Draft Wasteload Allocation Report For

OG&E McClain Generating Station (OK0045250)

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1. Problem Definition

In 2014, DO modeling of the Canadian River (OK520610020010_00, OK520610010010_20, OK520610010010_10, and OK520610010010_05) between Union City and Buckhead, OK was developed under the Canadian River Wasteload Allocation (WLA) Project by the Association of Central Oklahoma Governments (ACOG). Based on that project, seasonal WLA limits (see Appendix B) were given to OG&E McClain Generating Station (OK0045250) for the design flow of 0.189 MGD, which was different from Qe(30) in industrial permit (0.414 MGD).

To provide consistency with the current industrial permit, the 2014 Canadian River Water Quality Analysis Simulation Program (WASP) was updated. This report addresses dissolved-oxygen demanding substances only and does not address any other pollutant on the State's 303(d) list of impaired waters. This report addresses instream organic enrichment and dissolved oxygen (DO) through the use of wasteload allocations of DO-demanding substances (CBOD and ammonia).

The Canadian River (OK520610010010_20), the receiving stream for OG&E McClain Generating Station, is listed in the Oklahoma Water Quality Standards (OAC 252:730) as having the following beneficial uses:

- Aesthetics
- Agriculture
- Fish and Wildlife Propagation-Warm Water Aquatic Community (WWAC)
- Fish Consumption
- Primary Body Contact Recreation

Based on the 2022 Integrated Report, the Canadian River (OK520610010010_20) was not assessed for its beneficial uses, so it is assumed to meet all water quality standards. This WLA has been developed to ensure that the limits assigned to the discharge are stringent enough to maintain DO standards under critical conditions. Controls for any necessary pollutants will be established in the permitting process.

2. Endpoint Identification

The Canadian River is a perennial stream. Therefore, seasonal 7Q2 is considered as the critical low-flow. Details of the 7Q2 calculations are shown in Appendix N of 2014 Canadian River Wasteload Allocation Study (ACOG 2014).

The following numerical DO criteria for WWAC apply to the receiving stream:

<u>At Critical Low-Flow Condition (7Q2)</u>

Summer (Jun–Oct):	5.0 mg/L
Spring (Mar–May):	6.0 mg/L
Winter (Nov–Feb):	5.0 mg/L

Oklahoma's antidegradation policy (OAC 252:730-3) requires protecting all waters of the state from degradation of water quality. The allocated loadings/concentrations in this report were set with regard for all elements of the Oklahoma Water Quality Standards, which includes the antidegradation policy.

3. Source Analysis

3.1. Point Sources

Table 1. Point sources in WASP model

Discharger	Design flow (MGD)	Season	WLA (mg/L)
Minco	0.215	Summer	No Discharge
		Spring	12 $CBOD_5$, 30 TSS, 3.7 NH_3-N, 5 DO
		Winter	30 BOD_5, 90 TSS
Tuttle (West Creek)	0.51	Summer	30 BOD_5, 90 TSS
		Spring	
		Winter	
Tuttle (Worley Creek)	0.5	Summer	8 $CBOD_5$, 10 TSS, 2.3 NH_3-N, 6.5 DO
		Spring	30 BOD_5, 90 TSS
		Winter	
Mustang	3.0	Summer	7 $CBOD_5$, 10 TSS, 1.4 NH_3-N, 6.5 DO
		Spring	9 $CBOD_5$, 10 TSS, 3.75 NH_3-N, 5 DO
		Winter	13.5 $CBOD_5$, 22 TSS, 4.1 NH_3-N, 5 DO
Oklahoma City-South Canadian	8.66	Summer	8 $CBOD_5$, 30 TSS, 0.5 NH_3-N, 7.5 DO
		Spring	10 $CBOD_5$, 30 TSS, 1.0 NH_3-N, 7 DO
		Winter	25 $CBOD_5$, 30 TSS, 4.1 NH_3-N, 5 DO
OG&E McClain Generating Station	0.414*	Summer	9 $CBOD_5$, 10 TSS, 3.2 NH_3-N, 4 DO
		Spring	30 BOD_5, 30 TSS
		Winter	
Moore	9.0	Summer	5 $CBOD_5$, 10 TSS, 1.4 NH_3-N, 6.5 DO
		Spring	6 $CBOD_5$, 10 TSS, 1.4 NH_3-N, 7.4 DO
		Winter	15 $CBOD_5$, 20 TSS, 4.1 NH_3-N, 7.4 DO
Newcastle	1.5	Summer	18 $CBOD_5$, 30 TSS, 12 NH_3-N
		Spring	
		Winter	
Norman	16.0	Summer	8 CBOD5, 10 TSS, 1.6 NH_3-N, 6.5 DO
		Spring	13 CBOD5, 30 TSS, 4.1 NH_3-N, 5 DO
		Winter	25 CBOD5, 30 TSS, 4.1 NH_3-N, 5 DO
Noble	0.76	Summer	30 BOD_5, 30 TSS, 5DO
		Spring	30 BOD_5, 30 TSS
		Winter	
Lexington	0.261	Summer	30 BOD_5, 30 TSS
		Spring	
		Winter	

Discharger	Design flow (MGD)	Season	WLA (mg/L)
Purcell	0.78	Summer	30 BOD_5, 90 TSS
		Spring	
		Winter	

*Qe(30) in 2019 industrial permit (the design flow in 208 Plan: 0.189 MGD)

3.2. Non-Point Sources

WASP is a dynamic model. However, all time-variable inputs were specified as constants over the duration of the simulation except for water temperatures, which were specified with diurnal fluctuations that were repeated the same every day. Therefore, low-flow conditions for this project assume little or no runoff.

