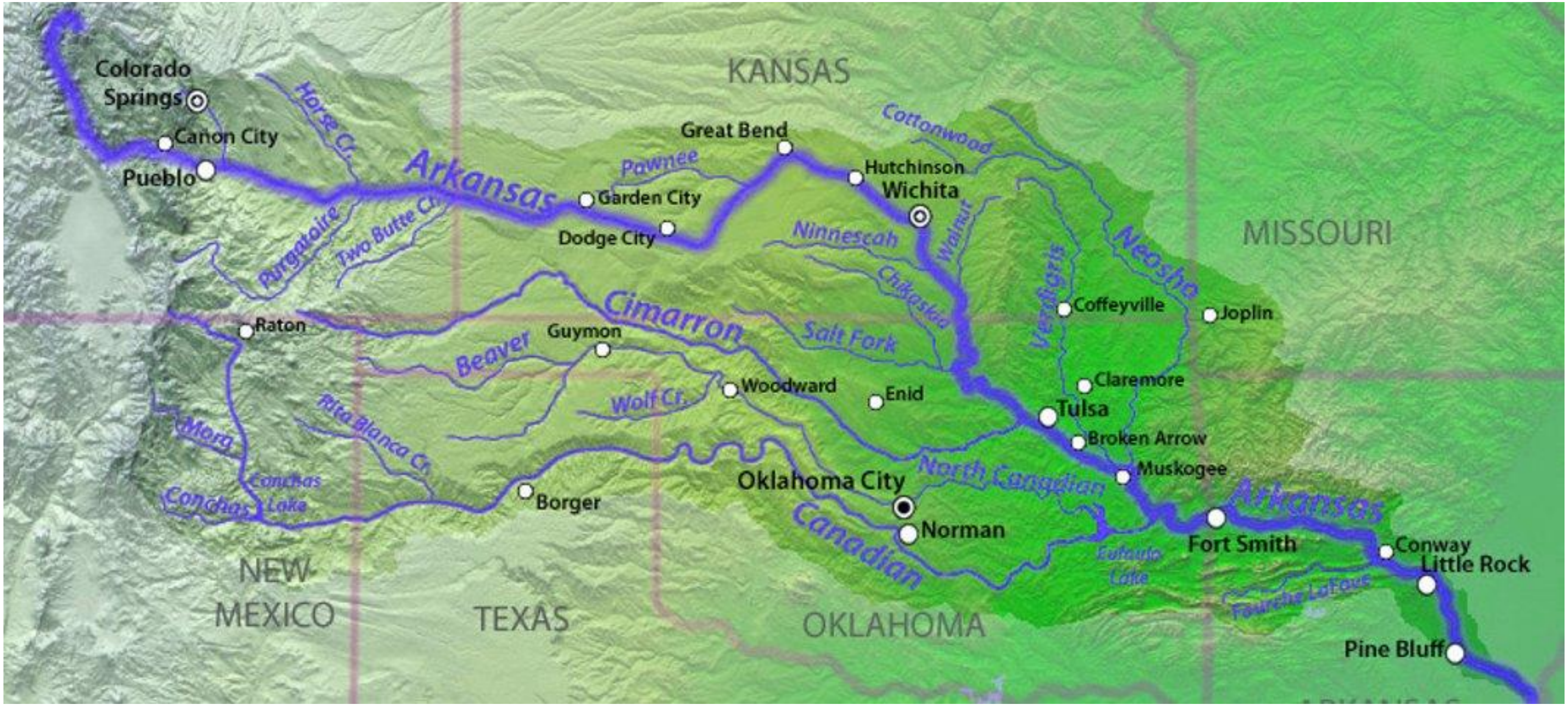
CITY OF TULSA

# Water Quality Monitoring at Zink Lake

Brooke Caviness, City of Tulsa
Barney Austin, Hazen and Sawyer

# Arkansas River Basin




Arkansas River Basin via The Encyclopedia of Earth

# History – Keystone Dam

- Authorized by Flood Control Act of 1950
- 1956 – Construction began
- 1964 – Completion for flood control
- 1968 – Commercial operation of hydropower
- Cost: $123 Million (1956 dollars)

# Previous Zink Dam

Constructed in 1982

7 feet in height

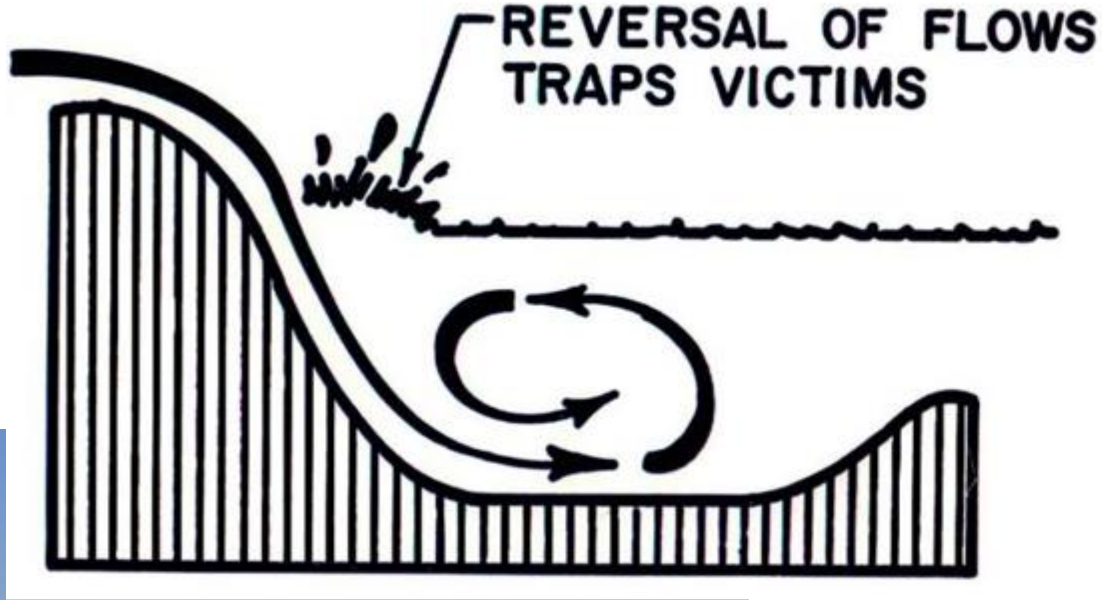
1,030 feet in length

Ogee spillway design

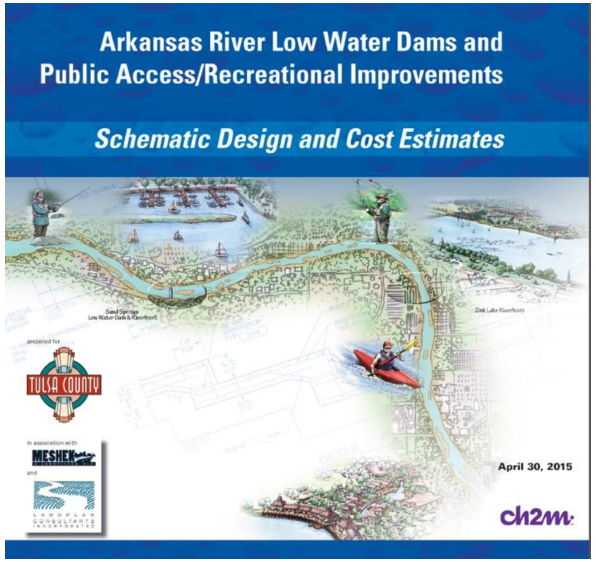
880' fixed dam

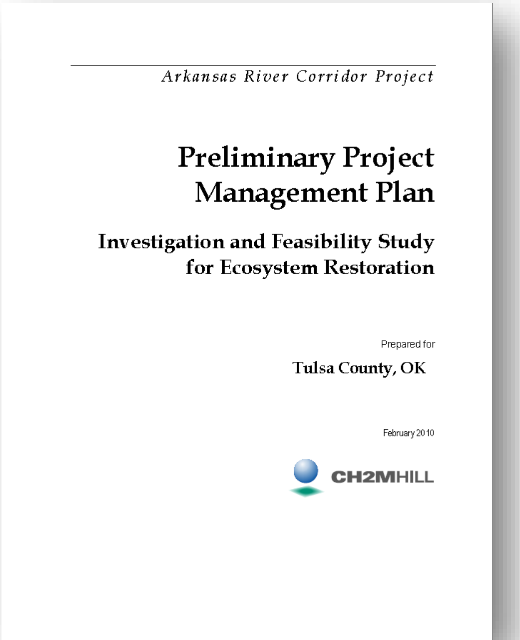
5' high gates

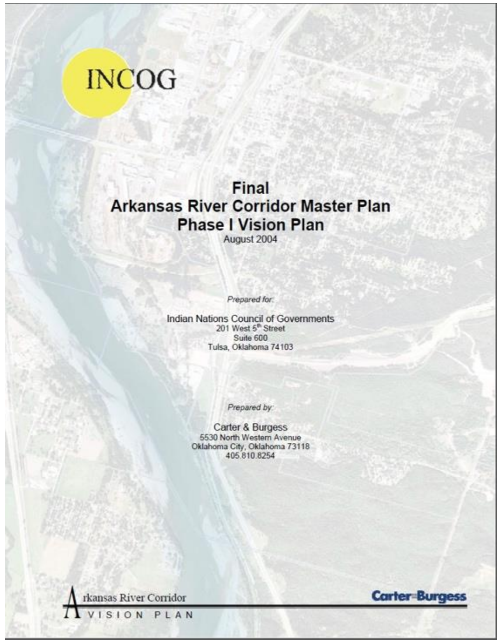
3 sections of 50'

