Occurrence of *Escherichia coli* and Enterococcus in Oklahoma Streams During the 2018 Recreational Season

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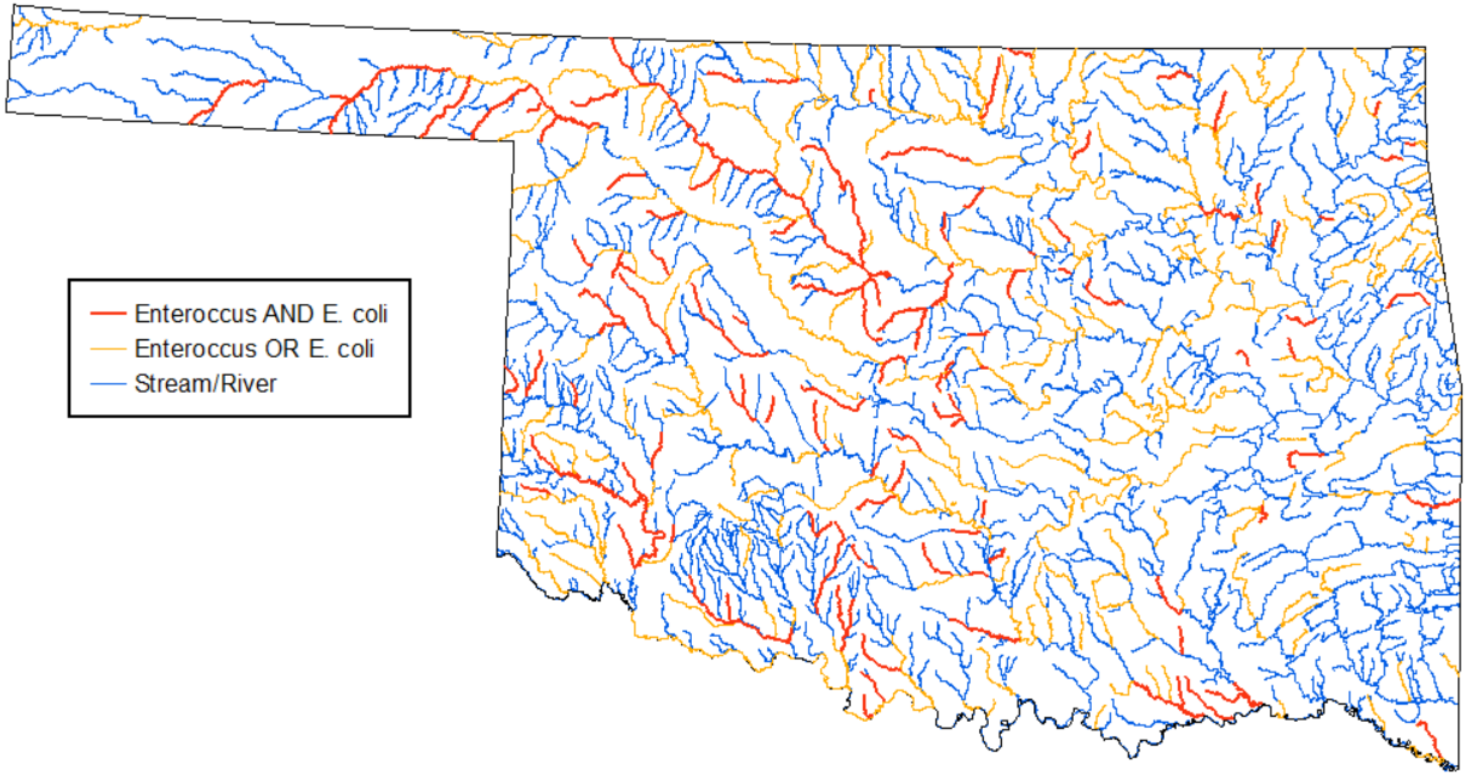
OKLAHOMA WATER SURVEY
OK H2O
at The UNIVERSITY of OKLAHOMA

Background

- 2016 303(d) list assessed 33,016 miles of streams
  - 7,537 miles impaired for enterococcus
  - 2,819 miles impaired for *E. coli*



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State of Impairment

- Resources for routine bacteria monitoring are limited.
  - Time and Dollars
- Impaired status unknown for many stream sites
  - Some as far back as 2001!
- Sites are generally only sampled routinely once every 5 years at minimum.
- Increased urbanization, land uses and climate change all factors to consider

Project Objectives

- Fill a need for monitoring pathogenic indicators in Oklahoma
- Evaluate legacy stream reaches for impairment status
- Provide the State with valuable information to assess human health risk and beneficial uses
- Potentially reduce state costs by removal from list
- Emphasis for continued monitoring and education

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Primary Body Contact Recreation

- A minimum of ***ten (10) samples is required*** to make an attainment determination.
- Samples must be taken during the recreation period of ***May 1 – September 30***.
- The geometric means will be compared to the appropriate screening value.
  - *Escherichia coli* (*E. coli*)
    - **Attained** if: the ***geometric mean*** of the samples ***does not exceed 126 colonies/100 mL***
    - **Not attained** if: the ***geometric mean*** of the samples ***exceeds 126 colonies/100 mL***
  - Enterococci
    - **Attained** if: the ***geometric mean*** of the samples ***does not exceed 33 colonies/100 mL***
    - **Not attained** if: the ***geometric mean*** of the samples ***exceeds 33 colonies/100 mL***

