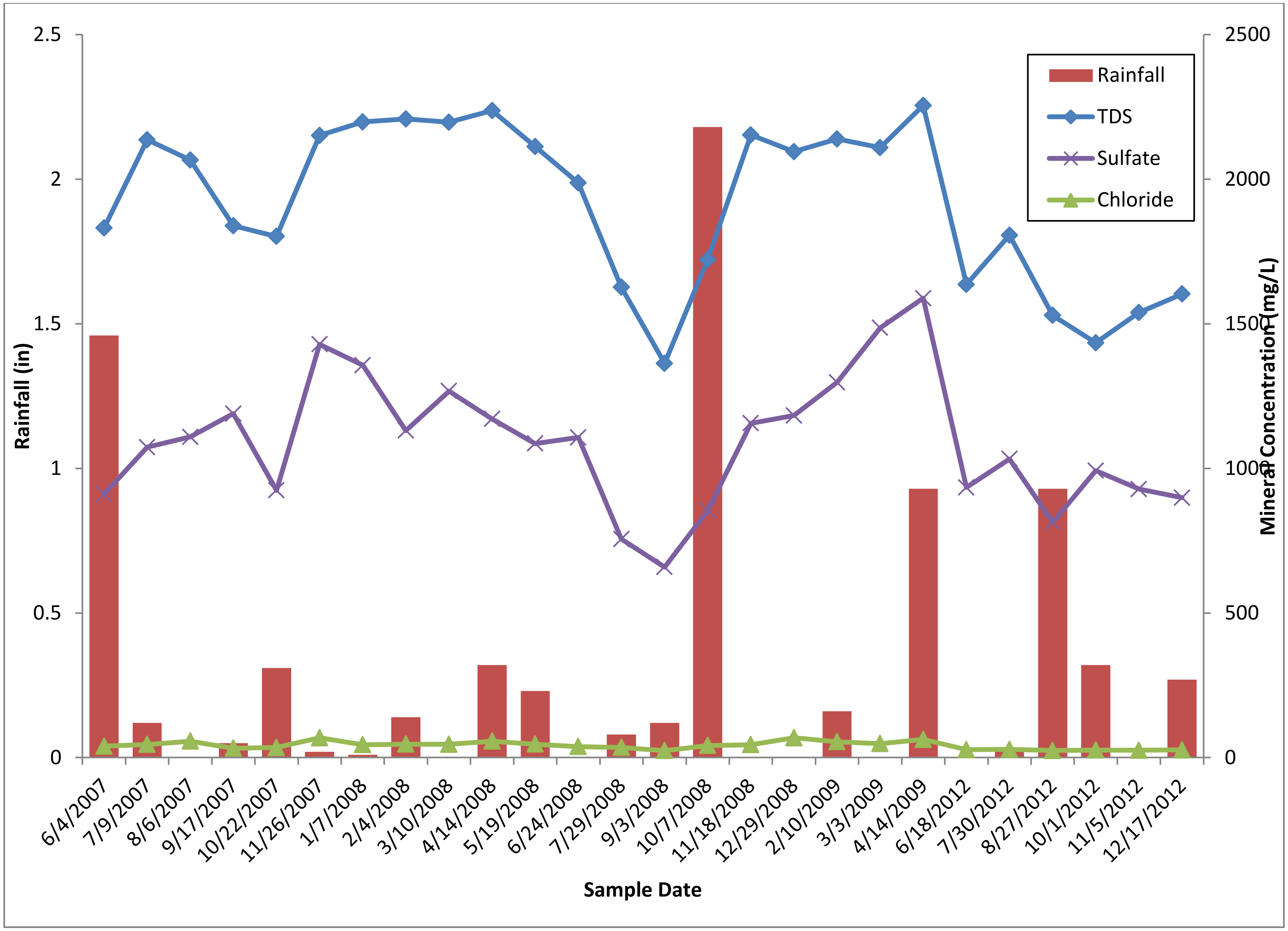
Waterbody ID	Waterbody Name	Indicator	Spring (April – May)		Summer (June – October)		Winter (November – March)	
			Number of Samples	Arithmetic Mean Concentration (mg/L)	Number of Samples	Arithmetic Mean Concentration (mg/L)	Number of Samples	Arithmetic Mean Concentration (mg/L)
OK720500010070_00	Bent Creek	Chlorides	3	**55.3**	13	34.9	10	47.4
		Sulfates	3	**1,281.9**	13	950.3	10	1,213.3
		TDS	3	**2,201.7**	13	1,752.1	10	2,039.2
OK720500020140_00	Beaver River at US 64, Rosston	Chlorides	4	**1,083.3**	8	929.9	7	1,072.4
		Sulfates	4	359.3	8	365.6	7	**402.0**
		TDS	0	-	3	**2,140.0**	0	-
OK720500020290_00	Beaver River at US 270, Beaver	Chlorides	8	3,026.3	14	**3,713.3**	16	2,989.4
		Sulfates	8	1,123.9	14	**1,162.3**	16	1,097.3
		TDS	6	6,550.0	11	**7,380.0**	12	6,989.2
OK720500020450_00	Beaver River at US 83, near Boyd	Chlorides	4	3,135.0	7	**3,260.0**	6	2,595.0
		Sulfates	4	**851.5**	7	837.2	6	746.8
		TDS	2	5,865.0	4	**5,965.0**	2	5,715.0
OK720500020500_00	Palo Duro Creek	Chlorides	1	862.0	4	**1,613.0**	5	1,192.8
		Sulfates	1	520.0	4	**2,314.8**	5	1,351.8
		TDS	1	2,541.0	4	**6,229.5**	5	4,296.2
OK720900000180_00	Cimarron River	Chlorides	3	**93.3**	7	66.3	7	89.2
		Sulfates	3	**1,043.6**	7	654.5	7	1,133.9
		TDS	3	1,770.7	7	1,355.3	7	**1,944.6**

2.2.2 Rainfall Evaluation

A comparison of chloride, TDS and sulfate concentrations to stream flow and precipitation was conducted for waterbodies in the Study Area which is displayed in **Figures 2-1** through **2-6**. Data were analyzed to determine whether a relationship existed between chloride, sulfate, and TDS concentrations and rainfall. The data sets were taken between 1999 and 2012. The rainfall data shown in the graphs are the sum of rainfall on the day of water quality sampling, plus the four days prior to the water quality sampling event (Mesonet 2012). The rainfall data for this analysis was obtained from the Mesonet weather station in or near the watershed.

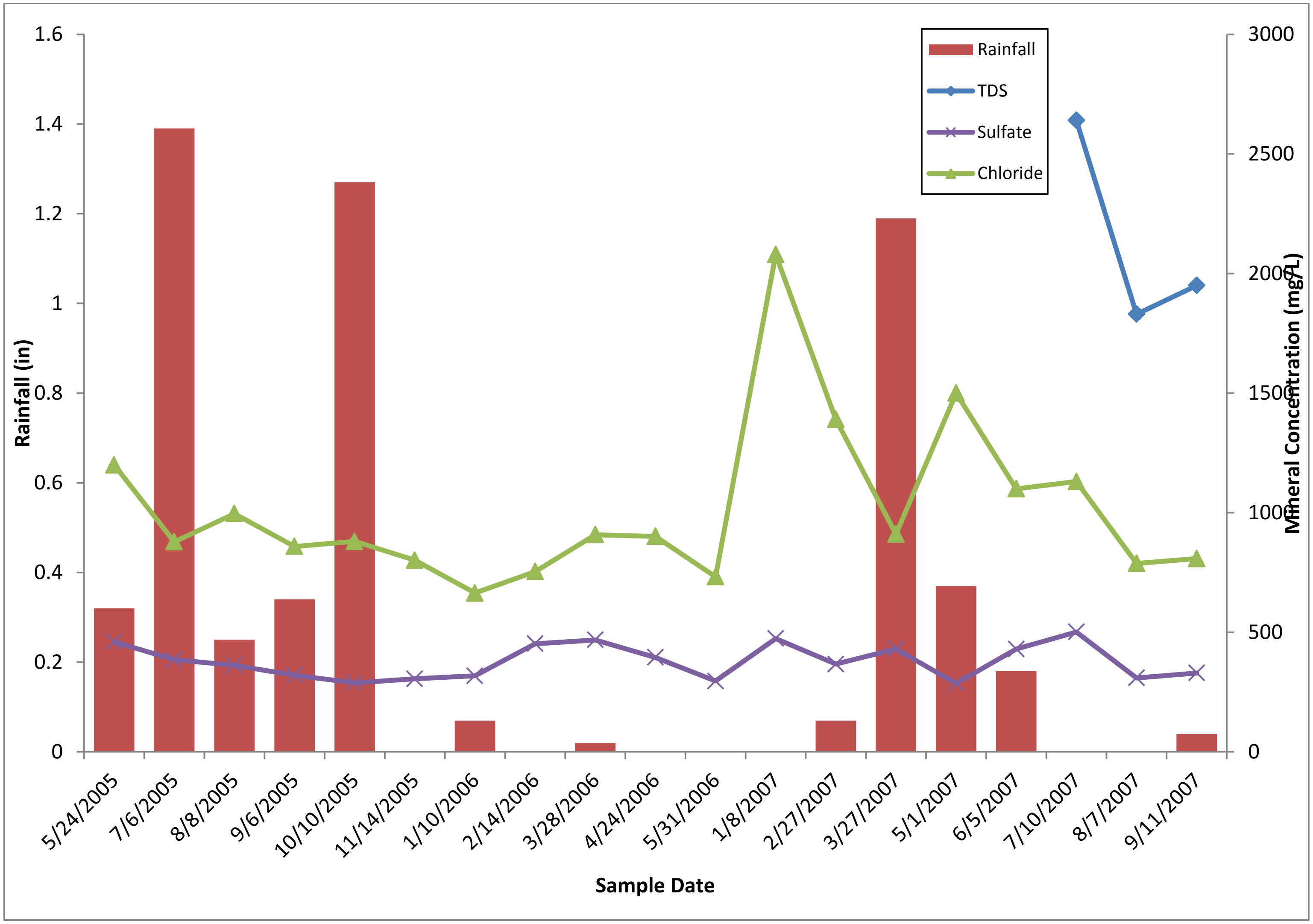
In general, the highest concentrations of minerals usually occur during relatively low flow periods. High flow periods (associated with rainfall events) usually resulted in a reduction of in-stream concentrations. The temporal pattern displayed in **Figures 2-1** through **2-6** suggests that considerable loading of minerals occurs under low flow conditions. This suggests that groundwater/surface water interaction, oil and gas production facilities, and/or irrigation flows may be mechanisms for transporting minerals to receiving waters. Stormwater runoff from the watershed does not have a major impact on the in-stream concentration of minerals in the Study Area.

Figure 2-1 Bent Creek (OK720500010070_00): Rainfall vs. Mineral Concentration



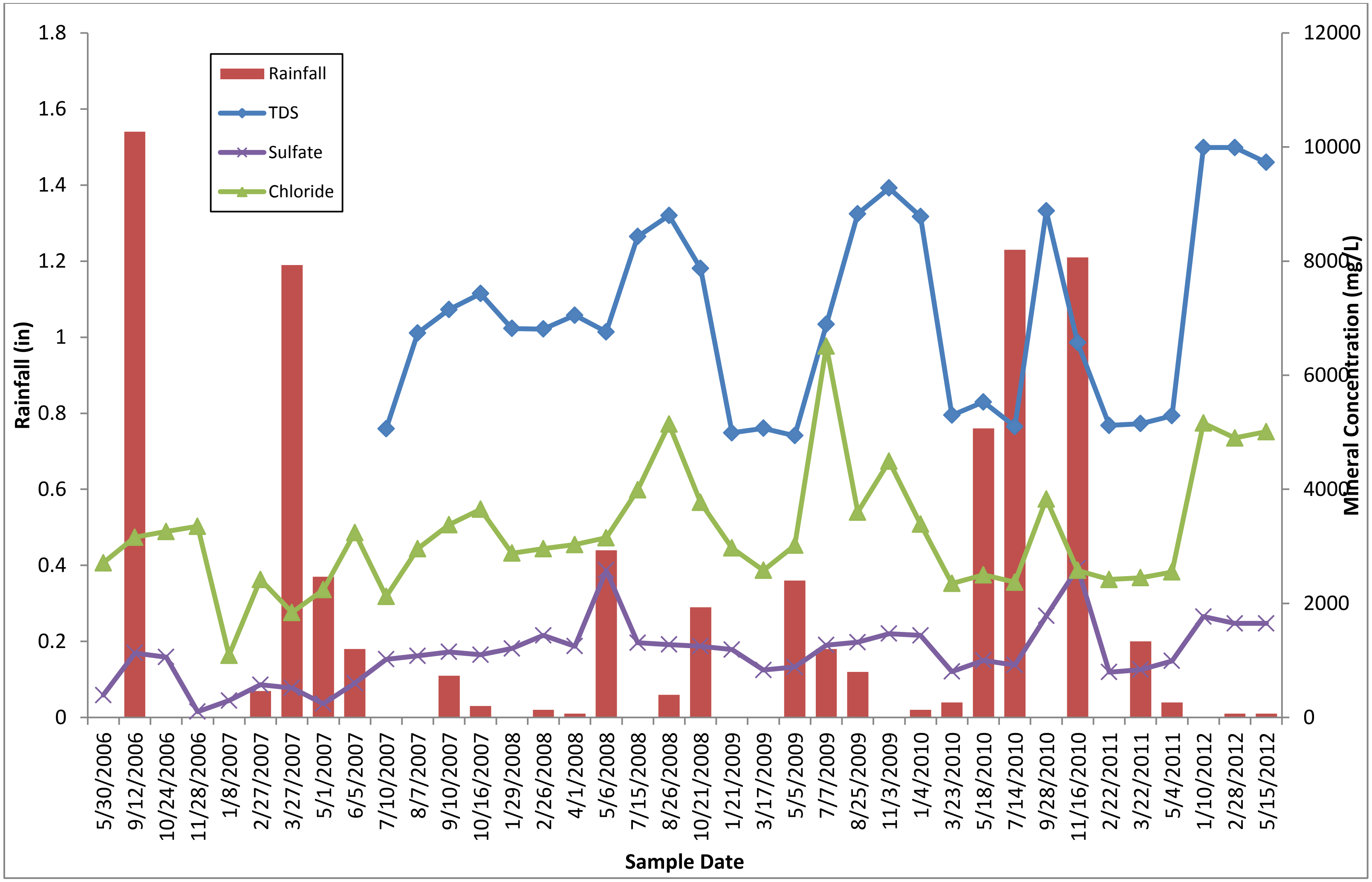
Rainfall Data Source: Mesonet 2012 Station - Seiling

Figure 2-2 Beaver River (OK720500020140_00): Rainfall vs. Mineral Concentration



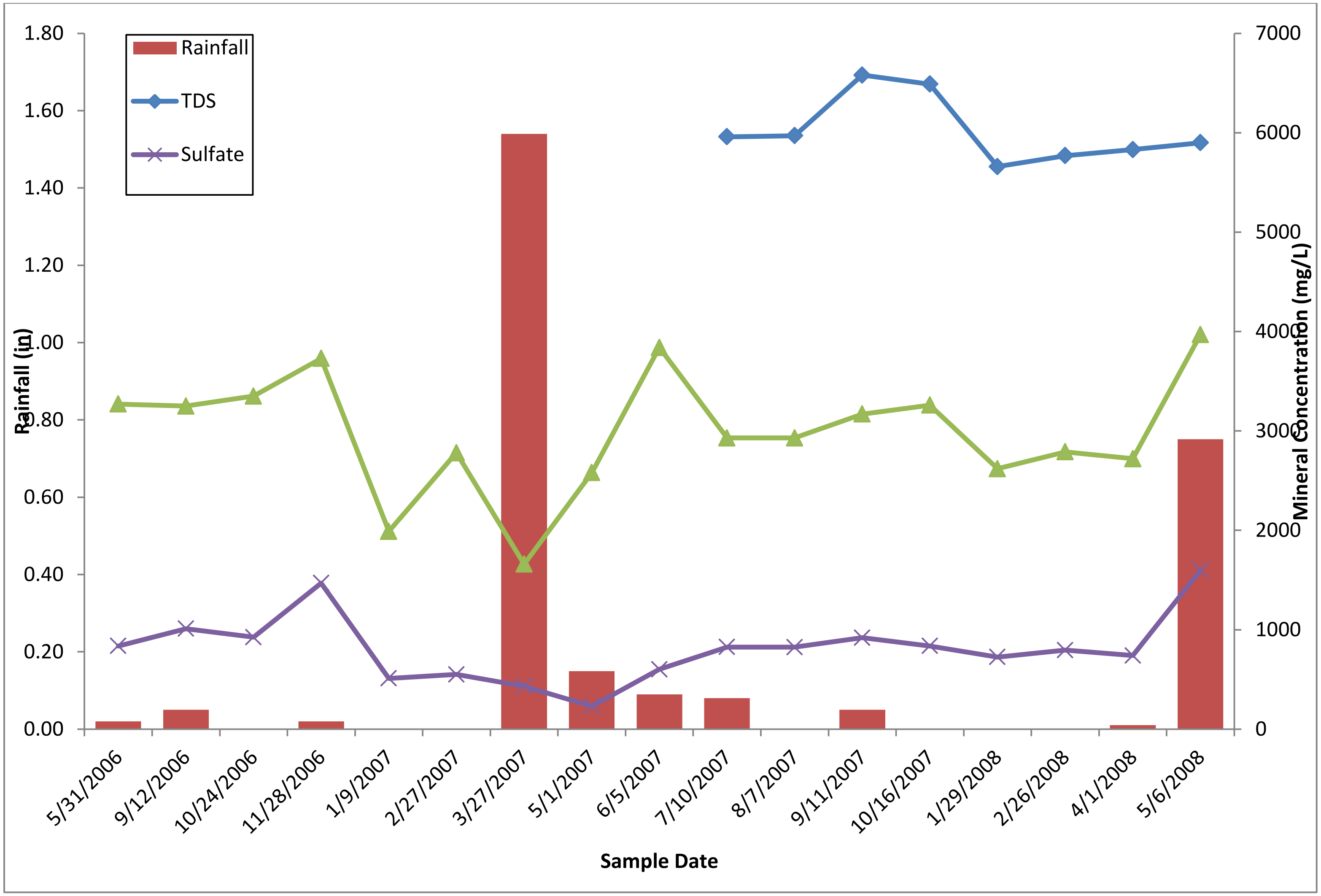
Rainfall Data Source: Mesonet 2012 Station - Beaver

Figure 2-3 Beaver River (OK720500020290_00): Rainfall vs. Mineral Concentration



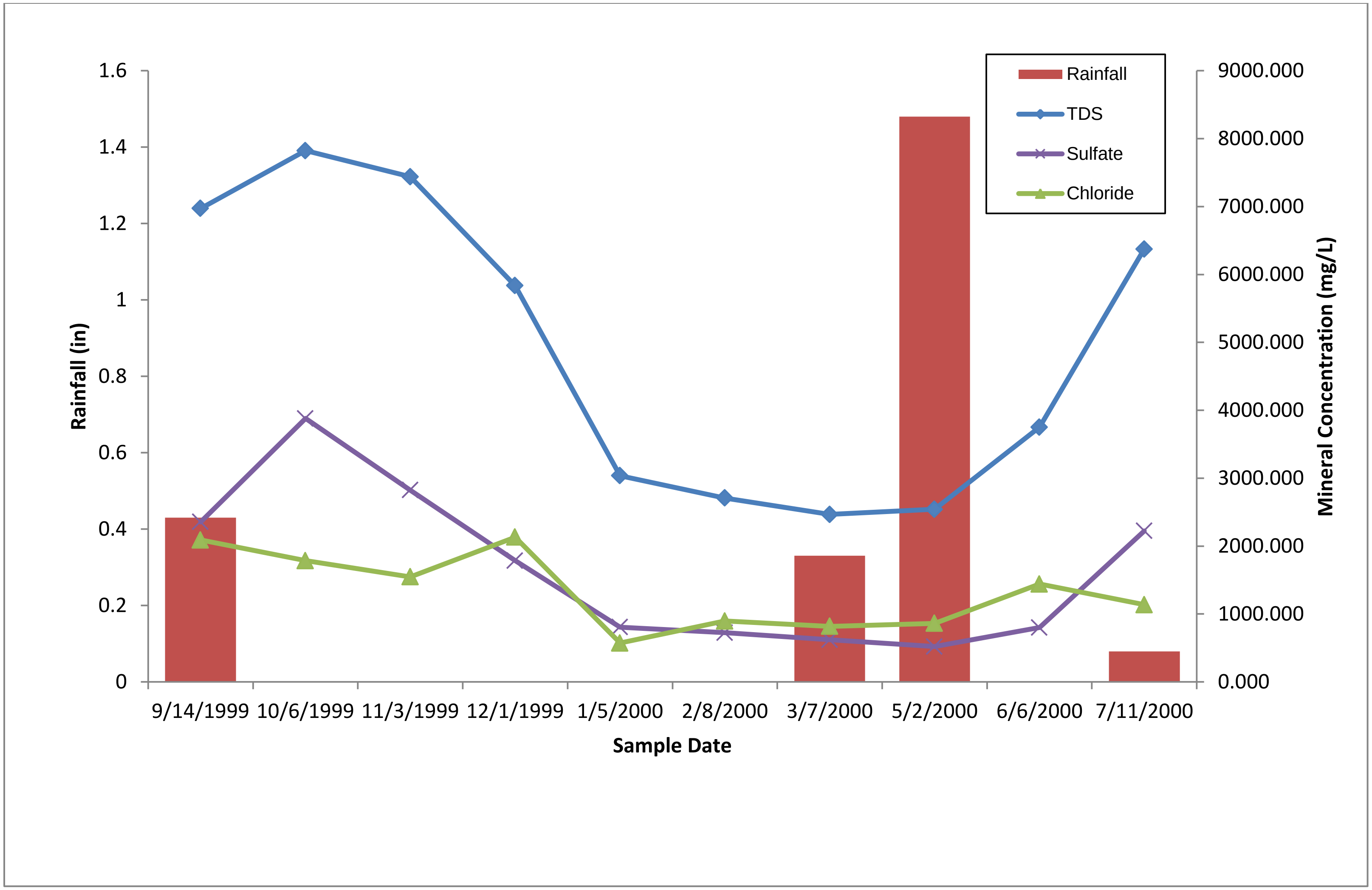
Rainfall Data Source: Mesonet 2012 Station - Beaver

Figure 2-4 Beaver River (OK720500020450_00): Rainfall vs. Mineral Concentration



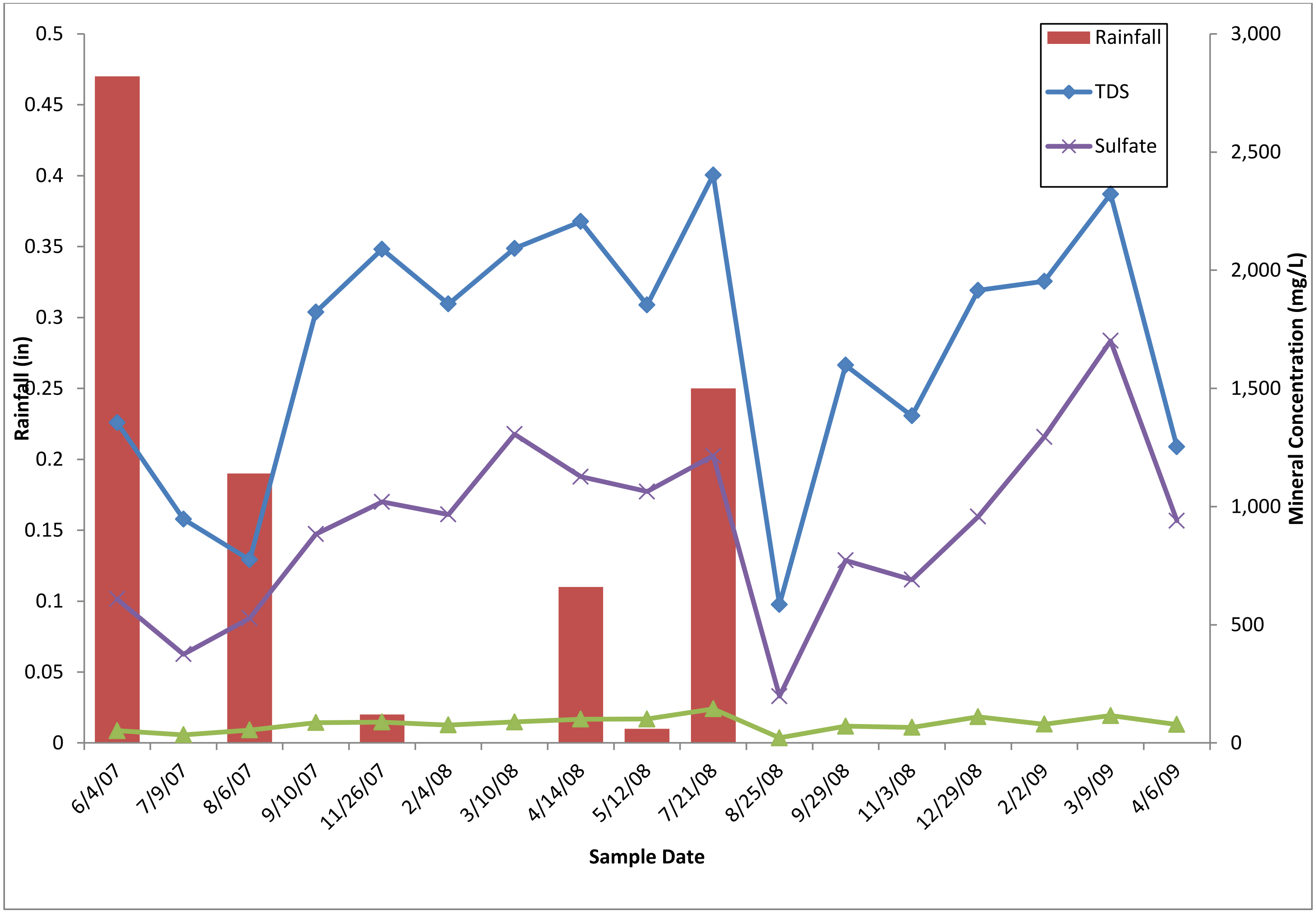
Rainfall Data Source: Mesonet 2012 Station - Hooker

Figure 2-5 Palo Duro Creek (OK720500020500_00): Rainfall vs. Mineral Concentration



Rainfall Data Source: Mesonet 2012 Station - Hooker

Figure 2-6 Cimarron River (OK720900000180_00): Rainfall vs. Mineral Concentration



Rainfall Data Source: Mesonet 2012 Station - Kenton

2.3 WATER QUALITY TARGET

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "*TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards*." Each individual water quality target established for chloride, sulfate, or TDS must demonstrate compliance with the both the long-term average and sample standard numeric criteria prescribed in Appendix F of the Oklahoma WQS Chapter 45 (785:45-5-13) (OWRB 2013). TMDLs for chloride, sulfate, and TDS in streams designated with an agriculture use must maintain both the yearly mean standard and no more than 10% of the samples may exceed the sample standard prescribed in Chapter 45 and 46. The water quality targets for chlorides, sulfates, and TDS summarized in **Table 2-5** are derived from Appendix F of the Oklahoma WQS Chapter 45. These criteria were used when one or more samples in each data set for each pollutant exceeded the criteria of 250, 250, and 700 mg/L for chloride, sulfate, and TDS respectfully, as defined in OAC 785:45-5-13(g). However, there were no numeric criteria for Cimarron River (OK720900000180_00). The allowable mineral load is derived by using the actual or estimated flow record multiplied by the water quality target. The line drawn through the water quality target (single sample standard) for any given flow represents the maximum load that still satisfies the WQS.

