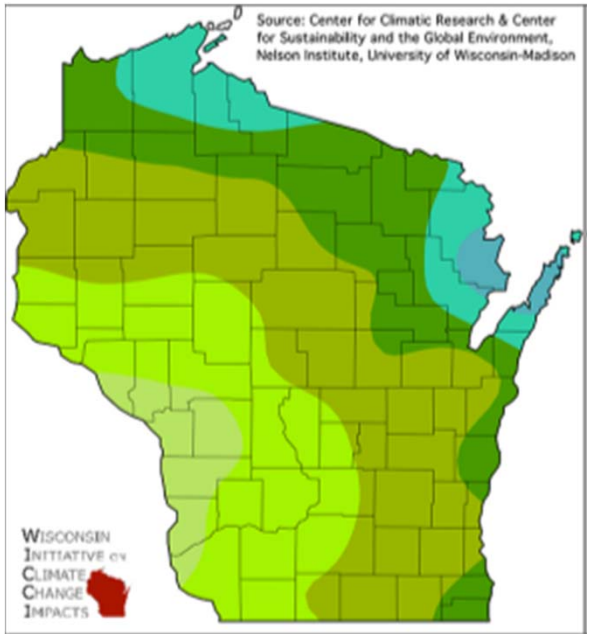
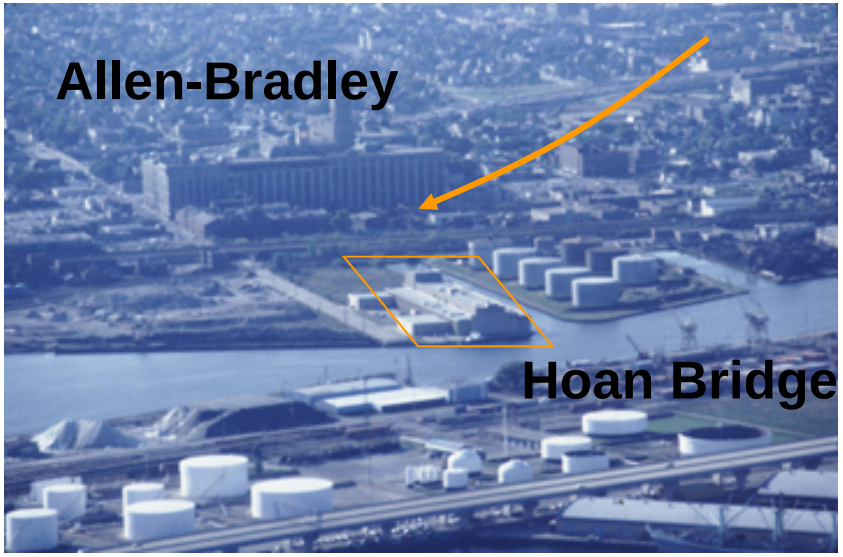
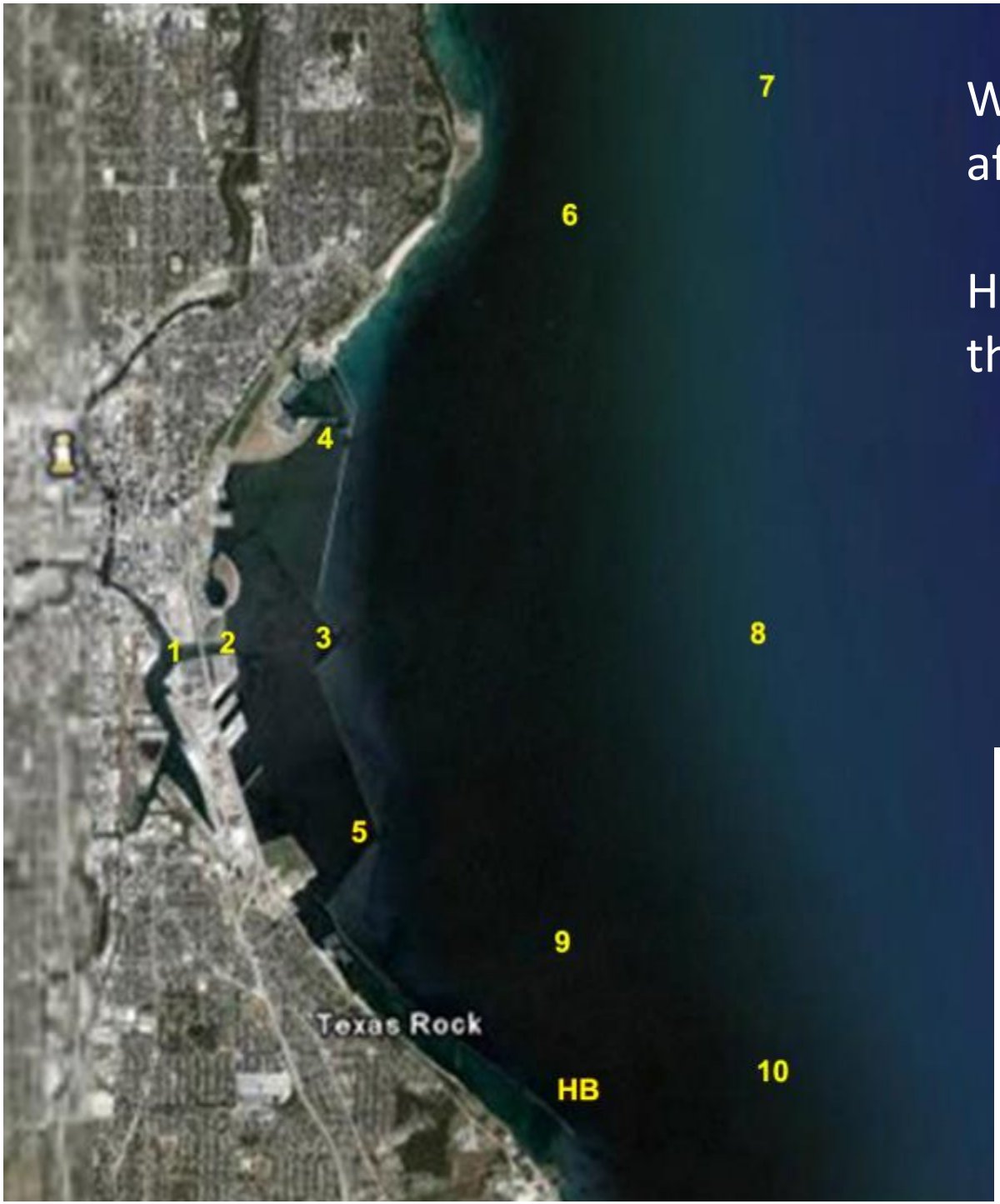
Climate Change: Effects of Extreme Rain Events and Human Health

Sandra McLellan
School of Freshwater Sciences
University of Wisconsin-Milwaukee



School of Freshwater Sciences@
Great Lakes WATER Institute
University of Wisconsin-Milwaukee





What runs off the land affects the water

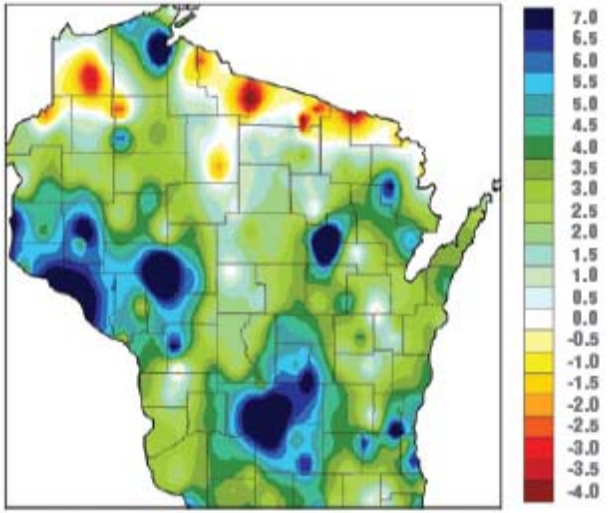
How will climate change this?

Today's talk

Waterborne disease and indicators of fecal pollution

Fecal pollution in Lake Michigan: Sources and distribution

Climate change influences on sources of waterborne pathogens

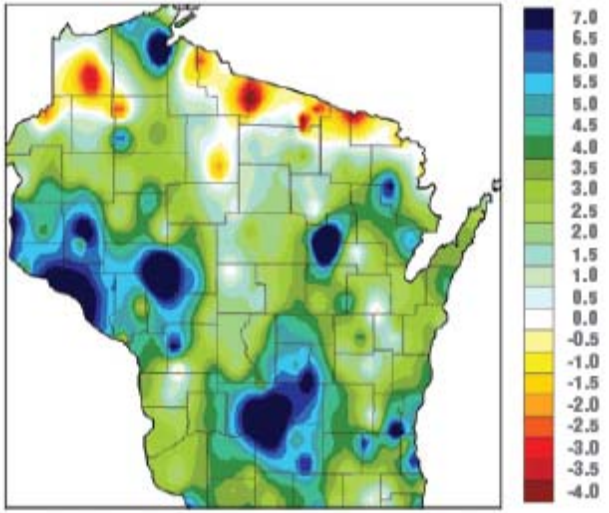


Today's talk

Waterborne disease and indicators of fecal pollution

Fecal pollution in Lake Michigan: Sources and distribution

Climate change influences on sources of waterborne pathogens



Waterborne disease

Sources of fecal pollution:

Agricultural runoff
Sewage discharges
Urban stormwater (non-point source runoff)
Wildlife

US: recreational waters and drinking water a concern
Outbreaks/illness (under-reported) Estimates: 12% of gastroenteritis

Milwaukee *Cryptosporidium* outbreak – largest in US history, 400,000 exposed

Waterborne disease

RECORD RAINFALL AND FLOW IN THE MILWAUKEE RIVER

Milwaukee *Cryptosporidium* outbreak – largest in US history, 400,000 exposed

Waterborne disease

Sources of fecal pollution:

Agricultural runoff

Sewage discharges

Urban stormwater (non-point source runoff)