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Why Monitor for *E. coli* and Enterococcus

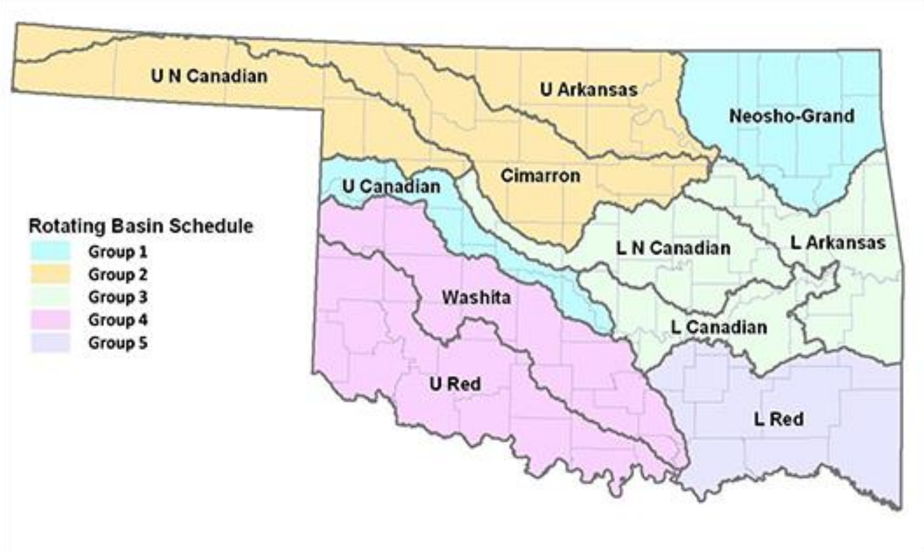
- Pathogenic indicator
- Human health
- Environmental health

