Bacterial Monitoring in Freshwaters

Jinjun Kan
Microbiology Division
Stroud Water Research Center

STROUD
WATER RESEARCH CENTER

Learning objectives

- **Understand basics for bacterial monitoring: including goals, study design, sampling strategies, monitoring methods etc.**

(why, when, where, what and how)

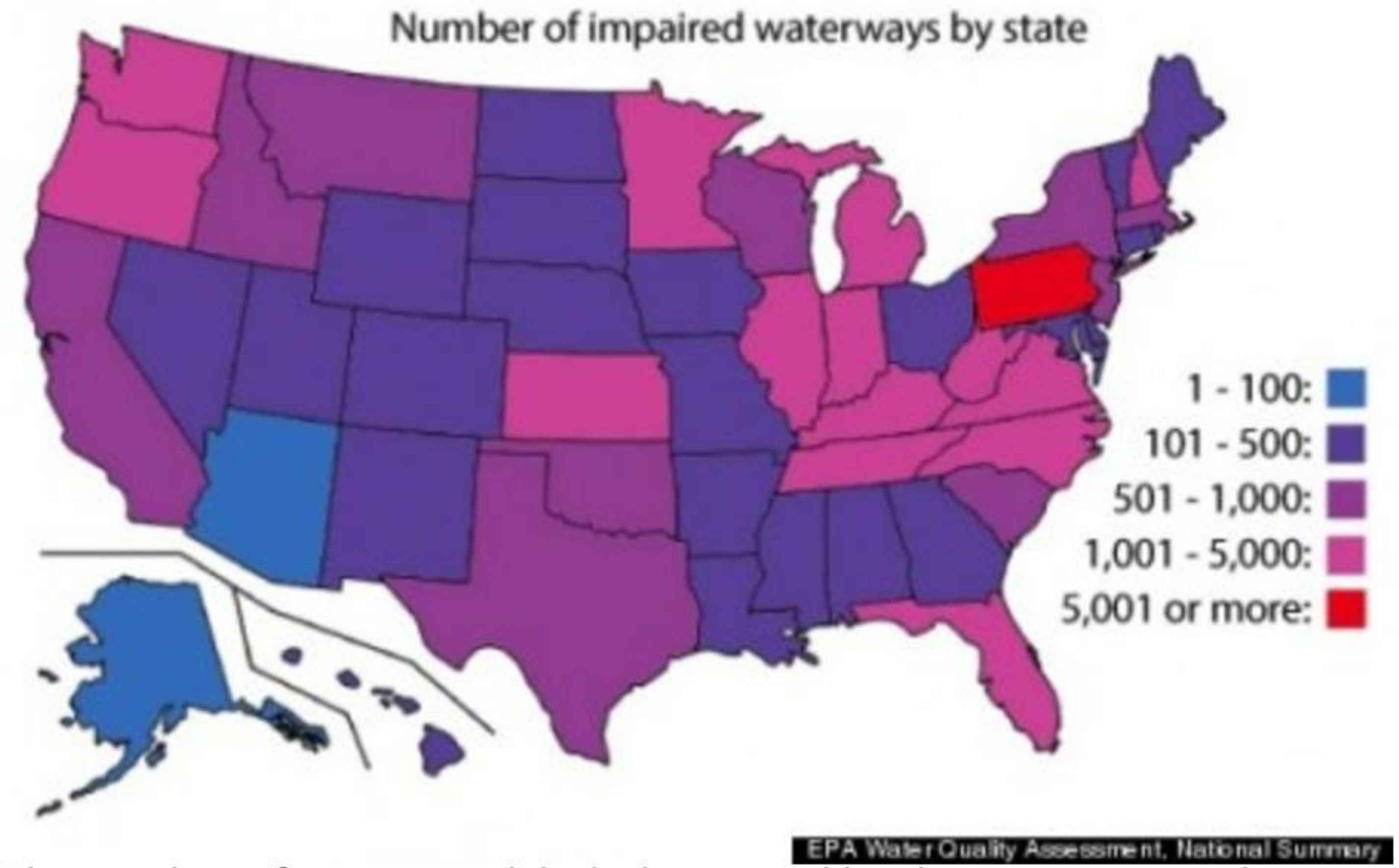
Why? Issues with microbes

- **Among all the TMDLs (including nutrients, sediments etc.), microbial contaminants (e.g. pathogenic bacteria) are ranked No. 1 causes for water quality degradation (U.S. EPA).**