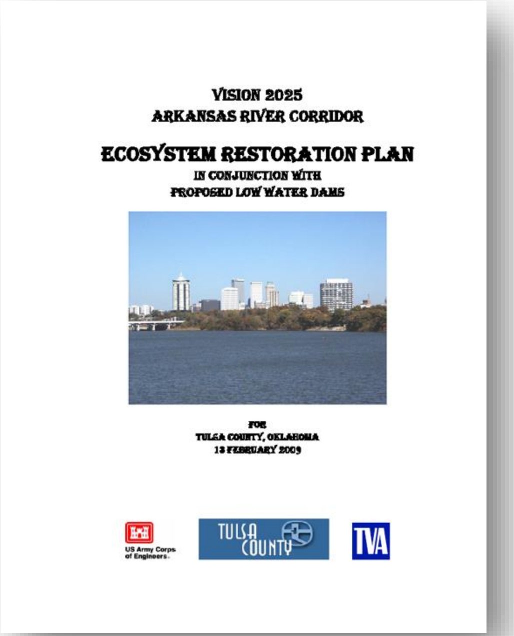


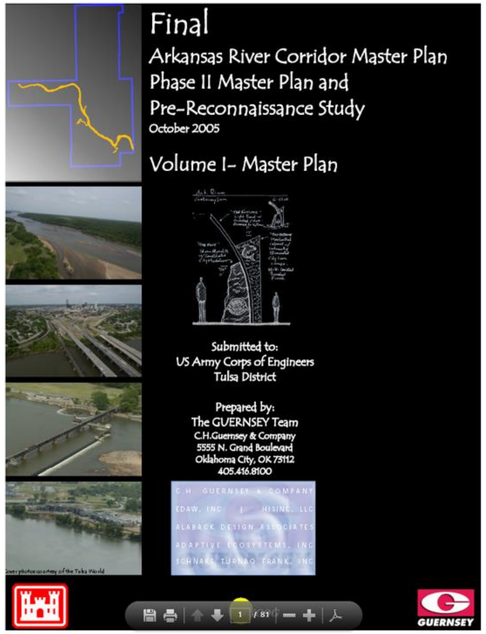

- Decades of discussion about river improvements
- 42 miles of river in Tulsa County
- Public meeting desires:
  - More water in the river
  - Development
  - Recreational areas along the corridor
  - Better Connections and access
  - Conservation and improvement to the native riverine habitat



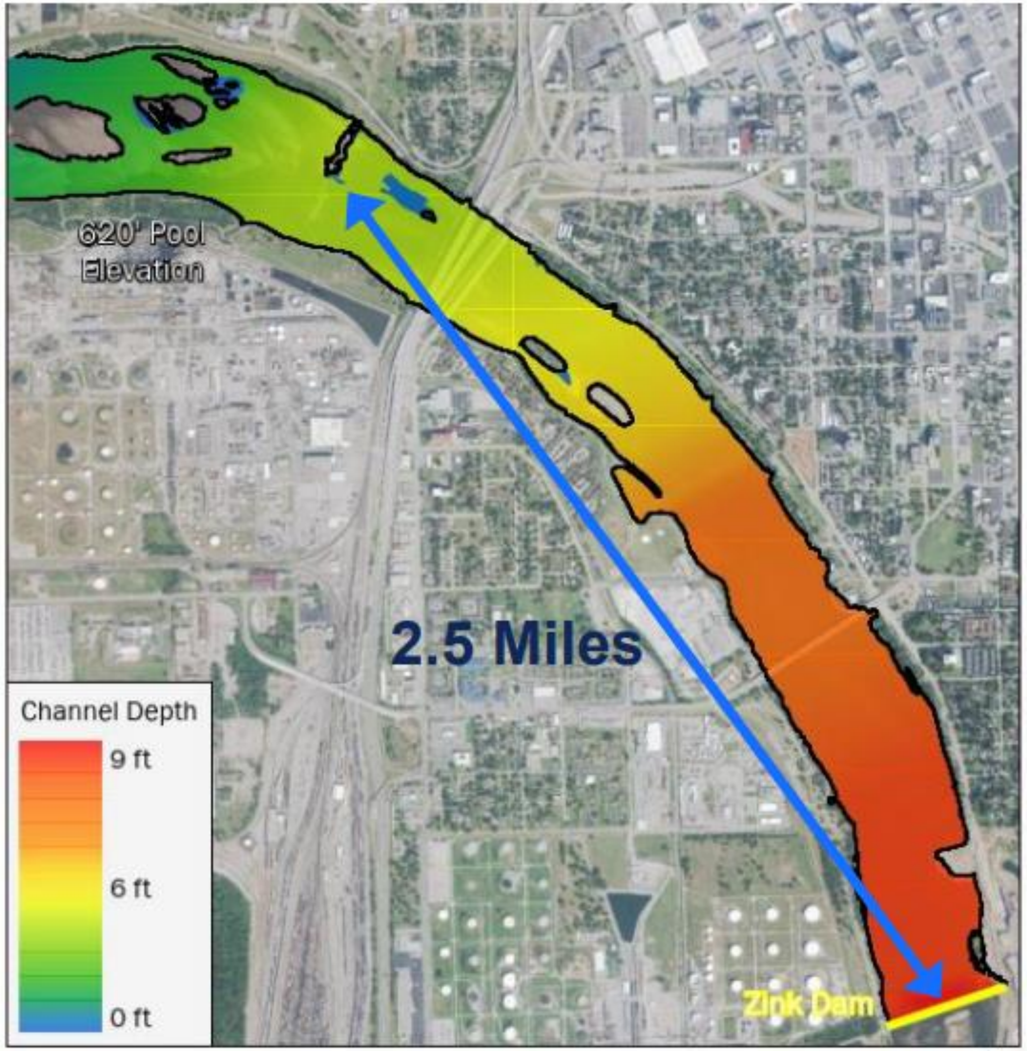



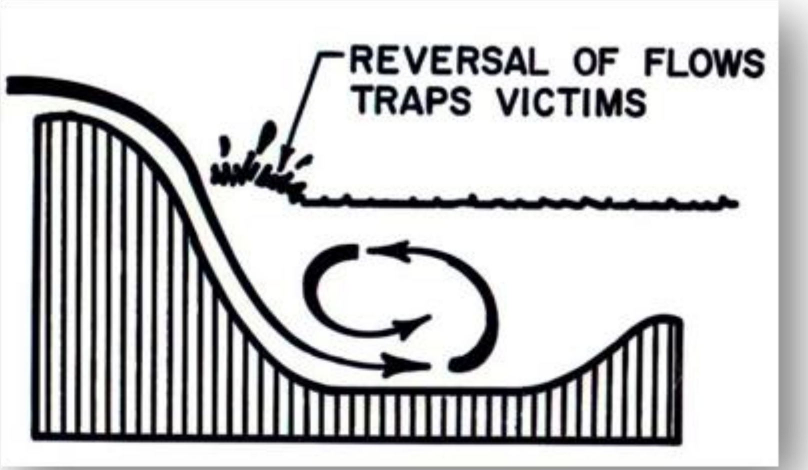
# Public Access

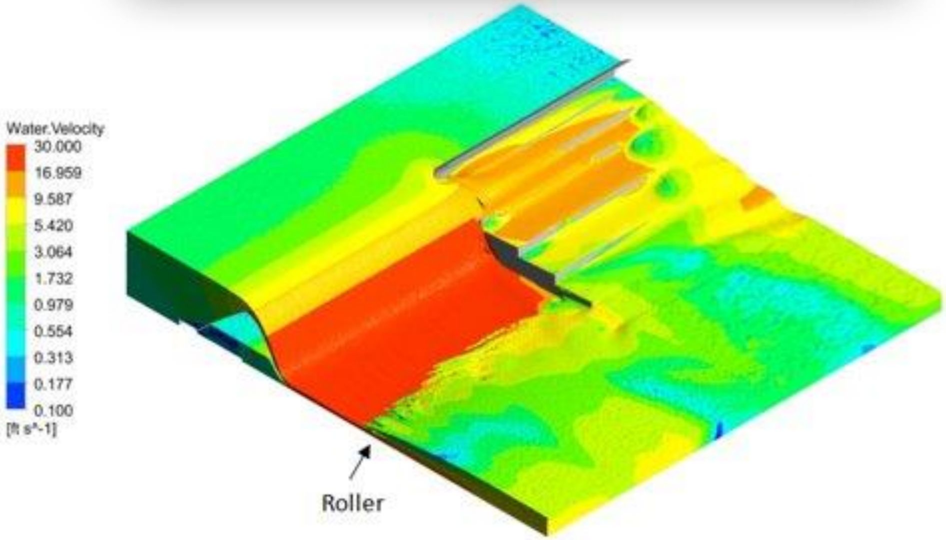



Zink Lake Depth Grid - Pool Elevation at 620'