Table 2-5 Water Quality Criteria for Waterbody/Pollutant Combinations

Beaver River Watershed				Chloride		Sulfates		TDS	
WBID	Waterbody Name	Length (miles)	Station	Yearly Mean Std (mg/L)	Sample Std (mg/L)	Yearly Mean Std (mg/L)	Sample Std (mg/L)	Yearly Mean Std (mg/L)	Sample Std (mg/L)
Segment: 720500									
OK720500010070_00	**Bent Creek**	18.1	AVG	735	945	723	977	2,442	3,010
OK720500020140_00	**Beaver River**	39							
OK720500020290_00	**Beaver River**	31.4	2340	1,455	1,893	890	1,192	3,847	4,938
OK720500020450_00	**Beaver River**	28.2	AVG	735	945	723	977	2,442	3,010
OK720500020500_00	**Palo Duro Creek**	15.8							
Segment: 720900									
OK720900000180_00	**Cimarron River**	19.24							

Source: OWRB 2011; Oklahoma Water Resources Board.
AVG = represents the averages of the historical data from various monitoring stations.

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. Chlorides, sulfates, and TDS may originate from point sources such as industrial and municipal continuous dischargers, mines, CAFOs, or nonpoint sources such as natural background sources from soils and geological formations, roadway salts used for deicing, agricultural irrigation, groundwater diversions, and abandoned or improperly capped oil and gas wells.

Point sources discharge treated wastewater and are permitted through the OPDES program. 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 or have historically contributed minerals to surface water as a result of rainfall runoff, or to groundwater that later flows into surface water. The potential nonpoint sources of chlorides, sulfates, and TDS considered in this report include:

- Background loads from the soil and local geological formations;
- Agricultural irrigation;
- Salts from roadway deicing;
- Groundwater;
- Commercial soil farming sites;
- Abandoned or improperly capped oil and gas wells;
- Historic oil and gas well related spill sites and drilling mud pits;
- Historic oilfield produced water/brine “evaporation pits” and holding pits; and
- Damaged and poorly maintained well casing and lines for underground injection wells.

For the TMDLs in this report, all sources of pollutant loading not regulated by OPDES permits were considered nonpoint sources. The following discussion describes what is known regarding point and nonpoint sources of minerals in the impaired watersheds. Where information was available on point and nonpoint sources of minerals originating in portions of the impaired watersheds located in Colorado, Kansas, New Mexico, and Texas, data were provided and summarized as part of each category. These data were provided to demonstrate that some of the mineral loading outside of Oklahoma’s jurisdiction may contribute to nonsupport of the agriculture use in Oklahoma. More than 90% of the Palo Duro Creek (OK720500020500_00) watershed acreage is located in Texas. The Cimarron River (OK720900000180_00) segment starts at the New Mexico border where the Cimarron River enters Oklahoma. This watershed has 34% of its acreage in Colorado and 54% in New Mexico. Less than 10% of the Beaver River (OK720500020140_00 and OK720500020290_00) watershed is located in Texas and Kansas. It is recognized that Oklahoma has no enforcement authority over mineral sources originating beyond the Oklahoma State boundary.

3.2 OPDES-PERMITTED FACILITIES

Under [40 CFR, §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 minerals loading into the watersheds include:

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

3.2.1 Continuous Point Source Dischargers

Continuous point source discharges such as municipal or industrial WWTFs, could result in discharge of elevated concentrations of chlorides and TDS. Sodium chloride is a common constituent in sewage, and any appreciable pollution is marked by an increase in chloride. Stormwater runoff from MS4 areas, which is regulated under the OPDES Program, can also contain dissolved mineral concentrations. 40 C.F.R. § 130.2(h) requires that OPDES-regulated stormwater discharges must be addressed by the wasteload allocation component of a TMDL. CAFOs are recognized by EPA as significant sources of pollution, and may have the potential to cause serious impacts to water quality if not properly managed.

3.2.1.1 OPDES Municipal WWTF

There are no active permitted municipal point source facilities within the Study Area in Oklahoma. However, there are three facilities upstream in the Palo Duro Creek watershed located in Texas. They are identified in **Table 3-1** and shown in **Figure 3-1**. But because they are in Texas, they will not receive a WLA in this study.

Table 3-1 Municipal WWTF in the Study Watershed

Permit No.	Name	Receiving Water	Facility Type	SIC Code	County	Design Flow (mgd)	Expiration Date	Sulfate, Chloride, TDS Permit Limits
WQ0010296001	City of Sunray WWTF	Unnamed tributary to Palo Duro Creek	Sewerage System	4952	Moore, TX	0.4	10/1/15	NA
WQ0010977001	City of Spearman WWTF	Horse Creek (tributary to Palo Duro Creek)	Sewerage System	4952	Hansford, TX	0.6	10/1/15	NA
WQ0010751001	City of Gruver WWTF	Farwell Draw (tributary to Palo Duro Creek)	Sewerage System	4952	Hansford, TX	0.2	10/1/15	NA

3.2.1.2 OPDES Industrial WWTF

There are no active permitted industrial point source facilities within the Study Area in Oklahoma. However, there is one in the Palo Duro Creek watershed located in Texas. It is identified in **Table 3-2** and shown in **Figure 3-1**.

Table 3-2 Industrial WWTF in the Study Watershed

Facility	Regulated Entity (RN) Number	County	Facility Type	Watershed
Diamond Shamrock Refining Company, L.P.	RN105694731	Moore, TX	On-site sewage facility	Palo Duro Creek

3.2.2 Stormwater Permits

Stormwater runoff from OPDES-permitted facilities (MS4s and quarries) 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. 2008). Based on data summarized in the NSQD, median chloride concentrations for runoff from urban land uses (commercial, industrial, open space, and residential) were all below 10 mg/L (Pitt et. al. 2008). In the NSQD median effluent TDS concentrations in stormwater from urban land uses ranged from 61 to 119 mg/L. EPA regulations [40 C.F.R. §130.2(h)] require that OPDES-regulated stormwater discharges must be addressed by the WLA component of a TMDL.

3.2.2.1 Municipal Separate Storm Sewer System Permit

3.2.2.1.1 Phase I MS4

In 1990 the EPA developed rules establishing Phase I of the NPDES Stormwater Program, designed to prevent harmful pollutants from being washed by stormwater runoff into MS4s (or from being dumped directly into the MS4) and then discharged into local 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 permits in the Study Area.

3.2.2.1.2 Phase II MS4

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 OPDES Stormwater Program. Phase II requires operators of regulated small MS4s to obtain OPDES 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: www.deq.state.ok.us/WQDnew/stormwater/ms4/. 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 2011) whose Standard Industrial Classification (SIC) code is listed on Table 1-2 of the MSGP. They are not required to monitor for minerals so they are not considered as a point source for minerals.

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 mined 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 12 of the MSGP. Specific effluent limitation guidelines for Sector J SIC codes (1422 - 1429, 1442, 1446) are referenced in Table 1-3 of the MSGP. The effluent guidelines [40 CFR part 436, Subpart B, C and D] are adopted by reference in the OPDES under OAC 252:606-1-3(b)(8). Mine dewatering discharges can happen at any time and has a pH limit of 6.0 to 9.0. There is one of these facilities in the Study Area.

3.2.2.2.2 Rock, Sand and Gravel Quarries

Stormwater from rock, sand and gravel quarries in Oklahoma fall under the MSGP. But **wastewater** generated at quarries is regulated under DEQ General Permit OKG950000. Wastewater discharges regulated by this Permit are process wastewater and stormwater runoff that comes in direct contact with active process areas associated with the mining of stone, sand, and gravel; cutting stone; crushing stone to size; washing and stockpiling of processed stone and sand; and washing and maintenance areas of vehicles and equipment. Permitted activities include discharge of industrial wastewater, construction or operation of industrial surface water impoundments, land application of industrial wastewater for dust suppression, and recycling of wastewater as wash water or cooling water. Wastewater and stormwater runoff from mining activities have the potential to contain elevated suspended solids, chlorides, TDS and elevated pH due to contact with minerals. Suspended solids, as well as fugitive dust from operations, are a potential source of metals. Oil and grease may be generated due to equipment washing activities.

General Permit OKG950000 does not allow discharge of wastewater into Outstanding Resource Waters, High Quality Waters, Sensitive Public & Private Water Supplies, and Appendix B Waters [OAC 785:45-5-25(c)(2)]. The General Permit contains technology-based effluent limits of 45 mg/L for TSS, 15 mg/L for oil and grease, and pH range of 6.0–9.0.

Based on the nature of the discharge, the permit assumes that the discharge should not contain minerals at high enough levels to violate numeric water quality criteria. However, the Permit includes a provision that when exceedances of water quality criteria are determined to be the result of a facility's discharge to receiving waters, DEQ may determine that the facility is no longer eligible for coverage under the General Permit. DEQ will then require the facility to apply for an individual discharge permit with additional chemical-specific limits or toxicity testing requirements as necessary to protect the beneficial uses of the receiving stream. The General Permit isn't applicable in this TMDL report because there aren't any rock/sand/gravel quarries located in the Study Area.

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 2012). Construction sites are not considered to be a point source for minerals.

3.2.3 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 CAFOs and SFOs in Oklahoma under what ODAFF calls the Agriculture Pollutant Discharge Elimination System (AgPDES). Through regulations (rules) established by the Oklahoma Concentrated Animal Feeding Operation (CAFO) Act (Title 2, Chapter 1, Article 20 – 40 to Article 20 – 64 of the State Statutes), Swine Feeding Operation (SFO) Act (Title 2, Chapter 1, Article 20 – 1 to Article 20 – 29 of the State Statutes), and Poultry Feeding

Operation (PFO) Registration Act (Title 2, Chapter 10-9.1 to 10-9.25 of the State Statutes), AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the State. All of these animal feeding operations (AFO) require an Animal Waste Management Plan (AWMP) to prevent animal waste from entering any Oklahoma waterbody. These plans outline how the animal feeding operator will prevent direct discharges of animal waste into waterbodies as well as any runoff of waste into waterbodies. The rules for all of these AFOs recommend using the USDA NRCS' Agricultural Waste Management Field Handbook to develop their Plan. NRCS has developed Animal Waste Management software to develop this Plan.

3.2.3.1 CAFO

A CAFO[2] 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 2014). Animal Waste Management Plans (Section 35:17-4-12) 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. AWMPs may include, but are not limited to, a Comprehensive Nutrient Management Plan per NRCS guidance or Nutrient Management Plan per EPA guidance.

CAFOs are designated by EPA as significant sources of pollution and may have the potential to cause serious impacts to water quality if not managed properly (ODAFF 2014). Potential problems for CAFOs can include animal waste discharges to waters of the State and failure to properly operate wastewater lagoons. CAFOs are considered no-discharge facilities for the purpose of the TMDL calculations in this report. Runoff of animal waste into surface waterbodies or groundwater is prohibited.

CAFOs can contribute chlorides which are found in animal waste. A preliminary study was conducted in the 1990s analyzing six years of groundwater quality data from seven dairy feedlots in New Mexico. Samples were obtained from groundwater monitoring wells located around dairy wastewater lagoons that were lined with either clay, concrete, or synthetic membranes. The results of this study indicated all contaminant levels exceeded water quality standards for nitrate, ammonia, chloride, and TDS at all dairies and all wells. The range for chloride in this study was from 65 to 2,820 mg/L, with a mean value of 975 mg/L. The TDS range was from 672 to 6,944 mg/L, with a mean value of 3,170 mg/L. It was determined that mean chloride and TDS levels were slightly higher for clay linings than for cement or synthetic linings. These results suggest that among the three lining types clay linings are least effective at reducing groundwater contamination (Arnold

[2] 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.

and Meister, 1999). This study suggests that CAFOs can be a source of mineral loading to receiving waters.

Oklahoma CAFO Rules require CAFOs to submit a *Documentation of No Hydrologic Connection* (OAC 35:17-4-10 [3]) 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. There are four cattle CAFOs located in the Beaver River watershed [three are in Beaver River (OK720500020450_00) and one in Beaver River (OK720500020290_00)]. The cattle CAFOs are highlighted in **Table 3-3** and shown in **Figure 3-1**. Most of these CAFOs are not operating at the capacity allowed in their license. For other states including Colorado, Kansas, New Mexico, and Texas, site specific data was not available. Therefore, the number of livestock based on the 2007 Agricultural Census is presented in **Table 3-4** by counties intersecting with the Study watershed.

3.2.3.2 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.[4] 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, to prevent swine waste from being discharged into surface or groundwaters. This Plan includes the BMPs being used to prevent runoff & erosion.[5] 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.

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3 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.

4 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)

5 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.

Oklahoma SFO Rules require SFOs to submit a *Documentation of No Hydrologic Connection* (OAC 35:17-3-12 [6]) for all retention structures designed to prevent any leakage of wastewater into waterbodies. For large SFOs with more than 1,000 animal units, monitoring wells or a leakage detection system for waste retention structures are required to be installed to monitor and control seepage/leakage [OAC 35:17-3-11(e)(6)].Thus, the potential for mineral loading from SFOs to a receiving stream is almost non-existent. There are 29 SFOs in this Study Area. Most of the SFOs in Oklahoma are not operating at the capacity allowed in their license. The SFOs are the AFOs that aren't highlighted in **Table 3-3**. They are also shown in **Figure 3-1**.

3.2.3.3 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. PFOs are required to develop an Animal Waste Management Plan (AWMP) or an equivalent document such as a Nutrient Management Plan (NMP). These plans describe how litter will be stored and applied properly in order to protect water quality of streams and lakes located in the watershed. Applicable BMPs shall be included in the Plan. There are no PFOs located in this Study Area.

Table 3-3 AGPDES-Permitted AFOs in Study Area

(Shaded entries are cattle CAFOs. The rest are SFOs.)

ODAFF Owner ID	EPA Facility ID	ODAFF ID	ODAFF License #	Max # of Swine > 55 lbs	Total # of Animal Units at Facility	County	Waterbody ID and Waterbody Name
AGN022163	OKG010225	15	1157	1,482	1,482	Beaver	**Beaver River** OK720500020450_00
AGN031946	OKG010203	16	1406	4,270	4,270	Beaver	
AGN031950	OKG010205	20	1410	2,135	2,135	Texas	
AGN031951	OKG010206	22	1412	2,880	2,880	Texas	
AGN031953	OKG010207	23	1413	2,135	2,135	Texas	
AGN031789	OKG010047	80	1376	1,338	1,338	Beaver	
AGN007220	OKG010046	225	74	0	55,000	Texas	
WQ0000095	OKU000453	237	970013	3,456	3,456	Texas	
WQ0000110	OKU000375	251	970027	3,456	3,456	Texas	
WQ0000116	OKU000451	257	970021	3,456	3,456	Texas	

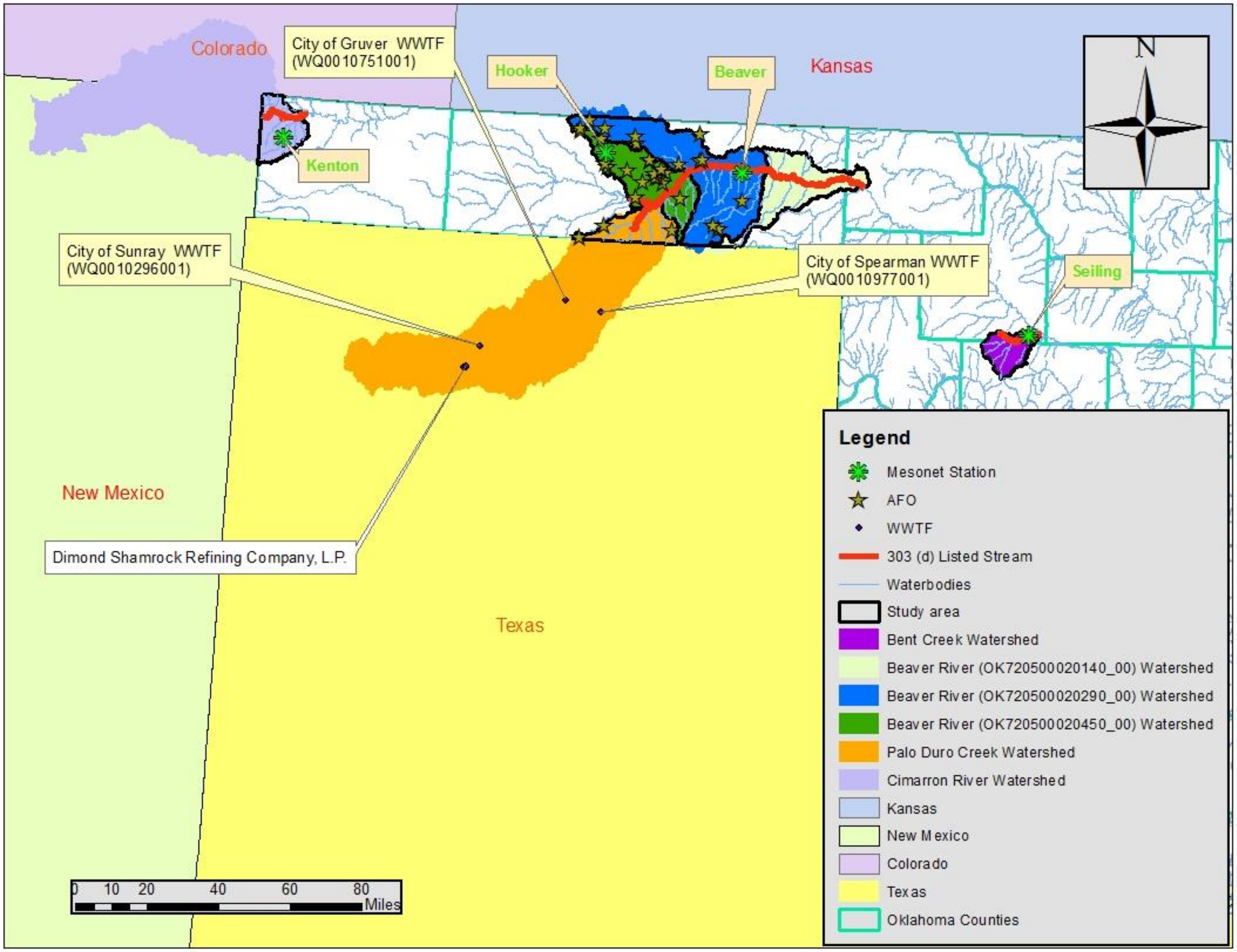
[6] USDA NRCS design specifications in the USDA NRCS Agricultural Waste Management Field Handbook Chapter 10 shall satisfy documentation of no hydrologic connection so long as the facility is designed by USDA NRCS and does not exceed one thousand (1,000) swine animal units.

ODAFF Owner ID	EPA Facility ID	ODAFF ID	ODAFF License #	Max # of Swine > 55 lbs	Total # of Animal Units at Facility	County	Waterbody ID and Waterbody Name
AGN032024	OKG010082	310	1430	0	1,000	Texas	**Beaver River** OK720500020450_00
WQ0000304		381	990008	0	4,500	Beaver	
WQ0000252		382	990009	3,024	3,024	Texas	
WQ0000253	OKU000494	383	990010	3,024	3,024	Texas	
AGN031946	OKG010203	384	1406	4,270	4,270	Beaver	
AGN031950	OKG010205	385	1410	2,135	2,135	Texas	
AGN031953	OKG010207	387	1413	2,135	2,135	Texas	
200223	OKU000293	482	200223	3,630	3,630	Texas	
WQ0000049	OKG010340	124	970009	2,212	2,212	Texas	**Palo Duro Creek** OK720500020500_00
WQ0000099	OKU000257	241	970032	8,640	8,640	Texas	
WQ0000120	OKU000490	280	980020	3,024	3,024	Beaver	
WQ0000107	OKU000259	248	970026	6,912	6,912	Texas	**Beaver River** OK720500020290_00
WQ0000108	OKU000290	249	980009	2,160	2,160	Texas	
WQ0000111	OKU000260	252	970028	15,984	15,984	Texas	
WQ0000114	OKU000293	255	980001	2,160	2,160	Texas	
AGN007238	OKG010009	281	93	0	30,000	Beaver	
AGN031433	OKG010171	331	1337	669	669	Beaver	
WQ0000267	OKU000245	386	990011	10,500	10,500	Beaver	
WQ0000248	OKU000498	395	200001	1,600	1,600	Beaver	
WQ0000248	OKU000498	396	200001	1,600	1,600	Beaver	
WQ0000267	OKU000245	443	990011	10,500	10,500	Beaver	
WQ0000279	OKU000399	455	200203	11,340	11,340	Beaver	
WQ200204	OKU000430	459	200204	2,296	2,296	Beaver	

Table 3-4 Livestock Number in Counties Outside of Oklahoma

COUNTY	Cattle and calves	Horses and ponies	Hogs and pigs	Goats	Waterbody ID	Waterbody Name
Las Animas, CO	49,257	1,828		698	OK720900000180_00	**Cimarron River**
Union, NM	135,884	1,095		141	OK720900000180_00	**Cimarron River**
Stevens, KS	51,469	486		322	OK720500020290_00	**Beaver River**
Hansford, TX	272,094	747			OK720500020500_00	**Palo Duro Creek**
Hartley, TX	303,454	394		64	OK720500020500_00	**Palo Duro Creek**
Hutchinson, TX	27,007	1,064		266	OK720500020500_00	**Palo Duro Creek**
Moore , TX	170,798	448		232	OK720500020500_00	**Palo Duro Creek**
Sherman, TX	155,399	522	135	61	OK720500020500_00	**Palo Duro Creek**

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



3.3 NONPOINT SOURCES

The following section provides general information on nonpoint sources contributing chlorides, sulfates, and TDS loading within the Beaver River watershed. Nonpoint sources include those sources that cannot be identified as entering a waterbody at a specific location. Nonpoint sources of minerals from natural sources include surface water runoff, soils, bedrock, and groundwater. Possible anthropogenic (those caused by people) sources of minerals are septic wastes, animal waste, fertilizer, agricultural irrigation runoff, road salting for deicing of roadways, and various oilfield operations (e.g. mud pits, produced water, soil farming, injection disposal wells). Based on data from the NSQD presented in subsection 3.2.2, runoff from urban areas is not considered to be a significant source of minerals.

3.3.1 Natural Background Loads

The Study Area addressed in this TMDL report covers a large area across northwestern Oklahoma. Local geological formations associated with each impaired watershed can have a direct effect on in-stream water quality. The natural sources of minerals originate from the bedrock and soils of the natural geological formations described above. Gypsum (dehydrated calcium), in the mineral form known as selenite, is a very soluble mineral and can lead to very high sulfate concentrations when dissolved to saturation. Sulfate is dissolved from many rocks and soils and in especially large quantities from gypsum and beds of shale. Chloride and TDS is present in surface water runoff, being dissolved from rocks or from natural salt deposits. Other sources of sulfate and chlorides include bedrock outcroppings and underlying alluvial sediments consisting of shale, siltstones, and sandstones.

This Study Area consists predominantly of marine rocks (characterized by fossiliferous shales, limestones, and dolomites) from the Permian age (245 – 290 million years ago). That was because during the Permian age, most of western Oklahoma was a shallow sea. During the Late Permian age, the climate in Oklahoma became more arid and the sea water evaporated. This left thick beds of salts such as gypsum ($CaSO_4 \cdot 2H_2O$) and anhydrite (calcium sulfate) which can be found in most of the exposed Permian rocks in the western half of Oklahoma. The Early Permian sea margin is characterized by marine red sandstone and shale. The red color, common in Permian sandstone and shale, is from iron oxides. Gray marine shale, anhydrite, limestone, dolomite, and other salts were deposited towards the center of the sea.

