Macatawa Watershed *Escherichia coli* Levels and Population Genomics

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November 30, 2017

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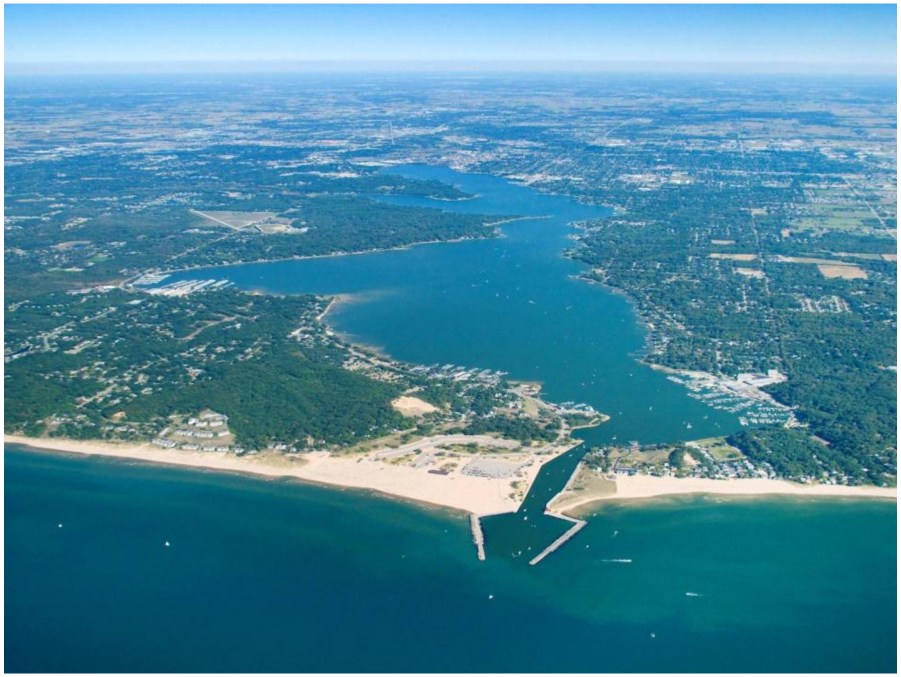
Macatawa Watershed Restoration



Outdoor Discovery Center Macatawa Greenway

PROJECT clarity

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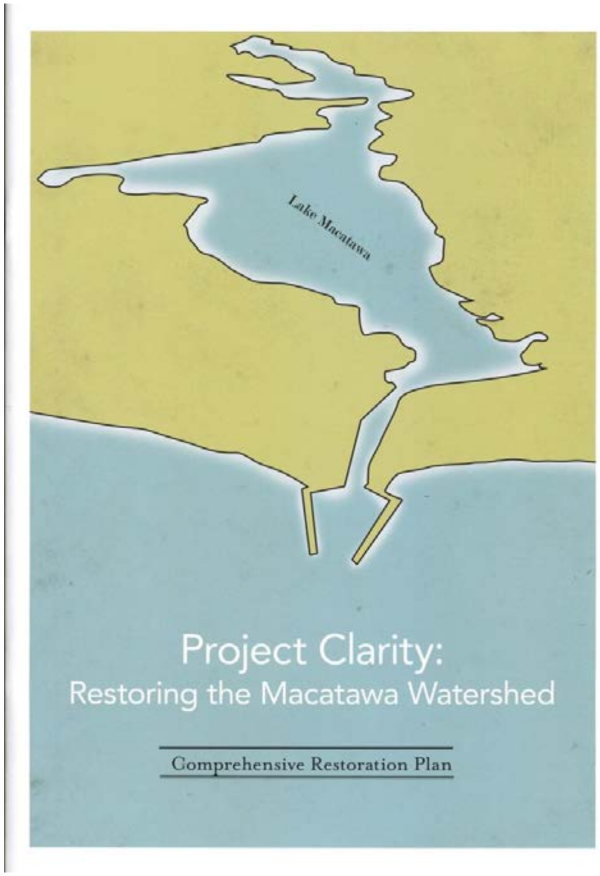
Project Clarity Restoration Plan



- ✓ Phase One: Research Results
- ✓ Phase Two: Implementation
- ✓ Restoration Team
- ✓ Investment of $11,976,000
- ✓ Multi-faceted approach
  - ID & Secure Land
  - Restoration
  - Best Management Practices (BMP)
  - Education & Information
  - Maintenance