- Paths and trails adjacent to water's edge
- Pedestrian bridge connections with sidewalks/trails
- Fishing from banks

# Enhanced Safety




- Existing Ogee weir
- New step design reduces hazard

# Sediment Management

- During high flow conditions (>40k cfs) all gates will be down enabling sediment transport
- Provides 'no rise' to base flood elevation

# Recreation Opportunities

- Zink Lake – increased length and increased pool depth to 10’ at the dam
- Whitewater flume

# Recreation Opportunities








# First some explanations…

AquaStrategies
Water Planning, Science & Engineering

→

HAZEN AND SAWYER
Environmental Engineers & Scientists

↓

AquaStrategies

Hazen

A & M Engineering and Environmental Services, Inc.
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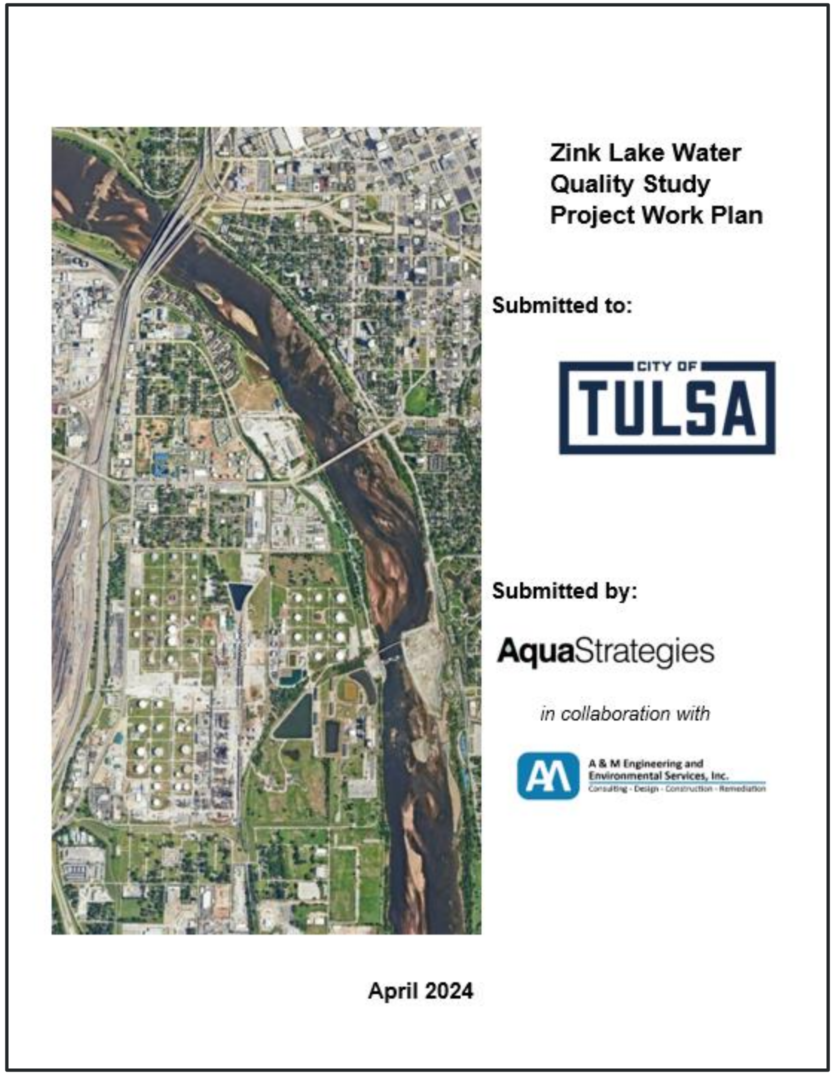
# Scope of work from City of Tulsa

| Task # | Description |
|---|---|
| Task 1 | Project Work Plan |
| Task 2 | Field Monitoring and Laboratory Analyses |
| Task 3 | Framework for Public Dashboard |
| Task 4 | Water Quality Analysis/Modeling |
| Task 5 | Project Management and Coordination |
| Task 6 | Reporting |

# Project Work Plan

Review of historical data
Contaminant source analysis
Water quality monitoring strategy
QA/QC plan
Project Health and Safety Plan
Public Information Dissemination


Zink Lake Water Quality Study Project Work Plan

Submitted to:

CITY OF TULSA

Submitted by:

AquaStrategies

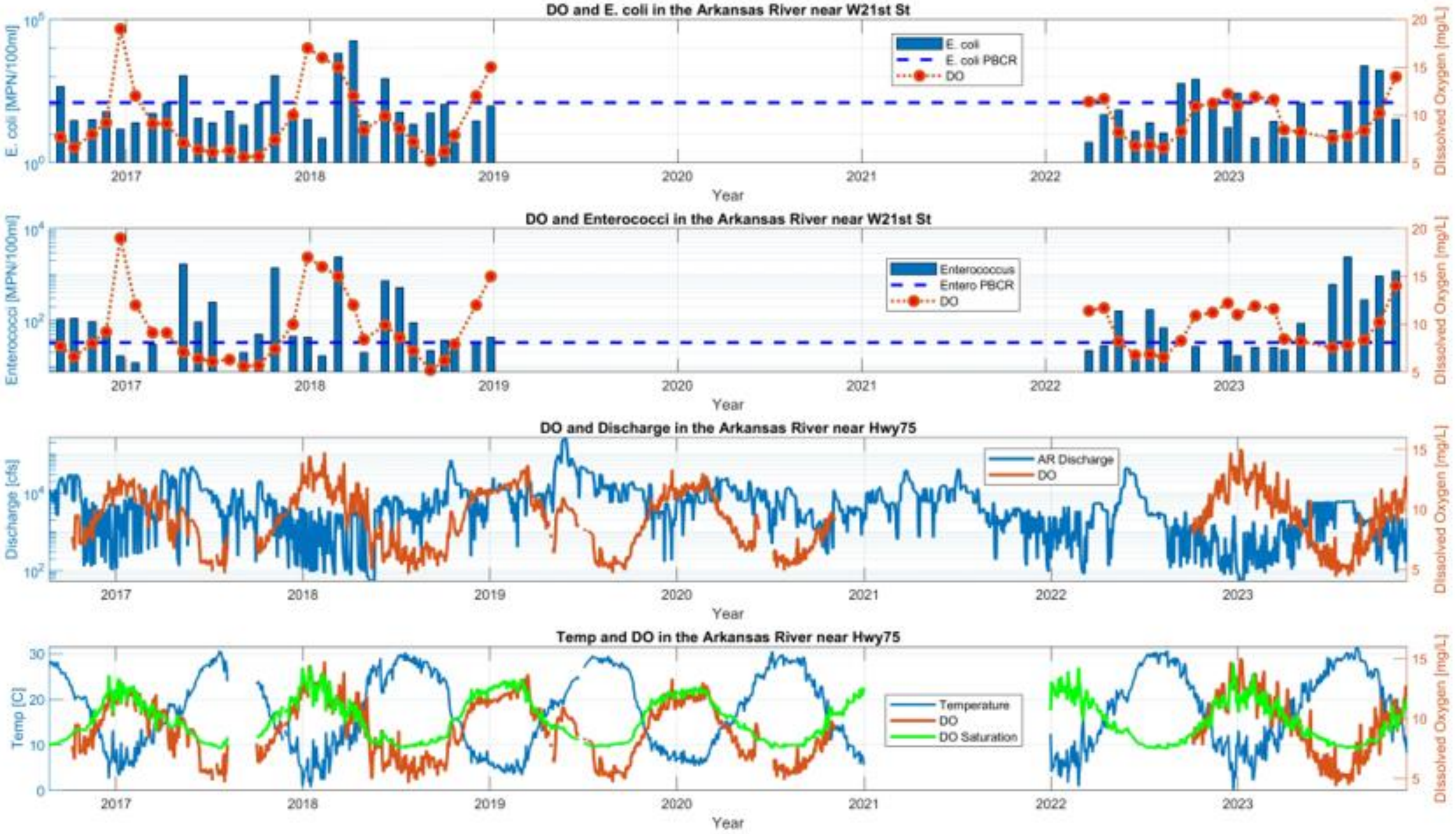
*in collaboration with*

A & M Engineering and Environmental Services, Inc.
Consulting · Design · Construction · Remediation

April 2024

# Sampling sites
# Moving the USGS streamgage...

# Historical water quality data




***DO and E.coli***

***DO and Enterococci***

***DO and Discharge***

***Temperature and DO***

*Figure 2. E. coli (upper panel), Enterococci (top-middle panel), and Dissolved Oxygen (DO) trends in the Arkansas River near W21st Street. Discharge and DO (lower-middle panel) and DO vs Temperature (lower panel) from the USGS gage station near Hwy 75.*