3.3. Background

The following background conditions for the Canadian River were used:

Table 2. Ambient concentrations

Headwater Inputs*	Season		
	Spring	Summer	Winter
Flow (7Q2)	135.3 cfs	8.97 cfs	92.69 cfs
CBODu	14.5 mg/L	7.09 mg/L	14.5 mg/L
Ammonia	0.28 mg/L	0.1 mg/L	0.28 mg/L
DO	8.26 mg/L	5 mg/L	8.26 mg/L

* From 2014 Canadian River Wasteload Allocation Study Appendix J and N

4. Modeling

4.1. Previous Models

In 2014, ACOG contracted Guernsey to develop WASP model and allocated WLAs to 12 facilities (Table 1) discharging to the Canadian River (OK520610020010_00, OK520610010010_20, OK520610010010_10, and OK520610010010_05). The original Guernsey report included detailed information about field studies, WASP model setup, calibration, and validation. In the 2014 report, several projection scenarios were simulated and the dischargers collectively selected Scenario D.

In 2018, ACOG modified Scenario D in 2014 WASP model to move the discharge from the Oklahoma City South Canadian WWTF to the Canadian River from an unnamed tributary.

In 2019, ACOG revised WASP model to incorporate Newcastle's design flow increase and new discharge location. The discharge location was moved about 2 miles upstream of the mouth of Pond Creek and the design flow was increased to 1.5 MGD from 0.852 MGD.

4.2. New Modeling

The simulations presented in this report are identical to ACOG's simulations, with the exception of the flow used for the OG&E McClain Generating Station. The effluent concentrations applied in the model for the McClain facility remain consistent with the current 208 Plan. However, the TSS limits for the facility were developed separately using a linear regression approach based on OWRB monitoring data collected downstream of the receiving stream segment (Appendix C).

5. Margin of Safety

An explicit margin of safety of 5% was applied to both the point and nonpoint source oxygen demand. A scale factor of 1.05263 (1.0 divided by 0.95) was applied to the sediment oxygen demand and all the inflow concentrations (ammonia and CBOD in ambient flow and point source effluent flow).

6. Model Results

WASP model results are shown in Figure 1. WASP plots of average DO indicated attaining DO water quality standards for all seasons.

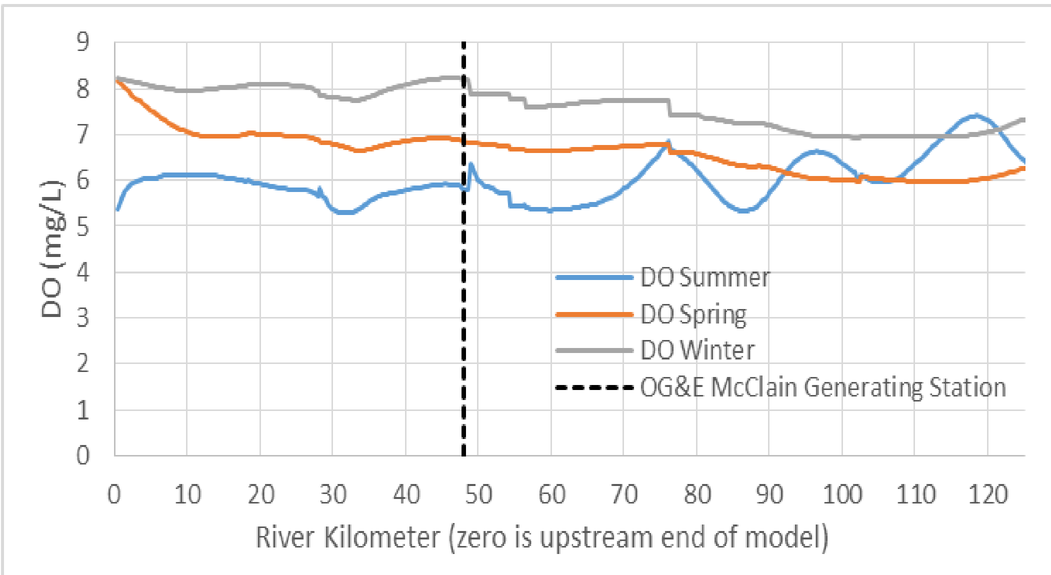


Figure 1. Average DO profile in WASP model boundary

7. Final Recommendations

The following changes are recommended for inclusion in the Oklahoma Water Quality Management Plan (208 Plan).