The Quaternary Age (the last 1.65 million years of geologic time) is divided into the Pleistocene Epoch (the "Great Ice Age") and the Holocene or Recent Epoch that we live in today. At the beginning of the Holocene Epoch, the Rocky Mountain glaciers from the Great Ice Age began to melt. The meltwater from the Rocky Mountains created the major rivers in Oklahoma along with the alluvium and terrace deposits comprised of gravel, sand, silt, and clay. These Quaternary sediments include fossil wood, snail shells, and bones & teeth of land vertebrates that lived in Oklahoma during the Pleistocene Epoch (e.g., horses, camels, bison, mastodons, mammoths). (Johnson, 2008)

The Cimarron River channel and floodplain consists of Quaternary-age alluvium composed of sand, gravel, silt, and clay. The alluvium on right bank is in contact with Pliocene-age basalt (the southern edges of Black Mesa) and left bank is bordered by Cretaceous-age sandstone.

The Beaver River channel and floodplain consists of Permian-age Flowerpot Shale composed of red-brown silty shale with some thin gypsum and dolomite beds, and rock salt in the middle and upper parts. It is surrounded by Tertiary-aged Ogallala Formation. The Ogallala consists of interbeded sand, siltstone, clay, gravel lenses, and thin limestone.

The Bent Creek channel and floodplain consists of Permian-age Flowerpot Shale and sandstone. It is contact with Quaternary-age terrace deposits on east.

The Tertiary (Pliocene Period) or Quaternary (Pleistocene and Holocene) age sediments can be found today in the Panhandle including Beaver, Cimarron, and Texas counties. These sediments composed of clay, silt, sand, and gravel are 25-100 ft thick on top of Permian sedimentary rocks. In Dewey, Harper and Woodward counties, Permian as well as Tertiary/Quaternary age rocks can be found at the surface as shown in **Table 3-5**. Permian rocks are mostly red-bed sandstones and shales, but they contain gypsum, halite, and rose rocks which minerals are more common.

Figure 3-2 Geological Surface Map

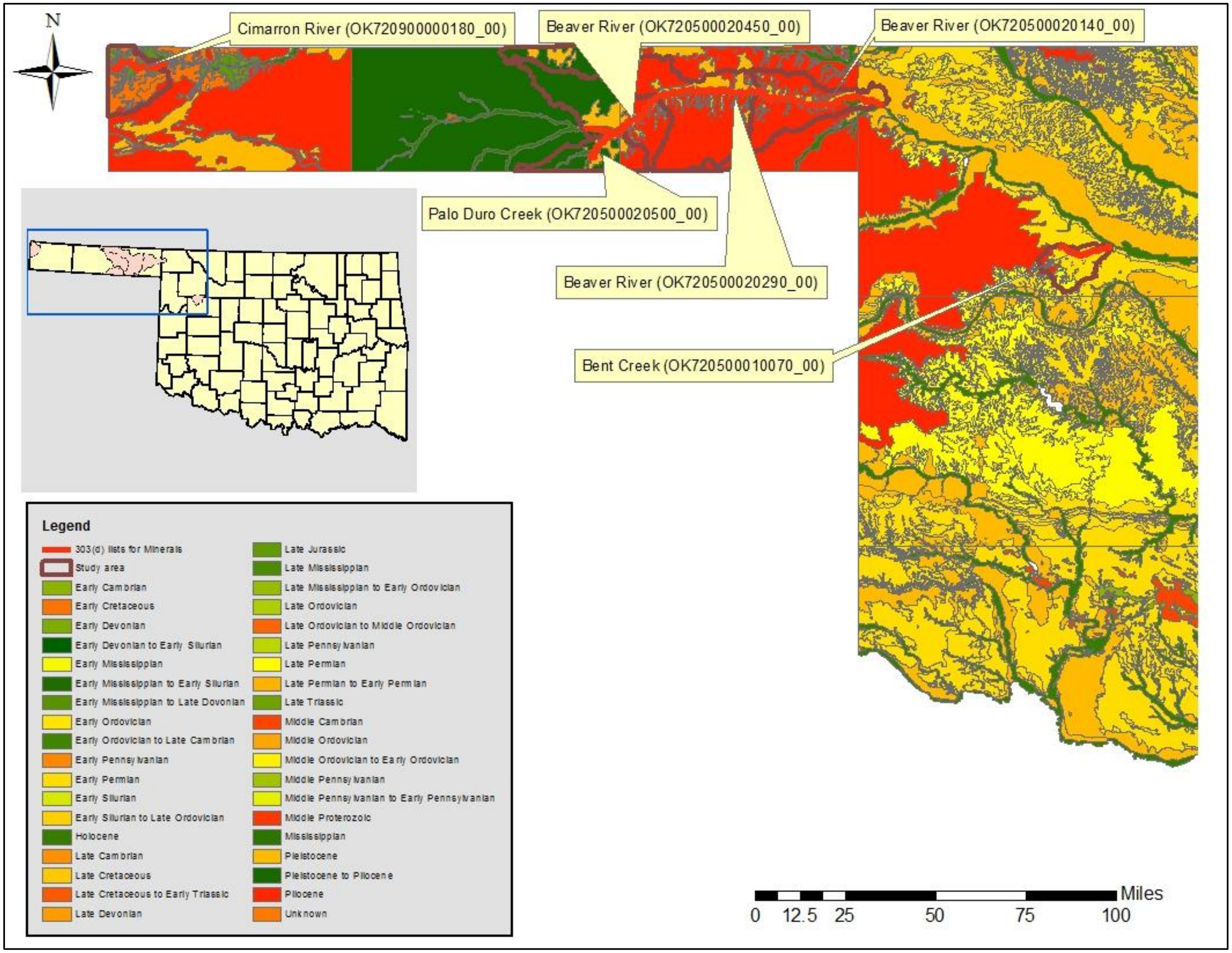


Table 3-5 Percentage of Geological Units at the County Surface

Geological Unit Description of the minerals in that county		**Percentage of each geological unit at the surface of the county** (west to east)					
		Cimarron	Texas	Beaver	Harper	Woodward	Dewey
Permian Period	Flowerpot Shale: Red-brown silty shale with some thin gypsum and dolomite beds in upper 50 feet and fine-grained sandstones in upper part to north. The middle and upper parts contain 50 feet or more of rock salt in the immediate subsurface.				**2%**	**5%**	
	Marlow Formation: Orange-brown fine-grained sandstone and siltstone, with some interbedded red-brown shale and silty shale in upper part and some thin gypsum beds at base				**26%**	**8%**	**3%**
	Blaine Formation: Alternating massive gypsum beds with red-brown shales, generally with a named dolomite at the base of each gypsum, and a greenish-gray shale at the base of each dolomite.				**9%**	**8%**	
	Rush Springs Formation: Orange-brown fine-grained sandstone with some interbedded red-brown shale, silty shale, and gypsum beds				**14%**	**17%**	**39%**
	Dog Creek Shale: Red-brown shale and silty shale, with gypsum, dolomite, and orange-brown sandstone.				**7%**	**6%**	
	Cloud Chief Formation: Red-brown and greenish-gray shale and siltstone with some orange-brown fine-grained sandstone and siltstone.				**4%**		**16%**
	Permian Rocks Undifferentiated: Red-brown and greenish-gray shale and siltstone with some orange-brown fine-grained sandstone and siltstone.		**1%**	**5%**			
Triassic Period	Dockum Group: Red-brown and greenish-gray shale and siltstone with some orange-brown fine-grained sandstone and siltstone.	**1%**					
Cretaceous Period	Dakota Sandstone: Buff to light-brown, fine- to medium-grained, thin bedded to massive sandstone with interbedded shales.	**10%**					
	Purgatoire Formation: Gray to black fossiliferous shale with sandstone in the upper part.	**3%**					
Pliocene and Pleistocene Period	Ogallala Formation: Gravel, sand, silt, clay, caliche, and limestone, locally cemented with calcium carbonate.	**61%**		**78%**	**6%**	**25%**	**4%**
	Pleistocene and Pliocene deposits, undifferentiated: Interfingering beds, tongues, and lenses of sand, silt, clay, gravel, sandstone, caliche, limestone, conglomerate, and volcanic ash.		**89%**				
	Terrace Deposits: Deposits of light-tan to gray gravel, sand, silt, clay, and volcanic ash. Sand dunes are common in many places.				**28%**	**24%**	**31%**
	Dune Sand: Fine to coarse, round to sub-round, windblown sand.	**16%**	**4%**	**10%**			
Holocene Period	Alluvium: Deposits of gravel, sand, silt, and clay. Generally light-tan to gray.	**3%**	**5%**	**7%**	**5%**	**6%**	**7%**

3.3.2 Mineral Contributions from Groundwater

Most natural recharge to the aquifers occurs as precipitation that falls directly on the alluvial deposits, infiltration of runoff from adjacent slopes, and infiltration from the streams that cross the deposits, especially during higher flows. Large, additional recharge may occur from induced stream infiltration when ground-water pumpage lowers the water table below the stream levels. During dry periods, water may discharge from the alluvium into the streams, thus contributing to base flow. The chemical quality of water in the alluvial deposits may vary between the alluvium and alluvial terraces, thus reflecting the quality of the major source of recharge. The source of recharge for the alluvium may be the river and that for the alluvial terraces may be precipitation and leakage from underlying or adjacent aquifers.

There is no single source of data that can adequately characterize groundwater quality that may influence each watershed requiring TMDLs in the Study Area. The water quality in any given aquifer varies greatly both spatially and temporally. Historic and recent groundwater data and studies are combined in this subsection to provide general inferences that suggest groundwater may be a source of mineral contamination of surface waters. All groundwater contains minerals dissolved from rocks and soils through which aquifers have come in contact. The quality of dissolved minerals in groundwater primarily depends on the type of rock or soil through which the water has passed, the length of contact time, and the pressure and temperature conditions (Norman 1955).

Chloride comes from groundwater in direct contact with halite (NaCl). Chloride concentrations in groundwater influence surface water quality either through groundwater/surface water interaction or by transporting groundwater to the land or receiving streams through human activities. In some groundwater, sodium chloride is the principal chemical constituent and occurs in such high concentrations that it makes the water unsuitable for most industrial, agricultural, and/or domestic uses. The residue left over from the evaporation of water consists primarily of minerals.

Sulfates come from groundwater in direct contact with gypsum. Gypsum is a very soluble mineral and can lead to very high sulfate concentrations when dissolved in groundwater. Saline waters (such as those with chloride and sulfates) from adjoining Permian bedrock aquifers can migrate into portions of alluvial aquifers. Salinity also increases with depth in most bedrock aquifers from brines that are present in underlying geological units.

Groundwater quality is generally good in the alluvium of the Ogallala aquifer, which underlies most of the impaired watersheds in the Study Area. The geographic boundary of the Ogallala aquifer is displayed in **Figure 3-3**.

The TDS content in a water sample is often used as a general indicator of water quality. Although OWRB considers groundwater with dissolved solid concentrations less than 5,000 mg/L (milligrams per liter) to be fresh, water is not considered desirable for drinking if the quantity of minerals exceeds 500 mg/L (OWRB 2013).

From 2002 to 2005, 34 samples were collected from 22 wells and submitted for laboratory analysis. Chloride concentrations had a mean value of 31 mg/L and a median value of 20 mg/L. These chloride samples had values ranging from 10 to 161 mg/L. The mean concentration for sulfate was 50 mg/L and the median concentration was 49 mg/L. The sulfate values for these samples ranged from 10 to 122 mg/L. The mean concentration for total dissolved solids (TDS) was 357 mg/L and the median concentration was 337 mg/L. The TDS values for these samples ranged from 208 to 671 mg/L.

Table 3-6 provides the data set of groundwater quality samples collected from the water wells in or near the Study Area. All the groundwater concentrations of chloride, sulfate, and TDS were less than the water quality standards.

The groundwater median chloride concentration near the chloride impaired waterbodies (three sements in the Beaver River and Palo Duro Creek) was less than the surface water median chloride concentration of impaired waterbodies by approximately 2,360 mg/L. All the groundwater chloride concentrations were less than the surface water median chloride concentration of their waterbodies.

Similar results were observed from TDS and sulfate data. The groundwater median TDS and sulfate concentrations near the impaired waterbodies [Beaver River (OK720500020290_00 & OK720500020450_00) and Palo Duro Creek (OK720500020500_00) for TDS; Bent Creek (OK720500010070_00), Beaver River (OK720500020290_00 & OK720500020450_00), and Palo Duro Creek (OK720500020500_00) for sulfates] were less than the surface water median concentrations of impaired waterbodies by approximately 2,890 mg/L and 1,000 mg/L, respectively. There was not much difference in groundwater mineral concentration between samples.

This indicates that minerals were leaching out from a source on the surface of the alluvium and mineral concentrations were diluted by deeper groundwater. Differences in mineral concentration between groundwater and surface water may be due to differences in rock configuration, depth of the groundwater below the surface, and location of a source.

3.3.3 Agricultural Irrigation

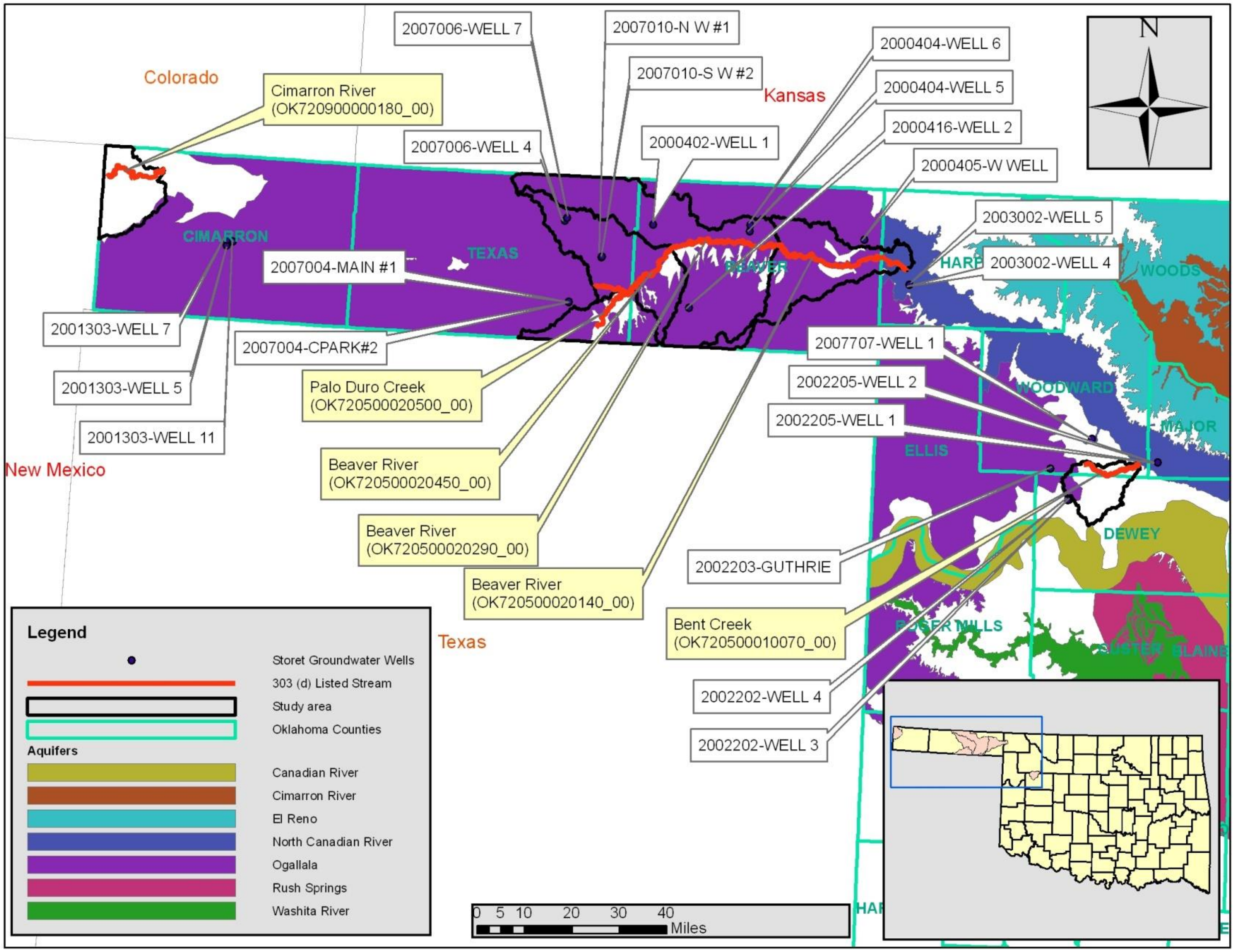
Irrigation of cropland from groundwater or surface water can result in the buildup of salts on the landscape over time. Irrigation return flows occur when artificially applied water that is not consumed by plants or evaporation, eventually migrates to an aquifer or surface water body. Over time, these return flows can carry higher concentrations of minerals to receiving waters. Irrigation return flows are expressly exempted from permit requirements under the Clean Water Act (P.L. 92-500, as amended). In the Study Area, the dominant land uses are herbaceous grasslands and cultivated crops. However for the cultivated crops in the impaired watersheds of the Study Area, irrigation is not used for increased production purposes. Therefore, irrigation return flows are not considered to be a significant transport medium for dissolved minerals in the Study Area.

Table 3-6 Groundwater Sampling Data Results in/near the Study Area

Well ID	Date Collected	Chloride (mg/L)	TDS (mg/L)	Sulfate (mg/L)	Waterbody ID	Waterbody Name
2001303-WELL 5	7/19/2004	40.9	326	48	OK720900000180_00	Cimarron River
2001303-WELL 7	6/23/2003	43	349	39.3	OK720900000180_00	Cimarron River
2001303-WELL 7	6/23/2003	43.2	356	39.8	OK720900000180_00	Cimarron River
2001303-WELL 11	7/19/2004	51.4	406	55.1	OK720900000180_00	Cimarron River
2007004-CPARK#2	10/25/2005	60.3	476	122	OK720500020500_00	Palo Duro Creek
2007004-MAIN #1	7/9/2003	40.4	435	86.8	OK720500020500_00	Palo Duro Creek
2007004-MAIN #1	7/9/2003	39.2	439	85.7	OK720500020500_00	Palo Duro Creek
2007006-WELL 4	9/18/2002	17.2	431	112	OK720500020450_00	Beaver River
2007006-WELL 7	6/18/2003	10	335	71	OK720500020450_00	Beaver River
2007006-WELL 7	4/28/2004	10	337	67.4	OK720500020450_00	Beaver River
2007006-WELL 7	4/28/2004	10	335	67.5	OK720500020450_00	Beaver River
2007010-N W #1	10/24/2005	19.4	321	60.1	OK720500020450_00	Beaver River
2007010-S W #2	6/17/2003	40	391	54.7	OK720500020450_00	Beaver River
2000402-WELL 1	5/4/2004	23.4	329	53.4	OK720500020290_00	Beaver River
2000402-WELL 1	5/4/2004	23.5	336	53.6	OK720500020290_00	Beaver River
2000404-WELL 5	9/12/2005	16.6	344	33.8	OK720500020290_00	Beaver River
2000404-WELL 6	9/16/2002	34.5	388	34.1	OK720500020290_00	Beaver River
2000416-WELL 2	10/1/2003	19.7	298	23.8	OK720500020290_00	Beaver River
2000416-WELL 2	10/10/2005	51.8	316	24.2	OK720500020290_00	Beaver River
2000405-W WELL	8/30/2004	130	518	50.9	OK720500020140_00	Beaver River
2003002-WELL 4	9/17/2002	37.1	421	35.9	OK720500020140_00	Beaver River
2003002-WELL 5	9/17/2002	161	671	86.6	OK720500020140_00	Beaver River
2007707-WELL 1	6/23/2003	10	280	20.3	OK720500010070_00	Bent Creek
2007707-WELL 1	6/23/2003	10	268	26.9	OK720500010070_00	Bent Creek
2007707-WELL 1	10/17/2005	10	208	15.8	OK720500010070_00	Bent Creek
2002202-WELL 3	10/19/2005	10	249	10	OK720500010070_00	Bent Creek
2002202-WELL 4	10/19/2005	10	255	10	OK720500010070_00	Bent Creek
2002203-GUTHRIE	4/27/2004	10	232	11.1	OK720500010070_00	Bent Creek
2002203-GUTHRIE	4/27/2004	10	237	11.3	OK720500010070_00	Bent Creek
2002203-GUTHRIE	10/24/2005	10	225	12.2	OK720500010070_00	Bent Creek
2002203-GUTHRIE	10/24/2005	10	229	12.8	OK720500010070_00	Bent Creek
2002205-WELL 1	9/7/2005	10	487	101	OK720500010070_00	Bent Creek
2002205-WELL 2	10/1/2003	21	453	89.4	OK720500010070_00	Bent Creek
2002205-WELL 2	10/1/2003	20.9	456	89.6	OK720500010070_00	Bent Creek

Source: EPA STORET (http://ofmpub.epa.gov/storpubl/dw_pages.resultcriteria)

Figure 3-3 Aquifers and Groundwater Sampling Sites



3.3.4 Oil and Gas Well Operations

The Oklahoma Corporation Commission regulates oil and gas activities through various Oil and Gas Division programs including Field Operations, Technical, Pollution Abatement, Underground Injection Control and Brownfields. These programs include regulatory oversight of field operations (exploration and/or production) for oil, gas, and brines; reclaiming facilities; underground injection; storage tank farms and transmission pipelines; waste disposal (waste mud pits and land application); spill cleanups from any of these; and sub-surface storage of oil and gas. The Corporation Commission has jurisdiction over the construction, operation, maintenance, site remediation, closure and abandonment of these facilities and activities. The Corporation Commission has sampled surface and groundwater around spills to determine the extent of any pollution. It has also sampled (and had other State agencies sample) streams in old oilfield areas to determine if historic oilfield activities have caused adverse impacts to the waters of the State, and to determine background water quality in these watersheds.

Well sampling results show that a sodium/chloride (Na/Cl) ratio below 0.6 can be indicative of a produced water/oilfield brine source (Morton, 1986). Production spills, mud pits and/or associated brine "disposal" pits can contribute to chlorides, sulfates, and TDS through groundwater filtration and surface runoff to nearby streams. However, there are no commercial pits in the Study Area. **Table 3-8** provides a summary of the number of oil and gas wells located in each watershed. Detailed data is not available to quantify or differentiate natural from human-induced nonpoint source loading of chlorides, sulfates, and TDS.

3.3.4.1 Produced Water Sampling

An historic data set of oil production water samples from oil wells located in the Study Area using data provided in **Appendix D** and summarized in **Table 3-7**. Drilled to depths of 0.5 to 5 miles, oil wells historically tapped into porous sandstone and limestone, and now also into fractured shale formations. Many formations are permeated with brine that is up to five times saltier than sea water and that can have radioactivity, heavy metals and/or other toxins.

Table 3-7 Oil Production Water Sampling Data in the Study Area

Waterbody ID	Waterbody Name	Number of Sample Well	Date	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
				Min	Max	Min	Max	Min	Max
OK720500010070_00	Bent Creek	6	5/65 – 2/68	8,190	44,300	12	490	15,900	69,800
OK720500020140_00	Beaver River	9	2/58 – 6/78	10,231	172,429	133	1,300	17,164	276,064
OK720500020290_00	Beaver River	16	4/56 – 6/78	5,198	169,215	67	1,381	11,521	274,383
OK720500020450_00	Beaver River	27	8/56 – 10/78	19,455	146,800	0	1,459	32,449	238,833
OK720500020500_00	Palo Duro Creek	18	5/56 – 3/79	1,560	144,000	148	6,532	7,540	234,700
OK720900000180_00	Cimarron River	1	7/8/1954	1,120		102		2,152	

3.3.4.2 Soil Farming

Soil farming is a land application activity that can be a source of pollutant loading to surface waters in the form of brine, metals, sediments and other organics. Soil farming, which is permitted by the Oklahoma Corporation Commission, is the application of oilfield drilling fluids to the soil for the purpose of disposing of the production waste without being a detriment to land or water (OAC 165:10-9-2). Items that can be disposed of at commercial soil farming sites are water based mud and water based mud cuttings.[7]

As a waste management approach, the application of drilling wastes to the land is done to allow the soil's naturally occurring microbial population to metabolize, transform, and assimilate waste constituents in place. However salts, unlike hydrocarbons, cannot biodegrade and may accumulate in excessive amounts in soils. As a result, application sites can be localized sources of excessive minerals. If exposed to rainfall runoff events, these sites can contribute additional loading to surface waters. The application of drilling wastes containing brine must be carefully applied to soil. If salt levels become too high, the soils may be damaged and treatment of hydrocarbons can be inhibited.

The Corporation Commission is responsible for administering the regulations that cover the permitting, construction, operation, and closure requirements for any commercial soil farming facility in accordance with OAC 165:10-9-2. These regulations define specific design criteria that must be adhered to by all commercial soil farming operations. Adherence to the design criteria outlined in OAC 165:10-9-2 includes requirements that: *All commercial soil farming facilities shall be operated and maintained at all times so as to prevent pollution. In the event of a non-permitted discharge from a commercial soil farming facility, sufficient measures shall be taken to stop or control the loss of materials and reporting procedures in 165:10-7-5 (c) shall be followed. Any materials lost due to such discharge shall be cleaned up as directed by a representative of the Conservation Division (OAC 165: 10-9-2(i)(11)).*

There are no commercial soil farming sites in the Study Area.