# Bacteria data and correlation with rainfall

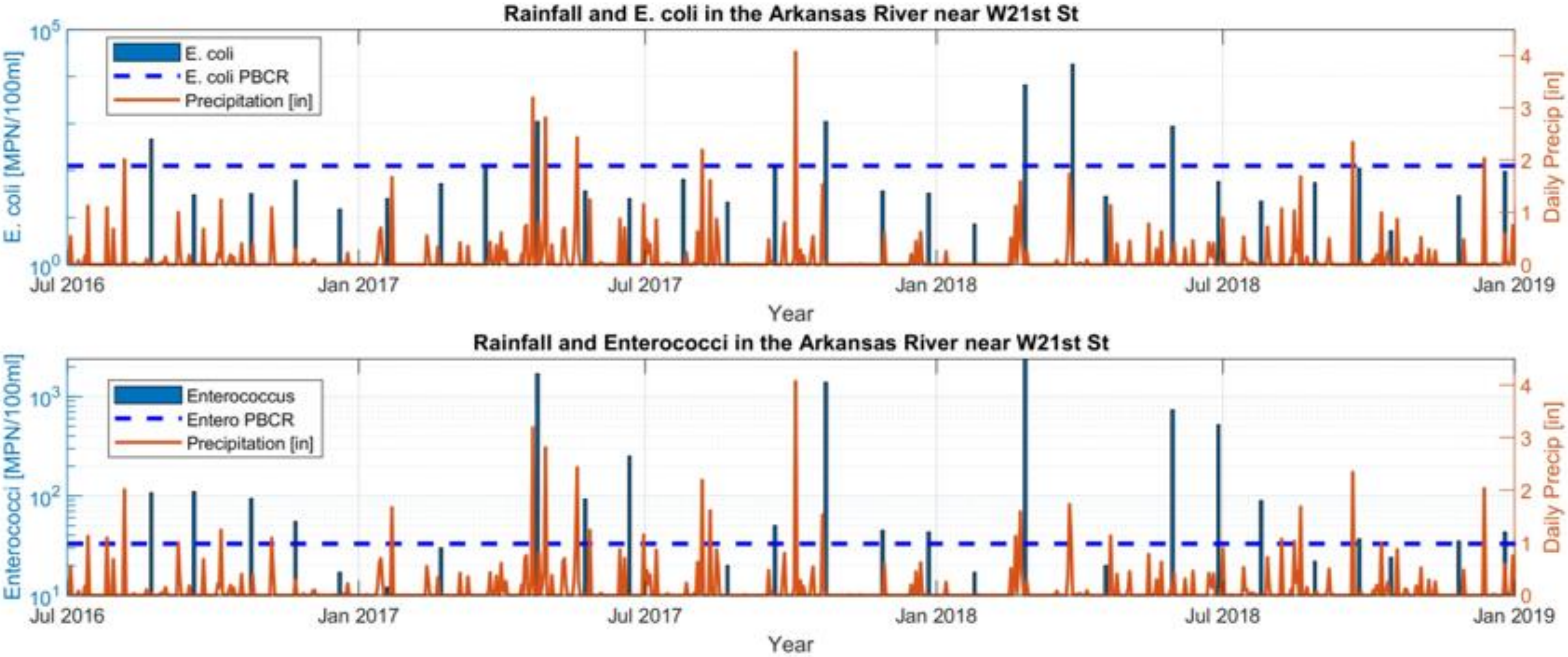



*Figure 3. E. coli (upper panel) and Enterococci (lower panel) concentrations vs rainfall near Tulsa Int. Airport.*

# Oklahoma Administrative Code for PBCR

(a) **PBCR waterbodies - May 1 through September 30.** When the use of a bacteriological indicator is determined to be necessary, the following bacteriological limitations shall apply from May 1 through September 30 to protect the PBCR beneficial use:

(1) **Escherichia coli (E. coli).** When E. coli is the bacteriological indicator:

(A) The monthly geometric mean shall not exceed 126/100 ml.

(B) The daily maximum for lakes shall not exceed 235/100 ml.

(C) The daily maximum for all waterbodies other than lakes shall not exceed 406/100 ml.

(2) **Enterococci.** When enterococci is the bacteriological indicator:

(A) The monthly geometric mean shall not exceed 33/100 ml.

(B) The daily maximum for lakes shall not exceed 61/100 ml.

(C) The daily maximum for all waterbodies other than lakes shall not exceed 108/100 ml.

# *E.coli* versus *Enterococci*

Water Air Soil Pollut (2023) 234:348
https://doi.org/10.1007/s11270-023-06355-z

**Validating Microbial Source Tracking Markers and Assessing the Efficacy of Culturable *E. coli* and *Enterococcus* Assays in Ozark Streams, USA**

**Dustin A. Browning · William E. Mausbach · Courtney Stookey · Stephen J. Nikolai · Joel Barrow · Darrell E. Townsend II**

Oklahoma Conservation Commission no longer uses Enterococci for assessment of suitability for primary body contact, per Shanon Philips (03/13/2024)

Oklahoma Administrative Code (785:45-5-16) states that compliance with Primary Body Contact for recreation "…shall be based upon meeting the requirements of one of the options specified in (1) or (2) of this subsection (c) for bacteria. Upon selection of one (1) group or test method, said method shall be used exclusively over the time period prescribed therefore.", where (1) refers to *E. coli* and (2) refers to *Enterococci*. As such we recommend that the City of Tulsa (City) use *E. coli* exclusively at this time, for the assessment of Primary Body Contact health risk.

# Proposed sampling schedule

*Table 1. Recommended initial parameters, analytical methods, and frequency of sampling for all four sampling sites.*

| **Analysis List** | **Method** | **Minimum Frequency** |
|---|---|---|
| *E. coli* | Water sample | Twice per week |
| pH | In-situ | Twice per week |
| Temperature | In-situ | Twice per week |
| Dissolved Oxygen | In-situ | Twice per week |
| Turbidity | In-situ | Twice per week |
| Electrical Conductivity | In-situ | Twice per week |
| Dissolved Cadmium | Water sample | Monthly |
| Total Petroleum Hydrocarbon | Water sample | Monthly |