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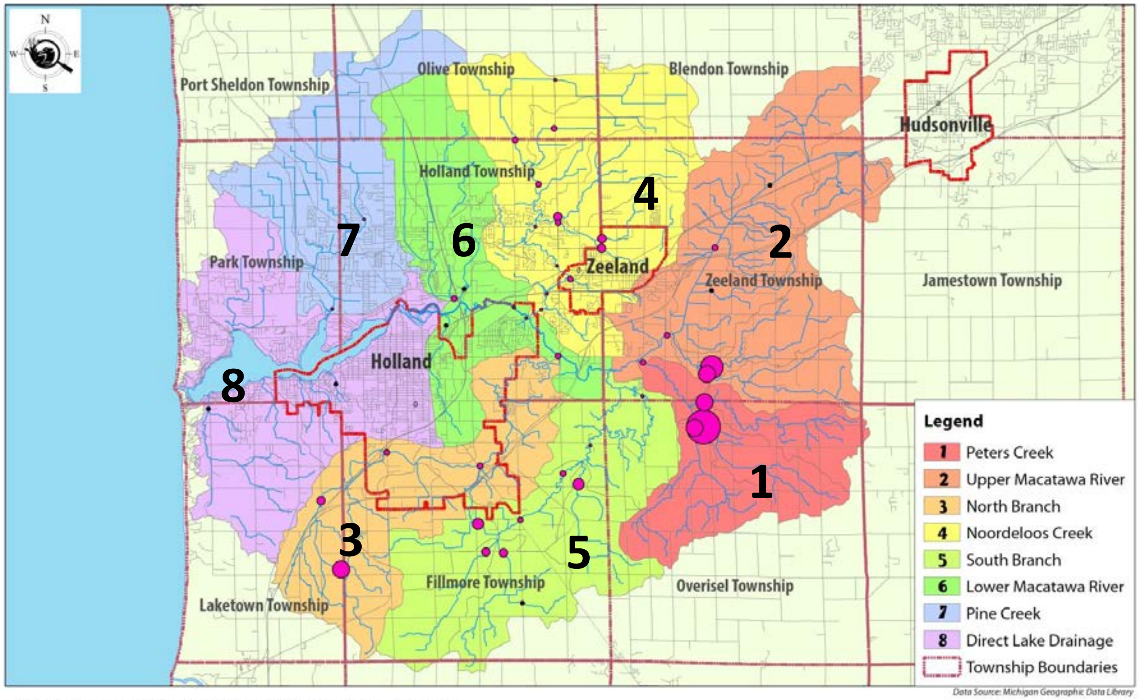
Macatawa Watershed