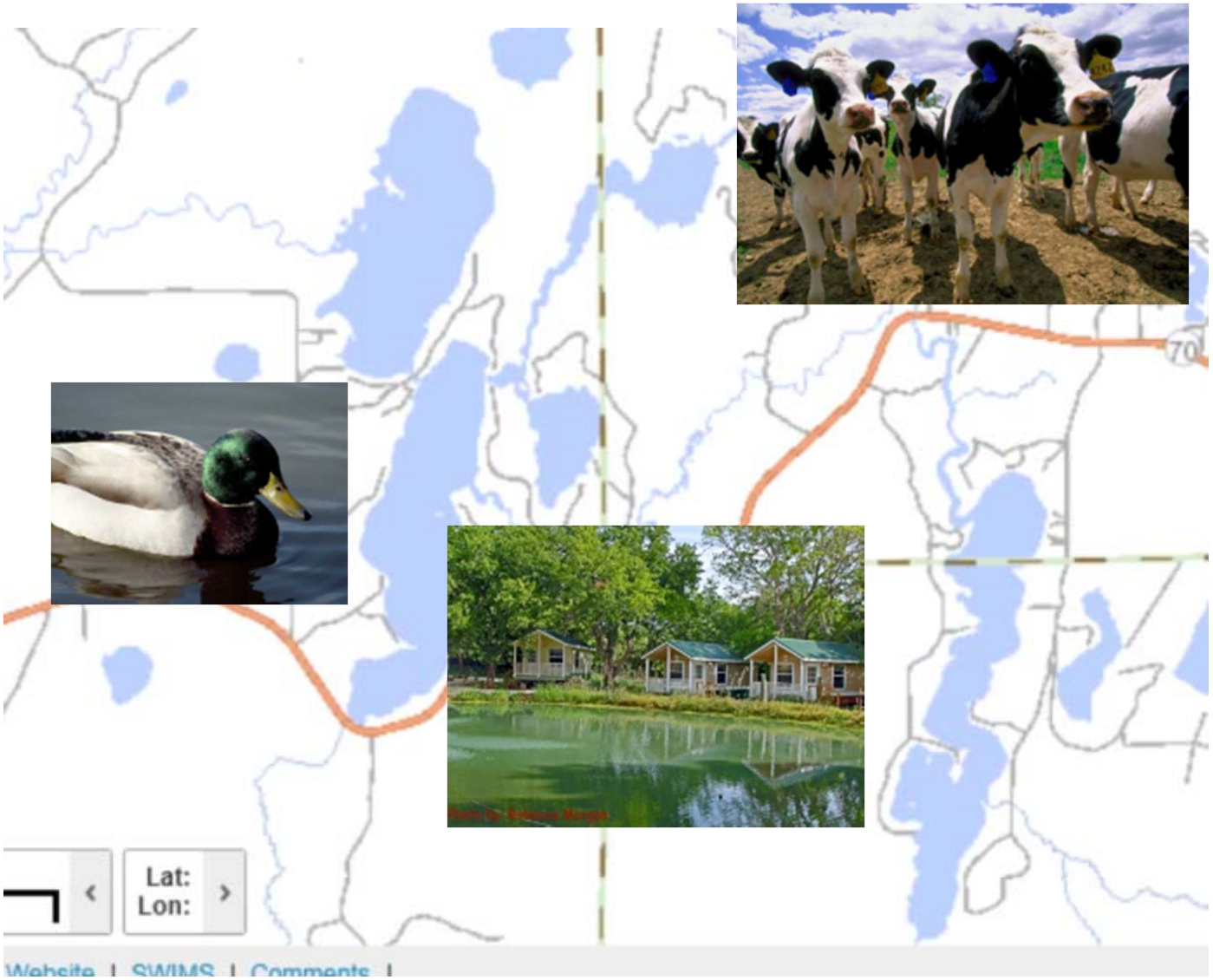
Wildlife

Urban: sewage contamination

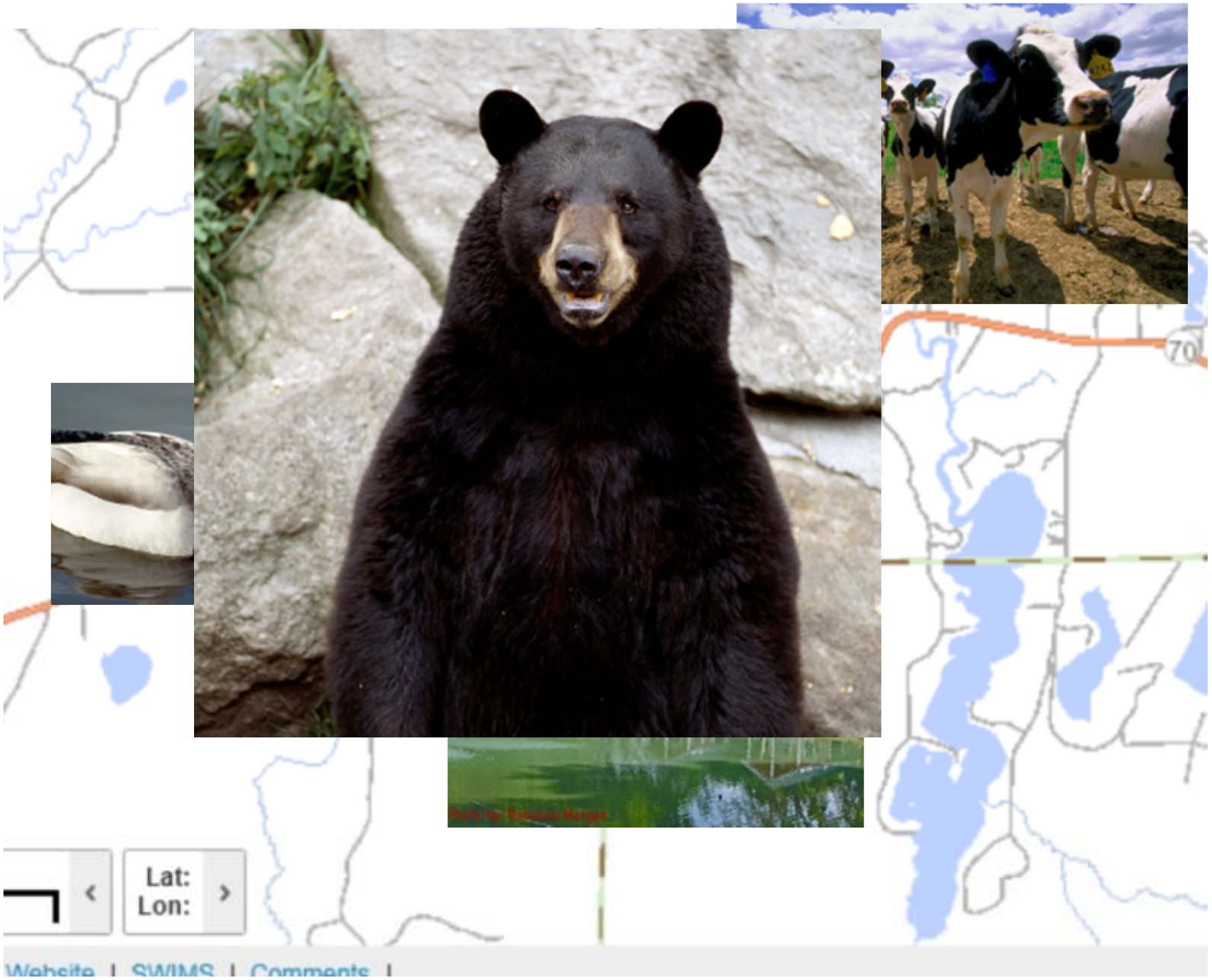
Rural: agricultural runoff

Smaller communities and vacation areas: septic failures

So what is the source to this lake?



So what is the source to this lake?



E. coli an indicator of human health risk?

EPA recommended indicator of fecal pollution

Present in almost all animals and easily detectable

PROBLEMS

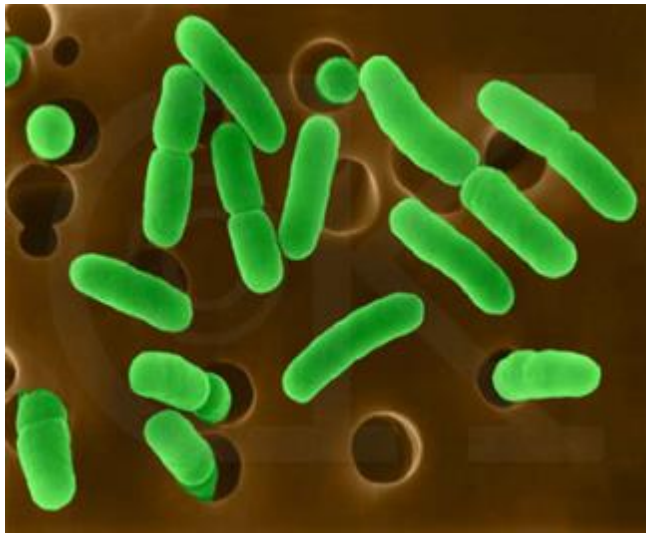
Does not differentiate the source, animal *vs.* human

Human sources = human pathogens

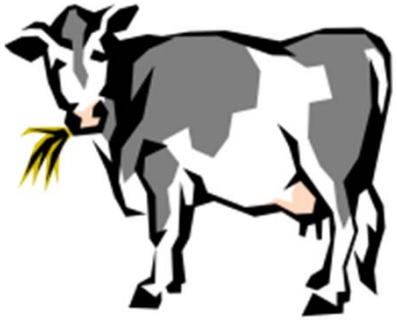
Animal sources may also be a concern: *E. coli* O157:H7, Salmonella spp.

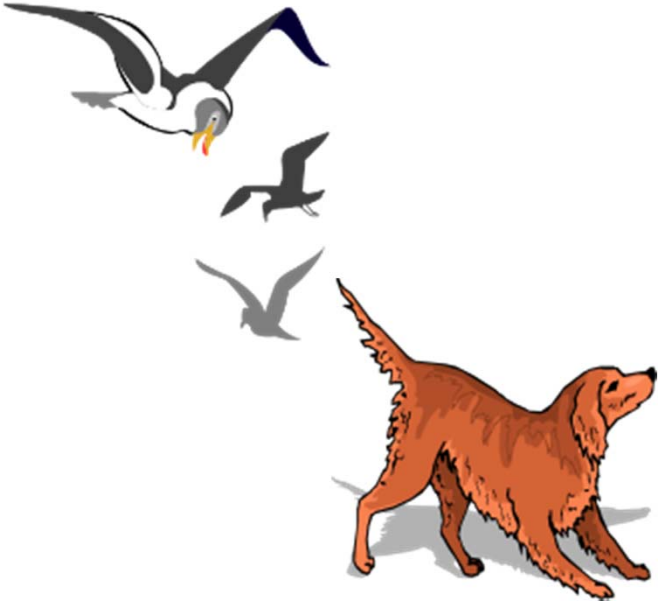
Other animals: birds, deer, etc.

