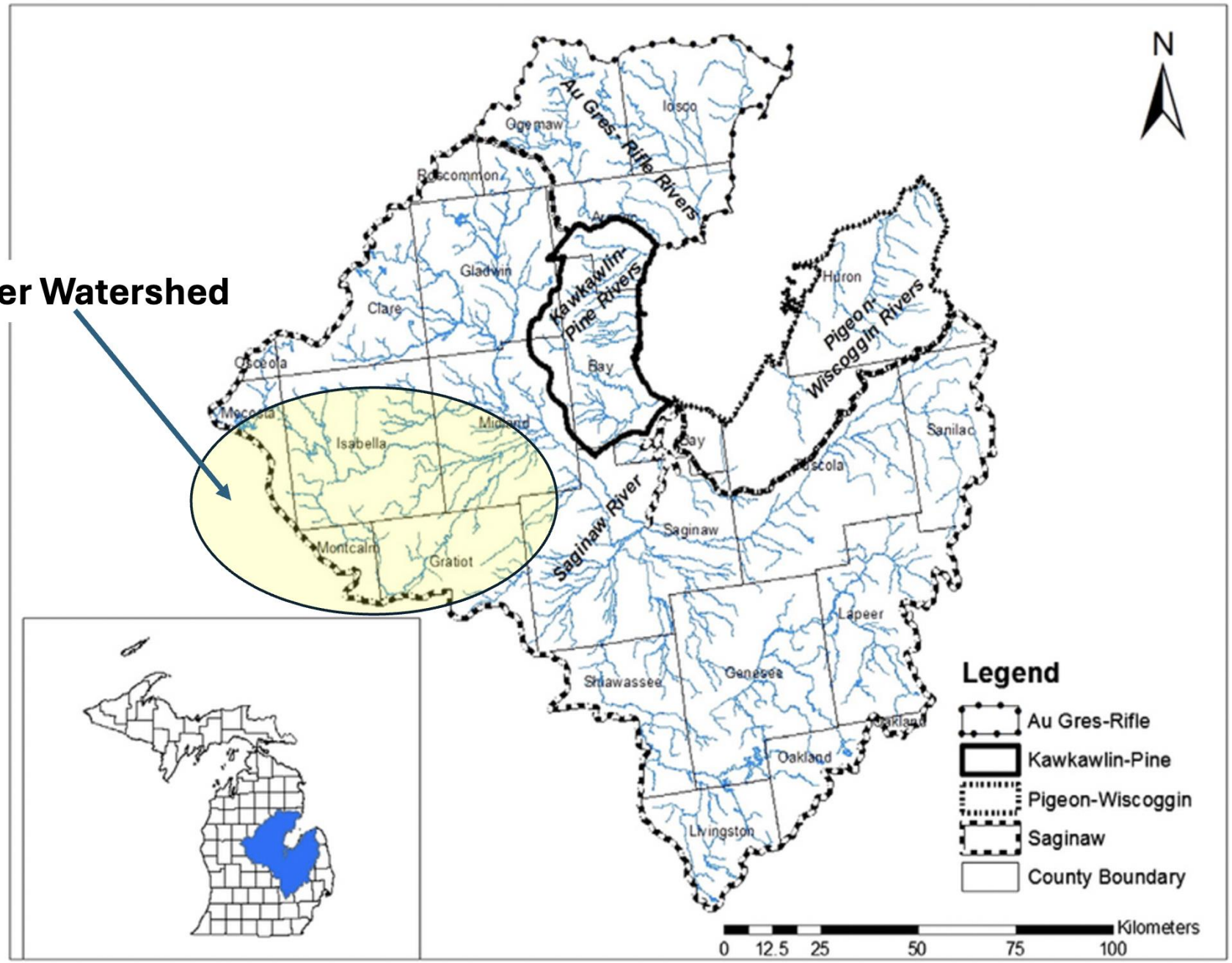
Twenty Year Assessment of the Upper Saginaw River Drainage Basin, Pine River Watershed

2004 – 2024

Lottie Carman, Kennedy Case, Charlotte Howald, Jack Veverka, Tim Keeton, Olivia Ayers, and Murray Borrello



Boundaries of the Saginaw Bay Basin and sub-watersheds in the state of Michigan, USA (inset) including tributary drainage network.

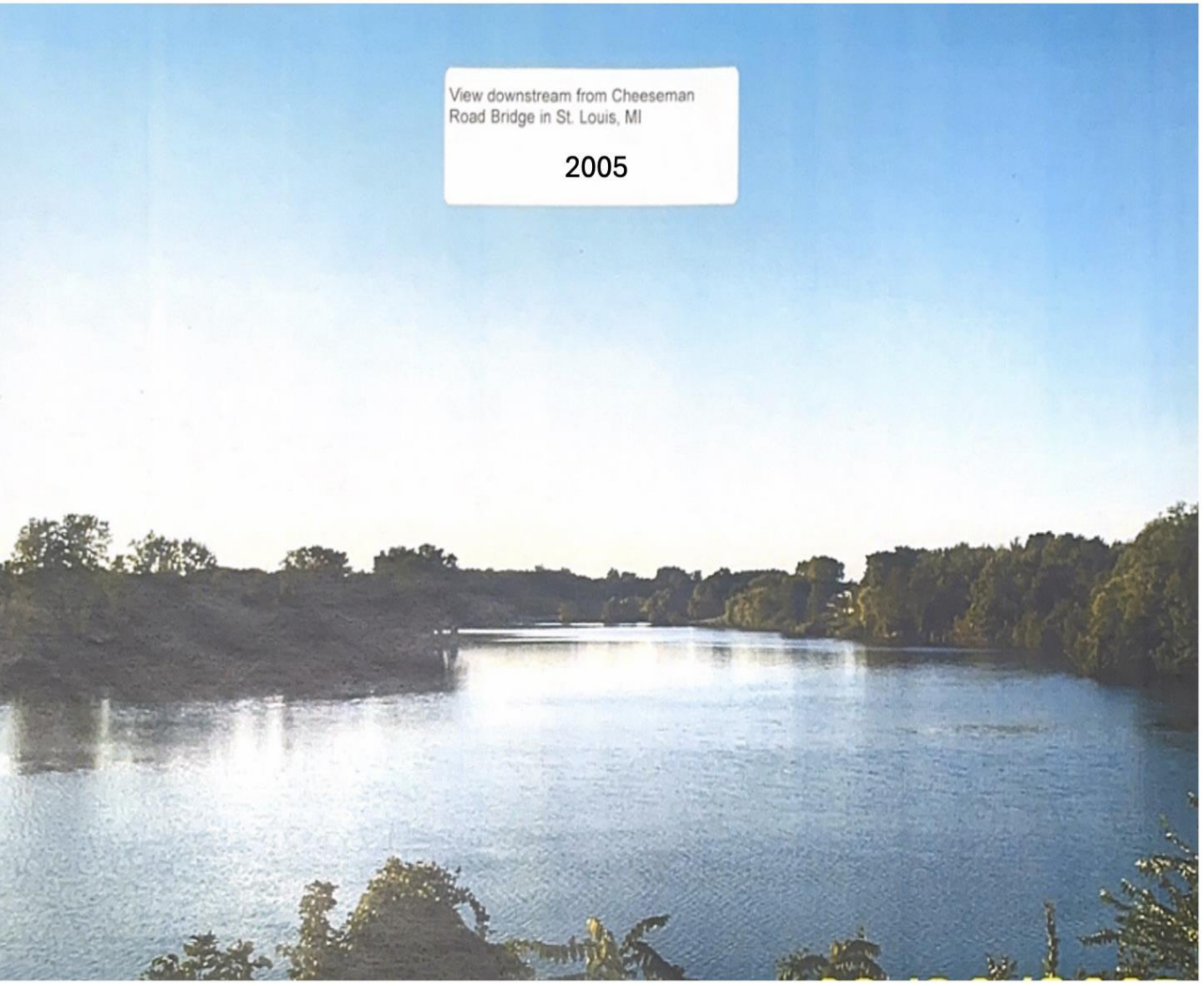
What Has Happened to the Pine River Watershed Over Time?

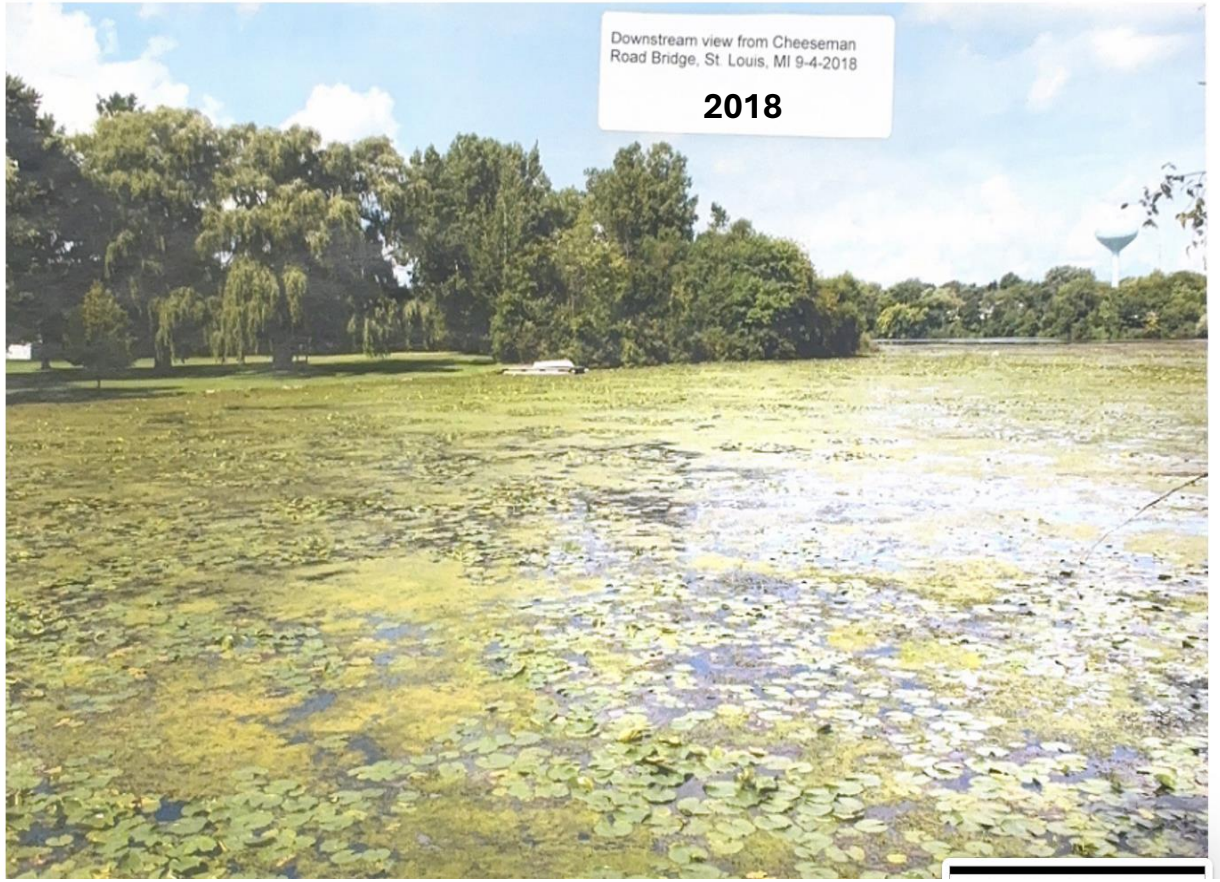
Visible Change in Water Quality: Algal Blooms

Mill Pond, 1980s

Mill Pond 2022

Looking downstream towards St. Louis at Cheesman Road bridge in St. Louis





Why This Study?

Why This Study?

- The Saginaw River Drainage Basin has been plagued by industrial pollution. By Mid-1990s, a new source of pollution (Agriculture) was evident in the headwaters region: Mostly in the Pine River Watershed.
- Alma College, along with the State of Michigan and others have conducted a significant amount of research on multiple aspects of the Pine River Watershed.
- ***There is enough information from the past 20 years to draw specific conclusions about what is happening to the Pine River Watershed, and the most likely causes.***
- We hope that appropriate agencies and individuals can use this information to make lasting change.

Presentation Overview

The Presentation is Broken into Three Parts According to what research was done and for what purpose beginning in 2004

PART 1: What is the role of large livestock facilities (CAFOs) to the algal blooms we see in the watershed?

PART 2: What pollutants are in the Pine River Watershed that may pose risks to human health and the environment?

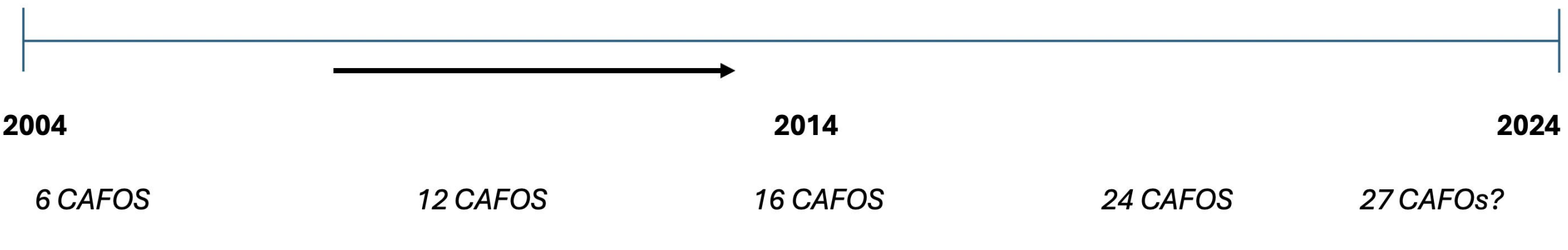
PART 3: How extensive is the impact of agricultural inputs to the watershed as a whole?

TIMELINE AND OVERVIEW OF HOW STUDY IS ORGANIZED

What are all the input mechanisms causing algal blooms and high levels of *E. coli* and how extensive is the problem in the watershed?

What, if any human health risks are there from agricultural inputs into Pine River?

Are CAFO facilities causing algal blooms? If so, can we measure their impacts directly?



Basics Parameters Used and What They Mean

Parameter	What it Means	Units of Measure
Nitrogen and Phosphorus	Nitrogen and phosphorus are "nutrients" or fertilizer. They cause algal growth. Too much can create algal blooms which negatively impacts the water ecosystem and can produce toxic substances called cyanotoxins.	mg/L <u>N and P in Healthy Streams</u> Phosphorus – up to 0.05 mg/L Nitrogen- ammonia – up to 0.04 mg/L
Thermotolerant *E. coli* and coliform bacteria	Coliform bacteria, specifically *E. coli* is only found in the gut of animals. We separate out *E. coli* from waterfowl, fish, frogs, and other non-mammals by incubating samples at higher temperatures (mammals such as humans and livestock are warmer blooded animals). Therefore all data you see will be referred to as Thermotolerant E. coli or TTEC.	Colony Forming Units/100mL or CFU/100ml Concentrations of TTEC vary in healthy streams depending on the amount of wildlife that interacts with that stream. A good benchmark would be somewhere below 100 CFU/100mL
Dissolved Oxygen and Temperature	Dissolved oxygen or DO, is the measure of how much O_2 there is in a water column. It is dependent on temperature. The higher the temperature, the less oxygen dissolved and vice versa.	mg/L (sometimes as %) Healthy streams should have more than 5 mg/L at any time. A healthy, warm water stream in the summer in Michigan should be ~ 9 mg/L – 15 mg/L depending on the temperature A correlation between DO and temperature for healthy streams should be a minimum of -70% to – 90%

Results 1: Assessing Whether CAFO Facilities are Negatively Impacting the Watershed

2004 - 2013

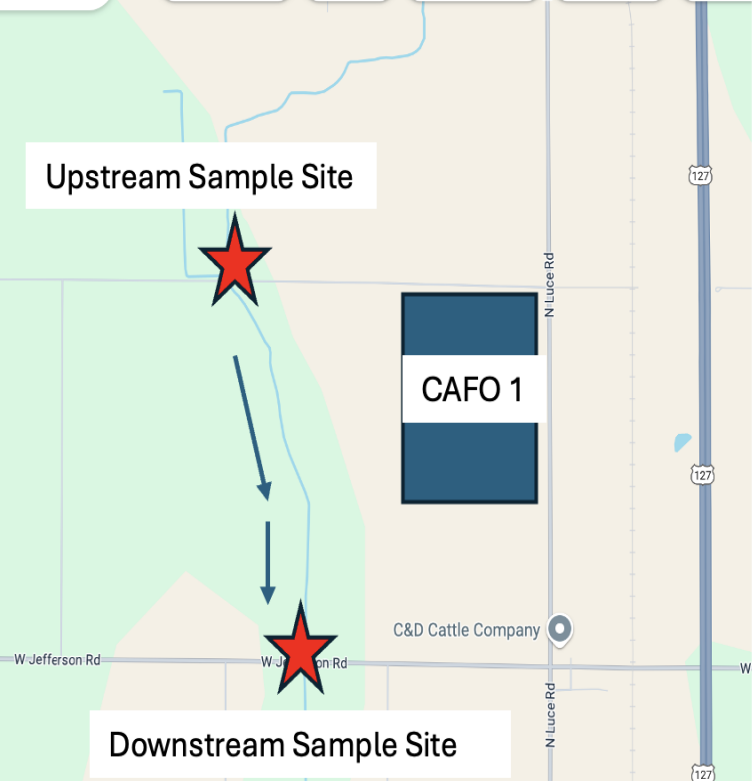
Outline of Study

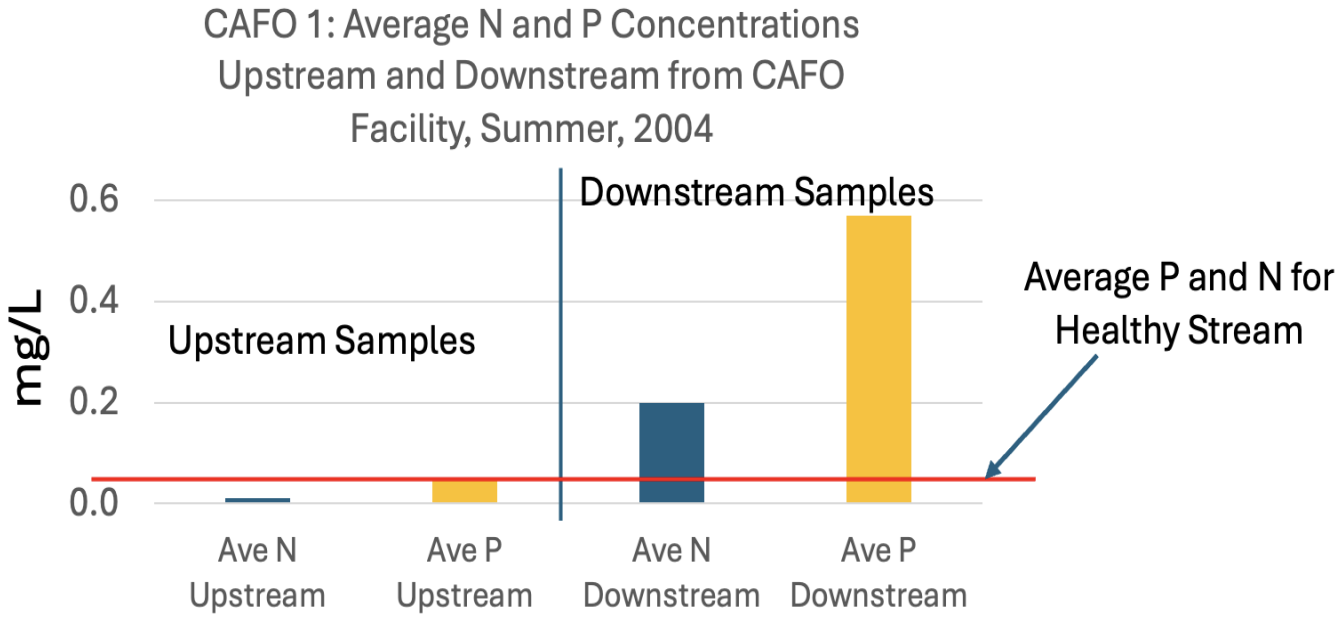
- From 2004 – 2013, large livestock facilities adjacent to drainage ditches or tributaries were assessed
- Samples of adjacent waterways were taken upstream and downstream of each facility
- N and P, DO and Temperature were measured
- Also, coliform bacteria were incubated and measured

Seven CAFOs were investigated in total. Three fit the criteria necessary to ensure the least confounding variables.