3.3.4.3 Land application

Land application[8] (aka land treatment, land spreading) uses the same natural soil processes as soil farming. But land application is a *one-time* application to a parcel of land of the drilling fluids, contaminated soils, petroleum

7 OK Corp Commission Rules: Title 165:10-7-24(b)

8 OK Corp Commission Rules: Title 165:10-7-26

hydrocarbon based drill cuttings, or drilling muds which are produced as waste constituents from oil well drilling. The following can be disposed of under a land application permit[9]:

- Oil based mud
- Crude oil contaminated soils
- Contaminated ground water (except refined products)
- Crude pipeline pigging wastes, contaminated soil, and residue from transmission and trunk lines
- Water or soil contaminated by refined product from E&P (exploration and production) operations
- Storm water and hydrostatic test water from E&P operations
- Refined petroleum product releases
- Refined petroleum product pigging wastes
- Water or soil contaminated by refined products from pipelines
- Hydrostatic test water from pipelines
- Tank bottoms from crude pipeline facilities
- Tank bottoms from refined product pipeline facilities

The land application boundary has to be at least 100 feet from any perennial stream, freshwater pond, lake, or wetland. The boundary also has to be at least 50 feet from any intermittent stream.[10] **Table 3-8** summarizes the 274 land application sites in the Study Area. The locations of these land application sites are displayed in **Figure 3-4**.

3.3.4.4 Underground Injection Control (UIC)

There are several different approaches used for injecting drilling wastes into underground formations for permanent disposal. The Corporation Commission is the lead agency for Oklahoma's Class II injection wells. DEQ implements the applicable Underground Injection Control (UIC) program requirements for all other injection wells in the State. The

[9] OK Corp Commission Rules: Title 165:10-7-24(b)

[10] OK Corp Commission Rules: Title 165:10-7-26(c)(6) – The location of these streams must be determined by using a USGS topographic map. This map can be found at the DEQ ArcGIS Viewer website under "USGS Quads": http://gis.deq.ok.gov/flexviewer/

Corporation Commission is responsible for implementing the regulations under Title 165 OAC Chapter 10, Subsection 5-1 through 5-10 to manage the UIC program statewide (Corporation Commission 2012). The regulations are designed to control and mitigate the potential for contamination from different classifications of underground injection wells. **Table 3-8** lists the numbers and concentration of UIC wells in each watershed. **Figure 3-4** display 152 UIC wells located within the Study Area watersheds.

Table 3-8 Oil and Gas Wells Located in Watersheds of Study Area

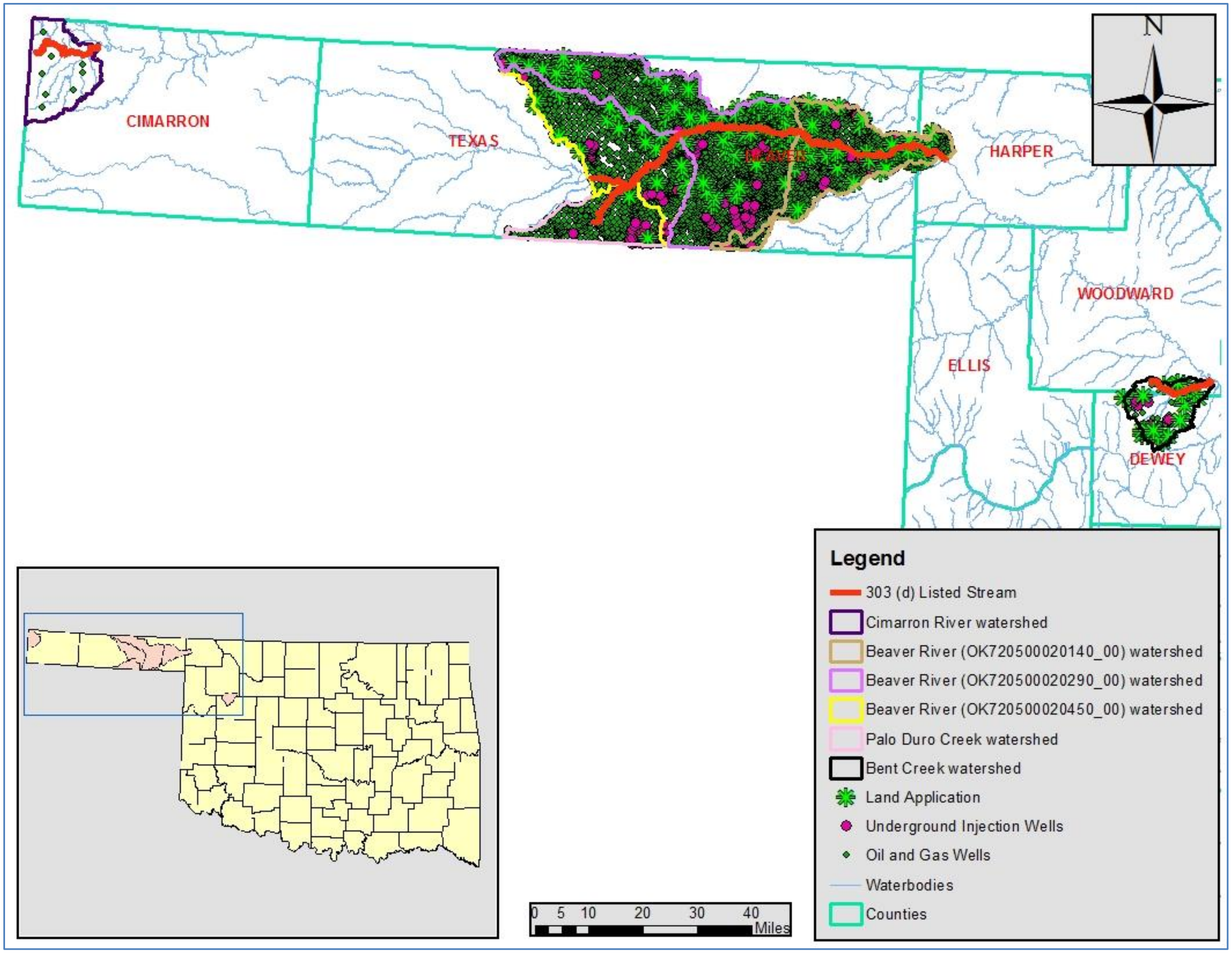
Waterbody ID	Watershed Name	Acres	Number of oil & gas (O&G) wells	UIC Well Count	Number of Permits for 1-time land application	O&G Wells Density - # per Acre	UIC Well Density - Count/Acre	Land Application Density - # per Acre
OK720500010070_00	Bent Creek	83,820	69	6	25	0.0008	0.00007	0.00030
OK720500020140_00	Beaver River	230,756	1,496	23	77	0.0065	0.00010	0.00033
OK720500020290_00	Beaver River	487,720	2,799	48	142	0.0057	0.00010	0.00029
OK720500020450_00	Beaver River	249,259	1,194	29	27	0.0048	0.00012	0.00011
OK720500020500_00	Palo Duro Creek	121,007	686	46	3	0.0057	0.00038	0.00002
OK720900000180_00	Cimarron River	121,184	11	0	0	0.0001	0	0
Total		**1,293,746**	**6,225**	**152**	**274**	**0.0048**	**0.00012**	**0.00021**

3.3.4.5 Abandoned Oil and Gas Wells

Many formations are permeated with brine that is up to five times saltier than sea water and that can have radioactivity, heavy metals and/or other toxins. Without extensive and costly plugging, brine can flow up the well shaft and seep into fresh water aquifers or reach the surface. In the mid-1960s oil-producing states enacted regulations to protect fresh water supplies by requiring that hundreds of feet of cement be poured in the wells at different levels in the process of closing them properly (Suro 1992).

There are at minimum 2.5 million abandoned oil and gas wells – none permanently capped – across the United States. Faulty installation of cement caps puts a select set of wellheads at risk, but aging cement and casing leakages mean that every abandoned well has a potential for contributing pollutants from aquifers to surface waters (Kotler 2011). Chlorides, brine and TDS pollutant loadings from uncapped wells can also build up on the ground surface and be transported by rainfall runoff to receiving streams, as well as being carried down into groundwater which later seeps into streams.

Figure 3-4 Oil and Gas Wells



3.3.5 Roadway Salts

In 2010, salt for highway deicing accounted for approximately 37% of the U.S. salt demand which equates to approximately 16,300,000 metric tons of salt being applied to our roads, parking lots, sidewalks and driveways (USGS 2010). U.S. consumption of salt for roadway deicing was about 11% more than that of 2009 (USGS 2010). Oklahoma used approximately 119,000 and 122,000 metric tons of rock salt, respectively in 2009 and 2010, most of which was used for roadway deicing (USGS 2010).

Studies have shown that, in urbanized areas, about 95% of the chloride inputs to a watershed are from road and parking lot deicing (USGS 2012). Applied salt typically dissolves into 40% sodium ions (Na+) and 60% chloride ions (Cl-) in the melting snow and ice and make their way into our environment (NHDES 2011). In highway deicing, salt has been associated with corrosion of bridge decks, motor vehicles, reinforcement bar and wire, and unprotected steel structures used in road construction. Surface runoff, vehicle spraying, and windblown actions also affect soil, roadside vegetation, and local surface water and groundwater supplies. Although evidence of environmental loading of salt has been found during peak usage, the spring rains and thaws usually dilute the concentrations of sodium in the area where salt was applied (USGS 2010). Given the low density of paved roadways traversing the watersheds to which salt is applied during winter storms in the Study Area, roadway salt contributions to in-stream pollutant loading is not considered a significant source.

3.4 SUMMARY OF SOURCES OF IMPAIRMENT

The data analyses discussions provided in Section 2 and 3 were conducted to evaluate whether certain flow conditions and spatial or temporal characteristics identify critical conditions associated with elevated levels of chlorides, sulfates, and TDS. Although dissolved mineral concentrations appear to be slightly higher during the summer low flow months, no significant relationships were found to define critical conditions for minerals associated with flow or season. The exceedance of water quality standards for minerals occurred uniformly throughout the year. Despite limited data, the following general deductions can be made regarding sources of minerals that can affect surface water quality in the impaired watersheds of the Study Area:

- Permitted facilities (WWTF, CAFOs) in the impaired watersheds contribute insignificant pollutant loading of chlorides, sulfates, and TDS.

- Given the limited number of developed land within the impaired watersheds of the Study Area, urban runoff contributes insignificant pollutant loading of chlorides, sulfates, and TDS.

- During high flow conditions, in-stream concentrations of minerals are lower because stormwater runoff provides dilution.

- Background concentrations of sulfate originate from drainage of geological formations and their high gypsum content.

- Groundwater flow can contribute minerals to receiving streams even under low flow conditions.

- The persistent availability of minerals may be attributed to historical oil and gas field development, underground injection well activities, and natural geology, despite various remediation efforts within the Study Area.

- Land application activities sites can result in the buildup of mineral concentrations on the land surface which could be transported to receiving waters under some rainfall runoff conditions.

- Given the limited number of paved roadways salted during winter storms within the impaired watersheds of the Study Area, roadway salts contribute insignificant pollutant loading of chlorides, sulfates, and TDS.

- The majority of mineral loadings in the Study Area originate from a variety of nonpoint sources, both background and anthropogenic sources.

- No critical conditions were identified for mineral TMDLs and therefore, mean annual conditions will need to be used to guide implementation.

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 as described in the following mathematical equation:

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

The WLA is the portion of the TMDL allocated to existing and future point sources. The LA is the portion of the TMDL allocated to nonpoint sources, including natural background sources. The MOS is intended to ensure that WQSs will be met. For chloride, sulfates, and TDS, TMDLs are expressed in pounds (lbs) per day which will represent the maximum one day load the stream can assimilate while still attaining the WQS.

4.2 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 identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the three following steps that are described in Subsections 4.2.1 through 4.2.3 below:

1. Prepare flow duration curves for gaged and ungaged WQM stations.

2. Estimate existing loading in the waterbody using ambient water quality data; and estimate loading in the waterbody using measured water quality data.

3. 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.

4.2.1 Development of Flow Duration Curves

Flow duration curves serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream gages to forecast future recurrence frequencies. Many WQM stations throughout Oklahoma do not have long-term flow data and therefore, flow frequencies must be estimated. One of the five waterbodies in the Study Area that require TMDLs does 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 C**.

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 C**.

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

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

Some instantaneous flow measurements were available from various agencies. These were not combined with the daily average flows or used in calculating flow percentiles, but were matched to chlorides, sulfates, or TDS grab measurements collected at the same site and time. When available, these instantaneous flow measurements were used in lieu of projected flows to calculate pollutant loads.

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0% and downward at a frequency near 100%, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100%. As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a “stair step” effect due to the USGS flow data rounding conventions near the limits of quantization. An example of a typical flow duration curve is shown in **Figure 4-1**.

4.2.2 Using Flow Duration Curves to Calculate Load Duration Curves

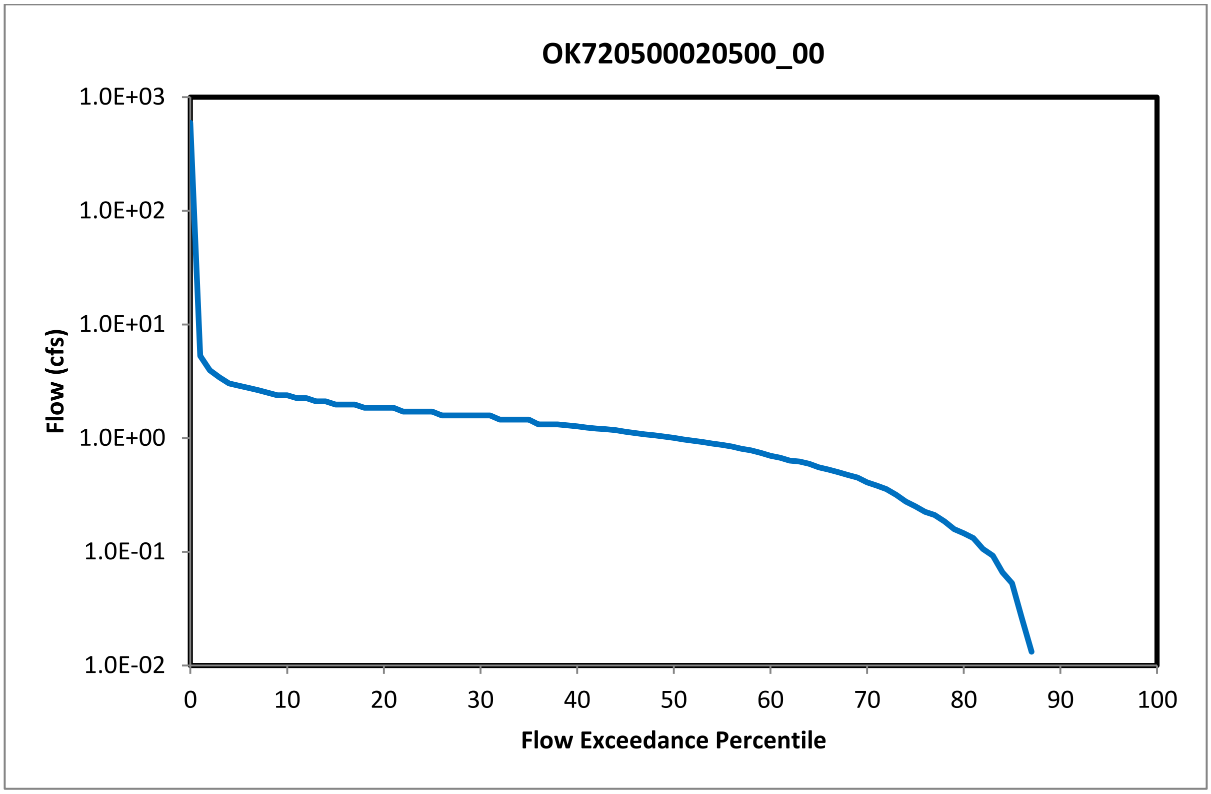
Existing in-stream loads can be estimated using LDCs. For chloride, sulfate, and TDS:

1. Match the water quality observations with the flow data from the same date.
2. Convert measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration.

4.2.3 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).

Figure 4-1 Flow Duration Curve for Palo Duro Creek (OK720500020500_00)



4.2.3.1 Step 1 - Generate LDCs

LDCs are similar in appearance to flow duration curves; however, for chloride, sulfate, or TDS the ordinate is expressed in terms of a load in lbs/day. The curve represents the single sample water quality criterion for chloride, sulfate, or TDS expressed in terms of a load through multiplication 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. Obtain water quality data for minerals.
4. 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.
5. For mineral TMDLs, match the water quality observations with the flow data from the same date and determine the corresponding exceedance percentile (See Section 5).

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow, in other words, the percent of historical observations that are equal to or exceed the measured or estimated flow.

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

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

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

Where:

WQS *is single sample criteria as indicated in* **Table 2-3.** *Values vary from* ***388 to 4824*** *mg/L for* ***chloride;*** *from* ***136 to 1173*** *for* ***sulfate,*** *and from* ***700 to 14,972*** *for* ***TDS.***

Unit conversion factor = 5.39377

Historical observations of chloride, sulfate, or TDS concentrations are paired with flow data and are plotted on the LDC for a stream. Loads representing exceedance of water quality criteria fall above the TMDL line.

4.2.3.2 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 the TMDLs in this report, an explicit MOS of 10% was selected. The 10% MOS has been used in other approved mineral TMDLs.

4.2.3.3 Step 3 - Calculate WLA

As previously stated, the pollutant load allocation for point sources is defined by the WLA. For mineral TMDLs a point source can be either a wastewater (continuous) or stormwater (MS4) discharge. Stormwater point sources are typically associated with urban and industrialized areas, and recent EPA guidance includes OPDES-permitted stormwater discharges as point source discharges and, therefore, part of the WLA.

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.

4.2.3.3.1 WLA for WWTF

OPDES permit limits for chloride, sulfate, and TDS are different from those of other parameters such as bacteria and turbidity (in terms of TSS) where permit limits are set equal to the instantaneous water quality standards. Permit limits for chloride, sulfate, and TDS are derived based on criterion long-term average (LTA). The criterion LTA and permitted design flow rate are used to calculate the WLAs for point source discharges. In cases where a permitted flow rate is not available for a WWTF, then the average of monthly flow rates derived from discharge monitoring reports can be used. WLA values for each OPDES wastewater discharger are then summed to represent the total WLA for a given waterbody. With this information, WLAs can be calculated using the approach as shown in the equations below.

WLA = Criterion LTA * flow * unit conversion factor (lbs/day)

Where:

Flow (mgd) = permitted flow or average monthly flow

Unit conversion factor = 8.3445

The criterion LTAs for chloride, sulfate, and TDS are determined using the method in OAC 252:690-3-79 through 3-85:

For impaired streams, since the stream flow cannot provide any dilution to effluent, water quality standards need to be met at the end of pipe. Therefore, the concentration based WLAs (CWLAs) are set to be equal to YMS (Yearly Mean Standard)--C_{YMS} and SS (Sample Standard)--C_{SS}, respectively.

$$CWLA_{YMS} = C_{YMS}$$

$$CWLA_{SS} = C_{SS}$$

CWLAs for the YMS criteria are already a long term average value, therefore YMS criteria LTAs are equal to the respective CWLAs.

$$LTA_{YMS} = CWLA_{YMS}$$

However, SS CWLA is a short term average, so the SS LTA is calculated on a 99% probability basis using the following equation:

$$LTA_{SS} = CWLA_{SS} * EXP\left[\ 0.5\ \ln(1 + Cv^2/4) - 2.326 * (\ln(1 + Cv^2/4))^{0.5}\ \right]$$

Where Cv is the variance of the effluent data for each mineral constituent. When fewer than 10 data point are available, a value of 0.6 is assumed for Cv.

The more stringent of the YMS and SS LTAs for each mineral constituent is used to develop water quality-based effluent limitations for that substance. OAC 785:45 requires that the long-term average mineral constituent concentrations used to develop permit limitations be not less than 700 mg/L for TDS and not less than 250 mg/L for chlorides and sulfates. The following equations are used to determine permit criterion LTA for each mineral constituent:

Chloride: $LTA_{Cl} = Max[250, Min(LTA_{YMS}, LTA_{SS})]$

Sulfate: $LTA_{SO4} = Max[250, Min(LTA_{YMS}, LTA_{SS})]$

TDS: $LTA_{TDS} = Max[700, Min(LTA_{YMS}, LTA_{SS})]$

4.2.3.4 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.

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

4.2.3.4.1 WLA for MS4s

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 cases the study watershed intersects only a portion of the permitted MS4 coverage areas.

4.2.3.5 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 if the arithmetic mean of the reduced values of all samples is less than the annual average criteria or if no more than 10% of the samples exceed the sample standard.

4.2.3.5.1 WLA Load Reduction

The WLA load reduction for mineral was not calculated as it was assumed that continuous dischargers (OPDES-permitted WWTFs) are adequately regulated to achieve WQS at the end-of-pipe and, therefore, no WLA reduction would be required.

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 mineral-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.

4.2.3.5.2 LA Load Reduction

After existing loading estimates are computed for each pollutant, nonpoint load reduction estimates for each waterbody 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. The PRG is the greater of:

1. Load reduction that ensures that no more than 10% of the samples exceed the sample standard or

2. Load reduction that ensures that the arithmetic mean of all data is less than the yearly mean standard.

The PRG is derived by selecting the greater of the two reductions.

SECTION 5 TMDL CALCULATIONS

5.1 FLOW DURATION CURVE

Following the same procedures described in Section 4.2, a flow duration curve for each waterbody requiring a TMDL in the Study Area was developed and are shown in **Figure 5-1** through **Figure 5-5**.

No flow gage exists on Bent Creek, segment OK720500010070_00. Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07157960 located in an adjacent watershed (Buffalo Creek near Lovedale, OK) since they are geographically close and have similar land uses. The flow duration curve was based on measured flows from 1966 to 1993.

The flow duration curve for the Beaver River (OK720500020140_00, OK720500020290_00, and OK720500020450_00) was estimated based on measured flows at USGS gage station 07234000 on the Beaver River at Beaver, OK. USGS flow data used to develop the flow duration curve range from 1937 to 2013.

The flow duration curve for Palo Duro Creek (OK720500020500_00) was estimated based on measured flows at USGS gage station 07233650 on Palo Duro Creek at Range, OK. USGS flow data used to develop the flow duration curve range from 1991 to 2010.