E. coli can survive/grow in the environment



Fecal Pollution contains a complex mixture of organisms





Fecal coliforms

E. coli

Klebsiella pneumoniae

Enterobacter cloaceae

Gram positive

enterococci

Anaerobes

Bacteroides spp.

Prevotella spp.

Clostridium perfringens

Actinobacteria

Clostridiales

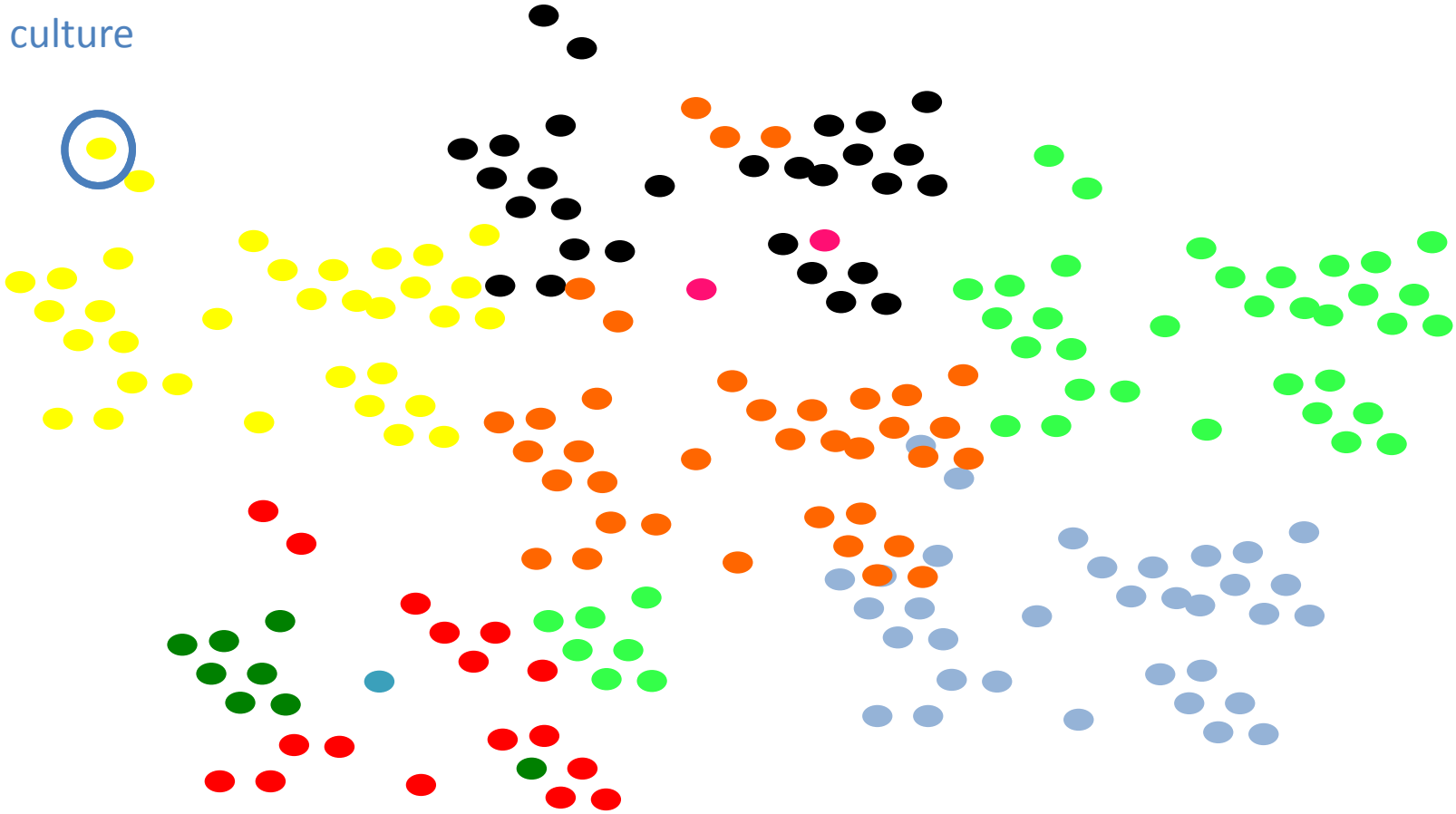
Pathogens

Salmonella

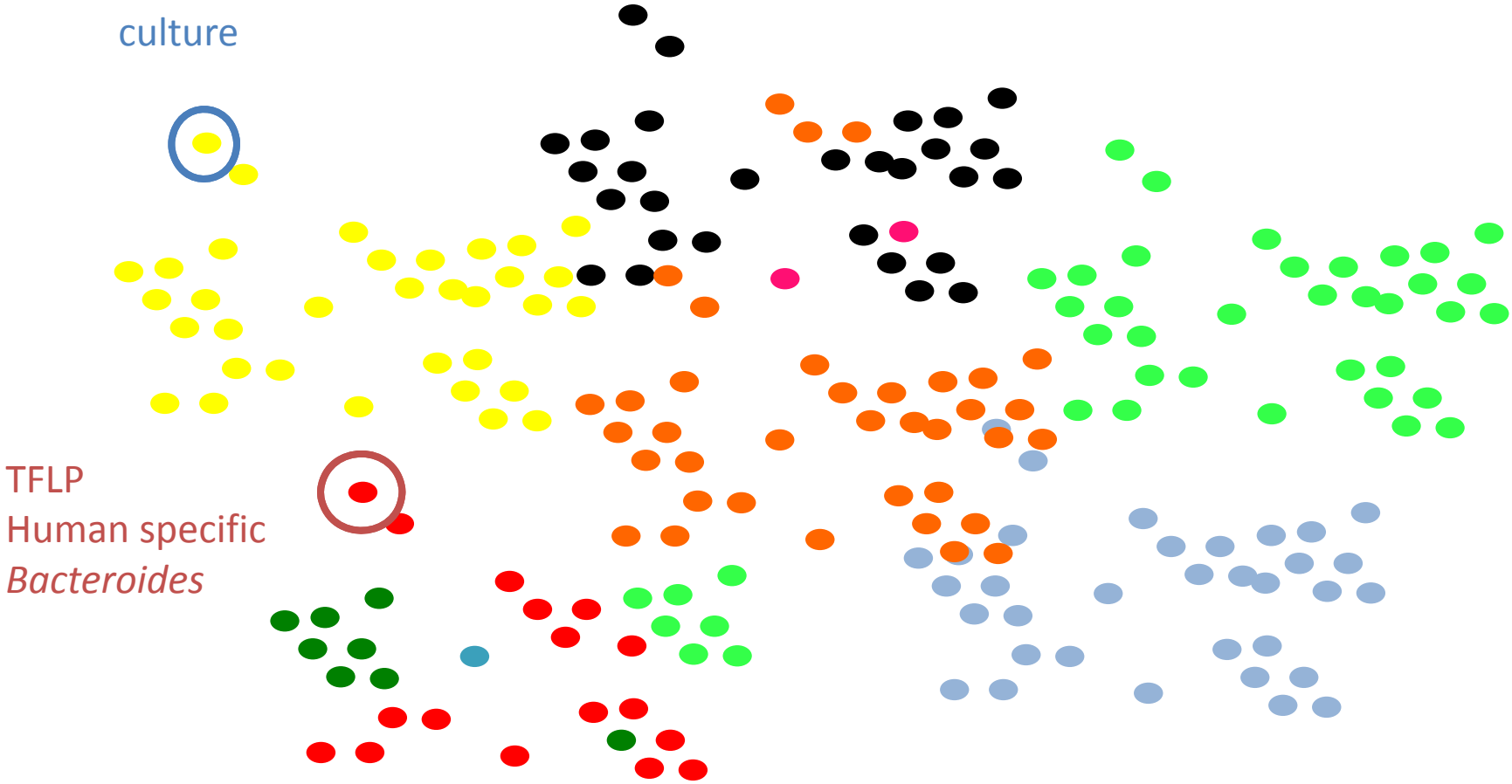
human viruses

Cryptosporidium

Sewage organisms 10^9 cells per ml

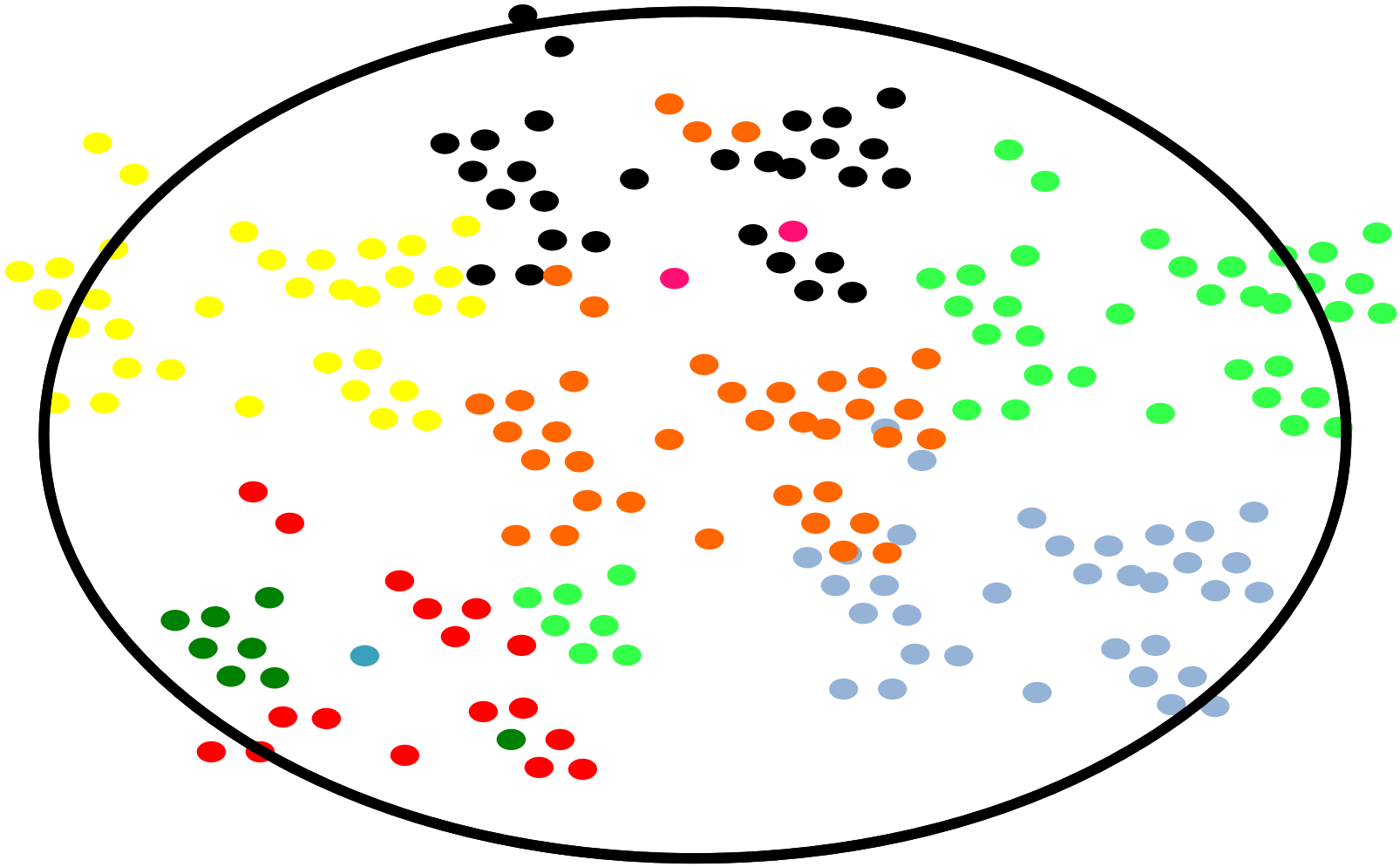


Sewage organisms 10^9 cells per ml



Sewage organisms 10^9 cells per ml

Illumina sequencing



Sequencing Sewage

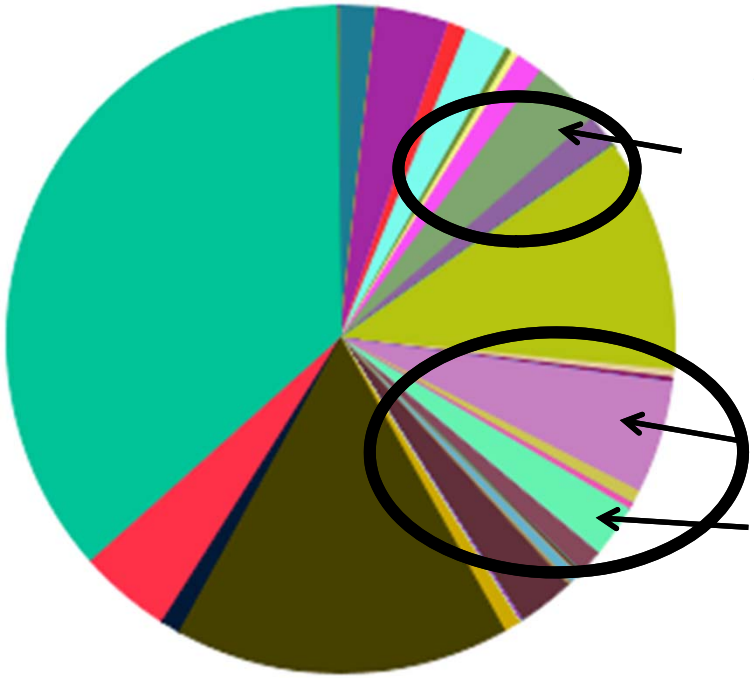
>30,000 reads per sample n=38
800 different taxa
20,000 different sequences