<u>Criteria for CAFO Facility</u>

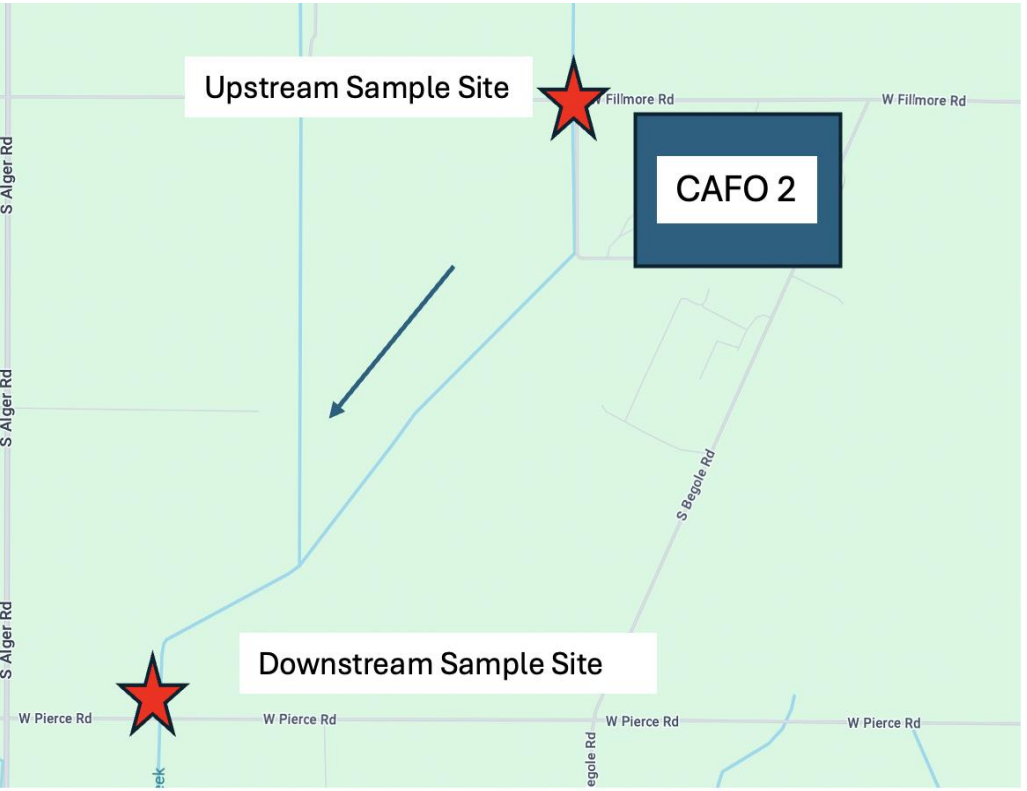
1. Tiled into adjacent waterway
2. Little-to-no other inputs into waterway between upstream and downstream sites
3. Upstream and downstream sites close to facility

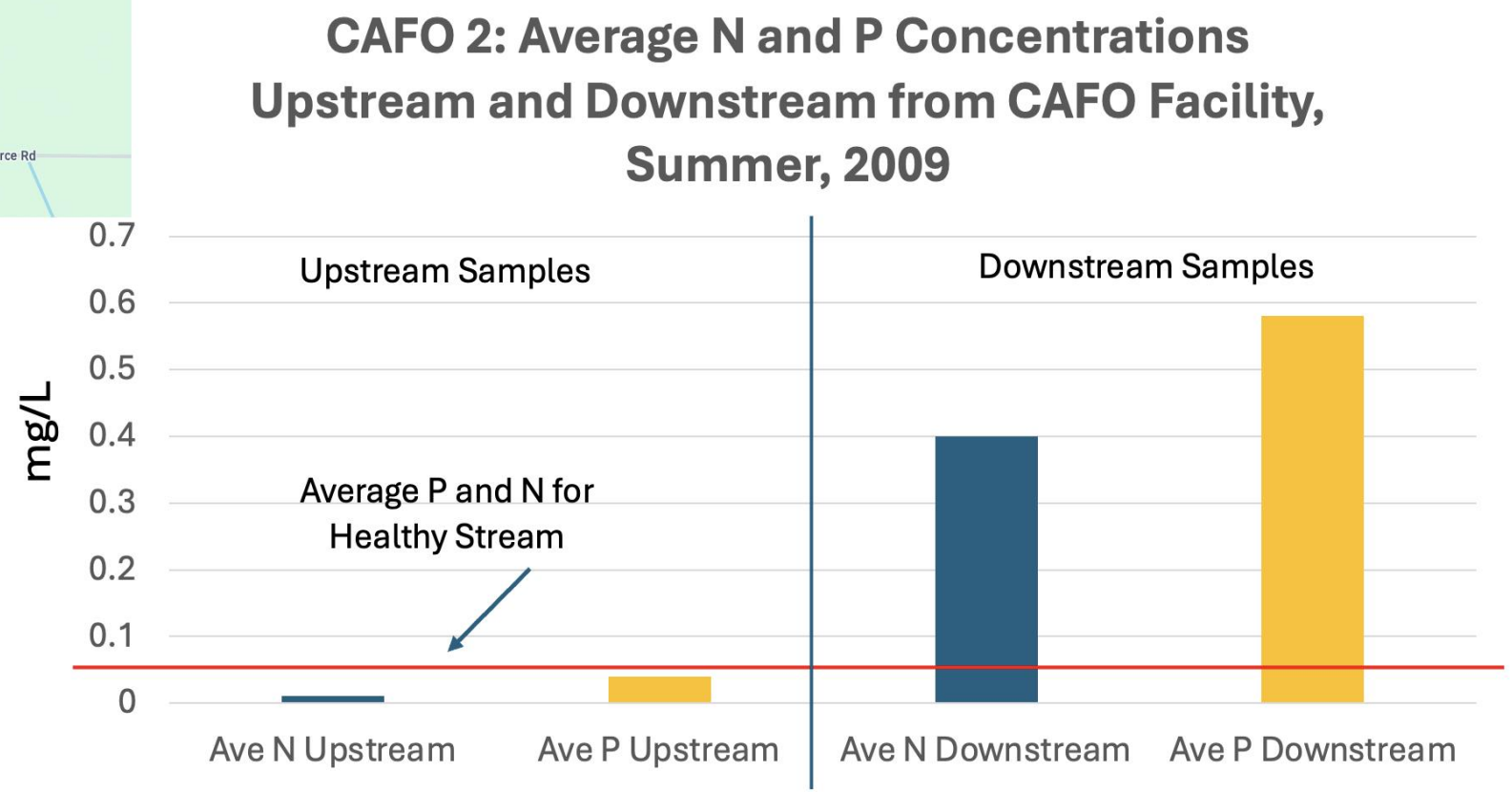


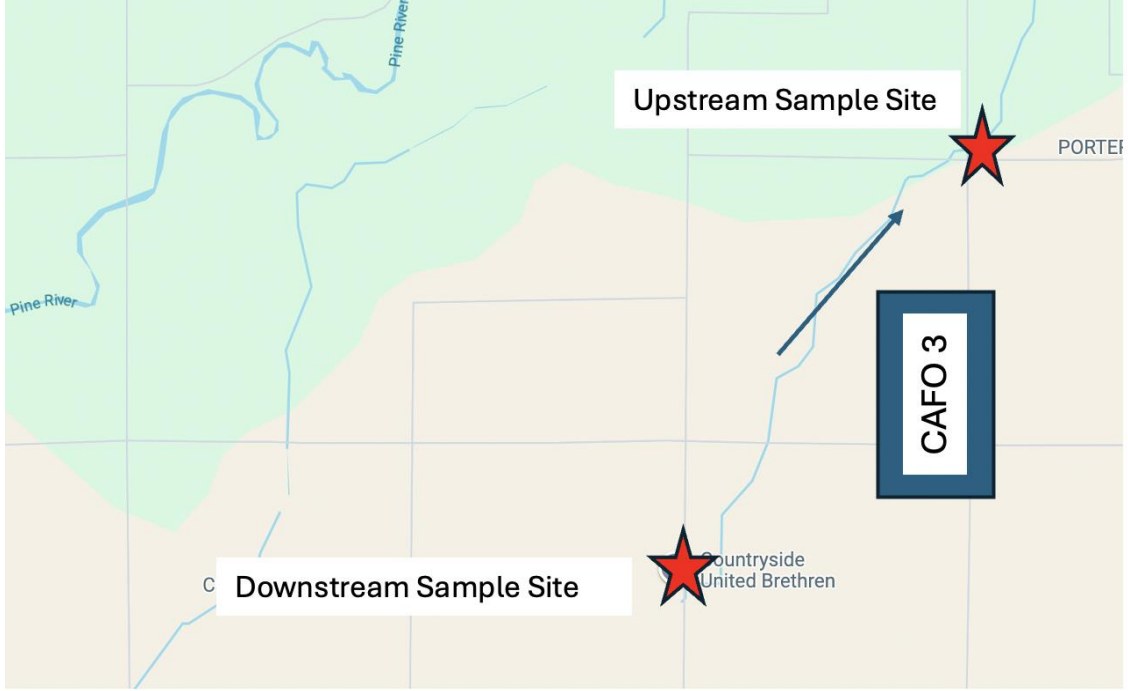


Upstream Site of CAFO 1 August 8, 2004

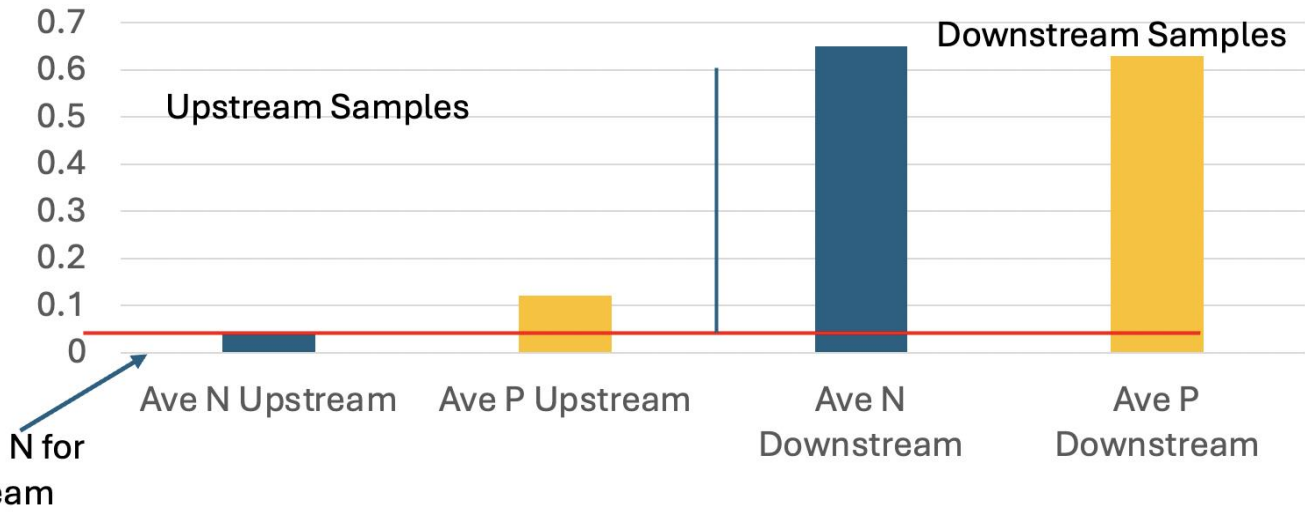
Downstream Site of CAFO 1 August 8, 2004

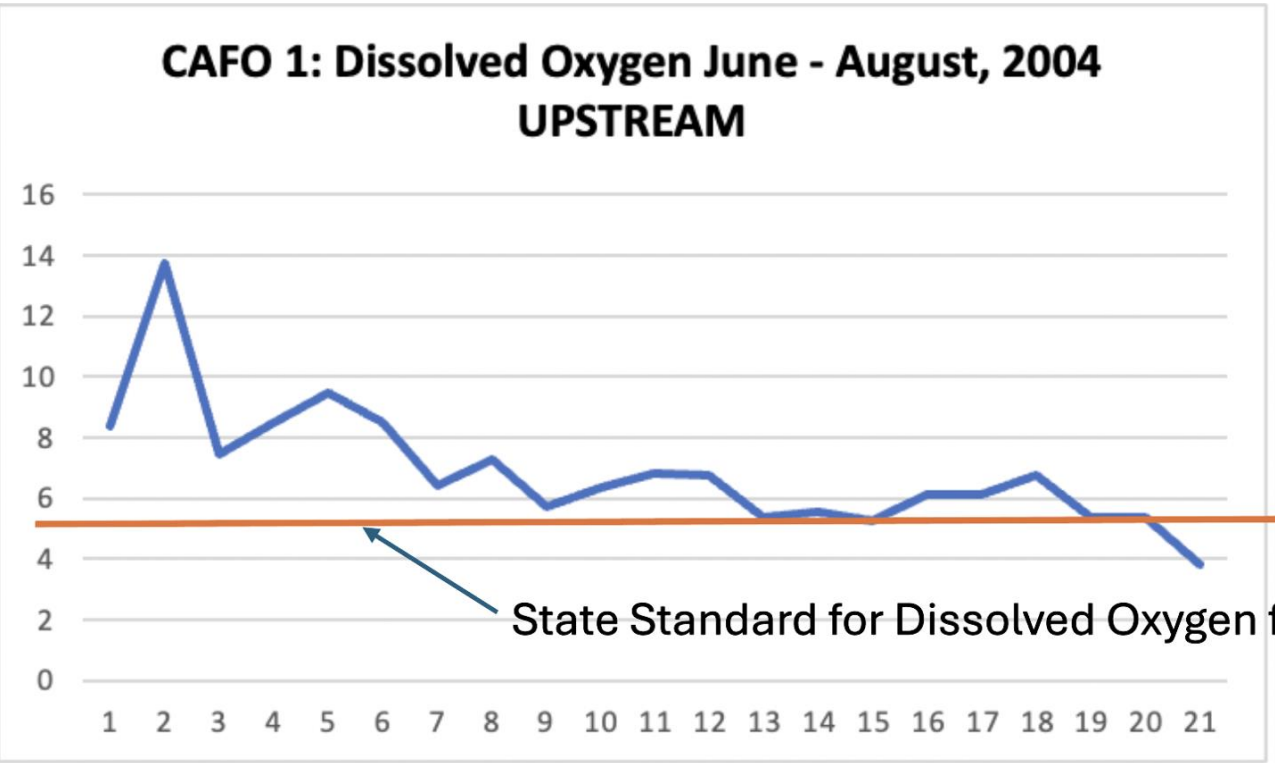

Upstream Sample Site
CAFO 2
Downstream Sample Site
W Fillmore Rd
W Fillmore Rd
S Alger Rd
S Alger Rd
S Alger Rd
S Begole Rd
W Pierce Rd
W Pierce Rd
W Pierce Rd
W Pierce Rd

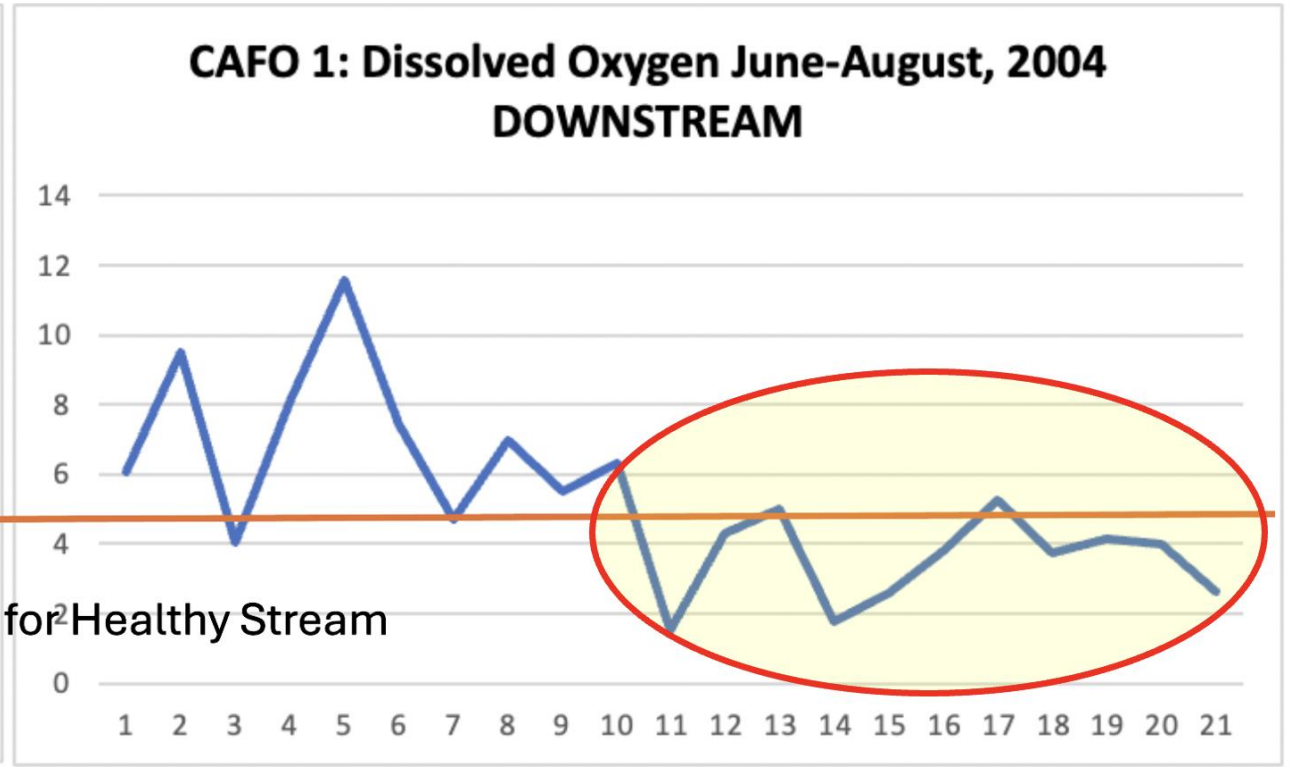

CAFO 2: Average N and P Concentrations Upstream and Downstream from CAFO Facility, Summer, 2009
mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Upstream Samples
Downstream Samples
Average P and N for Healthy Stream
Ave N Upstream
Ave P Upstream
Ave N Downstream
Ave P Downstream



