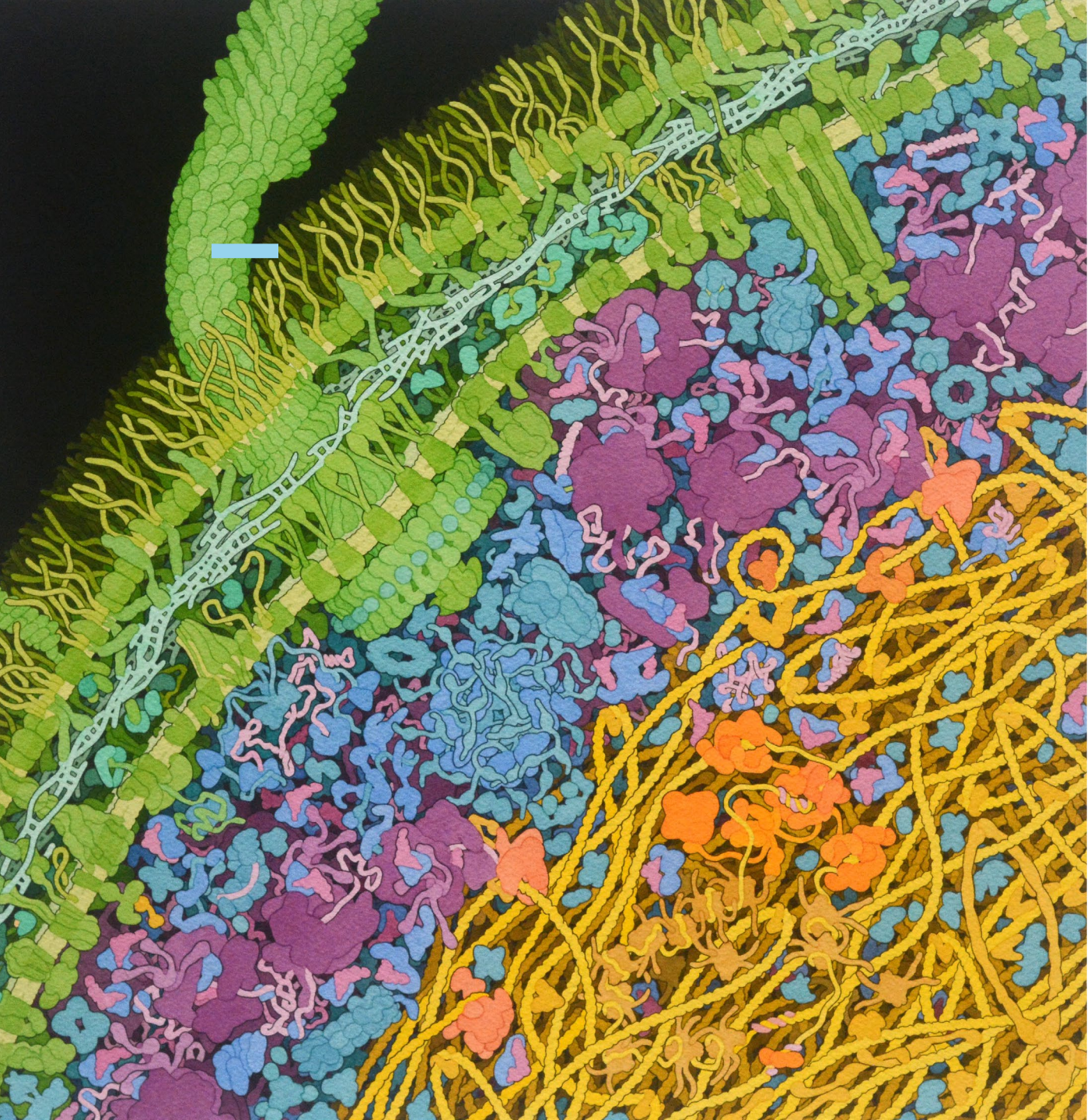


REGULATING BACTERIA IN OKLAHOMA'S SURFACE WATERS

OVERVIEW

WHY ARE BACTERIA REGULATED?

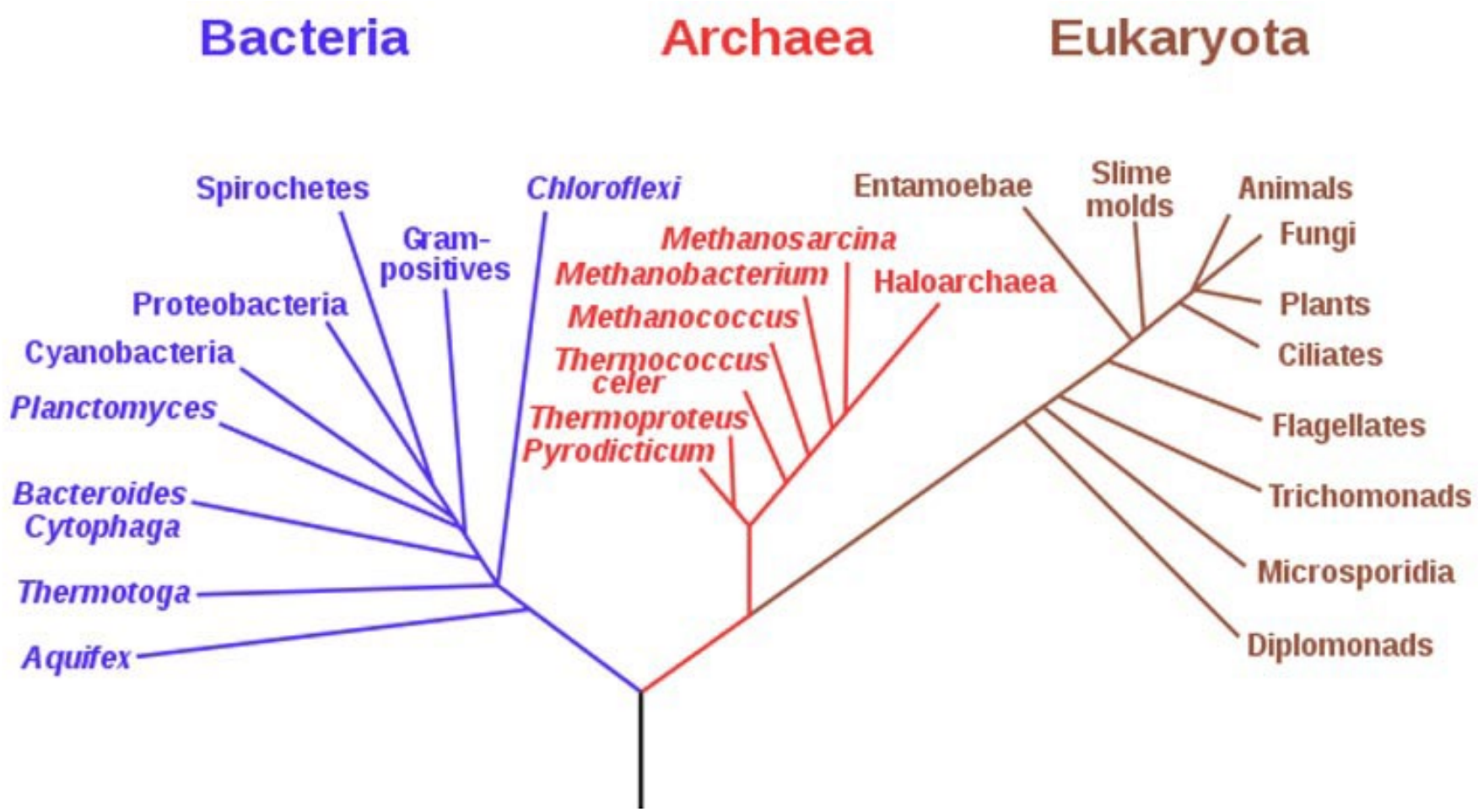
- What are bacteria?
- Sources of bacteria
- Pathogens and waterborne illnesses
- Indicators organisms

HOW ARE BACTERIA REGULATED?

- Water Quality Standards
- Beneficial uses and criteria
- Bacteria criteria development

WHY ARE BACTERIA REGULATED?

WHAT ARE BACTERIA?



WATERBORNE ILLNESSES BY THE NUMBERS

17 waterborne pathogens caused the following in 2014:

- 7.15 million illnesses
- 601,000 emergency department visits
- 118,000 hospitalizations
- 6,630 deaths
- $3.33 billion in direct healthcare costs for hospitalizations and emergency department visits

CDC estimates that each year 1 in 44 people gets sick from waterborne diseases in the United States.

From 2009–2019 public health officials from 31 states voluntarily reported:

- 119 untreated recreational water–associated outbreaks
- at least 5,240 cases
- 103 of the outbreaks (87%) during June–August
- The leading etiologies were enteric pathogens:
  - norovirus [22%]
  - Shiga toxin–producing *Escherichia coli* (STEC) [22%]
  - *Cryptosporidium* [19%]
  - *Shigella* [16%]

PATHOGENS VS. INDICATORS

PATHOGENS

VIRUSES

- *Norovirus*

PARASITES

- *Cryptosporidium, Giardia*

AMOEBAS

- *Naegleria fowleri*

BACTERIA

- *Escherichia coli* 0157:H7 (EHEC)
- *Legionella pneumophila, Shigella, Vibrio cholerae*

CYANOBACTERIA (BLUE-GREEN ALGAE)

- *Cylindrospermopsis, Microsystis*

INDICATORS

- Total coliform
- Fecal coliform
- *E.coli*
- *Enterococcus*

- Pathogens tend to occur in very low numbers and are very small it is very difficult to measure them directly.
- Indicators are easy to grow in a lab and their presence indicates that fecal contamination may have occurred.

INDICATOR ORGANISMS

Total coliforms

- Widespread in nature
- All members of the total coliform group can occur in human feces
- Can also be present in animal manure, soil, and submerged wood and in other places outside the human body.

Fecal coliforms

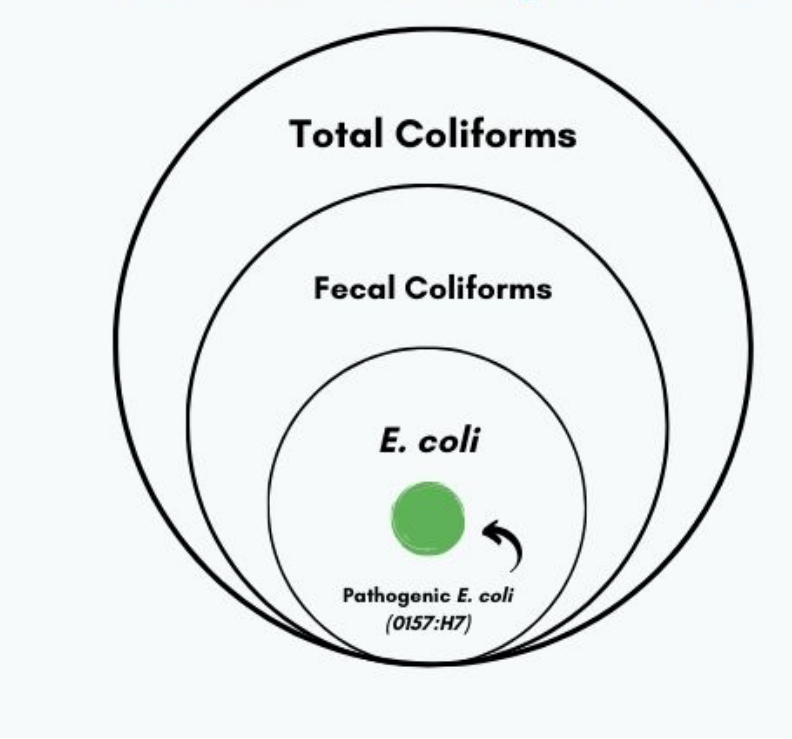
- a subset of total coliform bacteria, are more fecal-specific in origin.

E. coli

- A type of fecal coliform bacteria commonly found in the intestines of warm-blooded animals and humans
- The presence of *E. coli* in water is a strong indication of recent sewage or animal waste contamination.

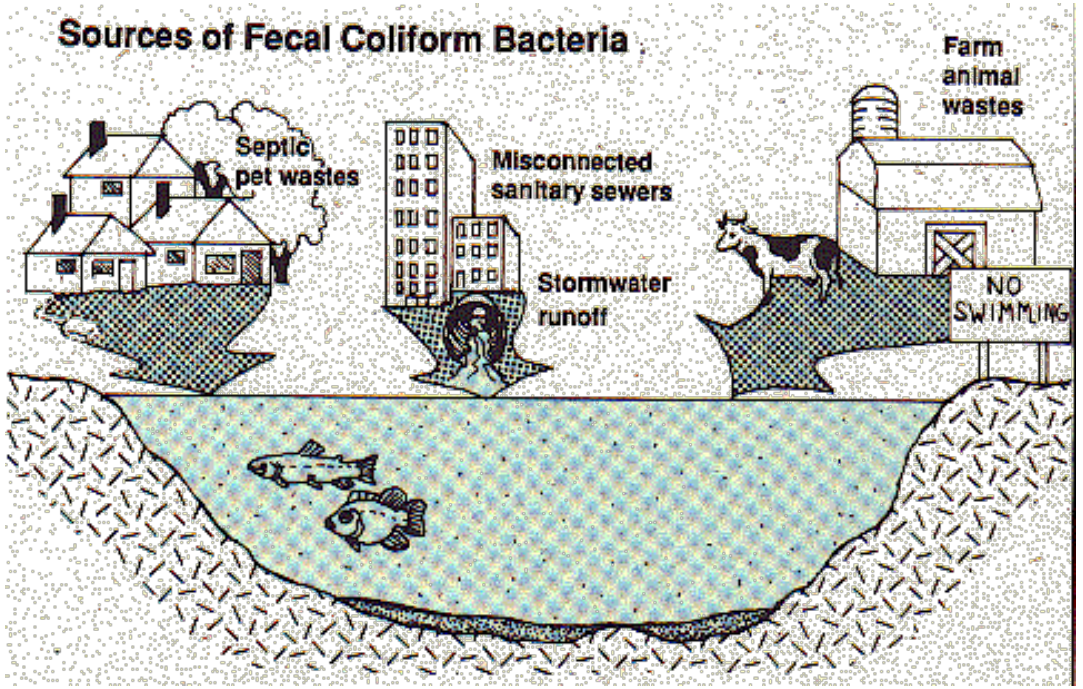
Enterococci

- a subgroup within the fecal streptococcus group.
- Enterococci are distinguished by their ability to survive in salt water
- EPA recommends enterococci as the best indicator of health risk in salt water used for recreation and as a useful indicator in fresh water as well.



SOURCES OF FECAL BACTERIA IN WATER

- Wastewater Treatment Plants
- On-site septic systems
- Sewage infrastructure
- Human feces
- Livestock
- Pet waste
- Wildlife



HOW ARE BACTERIA REGULATED?

WATER QUALITY STANDARDS AUTHORITY

- Federal Clean Water Act & Oklahoma state laws provide legal foundation & empower states to address water quality protection

- CWA required each state and territory to adopt water quality standards for all intrastate waters and provided for EPA review and approval or disapproval.

- Water Quality Standards are the rules & regulations adopted by the state directing water quality protection

- ODEQ delegated authority to promulgate WQS

- The Clean Water Act (CWA) is a statute.
  - Statutes are laws passed by Congress.
- The CWA gave EPA the authority to promulgate regulations.
  - These are rules to implement the statute.
  - This presentation will mention several of EPA's regulations under the CWA, including WQS (40 CFR 131), NPDES (40 CFR 122), and TMDL (40 CFR 130.7).
- EPA publishes guidance to assist states and authorized tribes
  - Guidance does not have the force of law.

WHAT ARE WATER QUALITY STANDARDS?

BENEFICIAL USES

- Water quality goals or desired condition for a specific water body
- Public and Private Water Supply, Primary Body Contact, Warm water aquatic community

CRITERIA

- Criteria protect beneficial uses by setting limits on pollutants or describing waterbody condition
- Criteria can be numeric or narrative statements

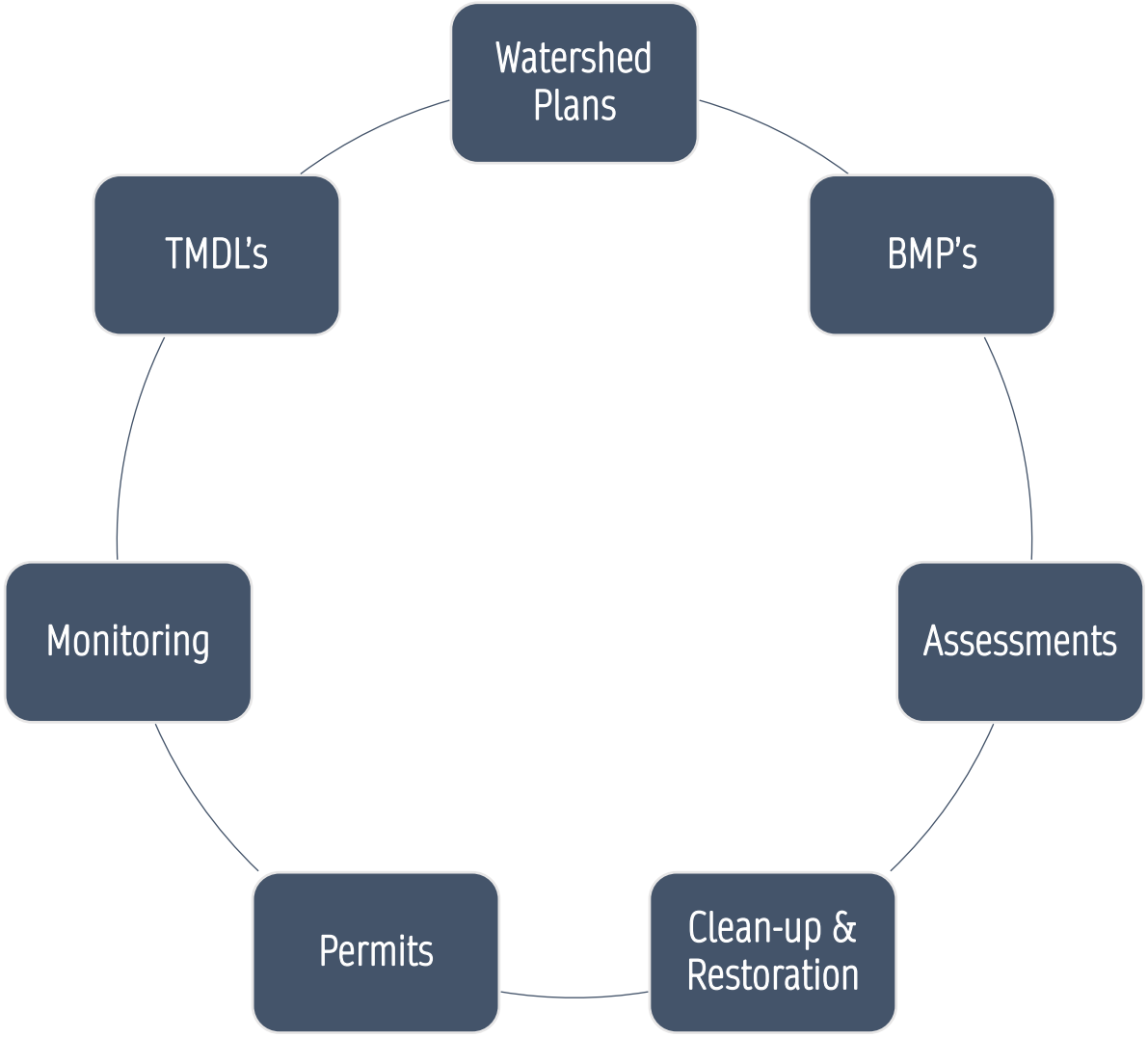
ANTIDEGRADATION POLICY

- Specifics the framework used in making decisions regarding the intentional lowering of water quality.
- Ensures good water quality is conserved where possible and lowered only when necessary & includes the public in the process

WQS IMPLEMENTATION

Water Quality Standards are applied by state agencies in various programs working to protect & improve water quality

- Conservation Commission
- Corporation Commission
- Dept. of Environment Quality
- Dept. of Agriculture Food & Forestry
- Oklahoma Water Resources Board



BENEFICIAL USES

Beneficial uses characterize the resource qualities, services, and ultimate goal for a waterbody

THE DESCRIPTOR

Primary Body Contact Recreation – involves direct body contact with water where a possibility of ingestion exists.

THE REAL THING

BENEFICIAL USES

- Beneficial uses characterize the resource qualities, services, and ultimate goal for a waterbody

THE DESCRIPTOR

Secondary Body Contact Recreation –is designated where ingestion of water is not anticipated. Associated activities may include boating, fishing or wading.

THE REAL THING

CRITERIA

- Criteria protect beneficial uses by setting limits on pollutants or describing waterbody condition

NUMERIC

Magnitude (or concentration) – how much of a parameter

Duration – period of time over which the instream concentration is averaged

Frequency – how often the magnitude can be exceeded

Magnitude- 126 cfu/100 ml

Frequency- Not to exceed

Duration- 30 days

NARRATIVE

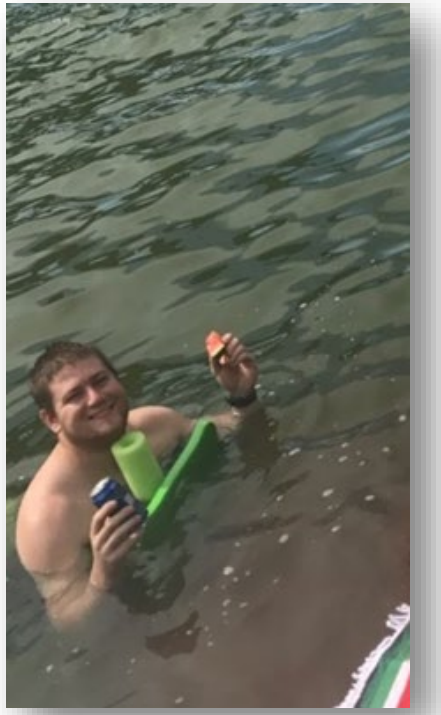
The water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.

Waters so designated shall be maintained to be free from human pathogens in numbers which may produce adverse health effects in humans.

CRITERIA TO PROTECT THE PRIMARY BODY CONTACT RECREATION BENEFICIAL USE
(MAY 1ST-SEPTEMBER 30TH)

INDICATOR	30 DAY GEO MEAN*
E. coli	126cfu/100 ml
Enterococcus	33cfu/100 ml

*For samples taken over a 30-day period this would be the average of the logarithmic values of that data set converted back to a base 10 number.