80% environmental origin

20% faecal origin

Acinetobacter
Aeromonas
Pseudomonas

Arcobacter
Betaproteobacteria



Actinobacteria
Bacteroides

Trichococcus

Clostridiales
Lachnospiraceae
Ruminococcaceae

sewage

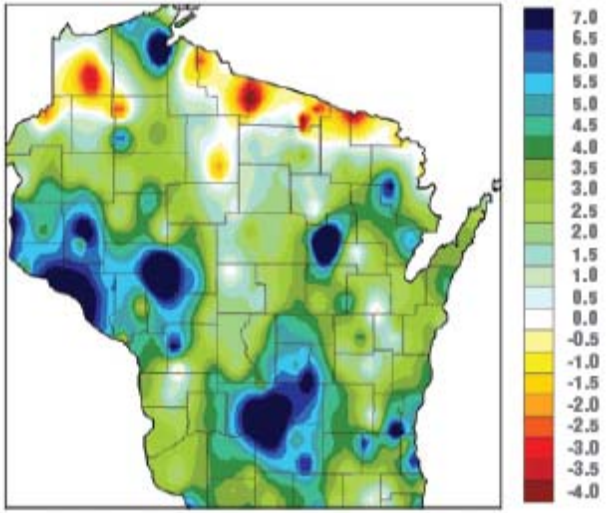
McLellan *et al.* 2010

Today's talk

Waterborne disease and indicators of fecal pollution

Fecal pollution in Lake Michigan: Sources and distribution

Climate change influences on sources of waterborne pathogens



Great Lakes - 20% of Earth's freshwater

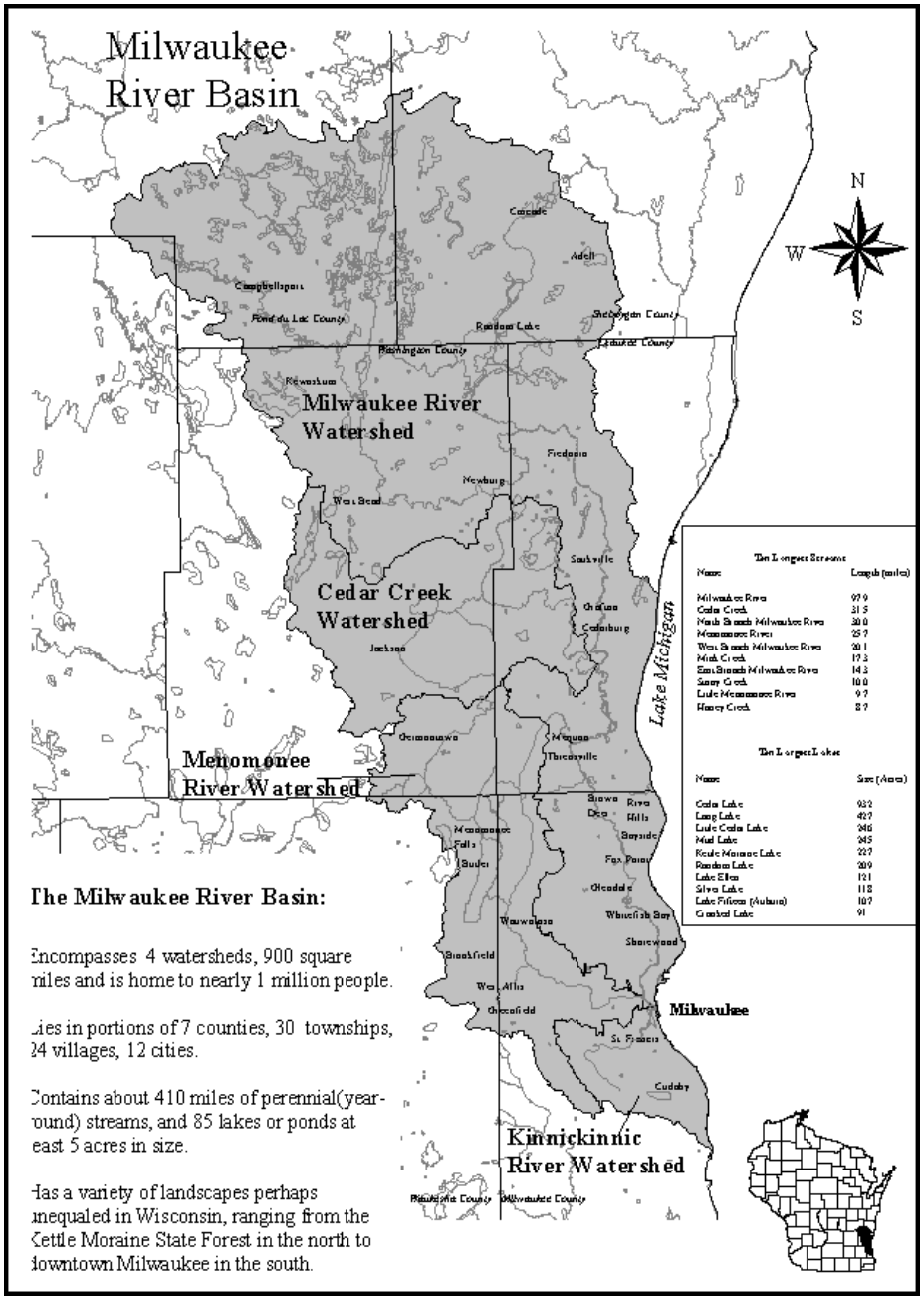
Drinking water source to 40M

500 beaches

Fecal pollution with pathogens enters from the watershed