Macatawa Watershed Priority Areas

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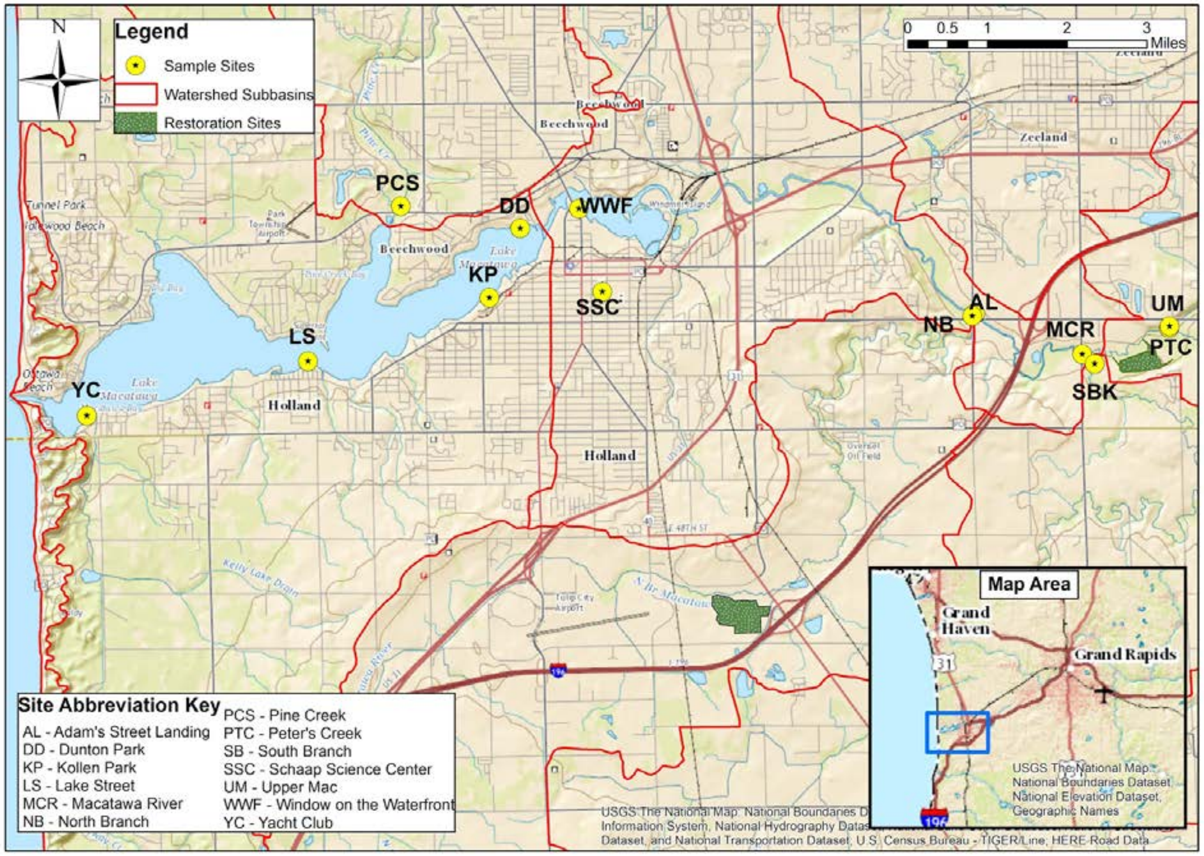
Day1: Watershed Sampling sites



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Day1: Watershed
Residential Research Community

Improving retention in the STEM fields for broad set of students:

Research experience
Residential component
Pre-college component
Peer mentors in courses
First Year Seminar
Intro Chem Lab
Intro Bio Lab

www.hope.edu/Day1

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Primary Projects

- Establishing Baseline Data for Chemical & Microbial Loads
  - Weekly sampling
  - Year long (August 2016 – August 2017)
  - Chemical – Total Suspended Solids, Phosphate, Nitrate, Dissolved Oxygen, Biochemical Oxygen Demand
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  - Microbial – *Escherichia coli* counts; Total bacterial community census
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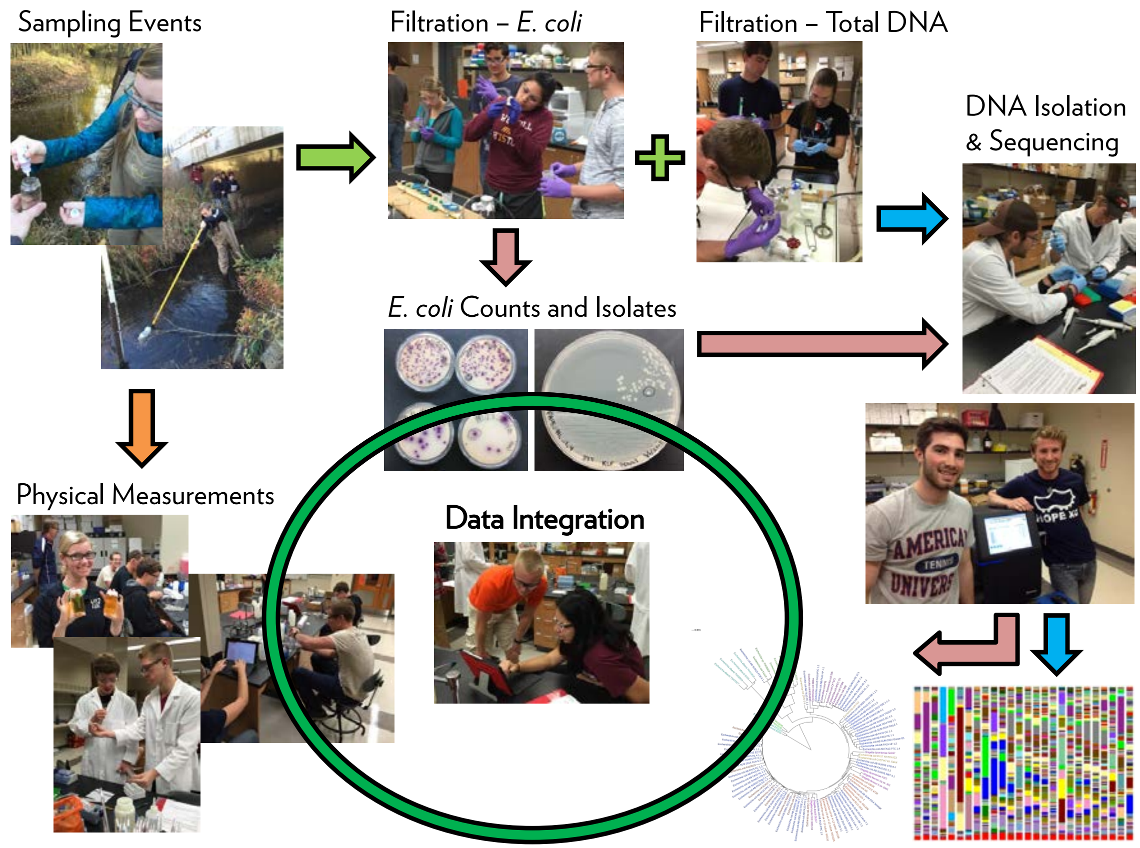
Day1 Watershed Course Research Experience