(39% rivers and streams, 13% of lakes, reservoirs and ponds; 30% of assessed bays and estuaries)

STROUD WATER RESEARCH CENTER

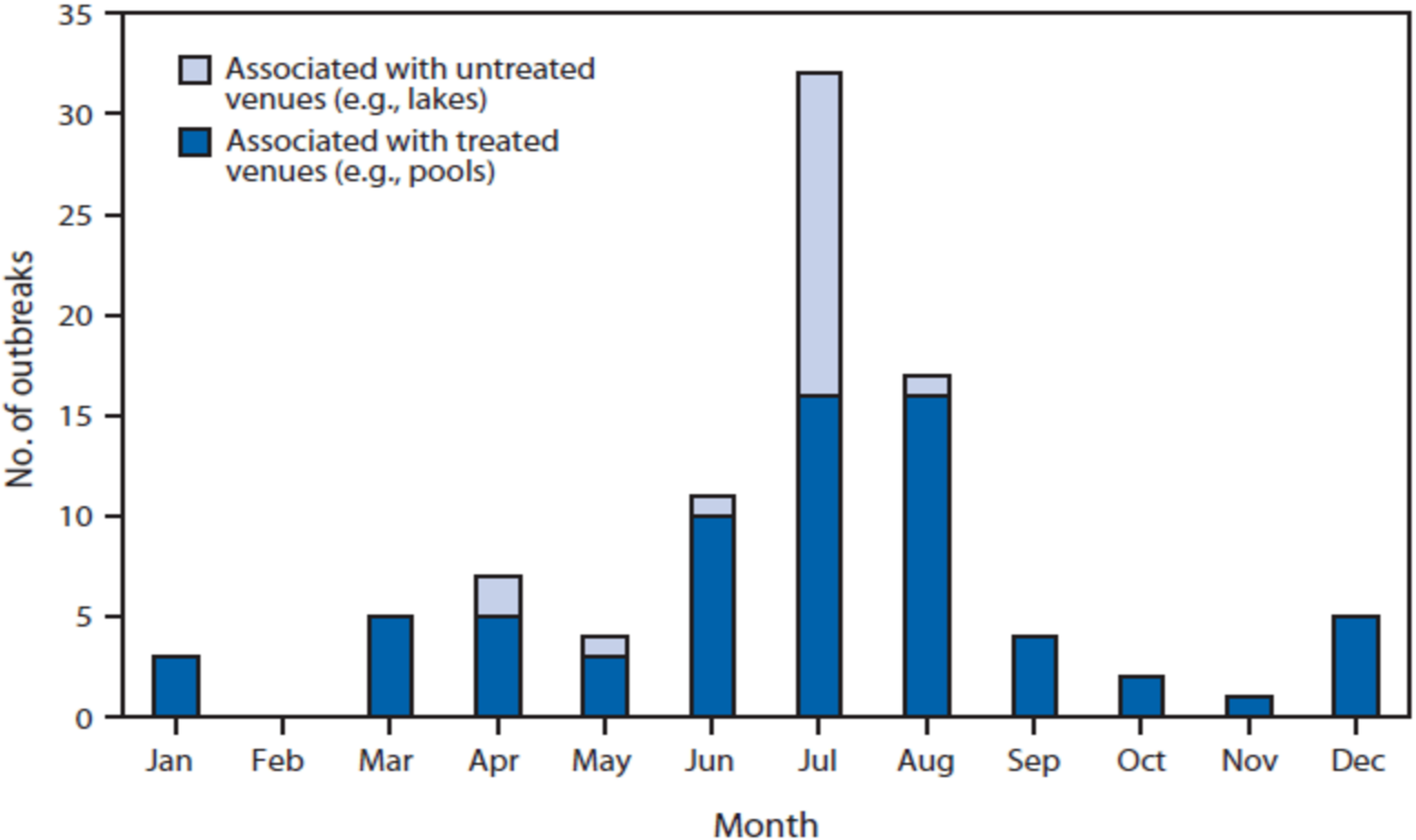
Impaired waterways in US



STROUD
WATER RESEARCH CENTER

Public Health Risk

- May cause a variety of diseases



Outbreaks of illness associated with recreational water (2011-2012)

Hlavsa et al. 2015 CDC

When?