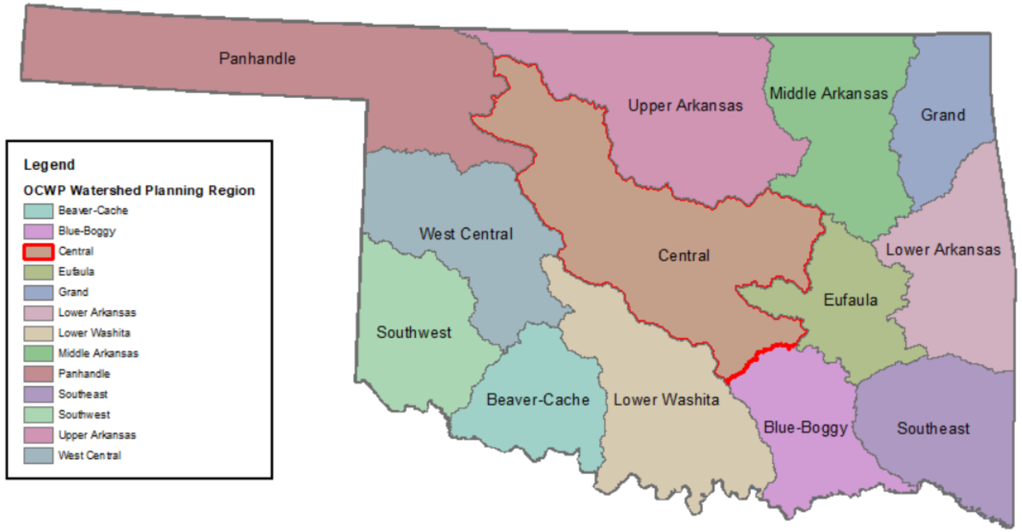
E. coli

Enterococcus

OWS 2018 Recreational Season Monitoring

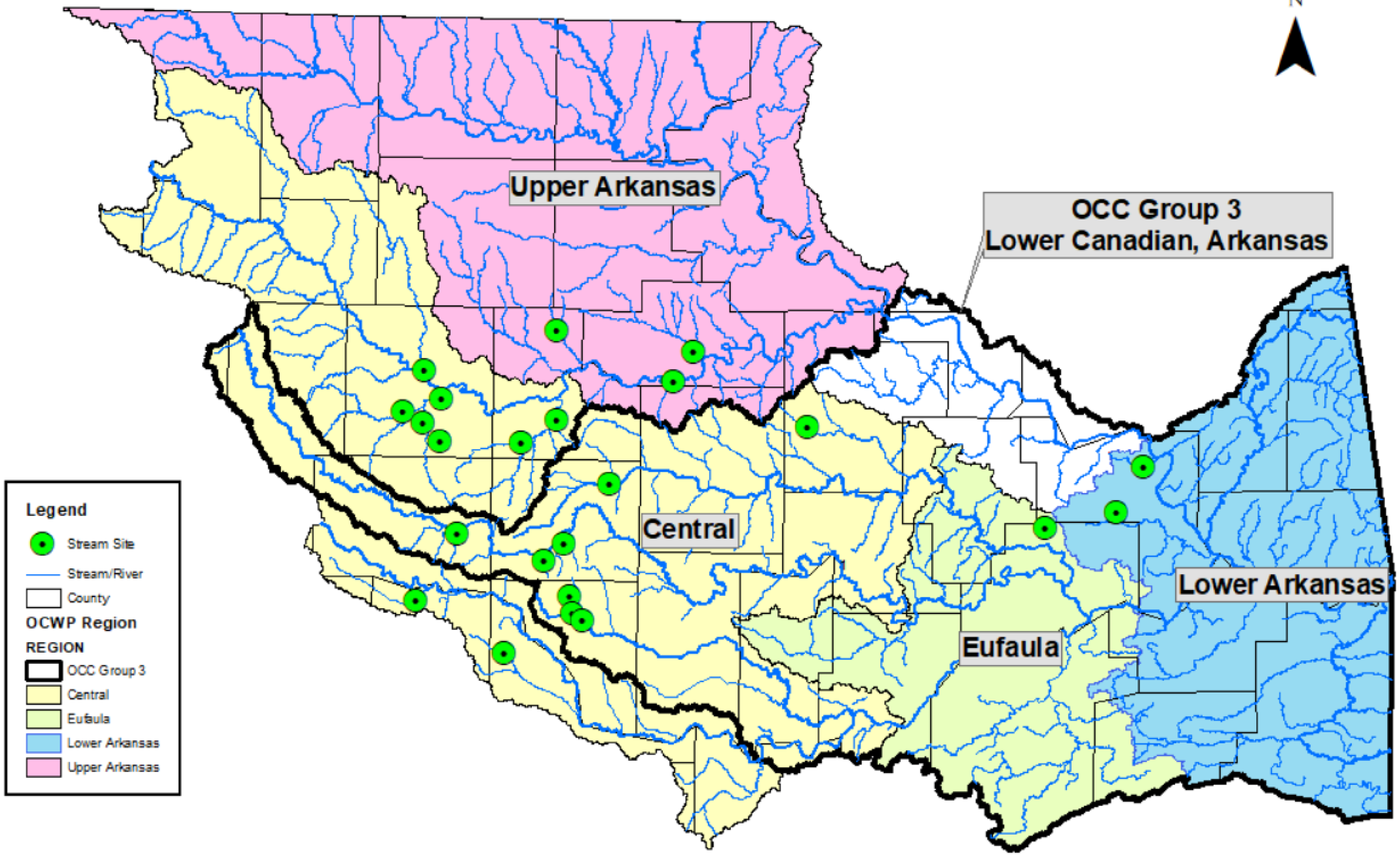
- 23 sites, within the Cimarron, Canadian, and Arkansas basins were monitored during the 2018 recreational season.
- Most sites coincided with the OCC Rotating Basin Monitoring Plan Schedule (Group 3)
- Additional sites were added for the Central/Upper Arkansas Oklahoma Comprehensive Watershed Planning Region (OWRB)

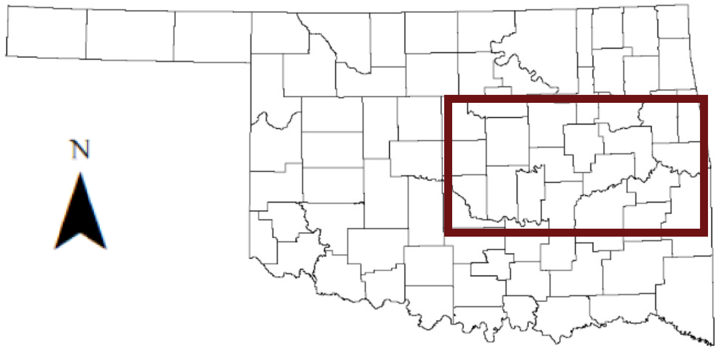




Waterbody	County	Last Sampled
Beaver Creek, West	Logan	**10/30/2001**
Buggy Creek	Canadian	9/27/2011
Butler Creek	Muskogee	5/4/2010
Canadian River, Deep Fork	Oklahoma	5/5/2010
Coody Creek	Muskogee	5/5/2010
Cottonwood Creek at Academy Rd	Logan	9/29/2008
Cottonwood Creek at HWY 74	Logan	**10/31/2001**
Crooked Oak Creek	Oklahoma	**10/31/2001**
Crutcho Creek	Oklahoma	**10/31/2001**
Deer Creek	Logan	**10/31/2001**
Dugout Creek	Payne	9/29/2008
Elm Creek, West	Cleveland	9/22/2008
Gentry Creek	McIntosh	6/2/2008
Kingfisher Creek	Kingfisher	9/30/2008
Little Deep Fork Creek	Creek	**3/26/2001**
Little River	Cleveland	9/22/2008
Rock Creek	Cleveland	9/22/2008
Shell Creek	Canadian	**10/31/2001**
Stillwater Creek	Payne	9/30/2008
Trail Creek	Kingfisher	**10/30/2001**
Turkey Creek	Kingfisher	9/30/2008
Uncle Johns Creek	Kingfisher	9/30/2008
Walnut Creek, North Fork	McClain	**11/5/2001**

Site Overview





Monitoring

Bacteria samples were collected using methods developed from USGS National Field Manual for the Collection of Water-Quality Data protocol for the collection of biological indicators

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Monitoring

- Stream parameters such as turbidity, dissolved oxygen, pH, and conductivity were measured.
- Ambient conditions (24-h precip and temperature)
- Visual observations