850 square miles drain to Milwaukee Harbor

Sewage, Agricultural runoff, Stormwater

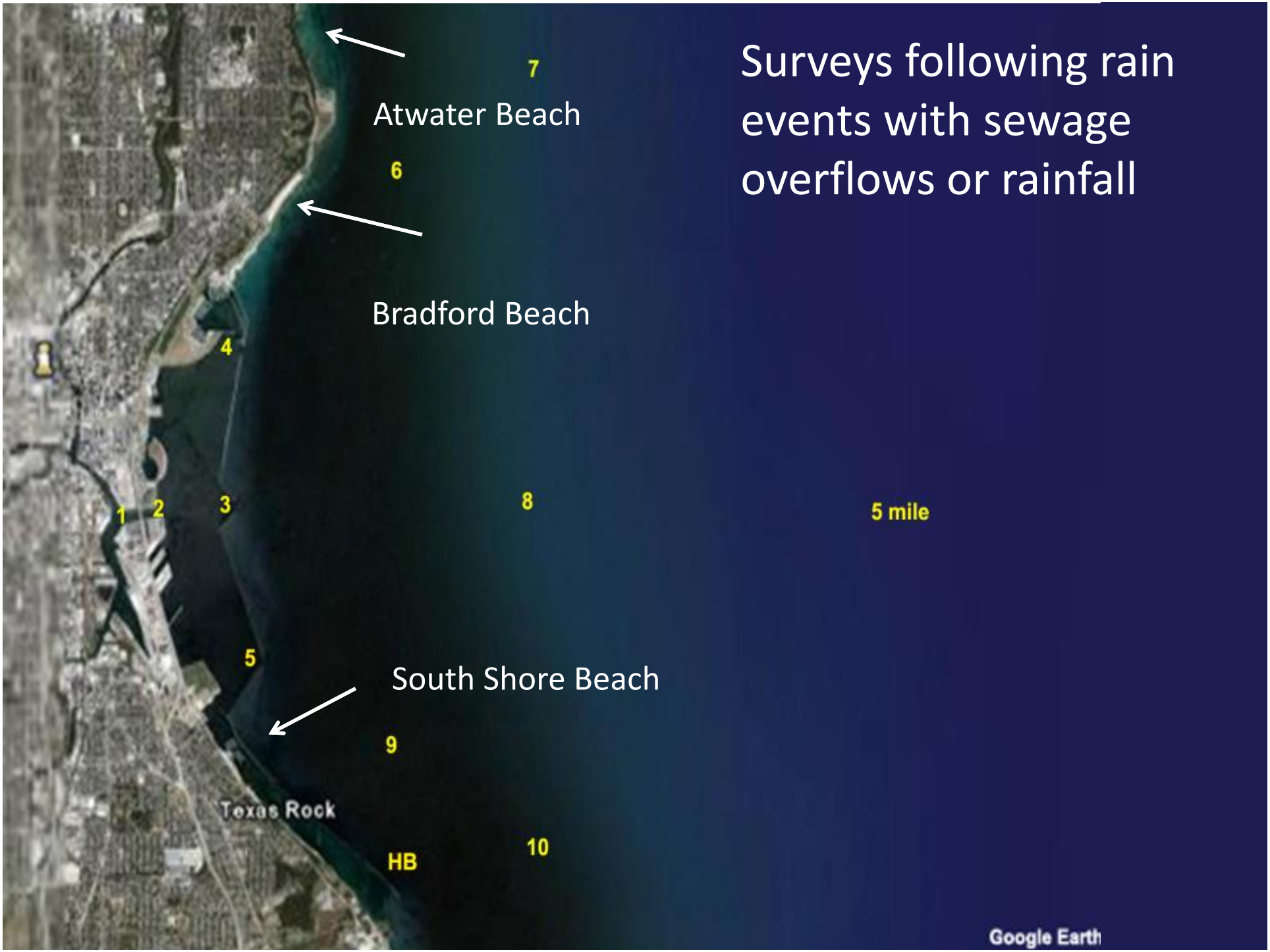


Failing sewer infrastructure: Introduces sewage every time it rains

All major cities have problems:

30% of sewage DOES NOT make it to the WWTP

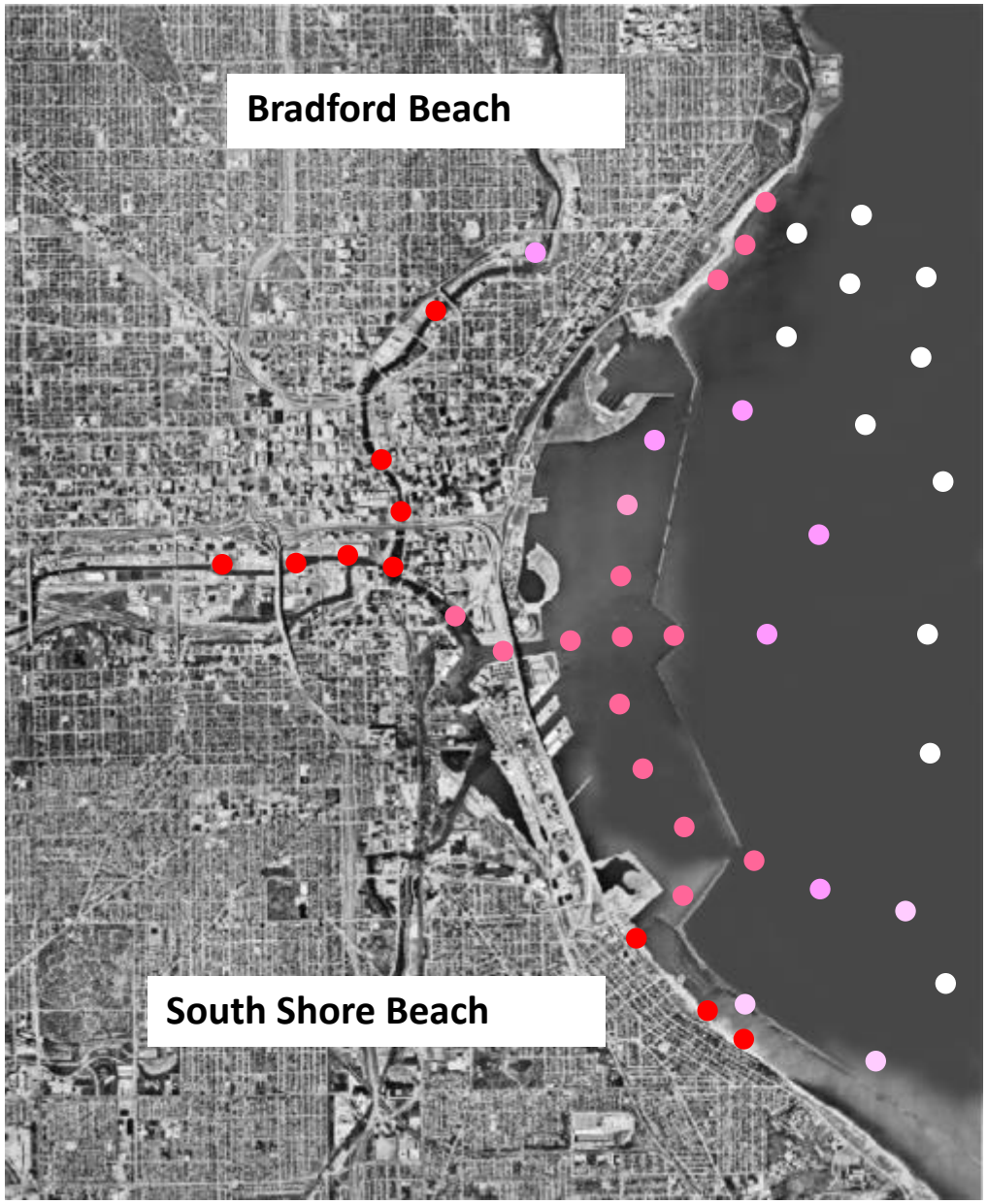

Can we track sewage
specific indicators?


Surveys following rain events with sewage overflows or rainfall
7
Atwater Beach
6
Bradford Beach
4
1
2
3
8
5 mile
5
South Shore Beach
9
Texas Rock
HB
10
Google Earth

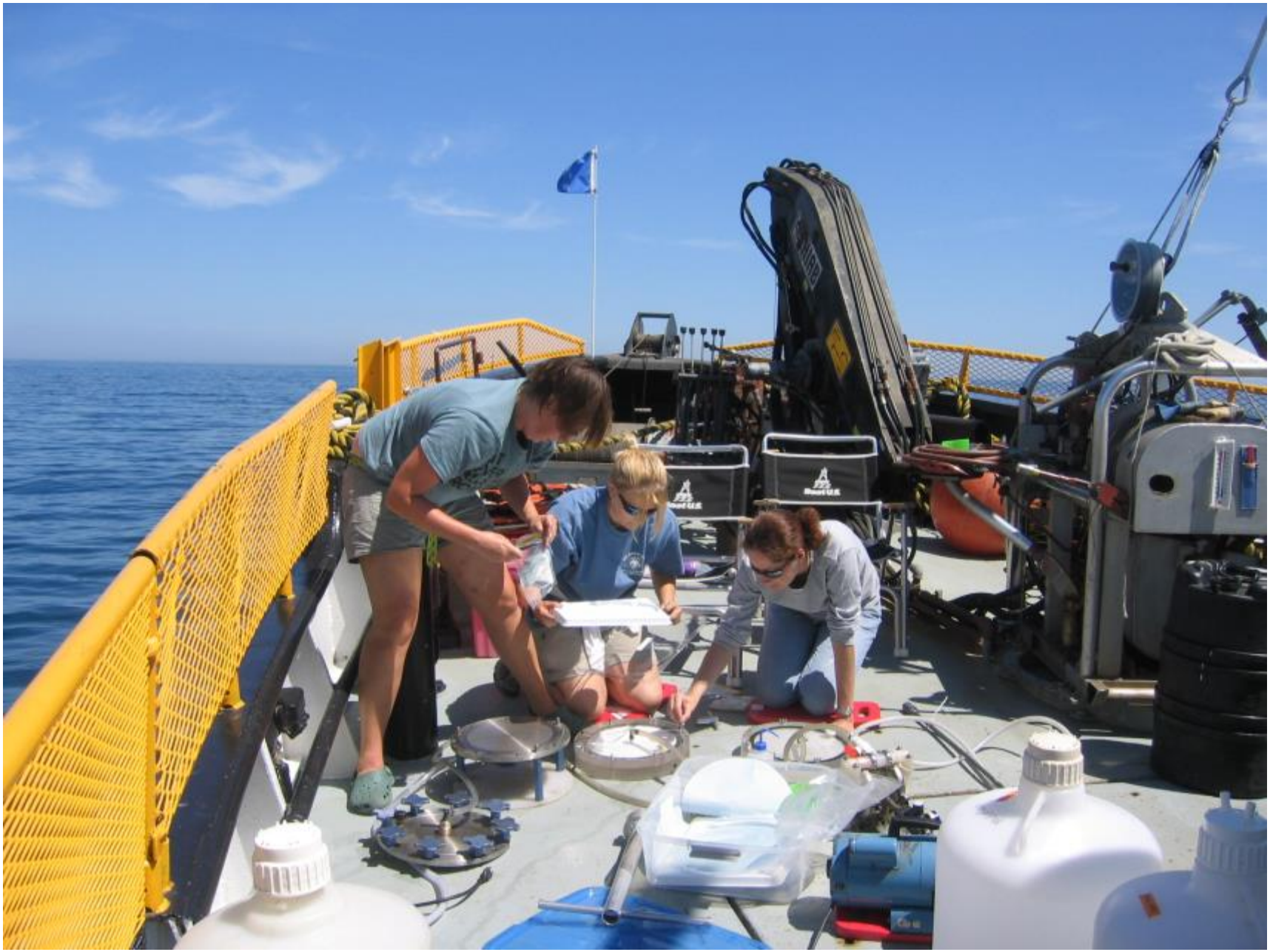
Rainfall
Urban stormwater
Sewage overflow