# Sampling safety and accuracy



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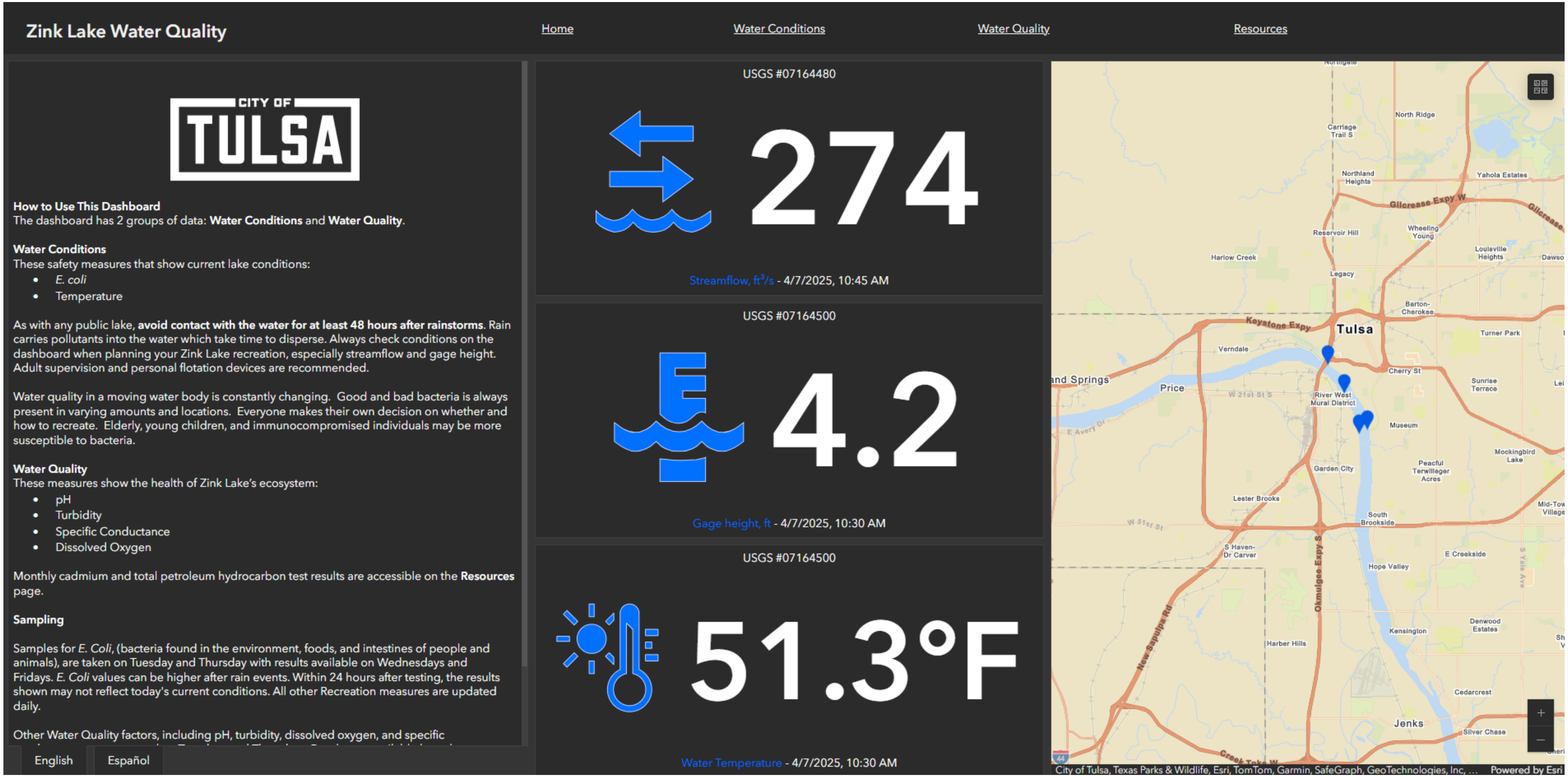
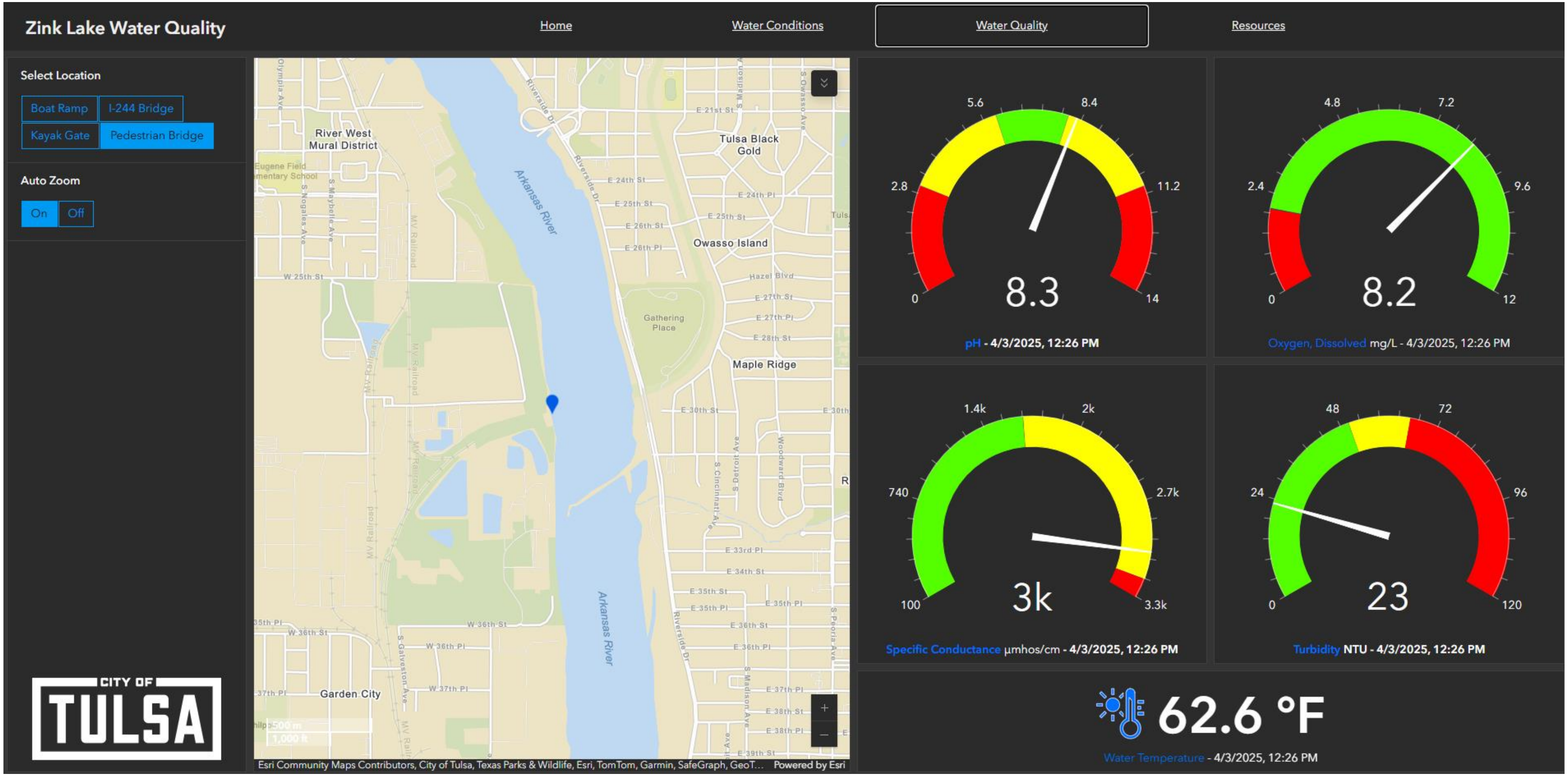
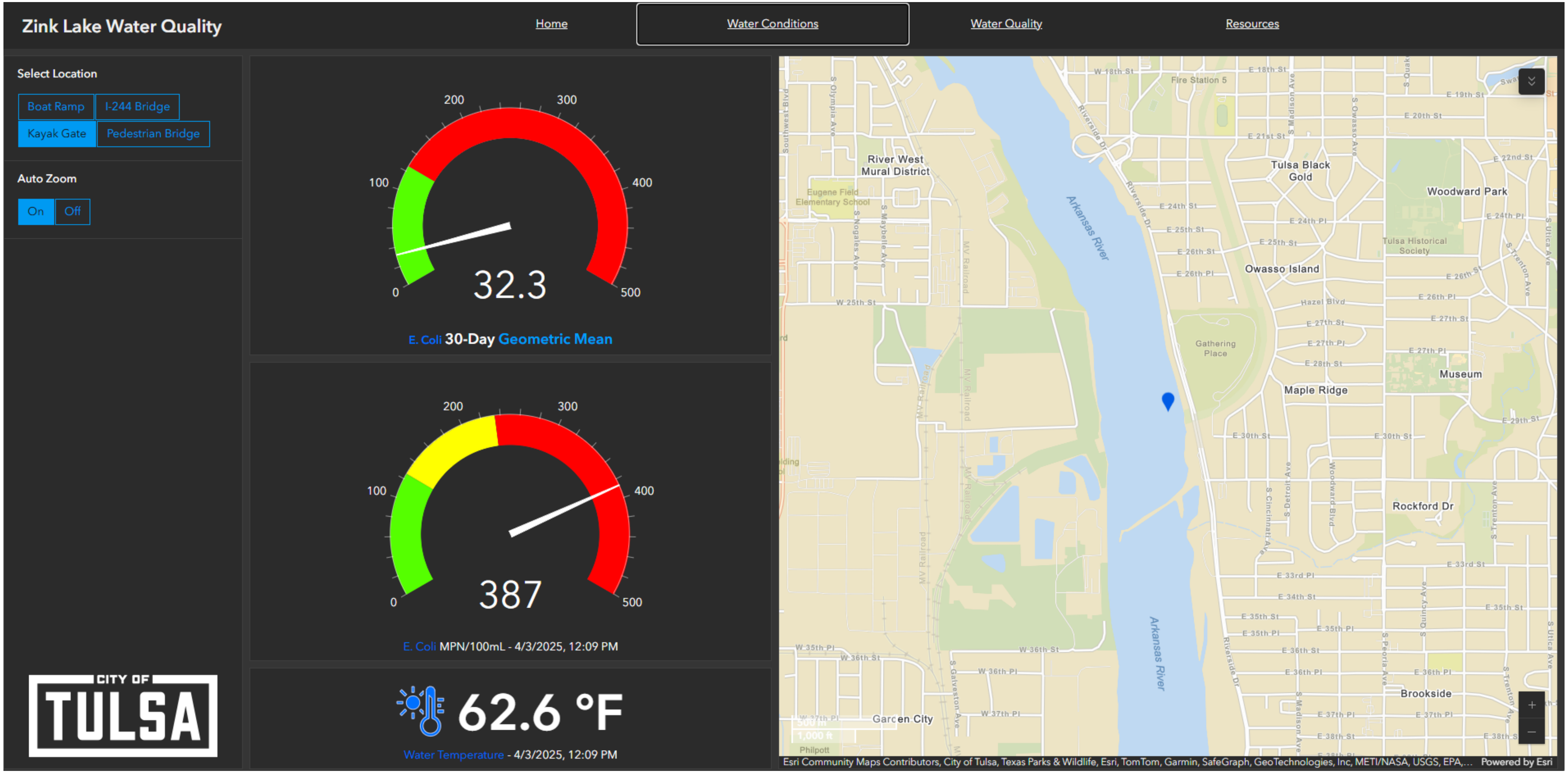
# Data viewer – Home Page