Figure 5-1 Flow Duration Curve for Bent Creek (OK720500010070_00)

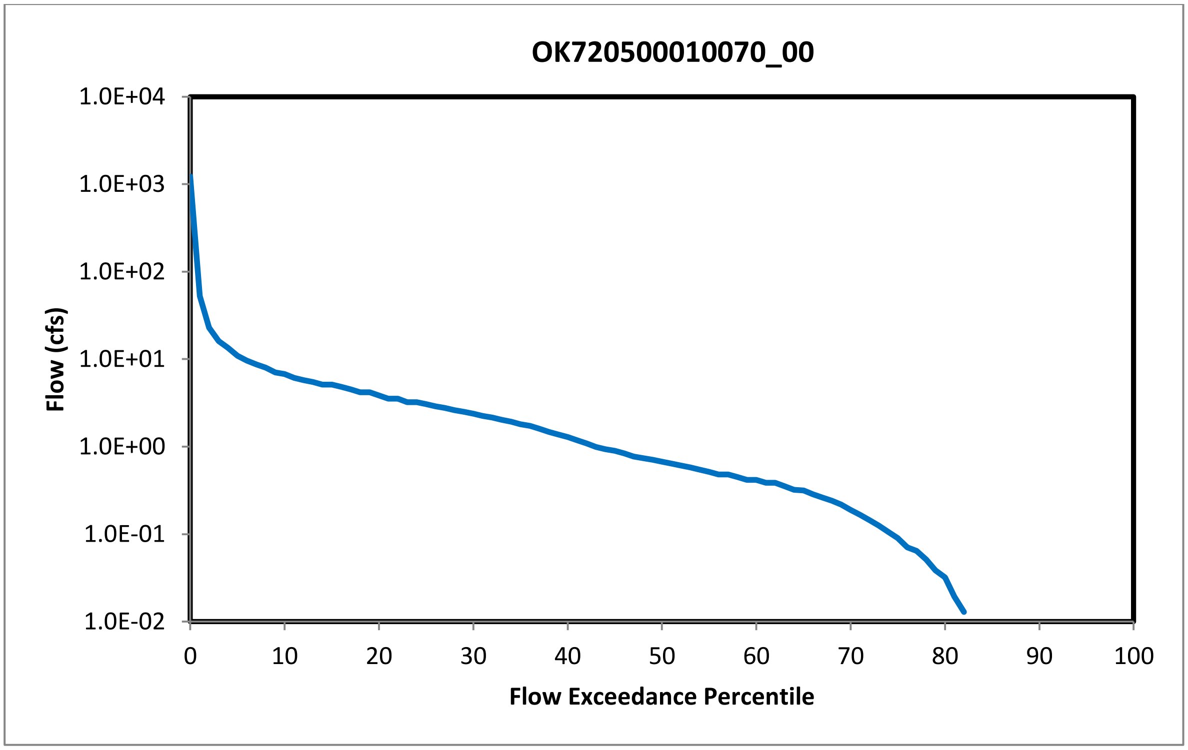


Figure 5-2 Flow Duration Curve for Beaver River (OK720500020140_00)

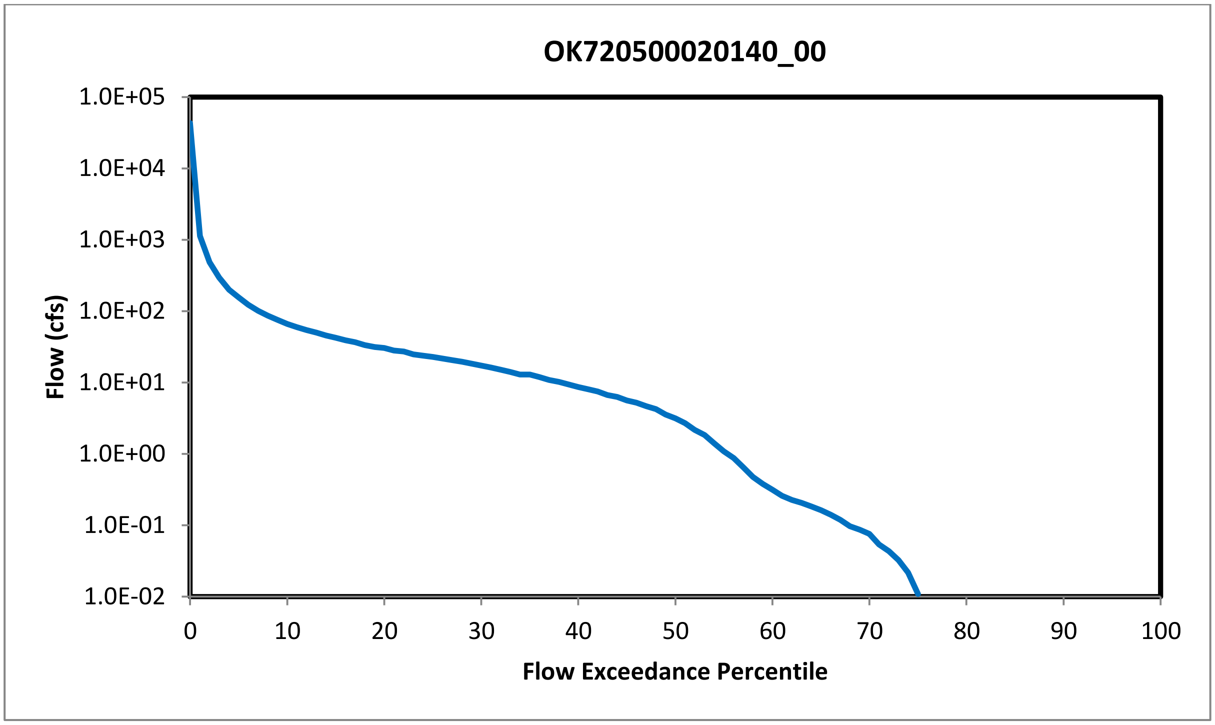


Figure 5-3 Flow Duration Curve for Beaver River (OK720500020290_00)

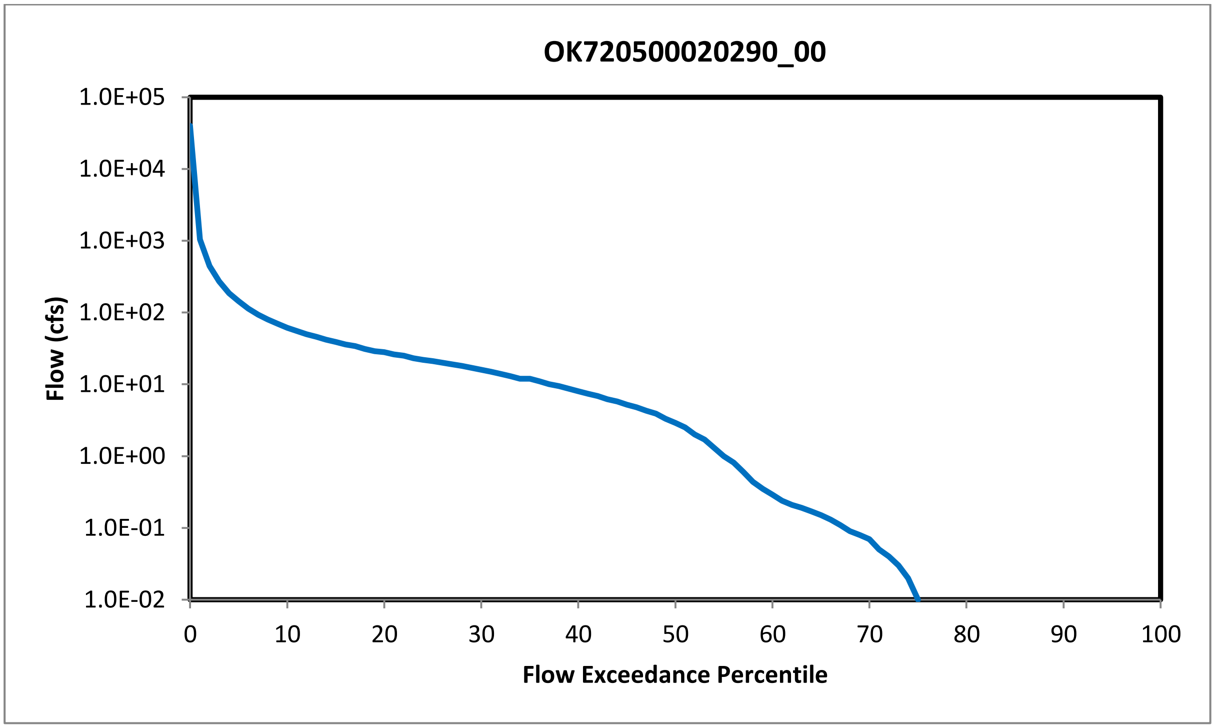


Figure 5-4 Flow Duration Curve for Beaver River (OK720500020450_00)

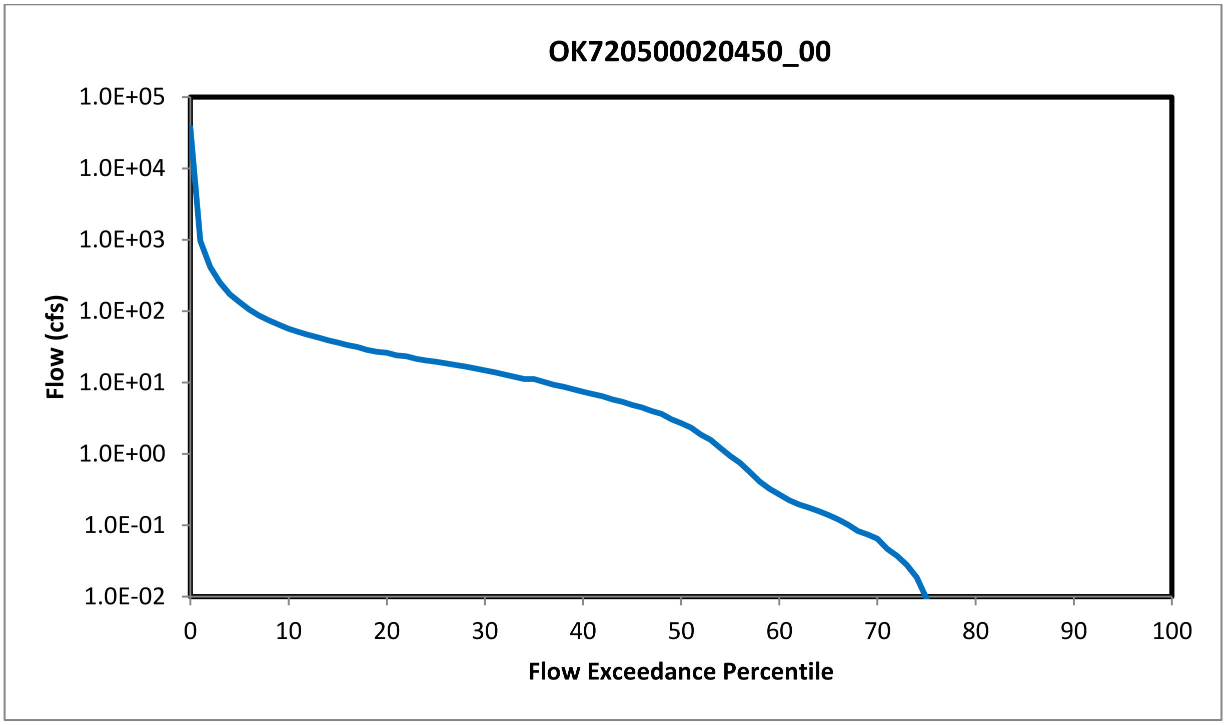
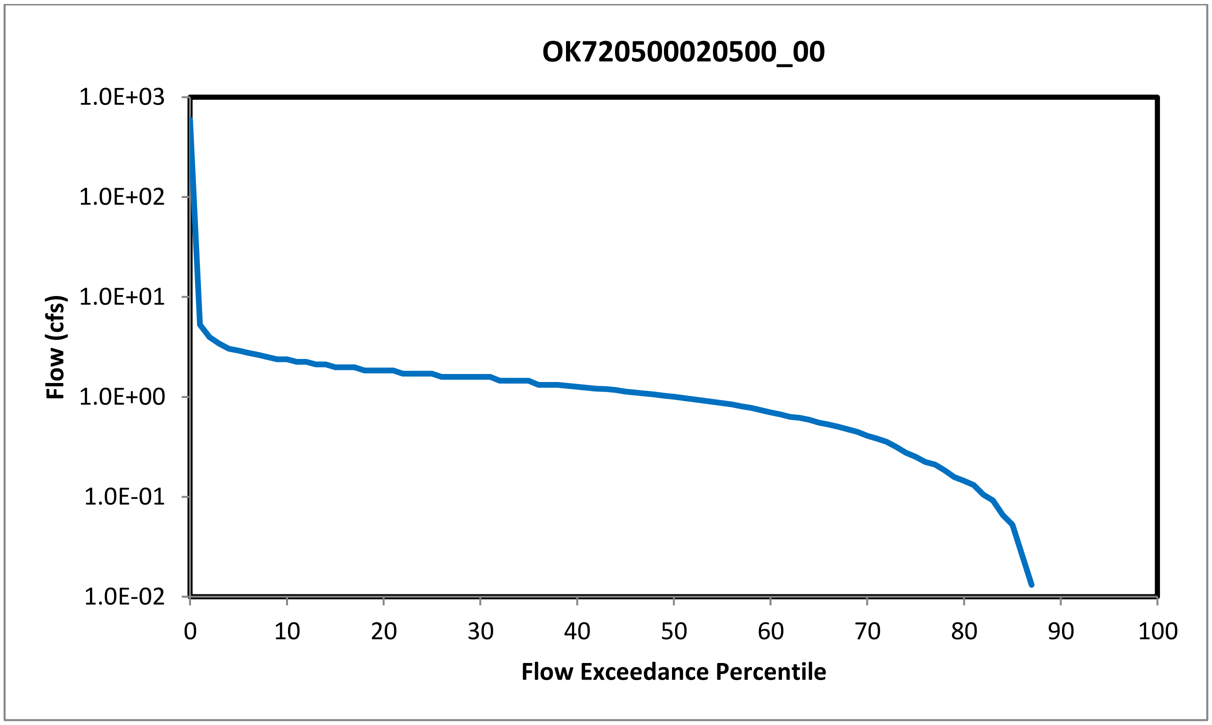


Figure 5-5 Flow Duration Curve for Palo Duro Creek (OK720500020500_00)



5.2 ESTIMATED LOADING AND CRITICAL CONDITIONS

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

To calculate the allowable chloride, sulfate, or TDS load at the WQ standard, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (5.39377) and the single sample WQ standard. This calculation produces the maximum chloride/sulfate load in the waterbody that will result in attainment of the standard. The allowable 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 load in pounds per day.

To estimate existing loading, chloride, sulfate, or TDS observations occurring from 1999 through 2012 are paired with the flows measured or projected on the same date for the waterbody. Pollutant loads are then calculated by multiplying the pollutant concentration by the flow rate and the unit conversion factor. The associated flow exceedance percentile is then matched with the flow from the tables provided in **Appendix C**. The observed loads are then added to the LDC plot as points. These points represent individual ambient water quality samples. Points above the LDC indicate the single sample WQS was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample did not exceed the WQS.

Figure 5-6 through **Figure 5-16** show the mineral LDCs developed for the waterbodies addressed in this TMDL report.

Figure 5-6 Load Duration Curve for Sulfate in Bent Creek (OK720500010070_00)

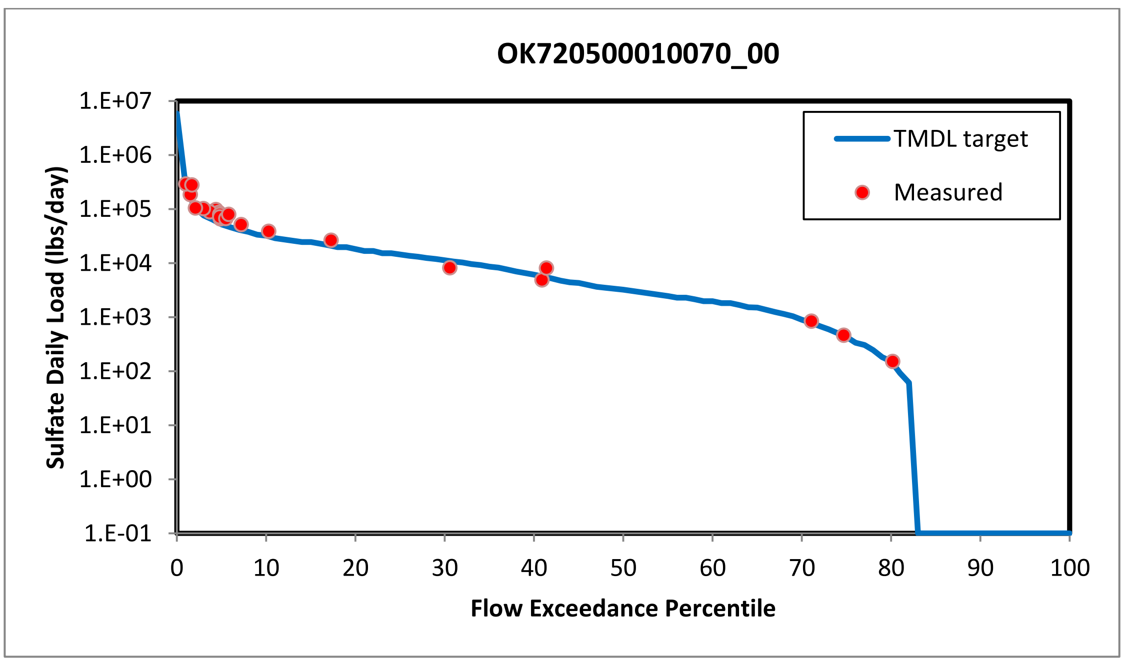


Figure 5-7 Load Duration Curve for Chloride in Beaver River (OK720500020140_00)

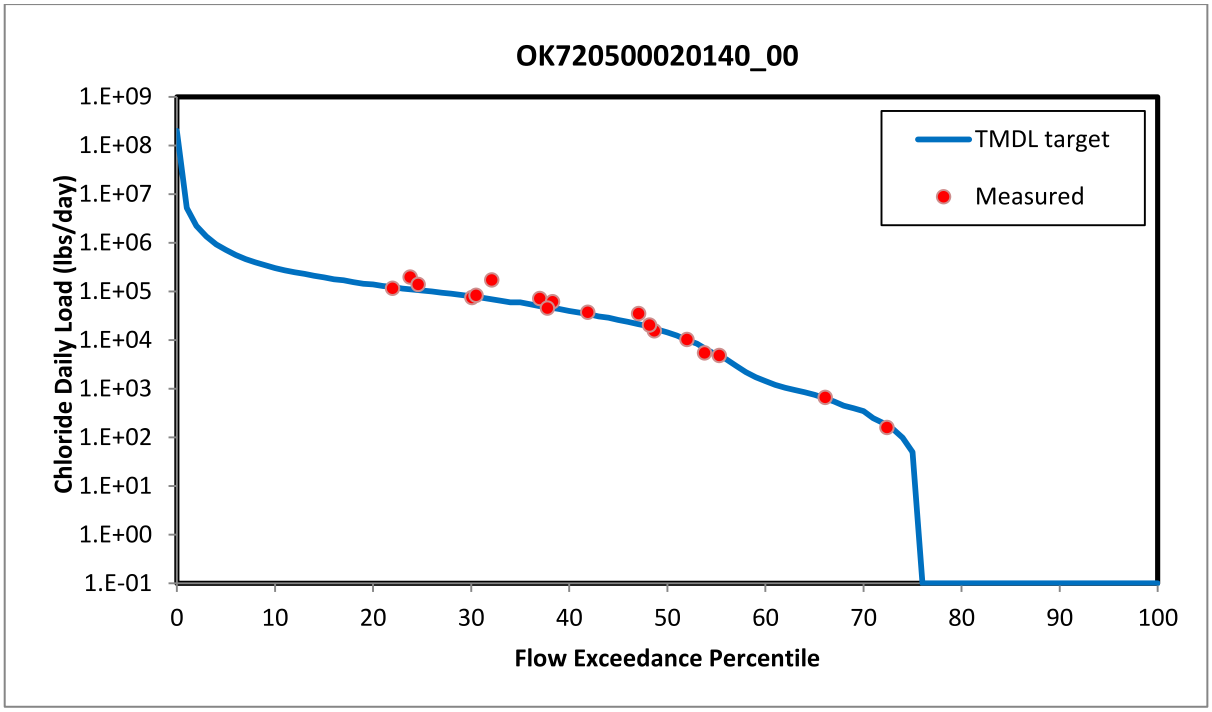


Figure 5-8 Load Duration Curve for Chloride in Beaver River (OK720500020290_00)

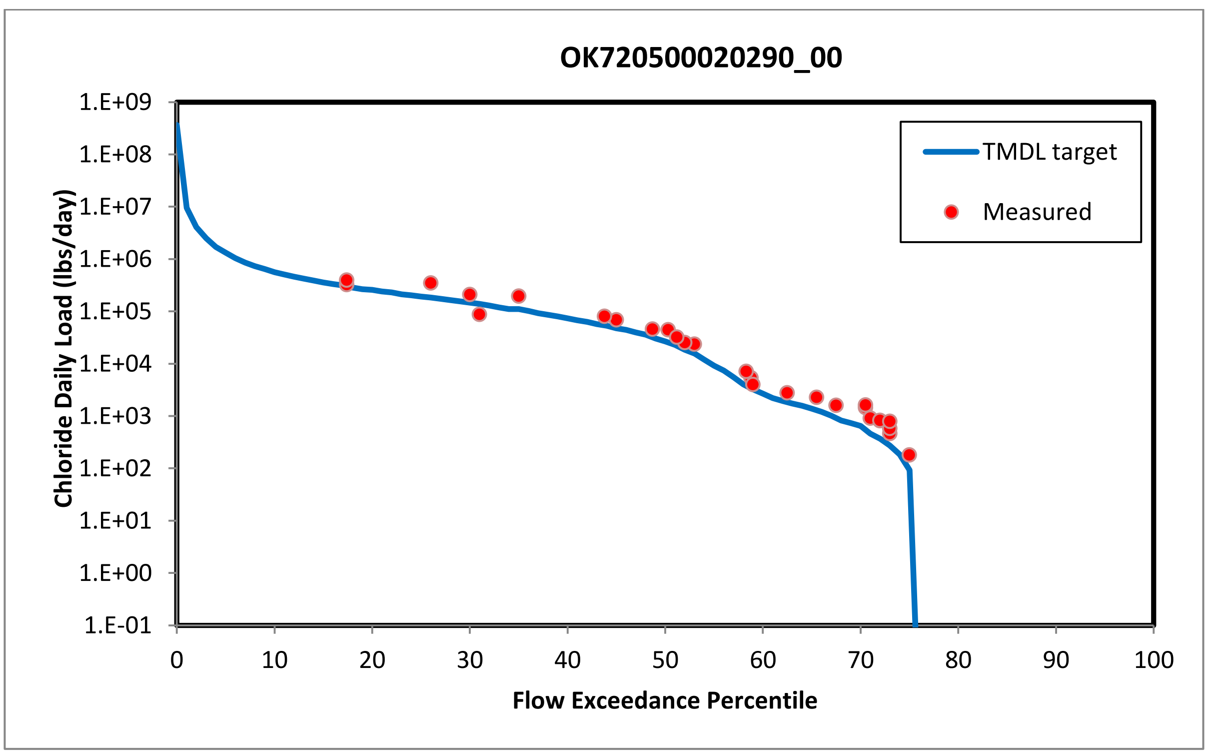


Figure 5-9 Load Duration Curve for Sulfate in Beaver River (OK720500020290_00)

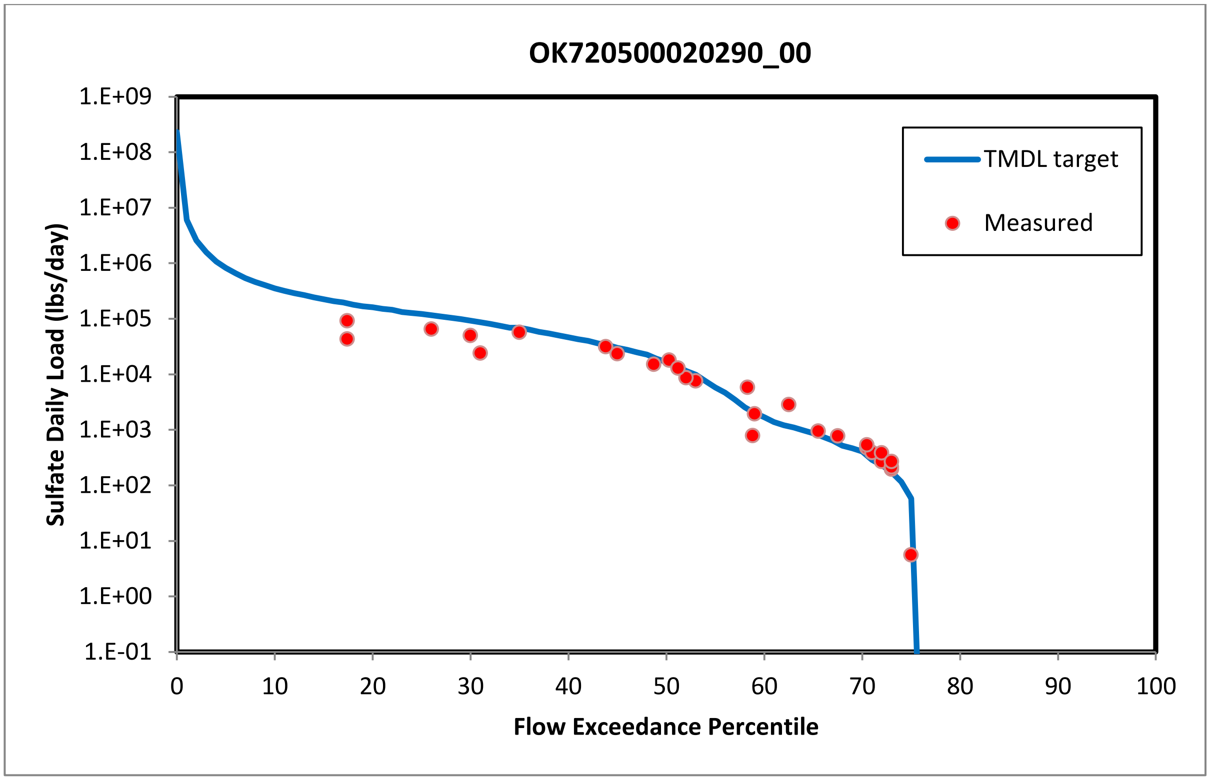


Figure 5-10 Load Duration Curve for TDS in Beaver River (OK720500020290_00)

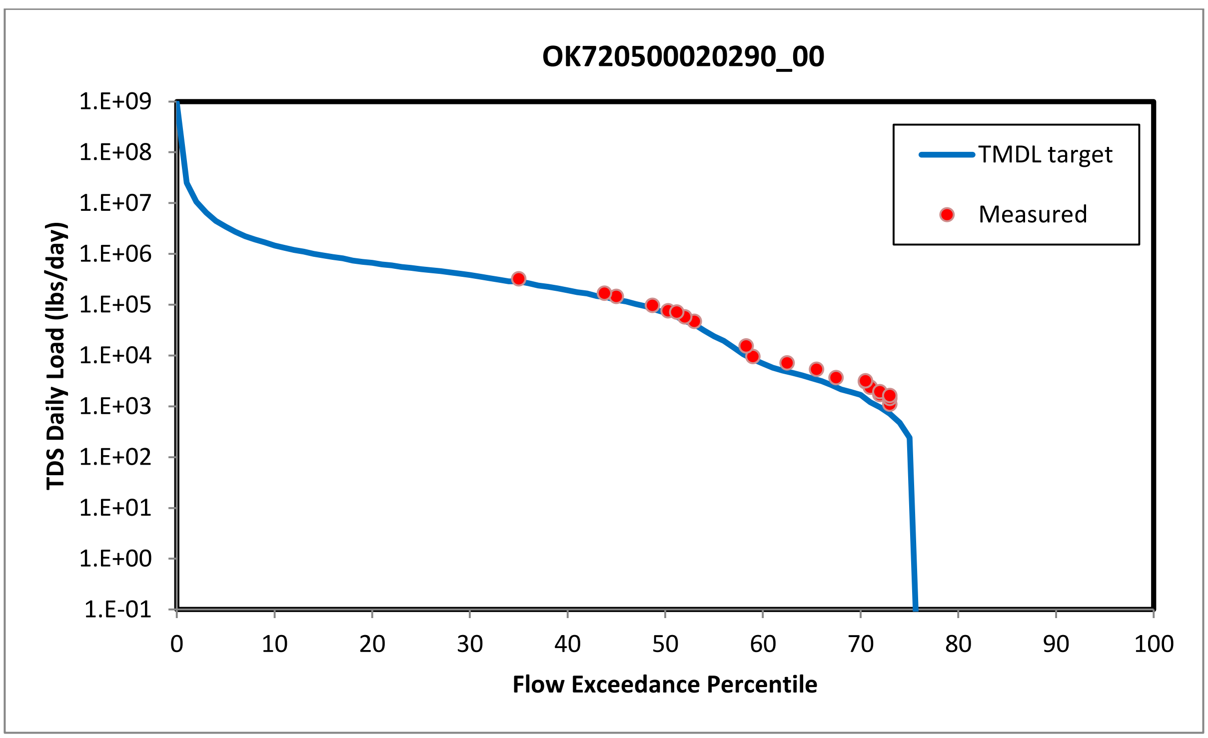


Figure 5-11 Load Duration Curve for Chloride in Beaver River (OK720500020450_00)