CAFO 3: Average N and P Concentrations Upstream and Downstream from CAFO Facility, Summer, 2013





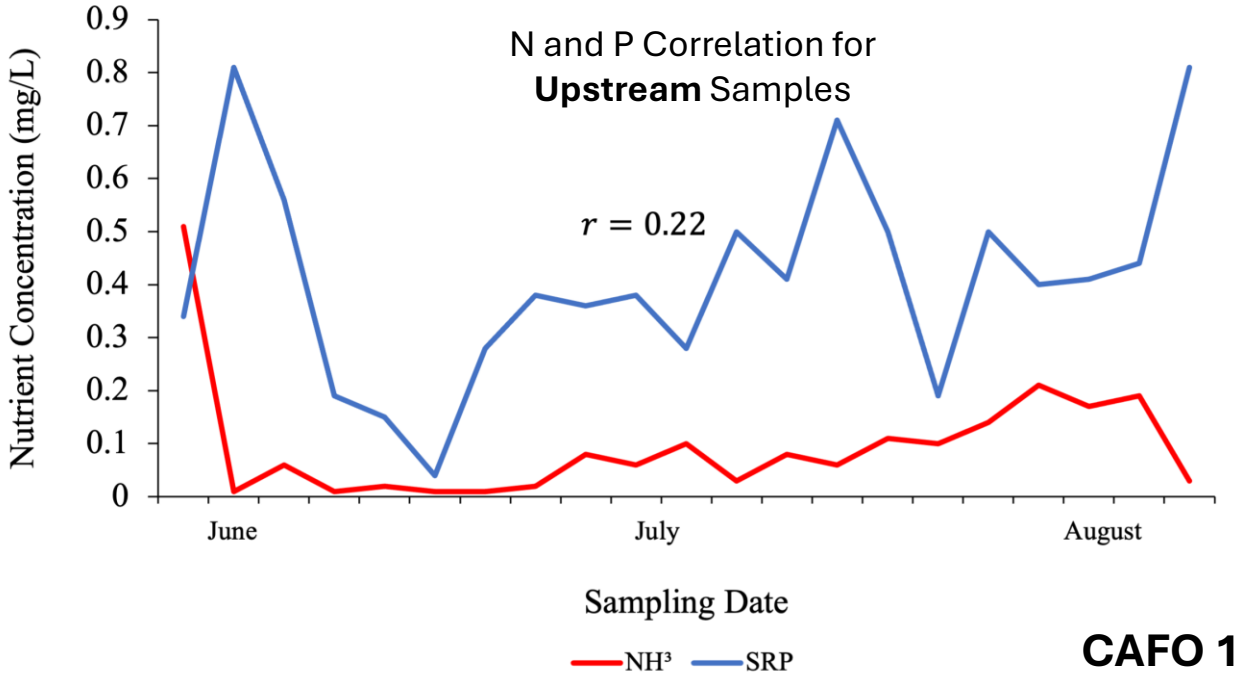


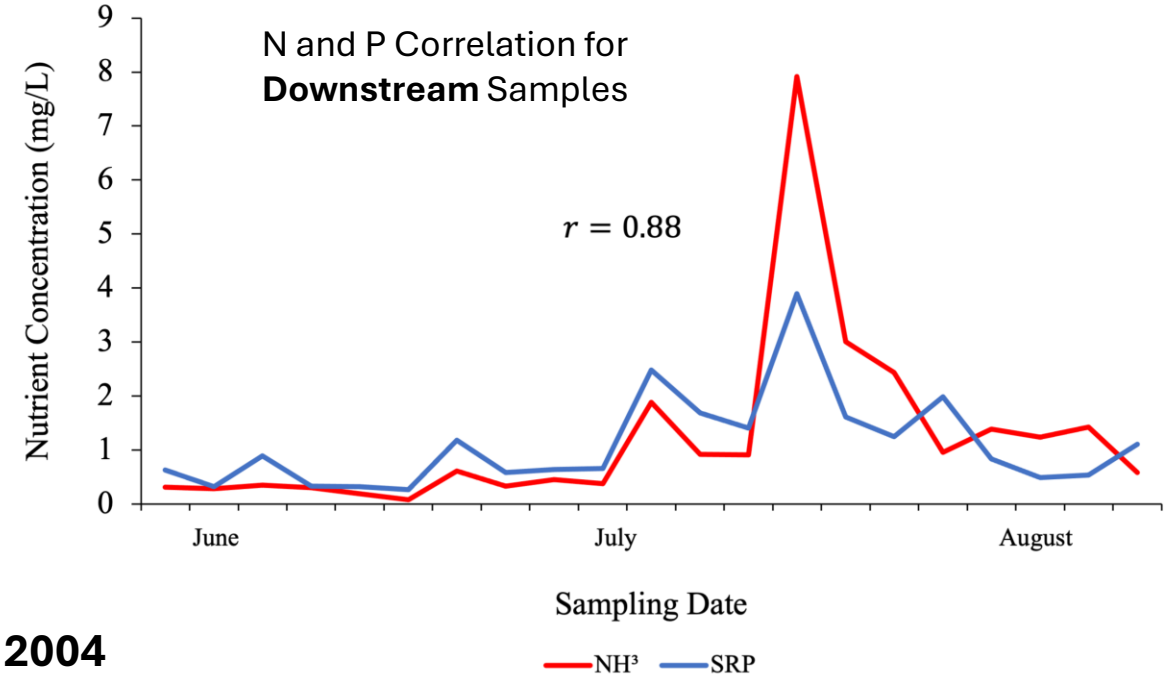
Dissolved oxygen concentrations are higher for the upstream site compared with the downstream site. Oxygen concentrations in the downstream site violate State water quality standards for over 50% of the time samples were taken.

What Else Did We Learn About CAFOs As Inputs for N and P?

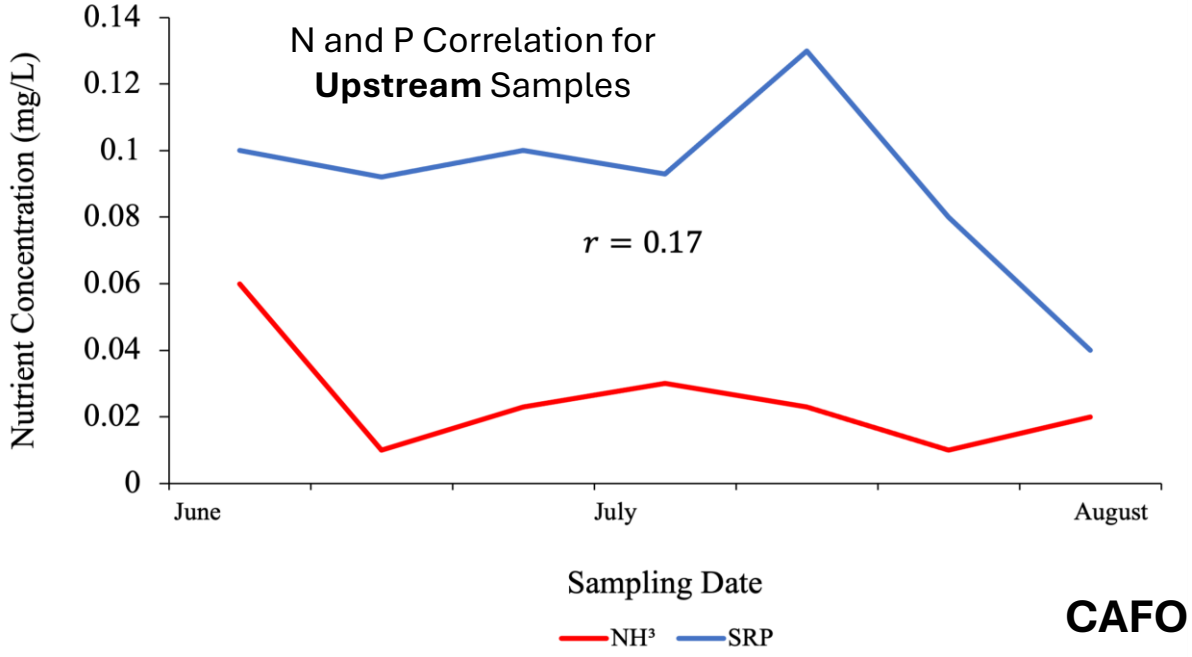
- We find a strong correlation between N and P *downstream* from the facilities compared with upstream

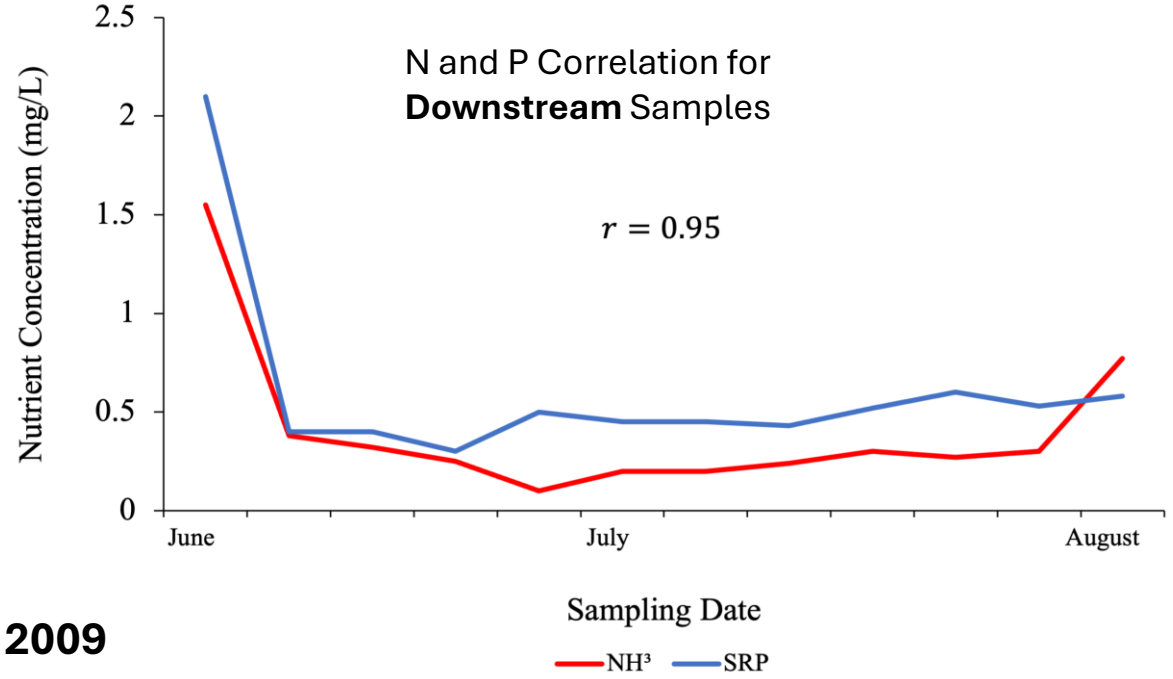
- In short: ***The higher the correlation between N and P, the closer you are to the absolute source of the nutrients***



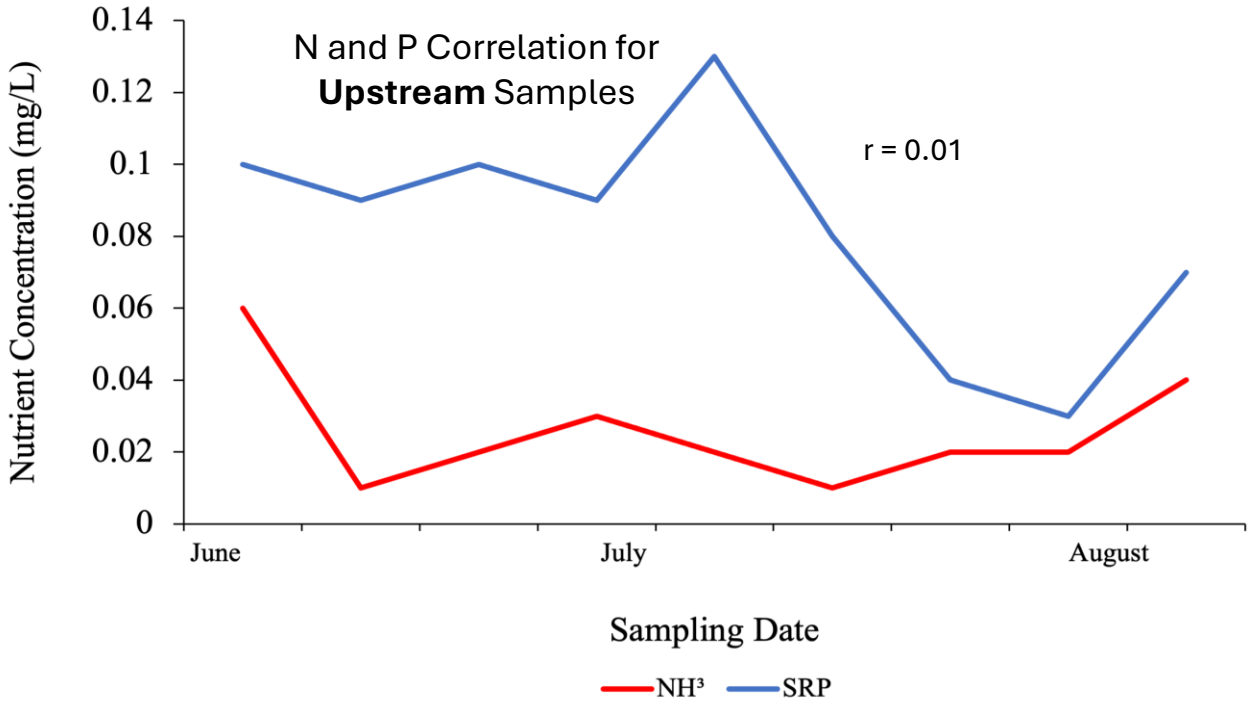


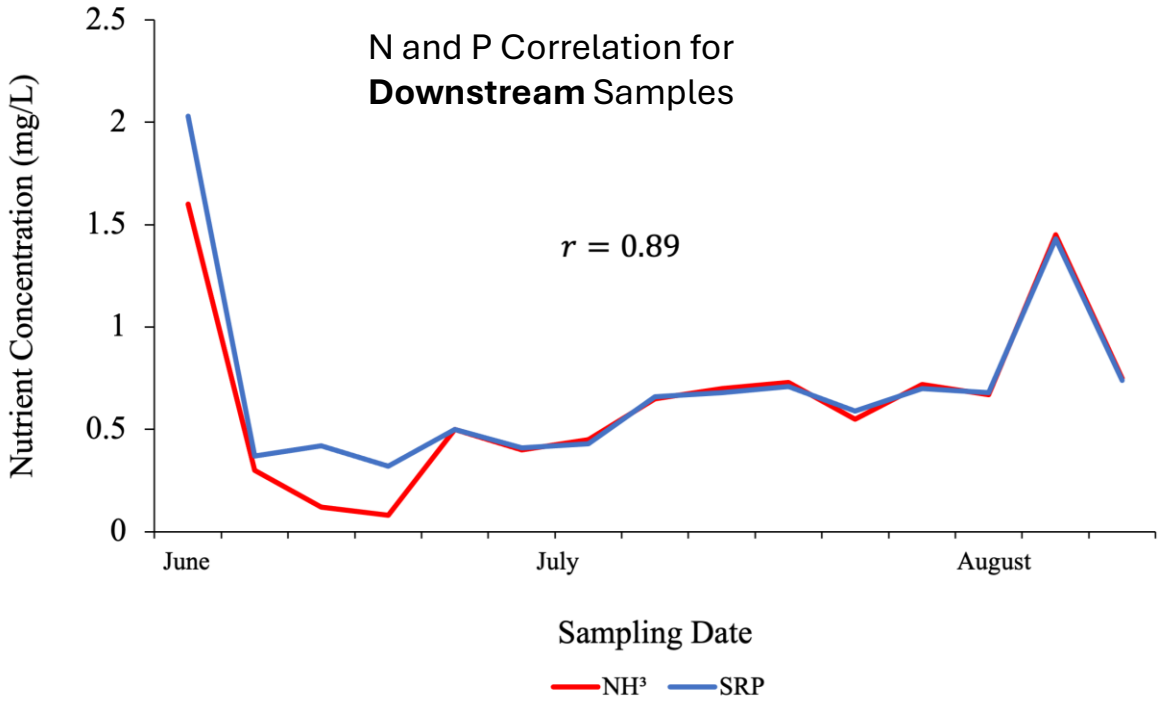
CAFO 1: 2004





CAFO 2: 2009





CAFO 3: 2013

For every CAFO we measured, there was a significantly higher correlation of N and P for the downstream samples indicating CAFOs are the source of high nutrient inputs into the watershed