HOW WE GOT THERE

Recreation Water Bacterial Limits for E. coli, and Enterococci Ambient Water Quality Criteria For Bacteria - January 1, 1986

- EPA published criteria recommendations based on epidemiological studies involving swimmers, looking at an association between water quality and illness.
- Designed to protect people from illnesses (including gastrointestinal, skin, eye, ear, etc. effects) due to exposure to fecal contamination in water, and kidney and liver damage due to exposure to certain cyanotoxins.
- Risk Threshold

- EPA published criteria recommendations based on epidemiological studies involving swimmers, looking at an association between water quality and illness.
  - The studies were conducted at two U.S. beaches, Lake Erie in Erie, Pennsylvania (29,976 participants) and Keystone Lake in Tulsa, Oklahoma (16,363 participants).
  - The Lake Erie studies were conducted in 1979, 1980, and 1982 on beaches considered to have good or excellent microbial water quality. One site was located approximately three-quarters of a mile northwest of a sewage outfall for the City of Erie.
  - The Keystone Lake studies were conducted in the summers of 1979 and 1980, and the beaches demonstrated variable water quality for bacteria.
  - The two beach sites at Keystone Lake were located 3 and 5 miles from an outfall for wastewater treatment facility. In 1979, the treatment plant released an average of 120,000 gallons of unchlorinated sewage per day into the lake. In 1980, this practice was discontinued, and sewage passed through a settling lagoon, an aeration basin, and was chlorinated before being released into the lake.
  - Water samples were tested for E. coli and enterococci (includes Streptococcus faecalis and Streptococcus faecium). Fecal coliforms were also monitored for two years during the Keystone Lake studies and in two years of the Lake Erie studies. Statistical analyses examined the relationship between the occurrence of GI illness in swimmers compared with a nonswimming control group.
  - For the study, swimming was defined as having all orifices immersed in water. Interviewers asked beachgoers during the initial interview about sex, age, race and ethnicity; whether a person swam; length of time and time of day in the water; illness symptoms they may have had in the previous week; and the reason, if a nonswimmer, why they did not enter the water. Follow-up interviewers asked the beachgoers about any illness symptoms that occurred since swimming at the beach
  - There were two phases of beach interviews—the first as beachgoers were leaving the beach area and a second follow-up telephone interview 8 to 10 days after swimming.
  - In the Keystone Lake study, symptoms for enteric diseases tended to be higher in swimmers than nonswimmers. In 1979, there was only one other group of symptoms (fever, headaches lasting greater than three hours, and backache) that showed significant differences between swimmers and nonswimmers. In 1980, statistical differences between swimmers and nonswimmers were found at one or both sampling locations with symptoms for GI, respiratory, and other illnesses.

CRITERIA TO PROTECT THE PRIMARY BODY CONTACT RECREATION BENEFICIAL USE
(MAY 1ST-SEPTEMBER 30TH)

INDICATOR	30 DAY GEO MEAN*
E. coli	126cfu/100 ml
Enterococcus	33cfu/100 ml

*For samples taken over a 30-day period this would be the average of the logarithmic values of that data set converted back to a base 10 number.

QUESTIONS?

WATER QUALITY DATA COLLECTION & ASSESSMENT

OKLAHOMA CONSERVATION COMMISSION

Outline

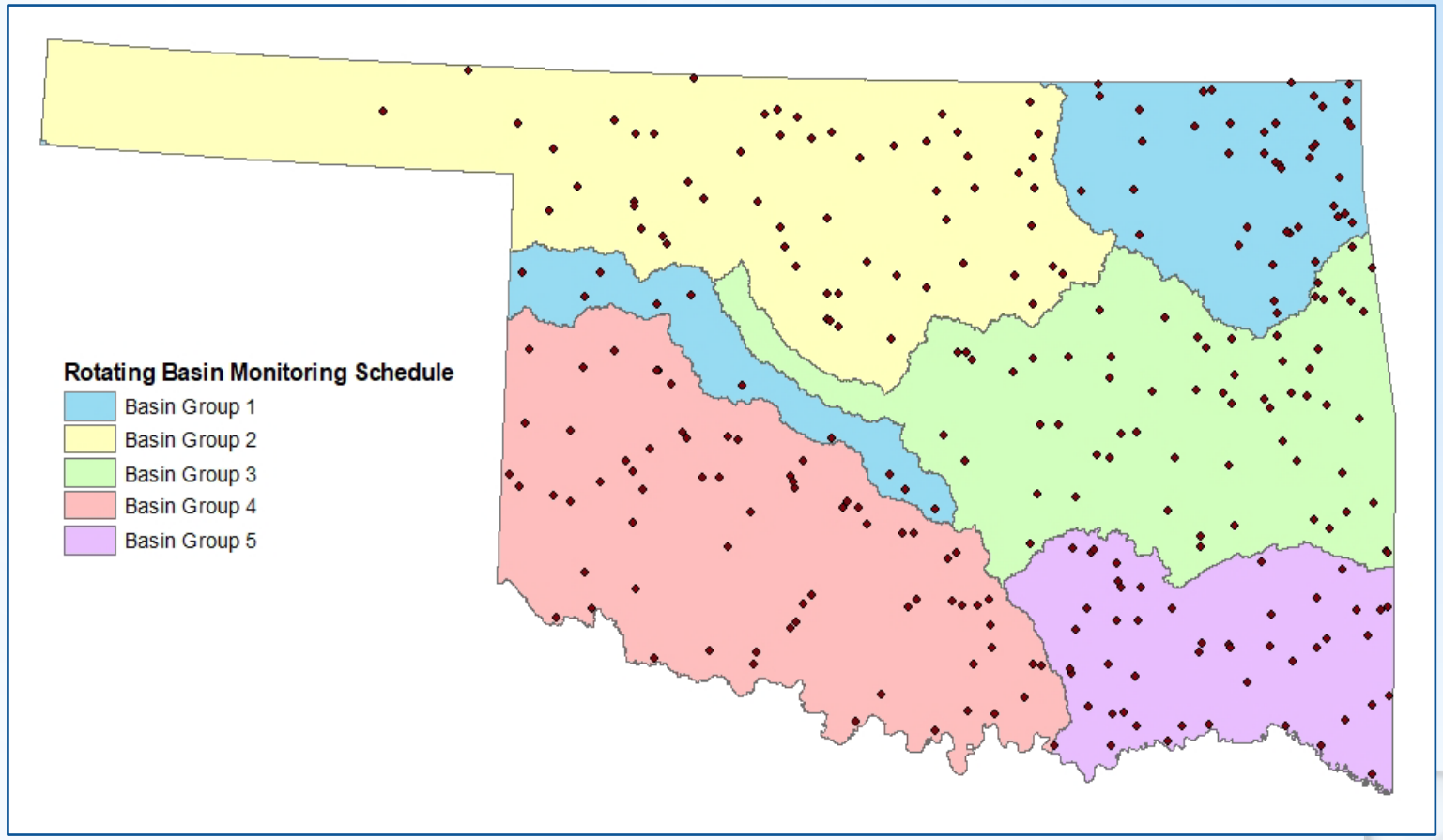
- Monitoring Program
  - Background
  - Methods
- Assessment
  - Internal Process
  - Beneficial Uses
- Bacteria Assessment
  - *Enterococcus* vs. *E. coli*
  - Holding Time and Spatial Variation
- Impairments
  - Success Stories and Conservation Practices
  - Special Projects

Oklahoma Conservation Commission
Water Quality Division

- Technical lead for Oklahoma's Nonpoint Source Program
- Responsible for identifying, prioritizing, and managing waters impacted by nonpoint source pollution
- Primarily focus on wadeable streams
- Assess streams using a rotating basin design (since 2001)

Rotating Basin Monitoring Sites

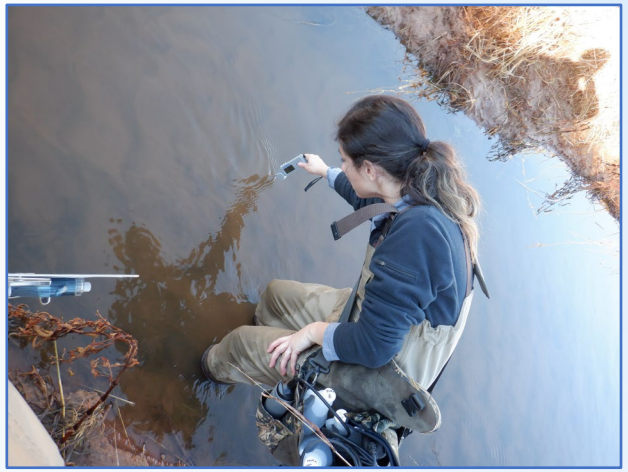
- Monitor at the outlet of most HUC 11's
- Approx. 270 fixed sites
- Water samples collected every 5 weeks for 2 years (Approx. 20 samples/site)



Physico-chemical Data

In-situ parameters:

- Water temperature
- **Dissolved oxygen**
- **pH**
- Specific conductance
- Alkalinity
- Hardness
- **Turbidity**
- Flow



Lab parameters:

- Nitrate, Nitrite, **Ammonia**, Total Kjeldahl Nitrogen
- Orthophosphate, Total Phosphorus
- **Chloride, Sulfate, TDS,** TSS
- ***E. coli***

Bacteria Sampling

Data Collection Schedule:

- *E. coli* samples are collected during the recreation period (May 1st – September 30th)
- Samples are collected during routine monitoring (every 5 weeks)
- Scheduled to avoid bias associated with flow conditions

Methods

- Utilize sterile 100 ml bottle
- Insert bottle opening downward and fill with current
- Immediately place on ice (do not submerge)
- If high flow or livestock- designated as ‘high’
- Holding time= 24 hr preferred but 48 hr acceptable
- Membrane filtration

Biological & Habitat Data

Parameters:

- **Fish** (Seine & Electroshock)
- **Macroinvertebrates**
- Habitat Assessment

Integrated Report Assessments

OCC data is used to update 305(b) & 303(d) lists

- Default Beneficial Uses:
  - Agriculture (livestock and irrigation)
  - Aesthetics
  - Fish & Wildlife Propagation (warm water)
    - Habitat limited- requires Use Attainability Analysis (UAA)
  - Primary Body Contact Recreation
    - Secondary Body Contact Recreation- requires UAA

Assessment Process

- Retrieve data meeting QA requirements within the IR time frame (5 years)
  - Sometimes combine with other data sources on same segment
- Most assessments are completed using Excel spreadsheets
- Streamlined biological assessments using R
- Final assessments are integrated into ATTAINS spreadsheets and submitted to ODEQ

Agriculture

Parameters:

- Chlorides
- Sulfates
- Total Dissolved Solids (TDS)

Assessment:

- Each parameter is assessed independently
- Must be attaining for all 3 parameters to be fully supporting for the Agriculture beneficial use
- Yearly mean less than site specific mean criteria and <10% of samples exceed site specific sample criteria

Aesthetics

Parameters:

- Nutrients
- Phosphorus – scenic rivers only
- Oil & Grease (visual assessment)
- Color

Assessment:

- Each parameter is assessed independently
- Primarily based on Oil & Grease assessments
  - Fully Supporting if no other parameters are Not Attaining

Fish & Wildlife Propagation

Chemical parameters:

- Ammonia, Dissolved-Oxygen, Oil & Grease, pH, Turbidity

Biological parameters:

- Fish, Macroinvertebrates

Assessment:

- All chemical and biological parameters are assessed independently
- Fully Supporting for F&WP beneficial use

1. Meet based on chemical parameters:
   - All 5 chemical parameters must be Attaining
   - No biological parameters are Not Attaining
2. Meet based on biological parameters:
   - Fish and/or macroinvertebrate assessments are Attaining
   - No chemical parameters are Not Attaining

Primary Body Contact Recreation

E. coli Assessment:

- Minimum of 10 samples required
- Calculate geometric mean of all samples $\left(\prod_{i=1}^{n} a_i\right)^{\frac{1}{n}} = \sqrt[n]{a_1 a_2 \cdots a_n}$
- Compare with WQS numerical criteria = 126 colonies/100 ml
  - Geomean ≤ 126 = Attaining
  - Geomean > 126 = Not Attaining

Primary Body Contact Recreation cont.

Examples of *E. coli* assessments

Sample #	Total Samples	Site Name	IR_WBID	Date	*E. coli*	Geomean	Assessment
1	0	Rainy Mountain Creek	OK310830020060_10	6/10/2019	0.5		
2	0	Rainy Mountain Creek	OK310830020060_10	7/23/2019	0.5		
3	0	Rainy Mountain Creek	OK310830020060_10	9/4/2019	70		
4	0	Rainy Mountain Creek	OK310830020060_10	9/16/2019	110		
5	0	Rainy Mountain Creek	OK310830020060_10	9/30/2019	90		
6	0	Rainy Mountain Creek	OK310830020060_10	5/11/2020	290		
7	0	Rainy Mountain Creek	OK310830020060_10	6/15/2020	620		
8	0	Rainy Mountain Creek	OK310830020060_10	7/20/2020	50		
9	0	Rainy Mountain Creek	OK310830020060_10	8/10/2020	160		
10	0	Rainy Mountain Creek	OK310830020060_10	8/24/2020	20		
11	0	Rainy Mountain Creek	OK310830020060_10	9/1/2020	130		
0	12	Rainy Mountain Creek	OK310830020060_10	9/28/2020	60	42.90	Attaining
1	0	Cavalry Creek	OK310830030070_00	6/9/2015	390		
2	0	Cavalry Creek	OK310830030070_00	6/30/2015	5000		
3	0	Cavalry Creek	OK310830030070_00	7/14/2015	210		
4	0	Cavalry Creek	OK310830030070_00	8/4/2015	8200		
5	0	Cavalry Creek	OK310830030070_00	9/8/2015	120		
6	0	Cavalry Creek	OK310830030070_00	6/11/2019	40		
7	0	Cavalry Creek	OK310830030070_00	7/24/2019	0.5		
8	0	Cavalry Creek	OK310830030070_00	5/12/2020	490		
9	0	Cavalry Creek	OK310830030070_00	6/16/2020	560		
10	0	Cavalry Creek	OK310830030070_00	7/21/2020	2500		
11	0	Cavalry Creek	OK310830030070_00	8/10/2020	320		
12	0	Cavalry Creek	OK310830030070_00	8/25/2020	120		
13	0	Cavalry Creek	OK310830030070_00	9/1/2020	250		
0	14	Cavalry Creek	OK310830030070_00	9/28/2020	40	240.16	Not Attaining

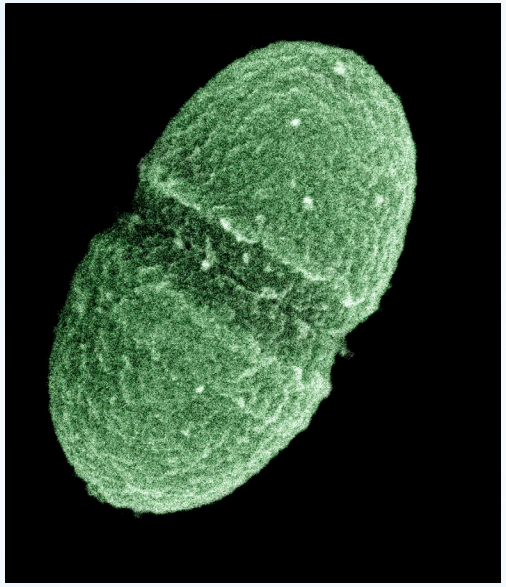
Secondary Body Contact Recreation

- Most streams are designated with PBCR use (default)
- Few streams are designated with SBCR use
  - Requires Use Attainability Analysis
  - Where ingestion of water is not anticipated
  - 0.5 m deep in Thalweg for 20% of segment

- Same assessment with different numerical criteria
  - Five times the PBCR criteria (630 colonies/100 ml)

Enterococcus vs. *E. coli*

- Enterococcus 33 colonies/100 ml vs. *E. coli*: 126 colonies/100 ml
- Stopped monitoring *Enterococcus* in 2011
- 123 streams impaired for Enterococcus delisted in 2020 and 2022 using more current *E. coli* data



Holding Time: Program Constraint

- 100 fixed sites per year
  - ~1000 water samples
  - ~200 macroinvertebrate samples
  - ~50 fish samples
- Sites sampled in groups of 10 over 2 days
- Holding time of 48 hours or greater acceptable for all parameters except *E. coli*
- Utilizing recommended holding times would be a significant logistical, safety and financial concern

Holding Time Effects

- Programmatic Goals
  - Swim beach advisories vs. 303(d) reporting
  - Misclassifying vs. Not Sampling

Holding Time Study

- COVID and temporary sampling adjustments in 2020
- Compare E. coli values at <24 and <48 hours

	24 hour		48 hour			
Month	Mean	SD	Mean	SD	p-value	Sample size
May	427	291	294	235	<0.001	17
Jul	223	229	222	202	0.99	29
Sep	2091	727	2085	723	0.8	10
Total	600	775	565	775	0.08	56

Spatial Variability in *E. coli*

- Spatial replicates collected at 5% of monitoring locations from similar habitat and flow since 2000 (~1000 replicates)

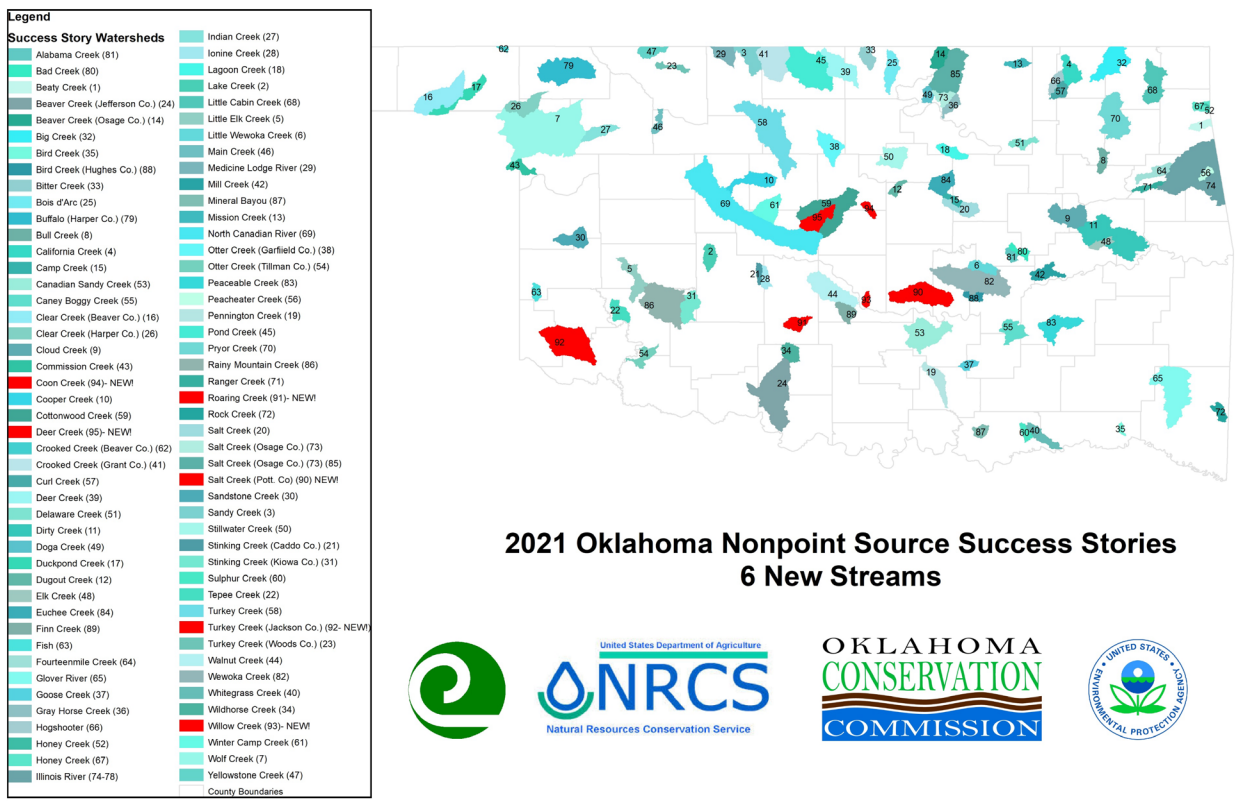
Month	Average RPD	Average ABS Difference (cfu/100ml)	Average Difference (cfu/100ml)	Sample Size
May	32%	84	-12	145
Jun	48%	52	-2	204
Jul	42%	50	6	207
Aug	41%	64	0	225
Sep	40%	59	4	179
Total	41%	60	0	960

Holding Time Conclusions

- Expanding holding times may introduce variability, particularly in the early part of the recreational period
- However, spatiotemporal variability is likely to have a greater influence on E. coli assessment
  - High flows
  - Sample season
  - With reach variation

Success Stories

- 94 streams delisted from the impaired waterbody list as a result of locally led conservation
- 40 streams delisted for E.coli

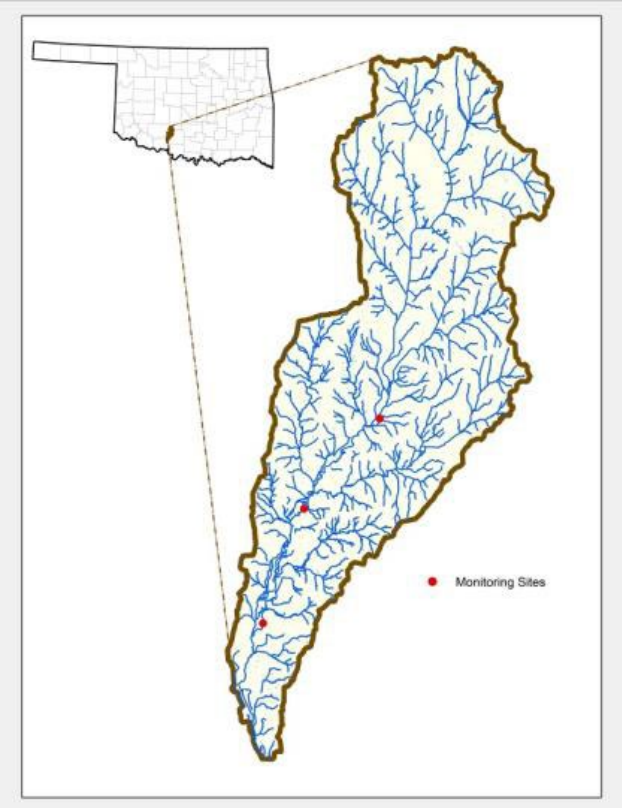


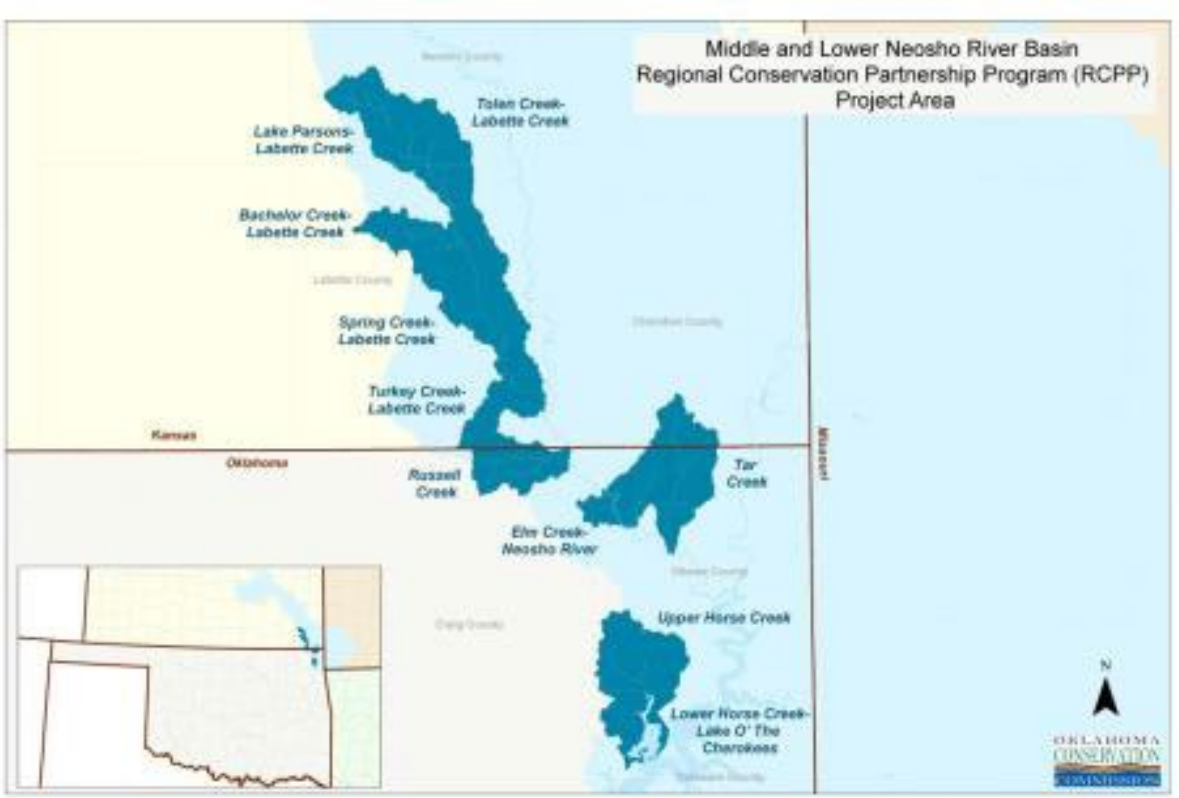
Conservation Practices Improve WQ

- Alternative Water Supply
- Riparian Fencing
- Cover crop and no-till

Focused Conservation through Special Projects

- National Water Quality Initiative
- Regional Conservation Partnership Project





Questions?