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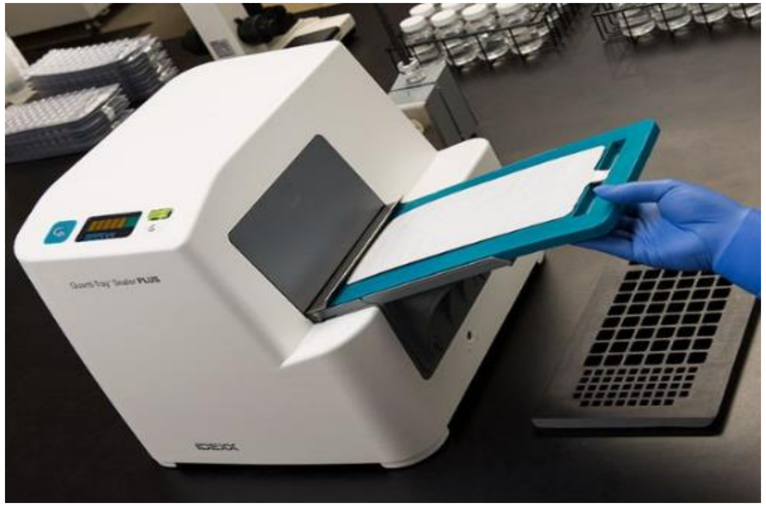
Bacteria Analysis

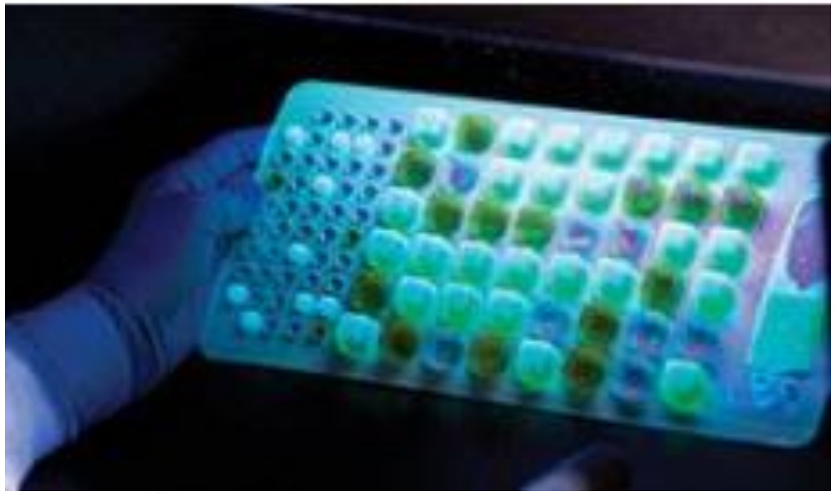
Prepared using Idexx Colilert, Enterolert and Quanti-Tray products using Standard Methods 9223B and 9230D for *E. coli* and enterococcus respectively.



Bacteria Analysis

A most probable number (MPN) is calculated based on the number of large and small wells that:

- Fluoresce under a long-wave ultraviolet light for both *E. coli* and Enterococcus



QA/QC

Total QA/QC	Total Samples	Total Percent QA/QC
81	260	31%

QA/QC Type per Total QA/QC				
Field Replicate	Field Blank	Laboratory Duplicate	Laboratory Blank	Positive/Negative Control
37%	31%	22%	2%	9%

QA/QC Type				
Field Duplicate	Field Blank	Laboratory Duplicate	Laboratory Blank	Positive/Negative Control
30	25	18	2	7

Field and Laboratory Quality Control Statistics	
E. coli Duplicate Mean Relative Percent Difference	17%
Enterococcus Duplicate Mean Relative Percent Difference	12%
Percentage of Field/Lab Blanks with positive results	0%