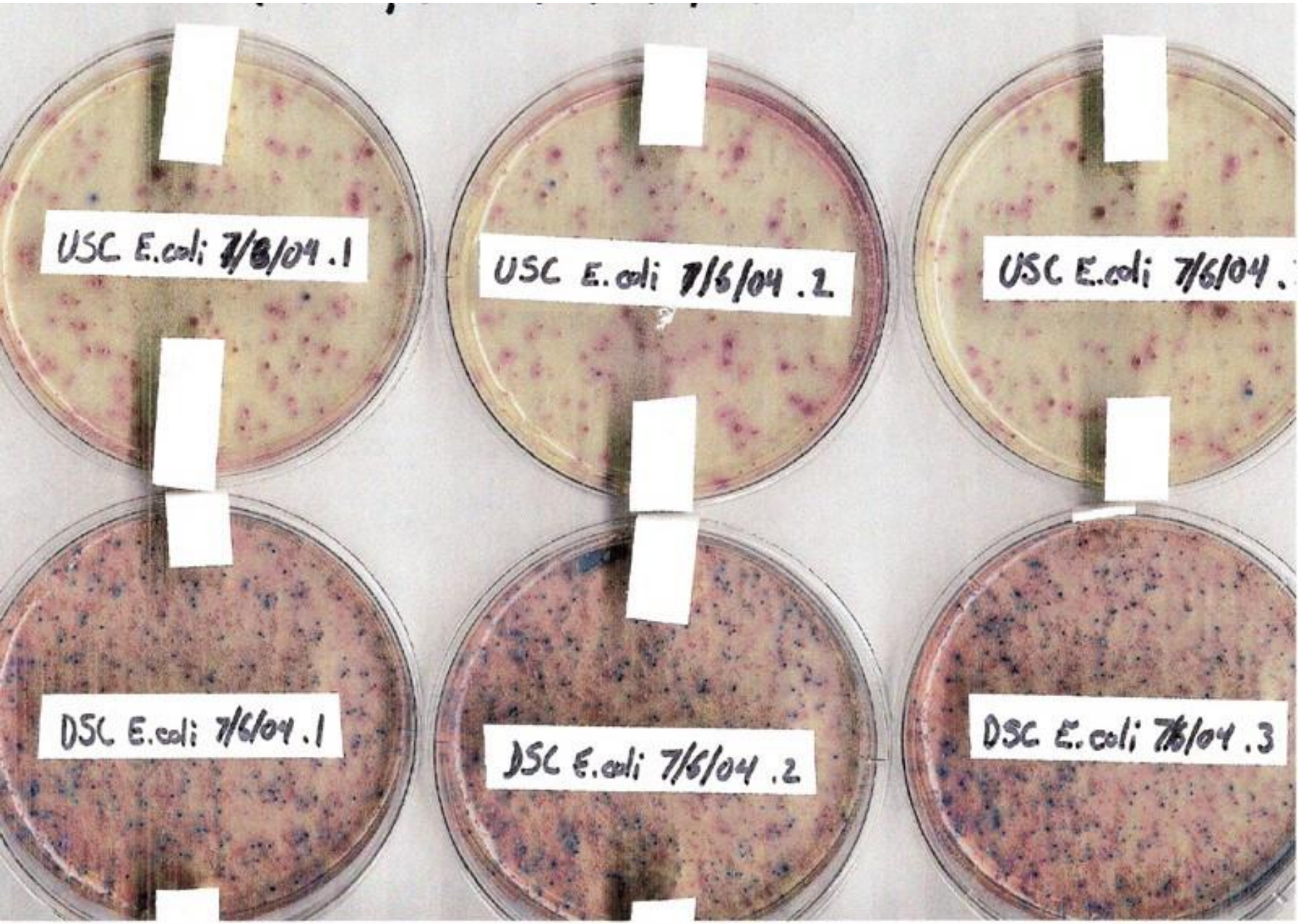
Take-Aways for Assessing CAFO Facility Impacts on the Pine River

Large livestock facilities (CAFOs) are responsible for discharging nutrients into the Pine River Watershed:

- They input high concentrations of N and P into county drains and tributaries of the Pine River
- Correlation analyses confirm CAFO facilities as *point source dischargers* of nutrients into the watershed
- CAFOs also discharge high concentrations of fecal coliform bacteria (*E. coli)* compared with upstream samples (this will be discussed next)…

Results 2: Assessing Human Health and Biological Risks in the Pine River Watershed and Their Sources

2007 - Present

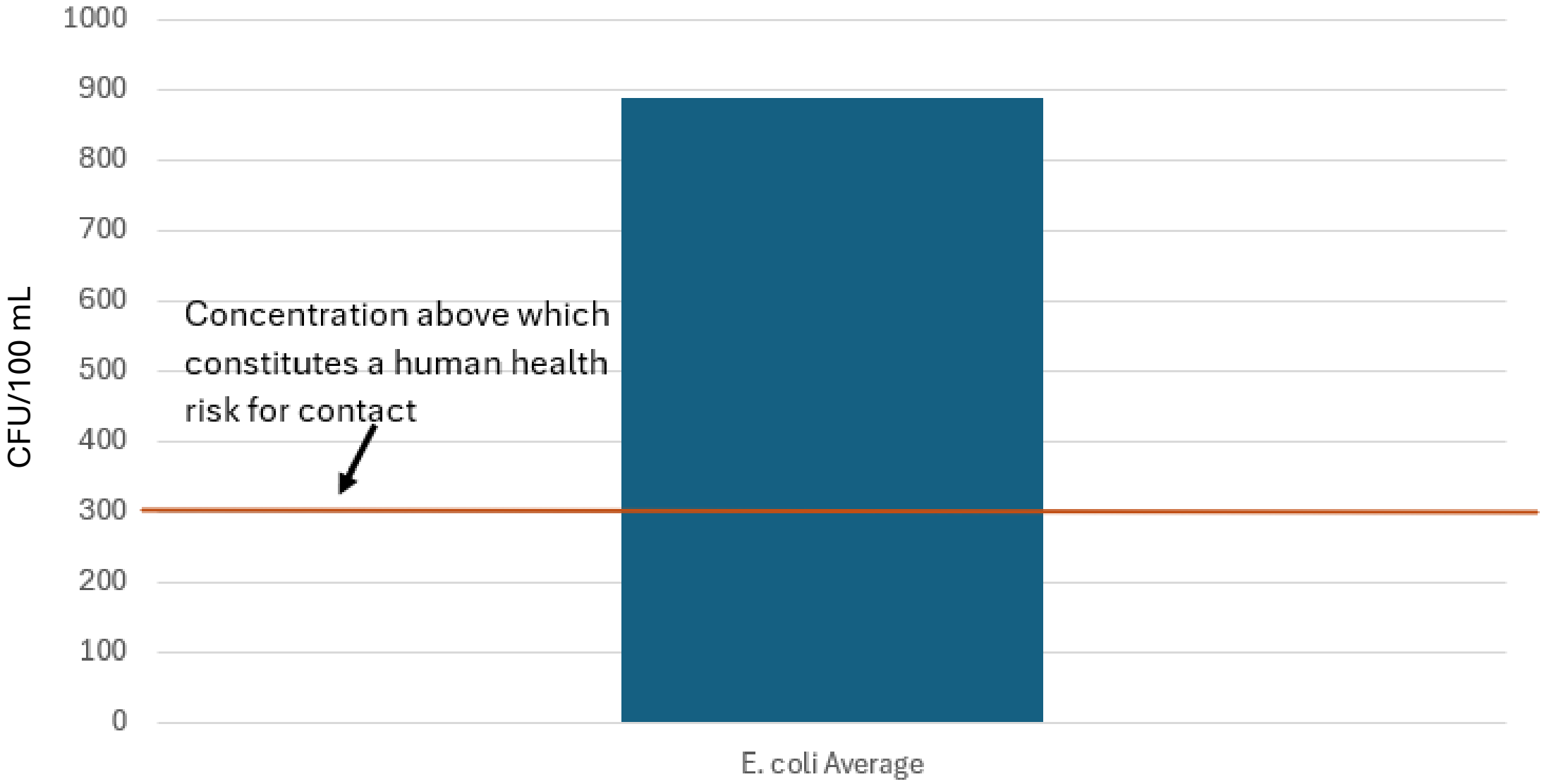


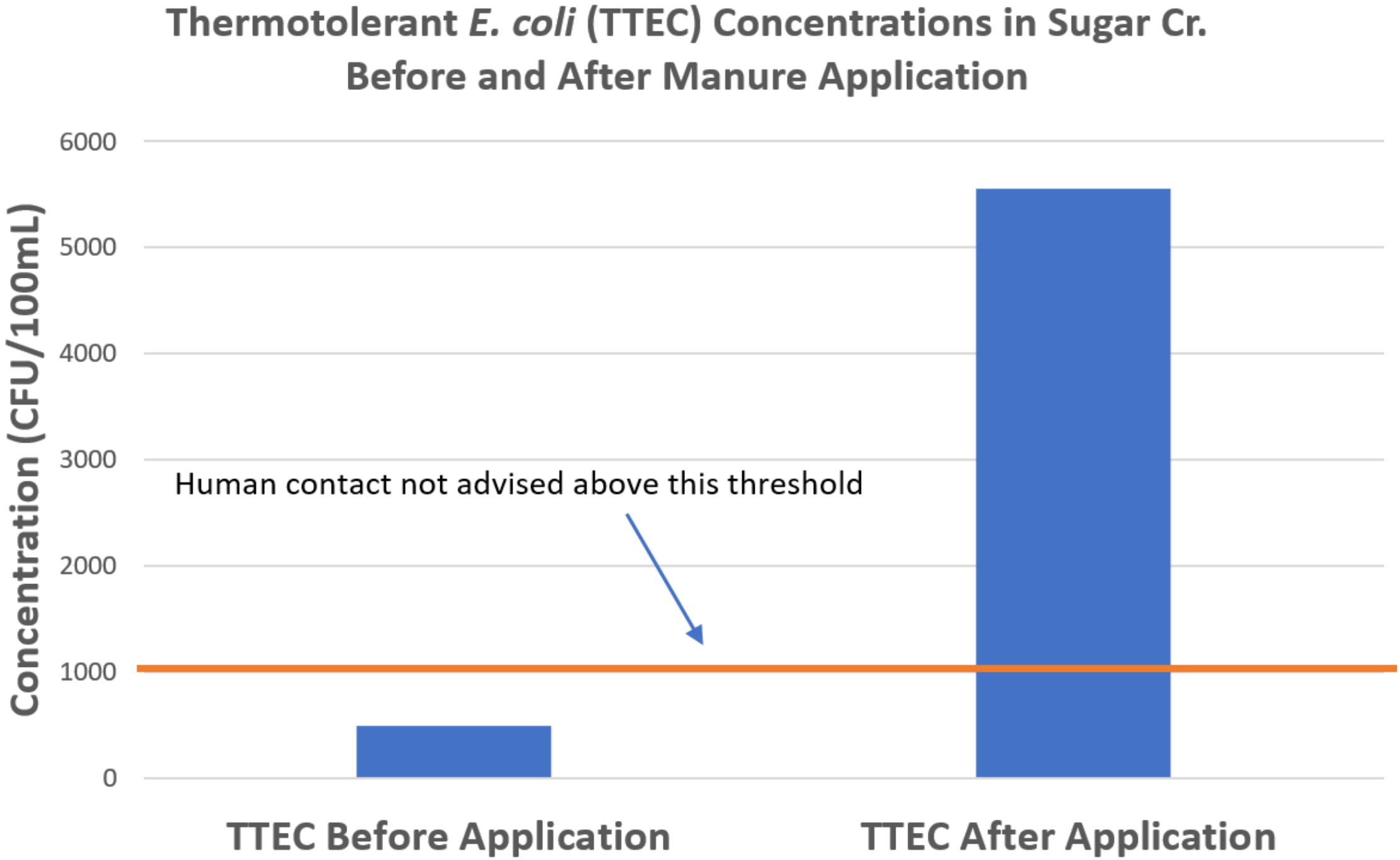
Fecal coliform bacteria from samples taken upstream and downstream of a CAFO in 2004 indicate there are extremely high concentrations of *E. coli* coming from CAFO point sources

E. coli Numbers of Concern

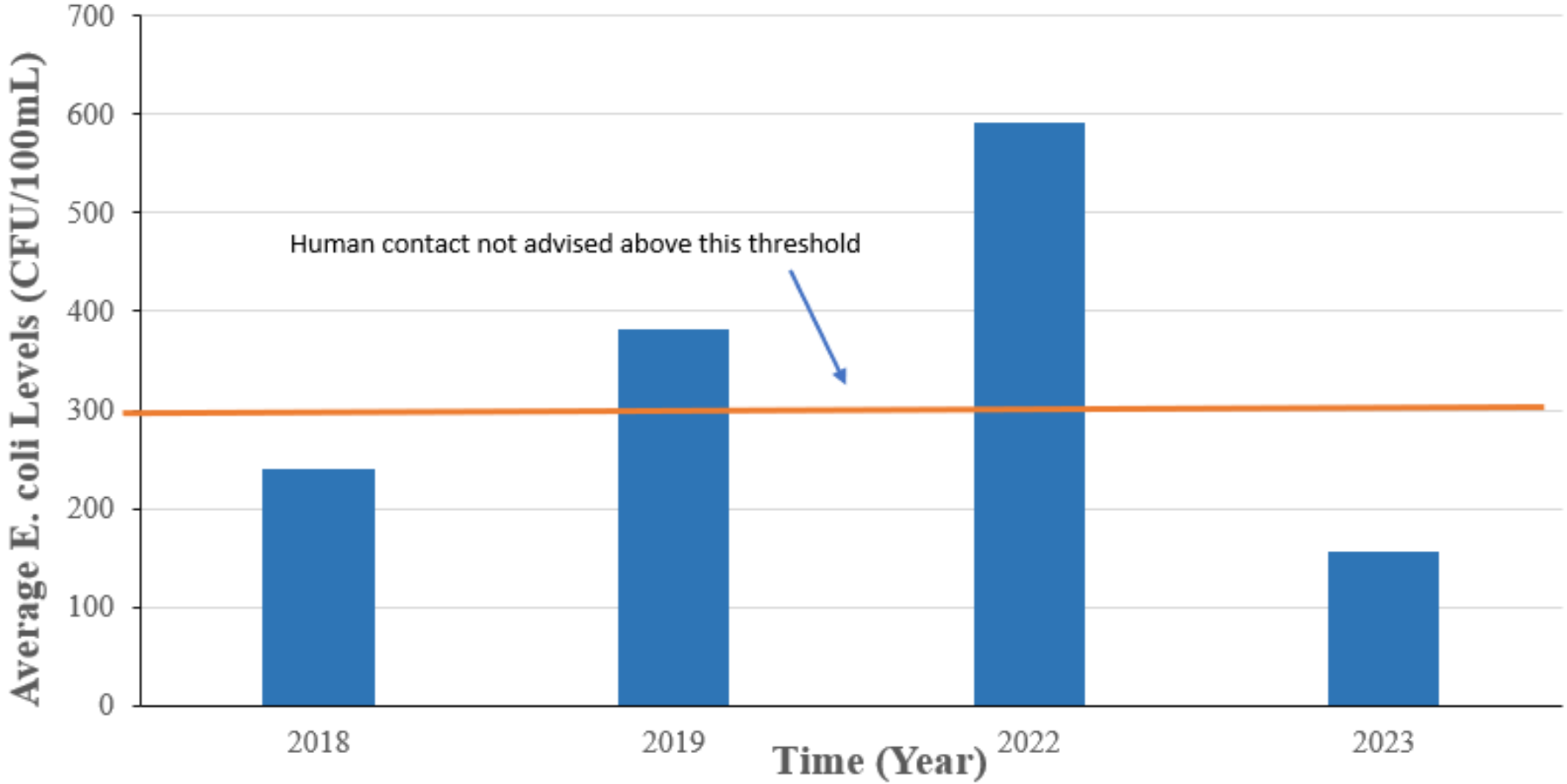
- 130 CFU/100mL
  - no swimming warning
- 300 CFU/100mL
  - Increased infection and illnesses
- 1000 CFU/100mL
  - People should not come into contact with the water
  - No exposure warning

Five-Year Average of Thermotolerant *E. coli* for All Sampling Sites Above Alma Dam (2019-2023)

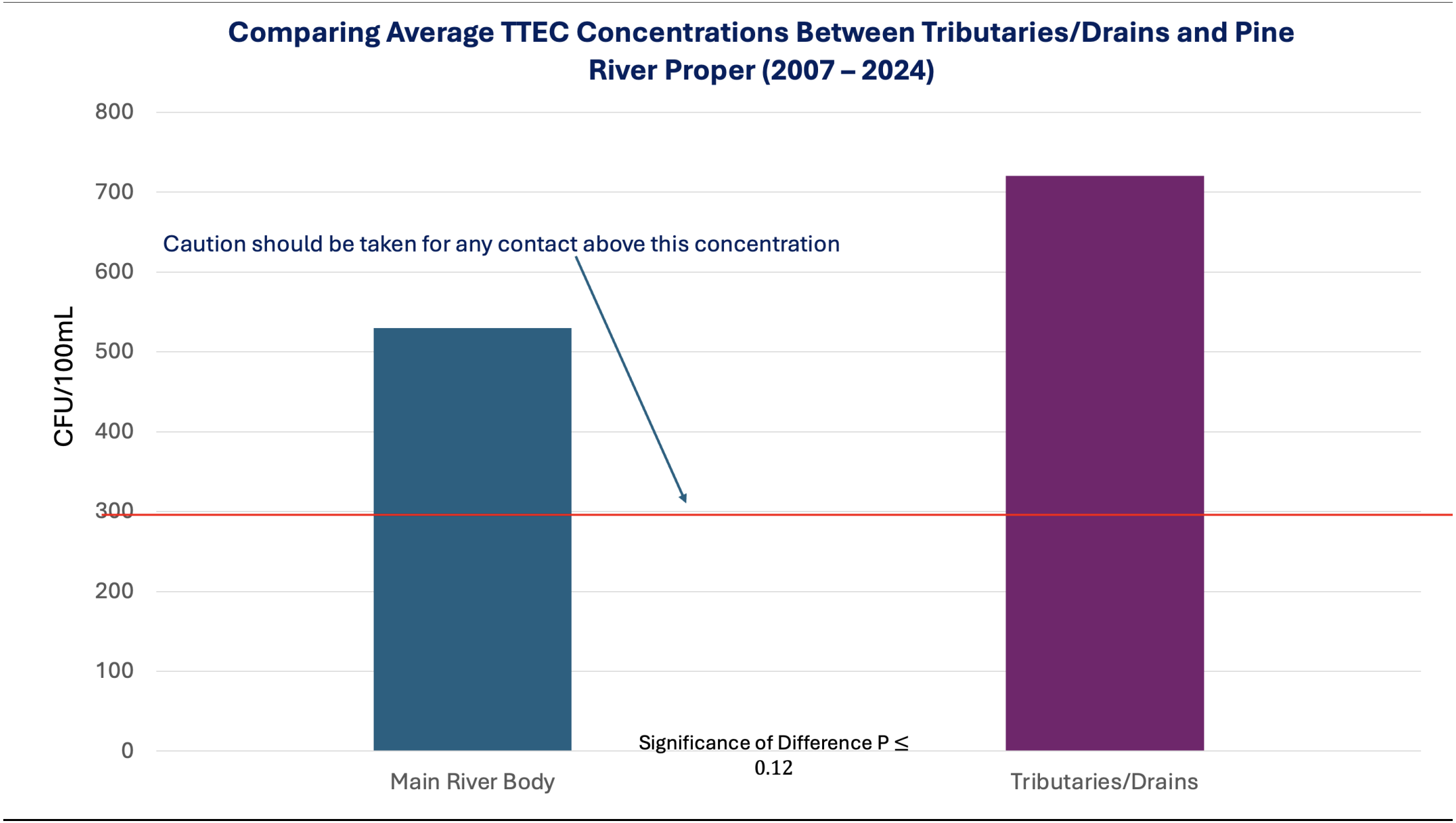



Thermotolerant E. coli (TTEC) Concentrations in Sugar Cr.
Before and After Manure Application
Concentration (CFU/100mL)
6000
5000
4000
3000
2000
1000
0
Human contact not advised above this threshold
TTEC Before Application
TTEC After Application