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TMDLs and Implementation in MS4s and The Use of QAPPs

December 1, 2022

Mohawk Water Treatment Plant Auditorium
3600 Mohawk Blvd, Tulsa, OK 74115

Presentation Prepared by INCOG

What Is A TMDL?

TMDL or Total Maximum Daily Load refers to the maximum amount of a pollutant that a waterbody can receive and still comply with the State's water quality standards.

A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate margin of safety (MOS), which takes into account the uncertainty between the model and the actual environment. This definition can be expressed by the following equation:

$$TMDL = WLA_{\_WWTP} + WLA_{\_MS4} + LA + MOS$$

How Is A TMDL Created?

- **Water Quality Monitoring** – Surface water quality data is collected by State, federal, and local agencies.
- **Waterbody Assessment** – Analysis of water quality data to determine if a waterbody is achieving water quality standards
- **303(d) List of Impaired Waterbodies** – Waterbodies in the State of Oklahoma that do not meet water quality standards are compiled in the State's 303(d) list.
- **TMDL Prioritization** – DEQ prioritizes watersheds containing impaired waterbodies for TMDL development. A rating system is utilized to determine a priority ranking value for each impaired watershed.

How Is A TMDL Created?

- **TMDL Development** – A Total Maximum Daily Load value for each cause of impairment in a waterbody is calculated using appropriate water quality models.
- **Public Review** – TMDL reports are published for public review and comment. DEQ accepts any comments submitted during the specified review period.
- **Report Submittal** – DEQ submits the TMDL report to EPA for review and approval.
- **EPA Approval** – EPA approves the TMDL report if the TMDL calculations are technically sound and the report satisfies required elements.

What Does The OKR04 Permit Have to Say About TMDLs

TMDL is mentioned 77 times in the
June 1, 2021 OKR04 Permit for Phase II MS4s

PART II: COVERAGE UNDER THIS PERMIT
II. C. Limitations on Coverage
6. Discharges not consistent with a TMDL are unauthorized. Discharge of a pollutant into any water for which a TMDL, or watershed plan in lieu of a TMDL, for that pollutant has been either established or approved by DEQ or U.S. Environmental Protection Agency (EPA) is prohibited, unless your discharge is consistent with that TMDL, or watershed plan.

What Must an OKR04 Permittee Do to Comply?

IV. B. Established Total Maximum Daily Load (TMDL) Allocations

IV.B.1. States:

SWMP Review and Modification: Your MS4 shall evaluate the existing SWMP in relation to the TMDL reduction goals. Any resulting modifications shall be implemented within two (2) years of the *effective date* of the TMDL and then as needed. At a minimum, your evaluation shall provide and identify each of the following items and information:…

What Must an OKR04 Permittee Do to Comply?

IV.B.2. States:

TMDL Pollutant Reduction Plan: Your MS4 shall participate in a coordinated regional pollutant reduction plan or develop their own individual plan. The plan must incorporate all approved TMDLs addressing the MS4's stormwater discharge(s) and place emphasis on all the POCs associated with impairments. At a minimum, the plan shall provide the following items:…

What Must an OKR04 Permittee Do to Comply?

IV.B.3. States:

TMDL Pollutant Monitoring Plan: Your MS4 shall participate in a coordinated regional pollutant monitoring plan or develop their own individual plan. The plan should be designed to establish the effectiveness of the selected BMPs and demonstrate progress toward achieving the reduction goals of the TMDLs or watershed plans, and eventual attainment of water quality standards.

What Must an OKR04 Permittee Do to Comply?

IV.B.4. States:

TMDL Baseline Monitoring Plan (Optional): Your MS4 may participate in a coordinated regional baseline monitoring plan or develop their own individual plan. The plan should be designed to determine the existing levels of POCs in your MS4's discharge(s) and identify high priority areas which may benefit from targeted BMPs.

What Must an OKR04 Permittee Do to Comply?

IV.B.5. States:

Monitoring Requirements: At a minimum, the monitoring plan(s) shall provide

a. a detailed description of the program goals, monitoring plan, and sampling and analytical methods,

b. a list and map of the selected TMDL pollutant monitoring sites,

c. the frequency of data collection to occur at each station or site,

d. the parameters to be measured relevant to the TMDL(s), and

e. the Quality Assurance Project Plan that complies with EPA requirements.

What Must an OKR04 Permittee Do to Comply?

IV.B.6. States:

Annual Reporting: Your MS4 shall include a TMDL implementation report as part of your annual report. The TMDL implementation report shall include the status and actions taken to implement the TMDL pollutant reduction plan and monitoring program. The TMDL implementation report shall provide…

What Must an OKR04 Permittee Do to Comply?

IV.B.7. States:

TMDL Implementation Schedule: The SWMP review and modification, TMDL pollutant reduction plan, and TMDL pollutant monitoring plan(s) shall be implemented as outlined in Table IV-1.

What Must an OKR04 Permittee Do to Comply?

Table IV-1 TMDL Implementation

	Option A	Option B
SWMP review and evaluation	no more than two years from TMDL effective date	
TMDL pollutant baseline monitoring plan	--	no more than three years from TMDL effective date
TMDL pollutant reduction plan	no more than three years from TMDL effective date	no more than 5 years after implementation of the baseline monitoring plan
TMDL pollutant monitoring plan	no more than three years from TMDL effective date	no more than 5 years after implementation of the baseline monitoring plan

What Must an OKR04 Permittee Do to Comply?

IV.B.8. States:

Existing Approved TMDLs: The following table (Table IV-2) lists existing approved TMDLs at the time of permit issuance, which are affected by MS4 stormwater discharges. This permit serves as notification of the requirement to implement these TMDLs for the applicable MS4 discharges. DEQ will provide written notification to MS4 sources identified in these TMDLs that are not subject to this permit.

What Must an OKR04 Permittee Do to Comply?

Table IV-2 (Portion of the Table as an Example)

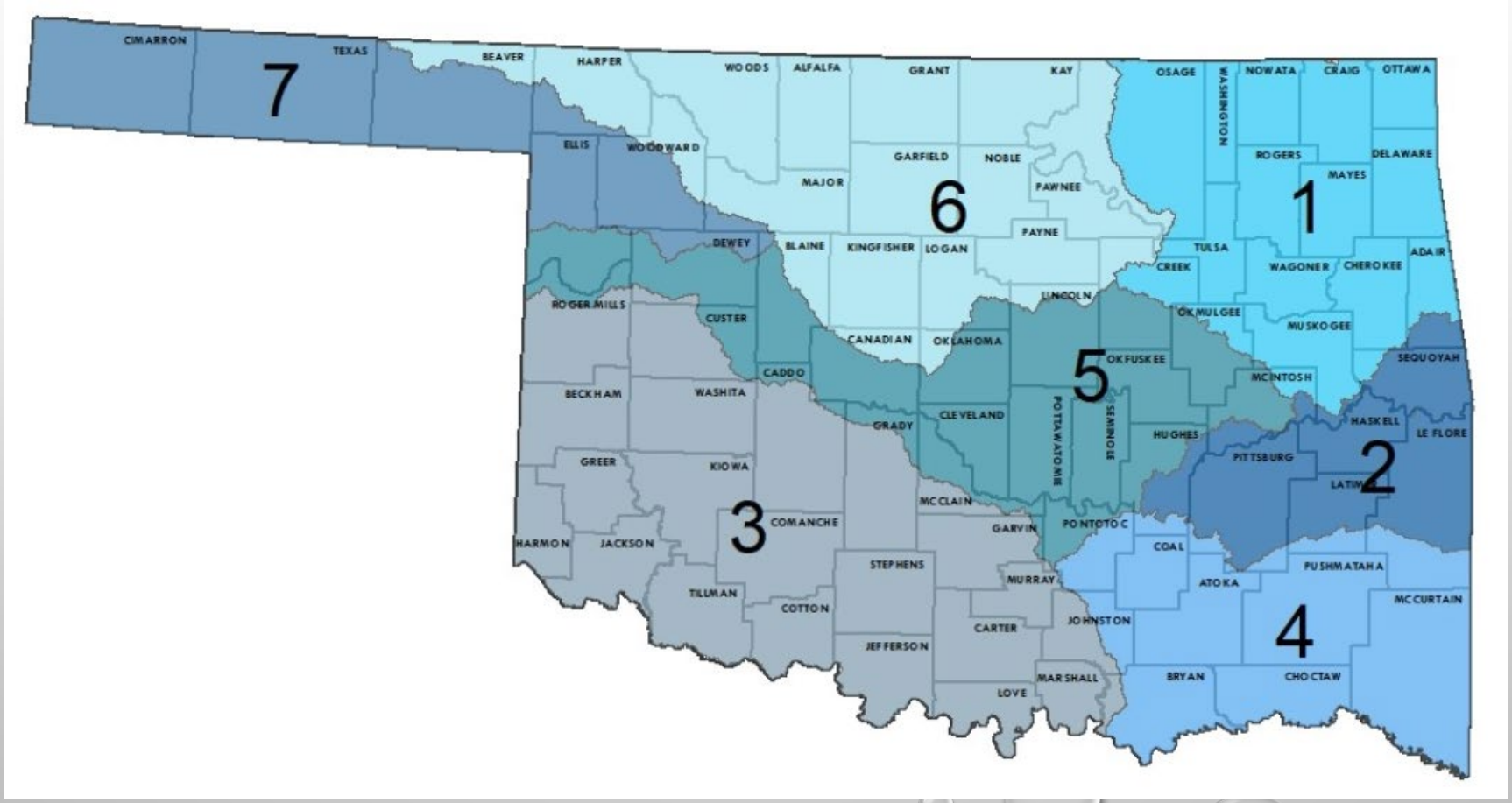
Watershed Basin	TMDL Report	Identified MS4 Sources	Effective Date
Basin 1 Middle Arkansas-Verdigris-Neosho	Neosho River Basin Bacteria TMDLs-2008	Miami	June 1, 2022
	Lower Bird Creek Watershed Bacteria TMDLs-2011	Catoosa, Broken Arrow, Owasso, Tulsa, Tulsa County	June 1, 2022
	Arkansas River and Verdigris River Area-Bacteria and Turbidity TMDLs-2012	Bixby, Broken Arrow, Claremore, Coweta, Jenks, Muskogee, Sand Springs, Sapulpa, Tulsa	June 1, 2022
	Arkansas River and Haikey Creek Bacteria TMDLs-2008	Bixby, Broken Arrow, Tulsa, Tulsa County	June 1, 2022

Where Can I Find a Complete List of Approved TMDLs for Oklahoma?

The 2022 Integrated Report for Oklahoma, in Appendix E, lists 636 completed TMDLs. (Portion of the Table as an Example)

Waterbody ID	Waterbody Name	Cause	TMDL ID	TMDL Completion Date
OK121400020190_00	Mission Creek	Escherichia coli	39220	9/28/2010
OK121400020190_00	Mission Creek	Turbidity	39220	9/28/2010
OK121400040010_00	Sand Creek	Escherichia coli	37064	9/15/2009
OK121400040010_00	Sand Creek	Enterococcus	37064	9/15/2009
OK121400050020_00	Copan Lake	Chlorophyll-a	60880	9/24/2014
OK121500010200_00	Verdigris River	Turbidity	42569	9/27/2012
OK121500010200_00	Verdigris River	Enterococcus	42569	9/27/2012

Seven TMDL Planning Basins



FINAL

BACTERIAL AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE ARKANSAS-VERDIGRIS RIVER STUDY AREA, OKLAHOMA (OK120400, OK120410, OK120420, OK121500, OK121600)

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

SEPTEMBER 2012

FINAL

BACTERIAL AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE ARKANSAS-VERDIGRIS RIVER STUDY AREA, OKLAHOMA (OK120400, OK120410, OK120420, OK121500, OK121600)

OKWBID

Arkansas River	OK120400010260_00	Arkansas River	OK120420010130_00
Coody Creek	OK120400010400_00	Polecat Creek	OK120420020010_00
Dirty Creek	OK120400020010_00	Polecat Creek	OK120420020050_00
Dirty Creek, South Fork	OK120400020030_00	Verdigris River	OK121500010200_00
Dirty Creek, Georges Fork	OK120400020110_00	Bull Creek	OK121500020090_00
Butler Creek	OK120400020160_00	Pea Creek	OK121500020100_00
Elk Creek	OK120400020190_00	Verdigris River	OK121500020260_00
Shady Grove Creek	OK120400020240_00	Dog Creek	OK121500020360_00
Arkansas River	OK120410010080_00	Verdigris River	OK121500030010_00
Cloud Creek	OK120410010100_00	Neosho River	OK121600010010_00
Snake Creek	OK120410010220_00	Chouteau Creek	OK121600010430_00
Arkansas River	OK120420010010_00		

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

SEPTEMBER 2012

Planning Basin 1 (11 TMDLs)
Middle Arkansas-Verdigris-Neosho

- Arkansas River and Haikey Creek Bacteria TMDLs – 2008
- Arkansas River and Verdigris River Area – Bacteria and Turbidity TMDLs – 2012
- Bird Creek Bacteria TMDLs – 2010
- Caney River Watershed Bacteria and Turbidity – 2010
- Copan Lake – Claremore Lake TMDLs – 2014
- Dog creek and Cat Creek TMDLs for Dissolved Oxygen – 2002
- Eucha – Spavinaw TMDLs – 2009
- Lower Neosho Basin Bacteria and Turbidity TMDLs – 2014
- Lower Bird Creek Watershed Bacteria TMDLs – 2011
- Neosho River Basin Bacteria TMDLs – 2008
- Verdigris River – Neosho River Bacteria and Turbidity TMDLs - 2012

Planning Basin 2 (2 TMDLs)
Lower Arkansas

- Lower Arkansas River Bacteria and Turbidity TMDLs - 2014
- Sans Bois Creek Area Bacteria TMDLs - 2008

Planning Basin 3 (13 TMDLs)
Washita – Upper Red

- Carl Blackwell Lake and Lake Humphreys Chlorophyll-a TMDLs - 2016
- Fort Cobb Lake and Watershed Nutrient TMDLs – 2006
- Lake Lawtonka – Waurika Lake – Lake Ellsworth Chlorophyll-a TMDLs – 2013
- Lower Red River Area Bacteria TMDLs – 2007
- Red River Bacteria and Turbidity TMDLs – 2012
- Red River Bacteria and Turbidity TMDLs – 2012
- Red River Bacteria and Turbidity TMDLs – 2018
- Rocky Lake and Tom Steed Lake Chlorophyll-a TMDLs – 2011
- Rush Creek Minerals TMDLs – 2013
- Upper Red River Area Bacteria TMDLs – 2008
- Washita River Bacteria TMDLs – 2012
- Washita River Bacteria TMDLs – 2007
- Washita River Bacteria and Turbidity TMDLs - 2010

Planning Basin 4 (5 TMDLs)
Lower Red

- Boggy Creek Area Bacteria TMDLs - 2007
- Little River Area Bacteria TMDLs - 2007
- Lower Red River and Little River Area Bacteria and Turbidity TMDLs - 2014
- Muddy Boggy Creek Area Bacteria and Turbidity TMDLs - 2012
- Sulphur Creek Turbidity TMDLs - 2010

Planning Basin 5 (8 TMDLs)
Canadian-North Canadian-Deep Fork

- Canadian River Area Bacteria TMDLs - 2008
- Lake Thunderbird Nutrient, Turbidity, and Dissolved Oxygen TMDLs 2013
- Lower Deep Fork of the Canadian River Area Bacteria and Turbidity TMDLs – 2011
- Lower North Canadian River Area Bacteria and Turbidity TMDLs – 2011
- Lower North Canadian and Deep Fork Area Bacteria and Turbidity TMDLs – 2014
- North Canadian River Area Bacteria TMDLs – 2010
- Upper Canadian River Area Bacteria TMDLs - 2007
- Upper Deep Fork Area Bacteria and Turbidity TMDLs – 2011

Planning Basin 6 (13 TMDLs)
Cimarron – Upper Arkansas

- Arkansas River and North Canadian River Area Bacteria and Turbidity TMDLs - 2014
- Black Bear Creek Turbidity TMDLs – 2010
- Carl Blackwell Lake and Lake Humphreys Chlorophyll-a TMDL – 2016
- Cimarron River Area Bacteria and Turbidity TMDLs – 2012
- Guthrie Lake and Liberty Lake Chlorophyll-a TMDLs – 2012
- Middle Cimarron River Area Bacteria and Turbidity – 2011
- Salt Creek and Sand Creek Area Bacteria TMDLs – 2009
- Salt Creek Area Turbidity TMDLs – 2010
- Salt Fork of the Arkansas River Area Bacteria and Turbidity TMDLs – 2011
- Skeleton Creek – Lower Cimarron River Area Bacteria TMDLs – 2009
- Skeleton Creek – Lower Cimarron River Area Turbidity TMDLs – 2010
- Turkey Creek Watershed Bacteria, Turbidity, and Dissolved Oxygen TMDLs – 2006
- Upper Cimarron River Area Bacteria TMDLs - 2011

Planning Basin 7 (4 TMDLs)
Beaver – Upper Cimarron

- Arkansas River and North Canadian River Area Bacteria and Turbidity TMDLs - 2014
- Beaver River Watershed Bacteria and Turbidity – 2010
- Beaver River Watershed Minerals TMDLs – 2014
- Upper Cimarron River Area Bacteria TMDLs – 2011

Quality Assurance Project Plan (QAPP)

The QAPP describes the policies and procedures for ensuring that work processes, products, or services satisfy expectations or specifications. The QAPP also documents how quality assurance (QA) and quality control (QC) are applied to your environmental data to assure that the results obtained are of the type and quality needed and expected. The EPA requires that all environmental data used in decision making be supported by an approved QAPP.

Your QAPP should include the following groups of elements:

- Project Management
- Data Generation and Acquisition
- Assessment and Oversight
- Data Validation and Usability

For More Information Contact:

Vernon Seaman

INCOG Water Quality Specialist

2 West Second St., Suite 800

Tulsa, OK 74103

918-579-9451 (Office)

918-899-6166 (Cell)

vseaman@incog.org

City of Tahlequah Source Tracking

Clinton Johnson, Director
Office of Energy and Environmental Sustainability
Indian Nations Council of Governments

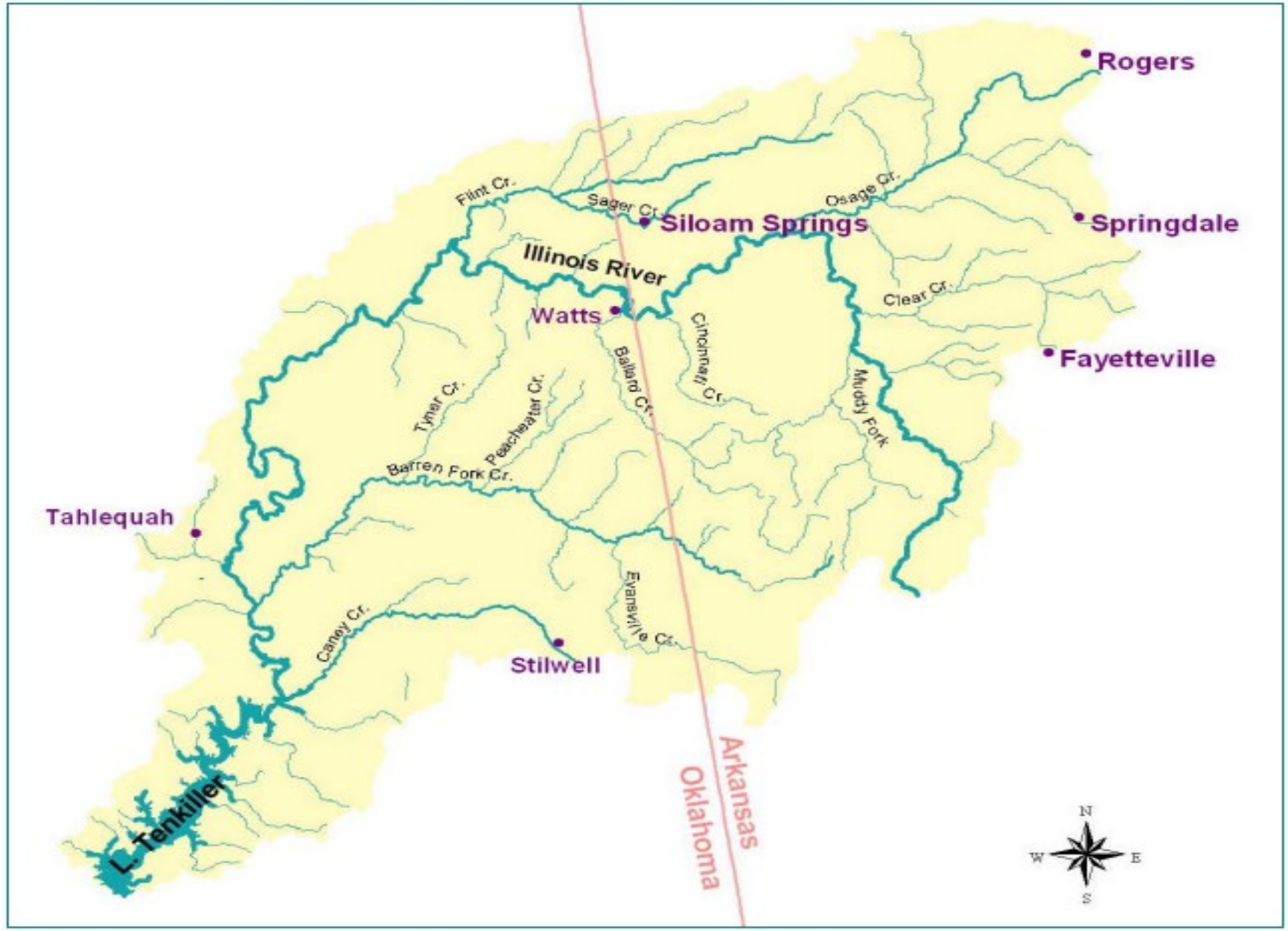
Jahna Hill MS, CFM, CISEC
Robison Wildlife Solutions