E. coli CFU/100 ml

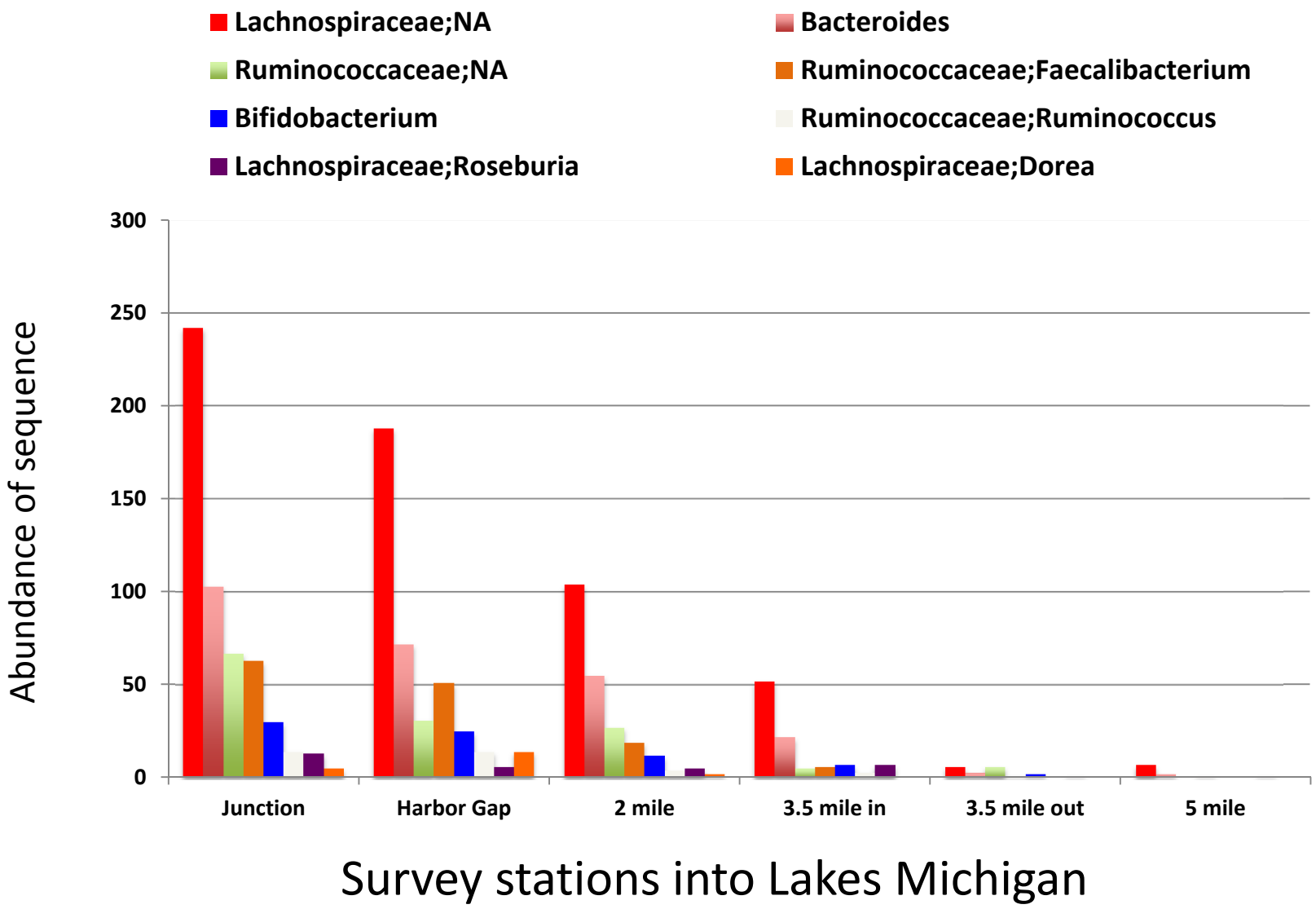
- 0-100
- 100-235
- 235-999
- 1000-9999
- 10,000-20,000



Bradford and South Shore Beach on Lake Michigan



Profiles of alternative indicators across transects into Lake Michigan

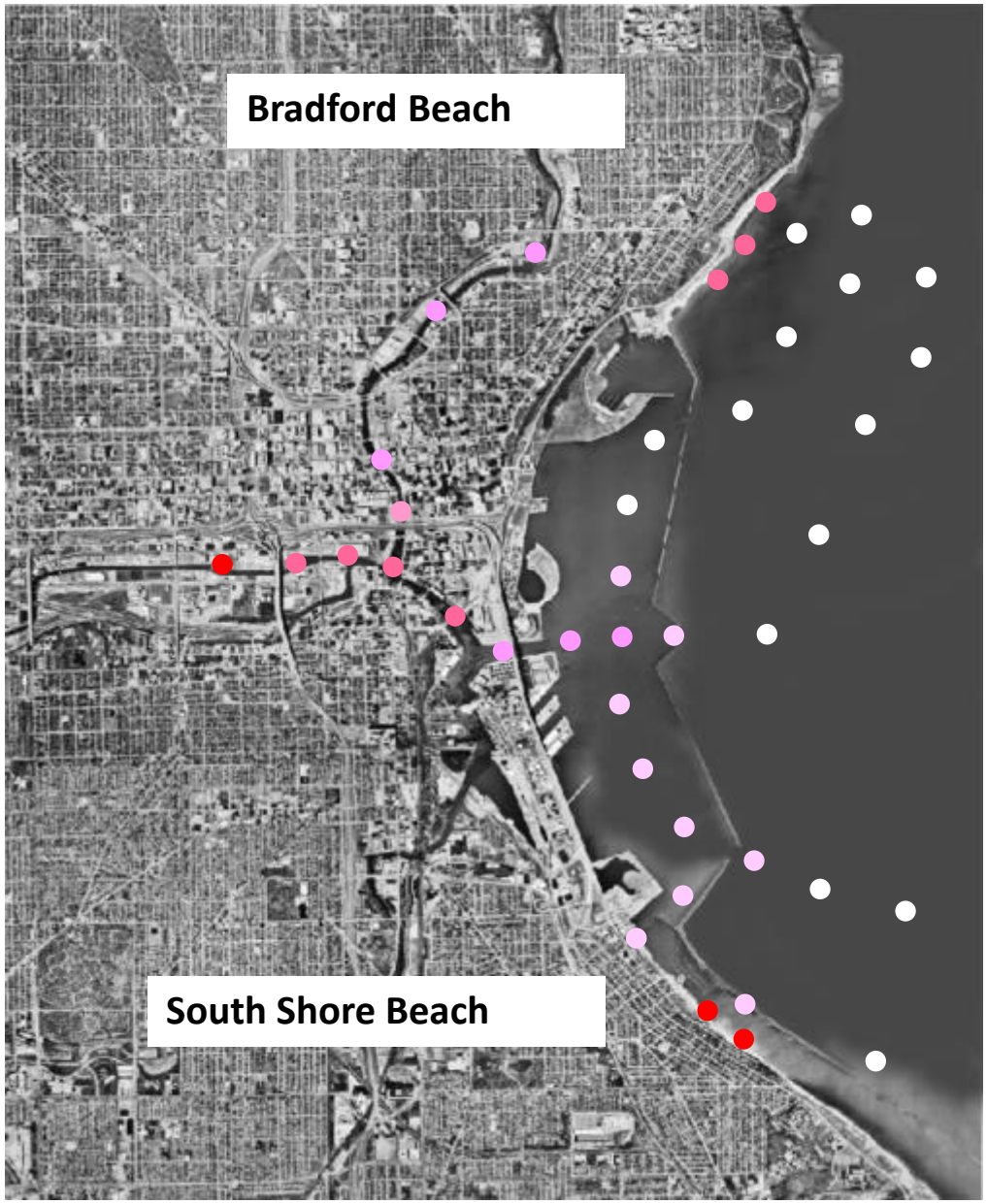


Atwater Beach

Rainfall
Urban stormwater
No sewage overflow

E. coli CFU/100 ml

- 0-100
- 100-235
- 235-999
- 1000-9999
- 10,000-20,000



Bradford and South Shore Beach on Lake Michigan

Localized sources at beaches

- Stormwater outfalls at beaches show evidence of sewage contamination

Atwater outfall 1

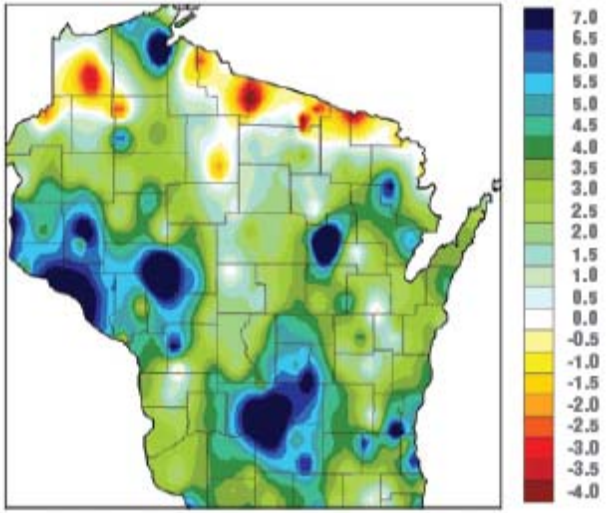
Atwater outfall 2

Today's talk

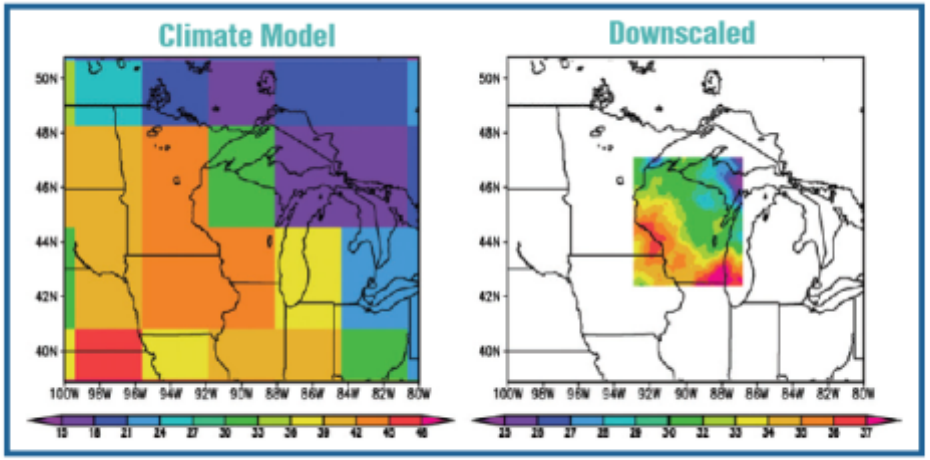
Waterborne disease and indicators of fecal pollution