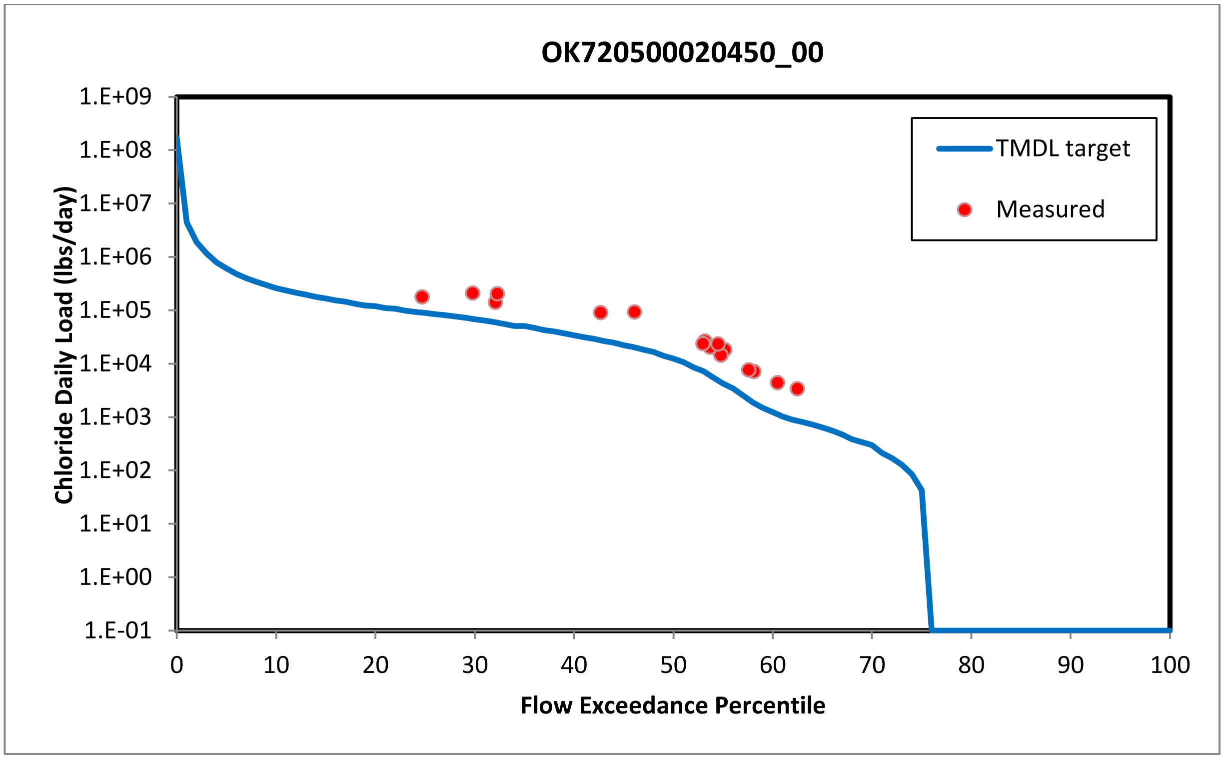


Figure 5-12 Load Duration Curve for Sulfate in Beaver River (OK720500020450_00)

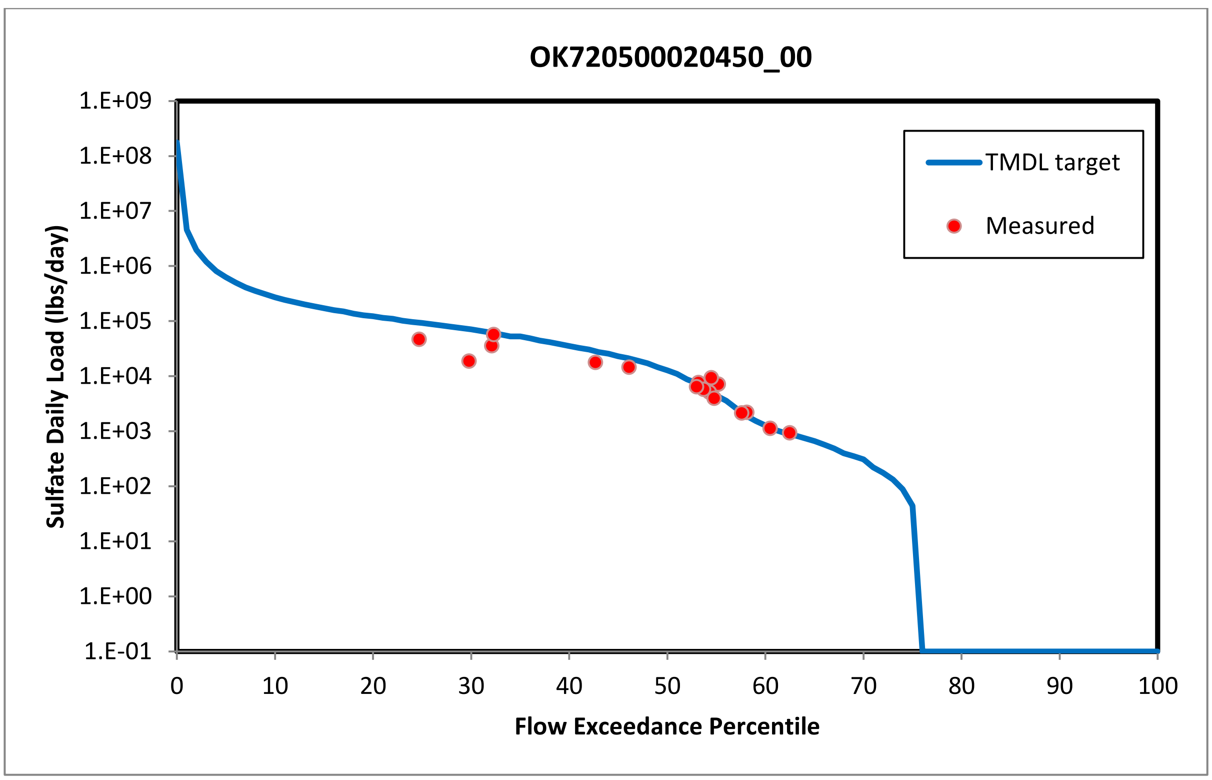


Figure 5-13 Load Duration Curve for TDS in Beaver River (OK720500020450_00)

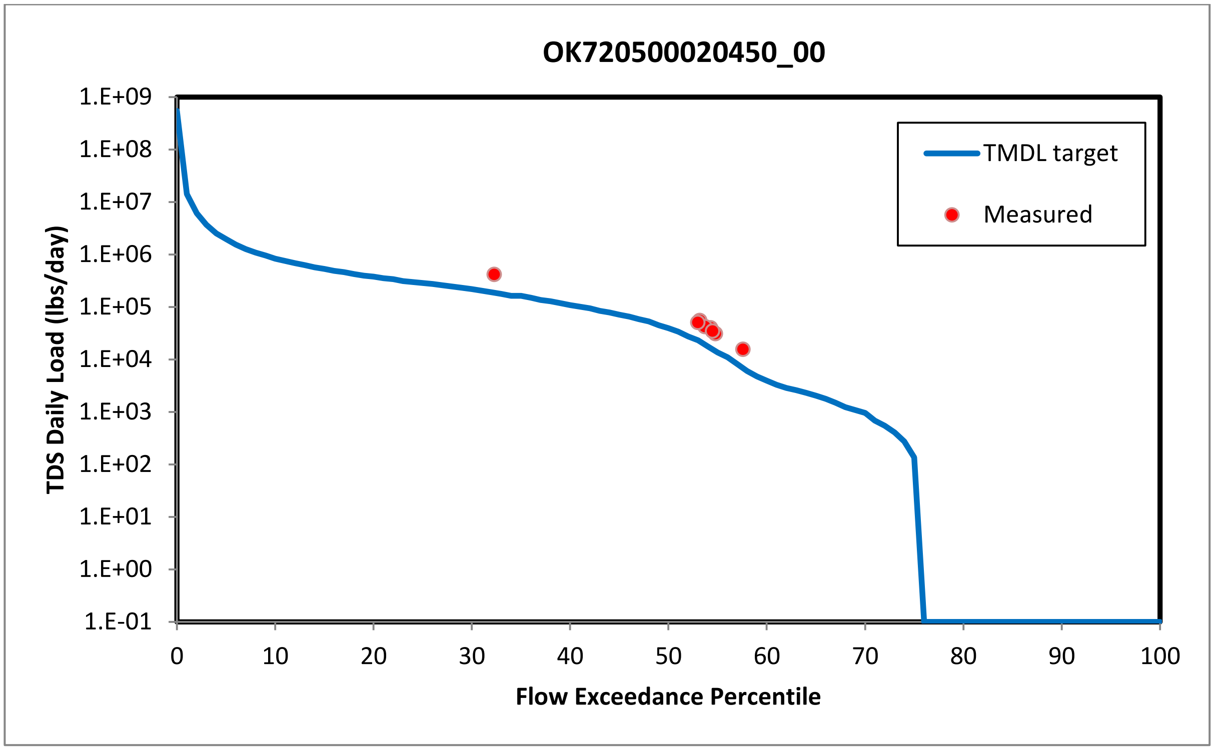


Figure 5-14 Load Duration Curve for Chloride in Palo Duro Creek (OK720500020500_00)

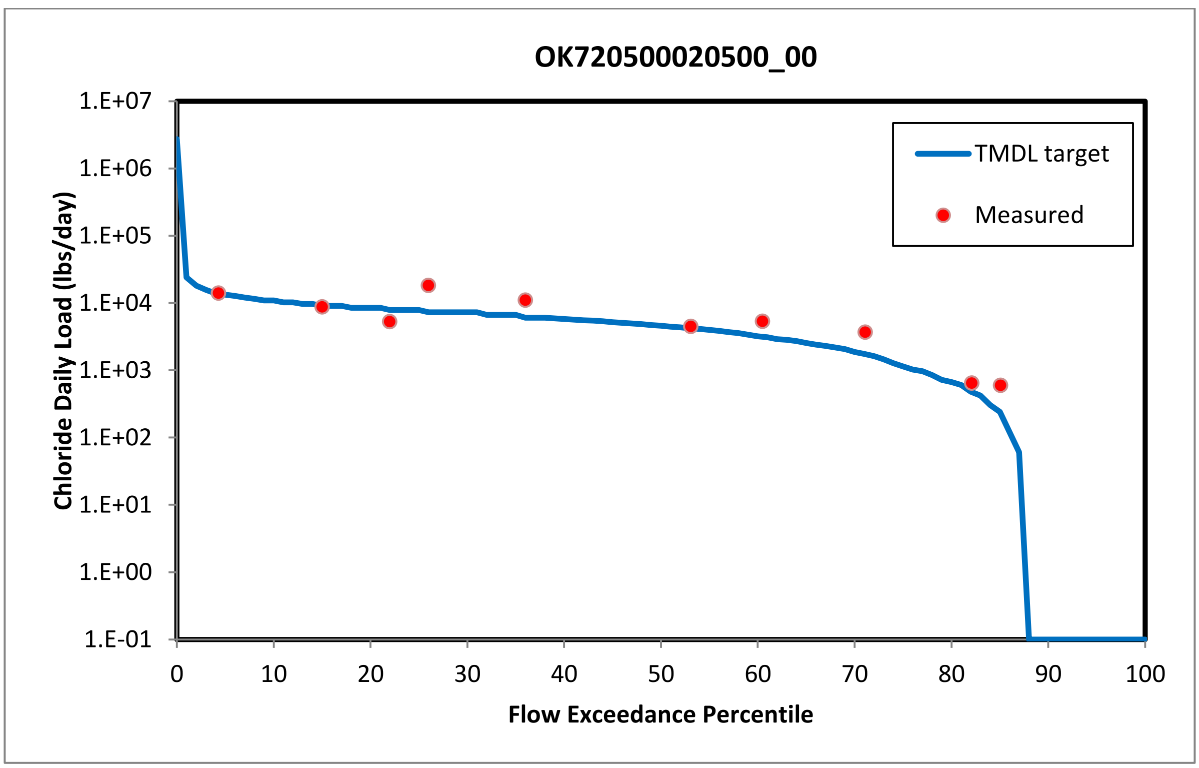


Figure 5-15 Load Duration Curve for Sulfate in Palo Duro Creek (OK720500020500_00)

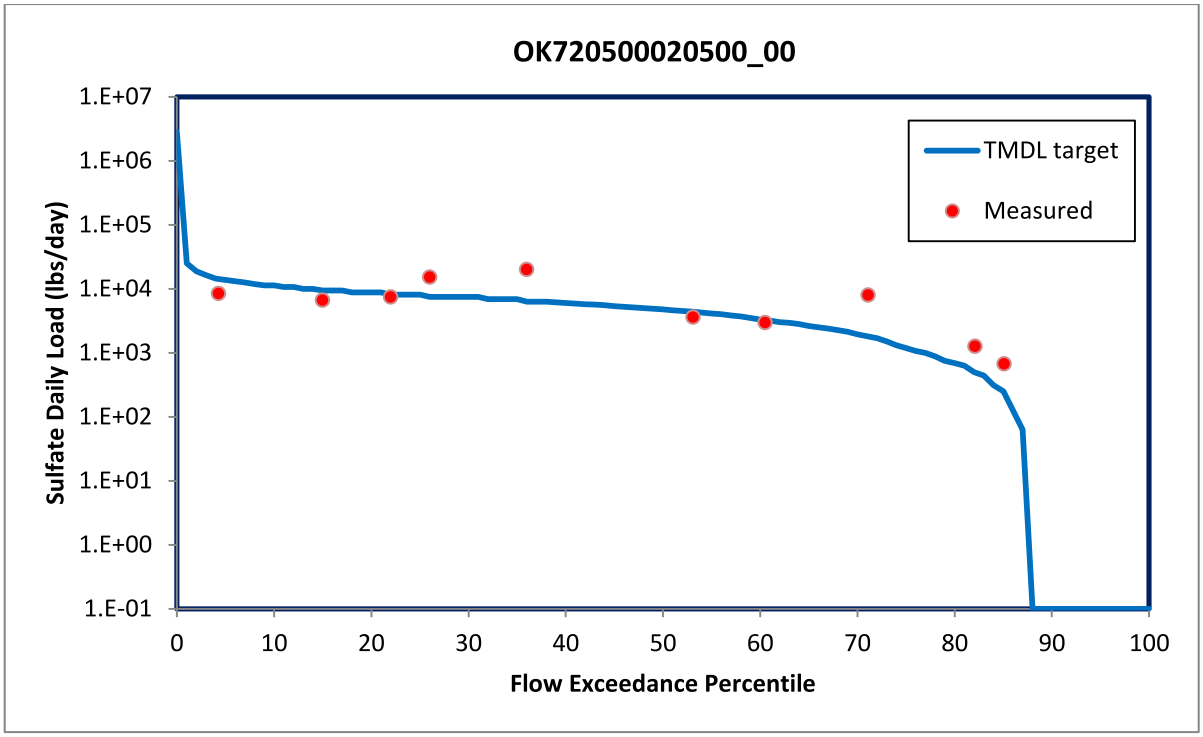
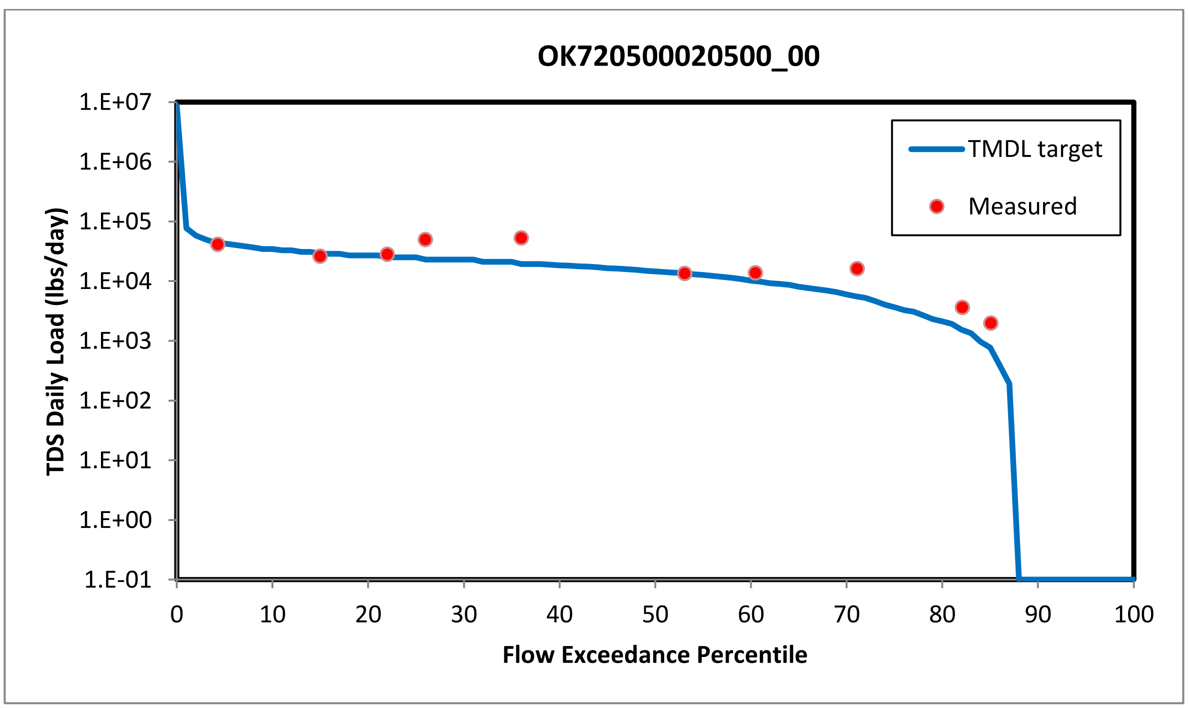


Figure 5-16 Load Duration Curve for TDS in Palo Duro Creek (OK720500020500_00)



5.3 ESTABLISHING PERCENT REDUCTION GOALS

The LDC approach recognizes that the assimilative capacity of a waterbody varies with flow condition. Existing loading and load reductions required to meet the TMDL water quality target can be calculated under different flow conditions. The difference between estimated existing loading and the water quality target is used to calculate the loading reductions required. PRGs for minerals are calculated using two criteria: 1) through an iterative process of taking a series of percent reduction values, applying each value uniformly to the concentrations of samples and verifying no more than 10% of the samples exceed the single sample WQS; and 2) calculating the required reduction for the average of all the data to be at or below the yearly mean WQS. The single sample WQS and the yearly mean WQS are defined in **Table 2-5** which were derived from Appendix F of the OAC 785:45. The PRG is the greater of the two reductions.

Table 5-1 lists the percent reductions necessary to meet the TMDL water quality target for each mineral in each of the impaired waterbodies in the Study Area. The PRGs range from 39.4% to 77.9%.

Table 5-1 TMDL Percent Reductions Required to Meet Water Quality Standards for Minerals

Waterbody ID	Waterbody Name	Required Reduction Rate					
		Chloride: Single Sample	Chloride: Average	Sulfate: Single Sample	Sulfate: Average	TDS: Single Sample	TDS: Average
OK720500010070_00	Bent Creek			38.5%	40.3%		
OK720500020140_00	Beaver River	43.4%	34.9%				
OK720500020290_00	Beaver River	66.0%	59.6%	39.4%	29.0%	54.4%	50.9%
OK720500020450_00	Beaver River	77.9%	77.9%	40.2%	20.1%	58.9%	64.5%
OK720500020500_00	Palo Duro Creek	59.4%	50.2%	68.9%	60.7%	63.6%	55.1%

5.4 WASTELOAD ALLOCATION

5.4.1 WLA for WWTFs

OPDES-permitted facilities discharging to impaired streams are required to meet the standards at the end of pipe. Thus, the WLA for each facility discharging to streams included in this TMDL Study is derived from the following equation:

$$WLA\_{WWTF} = WQS\_{LTA} * flow * \text{unit conversion factor (lb/day)}$$

Where:

WQS_{LTA} = is either the yearly mean standard (CYMS) or the sample standard (CSS) if either standard is greater than default.

Flow (mgd) = permitted flow. In cases where a permitted flow rate is not available for a WWTF, then the average monthly flow rate is used.

Unit conversion factor = 8.34449

However, there are no OPDES-permitted facilities in the Study Area in Oklahoma.

5.4.2 WLA for MS4s

There are no permitted MS4s in the Study Area, therefore a WLA for MS4s was not calculated.

5.5 LOAD ALLOCATION

As discussed in Section 3, nonpoint source loading to each waterbody emanate from a number of different sources. The data analysis and the LDCs indicate that exceedances for each waterbody are the result of a variety of nonpoint source loading. The LAs for each waterbodies are calculated as the difference between the TMDL, MOS, and WLA, as follows:

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

5.6 SEASONAL VARIABILITY

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation for the mineral TMDLs established in this report was accounted for by using more than five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.7 MARGIN OF SAFETY

Federal regulations [40 CFR §130.7(c)(1)] require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained. EPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for the lack of knowledge, then the MOS is considered explicit. For chloride, sulfate, and TDS TMDLs, an explicit MOS was set at 10%.

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 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 will vary with flow condition, and are calculated at every 5th flow interval percentile. **Tables 5-2** through **5-12** summarize the allocations for the five waterbodies in the Study Area that require mineral TMDLs.