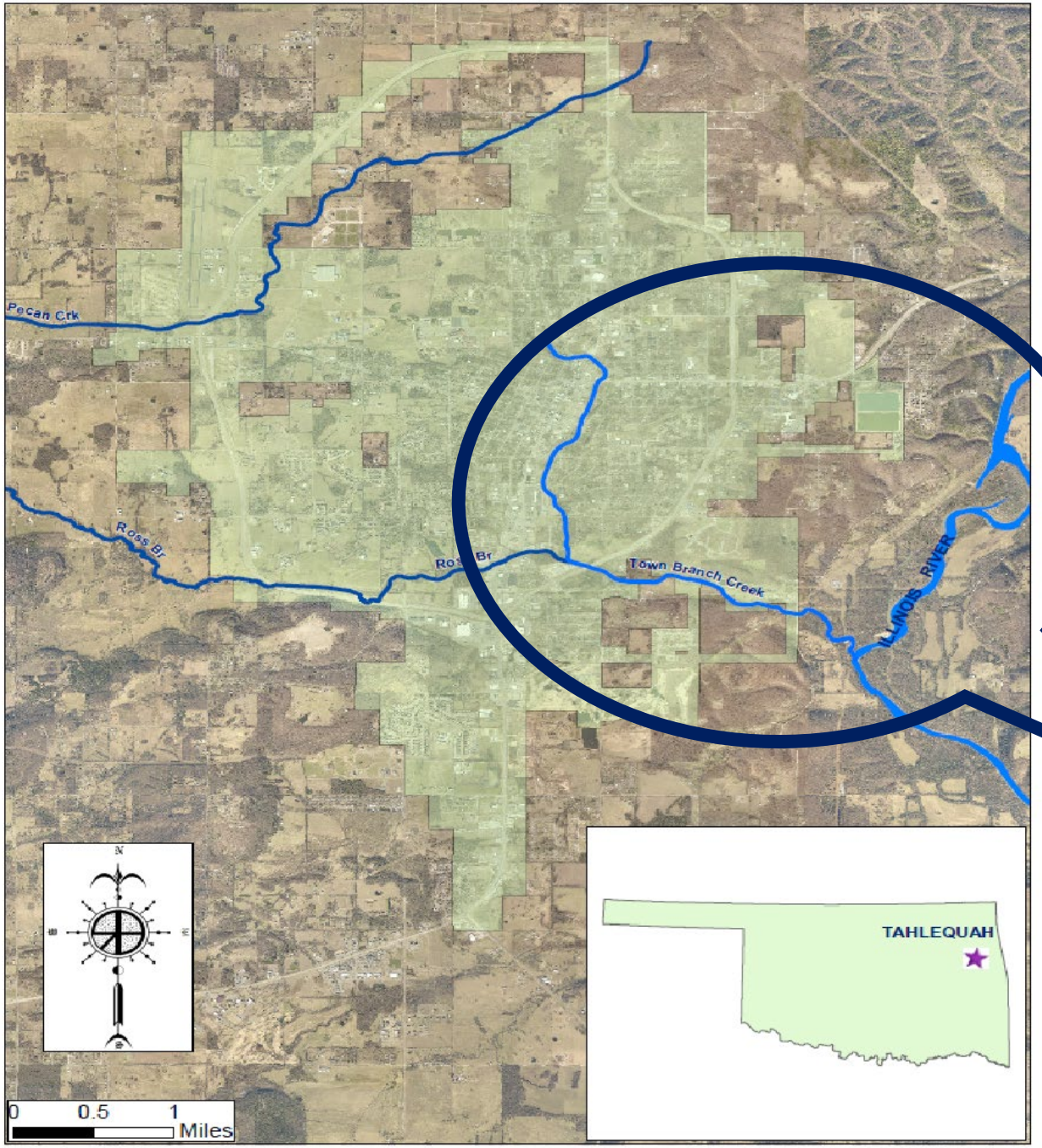
Managing Bacteria in Stormwater Workshop

December 1, 2022

Mohawk Water Treatment Plant


WAR EAGLE
WAR EAGLE

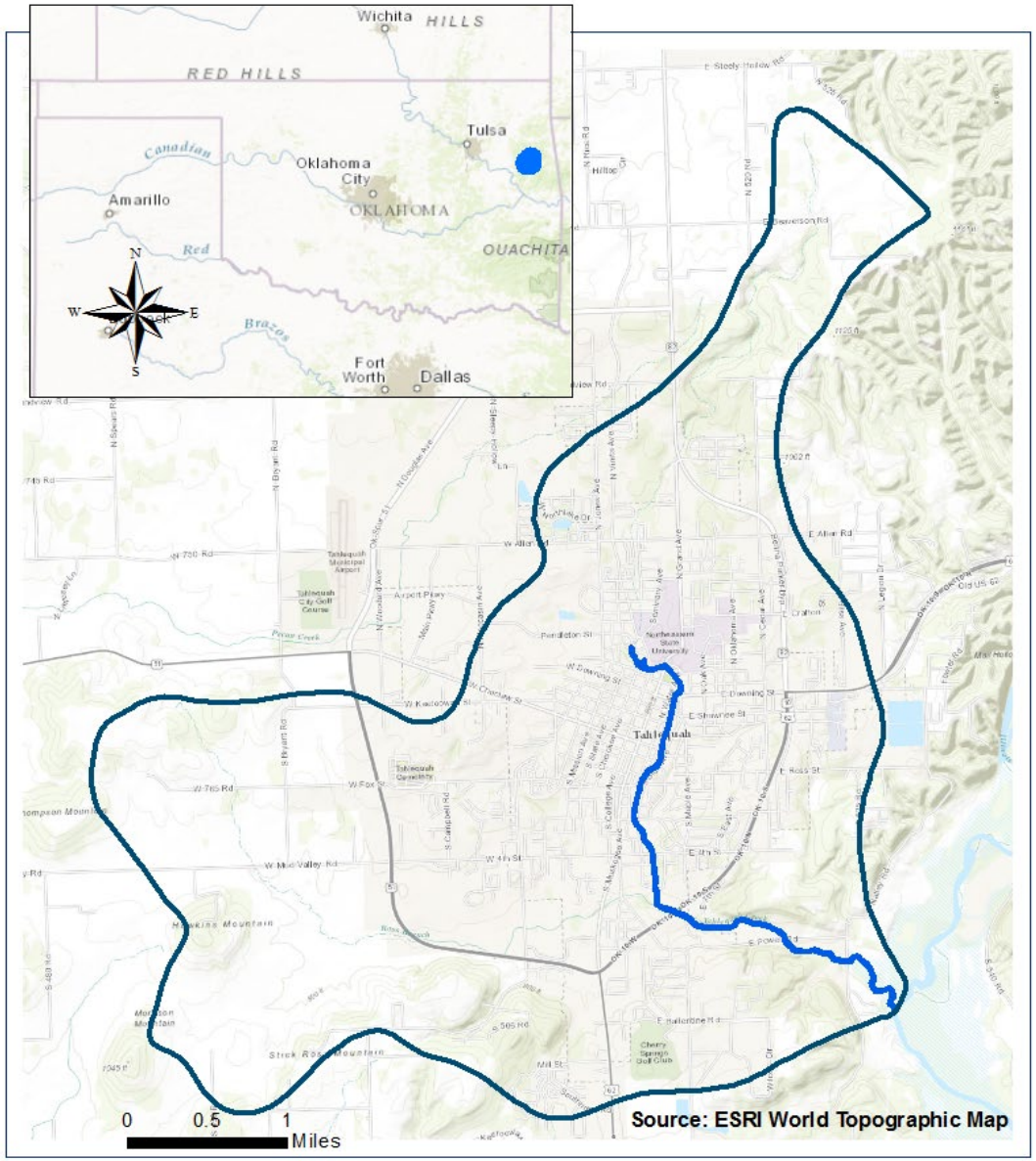

Rogers
Springdale
Fayetteville
Siloam Springs
Watts
Illinois River
Flint Cr.
Sager Cr.
Osage Cr.
Clear Cr.
Cincinnati Cr.
Ballard Cr.
Muddy Fork
Tyner Cr.
Peacheater Cr.
Barren Fork Cr.
Tahlequah
Evansville Cr.
Caney Cr.
Stilwell
L. Tenkiller
Arkansas
Oklahoma
N
W
E
S



Outstanding Resource Water

Scenic Illinois River Watershed

Town Branch Creek Watershed



Listed on 303(d) List of Impaired Waterbodies 2002 - Current

Waterbody ID	Waterbody Name	New WB	Units	Waterbody Size	WB Category	Cause Category	Impaired Use	Cause of Impairment	New Cause	TMDL Priority	TMDL ID	Unconfirmed Potential Sources
OK121700030040_00	Tahlequah Creek (Town Branch)		MILES	6.21	5a	5a	PBCR	Escherichia coli		1		46, 92, 108, 133, 136, 140

- Tahlequah Creek (Town Branch Creek) remains on the 303(d) List of Impaired Waters for *E. coli;* it was first listed as impaired in 2002 and biennial reports confirm the impairment continued into 2004, 2006, 2008, 2010, 2012, 2014, and 2016.

- Tahlequah Creek's impaired use affects Primary Body Contact Recreation.

Tahlequah's Water Quality

- **ODEQ 303(d) List of Impaired Water Bodies**
- **Tahlequah Creek (Town Branch Creek)**

  - ***Escherichia coli (E. coli)***

State numerical limit for Primary Body Contact Recreation

- **126 Colony Forming Units (CFU) per 100 mL**

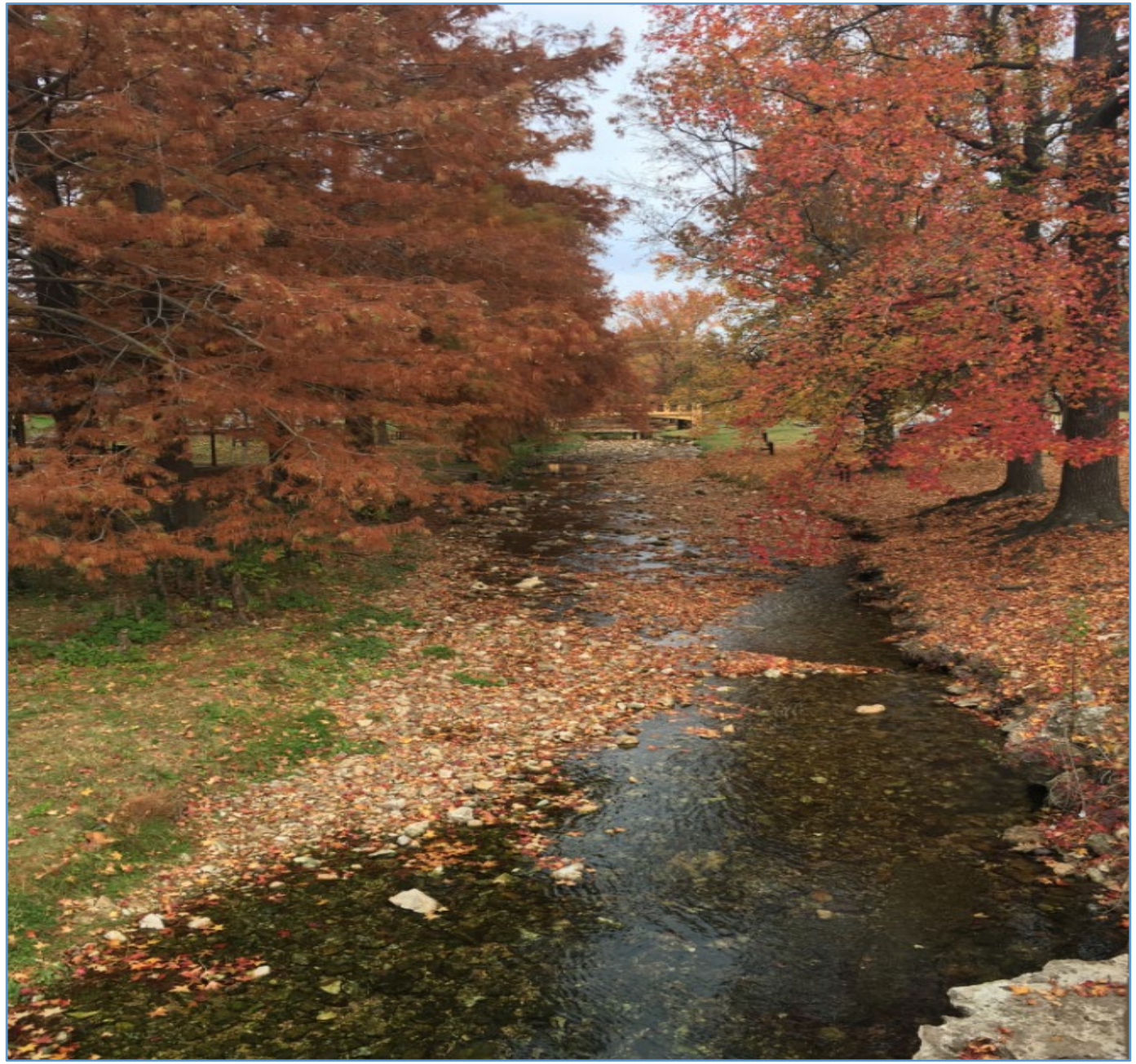
Swimming Advisory/Beach Closure

- **235 CFU per 100 mL**

Town Branch Creek at Sequoyah Park

Felts Park

Felts Park



Sequoyah Park

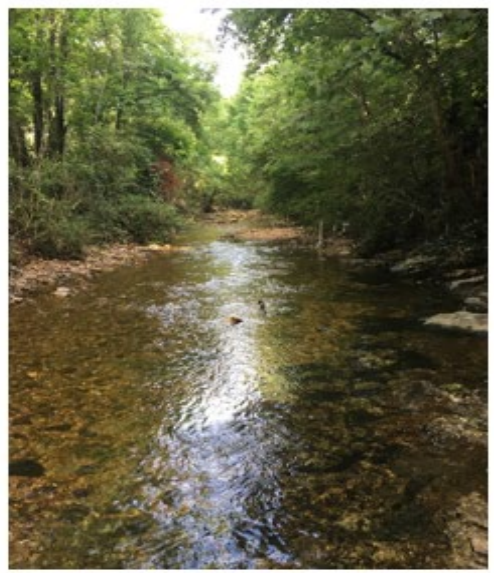
OKR04 Part III: Special Conditions states

“Operators seeking coverage under the Permit shall not be causing or have the reasonable potential to cause or contribute to a violation of a water quality standard”; Section III. C. Discharges to Outstanding Resource Waters states “Except for discharges of stormwater from temporary construction activities, new discharges located within the watershed of any waterbody designated Outstanding Resource Water in Oklahoma’s Water Quality Standards are not allowed and are not authorized by this permit. Discharges to Outstanding Resource Waters from MS4s existing as of June 25, 1992 are allowed but such stormwater discharges are prohibited from increased load of any pollutant”.

City of Tahlequah

Stormwater Program

OUTSTANDING RESOURCE WATER MONITORING PROGRAM



2019-2020

Annual Report

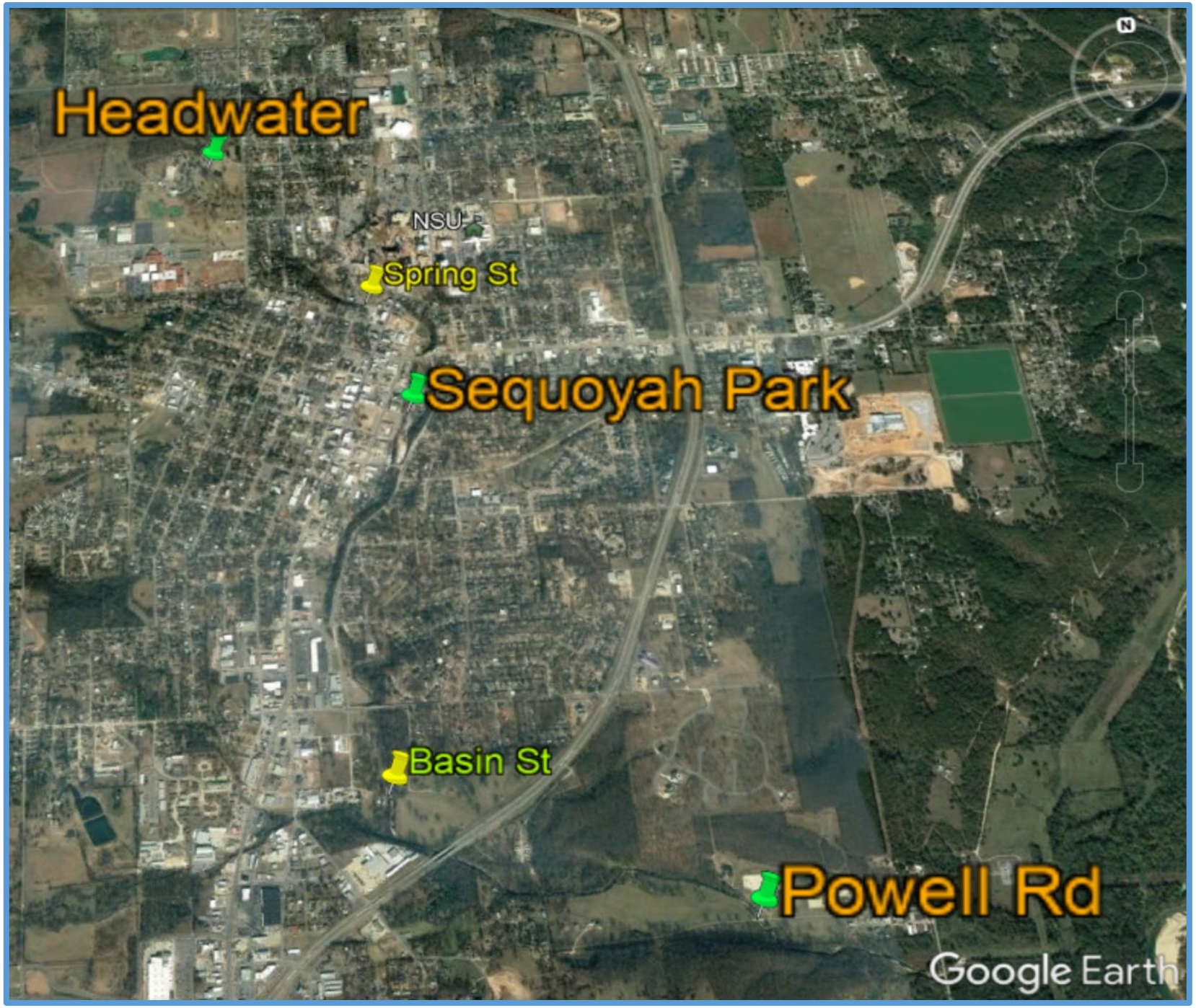
OUTSTANDING RESOURCE WATER MONITORING PROGRAM

City of Tahlequah Stormwater Program

Contents

ORWMP Partnerships

- Oklahoma Water Resources Board - sampling protocol
- City of Tulsa Stormwater Department - sampling protocol
- Accurate Labs - Lab analysis
- Partnerships include:
  - Tahlequah Public Works Authority (TPWA) - BMP support and sanitary sewer system maintenance, repairs, inspections
  - Cherokee Nation - Lab analysis
  - Grand River Dam Authority (GRDA) - Data sharing
  - Blue Thumb (Oklahoma Conservation Commission) - Data sharing, outreach, education
  - Friends of Town Branch Creek - Citizen scientist, data sharing, outreach


Headwater
NSU
Spring St
Sequoyah Park
Basin St
Powell Rd
Google Earth

Houston, we have a problem!!!

Table 3. City of Tahlequah - *E. coli* monitoring data and average daily flow at four selected locations along Town Branch Creek.

Sample Month	Sequoyah Park			Powell Bridge			Headwater			Methodist Home Spring		
	Sample (cfu)	Duplicate (cfu)	Average Daily Flow (ft^3/s)	Sample (cfu)	Duplicate (cfu)	Average Daily Flow (ft^3/s)	Sample (cfu)	Duplicate (cfu)	Average Daily Flow (ft^3/s)	Sample (cfu)	Duplicate (cfu)	Average Daily Flow (ft^3/s)
5/27/17	197	222	0.76	88.6	72.7	1.07	N/A	N/A	N/A	N/A	N/A	N/A
6/28/17	145	290	0.28	26	100	0.46	N/A	N/A	N/A	N/A	N/A	N/A
7/26/17	83	53	0.16	83	63	0.32	N/A	N/A	N/A	N/A	N/A	N/A
8/30/17	33	133	0.23	37	39	0.29	N/A	N/A	N/A	N/A	N/A	N/A
9/27/17	13	7	0.06	38	8	0.14	846	56	0.03	N/A	N/A	N/A
10/25/17	51	67	0.52	81	80	0.37	545	580	0.62	N/A	N/A	N/A
11/29/17	200	891	0.12	300	340	0.24	167	73	0.22	N/A	N/A	N/A
12/27/17	15	11	0.13	108	98	0.18	100	71	0.04	N/A	N/A	N/A
1/31/17	N/A	N/A	0.13	N/A	N/A	0.43	N/A	N/A	0.53	N/A	N/A	N/A
2/28/18	1	11	2.08	3	5	5.02	9	5	2.60	N/A	N/A	N/A
3/21/18	61	60	0.56	68	74	0.76	200	62	1.93	N/A	N/A	N/A
4/18/18	43	58	0.48	14	55	0.6	4	44	1.25	N/A	N/A	N/A
5/18/18	278	240	1.14	173	260	0.81	133	141	0.62	N/A	N/A	N/A
6/20/18	11300	8100	0.35	800	1100	1.53	10800	8500	0.09	N/A	N/A	N/A
6/27/18	200	250	0.19	109	118	0.28	290	300	0.08	191	280	0.08
7/25/2018	290	480	0.07	250	310	0.13	2100	2000	0.05	240	290	0.10

cfu = colony forming units

PUBLIC NOTICE

Town Branch Creek Water Quality

We recommend no creek entry

Be advised *E. coli* test results exceed the State of Oklahoma beach closure limit.

We recommend no creek entry until further test results indicate levels below the State limit.