# Data viewer – water quality parameters



# Data viewer (*E. coli*)



# Data viewer (other resources)

## Zink Lake Water Quality

Frequently Asked Questions

EPA Recreation Water Quality Criteria PDF

Oklahoma Department of Environmental Quality - Water Quality Standards

National Weather Service - TSA

USGS Stream Gage (Legacy)
USGS Stream Gage (Modern)
USGS Stream Dashboard

Zink Lake Cadmium and TPH PDF

City of Tulsa Stormwater Quality

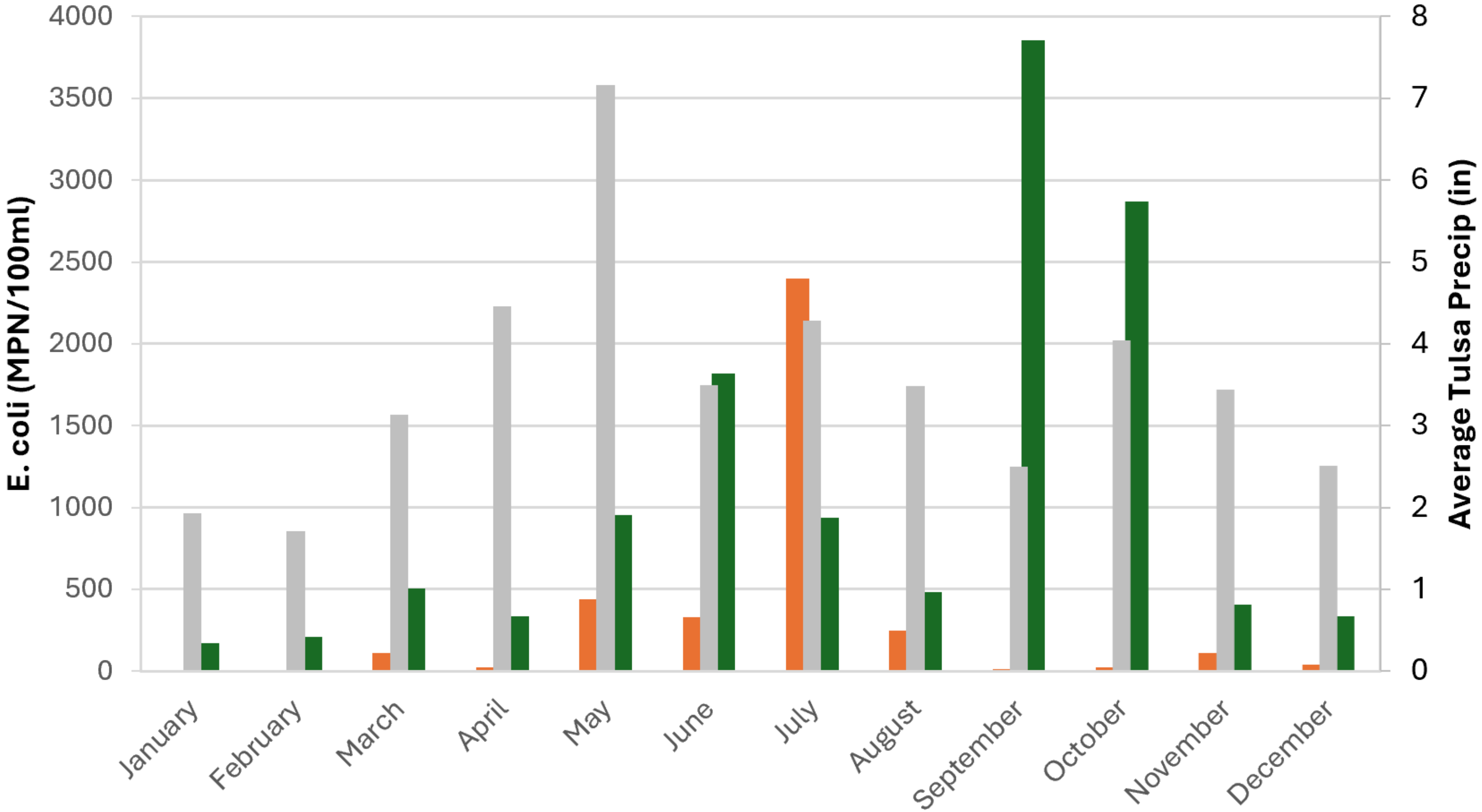
City of Tulsa Map Gallery

Contact the City of Tulsa

*Table 4. Summary statistics for water quality sampling station ZL3*

| | **Min** | **Median** | **Max** | **Mean** | **Std** |
|---|---|---|---|---|---|
| ***E. coli*** | 2.0 | 59.4 | 3310.0 | 218.9 | 527.2 |
| **DO** | 2.9 | 8.8 | 18.0 | 8.5 | 3.0 |
| **Conductivity** | 370.0 | 2400.0 | 4000.0 | 2426.4 | 679.3 |
| **Temperature** | 0.5 | 17.0 | 29.0 | 17.3 | 7.8 |
| **Tot. Coliform** | 125 | 8840 | 242000 | 48014 | 72180 |
| **Turbidity** | 3.3 | 10.0 | 120.0 | 16.5 | 18.8 |
| **pH** | 6.4 | 8.1 | 9.1 | 8.1 | 0.4 |
| ***E. coli* geom. mean** | 7.2 | 61.2 | 275.5 | 77.7 | 51.5 |

# Correlation: Precipitation and *E. coli*




Precipitation: Gray
Mean *E. coli*: Green
Modal *E. coli*: Orange

# Correlations

Table 6. Correlation table for all water quality parameters and environmental variables.

| | Ecoli | DO | Cond | Temp | TColi | Turb | pH | Release | PPT | Rmean | ARLOCALDRAINAGENO_1 | ARLOCALDRAINAGENO_2 | BERRYHILLCREEK | BIGHEARTCREEK | CHERRYCREEK | DOWNTOWN | ELMCREEK | HARLOWCREEK | OAKCREEK | PARKVIEWDRAINAGE | SWANCREEK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ecoli | 1.00 | -0.09 | -0.33 | 0.09 | 0.34 | 0.43 | -0.05 | 0.12 | 0.65 | 0.57 | 0.57 | 0.52 | 0.54 | 0.55 | 0.51 | 0.51 | 0.49 | 0.55 | 0.51 | 0.53 | 0.49 |
| DO | -0.09 | 1.00 | 0.13 | -0.80 | -0.63 | -0.02 | 0.20 | -0.04 | -0.11 | -0.20 | -0.20 | -0.20 | -0.20 | -0.18 | -0.19 | -0.20 | -0.20 | -0.20 | -0.21 | -0.21 | -0.20 |
| Cond | -0.33 | 0.13 | 1.00 | -0.12 | 0.03 | -0.38 | 0.09 | -0.48 | -0.29 | -0.38 | -0.38 | -0.35 | -0.37 | -0.36 | -0.34 | -0.34 | -0.33 | -0.35 | -0.33 | -0.35 | -0.33 |
| Temp | 0.09 | -0.80 | -0.12 | 1.00 | 0.61 | -0.08 | 0.09 | -0.02 | 0.06 | 0.13 | 0.13 | 0.13 | 0.12 | 0.12 | 0.13 | 0.14 | 0.14 | 0.13 | 0.14 | 0.14 | 0.13 |
| TColi | 0.34 | -0.63 | 0.03 | 0.61 | 1.00 | 0.06 | -0.03 | -0.15 | 0.23 | 0.25 | 0.25 | 0.22 | 0.22 | 0.22 | 0.21 | 0.23 | 0.22 | 0.24 | 0.25 | 0.25 | 0.21 |
| Turb | 0.43 | -0.02 | -0.38 | -0.08 | 0.06 | 1.00 | -0.23 | 0.32 | 0.31 | 0.34 | 0.34 | 0.31 | 0.34 | 0.36 | 0.31 | 0.31 | 0.30 | 0.33 | 0.30 | 0.31 | 0.30 |
| pH | -0.05 | 0.20 | 0.09 | 0.09 | -0.03 | -0.23 | 1.00 | -0.38 | -0.06 | -0.16 | -0.16 | -0.15 | -0.17 | -0.16 | -0.15 | -0.16 | -0.16 | -0.15 | -0.15 | -0.16 | -0.15 |
| Release | 0.12 | -0.04 | -0.48 | -0.02 | -0.15 | 0.32 | -0.38 | 1.00 | 0.11 | 0.14 | 0.14 | 0.15 | 0.13 | 0.15 | 0.13 | 0.15 | 0.14 | 0.13 | 0.12 | 0.12 | 0.12 |
| PPT | 0.65 | -0.11 | -0.29 | 0.06 | 0.23 | 0.31 | -0.06 | 0.11 | 1.00 | 0.71 | 0.71 | 0.68 | 0.65 | 0.63 | 0.67 | 0.66 | 0.65 | 0.68 | 0.63 | 0.68 | 0.66 |
| Rmean | 0.57 | -0.20 | -0.38 | 0.13 | 0.25 | 0.34 | -0.16 | 0.14 | 0.71 | 1.00 | 1.00 | 0.98 | 0.99 | 0.98 | 0.98 | 0.98 | 0.97 | 0.99 | 0.98 | 0.99 | 0.97 |
| ARLOCALDRAINAGENO_1 | 0.57 | -0.20 | -0.38 | 0.13 | 0.25 | 0.34 | -0.16 | 0.14 | 0.71 | 1.00 | 1.00 | 0.98 | 0.99 | 0.98 | 0.98 | 0.98 | 0.97 | 0.99 | 0.98 | 0.99 | 0.97 |
| ARLOCALDRAINAGENO_2 | 0.52 | -0.20 | -0.35 | 0.13 | 0.22 | 0.31 | -0.15 | 0.15 | 0.68 | 0.98 | 0.98 | 1.00 | 0.98 | 0.98 | 1.00 | 0.99 | 0.98 | 0.99 | 0.98 | 0.98 | 0.99 |
| BERRYHILLCREEK | 0.54 | -0.20 | -0.37 | 0.12 | 0.22 | 0.34 | -0.17 | 0.13 | 0.65 | 0.99 | 0.99 | 0.98 | 1.00 | 0.99 | 0.98 | 0.97 | 0.95 | 0.98 | 0.97 | 0.97 | 0.96 |
| BIGHEARTCREEK | 0.55 | -0.18 | -0.36 | 0.12 | 0.22 | 0.36 | -0.16 | 0.15 | 0.63 | 0.98 | 0.98 | 0.98 | 0.99 | 1.00 | 0.98 | 0.97 | 0.96 | 0.99 | 0.97 | 0.97 | 0.97 |
| CHERRYCREEK | 0.51 | -0.19 | -0.34 | 0.13 | 0.21 | 0.31 | -0.15 | 0.13 | 0.67 | 0.98 | 0.98 | 1.00 | 0.98 | 0.98 | 1.00 | 0.98 | 0.97 | 0.99 | 0.98 | 0.98 | 0.98 |
| DOWNTOWN | 0.51 | -0.20 | -0.34 | 0.14 | 0.23 | 0.31 | -0.16 | 0.15 | 0.66 | 0.98 | 0.98 | 0.99 | 0.97 | 0.97 | 0.98 | 1.00 | 1.00 | 0.98 | 0.98 | 0.98 | 0.99 |
| ELMCREEK | 0.49 | -0.20 | -0.33 | 0.14 | 0.22 | 0.30 | -0.16 | 0.14 | 0.65 | 0.97 | 0.97 | 0.98 | 0.95 | 0.96 | 0.97 | 1.00 | 1.00 | 0.97 | 0.97 | 0.96 | 1.00 |
| HARLOWCREEK | 0.55 | -0.20 | -0.35 | 0.13 | 0.24 | 0.33 | -0.15 | 0.13 | 0.68 | 0.99 | 0.99 | 0.99 | 0.98 | 0.99 | 0.99 | 0.98 | 0.97 | 1.00 | 0.99 | 0.99 | 0.97 |
| OAKCREEK | 0.51 | -0.21 | -0.33 | 0.14 | 0.25 | 0.30 | -0.15 | 0.12 | 0.63 | 0.98 | 0.98 | 0.98 | 0.97 | 0.97 | 0.98 | 0.98 | 0.97 | 0.99 | 1.00 | 1.00 | 0.97 |
| PARKVIEWDRAINAGE | 0.53 | -0.21 | -0.35 | 0.14 | 0.25 | 0.31 | -0.16 | 0.12 | 0.68 | 0.99 | 0.99 | 0.98 | 0.97 | 0.97 | 0.98 | 0.98 | 0.96 | 0.99 | 1.00 | 1.00 | 0.97 |
| SWANCREEK | 0.49 | -0.20 | -0.33 | 0.13 | 0.21 | 0.30 | -0.15 | 0.12 | 0.66 | 0.97 | 0.97 | 0.99 | 0.96 | 0.97 | 0.98 | 0.99 | 1.00 | 0.97 | 0.97 | 0.97 | 1.00 |