Fecal pollution in Lake Michigan: Sources and distribution

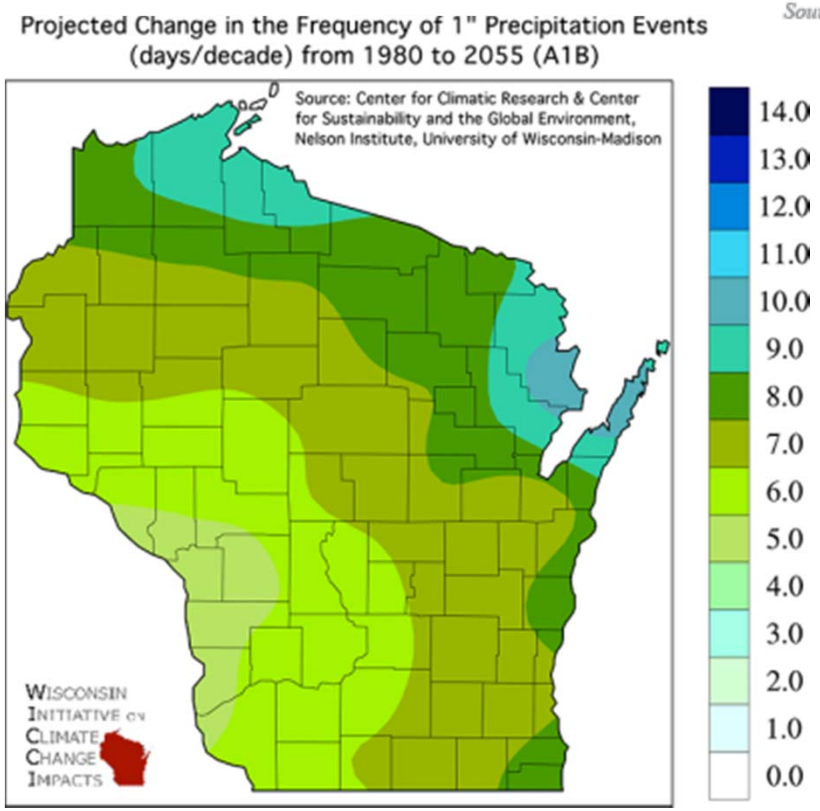
Climate change influences on sources of waterborne pathogens



How will our climate change?



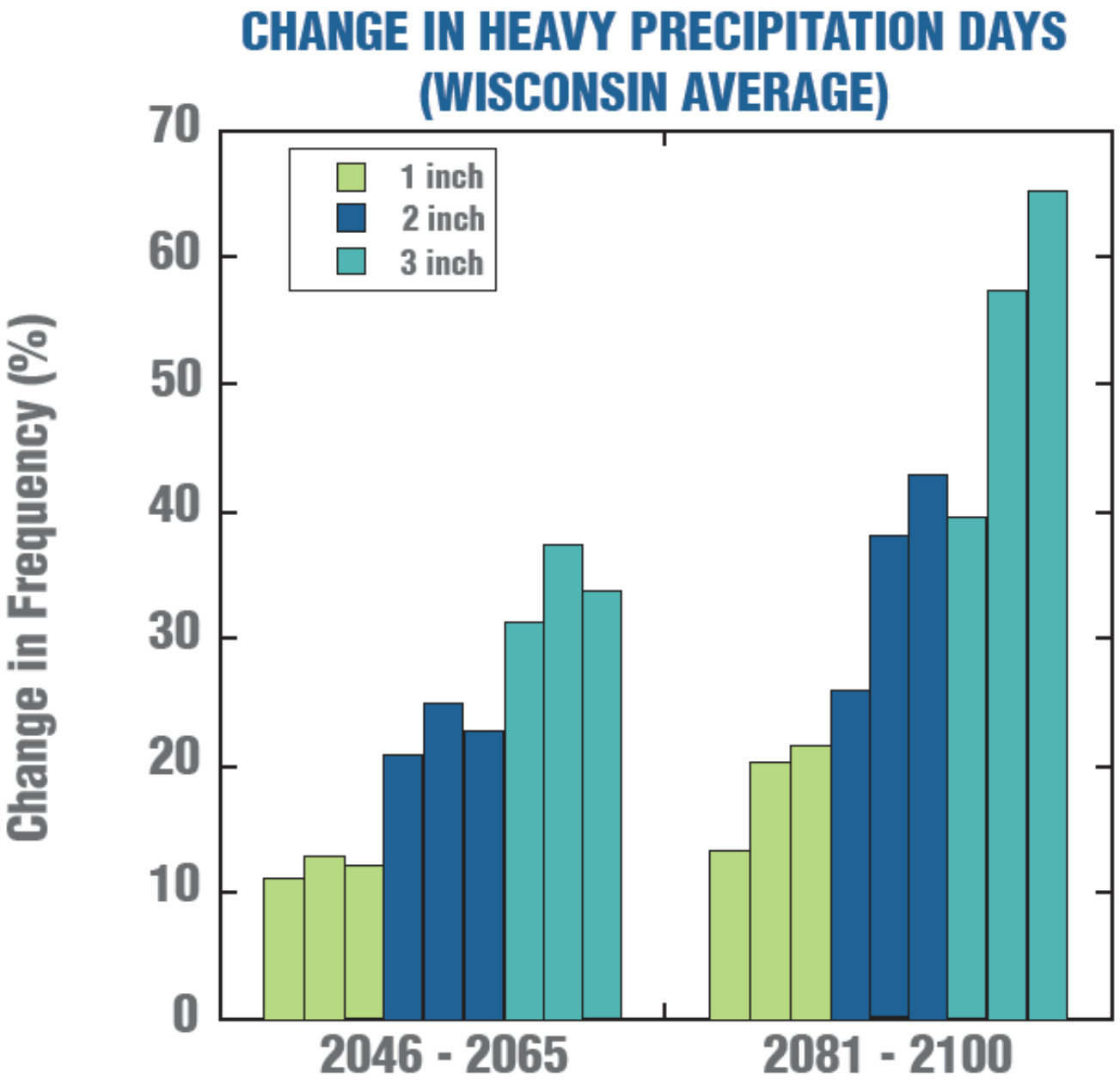
Source: David Lorenz, Nelson Institute Center for Climatic Research, University of Wisconsin-Madison



Increases of rainfall frequency and intensities projected for the Great Lakes

Intense rainfall or extreme rainfall inundates urban wastewater infrastructure and drives runoff

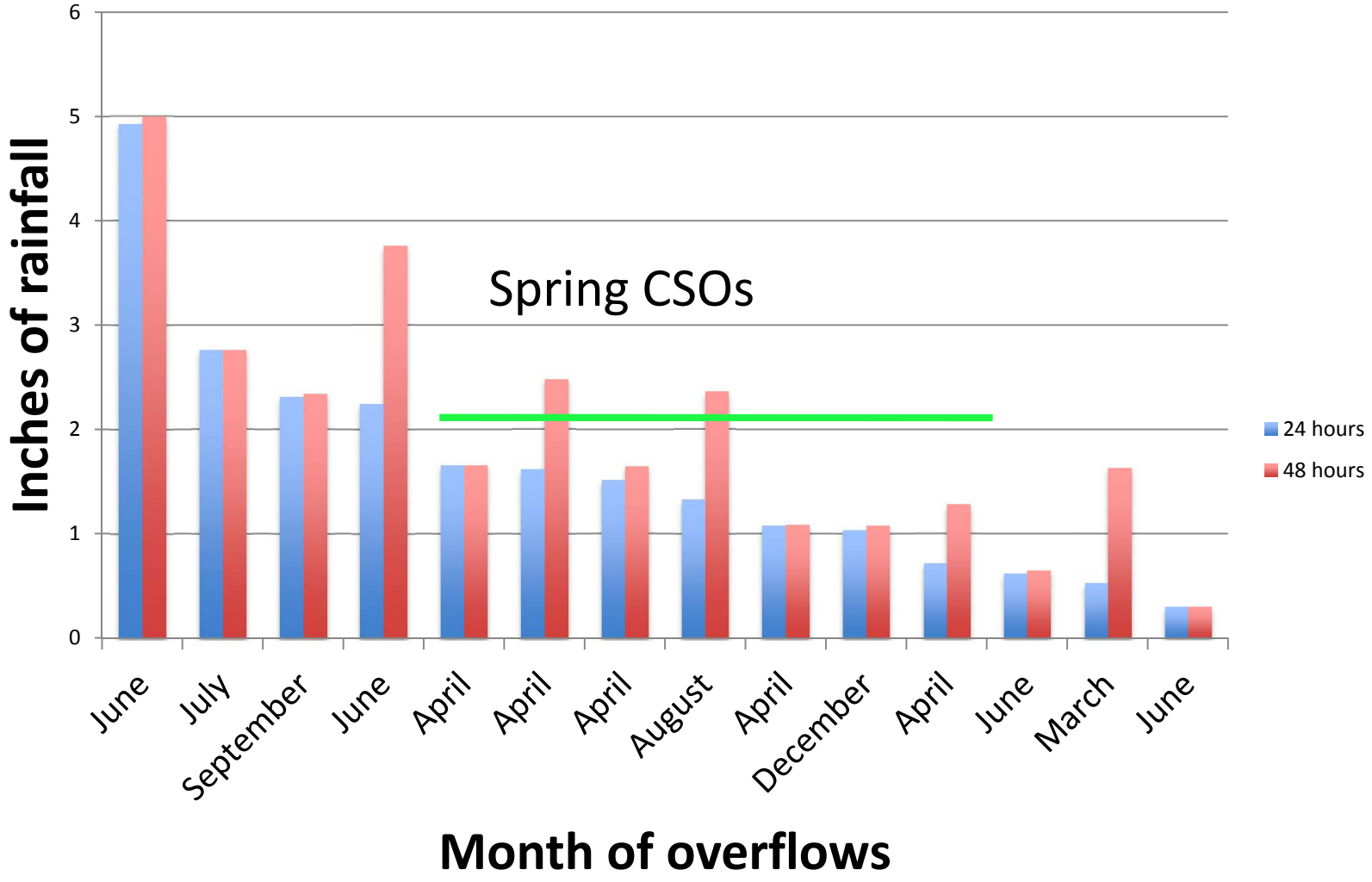
http://www.wicci.wisc.edu/climate-change.php