***The City strictly recommends that residents refrain from ingesting creek water.**

CITY OF TAHLEQUAH OKLAHOMA


North St
North St
N Jones Ave
W Seneca St
N Jones Ave
Minor St
Minor St
N Jones Ave
United Methodist
Children's Home
Mathes Park Dr
Tahlequah
Learning Center
York St
York St
N Jones Ave
Google

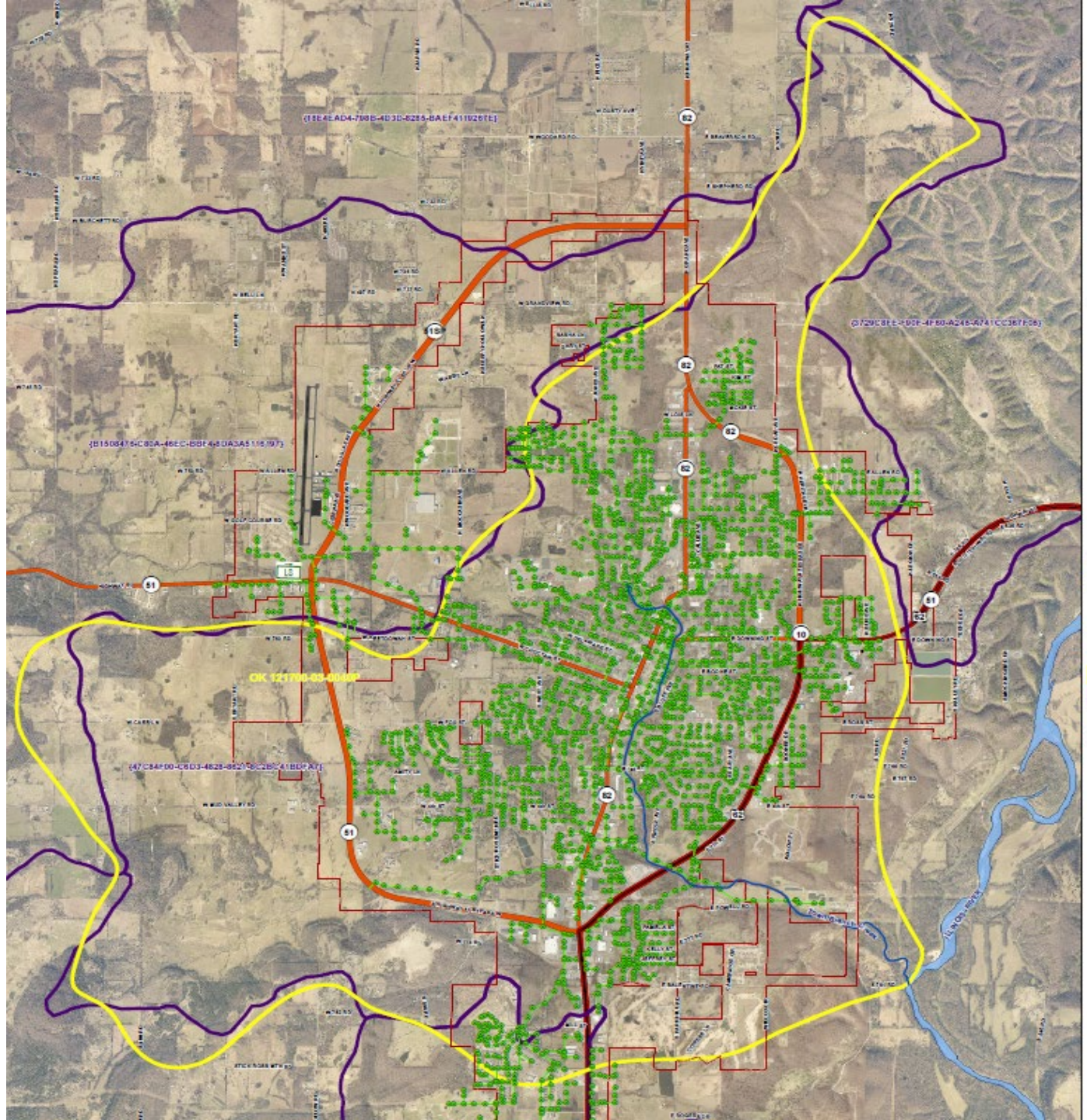
It’s the Geese!!!

Wait, what's that smell???

- *E. coli* DNA testing from Source Molecular Corporation in September 2018 indicated human as a source of contamination at the Town Branch Creek spring headwater located on private property.

- A Notice of Violation was issued, and the property owner submitted a Compliance Plan. They performed hydrostatic pressure testing and camera inspections of sewer lines which indicated lines were damaged and/or not properly connected to the City's sewer system and raw sewage had been discharged into the ground at the spring headwater for potentially decades.

- Sewer line repairs began in September 2018 to repair the damaged lines and make service connections where there never were any. Over 720 feet of sewer lines were replaced.



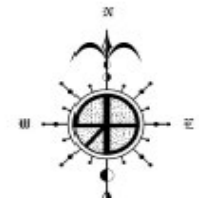
PUBLIC WORKS
Tahlequah
AUTHORITY

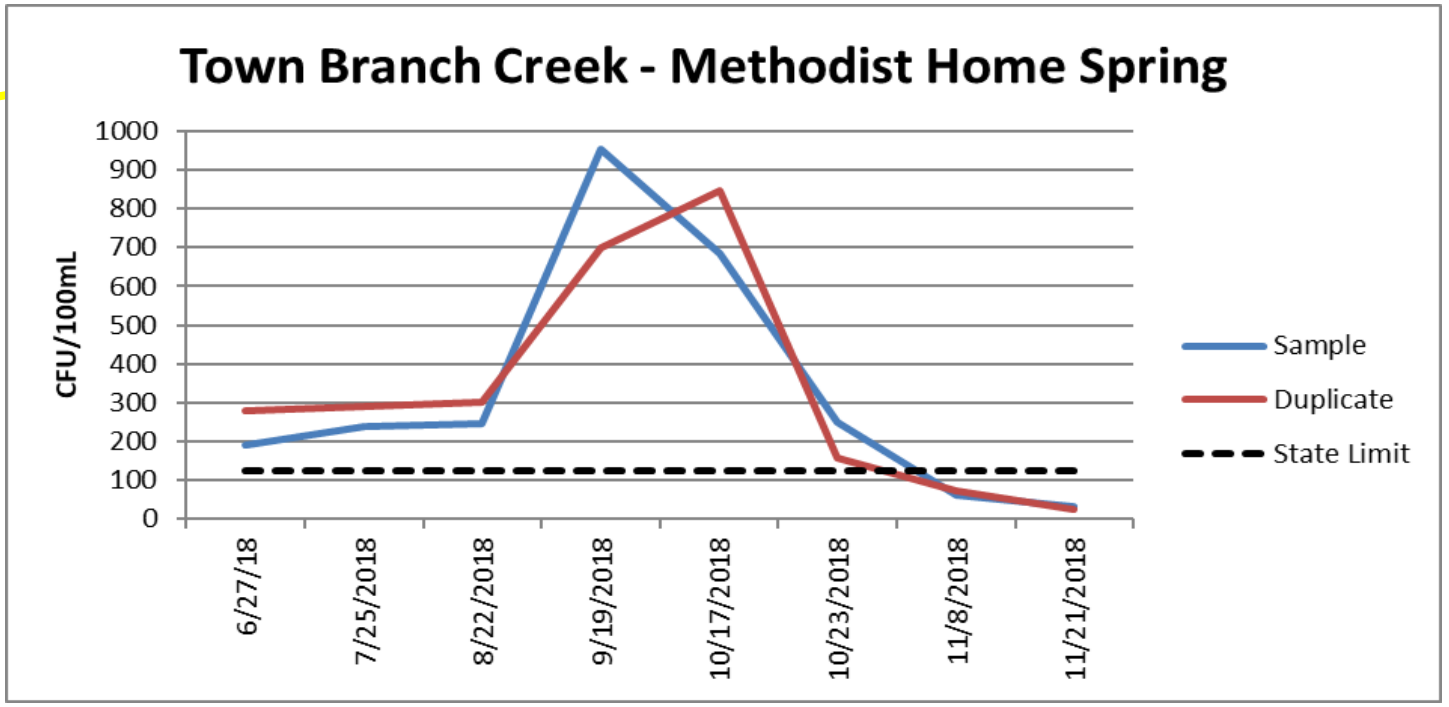
CITY OF
TAHLEQUAH OKLAHOMA
APRIL 2017

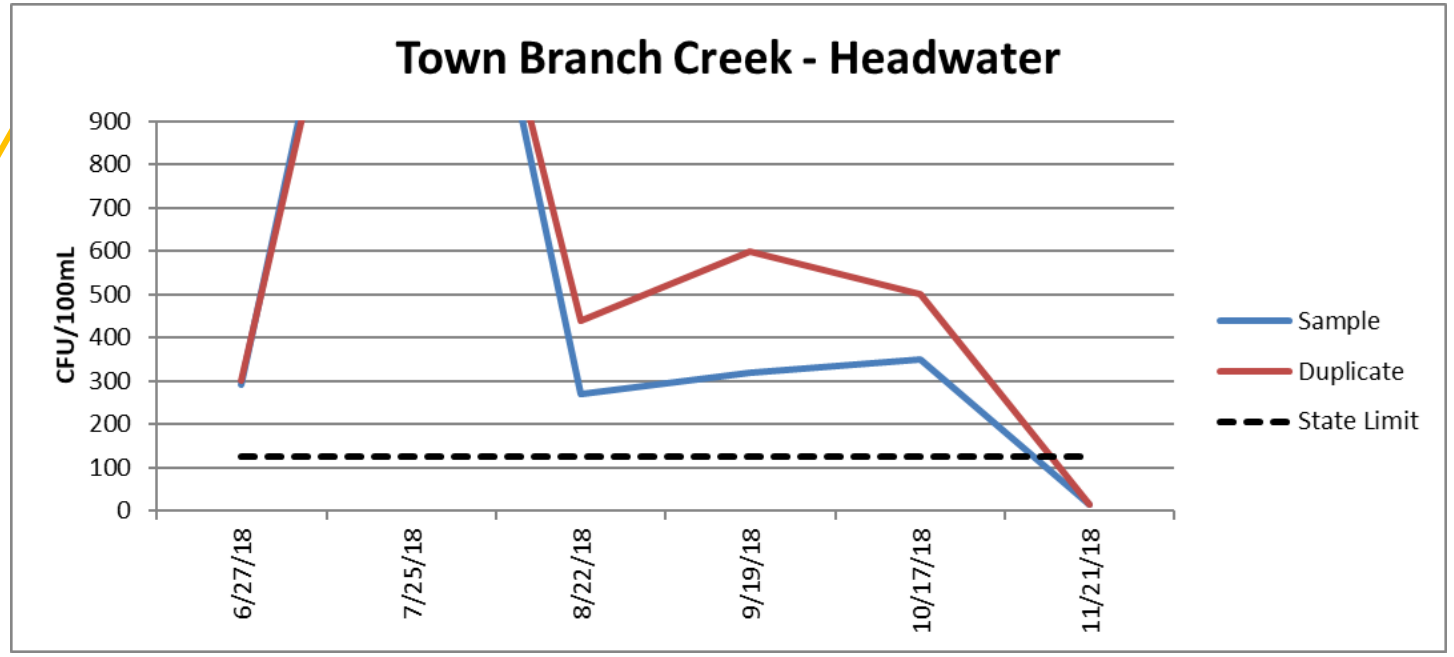
TOWN BRANCH CREEK WATERSHED and HUC12 WATERSHEDS

Legend

- LIFT STATIONS
- SAN. SEWER MANHOLES
- SAN. SEWER LINES
- TOWN BRANCH CREEK
- TOWN BRANCH WATERSHED
- HUC12 TAHLEQUAH
- ILLINOIS RIVER
- CITY LIMITS




Town Branch Creek - Methodist Home Spring
CFU/100mL
1000
900
800
700
600
500
400
300
200
100
0
6/27/18
7/25/2018
8/22/2018
9/19/2018
10/17/2018
10/23/2018
11/8/2018
11/21/2018
Sample
Duplicate
State Limit


Town Branch Creek - Headwater
CFU/100mL
900
800
700
600
500
400
300
200
100
0
6/27/18
7/25/18
8/22/18
9/19/18
10/17/18
11/21/18
Sample
Duplicate
State Limit

Kinsey's Plumbing Heat & Air
21438 Stick Ross Mtn Rd
Tahlequah, OK 74464
Phone: 456-9815
Fax: 458-0393

October 1, 2018

United Methodist Childrens Home
7 Mathis Park Dr.
Tahlequah, OK 74464

The City of Tahlequah used a camera on 6" sewer main and found a break in it. We replaced 60 ft. of 6" pvc sec 40 from manhole to manhole and installed two manhole covers and rings.

I ran camera in 6" line in driveway one building north of office. I found break . Dug it up and repaired 10 ft. of line.

On Laymans building we ran camera and found break under sidewalk do to rock. Replaced 60 ft. of 6" line. Remove rock and bed all sewers with screenings.

On Webb building we found low spot in road and a broke fitting. Replaced 40' of sewer.

In gyjm/school building we found low spots and backfall. Replaced 260 ft. of 4" pvc.

In Church building found some low spot holding water. We replaced 160 ft. of 4" pvc.

In RV Park we ran camera and found no problem.

In Christian House south of swimmimg pool we replaced 120 ft. of 4" pvc.

We found break behind Ferguson. Replaced 10 ft. and added a cleanout to camera Ferguson building.

Sincerely,

Wayne Kinsey Lic# 3698

Kinsey's Plumbing Heat & Air

Table 4. City of Tahlequah - State certified *E. coli* monitoring data at four select locations along Town Branch Creek.

Sample Month	Sequoyah Park		Powell Bridge		Headwater		Methodist Home Spring	
	Sample (cfu)	Duplicate (cfu)	Sample (cfu)	Duplicate (cfu)	Sample (cfu)	Duplicate (cfu)	Sample (cfu)	Duplicate (cfu)
7/25/2018	290	480	250	310	2100	2000	240	290
8/22/2018	660	36	290	260	270	440	245	300
9/19/2018	73	75	99	101	320	600	952	700
10/17/2018	32	29	108	197	350	500	685	846
11/21/2018	16	15	45	40	14	14	32	24
12/19/2018	340	410	109	115			46	36
1/16/2019	102	118	132	146			80	68
2/20/2019	300	310	165	159			30	34
3/20/2019	90	84	116	90	27	28	28	39
4/24/2019	430	380	365	400	110	116	29	3
5/15/2019	550	350	210	200	280	200	235	67
6/20/2019	700	620	0	550	136	46	36	46

cfu = colony forming units

Overall, combined *E. coli* results indicate that Tahlequah Creek is relatively healthy; however, several months throughout the year exceed Oklahoma Water Quality Standards.

Table 6. The geometric mean of state certified *E. coli* results for the City of Tahlequah data, excluding additional locations. The geometric mean was calculated for each site individually at each year and for both years combined and for all sites (overall) each year and for both years combined. The yearly and biyearly totals are listed in bold.

	Geometric Mean of *E. coli* (cfu)		
Sample	**2017-2018**	**2018-2019**	**2 Year Totals**
Methodist Home Spring		103	107
Headwater	173	150	161
Sequoyah Park	77	180	114
Powell Bridge	67	98	80
Overall	**81**	**129**	**104**
Duplicate			
Methodist Home Spring		80	87
Headwater	124	169	144
Sequoyah Park	111	141	124
Powell Bridge	78	173	112
Overall	**103**	**130**	**117**

Escherichia coli (E. coli) monitoring from (Tahlequah Creek) Town Branch Creek: May 2017 – February 2020

Started with monthly samples to Accurate Labs in Tulsa, OK to obtain state accredited results.

Results from June 2018 exceeded state water quality standards for recreational use, as well as beach closure limit; therefore, source tracking became necessary. *E. coli* DNA analyses from two locations in September 2018 and March 2019 indicated human contamination.

Cherokee Nation and Grand River Dam Authority assist with samples

Source tracking required expansion of sampling efforts and the Stormwater Program worked with partners to help extend resources to increase sampling locations from 3 to 13.

Cherokee Nation analyzed additional samples weekly during the recreation period, May 1st through September 30th.

GRDA shared *E. coli* data from their monitoring.

Friends of Town Branch Creek

Friends of Town Branch Creek had been collecting *E. coli* samples at two locations on Town Branch Creek with the support of Blue Thumb.

303(d) Biological Pollutant BMP Activities

1. Review sewer infrastructure inventory and maintenance records from TPWA in the 303(d) watershed and set priority areas.
2. Perform camera inspections of sewer lines that have the most plausible chance of impacting the 303(d) watershed.
3. Place educational signage near the frequent access areas of the creek regarding bacteria, its dangers and sources and what the public can do to help, including cleaning up pet waste.
4. Maintain existing pet waste stations
5. Adopt a Pet Waste Ordinance

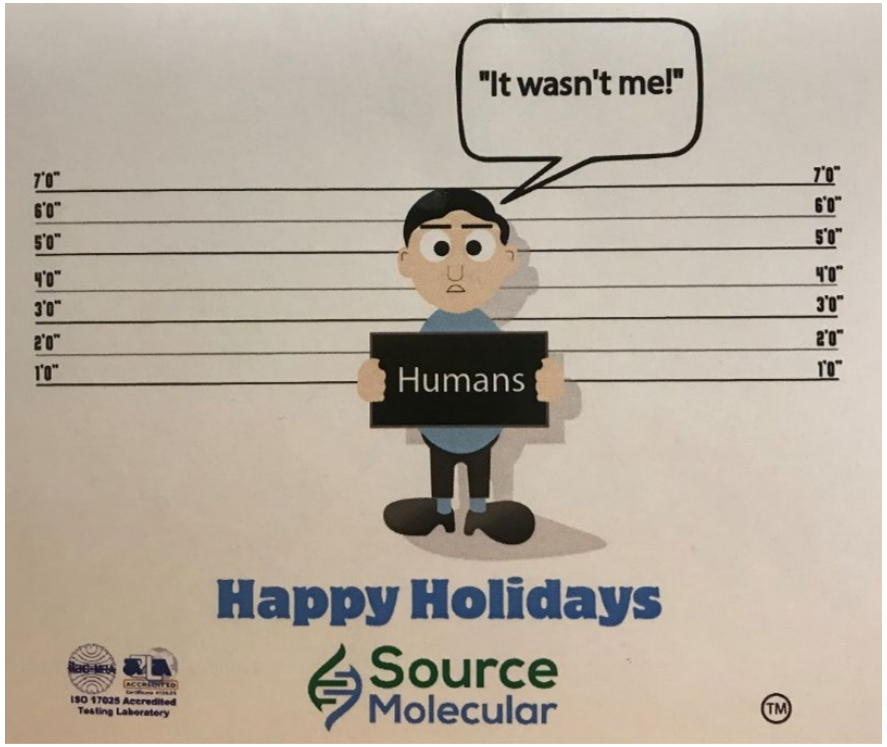
Sewer Infrastructure Inventory and Maintenance Records - Tahlequah Public Works Authority

Part III. A. 1. g. states that BMPs for bacteria include:

- Sanitary Sewer Systems
  - Improvements to sanitary sewers
  - Address lift station inadequacies
  - Improve reporting of violations
  - Strengthen controls

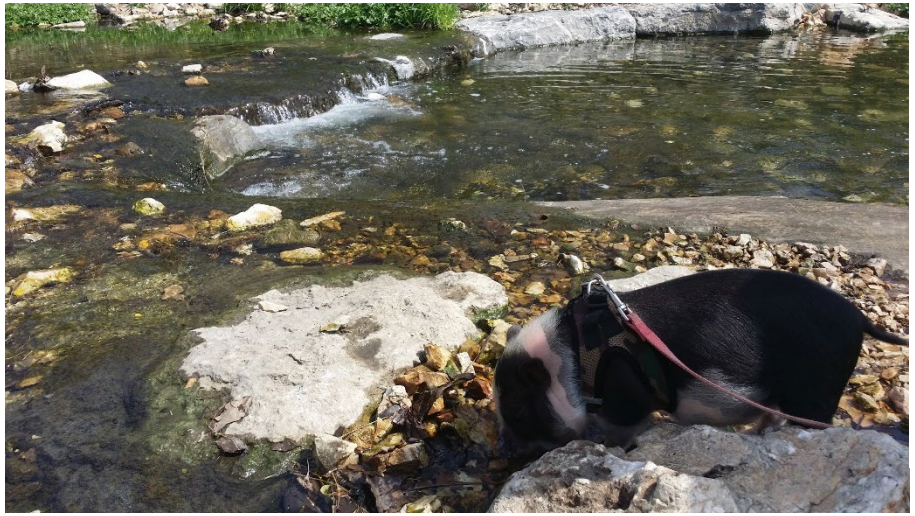
- On-site Sewage Facilities
  - Identify and address failing systems
  - Address inadequate maintenance of on-site sewage facilities

- Quarterly inspections should consist of the following information:
  - Type and size of material inspected
  - Existing and potential damages
  - Issues or concerns
  - Repair actions



Scoop the Poop!

Please remove pet waste from creek side

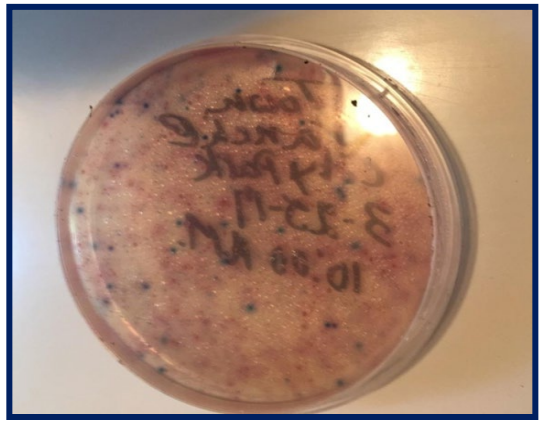


Public outreach and education

Public outreach and education

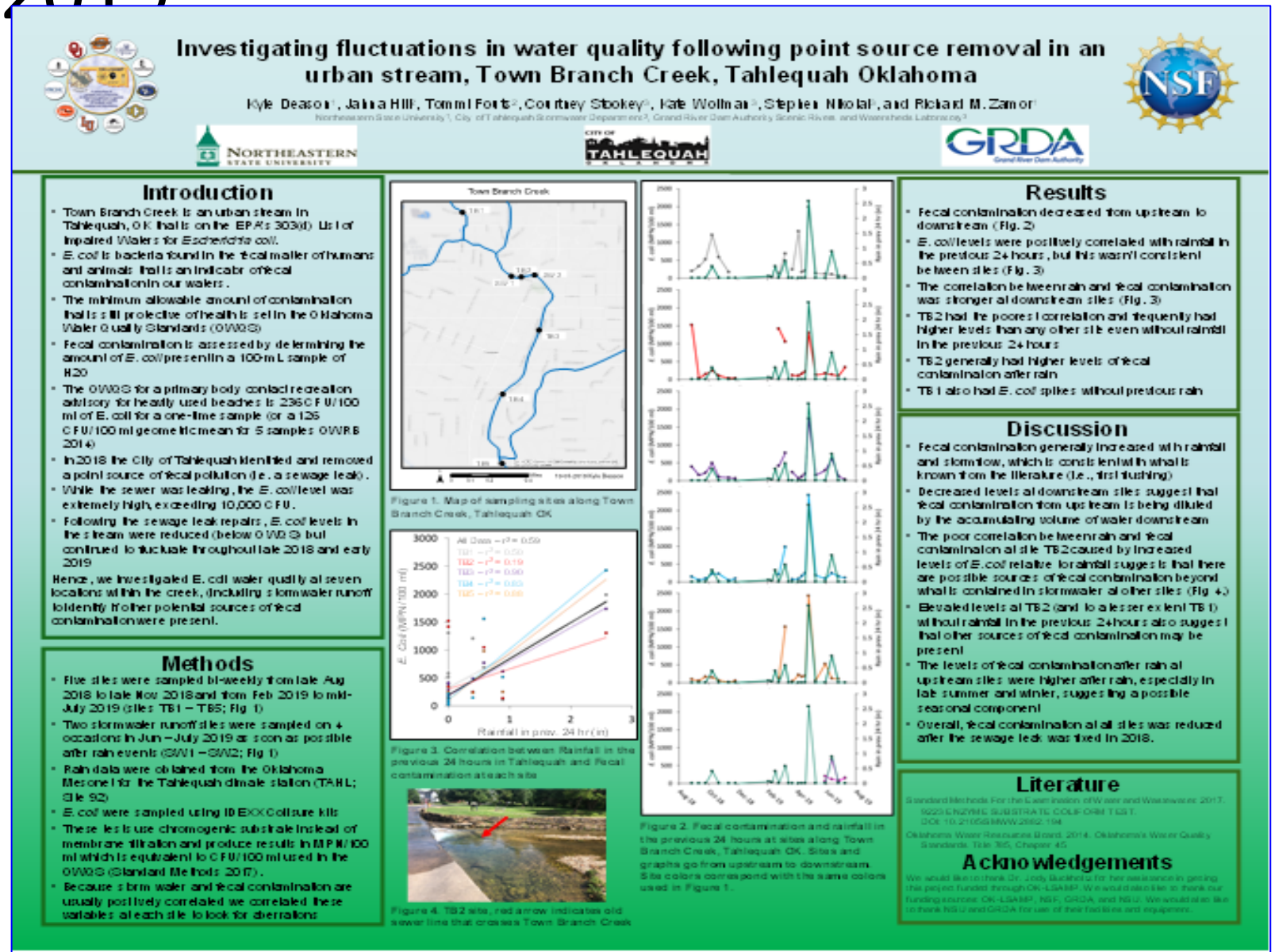
- Friends of Town Branch Creek
  - Mission Statement:
    - Preserve the unique biology and aesthetic value of Tahlequah's Town Branch Creek watershed through public education and involvement.