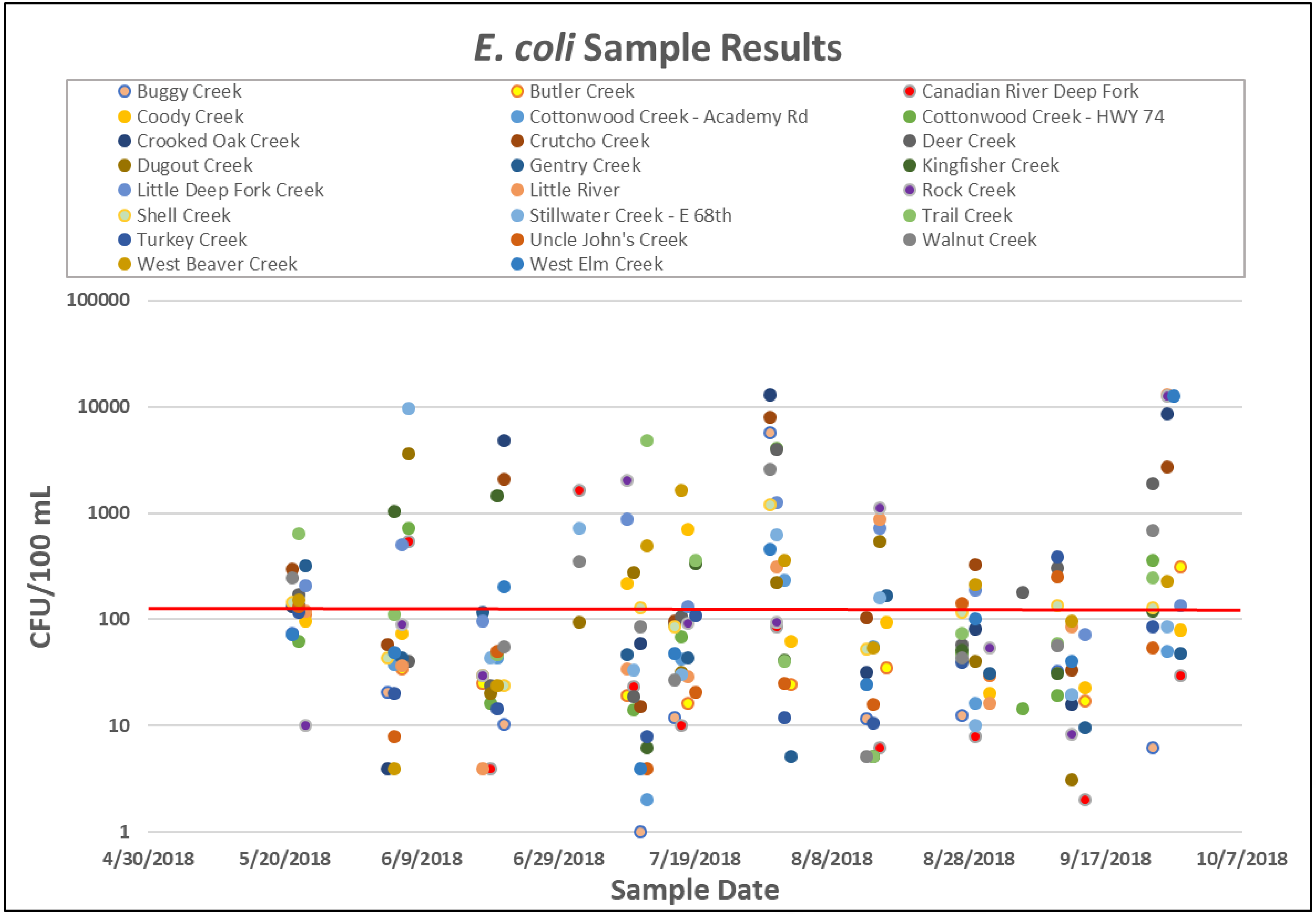
Enterococcus Positive and Negative Controls		
Enterococcus QA	MPN per 100 mL	Target MPN per 100 mL
Enterococcus 1	117.8	127
Enterococcus 2	125	127
Enterococcus 3	191.8	127
Streptococcus bovis	<1.0	<1.0
Escherichia coli	<1.0	<1.0

E. coli Positive and Negative Controls		
E. coli QA	MPN per 100 mL	Target MPN per 100 mL
E. coli 2	93.3	106
E. coli 3	108.6	106
Klebsiella variicola	<1.0	<1.0
Pseudomonas aeruginosa	<1.0	<1.0

- QAQC Protocol References
  - USGS Microbiology Program
  - ODEQ Requirements
  - SM For Examination of W and WW

Results

- Total of 230 Field Samples Collected
- 303(d) determination from a geometric mean of 10 samples



E. coli Sample Results
Buggy Creek
Butler Creek
Canadian River Deep Fork
Coody Creek
Cottonwood Creek - Academy Rd
Cottonwood Creek - HWY 74
Crooked Oak Creek
Crutcho Creek
Deer Creek
Dugout Creek
Gentry Creek
Kingfisher Creek
Little Deep Fork Creek
Little River
Rock Creek
Shell Creek
Stillwater Creek - E 68th
Trail Creek
Turkey Creek
Uncle John's Creek
Walnut Creek
West Beaver Creek
West Elm Creek
CFU/100 mL
100000
10000
1000
100
10
1
4/30/2018
5/20/2018
6/9/2018
6/29/2018
7/19/2018
8/8/2018
8/28/2018
9/17/2018
10/7/2018
Sample Date