# Predictability of *E. coli* - equation

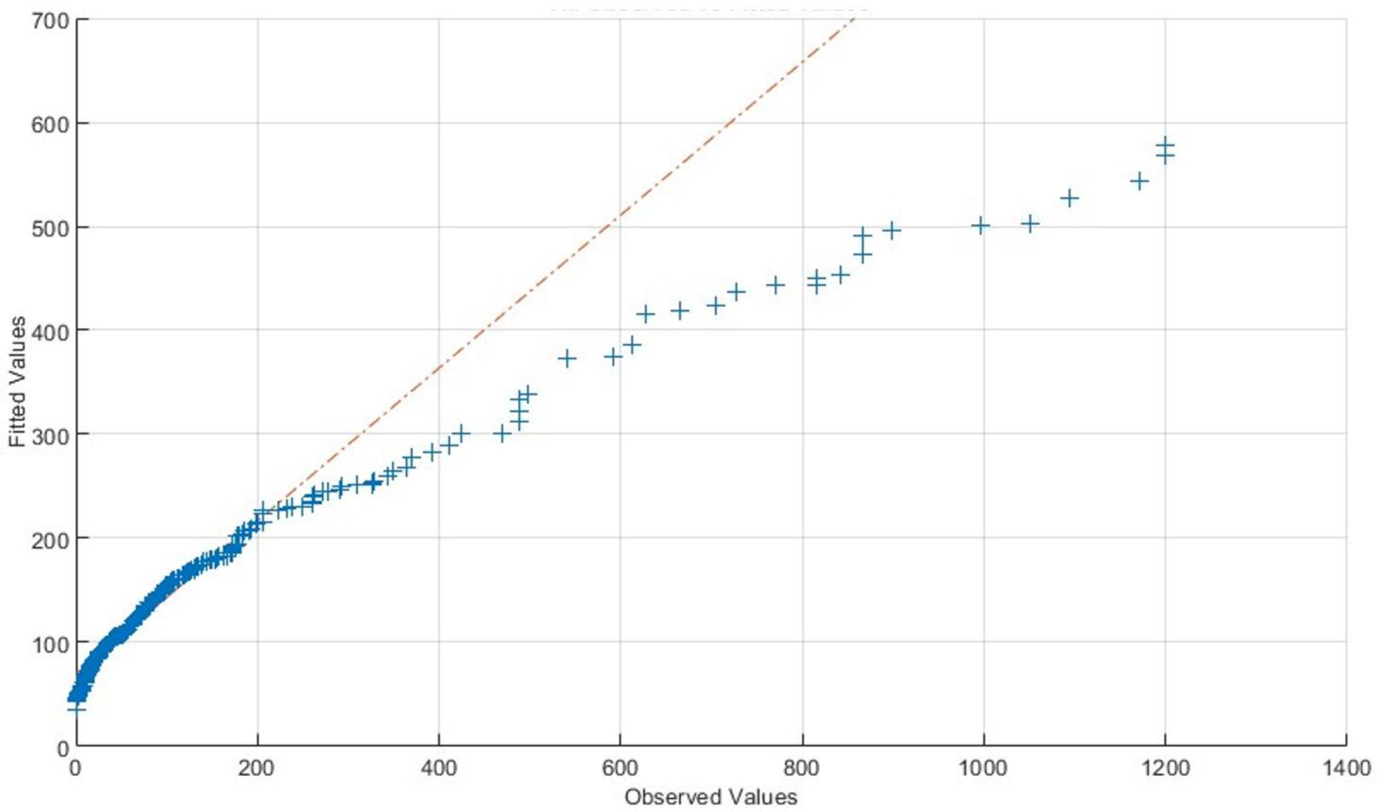



Figure 7. Observed vs fitted values using the Generalized Linear Mixed-Effects model

$$Ecoli = intercept + k_1 Turb + k_2 Cond + k_3 DO + k_4 Rmean + k_5 Rprism + k_6 Temp$$