Christi McDonald



Jason Gooper

Water quality project with Northeastern State University (NSU) professor and student completed in October 2019



Investigating fluctuations in water quality following point source removal in an urban stream, Town Branch Creek, Tahlequah Oklahoma

Kyle Deason[1], Jahna Hill[1], Tommi Fortis[2], Courtney Stookey[2], Kate Wollman[2], Stephen Nikolaiff[1], and Richard M. Zamor[1]

[1]Northeastern State University, [2]City of Tahlequah Stormwater Department, Grand River Dam Authority, Scenic Rivers and Watersheds Laboratory

Introduction

- Town Branch Creek is an urban stream in Tahlequah, OK that is on the EPA's 303(d) List of Impaired Waters for *Escherichia coli*.
- *E. coli* is bacteria found in the fecal matter of humans and animals that is an indicator of fecal contamination in our waters.
- The minimum allowable amount of contamination that is still protective of health is set in the Oklahoma Water Quality Standards (OWQS)
- Fecal contamination is assessed by determining the amount of *E. coli* present in a 100-mL sample of H20
- The OWQS for a primary body contact recreation advisory for heavily used beaches is 236 CFU/100 ml of E. coli for a one-time sample (or a 126 CFU/100 ml geometric mean for 5 samples OWRB 2014)
- In 2018 the City of Tahlequah identified and removed a point source of fecal pollution (i.e. a sewage leak).
- While the sewer was leaking, the *E. coli* level was extremely high, exceeding 10,000 CFU.
- Following the sewage leak repairs, *E. coli* levels in the stream were reduced (below OWQS) but continued to fluctuate throughout late 2018 and early 2019

Hence, we investigated E. coli water quality at seven locations within the creek, including stormwater runoff to identify if other potential sources of fecal contamination were present.

Methods

- Five sites were sampled bi-weekly from late Aug 2018 to late Nov 2018 and from Feb 2019 to mid-July 2019 (Sites TB1 – TB5; Fig. 1)
- Two stormwater runoff sites were sampled on 4 occasions in Jun – July 2019 as soon as possible after rain events (SW1 – SW2; Fig. 1)
- Rain data were obtained from the Oklahoma Mesonet for the Tahlequah climate station (TAHL; Site 92)
- *E. coli* were sampled using IDEXX Colilure kits
- These tests use chromogenic substrate instead of membrane filtration and produce results in MPN/100 ml which is equivalent to CFU/100 ml used in the OWQS (Standard Methods 2017).
- Because storm water and fecal contamination are usually positively correlated we correlated these variables at each site to look for aberrations

Figure 1. Map of sampling sites along Town Branch Creek, Tahlequah OK

Figure 3. Correlation between Rainfall in the previous 24 hours in Tahlequah and Fecal contamination at each site

Figure 4. TB2 site, red arrow indicates old sewer line that crosses Town Branch Creek

Figure 2. Fecal contamination and rainfall in the previous 24 hours at sites along Town Branch Creek, Tahlequah OK. Sites and graphs go from upstream to downstream. Site colors correspond with the same colors used in Figure 1.

Results

- Fecal contamination decreased from upstream to downstream (Fig. 2)
- *E. coli* levels were positively correlated with rainfall in the previous 24 hours, but this wasn't consistent between sites (Fig. 3)
- The correlation between rain and fecal contamination was stronger at downstream sites (Fig. 3)
- TB2 had the poorest correlation and frequently had higher levels than any other site even without rainfall in the previous 24 hours
- TB2 generally had higher levels of fecal contamination after rain
- TB1 also had *E. coli* spikes without previous rain

Discussion

- Fecal contamination generally increased with rainfall and stormflow, which is consistent with what is known from the literature (i.e., first flushing)
- Decreased levels at downstream sites suggest that fecal contamination from upstream is being diluted by the accumulating volume of water downstream
- The poor correlation between rain and fecal contamination at site TB2 caused by increased levels of *E. coli* relative to rainfall sugges is that there are possible sources of fecal contamination beyond what is contained in stormwater at other sites (Fig 4.)
- Elevated levels at TB2 (and to a lesser extent TB1) without rainfall in the previous 24 hours also suggest that other sources of fecal contamination may be present
- The levels of fecal contamination after rain at upstream sites were higher after rain, especially in late summer and winter, suggesting a possible seasonal component
- Overall, fecal contamination at all sites was reduced after the sewage leak was fixed in 2018.

Literature

Standard Methods For the Examination of Water and Wastewater. 2017. 9223 ENZYME SUBSTRATE COLIFORM TEST. DOI: 10.2105/SMWW.2882.194

Oklahoma Water Resources Board. 2014. Oklahoma Water Quality Standards. Title 785, Chapter 45

Acknowledgements

We would like to thank Dr. Jody Mashburn for her assistance in getting this project funded through OK-EPSCoR. We would also like to thank our funding sources: OK-EPSCoR, NSF, GRDA, and NSU. We would also like to thank NSU and GRDA for use of their facilities and equipment.


TahlequaH2O Celebration


TAHLEQUA

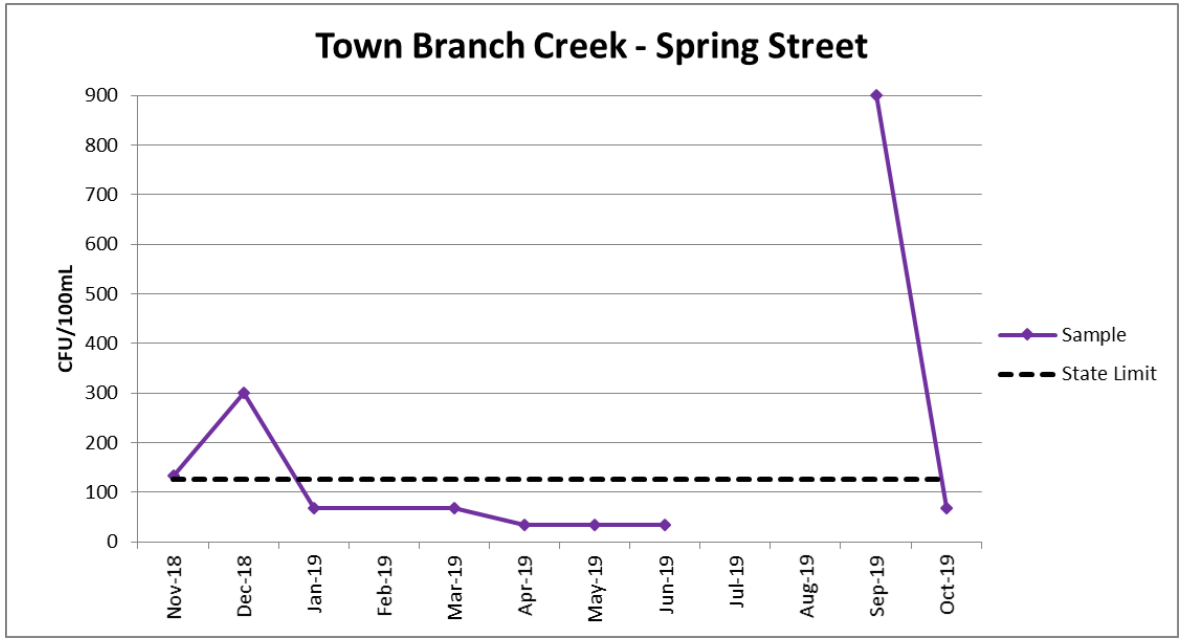
Discussion and Questions

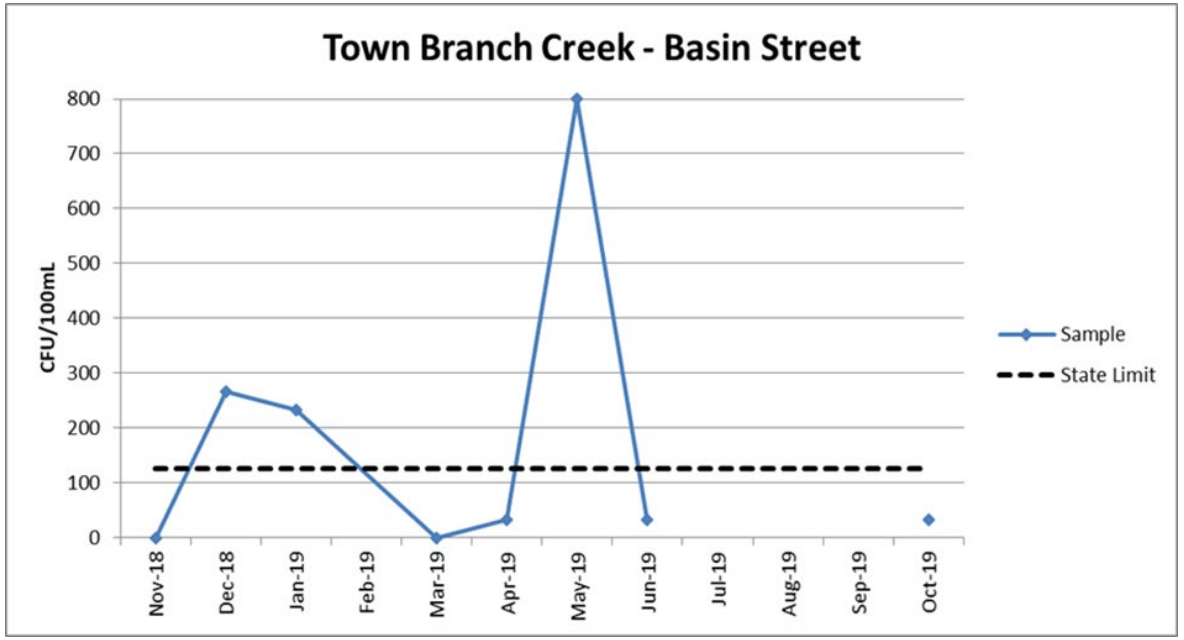
- Source identification is the most challenging aspect of addressing E. coli pollution, as potential sources include septic tanks, faulty or damaged sewer lines, and pet/wildlife waste.
- Planning
  - What happens if data remain consistent or increase? - Additional sampling locations and collaboration with other entities for support.
  - What happens after data suggests delisting?
  - Continued education
- Integration of data from various sources – QA consistency
  - Data organization and presentation
- Results are elevated at rain events.
  - First flush sampling would be beneficial - Integration with IDDE program.

Thank you for the support!!

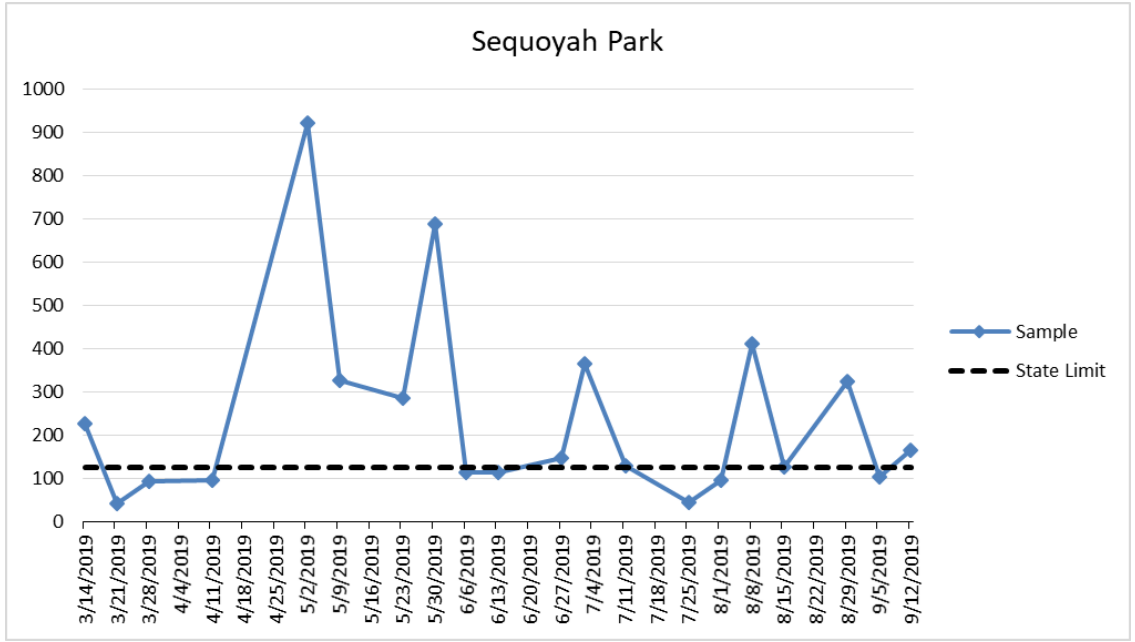
- City of Tahlequah - Tommi Fouts, City of Tahlequah Stormwater Program Intern
- Friends of Town Branch Creek
- Blue Thumb (Oklahoma Conservation Commission)
- Tahlequah Public Works Authority
- Cherokee Nation
- United Keetoowah Band of Cherokee Indians
- Grand River Dam Authority
- City of Tulsa
- Oklahoma Water Resources Board
- Northeastern State University


Headwater
NSU
Spring St
Basin St
Google Earth


Town Branch Creek - Spring Street
CFU/100mL
900
800
700
600
500
400
300
200
100
0
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Sample
State Limit


Town Branch Creek - Basin Street
CFU/100mL
800
700
600
500
400
300
200
100
0
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Sample
State Limit


Sequoyah Park
Felt's Park
N


Sequoyah Park
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900
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700
600
500
400
300
200
100
0
3/14/2019
3/21/2019
3/28/2019
4/4/2019
4/11/2019
4/18/2019
4/25/2019
5/2/2019
5/9/2019
5/16/2019
5/23/2019
5/30/2019
6/6/2019
6/13/2019
6/20/2019
6/27/2019
7/4/2019
7/11/2019
7/18/2019
7/25/2019
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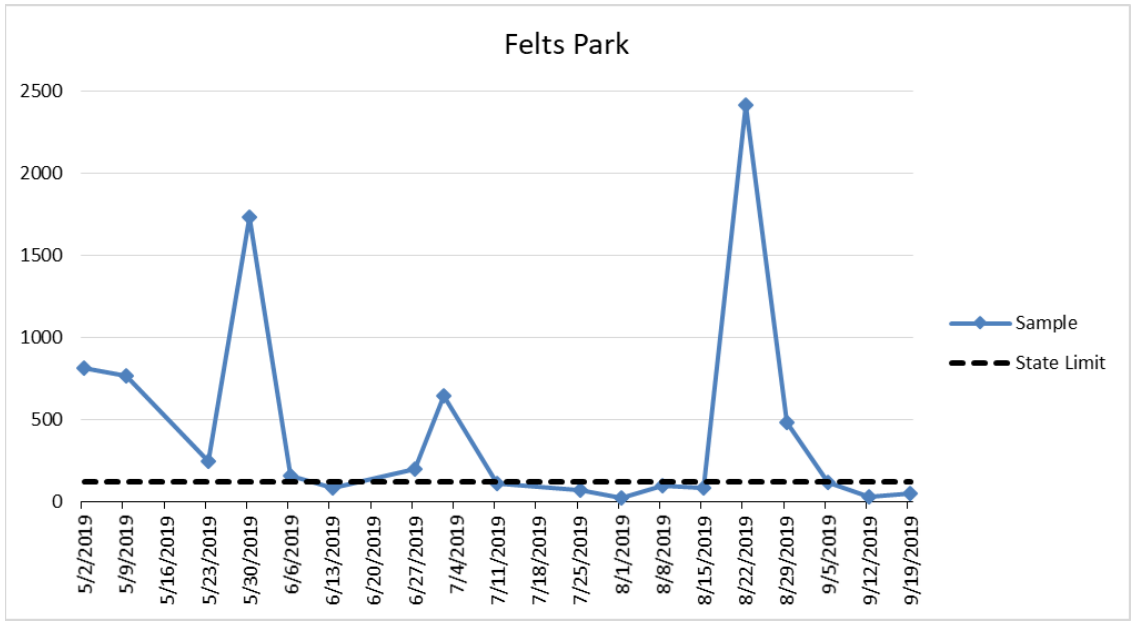
8/29/2019
9/5/2019
9/12/2019
Sample
State Limit


Felts Park
2500
2000
1500
1000
500
0
5/2/2019
5/9/2019
5/16/2019
5/23/2019
5/30/2019
6/6/2019
6/13/2019
6/20/2019
6/27/2019
7/4/2019
7/11/2019
7/18/2019
7/25/2019
8/1/2019
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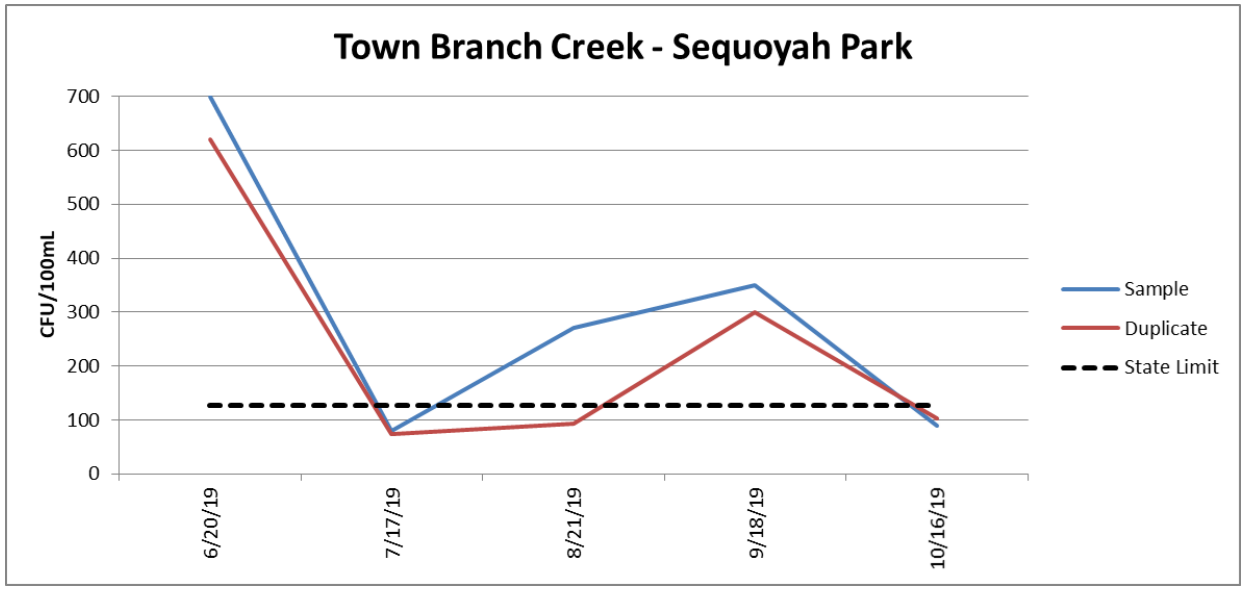
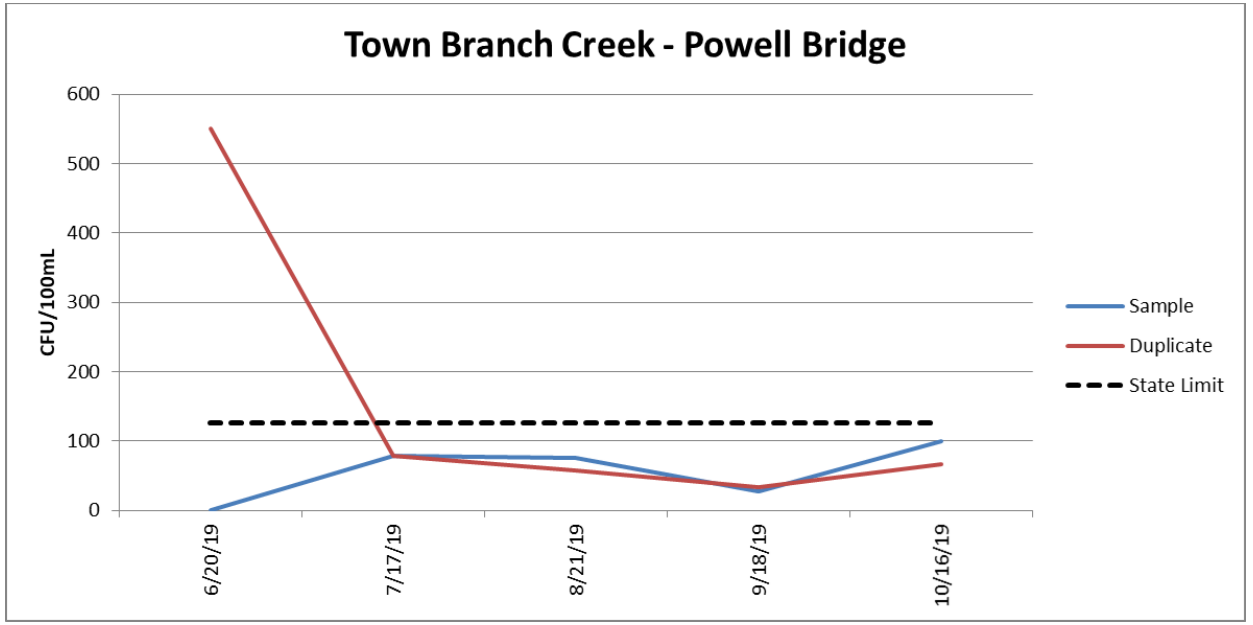
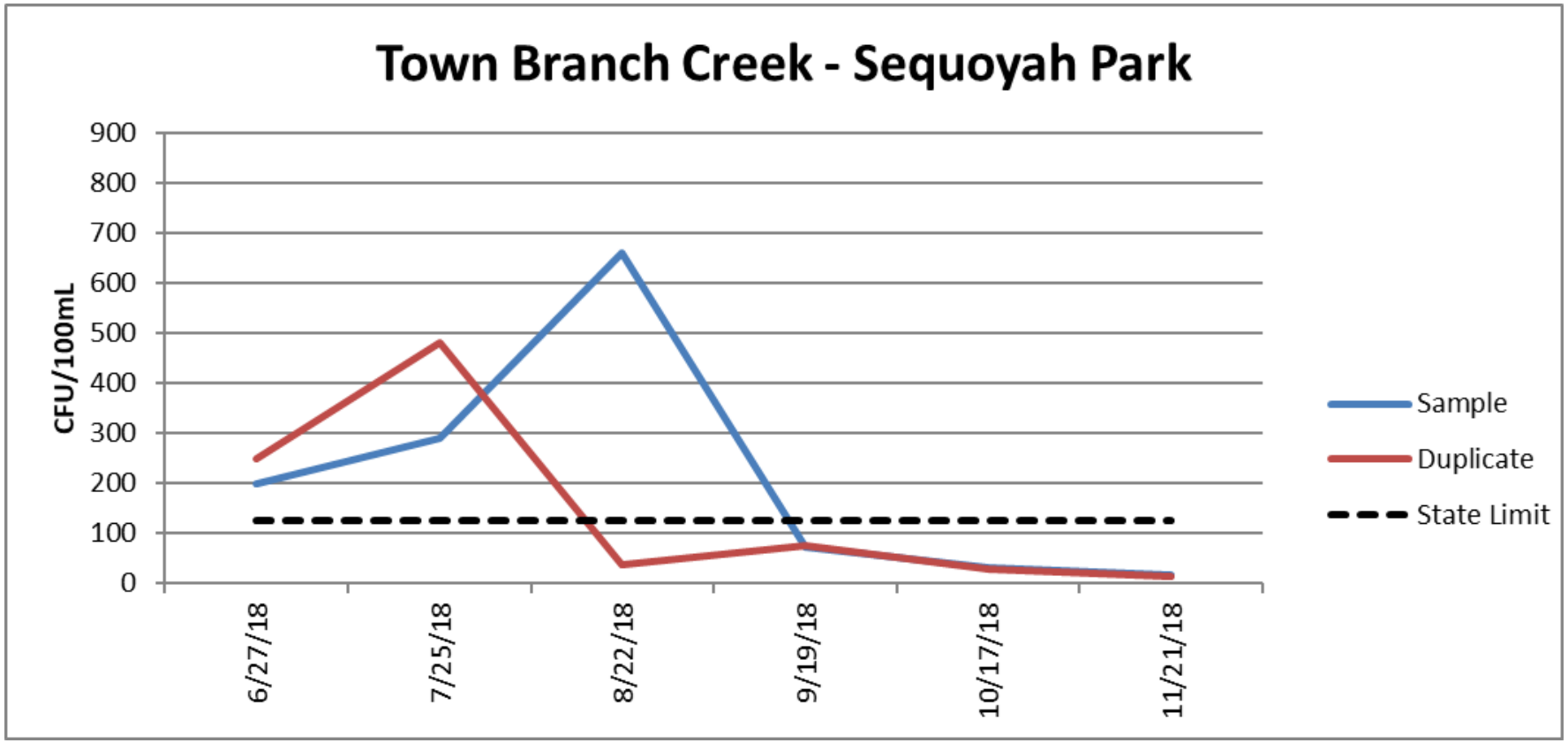
9/5/2019
9/12/2019
9/19/2019
Sample
State Limit