Table 5-2 Sulfate TMDL Calculation for Bent Creek (OK720500010070_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	1,229.7	6.48E+06	0.00E+00	0.00E+00	5.83E+06	6.48E+05
5	10.9	5.75E+04	0.00E+00	0.00E+00	5.18E+04	5.75E+03
10	6.7	3.55E+04	0.00E+00	0.00E+00	3.20E+04	3.55E+03
15	5.1	2.71E+04	0.00E+00	0.00E+00	2.44E+04	2.71E+03
20	3.9	2.03E+04	0.00E+00	0.00E+00	1.83E+04	2.03E+03
25	3.1	1.61E+04	0.00E+00	0.00E+00	1.45E+04	1.61E+03
30	2.4	1.25E+04	0.00E+00	0.00E+00	1.13E+04	1.25E+03
35	1.8	9.48E+03	0.00E+00	0.00E+00	8.53E+03	9.48E+02
40	1.3	6.77E+03	0.00E+00	0.00E+00	6.09E+03	6.77E+02
45	0.90	4.74E+03	0.00E+00	0.00E+00	4.26E+03	4.74E+02
50	0.67	3.55E+03	0.00E+00	0.00E+00	3.20E+03	3.55E+02
55	0.51	2.71E+03	0.00E+00	0.00E+00	2.44E+03	2.71E+02
60	0.42	2.20E+03	0.00E+00	0.00E+00	1.98E+03	2.20E+02
65	0.31	1.66E+03	0.00E+00	0.00E+00	1.49E+03	1.66E+02
70	0.19	9.98E+02	0.00E+00	0.00E+00	8.98E+02	9.98E+01
75	0.09	4.74E+02	0.00E+00	0.00E+00	4.26E+02	4.74E+01
80	0.03	1.69E+02	0.00E+00	0.00E+00	1.52E+02	1.69E+01
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-3 Chloride TMDL Calculation for Beaver River (OK720500020140_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	43,211.2	2.20E+08	0.00E+00	0.00E+00	1.98E+08	2.20E+07
5	154.9	7.89E+05	0.00E+00	0.00E+00	7.10E+05	7.89E+04
10	66.1	3.37E+05	0.00E+00	0.00E+00	3.03E+05	3.37E+04
15	42.2	2.15E+05	0.00E+00	0.00E+00	1.94E+05	2.15E+04
20	30.3	1.55E+05	0.00E+00	0.00E+00	1.39E+05	1.55E+04
25	22.7	1.16E+05	0.00E+00	0.00E+00	1.04E+05	1.16E+04
30	17.3	8.83E+04	0.00E+00	0.00E+00	7.95E+04	8.83E+03
35	13.0	6.62E+04	0.00E+00	0.00E+00	5.96E+04	6.62E+03
40	8.7	4.42E+04	0.00E+00	0.00E+00	3.97E+04	4.42E+03
45	5.6	2.87E+04	0.00E+00	0.00E+00	2.58E+04	2.87E+03
50	3.1	1.60E+04	0.00E+00	0.00E+00	1.44E+04	1.60E+03
55	1.1	5.52E+03	0.00E+00	0.00E+00	4.97E+03	5.52E+02
60	0.31	1.60E+03	0.00E+00	0.00E+00	1.44E+03	1.60E+02
65	0.16	8.28E+02	0.00E+00	0.00E+00	7.45E+02	8.28E+01
70	0.08	3.86E+02	0.00E+00	0.00E+00	3.48E+02	3.86E+01
75	0.01	5.52E+01	0.00E+00	0.00E+00	4.97E+01	5.52E+00
80	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-4 Chloride TMDL Calculation for Beaver River (OK720500020290_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	39,900.0	4.07E+08	0.00E+00	0.00E+00	3.67E+08	4.07E+07
5	143.0	1.46E+06	0.00E+00	0.00E+00	1.31E+06	1.46E+05
10	61.0	6.25E+05	0.00E+00	0.00E+00	5.61E+05	6.25E+04
15	39.0	3.98E+05	0.00E+00	0.00E+00	3.58E+05	3.98E+04
20	28.0	2.86E+05	0.00E+00	0.00E+00	2.57E+05	2.86E+04
25	21.0	2.14E+05	0.00E+00	0.00E+00	1.93E+05	2.14E+04
30	16.0	1.63E+05	0.00E+00	0.00E+00	1.47E+05	1.63E+04
35	12.0	1.23E+05	0.00E+00	0.00E+00	1.10E+05	1.23E+04
40	8.0	8.17E+04	0.00E+00	0.00E+00	7.35E+04	8.17E+03
45	5.2	5.31E+04	0.00E+00	0.00E+00	4.78E+04	5.31E+03
50	2.9	2.96E+04	0.00E+00	0.00E+00	2.66E+04	2.96E+03
55	1.0	1.02E+04	0.00E+00	0.00E+00	9.19E+03	1.02E+03
60	0.29	2.96E+03	0.00E+00	0.00E+00	2.66E+03	2.96E+02
65	0.15	1.53E+03	0.00E+00	0.00E+00	1.38E+03	1.53E+02
70	0.07	7.15E+02	0.00E+00	0.00E+00	6.43E+02	7.15E+01
75	0.01	1.02E+02	0.00E+00	0.00E+00	9.19E+01	1.02E+01
80	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-5 Sulfate TMDL Calculation for Beaver River (OK720500020290_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	39,900.0	2.57E+08	0.00E+00	0.00E+00	2.31E+08	2.57E+07
5	143.0	9.19E+05	0.00E+00	0.00E+00	8.27E+05	9.19E+04
10	61.0	3.92E+05	0.00E+00	0.00E+00	3.53E+05	3.92E+04
15	39.0	2.51E+05	0.00E+00	0.00E+00	2.26E+05	2.51E+04
20	28.0	1.80E+05	0.00E+00	0.00E+00	1.62E+05	1.80E+04
25	21.0	1.35E+05	0.00E+00	0.00E+00	1.22E+05	1.35E+04
30	16.0	1.03E+05	0.00E+00	0.00E+00	9.26E+04	1.03E+04
35	12.0	7.72E+04	0.00E+00	0.00E+00	6.94E+04	7.72E+03
40	8.0	5.14E+04	0.00E+00	0.00E+00	4.63E+04	5.14E+03
45	5.2	3.34E+04	0.00E+00	0.00E+00	3.01E+04	3.34E+03
50	2.9	1.86E+04	0.00E+00	0.00E+00	1.68E+04	1.86E+03
55	1.0	6.43E+03	0.00E+00	0.00E+00	5.79E+03	6.43E+02
60	0.29	1.86E+03	0.00E+00	0.00E+00	1.68E+03	1.86E+02
65	0.15	9.64E+02	0.00E+00	0.00E+00	8.68E+02	9.64E+01
70	0.07	4.50E+02	0.00E+00	0.00E+00	4.05E+02	4.50E+01
75	0.01	6.43E+01	0.00E+00	0.00E+00	5.79E+01	6.43E+00
80	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-6 TDS TMDL Calculation for Beaver River (OK720500020290_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	39,900.0	1.06E+09	0.00E+00	0.00E+00	9.56E+08	1.06E+08
5	143.0	3.81E+06	0.00E+00	0.00E+00	3.43E+06	3.81E+05
10	61.0	1.62E+06	0.00E+00	0.00E+00	1.46E+06	1.62E+05
15	39.0	1.04E+06	0.00E+00	0.00E+00	9.35E+05	1.04E+05
20	28.0	7.46E+05	0.00E+00	0.00E+00	6.71E+05	7.46E+04
25	21.0	5.59E+05	0.00E+00	0.00E+00	5.03E+05	5.59E+04
30	16.0	4.26E+05	0.00E+00	0.00E+00	3.84E+05	4.26E+04
35	12.0	3.20E+05	0.00E+00	0.00E+00	2.88E+05	3.20E+04
40	8.0	2.13E+05	0.00E+00	0.00E+00	1.92E+05	2.13E+04
45	5.2	1.38E+05	0.00E+00	0.00E+00	1.25E+05	1.38E+04
50	2.9	7.72E+04	0.00E+00	0.00E+00	6.95E+04	7.72E+03
55	1.0	2.66E+04	0.00E+00	0.00E+00	2.40E+04	2.66E+03
60	0.29	7.72E+03	0.00E+00	0.00E+00	6.95E+03	7.72E+02
65	0.15	4.00E+03	0.00E+00	0.00E+00	3.60E+03	4.00E+02
70	0.07	1.86E+03	0.00E+00	0.00E+00	1.68E+03	1.86E+02
75	0.01	2.66E+02	0.00E+00	0.00E+00	2.40E+02	2.66E+01
80	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-7 Chloride TMDL Calculation for Beaver River (OK720500020450_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	37,043.2	1.89E+08	0.00E+00	0.00E+00	1.70E+08	1.89E+07
5	132.8	6.77E+05	0.00E+00	0.00E+00	6.09E+05	6.77E+04
10	56.6	2.89E+05	0.00E+00	0.00E+00	2.60E+05	2.89E+04
15	36.2	1.85E+05	0.00E+00	0.00E+00	1.66E+05	1.85E+04
20	26.0	1.33E+05	0.00E+00	0.00E+00	1.19E+05	1.33E+04
25	19.5	9.94E+04	0.00E+00	0.00E+00	8.94E+04	9.94E+03
30	14.9	7.57E+04	0.00E+00	0.00E+00	6.81E+04	7.57E+03
35	11.1	5.68E+04	0.00E+00	0.00E+00	5.11E+04	5.68E+03
40	7.4	3.79E+04	0.00E+00	0.00E+00	3.41E+04	3.79E+03
45	4.8	2.46E+04	0.00E+00	0.00E+00	2.21E+04	2.46E+03
50	2.7	1.37E+04	0.00E+00	0.00E+00	1.24E+04	1.37E+03
55	0.93	4.73E+03	0.00E+00	0.00E+00	4.26E+03	4.73E+02
60	0.27	1.37E+03	0.00E+00	0.00E+00	1.24E+03	1.37E+02
65	0.14	7.10E+02	0.00E+00	0.00E+00	6.39E+02	7.10E+01
70	0.06	3.31E+02	0.00E+00	0.00E+00	2.98E+02	3.31E+01
75	0.01	4.73E+01	0.00E+00	0.00E+00	4.26E+01	4.73E+00
80	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-8 Sulfate TMDL Calculation for Beaver River (OK720500020450_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	37,043.2	1.95E+08	0.00E+00	0.00E+00	1.76E+08	1.95E+07
5	132.8	7.00E+05	0.00E+00	0.00E+00	6.30E+05	7.00E+04
10	56.6	2.98E+05	0.00E+00	0.00E+00	2.69E+05	2.98E+04
15	36.2	1.91E+05	0.00E+00	0.00E+00	1.72E+05	1.91E+04
20	26.0	1.37E+05	0.00E+00	0.00E+00	1.23E+05	1.37E+04
25	19.5	1.03E+05	0.00E+00	0.00E+00	9.25E+04	1.03E+04
30	14.9	7.83E+04	0.00E+00	0.00E+00	7.05E+04	7.83E+03
35	11.1	5.87E+04	0.00E+00	0.00E+00	5.28E+04	5.87E+03
40	7.4	3.91E+04	0.00E+00	0.00E+00	3.52E+04	3.91E+03
45	4.8	2.54E+04	0.00E+00	0.00E+00	2.29E+04	2.54E+03
50	2.7	1.42E+04	0.00E+00	0.00E+00	1.28E+04	1.42E+03
55	0.93	4.89E+03	0.00E+00	0.00E+00	4.40E+03	4.89E+02
60	0.27	1.42E+03	0.00E+00	0.00E+00	1.28E+03	1.42E+02
65	0.14	7.34E+02	0.00E+00	0.00E+00	6.60E+02	7.34E+01
70	0.06	3.42E+02	0.00E+00	0.00E+00	3.08E+02	3.42E+01
75	0.01	4.89E+01	0.00E+00	0.00E+00	4.40E+01	4.89E+00
80	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-9 TDS TMDL Calculation for Beaver River (OK720500020450_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	37,043.2	6.01E+08	0.00E+00	0.00E+00	5.41E+08	6.01E+07
5	132.8	2.16E+06	0.00E+00	0.00E+00	1.94E+06	2.16E+05
10	56.6	9.19E+05	0.00E+00	0.00E+00	8.27E+05	9.19E+04
15	36.2	5.88E+05	0.00E+00	0.00E+00	5.29E+05	5.88E+04
20	26.0	4.22E+05	0.00E+00	0.00E+00	3.80E+05	4.22E+04
25	19.5	3.17E+05	0.00E+00	0.00E+00	2.85E+05	3.17E+04
30	14.9	2.41E+05	0.00E+00	0.00E+00	2.17E+05	2.41E+04
35	11.1	1.81E+05	0.00E+00	0.00E+00	1.63E+05	1.81E+04
40	7.4	1.21E+05	0.00E+00	0.00E+00	1.09E+05	1.21E+04
45	4.8	7.84E+04	0.00E+00	0.00E+00	7.05E+04	7.84E+03
50	2.7	4.37E+04	0.00E+00	0.00E+00	3.93E+04	4.37E+03
55	0.93	1.51E+04	0.00E+00	0.00E+00	1.36E+04	1.51E+03
60	0.27	4.37E+03	0.00E+00	0.00E+00	3.93E+03	4.37E+02
65	0.14	2.26E+03	0.00E+00	0.00E+00	2.03E+03	2.26E+02
70	0.06	1.06E+03	0.00E+00	0.00E+00	9.50E+02	1.06E+02
75	0.01	1.51E+02	0.00E+00	0.00E+00	1.36E+02	1.51E+01
80	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-10 Chloride TMDL Calculation for Palo Duro Creek (OK720500020500_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	595.3	3.03E+06	0.00E+00	0.00E+00	2.73E+06	3.03E+05
5	2.9	1.48E+04	0.00E+00	0.00E+00	1.33E+04	1.48E+03
10	2.4	1.21E+04	0.00E+00	0.00E+00	1.09E+04	1.21E+03
15	2.0	1.01E+04	0.00E+00	0.00E+00	9.06E+03	1.01E+03
20	1.8	9.40E+03	0.00E+00	0.00E+00	8.46E+03	9.40E+02
25	1.7	8.73E+03	0.00E+00	0.00E+00	7.85E+03	8.73E+02
30	1.6	8.06E+03	0.00E+00	0.00E+00	7.25E+03	8.06E+02
35	1.4	7.38E+03	0.00E+00	0.00E+00	6.65E+03	7.38E+02
40	1.3	6.44E+03	0.00E+00	0.00E+00	5.80E+03	6.44E+02
45	1.1	5.77E+03	0.00E+00	0.00E+00	5.20E+03	5.77E+02
50	1.0	5.10E+03	0.00E+00	0.00E+00	4.59E+03	5.10E+02
55	0.87	4.43E+03	0.00E+00	0.00E+00	3.99E+03	4.43E+02
60	0.70	3.56E+03	0.00E+00	0.00E+00	3.20E+03	3.56E+02
65	0.55	2.82E+03	0.00E+00	0.00E+00	2.54E+03	2.82E+02
70	0.41	2.08E+03	0.00E+00	0.00E+00	1.87E+03	2.08E+02
75	0.25	1.28E+03	0.00E+00	0.00E+00	1.15E+03	1.28E+02
80	0.14	7.38E+02	0.00E+00	0.00E+00	6.65E+02	7.38E+01
85	0.05	2.69E+02	0.00E+00	0.00E+00	2.42E+02	2.69E+01
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-11 Sulfate TMDL Calculation for Palo Duro Creek (OK720500020500_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	595.3	3.14E+06	0.00E+00	0.00E+00	2.82E+06	3.14E+05
5	2.9	1.53E+04	0.00E+00	0.00E+00	1.37E+04	1.53E+03
10	2.4	1.25E+04	0.00E+00	0.00E+00	1.12E+04	1.25E+03
15	2.0	1.04E+04	0.00E+00	0.00E+00	9.37E+03	1.04E+03
20	1.8	9.72E+03	0.00E+00	0.00E+00	8.75E+03	9.72E+02
25	1.7	9.02E+03	0.00E+00	0.00E+00	8.12E+03	9.02E+02
30	1.6	8.33E+03	0.00E+00	0.00E+00	7.50E+03	8.33E+02
35	1.4	7.63E+03	0.00E+00	0.00E+00	6.87E+03	7.63E+02
40	1.3	6.66E+03	0.00E+00	0.00E+00	6.00E+03	6.66E+02
45	1.1	5.97E+03	0.00E+00	0.00E+00	5.37E+03	5.97E+02
50	1.0	5.27E+03	0.00E+00	0.00E+00	4.75E+03	5.27E+02
55	0.87	4.58E+03	0.00E+00	0.00E+00	4.12E+03	4.58E+02
60	0.70	3.68E+03	0.00E+00	0.00E+00	3.31E+03	3.68E+02
65	0.55	2.92E+03	0.00E+00	0.00E+00	2.62E+03	2.92E+02
70	0.41	2.15E+03	0.00E+00	0.00E+00	1.94E+03	2.15E+02
75	0.25	1.32E+03	0.00E+00	0.00E+00	1.19E+03	1.32E+02
80	0.14	7.63E+02	0.00E+00	0.00E+00	6.87E+02	7.63E+01
85	0.05	2.78E+02	0.00E+00	0.00E+00	2.50E+02	2.78E+01
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-12 TDS TMDL Calculation for Palo Duro Creek (OK720500020500_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WLA_{WWTF} (lbs/day)	WLA_{MS4} (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	595.3	9.67E+06	0.00E+00	0.00E+00	8.70E+06	9.67E+05
5	2.9	4.70E+04	0.00E+00	0.00E+00	4.23E+04	4.70E+03
10	2.4	3.85E+04	0.00E+00	0.00E+00	3.46E+04	3.85E+03
15	2.0	3.21E+04	0.00E+00	0.00E+00	2.89E+04	3.21E+03
20	1.8	2.99E+04	0.00E+00	0.00E+00	2.69E+04	2.99E+03
25	1.7	2.78E+04	0.00E+00	0.00E+00	2.50E+04	2.78E+03
30	1.6	2.57E+04	0.00E+00	0.00E+00	2.31E+04	2.57E+03
35	1.4	2.35E+04	0.00E+00	0.00E+00	2.12E+04	2.35E+03
40	1.3	2.05E+04	0.00E+00	0.00E+00	1.85E+04	2.05E+03
45	1.1	1.84E+04	0.00E+00	0.00E+00	1.66E+04	1.84E+03
50	1.0	1.63E+04	0.00E+00	0.00E+00	1.46E+04	1.63E+03
55	0.87	1.41E+04	0.00E+00	0.00E+00	1.27E+04	1.41E+03
60	0.70	1.13E+04	0.00E+00	0.00E+00	1.02E+04	1.13E+03
65	0.55	8.98E+03	0.00E+00	0.00E+00	8.08E+03	8.98E+02
70	0.41	6.63E+03	0.00E+00	0.00E+00	5.97E+03	6.63E+02
75	0.25	4.06E+03	0.00E+00	0.00E+00	3.66E+03	4.06E+02
80	0.14	2.35E+03	0.00E+00	0.00E+00	2.12E+03	2.35E+02
85	0.05	8.55E+02	0.00E+00	0.00E+00	7.70E+02	8.55E+01
90	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

5.9 TMDL IMPLEMENTATION

DEQ will collaborate with a host of other State agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources will be utilized so that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. DEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (DEQ 2012). The CPP can be viewed at DEQ's website: http://www.deq.state.ok.us/wqdnew/305b_303d/Final%20CPP.pdf. **Table 5-13** 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 5-13 Partial List of Oklahoma Water Quality Management Agencies

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

5.9.1 Point Sources

Point source WLAs are outlined in the Oklahoma Water Quality Management Plan (aka the 208 Plan) under the OPDES program. Land application activities that are permitted by the Corporation Commission are managed to address potential contamination that may emanate from commercial soil farming sites or one-time land application sites used for disposal of oil and gas development spoils.

5.9.2 Nonpoint Sources

Nonpoint source pollution in Oklahoma is primarily managed by the Oklahoma Conservation Commission (OCC). OCC works with other agencies that collect water monitoring information and/or address water quality problems associated with nonpoint source pollution. The State agencies OCC works with are DEQ, OWRB, Corporation Commission, and ODAFF. At the Federal level, OCC works with EPA, USGS, U.S. Army Corps of Engineers (USACE), and the National Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA).

In Oklahoma, the Corporation Commission has the primary responsibility for efforts to mitigate the pollutant load contributions from oil and gas production including land application sites used for disposal production waters and drilling muds. For example, the Corporation Commission locates and caps 250-400 wells per year Statewide in its efforts to reduce the availability of nonpoint source pollution to surface waters.

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 pollutant load reduction rates called for in this TMDL report are as high as 77.9%. DEQ recognizes that achieving reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of mineral loadings.

5.10 REASONABLE ASSURANCES

Reasonable assurance is required by the EPA guidance for a TMDL to be approvable only when a waterbody is impaired by both point and nonpoint sources and where a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. The impairments to the waterbodies in this report are not caused by point sources. Since point source dischargers in this TMDL report are not dependent on NPS load reductions, reasonable assurance does not apply.

SECTION 6 PUBLIC PARTICIPATION

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

The public comment period lasted 45 days from July 21, 2014 to September 4, 2014. During that time, the public had the opportunity to review the TMDL report and make written comments. Written comments received during the public notice period are a part of the public record of these TMDLs and can be found in Appendix E. Based on the comments received, some revisions were made to the final *Beaver River Watershed Mineral TMDL Report* before it was submitted to EPA for final approval.

There was no request for a public meeting.

After EPA's final approval, each TMDL is adopted into the WQMP.

SECTION 7 REFERENCES

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APPENDIX A: AMBIENT WATER QUALITY DATA 1999 TO 2012

Table Appendix A-1 Ambient Water Quality Data for Minerals at Bent Creek from 2007 to 2012

Waterbody ID	WQM Station	Date	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)
OK720500010070_00	OK720500-01-0070D	6/4/2007	39.4	910.8	1,831
OK720500010070_00	OK720500-01-0070D	7/9/2007	45.3	1,073.2	2,136
OK720500010070_00	OK720500-01-0070D	8/6/2007	56.6	1,108.8	2,066
OK720500010070_00	OK720500-01-0070D	9/17/2007	32.2	1,189.1	1,839
OK720500010070_00	OK720500-01-0070D	10/22/2007	34.9	924	1,802
OK720500010070_00	OK720500-01-0070D	11/26/2007	68.4	1,429	2,151
OK720500010070_00	OK720500-01-0070D	1/7/2008	44.6	1,356.4	2,198
OK720500010070_00	OK720500-01-0070D	2/4/2008	46.4	1,130.6	2,208
OK720500010070_00	OK720500-01-0070D	3/10/2008	46	1,267.1	2,197
OK720500010070_00	OK720500-01-0070D	4/14/2008	56.6	1,171	2,237
OK720500010070_00	OK720500-01-0070D	5/19/2008	46.4	1,086.1	2,113
OK720500010070_00	OK720500-01-0070D	6/24/2008	38.2	1,106.8	1,987
OK720500010070_00	OK720500-01-0070D	7/29/2008	35.3	755.4	1,626
OK720500010070_00	OK720500-01-0070D	9/3/2008	24.2	658.9	1,363
OK720500010070_00	OK720500-01-0070D	10/7/2008	41.9	854.2	1,722
OK720500010070_00	OK720500-01-0070D	11/18/2008	44.7	1,156.1	2,153
OK720500010070_00	OK720500-01-0070D	12/29/2008	68.6	1,182.8	2,095
OK720500010070_00	OK720500-01-0070D	2/10/2009	54.8	1,297.7	2,139
OK720500010070_00	OK720500-01-0070D	3/3/2009	48.5	1,486.2	2,109
OK720500010070_00	OK720500-01-0070D	4/14/2009	63	1,588.6	2,255
OK720500010070_00	OK720500-01-0070D	6/18/2012	27.2	934	1,636
OK720500010070_00	OK720500-01-0070D	7/30/2012	28.3	1,032.7	1,806
OK720500010070_00	OK720500-01-0070D	8/27/2012	24.3	813.6	1,529
OK720500010070_00	OK720500-01-0070D	10/1/2012	25.7	992.1	1,434
OK720500010070_00	OK720500-01-0070D	11/5/2012	25.3	928.5	1,539
OK720500010070_00	OK720500-01-0070D	12/17/2012	26.4	898.5	1,603
Bent Creek (numbers in red mean they are exceeding the single sample standard).		**# Samples**	**26**	**26**	**26**
		Arithmetic Mean	**42.0**	**1,090**	**1,914**
		Yearly Mean Standard	**735**	**723**	**2,442**
		Single Sample Criterion	**945**	**977**	**3,010**
		# Over Single Sample Criterion	**0**	**17**	**0**
		% Over Single Sample Criterion	**0**	**65.4**	**0**

Table Appendix A-2 Ambient Water Quality Data for Minerals at Beaver River (US 64) from 2005 to 2007

Waterbody ID	WQM Station	Date	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)
OK720500020140_00	720500020140-001AT	5/24/2005	1,200	460	
OK720500020140_00	720500020140-001AT	7/6/2005	878	385	
OK720500020140_00	720500020140-001AT	8/8/2005	996	362	
OK720500020140_00	720500020140-001AT	9/6/2005	859	320	
OK720500020140_00	720500020140-001AT	10/10/2005	880	288	
OK720500020140_00	720500020140-001AT	11/14/2005	801	305	
OK720500020140_00	720500020140-001AT	1/10/2006	664	318	
OK720500020140_00	720500020140-001AT	2/14/2006	754	452	
OK720500020140_00	720500020140-001AT	3/28/2006	908	468	
OK720500020140_00	720500020140-001AT	4/24/2006	901	395	
OK720500020140_00	720500020140-001AT	5/31/2006	732	296	
OK720500020140_00	720500020140-001AT	1/8/2007	2,080	474	
OK720500020140_00	720500020140-001AT	2/27/2007	1,390	367	
OK720500020140_00	720500020140-001AT	3/27/2007	910	430	
OK720500020140_00	720500020140-001AT	5/1/2007	1,500	286	
OK720500020140_00	720500020140-001AT	6/5/2007	1,100	430	
OK720500020140_00	720500020140-001AT	7/10/2007	1,130	501	2,640
OK720500020140_00	720500020140-001AT	8/7/2007	788	309	1,830
OK720500020140_00	720500020140-001AT	9/11/2007	808	330	1,950
Beaver River at US 64, Rosston (numbers in red mean they are exceeding the single sample standard).		**# Samples**	**19**	**19**	**3**
		Arithmetic Mean	**1,015**	**378**	**2,140**
		Yearly Mean Standard	**735**	**723**	**2,442**
		Single Sample Criterion	**945**	**977**	**3,010**
		# Over Single Sample Criterion	**7**	**0**	**0**
		% Over Single Sample Criterion	**36.8**	**0**	**0**

Table Appendix A-3 Ambient Water Quality Data for Minerals at Beaver River (US 270) from 2006 to 2012

Waterbody ID	WQM Station	Date	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)
OK720500020290_00	720500020290-001AT	5/30/2006	2,710	393	
OK720500020290_00	720500020290-001AT	9/12/2006	3,160	1,130	
OK720500020290_00	720500020290-001AT	10/24/2006	3,260	1,060	
OK720500020290_00	720500020290-001AT	11/28/2006	3,350	103	
OK720500020290_00	720500020290-001AT	1/8/2007	1,090	297	
OK720500020290_00	720500020290-001AT	2/27/2007	2,420	575	
OK720500020290_00	720500020290-001AT	3/27/2007	1,840	518	
OK720500020290_00	720500020290-001AT	5/1/2007	2,240	242	
OK720500020290_00	720500020290-001AT	6/5/2007	3,240	602	
OK720500020290_00	720500020290-001AT	7/10/2007	2,120	1,020	5,060
OK720500020290_00	720500020290-001AT	8/7/2007	2,960	1,080	6,740
OK720500020290_00	720500020290-001AT	9/10/2007	3,380	1,150	7,150
OK720500020290_00	720500020290-001AT	10/16/2007	3,650	1,100	7,430
OK720500020290_00	720500020290-001AT	1/29/2008	2,880	1,210	6,820
OK720500020290_00	720500020290-001AT	2/26/2008	2,960	1,440	6,810
OK720500020290_00	720500020290-001AT	4/1/2008	3,030	1,250	7,050
OK720500020290_00	720500020290-001AT	5/6/2008	3,150	2,580	6,760
OK720500020290_00	720500020290-001AT	7/15/2008	3,990	1,310	8,430
OK720500020290_00	720500020290-001AT	8/26/2008	5,140	1,280	8,800
OK720500020290_00	720500020290-001AT	10/21/2008	3,770	1,250	7,870
OK720500020290_00	720500020290-001AT	1/21/2009	2,970	1,190	4,990
OK720500020290_00	720500020290-001AT	3/17/2009	2,580	831	5,070
OK720500020290_00	720500020290-001AT	5/5/2009	3,020	884	4,940
OK720500020290_00	720500020290-001AT	7/7/2009	6,510	1,270	6,890
OK720500020290_00	720500020290-001AT	8/25/2009	3,600	1,320	8,830
OK720500020290_00	720500020290-001AT	11/3/2009	4,490	1,470	9,280
OK720500020290_00	720500020290-001AT	1/4/2010	3,390	1,440	8,780
OK720500020290_00	720500020290-001AT	3/23/2010	2,350	806	5,300
OK720500020290_00	720500020290-001AT	5/18/2010	2,500	1,000	5,530
OK720500020290_00	720500020290-001AT	7/14/2010	2,370	920	5,100
OK720500020290_00	720500020290-001AT	9/28/2010	3,830	1,780	8,880
OK720500020290_00	720500020290-001AT	11/16/2010	2,580	2,620	6,570
OK720500020290_00	720500020290-001AT	2/22/2011	2,420	797	5,120
OK720500020290_00	720500020290-001AT	3/22/2011	2,450	840	5,150
OK720500020290_00	720500020290-001AT	5/4/2011	2,550	992	5,290
OK720500020290_00	720500020290-001AT	1/10/2012	5,160	1,770	9,990
OK720500020290_00	720500020290-001AT	2/28/2012	4,900	1,650	9,990
OK720500020290_00	720500020290-001AT	5/15/2012	5,010	1,650	9,730
Beaver River at US 270, Beaver (numbers in red mean they are exceeding the single sample standard).		**# Samples**	**38**	**38**	**29**
		Arithmetic Mean	**3,237**	**1,127**	**7,047**
		Yearly Mean Standard	**1,455**	**890**	**3,847**
		Single Sample Criterion	**1,893**	**1,192**	**4,938**
		# Over Single Sample Criterion	**36**	**17**	**29**
		% Over Single Sample Criterion	**94.7**	**44.7**	**100**