OG&E McClain Generating Station

Proposed Design Flow: 0.414 MGD

Summer (Jun–Oct): 9 mg/l $CBOD_5$; 3.2 mg/l NH_3; 4.0 mg/l DO; 72 mg/L TSS (Daily Maximum)

Spring (Mar–May): 30.0 mg/l BOD_5; 72 mg/L TSS (Daily Maximum)

Winter (Nov–Feb): 30.0 mg/l BOD_5; 72 mg/L TSS (Daily Maximum)

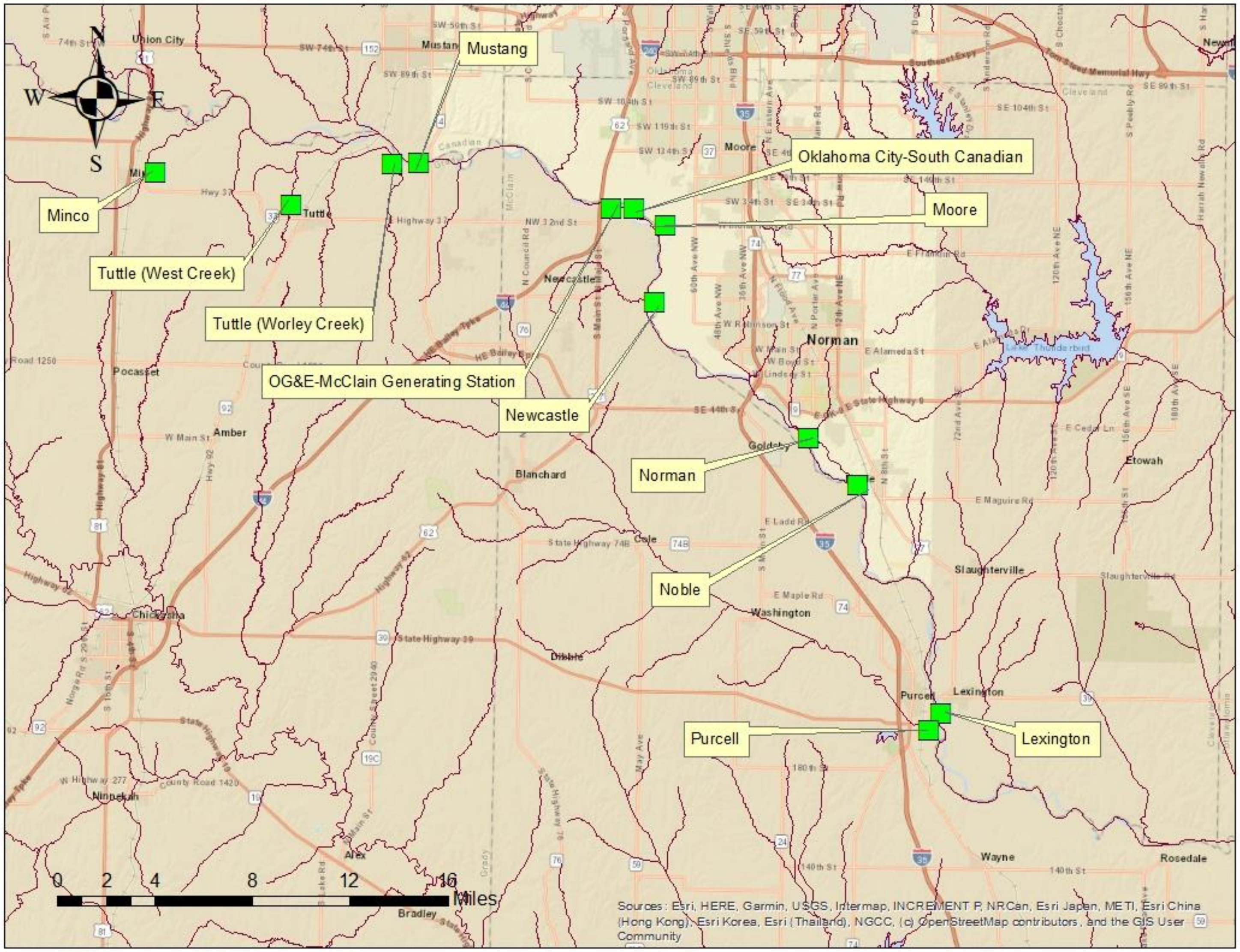
8. Public Participation

This Draft WLA report will be submitted to EPA for technical review and acceptance. After EPA's review, the proposed WLA limits will be sent for public comments. Public comments received during this period will be responded to and become part of the WLA report.