Weekly Sampling – Full Year

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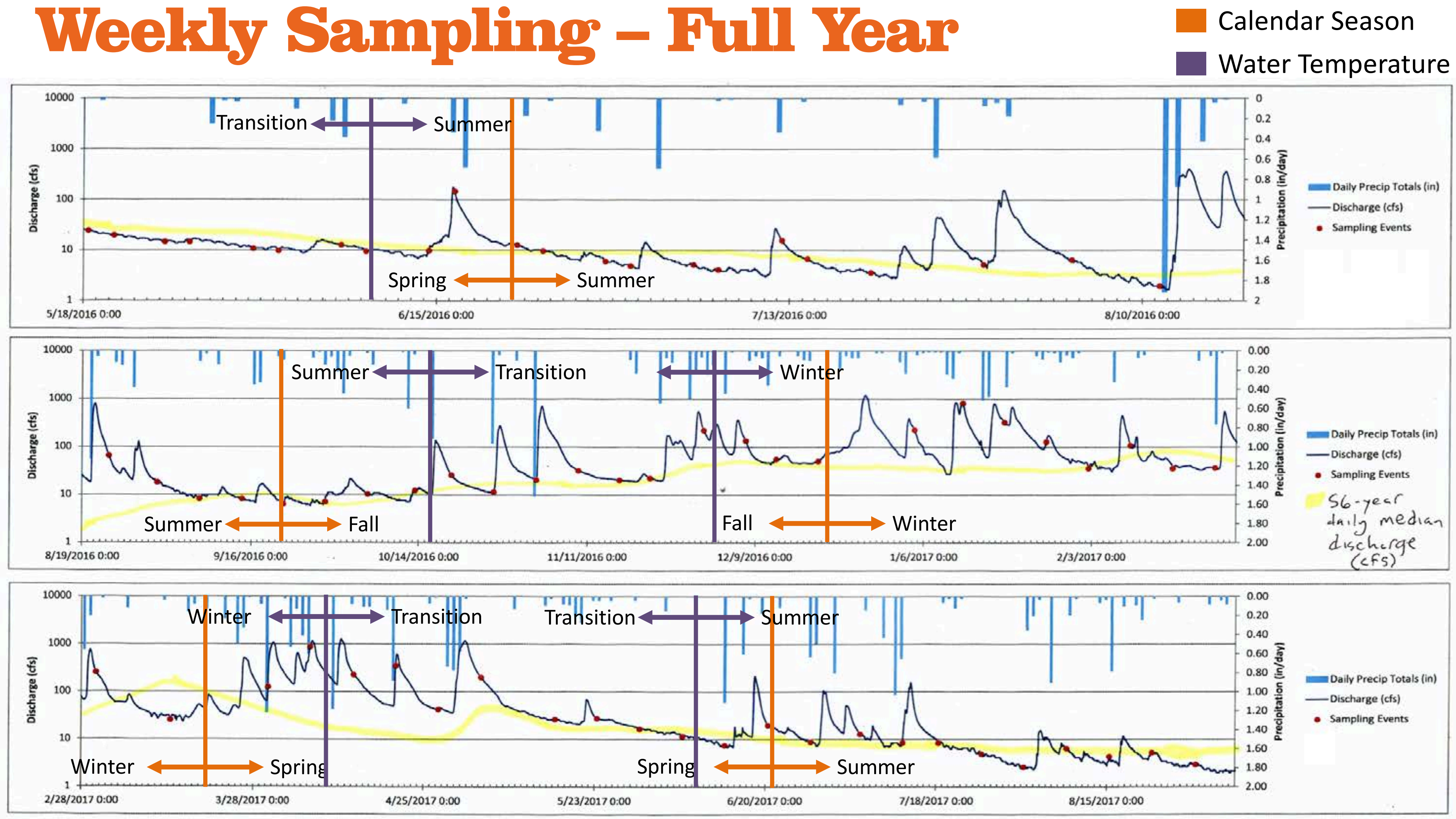