Average *E. coli* Concentrations at Alma Boat Launch (2018-2023)



E. coli Comes From PR Tributaries and Ditches/Drains



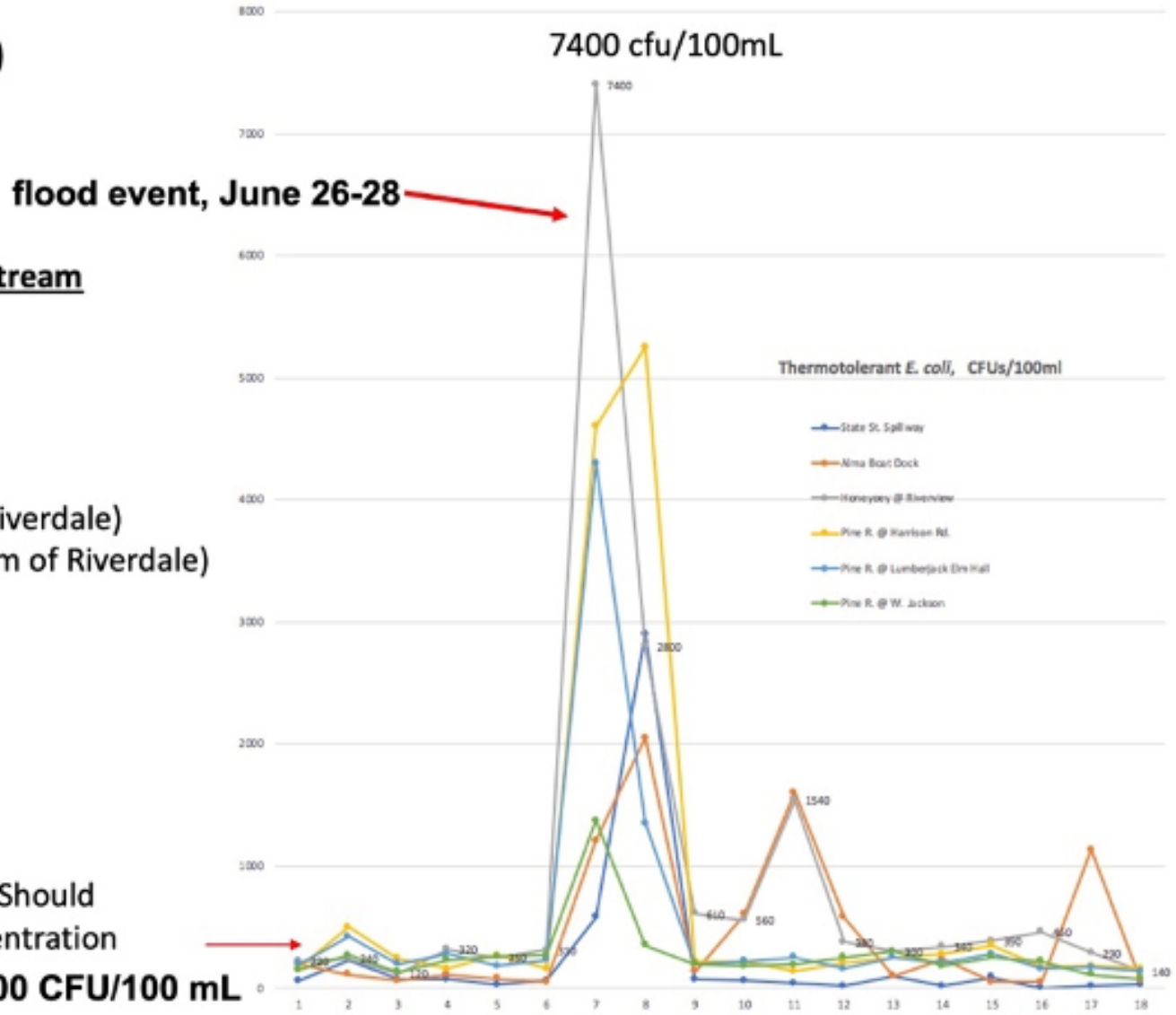
Drain tiles allow the "flushing" of nutrients and *E. coli* into the watershed after rain events. This is proof that the overwhelming amount of bacteria and nutrients are NOT coming from leaking septic systems or even direct connects, but from manure application sites and CAFO sites which are tiled.

Summer 2018 (June 6- Aug 2)
Rain Event on June 26-27
Showing Spike in *E. coli*

Sampling sites (tributaries of Pine River upstream of Alma Dam)

KEY:

Gray	Honeyoey at Riverview
Yellow	PR at Harrison Rd
Light Blue	State St. Spillway
Green	PR at Jackson (Upstream Riverdale)
Dark Blue	RP at Elm Hall (Downstream of Riverdale)



What All This *E. coli* Means for Our Health

- *E. coli* strain O157:H7
  - Pathogen
    - Resides in intestines of cattle, pigs, and other livestock
  - Produces a toxin extremely dangerous in humans
  - Toxins excreted by *E. coli* are known for producing Hemolytic Uremic Syndrome (HUS) in kids
    - Blood clots
    - Urine in bloodstream
    - Kidney failure

DNA Pollution: Why It Matters

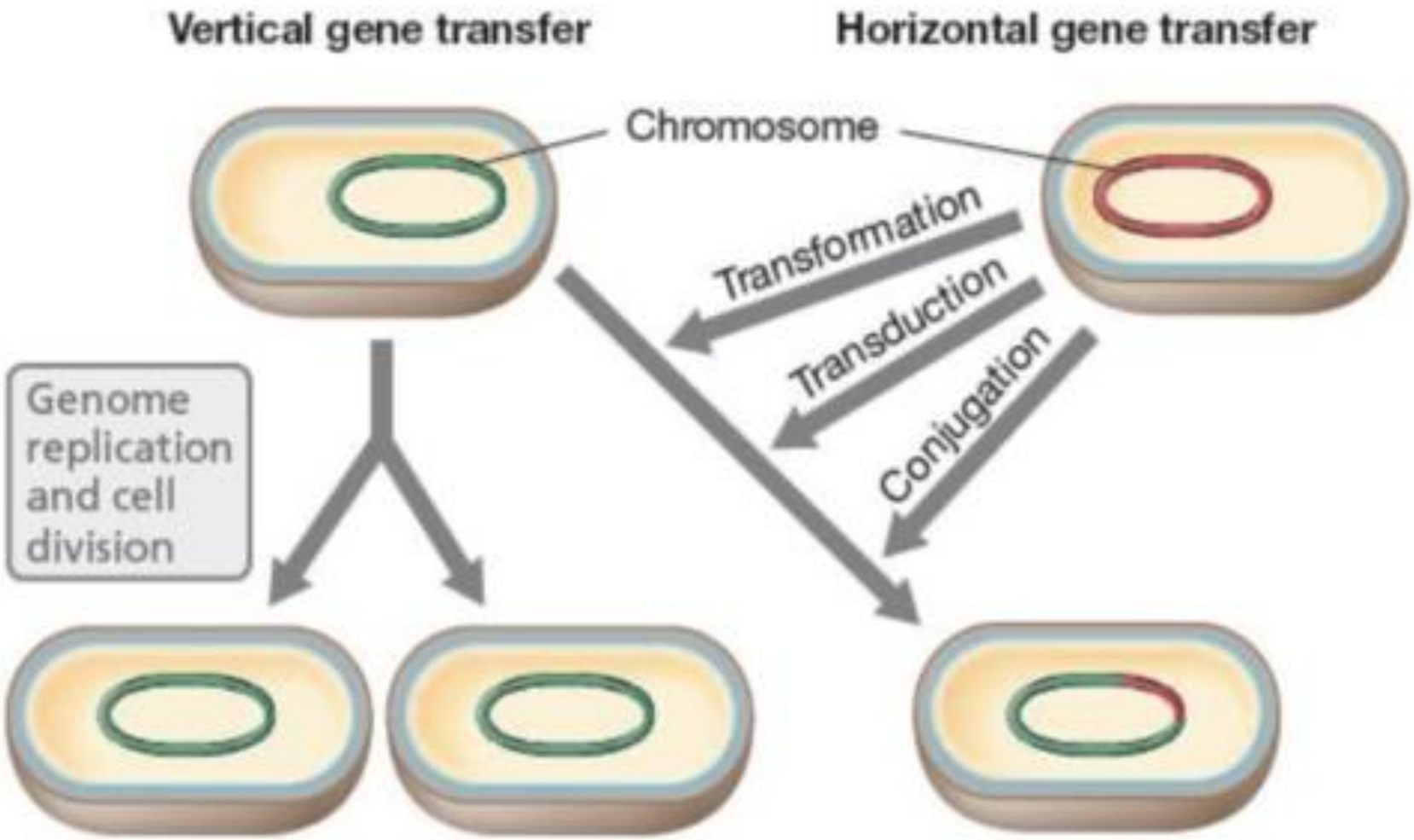
- **While *E. coli* levels may rise and fall, the bacteria leave behind their DNA**

This is a form of “DNA Pollution”

DNA pollution lingers in sediments and can be picked up and used by other bacteria, including human pathogens

Several studies conducted by Alma College demonstrate the presence, relative concentration, and source of these genes

Gene Transfers



Do We See This DNA Pollution in the Pine River?

- The more antibiotics given to animals, the more resistant the bacteria that is found in the waste
- Alma College first looked at background levels of some of the genes that cause antibiotic resistance
- Then, sediment samples were collected to assess the presence of these "resistance genes"

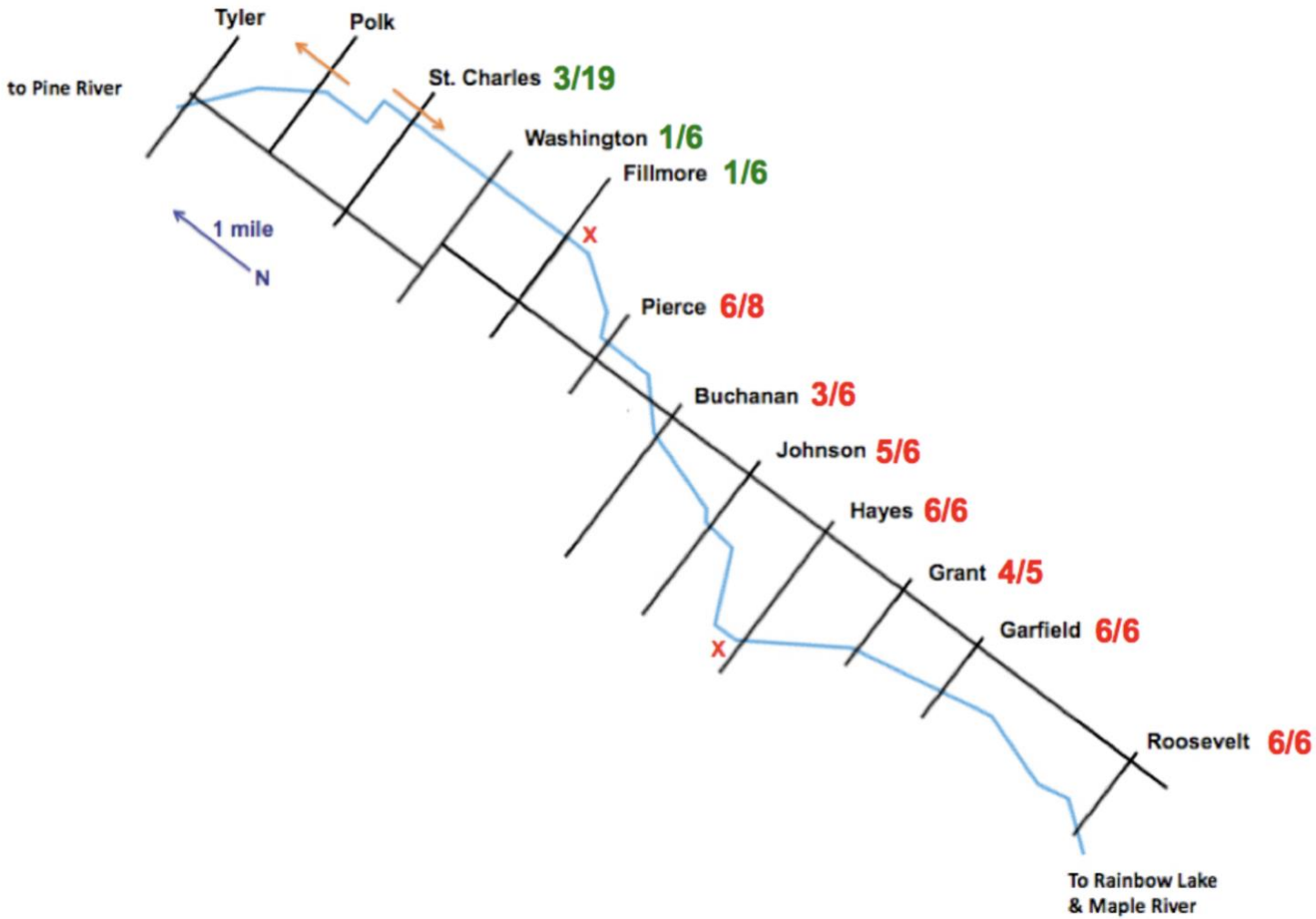
Background Samples

Soil/Sediment Location	No. of Samples Tested for TetW	No. of Positives for TetW
Pine River and Soils at Douglas Road	12	0/12
Hayes Cemetery	3	0/3
Riverside Park, Alma	3	1/3
Alma College Campus	12	1/12
Ecological Station (Vestaburg)	12	1/12
Arcadia Drainage Berms	18	1/18
Total	**60**	**4/60 = 7% Positive for TetW**

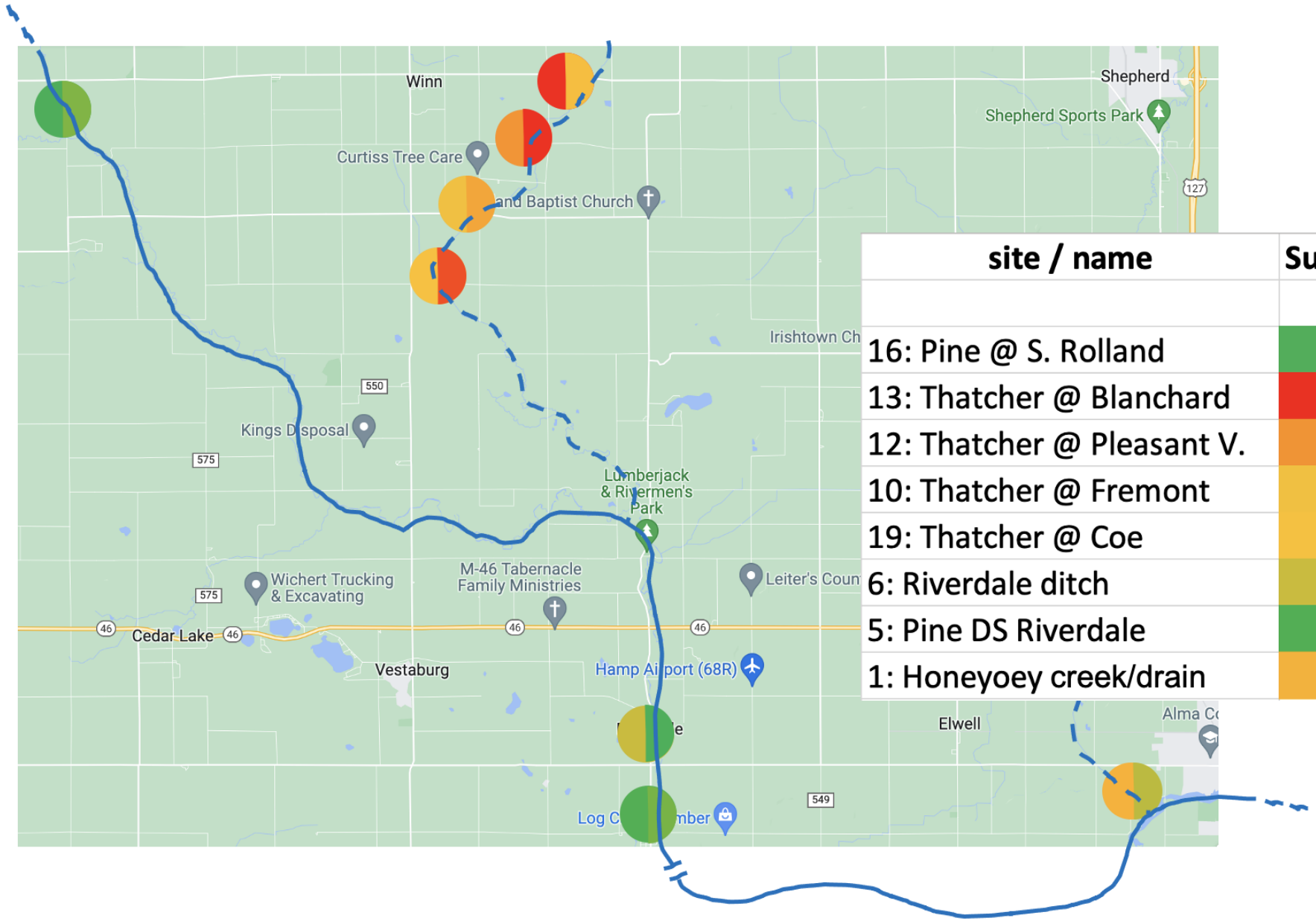
Agriculturally Impacted Samples

Soil/Sediment Location	No. of Samples Tested for TetW	No. of Positives for TetW
Upstream of CAFO		
Arcadia at W. St. Charles	19	3/19
Washington Rd.	6	1/6
Filmore Rd.	6	1/6
Downstream from CAFOs		
Pierce Rd.	8	6/8
Buchanan Rd.	6	3/6
Johnson Rd.	6	5/6
Hayes Rd.	6	6/6
Grant Rd.	5	4/5
Garfield Rd.	6	6/6
Roosevelt Rd.	6	6/6
Total	**43**	**36/43 = 84% Positive for TetW**