9. References

1. Association of Central Oklahoma Governments (ACOG) (2014). *Wasteload Allocation Study – Canadian River – Union City to Wayne, Oklahoma*
2. Christensen, V. G., Jian, X., and Ziegler, A. C. (2000). *Regression Analysis and real-time water-quality monitoring to estimate constituent concentrations, loads, and yields in the Little Arkansas River, south-central Kansas*, 1995-99 (DOI: 10.3133/wri004126). U.S. Department of the Interior, U.S. Geological Survey. Available from https://pubs.er.usgs.gov/publication/wri004126.
3. Helsel, D.R. and Hirsch, R.M. (2002). *Statistical methods in water resources. Techniques of Water Resources Investigations*, Book 4, Chapter A3, U.S. Geological Survey. Available from https://pubs.usgs.gov/publication/tm4A3.
4. *Oklahoma Continuing Planning Process, 2012 edition*, Oklahoma Department of Environmental Quality, State of Oklahoma, 2013.
5. *Title 252, Oklahoma Administrative Code, Chapter 730 Oklahoma's Water Quality Standards,* State Of Oklahoma, 2023.

Figure 2. Point sources in WASP model



Appendix A – WASP Model Setup

A.1. Overview

The 2019 WASP model was revised to simulate increased flow of OG&E McClain Generating Station. Other than the increased effluent flow for the OG&E McClain Generating Station, all other inputs remained same as the 2019 WASP model.

A.2. WASP model segments

The WASP model was applied to the Canadian River from the US Highway 81 Bridge near Union City and Minco to the confluence of Buckhead Creek near Rosedale. In addition to simulating the main stem of the Canadian River, the WASP model was extended into the four tributaries that are listed in Appendix Table A-1.

Appendix Table A- 1. Lengths of streams and segments in WASP model

Stream	Stream Length (km)	Segment Numbers in Model	Segment Length (km)
Canadian River	125.5	1 - 410	0.5 or 0.2
UTM (Unnamed tributary below Moore Wastewater Treatment Plant [WWTP])	5.1	411 - 461	0.1
UTOC (Unnamed trib. below Oklahoma City WWTP)	3.7	462 - 498	0.1
Buggy Creek below Minco WWTP	6.3	499 - 561	0.1
Pond Creek / Tim's Creek below Newcastle WWTP	4.0	562 - 601	0.1

The WASP model simulates a stream as "a series of boxes" along the length of the stream. The WASP model refers to these boxes as segments. Segment length along the Canadian River was set to 0.5 km for most areas and 0.2 km immediately downstream of point source or tributary inflows. The purpose of the shorter segments is to provide greater spatial resolution to simulate any DO sags downstream of point sources. The segment length for each of the tributary segments was 0.1 km.

A.3. WASP model coefficients

The WASP model coefficients were established through model calibration based on comparisons of predicted and observed DO as well as visual observations recorded during the field studies. These coefficients are listed in Appendix Table A-2.

Appendix Table A- 2. WASP model coefficients

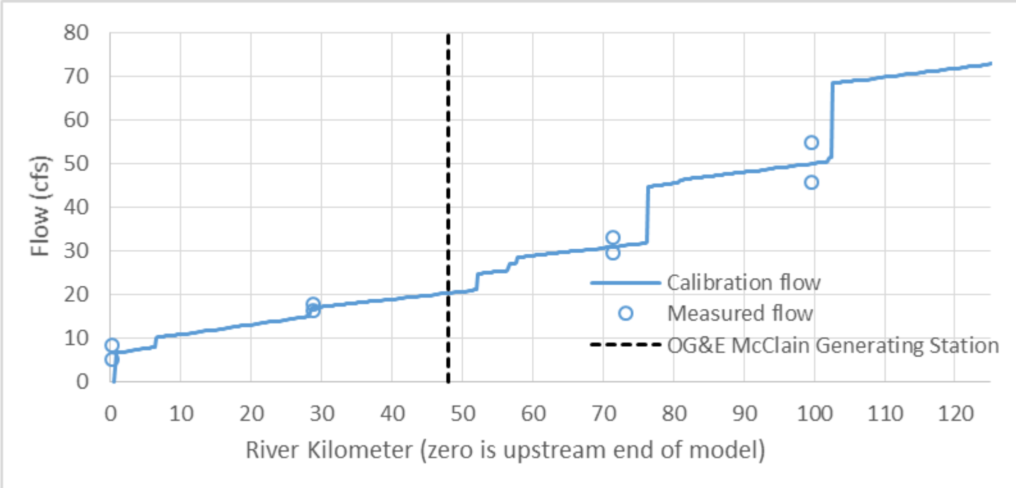
Model coefficient	Values
CBOD1 (ambient sources) decay rate at 20ºC (1/day)	0.13
CBOD1 Decay Rate Temperature Correction Coefficient	1.047
CBOD2 (point sources) decay rate at 20oC (1/day)	0.16
CBOD2 Decay Rate Temperature Correction Coefficient	1.047
CBOD Half Saturation Oxygen Limit (mg O_2/L)	0.5
SOD at 20ºC (g/m^2/day)	0.3 – 4