# Predictability of *E. coli* – Machine Learning

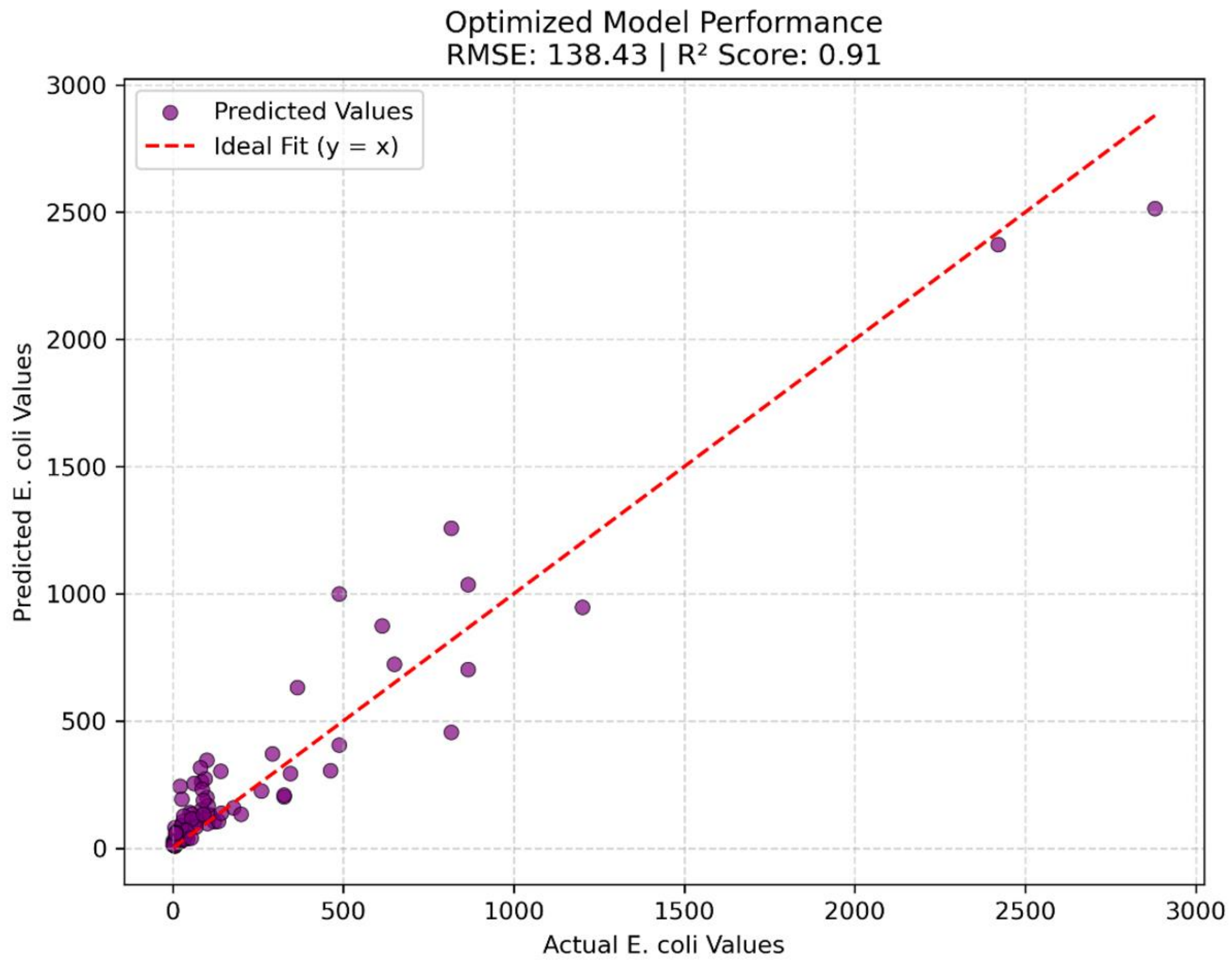
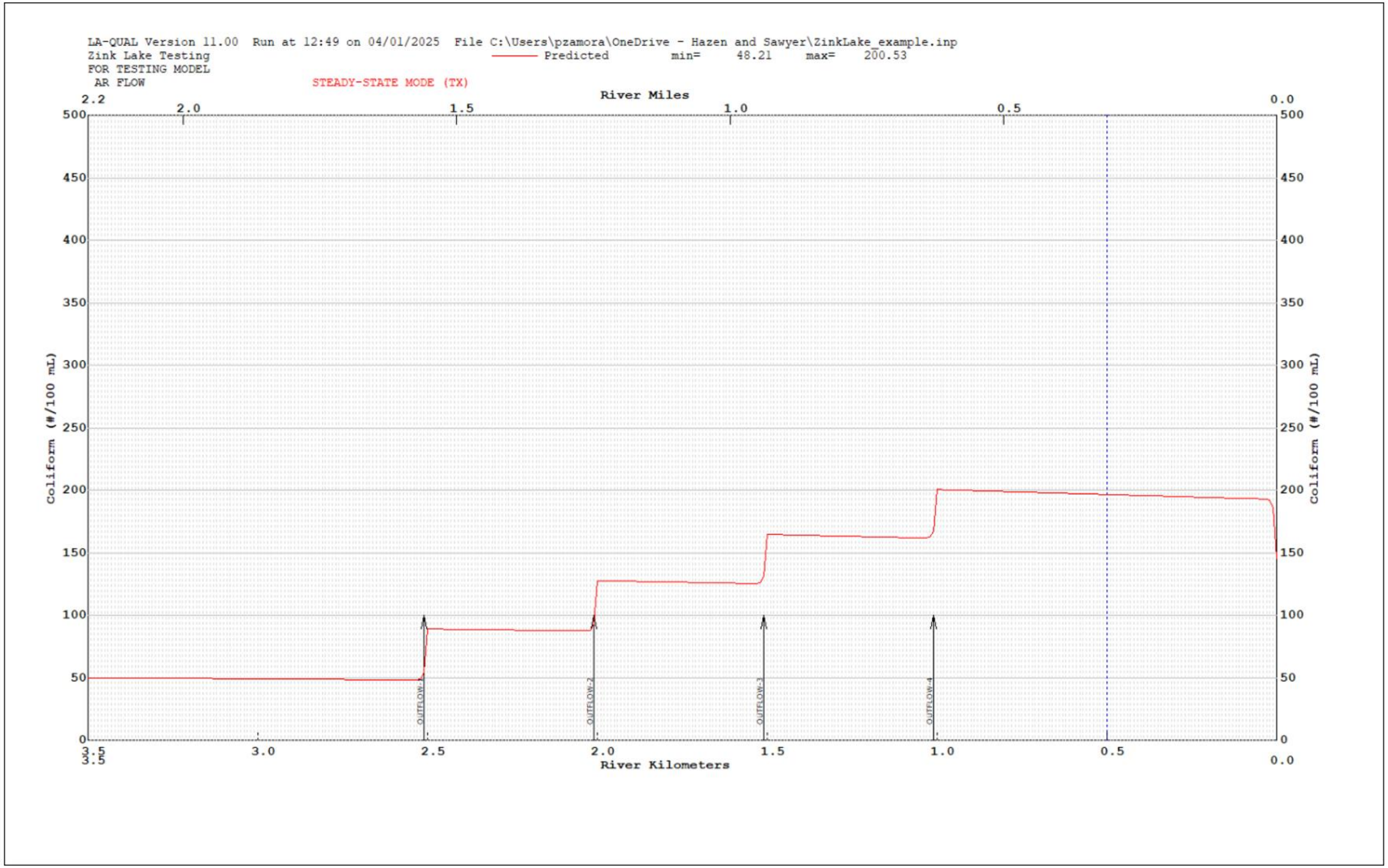


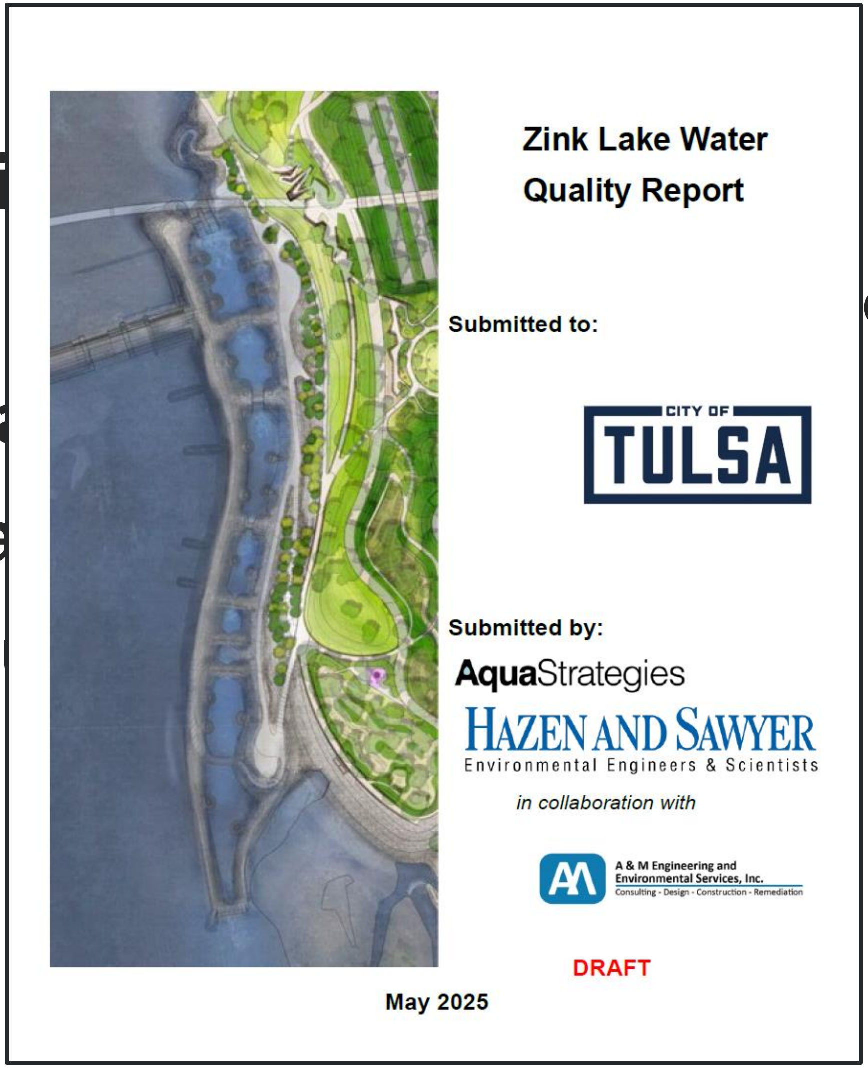

Figure 8. Actual vs predicted values fit using Machine Learning algorithm Random Forest

# Predictability of *E. coli* - Water Quality Model



# Recommended next steps

1. Continue monitoring and displayi
2. Collect water quality data on stor e
3. Consider building a 2-D water qu
4. Perform DNA analysis on bacteria
5. Conduct bathymetric/sediment s



# THANK YOU

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