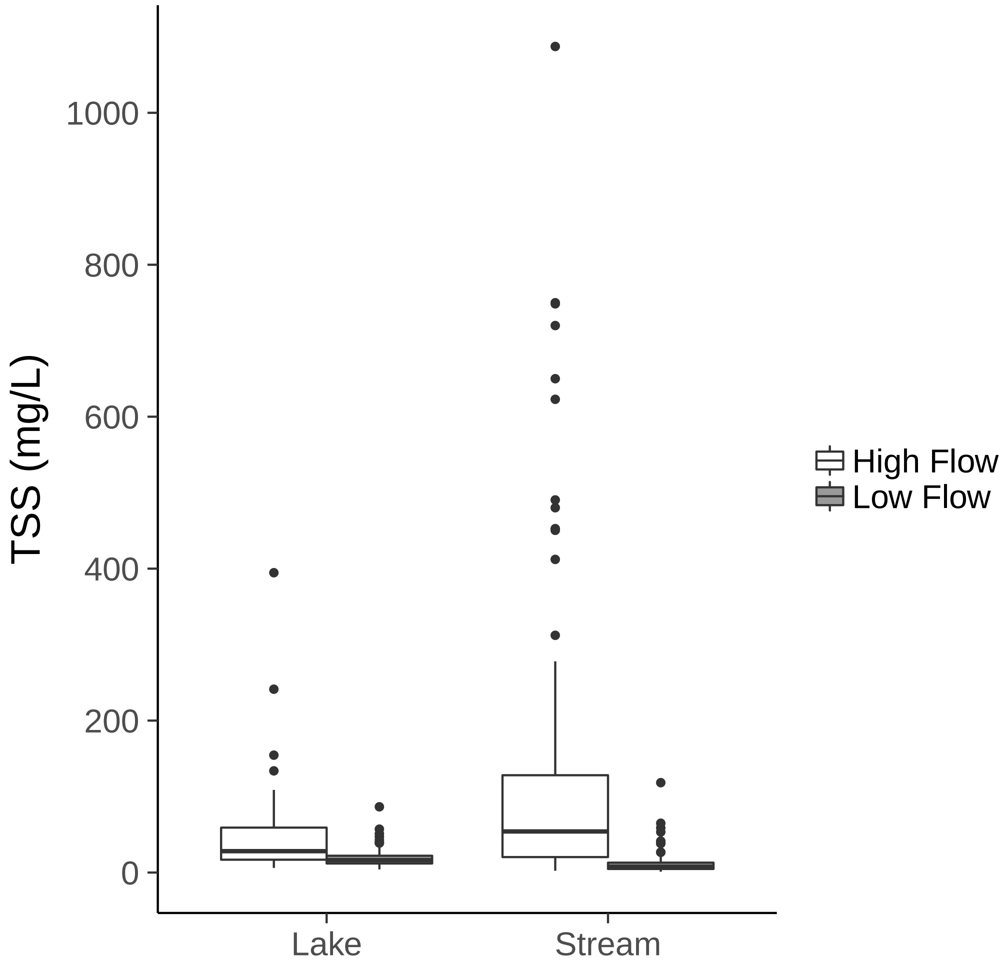

Total Suspended Solids

- Total Suspended Solids (TSS)
- High flow conditions
  - Stream sites on average **higher** than Lake sites
  - Extreme outliers observed in Stream sites
  - Lake site average levels vary by 2-fold range compared to low flow conditions
- Dilution effect from east to west in Lake sites
- Correlated with PO_4^{3-}