Model coefficient	Values
Nitrification Rate Constant at 20ºC (1/day)	0.4
Nitrification Temperature Correction Coefficient	1.073
Half Saturation Constant for Nitrification Oxygen Limit (mg O_2/L)	2.5
Denitrification Rate Constant at 20ºC (1/day)	0.75
Denitrification Temperature Correction Coefficient	1.045
Half Saturation Constant for Denitrification Oxygen Limit (mg O_2/L)	0.5
Dissolved Organic Nitrogen Mineralization Rate Constant at 20ºC (1/day)	0.02
Dissolved Organic Nitrogen Mineralization Temperature Coefficient	1.02
Dissolved Organic Phosphorus Mineralization Rate Constant at 20ºC (1/day)	0.05
Dissolved Organic Phosphorus Mineralization Temperature Coefficient	1.08
Algae Nitrogen to Carbon Ratio (mg N/mg C)	0.2
Algae Phosphorus to Carbon Ratio (mg P/mg C)	0.025
Carbon to Chlorophyll Ratio (mg C/mg Chl)	60
Maximum Growth Rate at 20ºC (1/day)	0.53 – 4.25
Temperature Correction Coefficient for Growth	1.06
Respiration Rate at 20ºC (1/day)	0.125 – 0.2
Temperature Correction Coefficient for Respiration	1.06
Death Rate from Non-Zooplankton Predation (1/day)	0.05
Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.3
Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.04
Optimal Light Saturation (Ly/day)	500
Fraction of Nitrogen from Algal Death and Respiration that is Recycled to Organic N	1
Fraction of Phos. from Algal Death and Respiration that is Recycled to Organic P	1

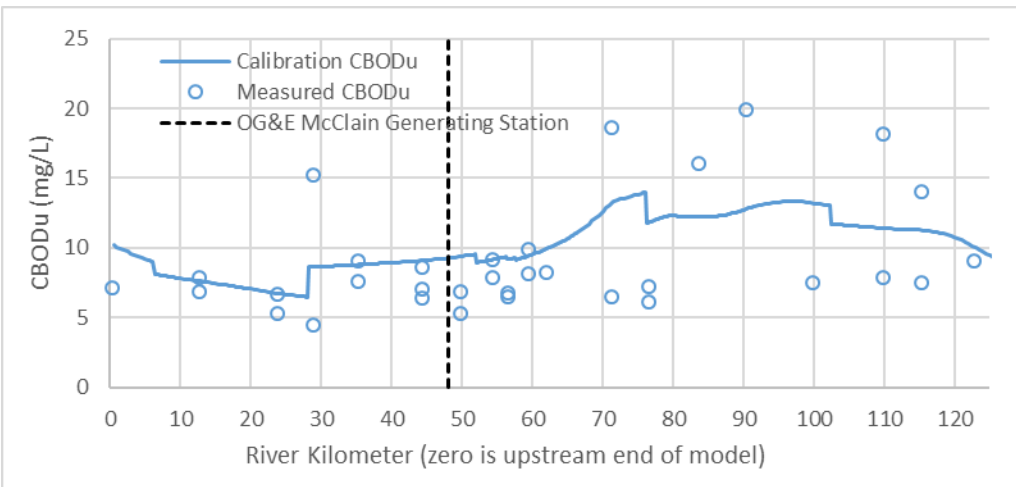
A.4. WASP model calibration

The headwater and tributary inflow rates for the calibration simulation were based entirely on field measurements from the August 8-13 field study. Detailed calibration results can be found in the 2014 Canadian River Wasteload Allocation Study (ACOG 2014). Appendix Figure A-1 illustrates calibrated flow. Calibrated flows for the Canadian River correlated well when they were compared with measured flows.

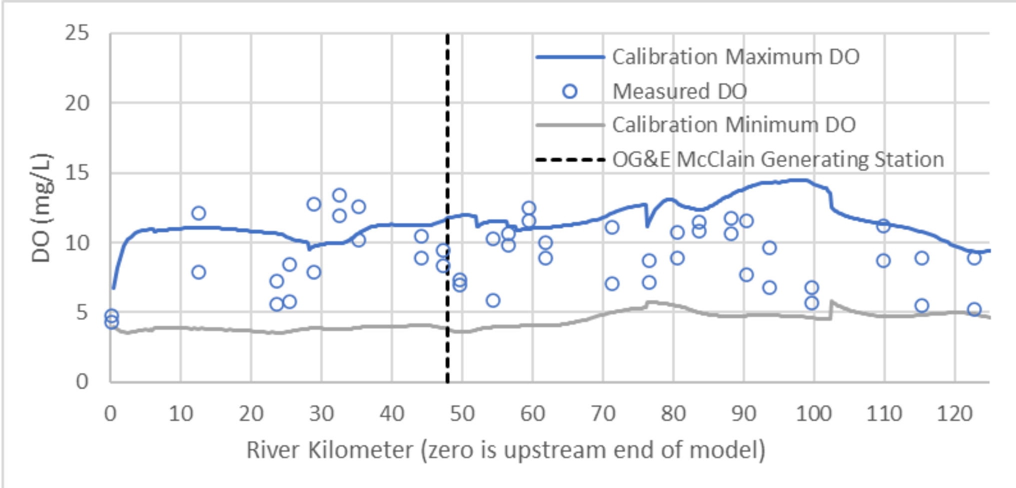
Calibrated CBODu values were similar or overestimated in comparison to measured CBODu, whereas calibrated DO values were similar or underestimated with respect to measured DO. Because the model overestimates CBOD and underestimates DO for the given point-source inputs, it predicts greater oxygen demand and lower dissolved oxygen than actually occur in the stream. To meet the DO criterion under these more stringent modeled conditions, the proposed effluent limits must be set lower than what would be required under true field conditions. This makes the modeling approach conservative for developing WLA limits.