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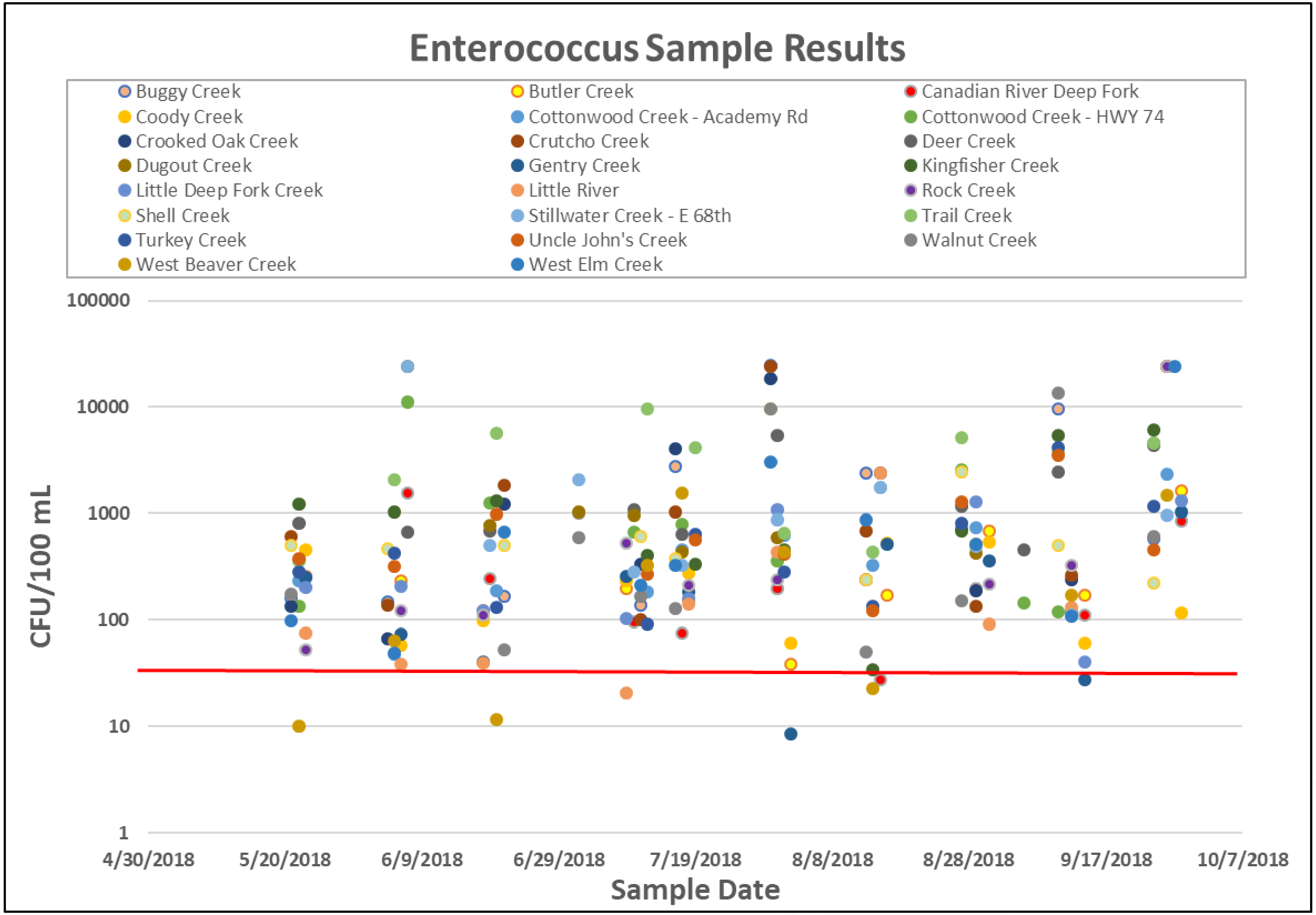
Enterococcus Sample Results
Buggy Creek
Butler Creek
Canadian River Deep Fork
Coody Creek
Cottonwood Creek - Academy Rd
Cottonwood Creek - HWY 74
Crooked Oak Creek
Crutcho Creek
Deer Creek
Dugout Creek
Gentry Creek
Kingfisher Creek
Little Deep Fork Creek
Little River
Rock Creek
Shell Creek
Stillwater Creek - E 68th
Trail Creek
Turkey Creek
Uncle John's Creek
Walnut Creek
West Beaver Creek
West Elm Creek
100000
10000
1000
100
10
1
CFU/100 mL
4/30/2018
5/20/2018
6/9/2018
6/29/2018
7/19/2018
8/8/2018
8/28/2018
9/17/2018
10/7/2018
Sample Date

Geometric Mean Summary

Site	*E. coli* (CFU/100mL)	Enterococcus (CFU/100mL)
Buggy Creek	22	902
Butler Creek	36	221
Canadian River Deep Fork	27	219
Coody Creek	77	169
Cottonwood Creek @ Academy Rd	36	307
Cottonwood Creek @ HWY 74	82	770
Crooked Oak Creek	191	770
Crutcho Creek	257	862
Deer Creek	155	1230
Dugout Creek	102	966
Gentry Creek	46	132
Kingfisher Creek	84	776
Little Deep Fork Creek	268	327
Little River	98	199
Rock Creek	140	374
Shell Creek	108	666
Stillwater Creek @ E 68th	117	846
Trail Creek	129	2310
Turkey Creek	37	412
Uncle John Creek	36	534
Walnut Creek	110	385
West Beaver Creek	127	147
West Elm Creek	98	489

Results Highlights

- *E. coli*
  - **16** of the **23** streams sampled are eligible for delisting
  - 151 of the 230 individual samples were ≤ 126 CFU/100mL
- Enterococcus
  - **0** of the **23** streams sampled are eligible for delisting
  - Only 7 of the 230 individual samples were ≤ 33 CFU/100mL