Recreational season: June-August; Primary and secondary contact

STROUD
WATER RESEARCH CENTER

When

Baseflow: providing baseline data and reflect normal conditions

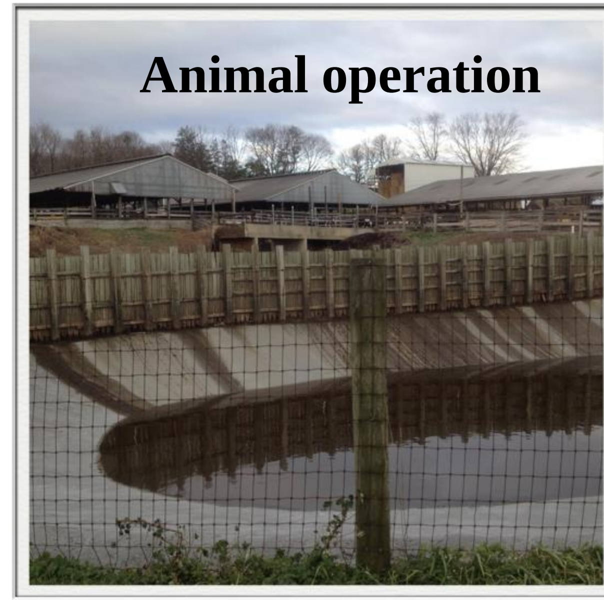
Storm flow: always higher because of the high turbidity and particles; if storm sampling, try to cover the full spectrum of hydrograph and turbidity graph

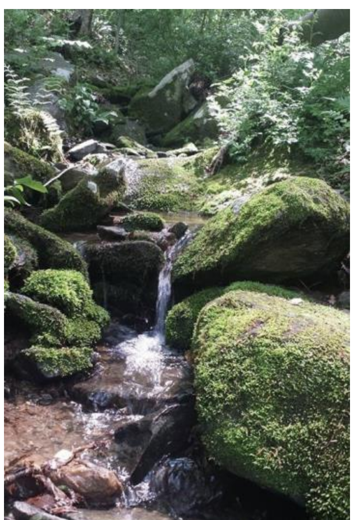
Time of a day: Same time of a day, but it is not easy to control. Different physical, chemical and hydrological conditions like pH, water level, light, dissolved oxygen, flow, temperature etc. etc.

In general, the more data the better (variability, sensitivity, dynamics etc.)

STROUD WATER RESEARCH CENTER

Where?





Forested

Wastewater treatment plant

Where

Background collection: stream/watershed maps, critical infrastructure, review reports, historic data, storm water and wastewater management, etc.

Sampling sites: in a well mixed area of flowing water; pick good control sites

Point sources (e.g. wastewater treatment, animal operation etc.): upstream vs. downstream

Non-point sources (agriculture-crop, urbanization etc.): spatial coverage; same location in repeated sampling; control sites

STROUD WATER RESEARCH CENTER

What: Fecal Indicator Bacteria

Pathogenic microbes are likely associated with fecal waste, BUT very difficult to measure directly (expensive and impractical)

Fecal indicator bacteria (FIB)

a. *Be present when pathogens are present and vice versa*

b. *More numerous than pathogen*

c. *Easier to cultivate in lab than pathogen*

d. *More resistant to die-off in field than pathogen*

STROUD™ WATER RESEARCH CENTER

What Bacteria being monitored

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

- Public health agencies have used total coliforms and fecal coliforms as indicators since 1920s
  - non-fecal origin bacterial groups
  - coliforms can regrow in natural environments
  - Still being used in many states and agencies

- *E. coli* and *Enterococcus*
  - More specific bacterial groups
  - Commonly used in these days
  - Recommended by US EPA (2012)

STROUD™ WATER RESEARCH CENTER

What bacteria should I monitor?

Depends on what you want to know

- **Health risk from recreational water contact**:

  Best indicators in freshwater*: E. coli* and *enterococci*; for salt water, *enterococci*

- **Meets state water quality standards**

  Follow the state standards, may be total or fecal coliform

Stroud Water Research Center

State Bacteria Monitoring

Water contact (WC): Swimming season- *E.coli* and fecal coliform; non-swimming season- fecal coliform.