Appendix Figure A- 1. Calibration flow against August measured flow in Canadian River WASP boundary



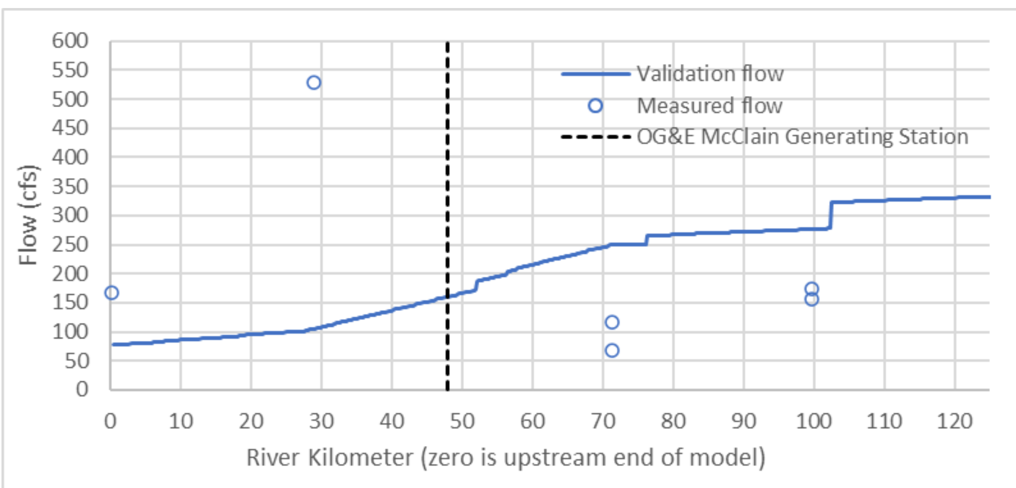
Appendix Figure A- 2. Calibration CBODu against August measured CBODu in Canadian River WASP boundary



Appendix Figure A- 3. Calibration DO against August measured DO in Canadian River WASP boundary

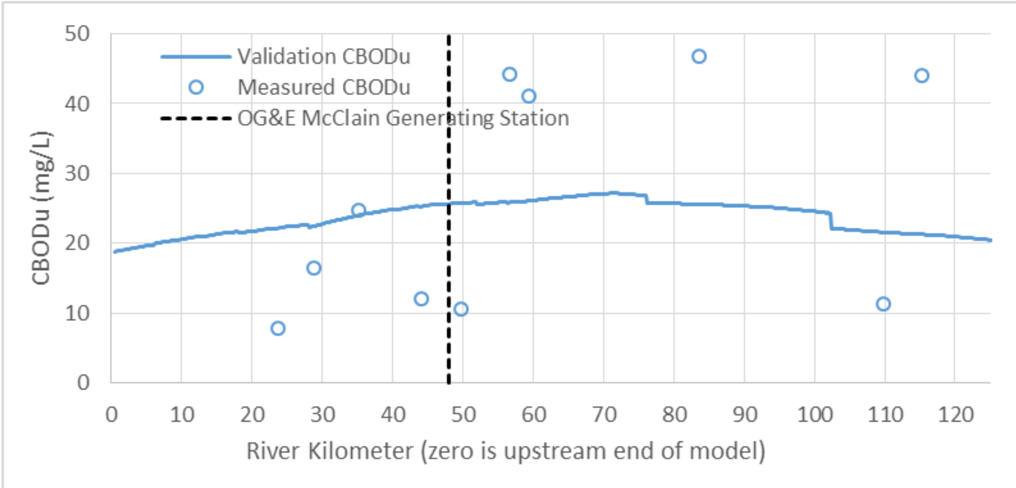
A.5. WASP model validation

All the calibration parameters were kept the same for the final calibration run. Conditions from the September 12-17 field study were simulated for the model validation. During the field study, there was a rainfall event and the instantaneous measured flows were not representative of the average flows in the Canadian River. However, the WASP simulation showed good average flows both before and after the rainfall event (Appendix Figure A-4).