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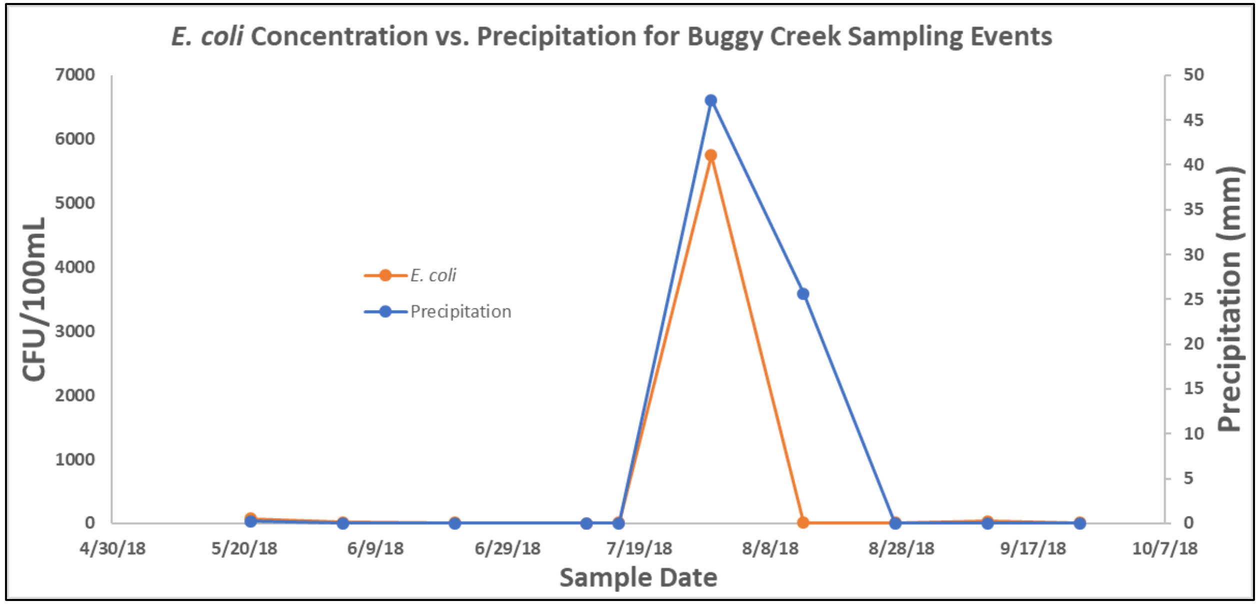
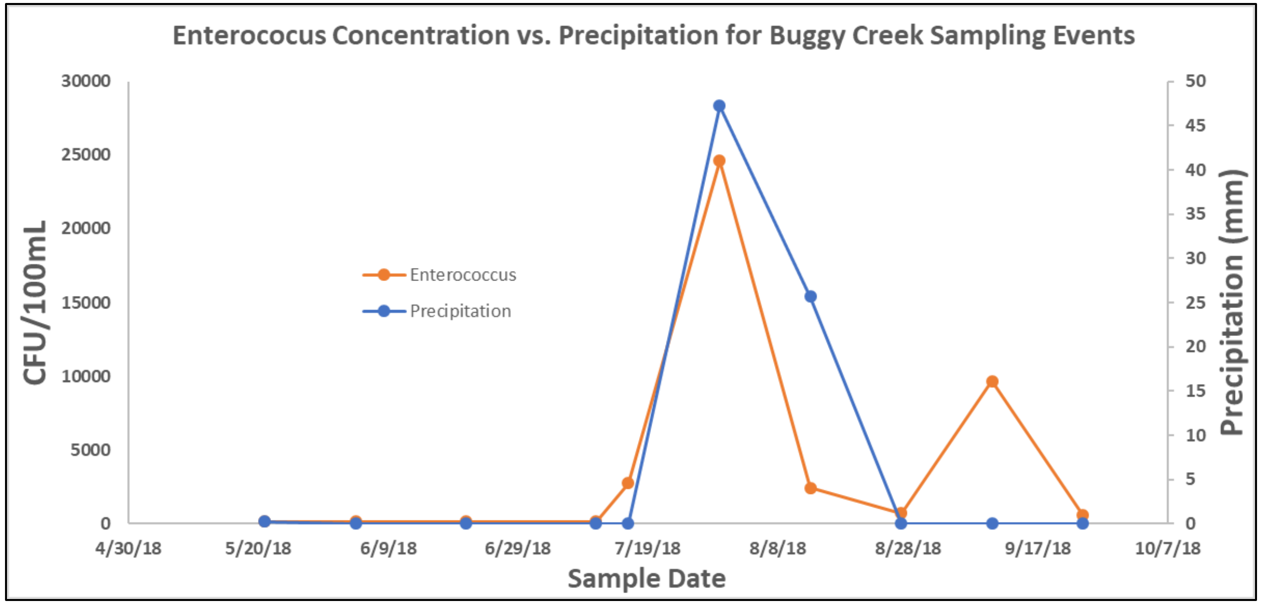
What can precipitation tell us?





- Precipitation based on 24-h rainfall from nearest Mesonet sites
- Simple linear regression indicates that rainfall is significant ($p < 0.0001$, $n = 230$) for all samples collected for *E. coli* and enterococcus

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More About Precipitation

- Antecedent dry period days was not statistically significant for a subset of 3 sites ($n=30$, $p=0.05$).
  - Precipitation was significant ($p < 0.005$).
- Precipitation might be a predictor for bacteria concentrations
- Further evaluation needed to determine correlations and predictions based on precipitation events and bacteria concentrations

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Discussion

- Results suggest re-evaluating the stream reaches
  - Temporal and spatial considerations
  - Unknowns- Land use? BMPs? Sources? Indicators? Climate? Seasonality?
- How can we effectively monitor watersheds?
  - Must monitor more regularly to keep up with changes in stream dynamics, climate conditions and anthropogenic influences
  - Important to collect additional data and information
  - Evaluate ancillary data for pathogen prediction