Portable Water supply (PWC): Total coliform

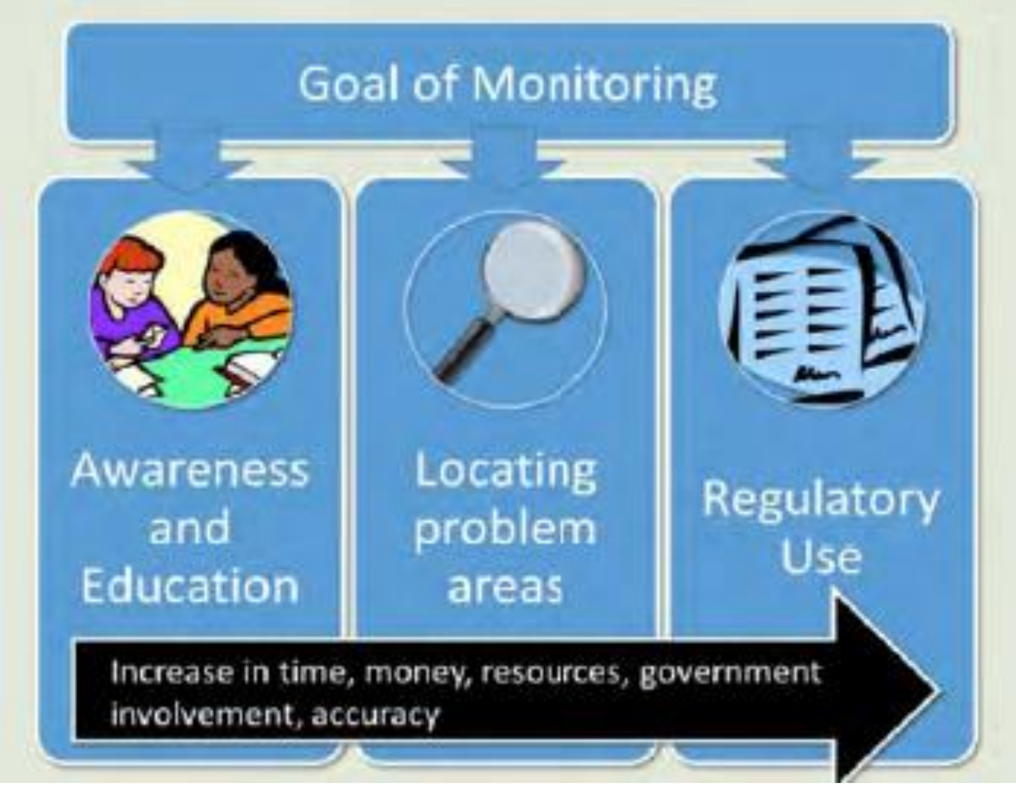
Total and fecal coliform

Primary: *E.coli* and *Entero*
Secondary: Fecal coliform

E.coli and *Entero*

Primary: *Entero*
Secondary: *Entero*

Understand your goals



- *Do you want to know whether swimming in your stream poses a health risk?*
- *Do you want to know whether your stream is meeting state water quality standards*

Method selection

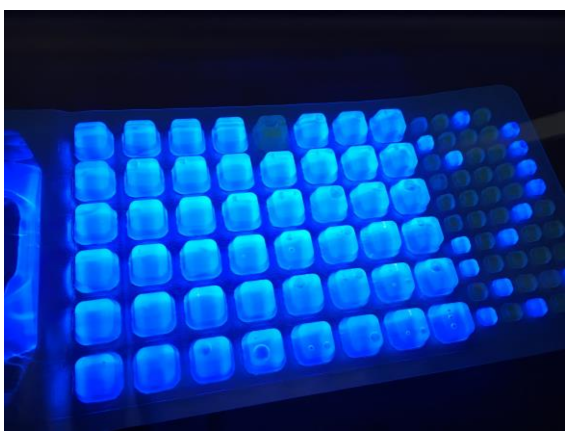
- Use stringent, EPA-approved methods if:
  a) Providing data to State or other regulatory body
  b) Providing scientific evidence of a problem
  c) Other reasons to provide defensible data