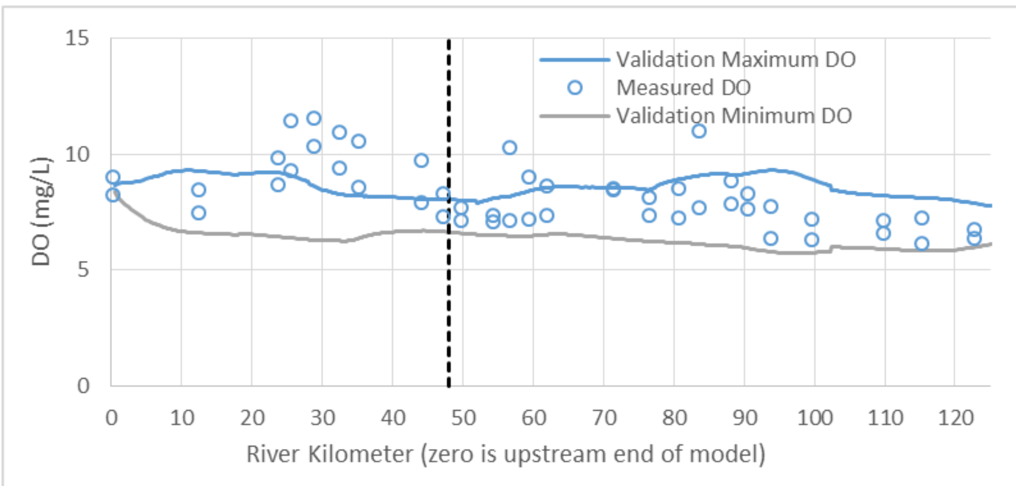


Appendix Figure A- 4. Validation flow against September measured flow in Canadian River WASP boundary

Validation CBODu and DO showed similar results with calibrations. Detailed validation results were presented in Appendix M of 2014 Canadian River Wasteload Allocation Study (ACOG 2014).



Appendix Figure A- 5. Validation CBODu against September measured CBODu in Canadian River WASP boundary



Appendix Figure A- 6. Validation DO against September measured DO in Canadian River WASP boundary

Appendix B – Current 208 Plan for OG&E McClain Generating Station

FACILITY 208:	**OG & E McClain Generating Station***	CITY/TOWN:	Newcastle
FACILITY LEGAL LOCATION:	S35 T10N R04W N/S	**COUNTY:**	McClain
NPDES #:	**OK0045250**	**SIC CODE:**	4911
STATE FACILITY NUMBER:	**47000140**	**OPERATIONS DESCRIPTION:**	Power Plant
OUTFALL NUMBER:	**001**		
WASTE WATER DESCRIPTION:	Wastewater from cooling tower blowdown, low volume waste, heat recovery steam generator, and steam turbine.		
TREATMENT PROCESS:	IMPOUNDMENT		
EVALUATION TYPE:	Wasteload allocation study		
RECEIVING STREAM:	Canadian River (OK Waterbody ID: OK520610010010_20)		
7 DAY 2 YEAR LOW FLOW (MGD):	14.5		
STREAM CLASS:	PERENNIAL	**SEGMENT:**	520610
CRITICAL EFFLUENT FLOW(MGD):	0.189	**PROJECTED MAXIMUM FLOW (MGD):**	
POINT OF DISCHARGE:	S35 T10N R04W NE/SW/NW		
LATITUDE:	35º 18’ 01” N	**LONGITUDE:**	97º 35’ 28” W
WASTELOAD ALLOCATION*: For Dissolved Oxygen Demanding Substances (Final Discharge only, no internal monitoring points)	**Spring & Winter Limits (Nov- May):** **30 mg/L BOD_5 and 72 mg/l TSS (Daily Maximum)** **Summer Limits (Jun- Oct):** **9 mg/L $CBOD_5$, 72 mg/l TSS (Daily Maximu), 3.2 mg/L NH_3-N,and 4 mg/L DO**		
		EPA TECHNICAL APPROVAL DATE:	**2/1/2024**
		EPA FINAL APPROVAL DATE:	**6/30/2015**
		RECORD LAST UPDATED:	**4/29/2026**
*Updated WLA based on Wasteload Allocation Study (Oct. 2014) of Canadian River (Union City to Wayne, OK)			

Appendix C – Linear Regression Method

C.1. Overview

Turbidity is a commonly measured indicator of the suspended solids load in streams. However, turbidity is an optical property of water, which measures scattering of light by suspended solids and colloidal matter. Additionally, the WASP model is not the appropriate tool for developing TSS limits, as the model is not configured to simulate solids transport or settling processes that determine TSS behavior in receiving waters.

For WLA development, a gravimetric (mass-based) measure of solids loading is required to express loads. Because turbidity and TSS are often strongly correlated, TSS is used as the surrogate for turbidity in load calculations. To quantify the relationship between turbidity and TSS, a linear regression was developed using data collected from 2015–2022 at OWRB's Canadian River monitoring station near Purcell, OK (Station ID: 520610010010-001AT).