Potential Economic Impact

- Estimated $73M per year as remediation cost avoidance if all 5,800 miles of *E. coli* and enterococcus impaired streams are removed
  - Assuming the average cost of monitoring a stream reach is $2.36 per foot per year
- Estimated $5.5M per year in recreational value if all 5,800 miles of *E. coli* and enterococcus impaired streams are removed
  - $770 per mile in recreational value
- If all 16 sites that attained *E. coli* determination were removed, approximately $3.7M in remediation cost avoided

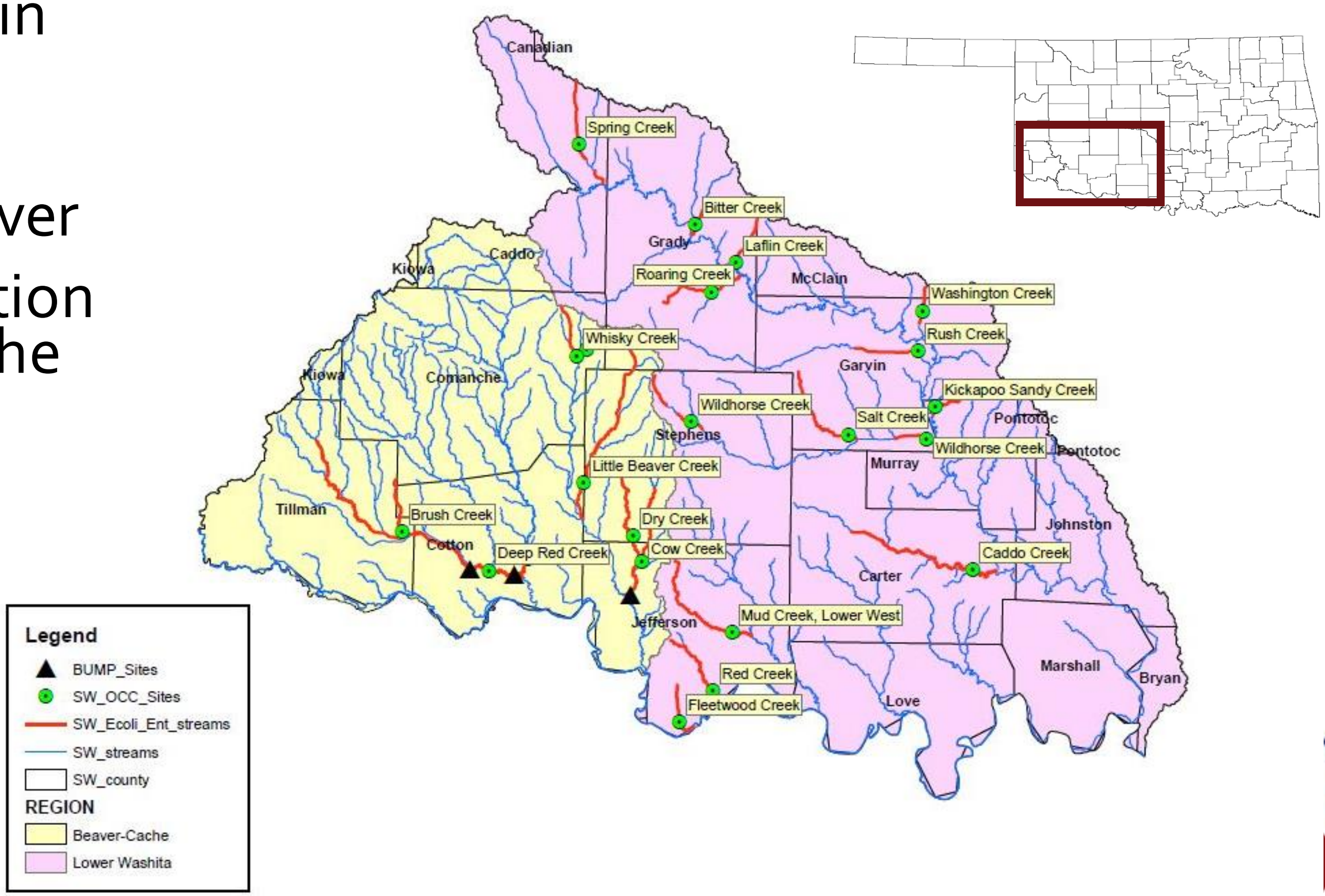
Values used to calculate economic impact from Sanders, L.D., R.G. Walsh, and J.R. McKean, 1991 and USEPA, 2018

Looking Forward

- Evaluate streams for de-listing
- Increase monitoring efforts
- Research effective methods
  - Source Tracking
  - Indicator Species
  - Spatial and Temporal Factors
  - Predictions and Models
- **Education**!

Upcoming Monitoring

- Following the rotating basin schedule
  - Southwest region is next
- Washita and Upper Red River
- Expected future collaboration with ODEQ/EPA through the TMDL Program



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Acknowledgements

- This project was completed with the help of many OU students and Oklahoma Water Survey student assistants and staff. Thank you for your hard work!
- OWRB, OCC, and ODEQ for planning assistance and GIS data.

Thank You!

Here's the link to the data on our website!

http://ou.edu/okh2o/monitoring/data-portal/bacteria-data

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