- Use simple methods if:
  a) New bacteria monitoring program without funds for big investments;
  b) Data for internal management decisions only
  c) Just need sense of baseline or magnitude of bacteria in your area of concern

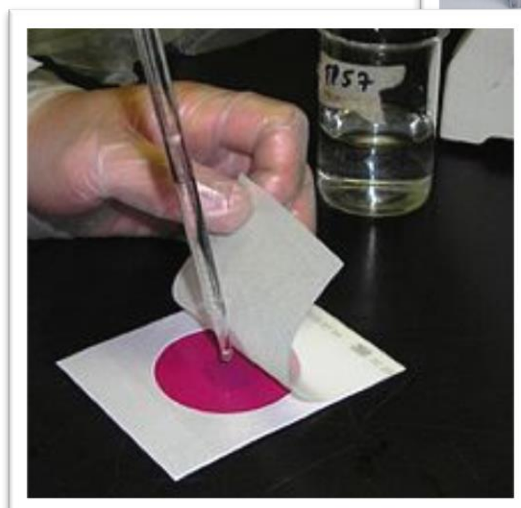
STROUD™ WATER RESEARCH CENTER

Setups at Stroud Center

IDEXX Colilert and Enterolert
(EPA-approved method)



Simple method (3M Petrifilm)



Collecting water samples

- Use Whirl-pak® to sample upstream of yourself
    - **Factory-sealed, presterilized, disposable**

- Clearly label samples and blank

- Collect water from a well mixed area of flowing water

- Baseflow, once a month or 5 times within 30 days, same time of day, different season or summer

- Place **samples in cooler with ice** after collection
    - **Exposure to UV will decrease bacteria levels**

- **Holding time** for samples on ice or refrigeration is for **6 hours, but no more than 24 hours**

QA/QC

- **Sample collection**:
  - Sterile sampling bags (whirl-pak) with appropriate labels (site, name, sample date, time), avoid contamination
  - Proper sampling: glove worn, flowing water, no sediment included; fill the bag about 2/3 full
  - Transporting samples: holding time (6 hours), storage temperature 1-4°C; do not allow melted ice water to submerge your sample

- **Sample processing**:
  - Glove worn, sterile bottles, pipettes and pipette tips, etc.
  - Blank/control: field blank, and negative controls, etc.
  - Replicates

- **Data management, interpretation and reporting**

STROUD™ WATER RESEARCH CENTER

Bacteria are not alone!

Bacterial growth can be impacted by almost all physical, chemical conditions, therefore it is important to measure environmental parameters, water chemistry etc.:

- **Nutrients**
- **pH**
- **Temperature**
- **Oxygen and other gases**
- **Ionic strength and osmotic pressure**
- **Light**

STROUD
WATER RESEARCH CENTER

What may increase bacterial

- **Point or non-point source contaminations**

- **Increased temperature: survival and proliferation of bacteria (summer vs. winter)**

- **Rainfall and flooding: facilitate rapid transportation**

Ontario Canada (Marsalek and Rochfort, 2004)

E. coli in stormwaters: 10^3 – 10^4 cfus per 100 ml

in sewer overflows: 10^6 cfus per 100 ml

STROUD™ WATER RESEARCH CENTER

What may decrease bacterial

- **Lower temperature: survival and proliferation of bacteria (winter)**

- **BMPs, restoration efforts: Pasture management, runoff management, riparian protection, manure management etc.**

Buffers can reduce bacteria by 43 to 57%, especially in agricultural watersheds

Fencing livestock out of streams is a highly effective method of reducing the amount of bacteria in surface waters (A. Boyer, DNREC, DE)

STROUD WATER RESEARCH CENTER

Role of Citizen Monitoring

- Fill gaps of agencies' water monitoring programs
  a) Use more specific bacterial indicators
  b) Monitor where agencies are not
  c) Monitor when agencies are not
  d) Local water quality issues

STROUD™ WATER RESEARCH CENTER

Summary

Monitoring bacteria: why, when, where, what, how

a. Why: identify issues, problems or general goal
b. When: Same time of day; baseflow or storm samples; once a month or 5 times within 30 days
c. Where: up vs. downstream, same location and in a well mixed area of flowing water;
d. What: Total, Fecal, *E.coli*, *Enterococci* or others
e. How: methods selection