Table Appendix A-4 Ambient Water Quality Data for Minerals at Beaver River (US 83) from 2006 to 2008

Waterbody ID	WQM Station	Date	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)
OK720500020450_00	720500020450-001AT	5/31/2006	3,270	837	
OK720500020450_00	720500020450-001AT	9/12/2006	3,250	1,010	
OK720500020450_00	720500020450-001AT	10/24/2006	3,350	925	
OK720500020450_00	720500020450-001AT	11/28/2006	3,730	1,470	
OK720500020450_00	720500020450-001AT	1/9/2007	1,990	510	
OK720500020450_00	720500020450-001AT	2/27/2007	2,780	550	
OK720500020450_00	720500020450-001AT	3/27/2007	1,660	432	
OK720500020450_00	720500020450-001AT	5/1/2007	2,580	229	
OK720500020450_00	720500020450-001AT	6/5/2007	3,840	602	
OK720500020450_00	720500020450-001AT	7/10/2007	2,930	825	5,960
OK720500020450_00	720500020450-001AT	8/7/2007	2,930	824	5,970
OK720500020450_00	720500020450-001AT	9/11/2007	3,170	920	6,580
OK720500020450_00	720500020450-001AT	10/16/2007	3,260	837	6,490
OK720500020450_00	720500020450-001AT	1/29/2008	2,620	725	5,660
OK720500020450_00	720500020450-001AT	2/26/2008	2,790	794	5,770
OK720500020450_00	720500020450-001AT	4/1/2008	2,720	740	5,830
OK720500020450_00	720500020450-001AT	5/6/2008	3,970	1,600	5,900
Beaver River at US 83, near Boyd (numbers in red mean they are exceeding the single sample standard).		**# Samples**	**17**	**17**	**8**
		Arithmetic Mean	**2,991**	**814**	**6,020**
		Yearly Mean Standard	**735**	**723**	**2,442**
		Single Sample Criterion	**945**	**977**	**3,010**
		# Over Single Sample Criterion	**17**	**3**	**8**
		% Over Single Sample Criterion	**100**	**17.6**	**100**

Table Appendix A-5 Ambient Water Quality Data for Minerals at Palo Duro Creek from 1999 to 2000

Waterbody ID	WQM Station	Date	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)
OK720500020500_00	720500020500-001AT	09/14/1999	2,090	2,356	6,972
OK720500020500_00	720500020500-001AT	10/06/1999	1,785	3,880	7,822
OK720500020500_00	720500020500-001AT	11/03/1999	1,547	2,824	7,438
OK720500020500_00	720500020500-001AT	12/01/1999	2,131	1,786	5,834
OK720500020500_00	720500020500-001AT	01/05/2000	571	806	3,036
OK720500020500_00	720500020500-001AT	02/08/2000	897	723	2,708
OK720500020500_00	720500020500-001AT	03/07/2000	818	620	2,465
OK720500020500_00	720500020500-001AT	05/02/2000	862	520	2,541
OK720500020500_00	720500020500-001AT	06/06/2000	1,440	800	3,750
OK720500020500_00	720500020500-001AT	07/11/2000	1,137	2,223	6,374
Palo Duro Creek (numbers in red mean they are exceeding the single sample standard).		**# Samples**	**10**	**10**	**10**
		Arithmetic Mean	**1,328**	**1,654**	**4,894**
		Yearly Mean Standard	**735**	**723**	**2,442**
		Single Sample Criterion	**945**	**977**	**3,010**
		# Over Single Sample Criterion	**6**	**5**	**7**
		% Over Single Sample Criterion	**60.0**	**50.0**	**70.0**

Table Appendix A-6 Ambient Water Quality Data for Minerals on the Cimarron River (US 64) from 2007 to 2009

Waterbody ID	WQM Station	Date	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)
OK720900000180_00	OK720900-00-0180C	6/4/2007	52.0	609	1,355
OK720900000180_00	OK720900-00-0180C	7/9/2007	34.4	375	947
OK720900000180_00	OK720900-00-0180C	8/6/2007	54.6	528	775
OK720900000180_00	OK720900-00-0180C	9/10/2007	86.2	884	1,823
OK720900000180_00	OK720900-00-0180C	11/26/2007	88.2	1,020	2,089
OK720900000180_00	OK720900-00-0180C	2/4/2008	76.0	966	1,857
OK720900000180_00	OK720900-00-0180C	3/10/2008	88.6	1,307	2,092
OK720900000180_00	OK720900-00-0180C	4/14/2008	100.5	1,127	2,206
OK720900000180_00	OK720900-00-0180C	5/12/2008	101.0	1,064	1,853
OK720900000180_00	OK720900-00-0180C	7/21/2008	144.4	1,215	2,403
OK720900000180_00	OK720900-00-0180C	8/25/2008	21.4	198	586
OK720900000180_00	OK720900-00-0180C	9/29/2008	71.1	773	1,598
OK720900000180_00	OK720900-00-0180C	11/3/2008	66.0	691	1,384
OK720900000180_00	OK720900-00-0180C	12/29/2008	110.8	958	1,915
OK720900000180_00	OK720900-00-0180C	2/2/2009	79.5	1,295	1,953
OK720900000180_00	OK720900-00-0180C	3/9/2009	115.5	1,702	2,322
OK720900000180_00	OK720900-00-0180C	4/6/2009	78.3	941	1,253
Cimarron River		**# Samples**	**17**	**17**	**17**
		Arithmetic Mean	**81**	**921**	**1,671**
		Yearly Mean Standard			
		Single Sample Criterion			
		# Over Single Sample Criterion			
		% Over Single Sample Criterion			

APPENDIX B: OIL PRODUCTION WELL WATER SAMPLING DATA

Table Appendix B-1 Oil Production Well Water Sampling Data

Waterbody	Watershed Name	Well ID	County	Date	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)
OK720500010070_00	Bent Creek	35000349	Woodward	5/13/1966	44,300	230	69,800
OK720500010070_00	Bent Creek	35000406	Dewey	2/8/1965	8,550	82	16,400
OK720500010070_00	Bent Creek	35000407	Dewey	2/8/1965	8,190	80	15,900
OK720500010070_00	Bent Creek	35000522	Dewey		9,599	12	18,495
OK720500010070_00	Bent Creek	35000523	Dewey		11,349	266	21,398
OK720500010070_00	Bent Creek	35002848	Dewey	2/2/1968	8,620	490	16,955
OK720500020140_00	Beaver River	35000233	Beaver		105,680	191	171,290
OK720500020140_00	Beaver River	35000234	Beaver		172,429	282	276,064
OK720500020140_00	Beaver River	35000762	Beaver	3/7/1961	147,000	760	229,780
OK720500020140_00	Beaver River	35002513	Beaver	2/5/1958	144,782	172	233,879
OK720500020140_00	Beaver River	35002516	Beaver	7/23/1959	103,394	289	167,530
OK720500020140_00	Beaver River	35006719	Beaver		80,720	1,300	131,400
OK720500020140_00	Beaver River	35006720	Beaver		82,200	200	132,370
OK720500020140_00	Beaver River	35012456	Beaver	4/14/1978	10,231	133	17,164
OK720500020140_00	Beaver River	35012690	Beaver	6/30/1978	131,434	154	213,519
OK720500020290_00	Beaver River	35000326	Beaver	3/11/1970	7,299	308	12,890
OK720500020290_00	Beaver River	35000494	Beaver	5/13/1961	5,198	139	11,521
OK720500020290_00	Beaver River	35000497	Beaver	3/23/1960	15,253	463	28,101
OK720500020290_00	Beaver River	35000503	Beaver	4/5/1956	149,545	293	242,455
OK720500020290_00	Beaver River	35000796	Beaver		138,600	196	229,507
OK720500020290_00	Beaver River	35000797	Beaver		147,584	205	239,050
OK720500020290_00	Beaver River	35000836	Beaver	10/27/1959	104,244	225	169,714
OK720500020290_00	Beaver River	35000837	Beaver	10/27/1959	144,310	160	234,011
OK720500020290_00	Beaver River	35000838	Beaver	10/27/1959	145,374	160	235,725
OK720500020290_00	Beaver River	35000840	Beaver	12/10/1959	78,715	1,300	129,534
OK720500020290_00	Beaver River	35002530	Beaver	6/29/1962	156,824	1,381	256,339
OK720500020290_00	Beaver River	35002672	Beaver	11/4/1959	169,215	186	274,383
OK720500020290_00	Beaver River	35011087	Beaver	6/22/1977	123,077	115	200,700
OK720500020290_00	Beaver River	35011170	Texas	3/31/1970	31,358	67	50,706
OK720500020290_00	Beaver River	35011378	Beaver	6/7/1978	124,380	159	200,743
OK720500020290_00	Beaver River	35012127	Beaver	6/22/1966	141,501	931	231,412
OK720500020450_00	Beaver River	35000803	Beaver	8/20/1956	20,175	320	34,321
OK720500020450_00	Beaver River	35002860	Texas	8/22/1966	140,456	263	225,471
OK720500020450_00	Beaver River	35010022	Beaver		23,518	251	40,261
OK720500020450_00	Beaver River	35010031	Texas		146,800	368	238,833
OK720500020450_00	Beaver River	35011121	Beaver	8/20/1956	20,645	327	35,121

Waterbody	Watershed Name	Well ID	County	Date	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)
OK720500020450_00	Beaver River	35011124	Beaver	11/29/1971	19,455	3	32,449
OK720500020450_00	Beaver River	35011401	Beaver	8/21/1973	21,738	3	36,747
OK720500020450_00	Beaver River	35011404	Beaver	8/21/1973	22,149	0	37,283
OK720500020450_00	Beaver River	35012119	Beaver	2/9/1970	38,095	84	63,236
OK720500020450_00	Beaver River	35012120	Beaver	5/28/1968	46,075	0	75,290
OK720500020450_00	Beaver River	35012121	Beaver	6/3/1968	36,458	239	60,575
OK720500020450_00	Beaver River	35012122	Beaver	8/30/1968	50,903	200	83,595
OK720500020450_00	Beaver River	35012123	Beaver	6/10/1967	24,140	35	39,505
OK720500020450_00	Beaver River	35012124	Beaver	5/19/1968	50,177	264	82,305
OK720500020450_00	Beaver River	35012125	Beaver	8/30/1968	40,102	131	66,284
OK720500020450_00	Beaver River	35012126	Beaver	5/12/1967	41,409	315	68,479
OK720500020450_00	Beaver River	35012128	Beaver	10/6/1961	19,998	16	33,602
OK720500020450_00	Beaver River	35012143	Beaver	1/20/1977	143,762	1,403	236,114
OK720500020450_00	Beaver River	35012145	Beaver	10/11/1978	135,523	1,459	223,505
OK720500020450_00	Beaver River	35012146	Beaver	10/11/1978	134,293	1,446	221,735
OK720500020450_00	Beaver River	35012153	Beaver	4/16/1967	23,886	115	40,054
OK720500020450_00	Beaver River	35012154	Beaver	4/5/1967	39,553	209	64,534
OK720500020450_00	Beaver River	35012155	Beaver	4/7/1967	23,785	14	39,154
OK720500020450_00	Beaver River	35012156	Beaver	4/7/1967	45,820	317	75,082
OK720500020450_00	Beaver River	35012157	Beaver	4/7/1967	24,476	196	41,116
OK720500020450_00	Beaver River	35012158	Beaver	4/7/1968	40,142	39	65,293
OK720500020450_00	Beaver River	35012164	Beaver	10/12/1976	22,251	44	37,554
OK720500020500_00	Palo Duro Creek	35000768	Texas	6/11/1958	1,560	1,660	7,540
OK720500020500_00	Palo Duro Creek	35000771	Beaver	12/12/1956	144,000	640	234,700
OK720500020500_00	Palo Duro Creek	35000774	Beaver	9/18/1958	51,000	164	83,900
OK720500020500_00	Palo Duro Creek	35000776	Beaver	9/18/1958	46,800	372	76,600
OK720500020500_00	Palo Duro Creek	35000777	Beaver	6/26/1959	37,200	756	62,200
OK720500020500_00	Palo Duro Creek	35000778	Beaver	6/25/1959	40,800	498	67,500
OK720500020500_00	Palo Duro Creek	35000779	Beaver	5/28/1956	14,000	229	24,300
OK720500020500_00	Palo Duro Creek	35000781	Beaver	11/11/1956	54,000	372	88,000
OK720500020500_00	Palo Duro Creek	35000782	Beaver	11/12/1956	52,800	286	86,000
OK720500020500_00	Palo Duro Creek	35000783	Beaver	9/17/1958	42,000	148	69,200
OK720500020500_00	Palo Duro Creek	35000785	Beaver	10/2/1956	35,400	408	59,500
OK720500020500_00	Palo Duro Creek	35000798	Texas		82,465	1,359	137,556
OK720500020500_00	Palo Duro Creek	35000800	Beaver		42,780	180	70,865
OK720500020500_00	Palo Duro Creek	35009875	Beaver		36,851	425	61,731
OK720500020500_00	Palo Duro Creek	35009879	Beaver	11/25/1956	24,585	4,576	48,241

Waterbody	Watershed Name	Well ID	County	Date	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)
OK720500020500_00	Palo Duro Creek	35010033	Texas	6/26/1957	137,207	219	212,294
OK720500020500_00	Palo Duro Creek	35011083	Texas	3/22/1979	132,000	420	216,040
OK720500020500_00	Palo Duro Creek	35012149	Beaver	11/3/1976	90,790	6,532	158,600
OK720900000180_00	Cimarron River	35011132	Cimarron	7/8/1954	1,120	102	2,152

APPENDIX C: GENERAL METHOD FOR ESTIMATING FLOW FOR UNGAGED STREAMS AND ESTIMATED FLOW EXCEEDANCE PERCENTILES

Appendix C

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 **Table Appendix C-1**. The average curve number was then calculated from all the grid cells within the delineated watershed.

Table Appendix C-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

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).

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):

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

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

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

Thus, the runoff curve number equation can be rewritten:

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

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

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

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:

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

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** (on page C-5) 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 gages were present upstream or downstream, flows were estimated for the WQM station from a gage on an adjacent watershed of similar size and properties, via the same procedure described previously for upstream or downstream gages.

References

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

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

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

Table Appendix C-2 Estimated Flow Exceedance Percentiles

Stream Name	Bent Creek	Beaver River	Beaver River	Beaver River	Palo Duro Creek
WBID Segment	OK720500010070_00	OK720500020140_00	OK720500020290_00	OK720500020450_00	OK720500020500_00
Drainage Area (square miles)	131	8,649	7,986	7,414	1,993
USGS Gage Reference	07157960 (adjacent)	07234000 (upstream)	07234000 (in-stream)	07234000 (downstream)	07233650 (in-stream)
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
0	1,230	43,211	39,900	37,043	595
1	53	1,126	1,040	966	5.3
2	23	483	446	414	4.0
3	16	295	272	253	3.4
4	13	200	185	172	3.0
5	11	155	143	133	2.9
6	10	122	113	105	2.8
7	8.7	101	93	86	2.6
8	8.0	87	80	74	2.5
9	7.1	76	70	65	2.4
10	6.7	66	61	57	2.4
11	6.1	60	55	51	2.2
12	5.8	54	50	46	2.2
13	5.5	50	46	43	2.1
14	5.1	45	42	39	2.1
15	5.1	42	39	36	2.0
16	4.8	39	36	33	2.0
17	4.5	37	34	32	2.0
18	4.2	34	31	29	1.8
19	4.2	31	29	27	1.8
20	3.9	30	28	26	1.8
21	3.5	28	26	24	1.8
22	3.5	27	25	23	1.7
23	3.2	25	23	21	1.7

Stream Name	Bent Creek	Beaver River	Beaver River	Beaver River	Palo Duro Creek
WBID Segment	OK720500010070_00	OK720500020140_00	OK720500020290_00	OK720500020450_00	OK720500020500_00
Drainage Area (square miles)	131	8,649	7,986	7,414	1,993
USGS Gage Reference	07157960 (adjacent)	07234000 (upstream)	07234000 (in-stream)	07234000 (downstream)	07233650 (in-stream)
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
24	3.2	24	22	20	1.7
25	3.1	23	21	19	1.7
26	2.9	22	20	19	1.6
27	2.8	21	19	18	1.6
28	2.6	19	18	17	1.6
29	2.5	18	17	16	1.6
30	2.4	17	16	15	1.6
31	2.2	16	15	14	1.6
32	2.2	15	14	13	1.4
33	2.0	14	13	12	1.4
34	1.9	13	12	11	1.4
35	1.8	13	12	11	1.4
36	1.7	12	11	10	1.3
37	1.6	11	10	9.3	1.3
38	1.5	10	9.4	8.7	1.3
39	1.4	9.4	8.7	8.1	1.3
40	1.3	8.7	8.0	7.4	1.3
41	1.2	8.0	7.4	6.9	1.2
42	1.1	7.5	6.9	6.4	1.2
43	1.0	6.7	6.2	5.8	1.2
44	0.93	6.3	5.8	5.4	1.17
45	0.90	5.6	5.2	4.8	1.13
46	0.83	5.2	4.8	4.5	1.11
47	0.77	4.7	4.3	4.0	1.08
48	0.74	4.2	3.9	3.6	1.05
49	0.71	3.6	3.3	3.1	1.03

Stream Name	Bent Creek	Beaver River	Beaver River	Beaver River	Palo Duro Creek
WBID Segment	OK720500010070_00	OK720500020140_00	OK720500020290_00	OK720500020450_00	OK720500020500_00
Drainage Area (square miles)	131	8,649	7,986	7,414	1,993
USGS Gage Reference	07157960 (adjacent)	07234000 (upstream)	07234000 (in-stream)	07234000 (downstream)	07233650 (in-stream)
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
50	0.67	3.1	2.9	2.7	1.00
51	0.64	2.7	2.5	2.3	0.97
52	0.61	2.2	2.0	1.9	0.95
53	0.58	1.8	1.7	1.6	0.92
54	0.55	1.4	1.3	1.2	0.90
55	0.51	1.1	1.0	0.93	0.87
56	0.48	0.9	0.8	0.75	0.84
57	0.48	0.6	0.6	0.56	0.80
58	0.45	0.5	0.44	0.41	0.78
59	0.42	0.4	0.35	0.32	0.74
60	0.42	0.3	0.29	0.27	0.70
61	0.39	0.3	0.24	0.22	0.67
62	0.39	0.2	0.21	0.19	0.63
63	0.35	0.2	0.19	0.18	0.62
64	0.32	0.2	0.17	0.16	0.59
65	0.31	0.2	0.15	0.14	0.55
66	0.29	0.1	0.13	0.12	0.53
67	0.26	0.1	0.11	0.10	0.50
68	0.24	0.1	0.09	0.08	0.47
69	0.22	0.1	0.08	0.07	0.45
70	0.19	0.1	0.07	0.06	0.41
71	0.17	0.1	0.05	0.05	0.38
72	0.14	0.04	0.04	0.04	0.36
73	0.13	0.03	0.03	0.03	0.32
74	0.11	0.02	0.02	0.02	0.28
75	0.09	0.01	0.01	0.01	0.25

Stream Name	Bent Creek	Beaver River	Beaver River	Beaver River	Palo Duro Creek
WBID Segment	OK720500010070_00	OK720500020140_00	OK720500020290_00	OK720500020450_00	OK720500020500_00
Drainage Area (square miles)	131	8,649	7,986	7,414	1,993
USGS Gage Reference	07157960 (adjacent)	07234000 (upstream)	07234000 (in-stream)	07234000 (downstream)	07233650 (in-stream)
Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
76	0.07	0	0	0	0.22
77	0.06	0	0	0	0.21
78	0.05	0	0	0	0.18
79	0.04	0	0	0	0.16
80	0.03	0	0	0	0.14
81	0.02	0	0	0	0.13
82	0.01	0	0	0	0.11
83	0	0	0	0	0.09
84	0	0	0	0	0.07
85	0	0	0	0	0.05
86	0	0	0	0	0.03
87	0	0	0	0	0.01
88	0	0	0	0	0
89	0	0	0	0	0
90	0	0	0	0	0
91	0	0	0	0	0
92	0	0	0	0	0
93	0	0	0	0	0
94	0	0	0	0	0
95	0	0	0	0	0
96	0	0	0	0	0
97	0	0	0	0	0
98	0	0	0	0	0
99	0	0	0	0	0
100	0	0	0	0	0

APPENDIX D: STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix D

State of Oklahoma Antidegradation Policy

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

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

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

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

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

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

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

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

785:46-13-1. Applicability and scope

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

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

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

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

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

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

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

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

785:46-13-2. Definitions

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

"Specified pollutants" means

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

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

(C) Phosphorus;

(D) Total Suspended Solids (TSS); and

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

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

(a) General.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX E: RESPONSES TO PUBLIC COMMENTS

Scott A. Thompson
Executive Director

Mary Fallin
Governor

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Response to Public Comments Received for the Draft Mineral TMDL Report for the Beaver River Watershed

September 10, 2014

1. Comment sent via email from Quang Pham, ODAFF AgPDES Deputy Director:

The following comments on sub-sections of 3.2.3.1 on CAFO, and 3.2.3.2 for SFO of the Beaver River Minerals TMDL Draft Report are submitted to you for your consideration:

For 3.2.3.1 CAFO

1- Recommend to add the following paragraph immediately after the third paragraph of 3.2.3.1

Oklahoma Rules requires CAFOs submitting Documentation of No Hydrologic Connection (OAC 35:17-4-10) for all retention structures to prevent any leaking of wastewater to water-bodies. Thus, the potential for mineral loading from CAFOs to the receiving stream is almost non-existent.

2- Recommend to add one sentence to the last paragraph of this sub-section as follows:

There are four cattle CAFOs located in the Beaver River watershed [three are in Beaver River (OK720500020450_00) and one in Beaver River (OK720500020290_00)]. The cattle CAFOs are highlighted in Table 3-3 and shown in Figure 3-1. *Most of these CAFOs are not operating at capacities allowed in the licenses.* For other states including Colorado, Kansas, New Mexico, and Texas, site specific data was not available. Therefore, the number of livestock based on the 2007 Agricultural Census is presented in Table 3-4 by counties intersecting with the Study watershed.

For 3.2.3.2 SFO

1- Recommend to remove the second paragraph of this sub-section as shown below

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. According to the SFO Act, a "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 postharvest residues are not grown during the normal growing season on any part of the lot.

~~A "concentrated swine feeding operation " has a certain number of swine [2] and either discharges its pollutants into nearby waterbodies through a ditch, flushing system or other constructed device, or the pollutants flow directly into waterbodies that flow through or come into direct contact with swine at the facility.~~

2- Recommend to add languages to the last paragraph of this sub-section as follows:

SFOs are required to develop a Swine Waste Management Plan to prevent swine waste from being discharged into surface or groundwaters. This Plan includes the BMPs being used to prevent runoff & erosion. The Swine Waste Management Plan may include, but is not limited to, a Comprehensive Nutrient Management Plan per NRCS guidance or Nutrient Management Plan per EPA guidance. *For large SFO with more than 1,000 animal units, monitoring wells or leakage detection system for waste retention structures are required to install to monitor and control seepage/leakage (OAC 35:17-3-11 (e) (6). Oklahoma Rules requires SFOs submitting Documentation of No Hydrologic Connection (OAC 35:17-3-12) for all retention structures to prevent any leaking of wastewater to water-bodies. Thus, the potential for mineral loading from SFOs to the receiving stream is almost non-existent.* There are 29 SFOs in this Study Area. *Most of the SFOs in Oklahoma are not operating at capacities allowed in the licenses.* The SFOs are the AFOs that aren't highlighted in Table 3-3. They are also shown in Figure 3-1.

DEQ Response:

Those changes were made to this Report. Thank you for your comments.

2. Staff identified changes:

- To the Acronyms and Abbreviations list, the following were added:
  - AFO
  - AgPDES
  - MSGP
  - NPS
  - USACE
  - WQ
- In the References Section, 7 ODAFF references were updated with the newly posted Acts and Rules regarding AgPDES.
- Corrected the PRISM reference and added a reference regarding the statement that, "Well sampling results show that a sodium/chloride (Na/Cl) ratio below 0.6 can be indicative of a produced water/oilfield brine source".
- Corrected hyperlink problems in Sections ES-1 and 1.1.
- Moved the appendix with well sampling results so that it follows the appendix with stream sampling results.
- Moved a paragraph about what TMDLs are from Section 6 to Section 1.