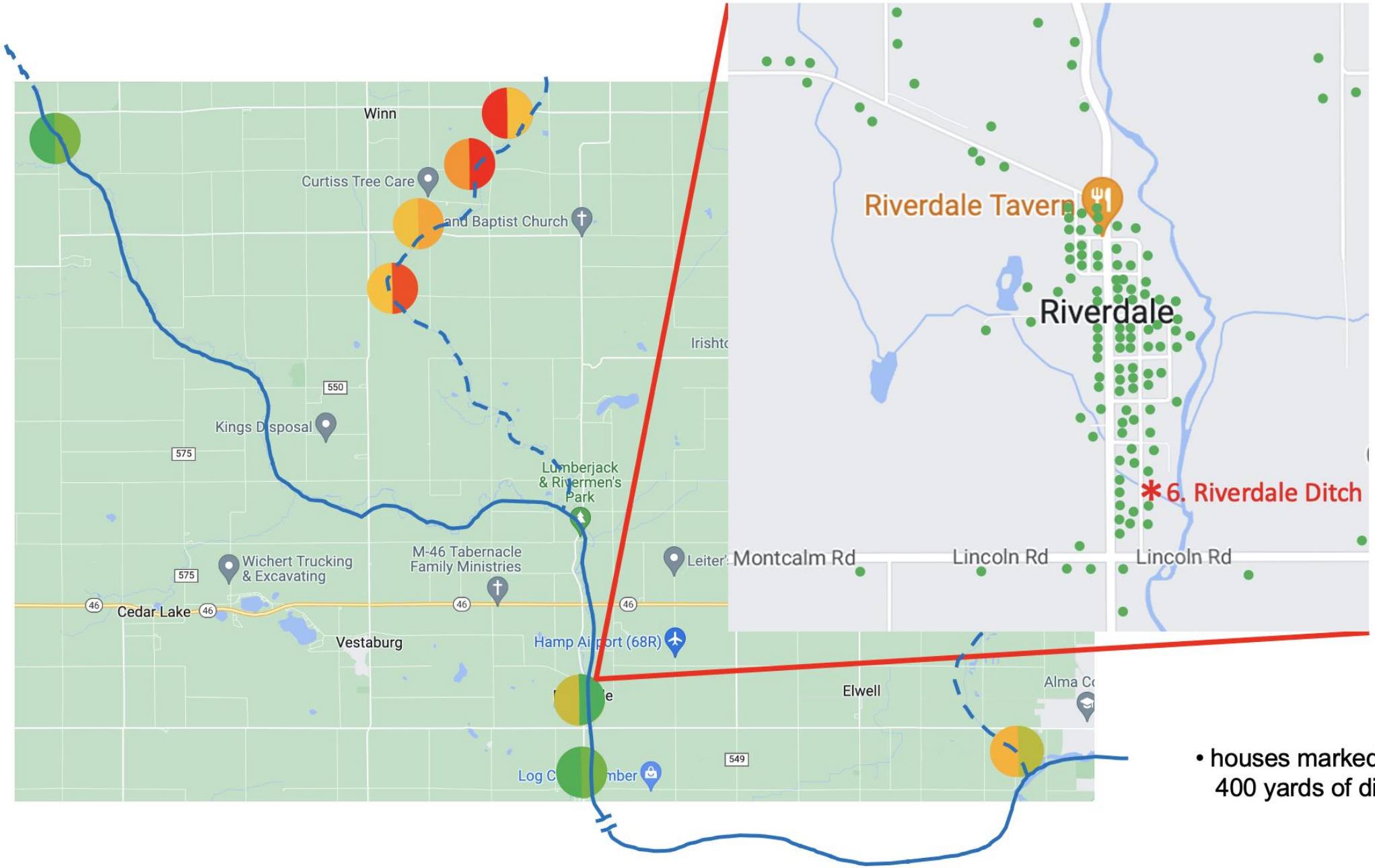
ARG Prevalence: Maple River Watershed



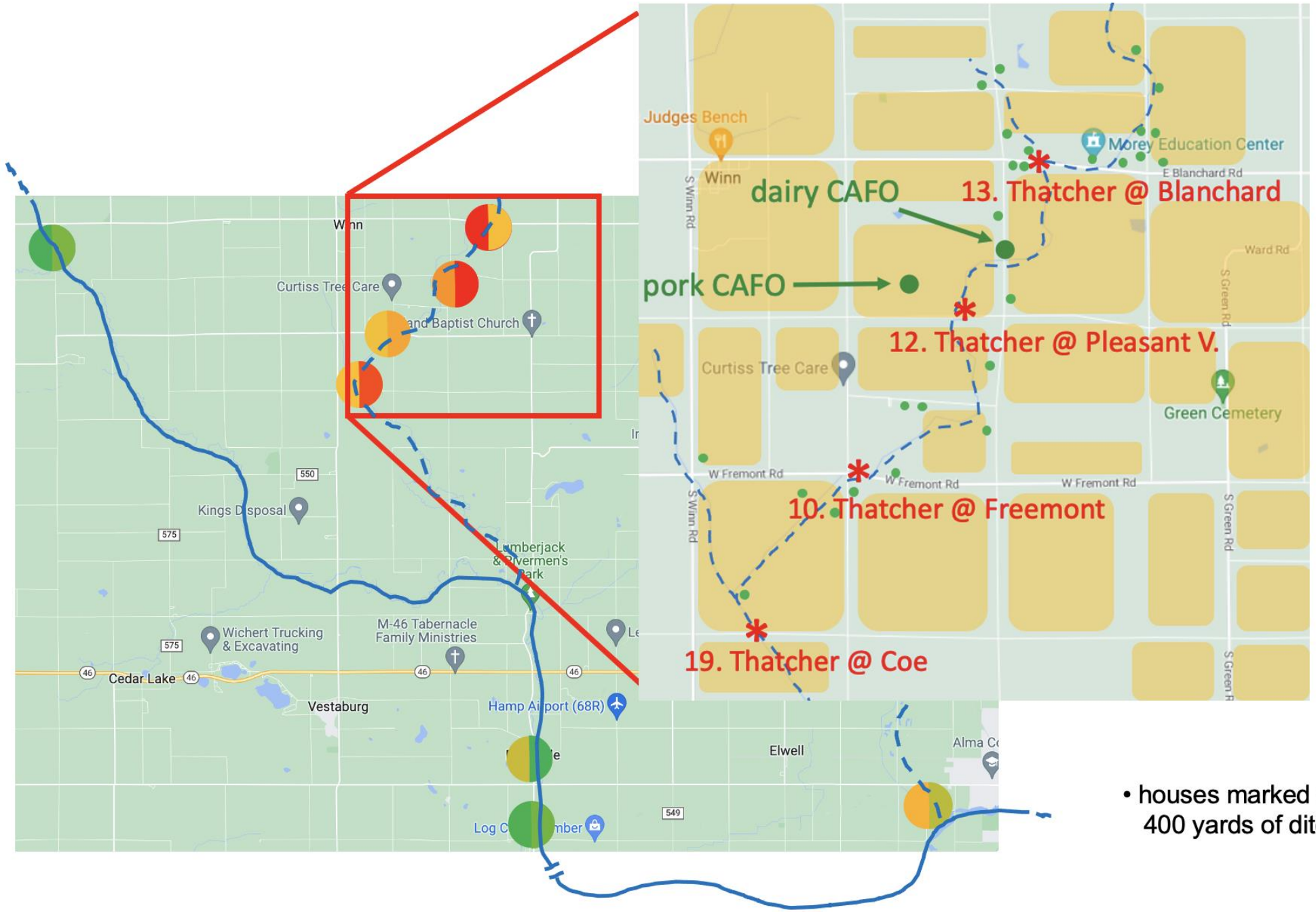
Antibiotic Resistance Genes – Mapping Where They Are and Where They are Coming From



site / name	Sul-1	TetW22
16: Pine @ S. Rolland	1	4.1
13: Thatcher @ Blanchard	380	9.8
12: Thatcher @ Pleasant V.	109.9	74.5
10: Thatcher @ Fremont	17.03	18.3
19: Thatcher @ Coe	17.88	51.6
6: Riverdale ditch	14.12	1
5: Pine DS Riverdale	2.77	3.8
1: Honeyoey creek/drain	48.17	6.1



• houses marked are within 400 yards of ditch or river



- houses marked are within 400 yards of ditch

- engineered drains/creeks near CAFO operations are hotspots* for ARGs

  * these hotspots have been shown to provide ARGs of medical importance to local bacteria populations (previous study)

- lingering DNA pollution appears to be restricted to creeks and ditches near CAFO operations

- the human septic systems in Riverdale do NOT contribute to this problem

- human antibiotic use is not a local environmental danger – CAFOs are.

Takeaways for Human Health Risks

- Children are disproportionately affected by *E. coli* strain 0157:H7
- Average *E. coli* levels in Pine River and its tributaries are extremely high and in concentrations believed to be potential harmful for human contact
- *E. coli* and other bacteria found in sites affected by livestock facilities and manure application sites are highly resistant to antibiotics, including some predominantly used in human population
- Agricultural inputs affect the entire watershed

Results 3: How Widespread Are Agricultural Impacts in the Watershed + Downstream Expansion of the Problem

2012 - Present

- Reports of an expanding algal bloom were reported as early as 2012
- Aerial photos and resident complaints confirm that the algae were expanding into the headwaters
- By 2019, St. Louis residents complained to the City Council that algal blooms appeared in the Pine River where there were never blooms
- Beginning in 2013, manure dumps in early spring were being recorded

Raw manure in Pine River just upstream of the Alma Dam, 2022

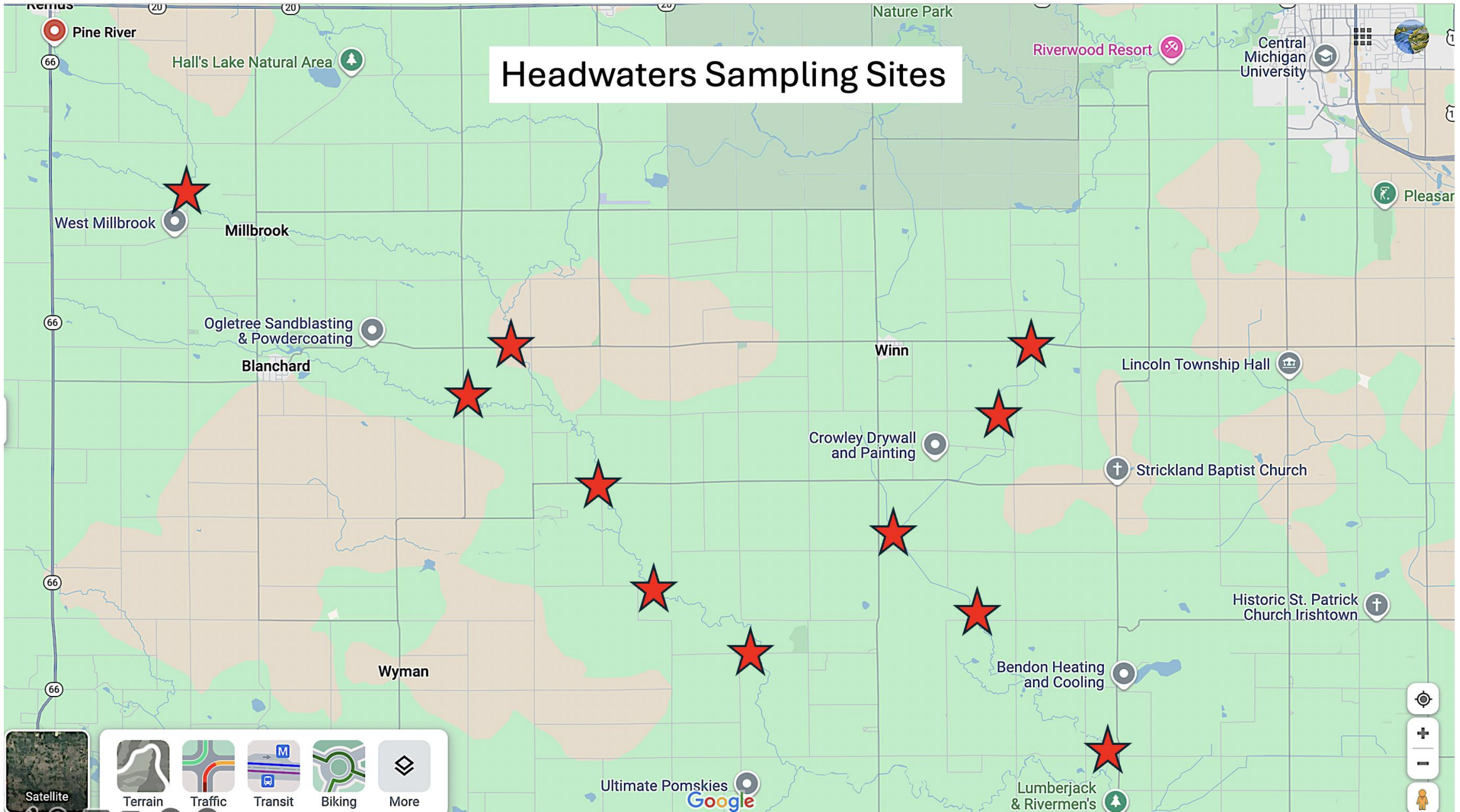
Manure dumps are now an annual occurrence sometimes occurring two or three times – usually in the area of the Pine River above the mill pond

Raw manure dump, Pine River, May, 2024

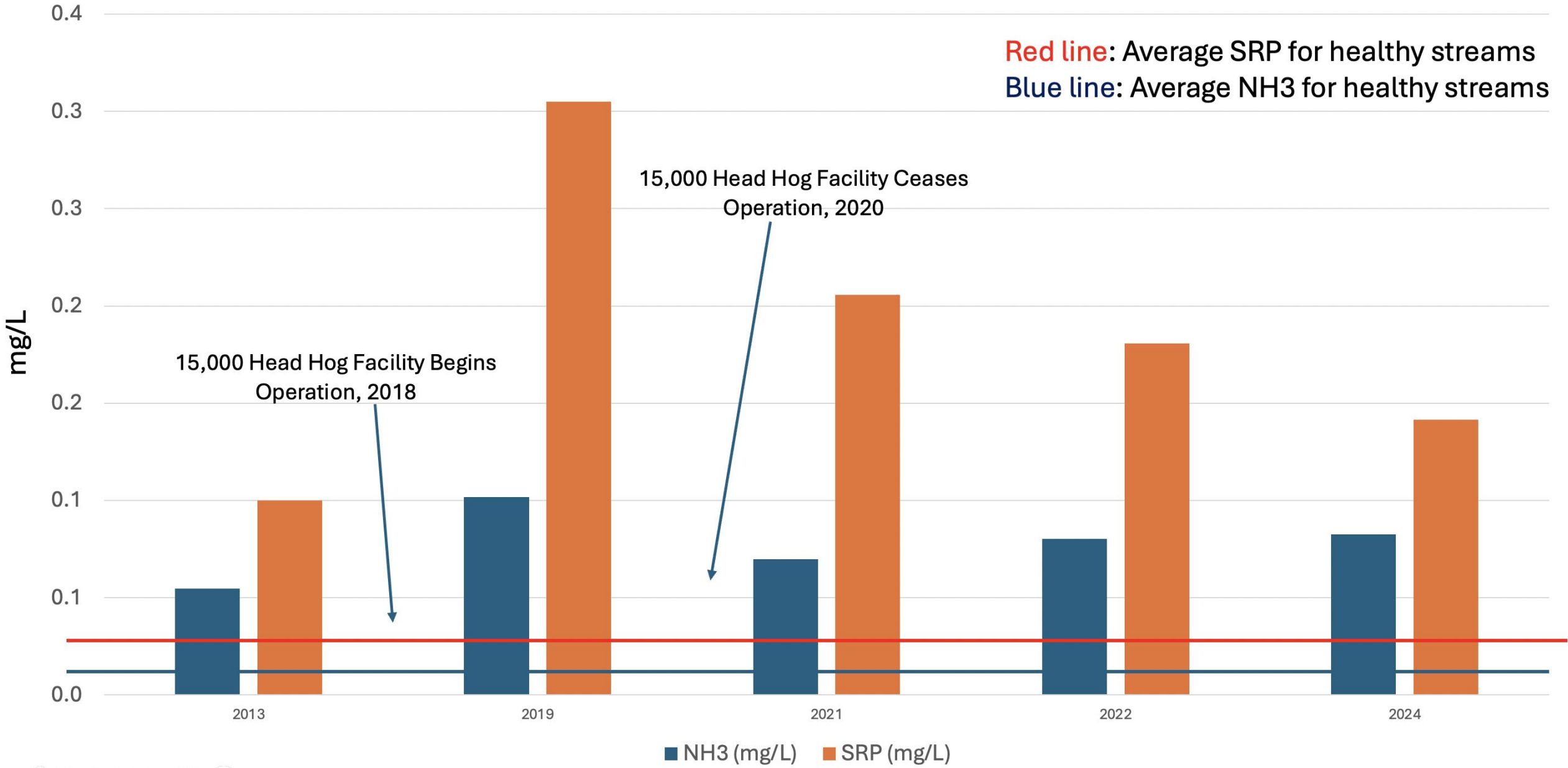
Outline of Study

- The Pine River Watershed was broken up into three sections:
  - **Headwaters**: From the very beginning of the Pine River to Lumberjack Park
  - **Main Trunk:** From Lumberjack Park to the Alma Dam
  - **Downstream**: Between Alma Dam and the St. Louis Dam