STROUD WATER RESEARCH CENTER

Jinjun Kan, PhD
Stroud Water Research Center

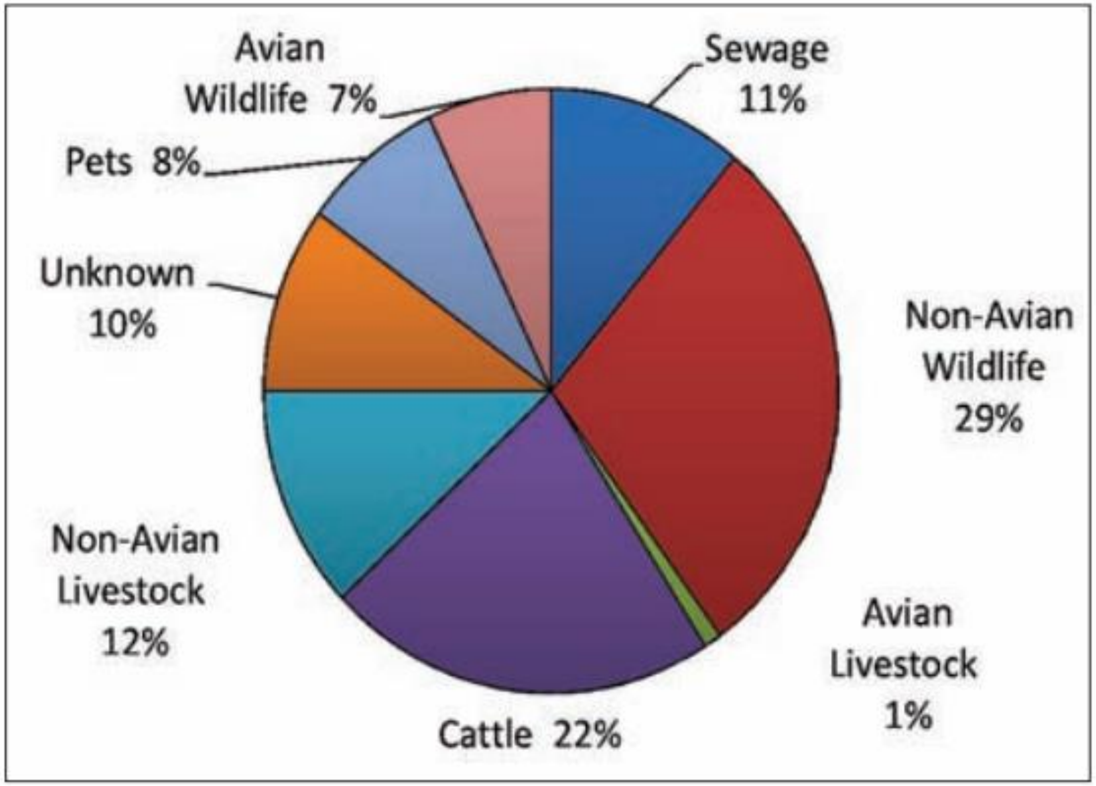
jkan@stroudcenter.org
610 268 2153 ext 280

How source tracking can help?

To pinpoint specific sources of bacteria

STROUD
WATER RESEARCH CENTER

How source tracking can help?



Peach Creek Watershed, TX

STROUD WATER RESEARCH CENTER

BMP	Land Area Needed	Cost	Total Nitrogen % Reduction	Total Phosphorus % Reduction	Suspended Solids % Reduction	Bacteria Reduction %
Buffer Strips	Low	Medium	20 - 60	20 - 60	20 - 80	43-57
Constructed Wetlands	N/A	N/A	-103	-217	-398	78-90
Sand Filters	N/A	N/A	47	41	57	36-83
Dry Detention Pond	High	High	15	25	70	
Infiltration Trenches	Low	Medium	45 - 70	50 - 75	75 - 99	
Wet Ponds*	Medium	High	0.4	0.5	55-94	44-99
Biofiltration	N/A	N/A	25	34		>99
Bioswales	Low	Medium	25	34	70	
Storm water wetlands	N/A	N/A	30	49	N/A	78-90

*If Properly Managed

(A. Boyer, DNREC, DE)

Stroud Water Research Center