CITY OF TAHLEQUAH OKLAHOMA


N
Sequoyah Park
Felt's Park


Town Branch Creek - Sequoyah Park
CFU/100mL
900
800
700
600
500
400
300
200
100
0
6/27/18
7/25/18
8/22/18
9/19/18
10/17/18
11/21/18
Sample
Duplicate
State Limit

Bacteria Monitoring in the Oklahoma River

Dawson McNeill-

Environmental Unit Supervisor

Overview of Storm Water Quality

- Administrative: 7 positions
- Construction: 8 positions
- Environmental Water Quality: 8 positions
- Household Hazardous Waste Collection Facility: 7 positions
- Industrial: 5 positions
- Outreach: 1 positions

Environmental Section Responsibilities

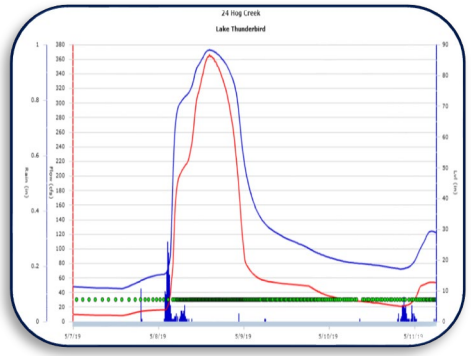
OKC

Primary

- Wet Weather Analytical Monitoring
- Priority Watershed Based Monitoring (ended with 2013 permit)
- Illicit Discharge Detection & Elimination (IDDE)
- Total Maximum Daily Load Monitoring
- Trend and Load Based Monitoring (Waiting on new permit approval)
- **Bacteria monitoring (revocable permit)**
- Adult mosquito surveillance and larvicide application program
- Storm Drain Curb Marking
- Floatable Debris Monitoring
- Special Project Assignments (BMP installation/monitoring)

Shared (other sections/departments)

- Waterway Clean Sweep Program
- Pesticide General Permit
- Pollution Complaints and Spill Response Program



North Canadian /Oklahoma River Bacteria Monitoring Program

- Started in late 2008
- *E. coli* and *Enterococci* samples collected on a weekly basis
- Sample analysis ran primarily through OKC Utilities Laboratory or inhouse laboratory
- Approximately 1,138 samples collected since start of program

Boathouse International Triathlon

May 16-17, 2009

Oklahoma River water caused triathletes' illness, health department says

THE ASSOCIATED PRESS

Published: Wed, June 10, 2009 12:00 AM | Updated: Wed, June 10, 2009 3:49 PM

Triathletes compete during the Boathouse International Triathlon last month. Photo by John Clanton

- Included a 1.5-kilometer swimming event
- 367 participants
- 218 responded to Health Department Survey
- 45 respondents reported symptoms
- Stool sample analysis from participants indicated viral, parasites and bacterial indicators of water contaminated with human or animal waste

Boathouse International Triathlon

E.coli sample results

Year	Site Number	Type	Date	E. coli (CFU)
2009	1359	Sample	5/11/2009	250
2009	1359	Sample	5/12/2009	38730
2009	1359	Sample	5/13/2009	3930
2009	1359	Sample	5/14/2009	5830
2009	1359	Sample	5/15/2009	573
		Event	5/16/2009	
		Event	5/17/2009	
2009	1359	Sample	5/18/2009	520
2009	1359	Sample	5/19/2009	279
2009	1359	Sample	5/21/2009	201

- Samples were acquired on May 11-15 and May 18, 19, 21
- Rain occurred May 12th and May 16th
- Sample results on May 15th indicated *E. coli* reductions
- Overnight rainfall may have raised *E. coli* concentrations to similar conditions as the May 12th sample value

Boathouse International Triathlon

Proactive Approach

Triathlon: Oklahoma City takes proactive steps on river quality

BRIAN KIMBALL

Published: Thu, June 11, 2009 12:00 AM | Updated: Thu, June 11, 2009 9:08 AM

Contamination in the Oklahoma River, including from E. coli bacteria, caused nearly four dozen triathletes to become sick after a race in May, the state Health Department confirmed Wednesday.

Samples were taken of the water in the river in the days leading up to the Boathouse International Triathlon, and on the day of the event, but organizers said the levels of bacteria and parasites were within the acceptable range and went ahead with the triathlon.

- Oklahoma City, OWRB, ODEQ, City-County Health Department, and the State Department of Health met to develop recommendations to prevent similar occurrences
- Outcome – Continuous monitoring and special events monitoring in support of revocable permits for “Primary Body Contact Recreation (PBCR)” activities

Boathouse International Triathlon

Oklahoma City Actions and recommendations

- Revocable Permit Language updates for PBCR events
  - Numerical criteria risk levels/actions
  - Added primary body contact as water skiing, swimming, wading, full or partial immersion

Numerical Criteria Based on Microbial Parameter for Bacteria

Numerical Criteria	Units	Risk Level	Action
≥ 407	cfu/100 ml	Elevated	Primary Body Contact Activities Cancelled

- Primary Body Contact Recreation standard for “Swimming Advisory or Permitting Purposes” 785:45-5-16
  - “For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 235/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 406/100 ml in all other Primary Body Contact Recreation beneficial use areas.”

Success Stories

Holiday River Parade

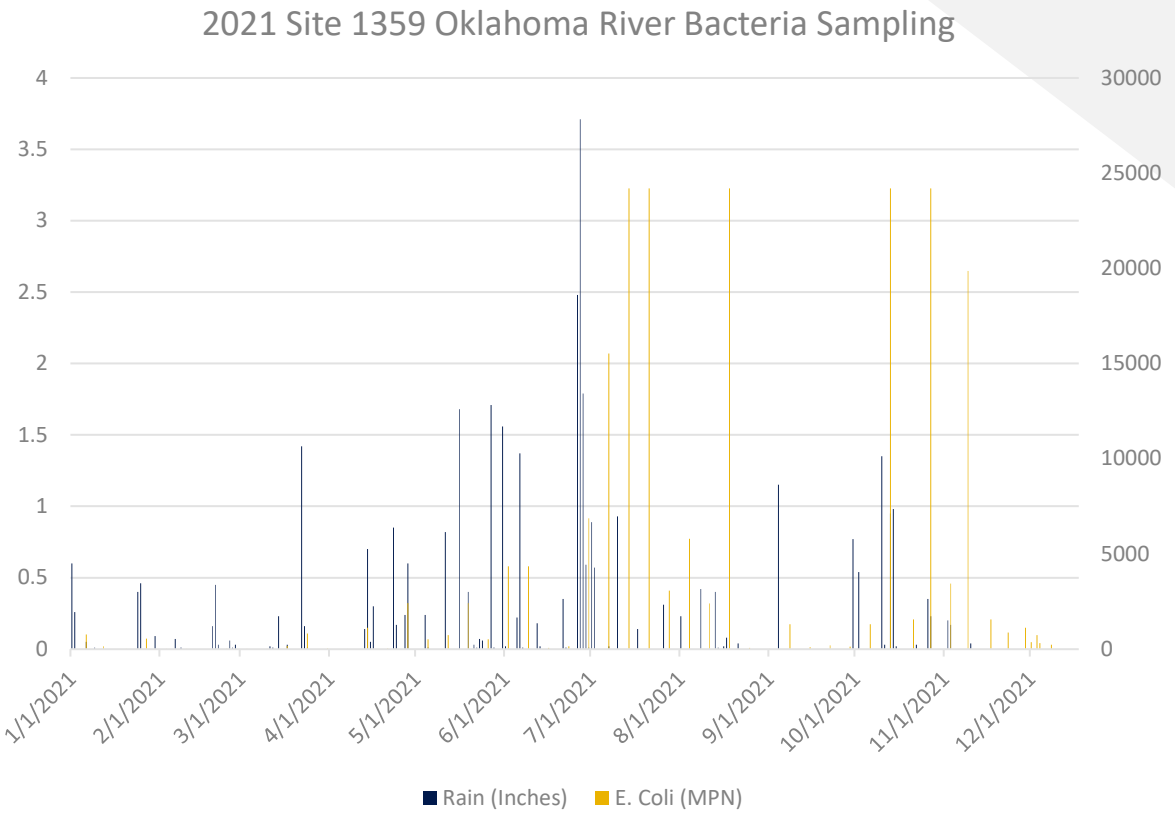
- Revocable Permit between the City of OKC and The Riversport Foundation
- Event scheduled for 12-4-21
  - Last event was in 2018
  - Thousands expected in attendance including Mayor David Holt
- Water quality testing must be performed for Primary Body Contact Recreation
  - SWQ is responsible for collection of water quality samples, analyzing data, and providing guidance in accordance with the Revocable Permit

Pictures taken from The Oklahoman

Success Stories

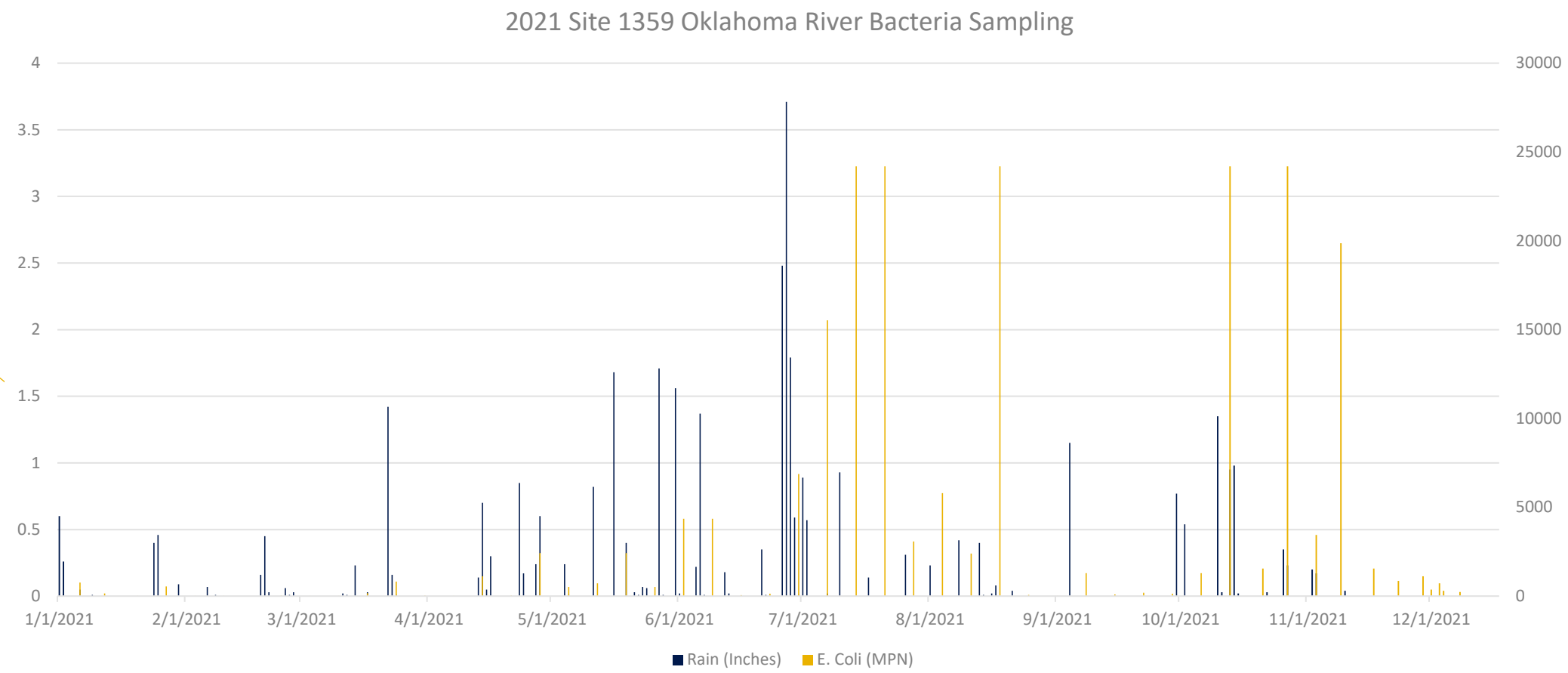
Holiday River Parade

- *E. coli* results were not receding after insufficient rainfall for 2 months
- Possibility of Primary Body Contact activities being cancelled due to elevated *E. coli* levels (>407 CFU)
- 3-day consecutive rainfall
  - 6/26/21-6/28/21= 7.98 inches
- 5 analytical *E. coli* results >=24,196 MPN
  - All results post damaging rain event
- Highest *E. coli* result prior to damaging rain event
  - 4,352 MPN



Success Stories

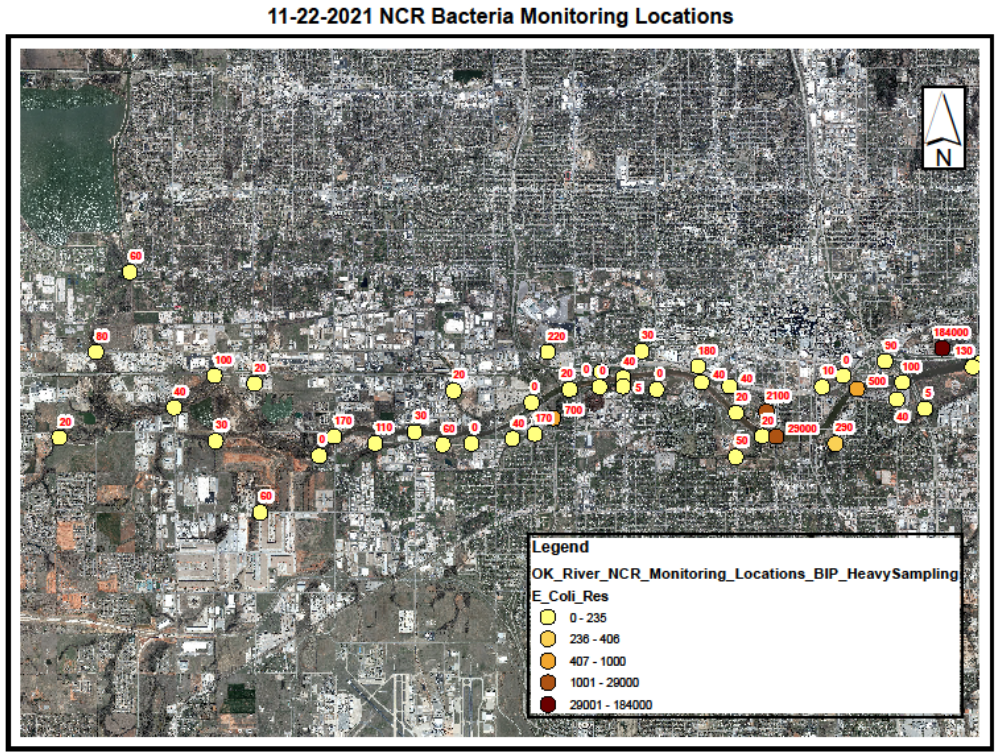
Holiday River Parade



Success Stories

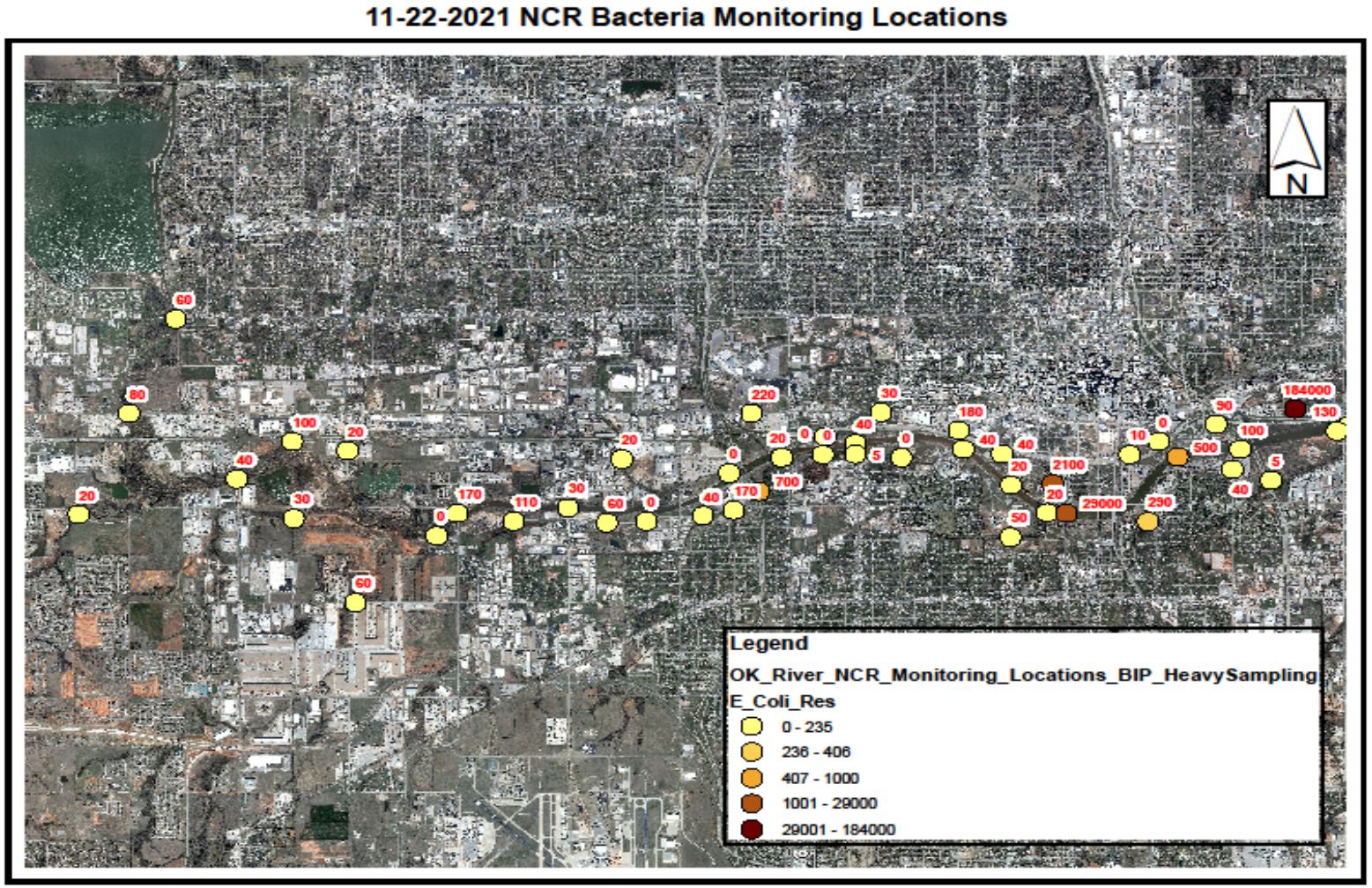
Holiday River Parade

- Once a problem within the watershed was determined, a shotgun sampling approach along the Oklahoma River was initiated
- *E. coli* was the only analytical tested
- 45 sampling sites visited
  - 7 sites dry
- 5 sites exhibited “Elevated” results
  - 500, 700, 2100, 29000, and 184000 MPN
- Next move is to trace the source of the elevated results