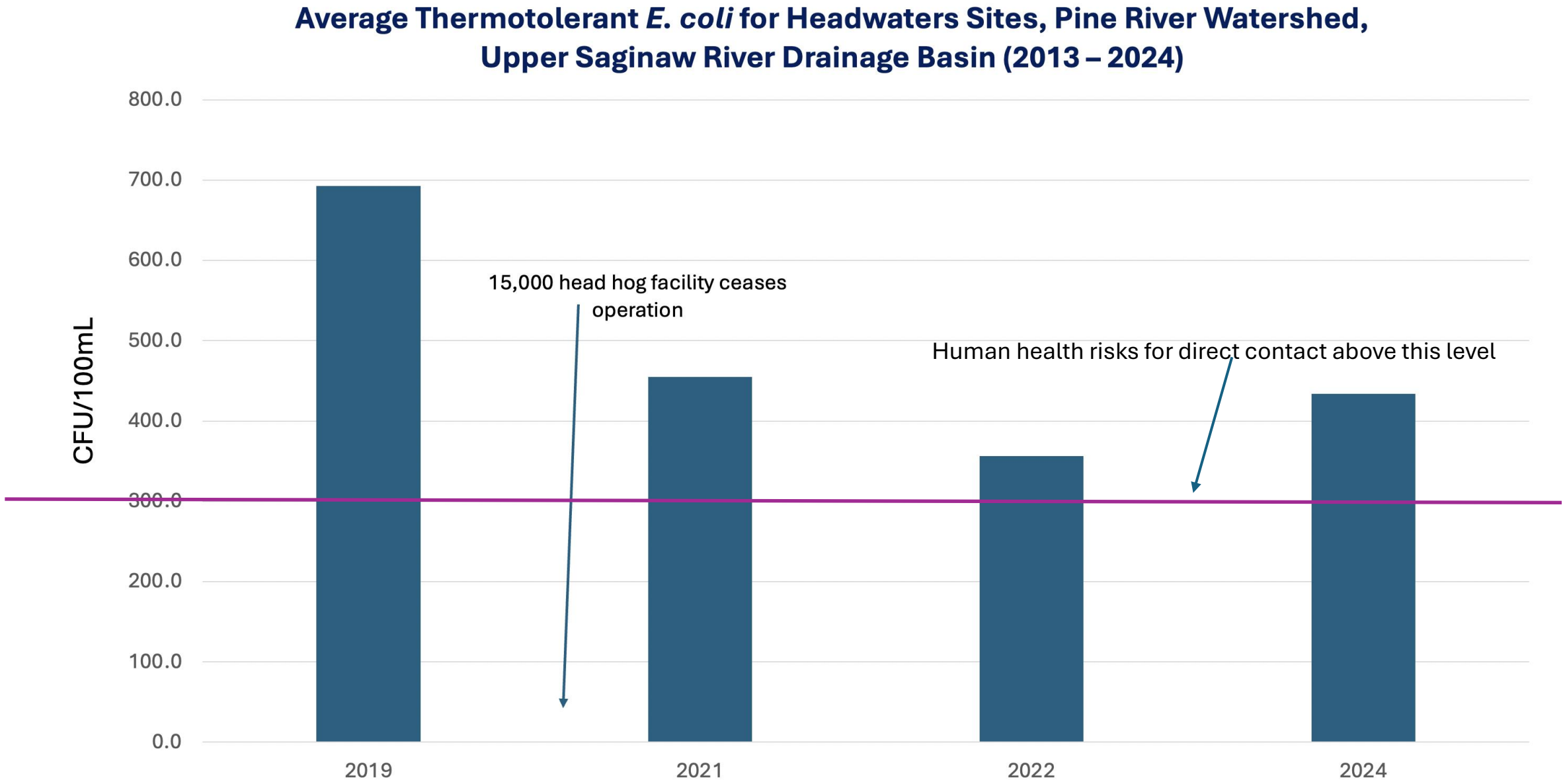
Headwaters Sites



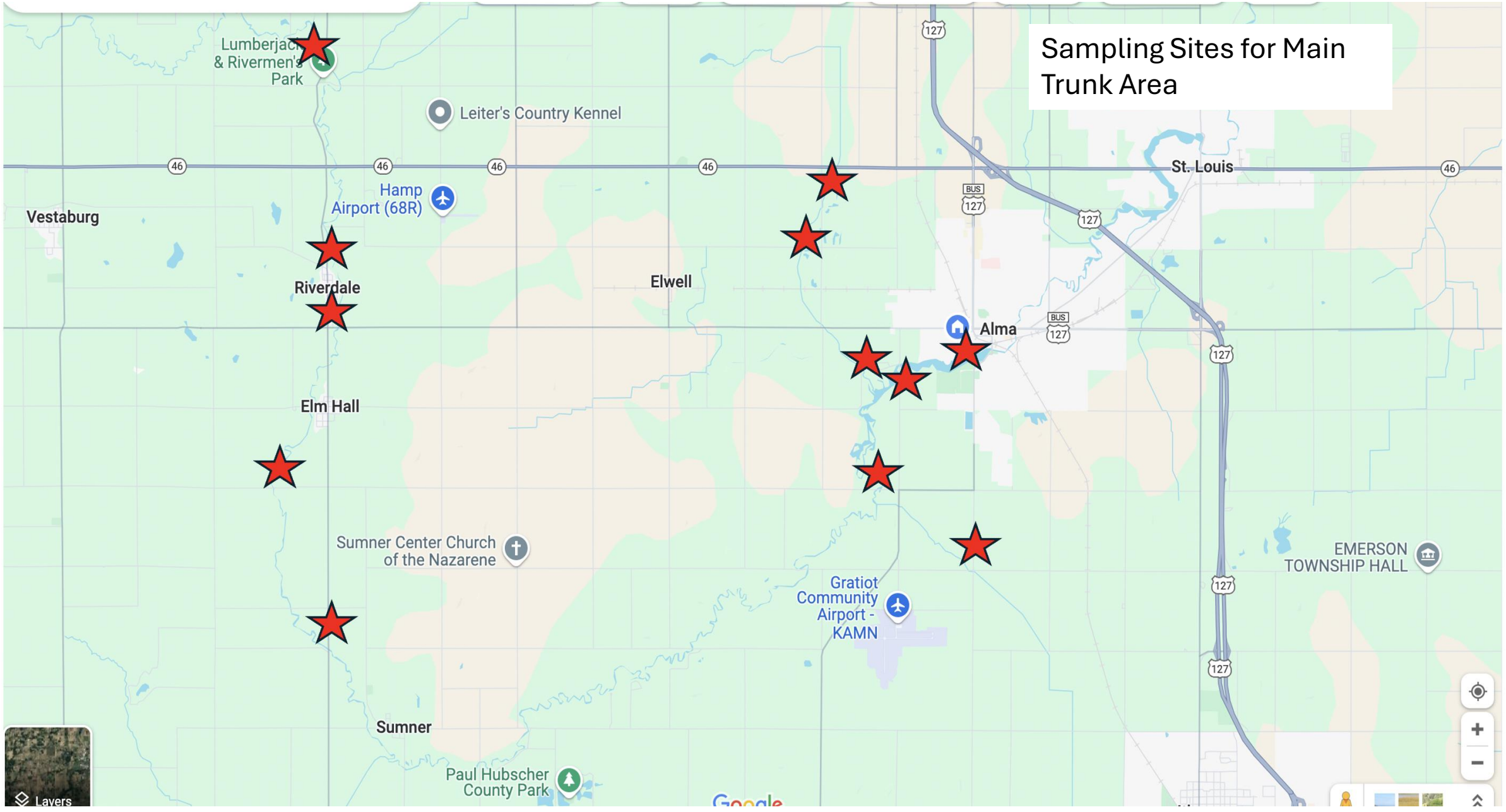
Nutrient Averages By Year, Headwaters of Pine River Watershed, Saginaw River Drainage Basin (2013 - 2024)



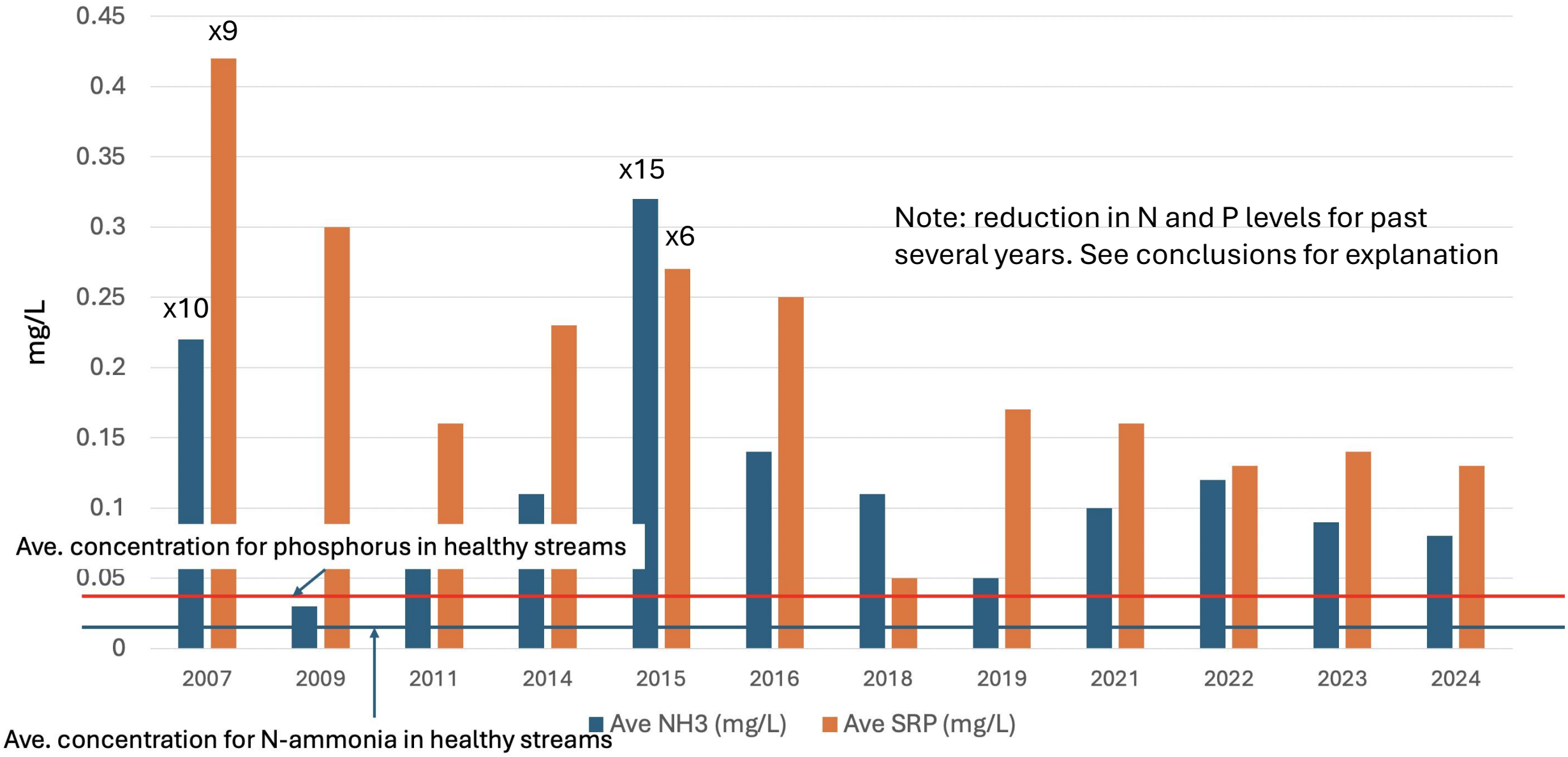
Thermotolerant *E. coli* in the Headwaters



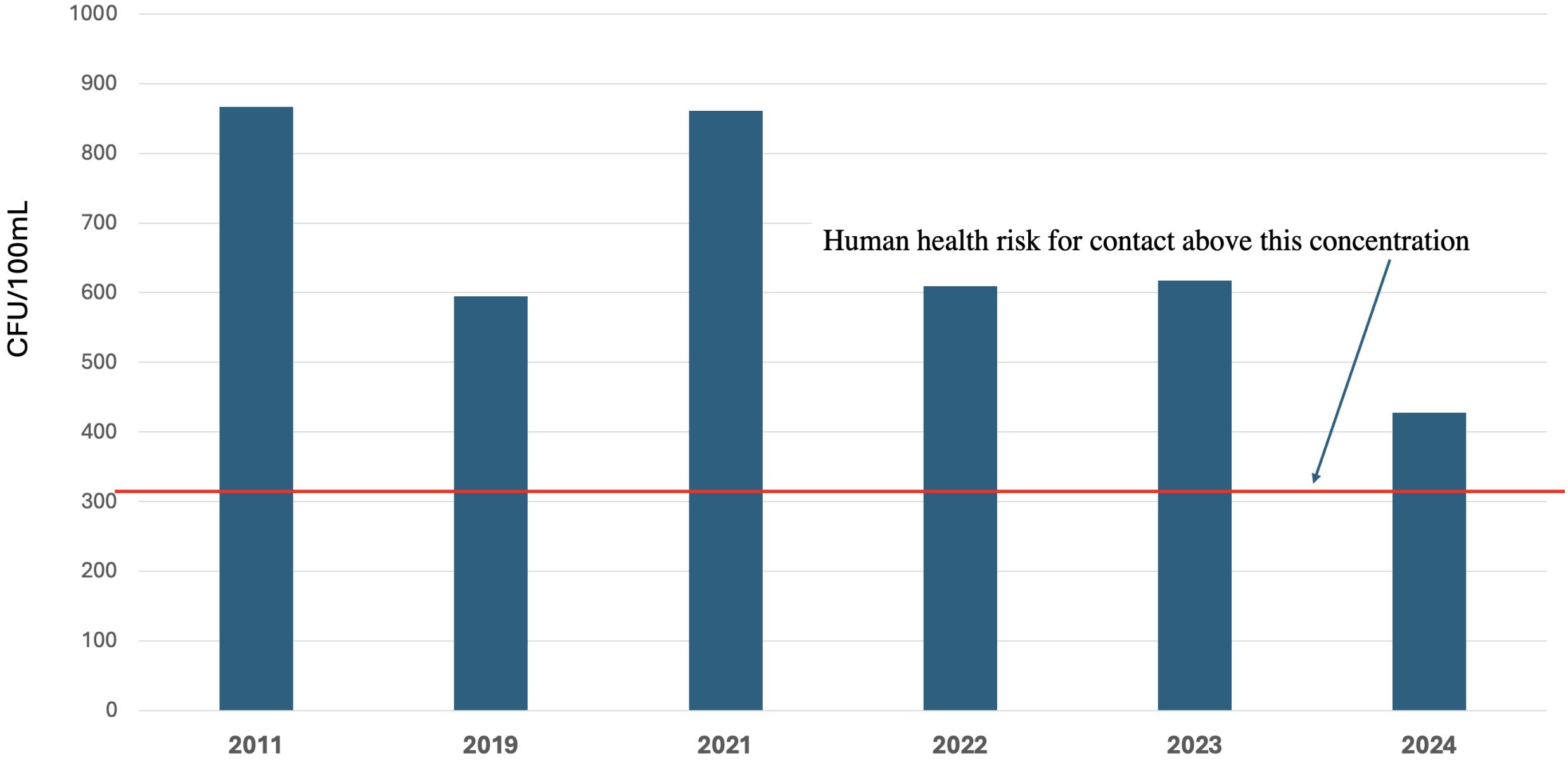
Main Trunk


Sampling Sites for Main Trunk Area
Lumberjack & Rivermen's Park
Leiter's Country Kennel
Hamp Airport (68R)
Vestaburg
Riverdale
Elwell
St. Louis
Alma
Elm Hall
Sumner Center Church of the Nazarene
Gratiot Community Airport - KAMN
EMERSON TOWNSHIP HALL
Sumner
Paul Hubscher County Park
Layers
Google
46
127
BUS 127

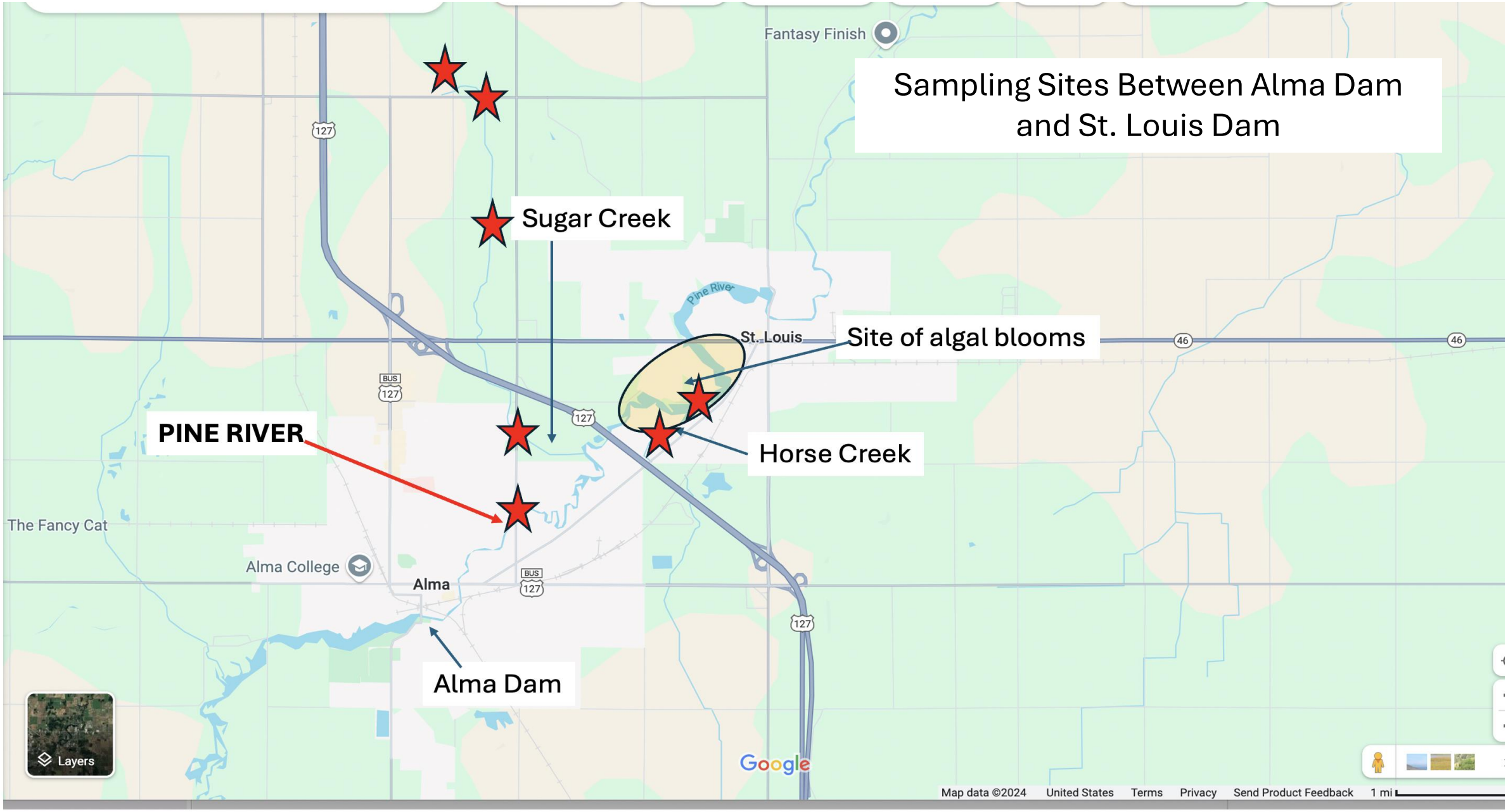
Annual Average Nutrients for Main Trunk Region of the Pine River Watershed (2007 – 2024)