C.2. Regression Method

A relationship is necessary to predict TSS concentrations from measured turbidity values, but also to translate the TSS-based TMDL back to in-stream turbidity values. For this purpose, an alternate regression fitting procedure known as the line of organic correlation (LOC) was applied. To apply LOC, TSS samples of less than 10 were replaced with 9.99 and then both turbidity and TSS data were log-transformed to minimize effects of their non-linear data distribution. The LOC has three advantages over OLS (Helsel and Hirsch 2002):

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

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

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

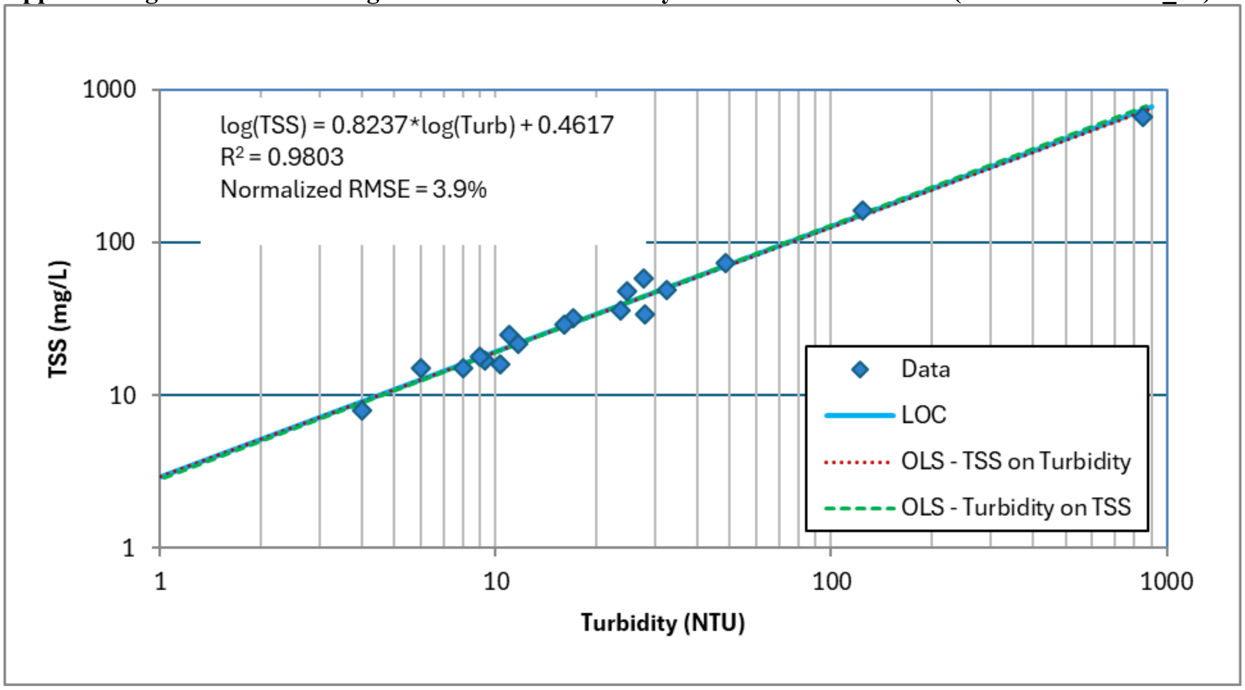
m1 is the slope of the LOC line
m is the TSS on turbidity OLS slope
m' is the turbidity on TSS OLS slope
r is the TSS-turbidity correlation coefficient
sy is the standard deviation of the TSS measurements
sx is the standard deviation of the turbidity measurements

The r can range from -1 to 1 with 0 indicating no correlation, and negative r indicating an inverse correlation. Correlation values of 0 to 0.5 indicate a weaker correlation whereas values greater than 0.5 indicate a strong correlation. As a result, correlations of approximately 0.5 or greater are commonly used in TMDL studies (Christensen, Jian, and Ziegler; 2000). This Study considered an R-square (R2 or coefficient of determination) value of approximately 0.5 or greater to represent a satisfactory relationship between turbidity and TSS, if based on at least 10 observations.

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

The NRMSE and R-square (r2) were used as the primary measures of goodness-of-fit. As shown in Figure 4 1, the LOC yields a NRMSE value of 3.9% which means the root mean square error (RMSE) is 3.9% of the average of the measured TSS values. The R-square (R2) value indicates the fraction of the total variance in TSS or turbidity observations that is explained by the LOC. The regression equation can be used to convert the turbidity standard of 50 NTUs to TSS goals of 72 mg/L.

Appendix Figure C-1 Linear Regression for TSS-Turbidity for the Canadian River (OK520610010010_05)



It was noted that there were a few outliers that exerted undue influence on the regression relationship. These outliers were identified by applying the Tukey's Boxplot method to the dataset of the distances from observed points to the regression line. The Tukey Method is based on the interquartile range (IQR), the difference between the 75th percentile (Q3) and 25th percentile (Q1) of distances between observed points and the LOC. Using the Tukey method, any point with an error greater than Q3 + 1.5* IQR or less than Q1 – 1.5*IQR was identified as an outlier and removed from the regression dataset. The above regressions were calculated using the dataset with outliers removed.

The Tukey Method is equivalent to using three times the standard deviation to identify outliers if the residuals (observed - predicted) follow a normal distribution. The probability of sampling results being within three standard deviations of the mean is 99.73% while the probability for the Tukey Method is 99.30%. If three times the standard deviation is used to identify outliers, it is necessary to first confirm that the residuals are indeed normally distributed. This is difficult to do because of the size limitations of the existing turbidity and TSS dataset. Tukey's method does not rely on any assumption about the distribution of the residuals. It can be used regardless of the shape of distribution.