Success Stories

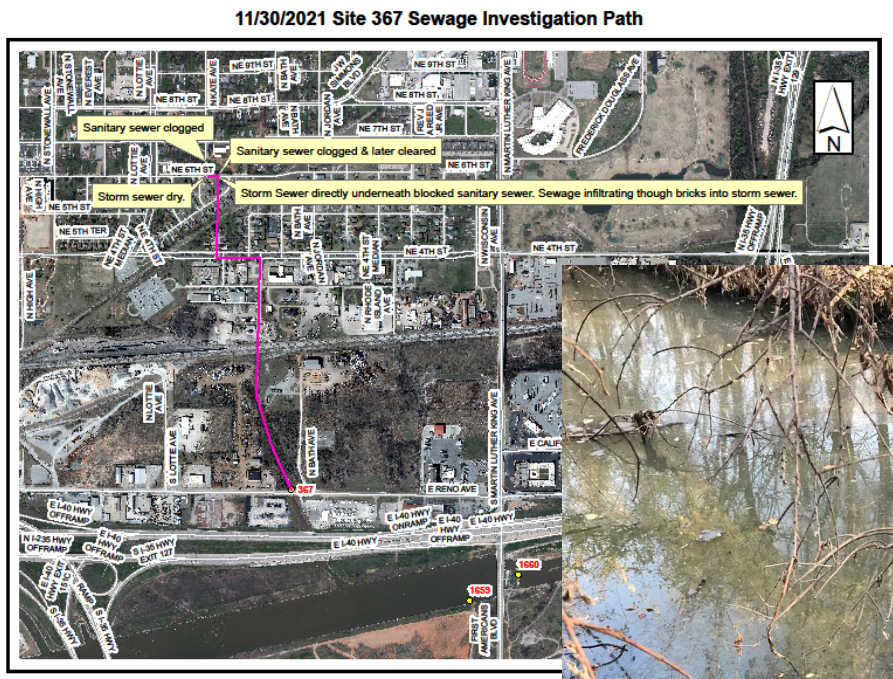
Holiday River Parade



Success Stories

Holiday River Parade

- Site 367
  - Highest *E. coli* Result (184,000 MPN)
- Source was tracked up to clogged sanitary sewer
- Sewage infiltrating though brick lining into storm sewer that was located directly underneath (no surfacing sewage)
- OKC Utilities notified
  - Sanitary sewer unclogged
  - Storm sewer cleaned out



Success Stories

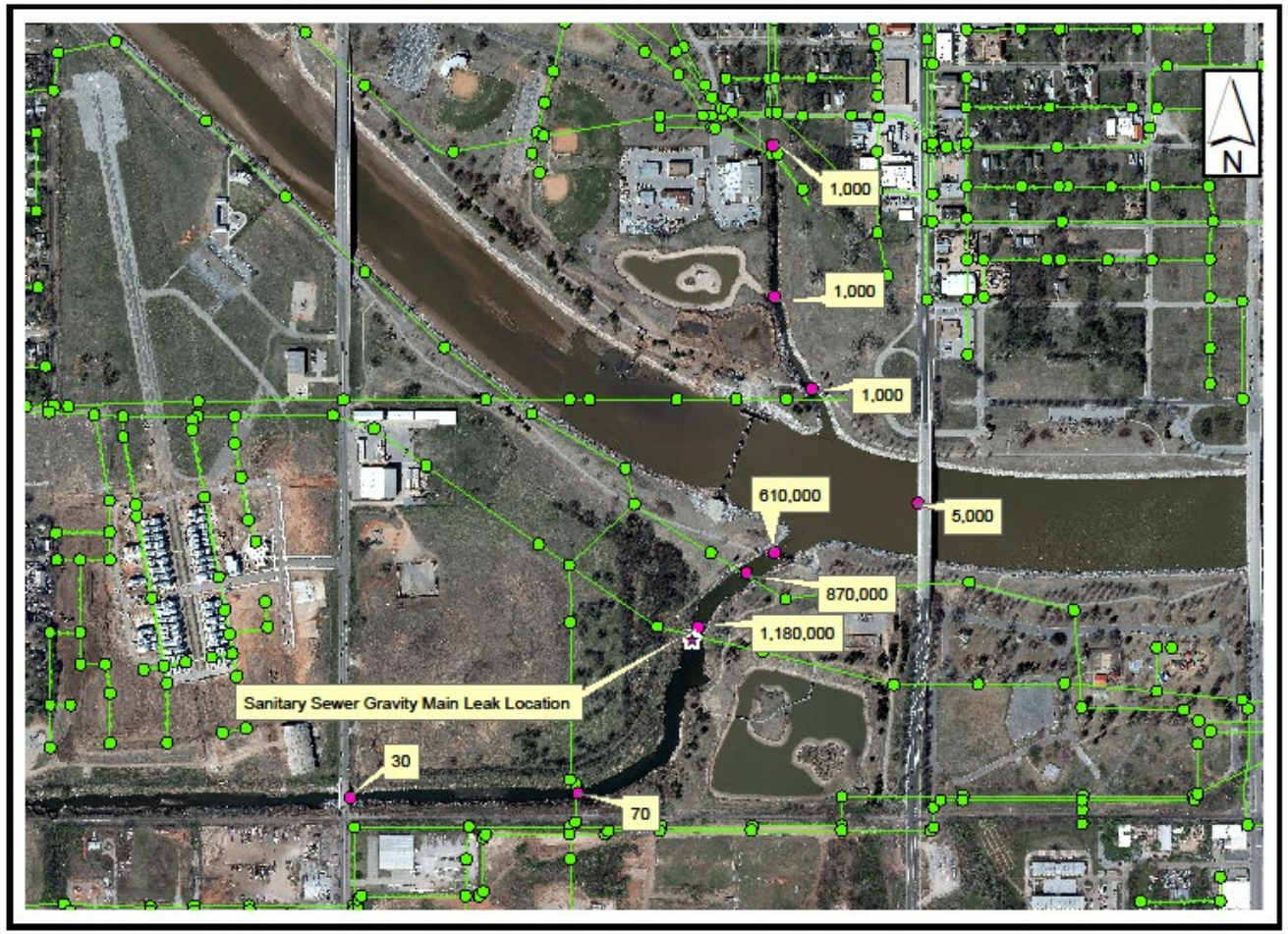
Holiday River Parade

- Site 1369
  - 2nd highest *E. coli* Result (29,000 MPN)
- 11-30-21
  - Dry Weather (IDDE) Kit utilized throughout Brock Creek
  - Entire creek blueish in color and giving possible false positive results
  - Optical Brightener Swath placed out at multiple locations
  - Not able to narrow down source
- 12-1-21
  - Initiate 2nd *E. coli* sampling phase
- 12-2-21
  - Optical Brightener Swath and water sample collected and analyzed
  - Dye test confirmed main sanitary sewer leak into Brock Creek
    - Main sanitary sewer line drops down into the river and breaks into 2-24 inch gravity fed lines
    - Utilities notified

Success Stories

Holiday River Parade

- Site 1369
- 2nd *E. coli* sampling phase results
  - Results were sent after leak was found

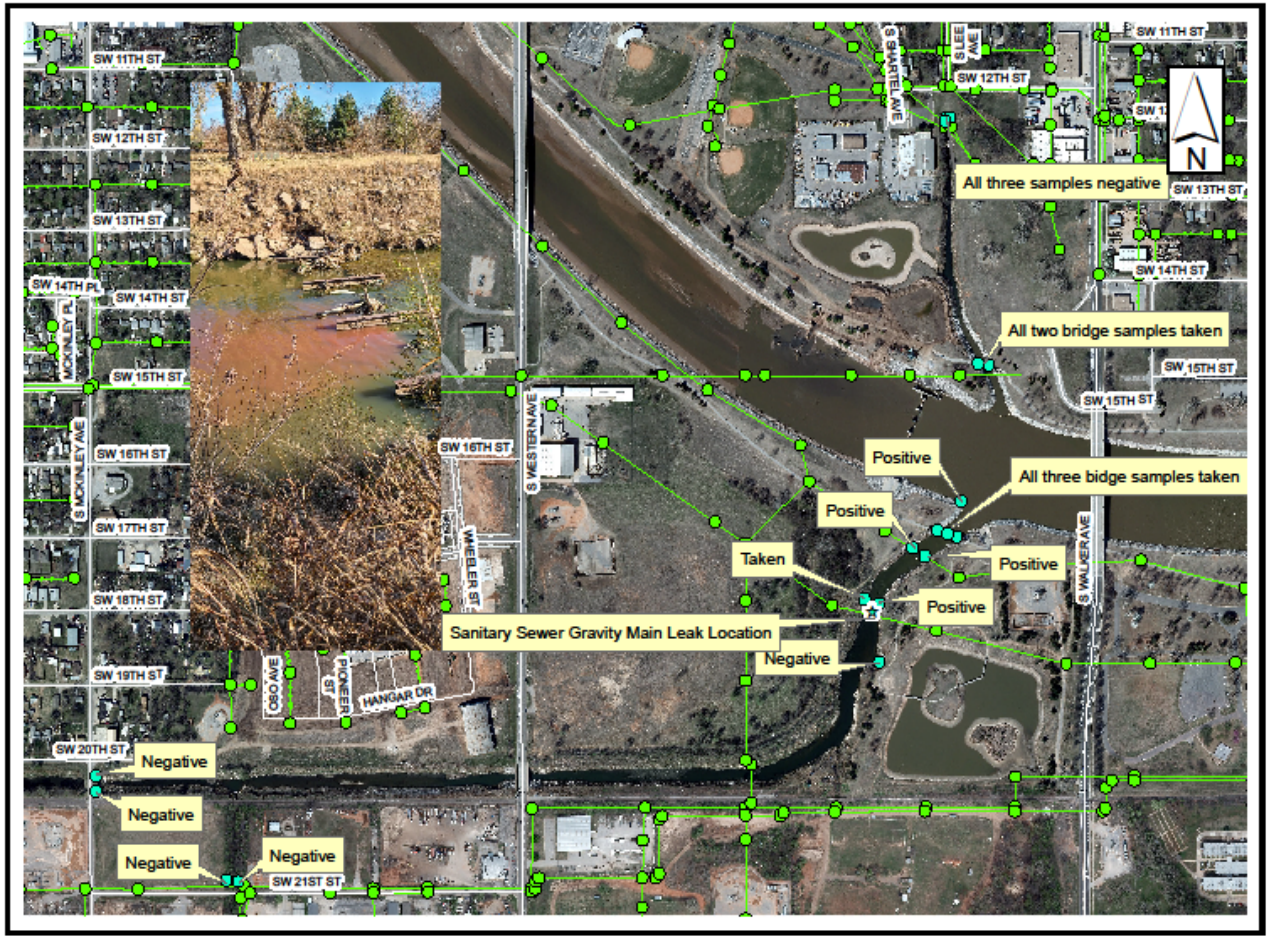


Success Stories

Holiday River Parade

- Site 1369
- Optical Brightener Swath Results
  - Several swaths were stolen/cut
- Swath on left side is positive, swath on right side is negative

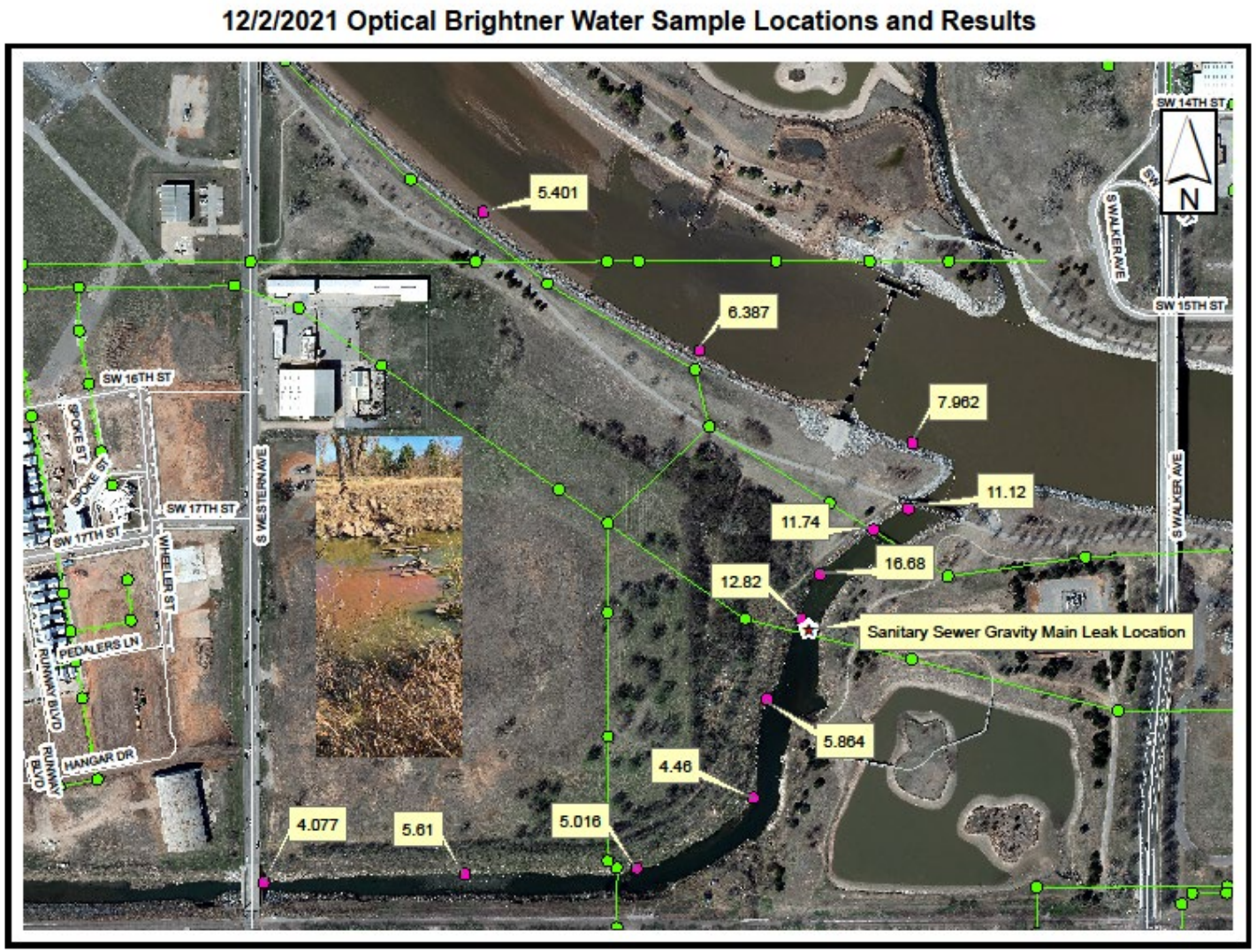
12/2/2021 Optical Brightner Swath Sample Locations and Results



Success Stories

Holiday River Parade

- Site 1369
- Optical Brightener Water Sample Results



Note: Results are relative to the concentration used to calibrate the meter.

Success Stories

Holiday River Parade

- Utilities have capped off leaking sanitary sewer line
- Repairs are underway
  - Final plans submitted in May

Success Stories

Holiday River Parade

- *E. coli* results were still fluctuating from moderate to elevated levels after sources were confirmed and stopped
  - 12-1-21: 365 MPN
  - 12-3-21: 727 MPN (Day prior to event)
  - 12-4-21: 308 MPN (Day of event)
- *E. coli* results have dropped significantly

Picture taken from https://holidayboatparade.org/

Success Stories

Holiday River Parade

- *E. coli* sample cost = $65.00
- Total samples ran = 47
- Total cost = $3,055.00

Success Stories

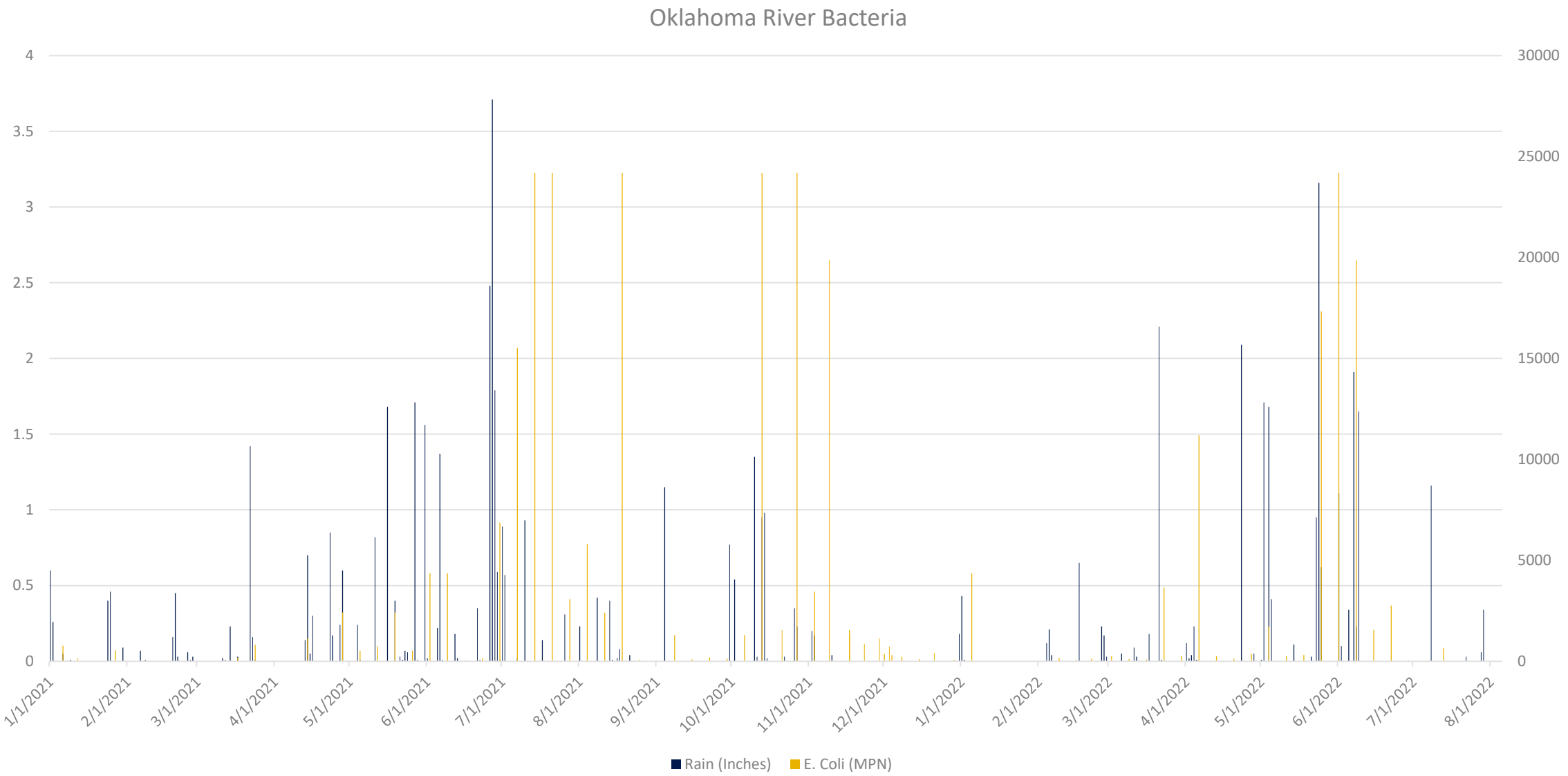
Holiday River Parade

Other High Results

- Staff inspected the lower levels as indicated in the initial “shotgun” sampling approach
- Staff used several approaches including optical brightener monitoring and dry weather screening
- No sources were detected

Picture: SW 12th and Lee Outfall with non-contact flow meter.

OKC


Oklahoma River Bacteria
4
3.5
3
2.5
2
1.5
1
0.5
0
30000
25000
20000
15000
10000
5000
0
1/1/2021
2/1/2021
3/1/2021
4/1/2021
5/1/2021
6/1/2021
7/1/2021
8/1/2021
9/1/2021
10/1/2021
11/1/2021
12/1/2021
1/1/2022
2/1/2022
3/1/2022
4/1/2022
5/1/2022
6/1/2022
7/1/2022
8/1/2022
Rain (Inches)
E. Coli (MPN)

Thank You.

Dawson McNeill

405-618-7433

dawson.mcneill@okc.gov

https://www.okc.gov/departments/public-works/divisions/storm-water-quality

https://www.giantmicrobes.com/us/products/jirms-evil-ecoli.html

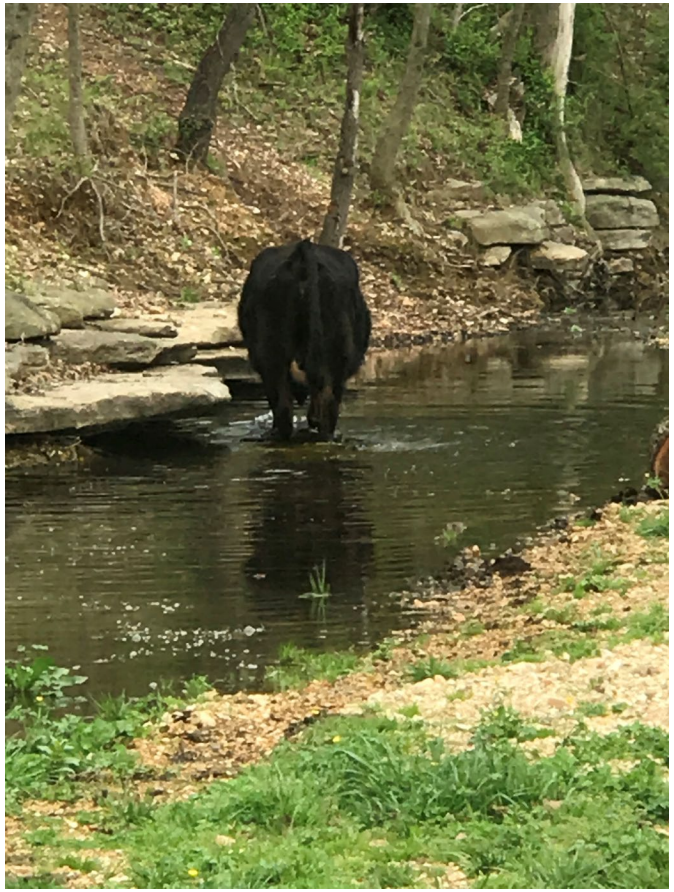
Addressing the Evil E. coli! Through Best Management Practices

Jeri Fleming

Grand River Dam Authority

Dry Weather Sources

- Septic tanks
- Leaking Sewer lines
- Transient population
- Wildlife
- Cattle/Horses
- Pets



Wet Weather Sources

- Same as dry weather plus
  - Sewage Lagoons
  - Wastewater treatment plant (flooding)
  - Urban streets and yards
  - Agriculture

Urban Best Management Practices

- Pick up pet waste
- Manage wildlife, in particular birds
  - Develop a wildlife management plan
  - Relocate birds
    - GRDA had to do this due to an E. coli outbreak at Bernice State Park
- Street sweeping
- Find and repair sewage leaks
- Construction site BMPS
- Low Impact Development
- Constructed wetlands

Urban Best Management Practices

- Education and outreach
  - Don’t just talk about picking up pet waste
  - Overwatering lawns increases bacteria levels
- Infiltration
  - Basins, trenches
  - Bioinfiltration
    - Bioretention or rain gardens
  - Permeable pavement
  - Tree Trench/tree box
  - Dry swales with check dams
- Maintenance
  - Stormwater BMPs
  - Storm drain cleaning
  - Catch basin cleaning

Rural Best Management Practices

- Septic Tanks
  - Proper maintenance
  - Replace when fails
- Stream fencing
- Livestock manure management
  - Long-term storage
- Vegetative Buffers
  - Effective depends on width and type of vegetation

Poop jokes aren’t my favorite, but they are a solid #2