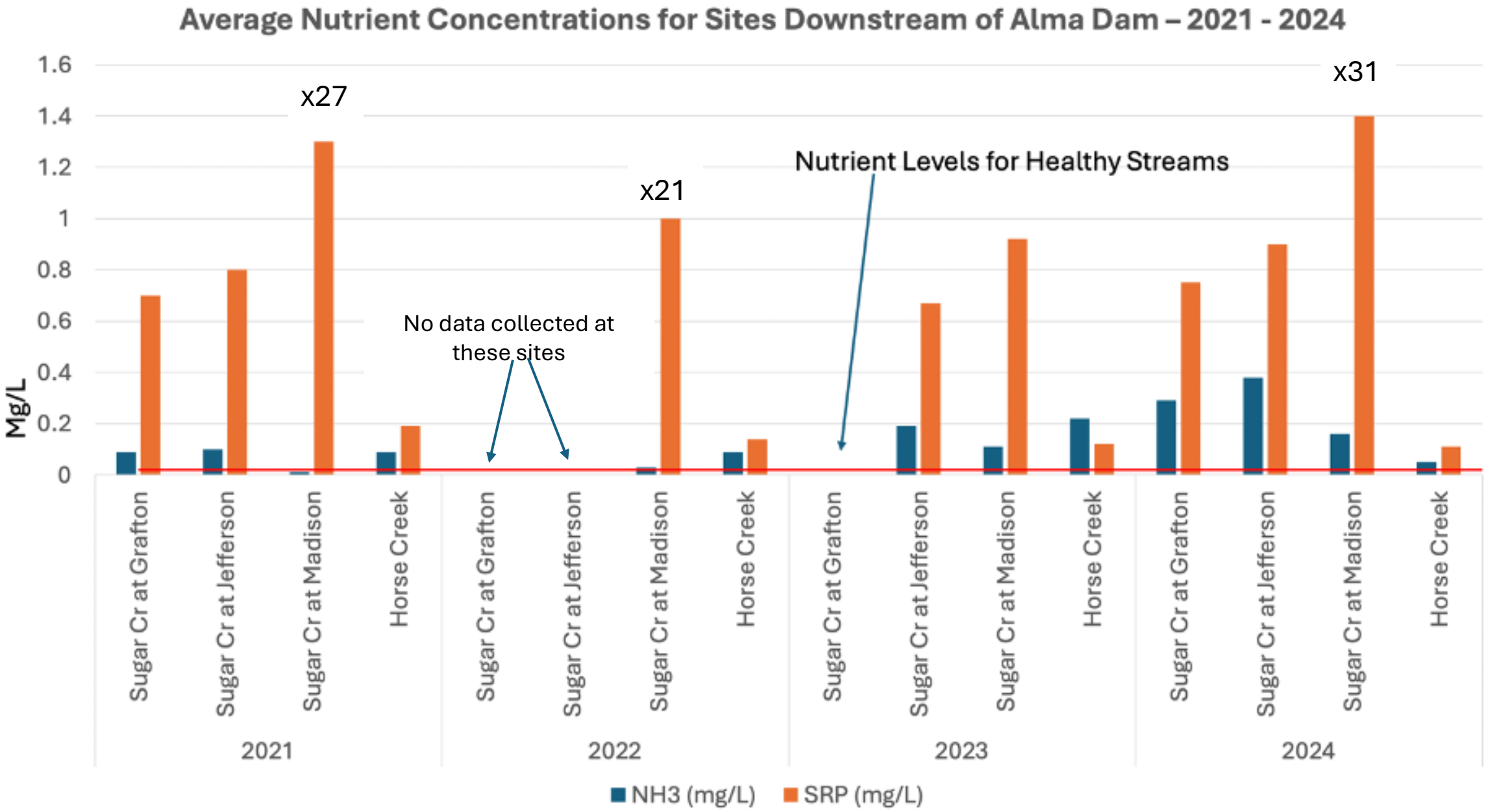
Average Thermotolerant *E. coli* for Main Trunk Sites Pine River Watershed



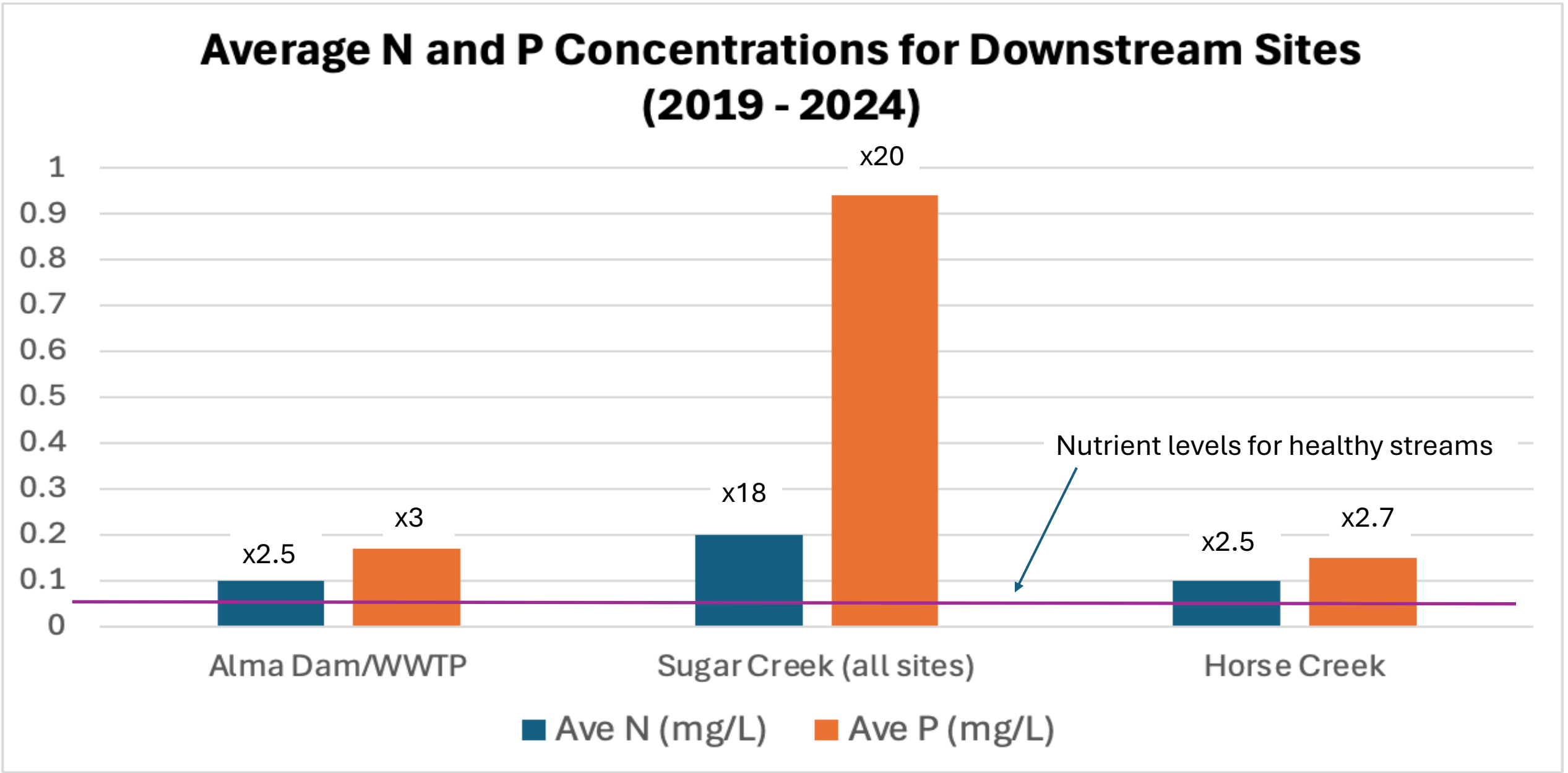
Downstream Sites

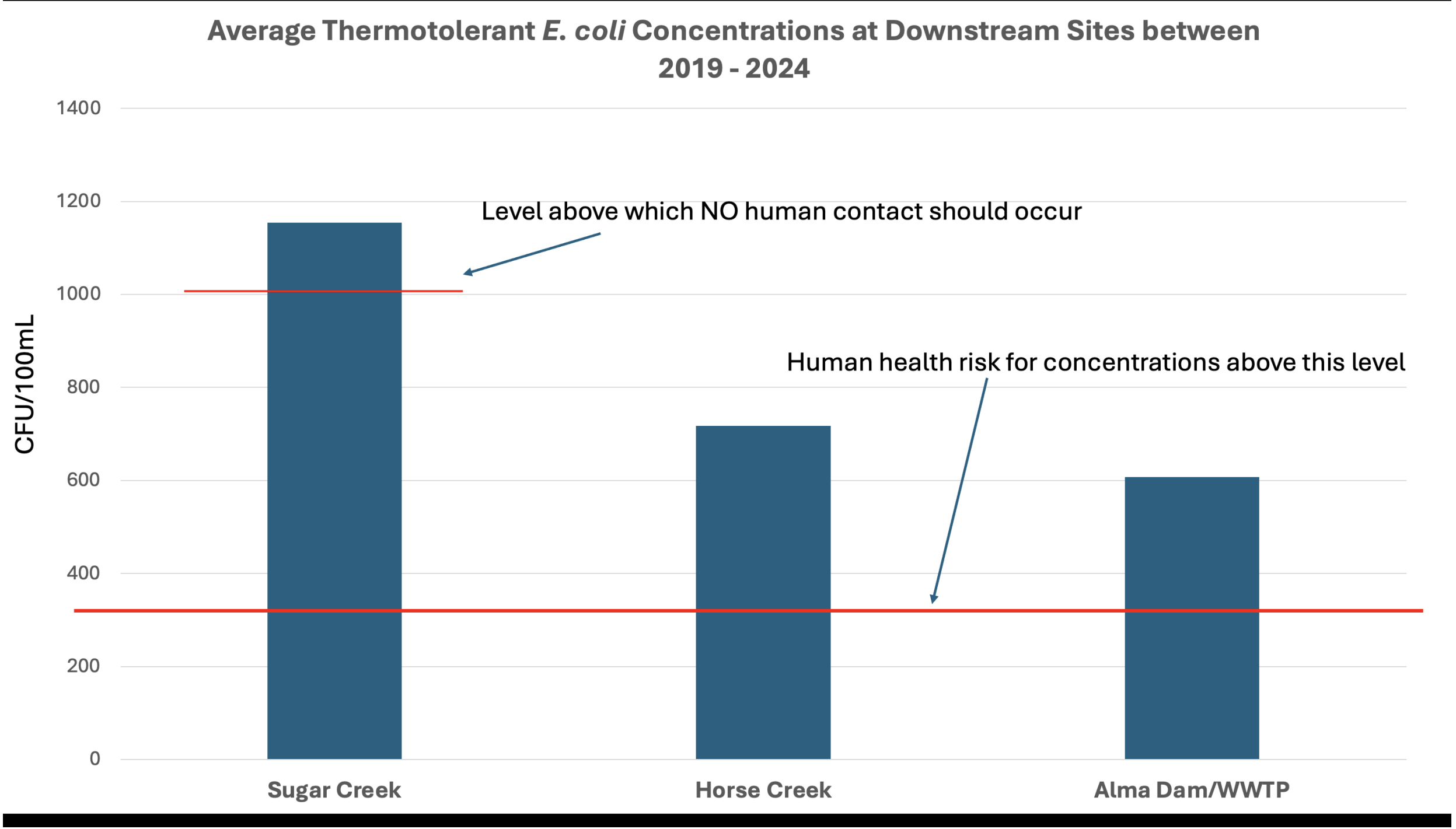


Nutrient Averages Downstream of Alma Dam



Which Sites Have the Most Impact




Average Thermotolerant E. coli Concentrations at Downstream Sites between 2019 - 2024
1400
1200
1000
800
600
400
200
0
CFU/100mL
Level above which NO human contact should occur
Human health risk for concentrations above this level
Sugar Creek
Horse Creek
Alma Dam/WWTP

Conclusions

- ***Twenty years of extensive research by Alma College and other entities, including the State of Michigan have produced irrefutable evidence of the following:***

1. **The Upper Saginaw River Drainage Basin, specifically, the Pine River Watershed is heavily impacted by agricultural pollution which consists of heavy and pervasive algal blooms and extremely high concentrations of potentially harmful antibiotic resistant, thermotolerant *E. coli* bacteria**

2. **The source of this pollution is manure produced and discharged at large livestock facilities, application sites, as well as infrequent but regular occurrences of direct discharge**

Conclusions

- **Underdrains Transport N,P, and Bacteria.**

- **CAFOs are Point Source Dischargers.** It is unequivocal that CAFO facilities act as point source dischargers, discharging high concentrations of nutrients and bacteria into drainage ditches and tributaries of the Pine River

- **Despite the fact there are leaking septic systems around the county, there is <u>no evidence</u> that leaking septic systems are playing any role in the state of the watershed as described in this presentation.**

- **Manure Application Events Dump N, P, and Bacteria into the Watershed.**

Further

- Antibiotic resistant TTEC found in the watershed poses a significant risk to human health and health of the environment in the following ways:
  - ***Average*** concentrations of antibiotic resistant TTEC at nearly every site measured are many times over what the State Health Department has determined to be unsafe for direct human contact
  - Since 2007, only 3 out of 30+ sites exhibited average TTEC *below* swim risk concentrations
  - Rain events cause spikes in potentially harmful bacteria concentrations many times higher than the State Health Department's absolute "no-contact" criteria

Further

- Antibiotic resistant TTEC found in the watershed poses a significant risk to human health and health of the environment in the following ways:
    - **Antibiotic resistance genes** are prevalent in river sediment. These pose health risks as other, more pathogenic bacteria can assimilate and utilize these genes to create resistance. This has been observed over the past 15 years.
    - Past studies have shown that **merely fishing in the Pine River** results in the transfer of this antibiotic resistant TTEC from fish mucus to human hands

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Are anglers exposed to *Escherichia coli* from an agriculturally impacted river?

Bonnie M. Hamilton · Amanda D. Harwood · Hunter R. Wilson · Timothy P. Keeton · Murray C. Borrello

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Abstract The Pine River, in the central, Lower Peninsula region of Michigan, has a long history of contamination. Livestock facilities and manure application sites along the Pine River and its tributaries have led to elevated nutrient levels. In addition to nutrient loading and associated low levels of dissolved oxygen, the presence *Escherichia coli* bacteria have caused environmental and human health concerns. According to the Michigan Department of Health and Human Services, and the Michigan Department of Environment, Great Lakes, and Energy, *E. coli* counts in summer months consistently have exceeded safe levels for human contact since 2005. Though it is recommended that residents do not swim in the Pine River, there are no specific restrictions on recreational fishing which is prevalent. Few studies coliform and *E. coli* bacteria accumulated both on caged and resident fish. This result led to further testing showing *E. coli* to be found on anglers' hands whether or not they handled or interacted with resident fish. This study suggests that fishing in rivers with heavy bacterial loading from agricultural runoff may expose anglers to potentially harmful *E. coli*.

Keywords *Escherichia coli* · Angler · Bacteria · Fish

Introduction

Nutrient and bacterial loading in our nations streams and

Conclusions

While previous studies have demonstrated the presence of *E. coli* in the Pine River, angler exposure to *E. coli* was unknown. The current study determined that *E. coli* can be detected in fish mucus of both caged and resident fish, indicating heavy bacterial loading in streams which results in accumulation of potentially harmful bacteria in fish mucus. Regardless of number and fish species caught, it was determined that recreational angling activities resulted in the presence of *E. coli* on angler hands. This suggests a recreational pathway of exposure to *E. coli*—a pathway similar to documented occupational biohazards in fishing industries. Furthermore, there is a potential for cross-contamination during fish cleaning as well as oral exposure by contaminated hands. It is important to note, however, that while anglers have a high likelihood of exposure to these bacteria, the human health risk posed to anglers through direct contact with elevated levels of *E. coli* in fish mucus is unknown. As industrial agricultural practices continue to impair river systems, further biological monitoring, epidemiological evaluations, and risk assessments are pertinent in order to preserve ecological integrity and protect human health.

Acknowledgments The authors would like to thank Alma College for their monetary contributions to support environmental research. The authors would also like to acknowledge Dr. Jeff

Further

- Climate Change is exacerbating the negative effects of agricultural pollution

- Water in the Pine River watershed is warming resulting in:
  - Longer algal blooms (2024 saw algal blooms well into October)
  - Longer times for TTEC to be viable in the water
  - Heavier and more frequent rain events flush out bacteria posing heightened health risks
  - Higher risk of flooding as per current climate models poses significant health risks to those who live near Pine River watershed and come in contact with flood waters

Other Considerations

- Preliminary studies have shown degradation of the Pine River Watershed has led to tangible economic impacts which include:
  - Lower property values for homes adjacent to the Pine River upstream of Alma Dam
  - The City of Alma was forced to move off of river water as a buffering agent due to heavily impacted water quality
  - There is a loss in recreation and visits to local parks adjacent to the river by local residents and visitors
  - Higher sedimentation and different kind of sediment behind the Alma dam

Finally

- The evidence for impairment of the watershed here and across the nation and their causes has been irrefutable for at least the last 15-20 years, however:
  - There have been no policy changes other than minor changes to the current CAFO permits (which were immediately fought in court by Farm Bureau) for the past 20 years
  - For the past several election cycles, the local, state, and federal representatives have, for the most part either supported the status quo – or are trying to roll back regulations for CAFOs
  - **There is a strong and growing sentiment among the local population** that enough is not being done to address the persistent algal blooms and unhealthy river. They want action

THE END?