http://www.wicci.wisc.edu/climate-change.php

Spring rainfall sensitive parameter

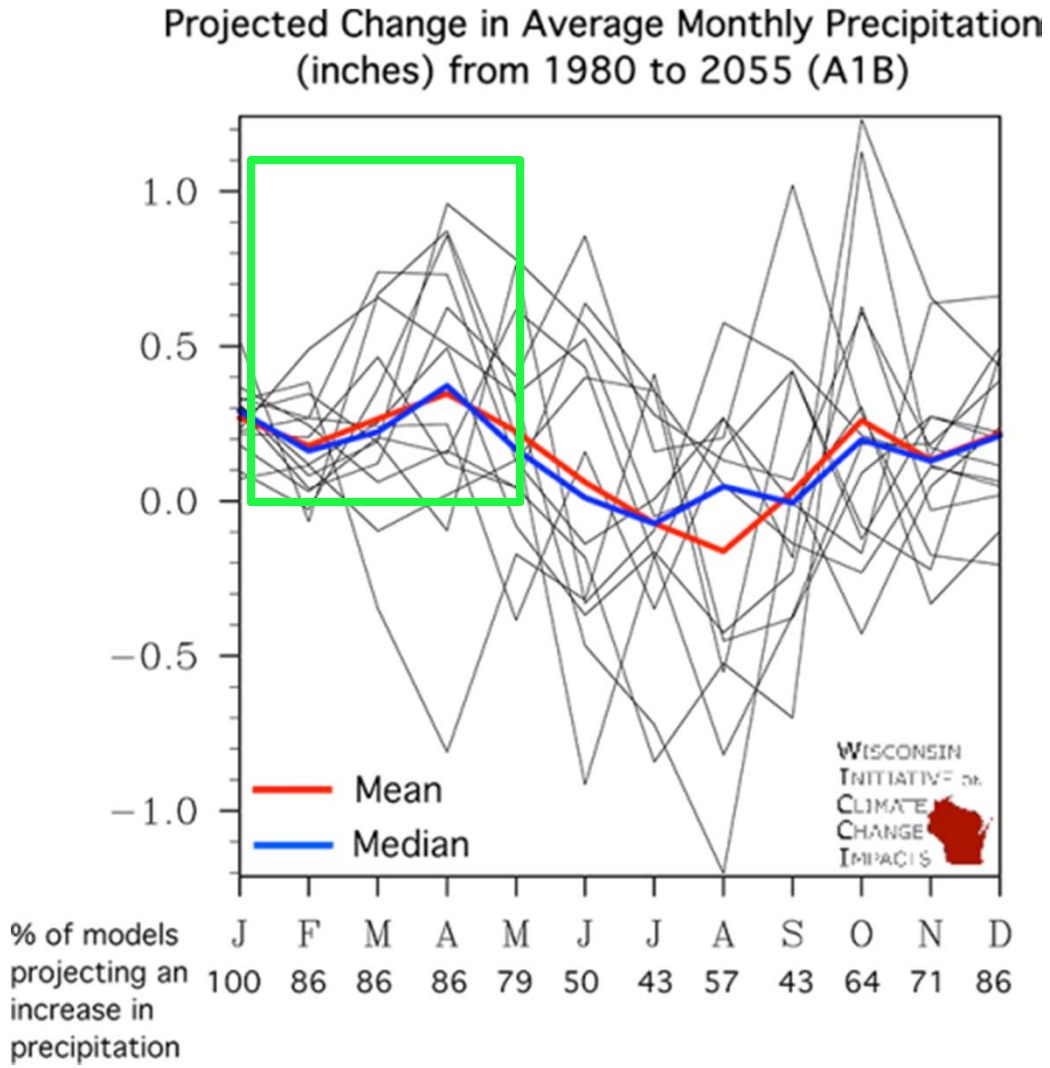
overflows that have occurred with less than 2 inches of rain occur in spring



Global climate models and uncertainty

- Changes for some climate parameters are uncertain, e.g. average annual rainfall

Models all agree: more rain in winter and spring



How do we link climate projections to estimates of pathogens burdens?

Current climate conditions
1940-2004

↓

Run modeling of the sewer system
MACRO

↓

Evaluate system capacity
What is the threshold for CSOs?
When do they occur? Statistics

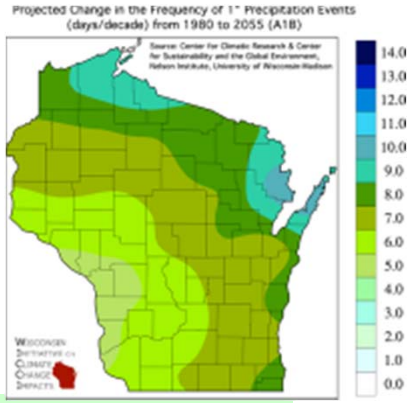
Existing facility planning and water quality efforts in our region

15 million dollar effort

Southeastern Wisconsin Regional Planning Commission

Answers the question, how do we need to improve the system in the next 20 years?

How do we link climate projections to estimates of pathogens burdens?



Current climate conditions
1940-2004

↓

Run modeling of the sewer system
MACRO

↓

Evaluate system capacity
What is the threshold for CSOs?
When do they occur? Statistics

Climate projections: use
downscaled climate models

↓

Run modeling of the sewer system
MACRO

↓

Evaluate CHANGE
How many more CSOs?
When do they occur? Statistics

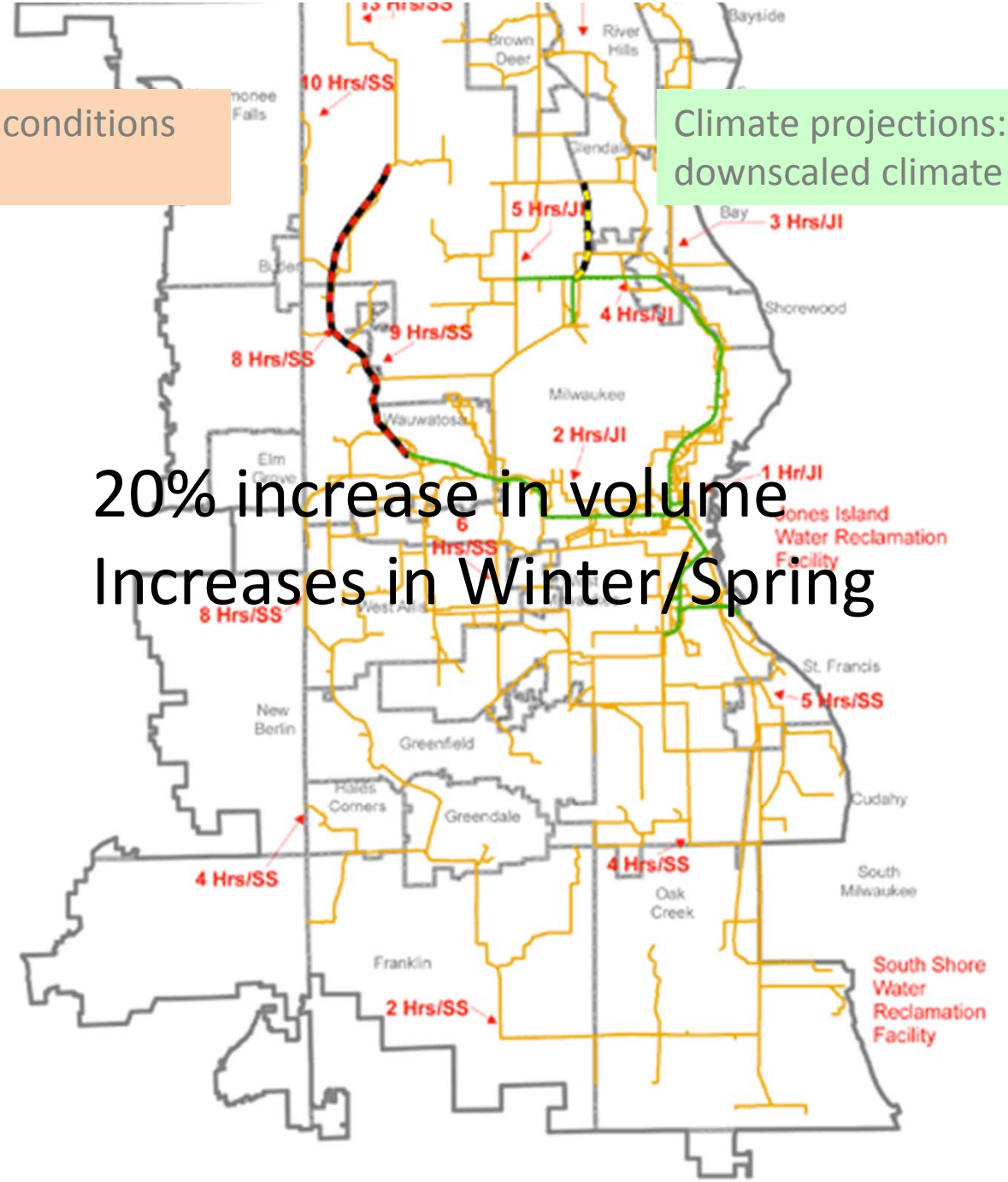
Current climate conditions
1940-2004

Number of CSOs

202

Volume of CSOs

152,571 acre/ft



20% increase in volume
Increases in Winter/Spring

Climate projections: use downscaled climate models

Number of CSOs

223

Volume of CSOs

184,928 acre/ft

What's next

How will climate change other sources of pathogens leaking sewers, direct runoff from farms, leaking septic?

How does temperature alter runoff (less runoff?)

Examine adaptation strategies targeting spring timeframe

School of Freshwater Sciences @ the Great Lakes WATER Institute

Visiting Professor Ryan Newton

Graduate students
Amber Koskey
Danielle Cloutier
Chelsea Corson
Hayley Templer

Postdocs
Jen Fisher

Undergraduates
Morgan Schroeder
Katie Halmo
Nick Myers

Research Specialists
Deb Dila
Pat Bower
Melinda Bootsma

Collaborators

Mitch Sogin	Marin Biological Laboratory
Michael Hahn	Southeastern Wisconsin Regional Planning Commission
David Bennett	Brown and Caldwell
David Lorenz	UW-Madison, Center for Climate Research
Steve Corsi– USGS	
Istvan Lauko	UW-Milwaukee, Mathematical Sciences
Gabriella Pinter	

Funding
NIH NIAID and NIEHS
MMSD
NOAA
University of Wisconsin Sea Grant
CDC