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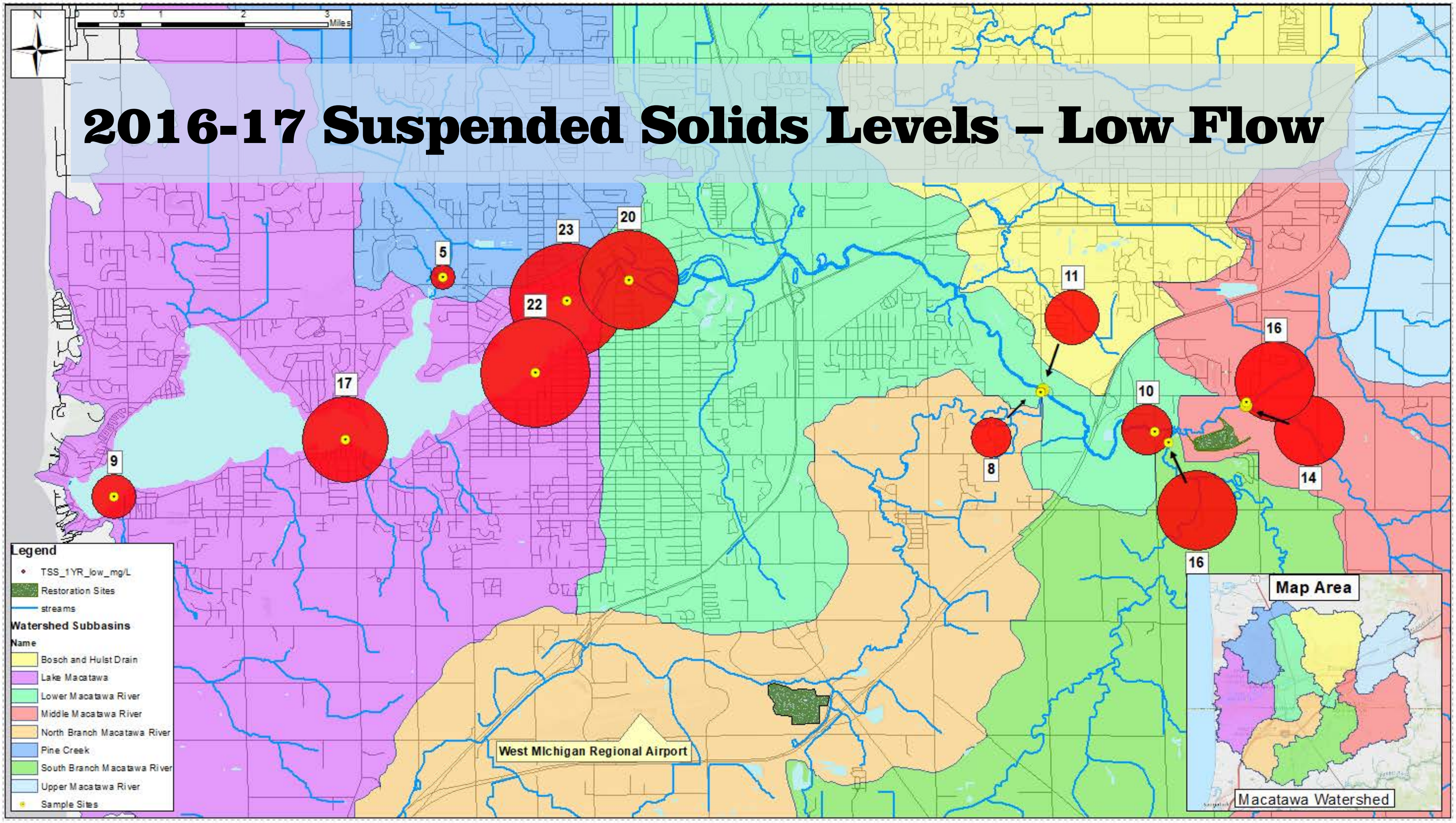
2016-17 Suspended Solids Levels – Low Flow



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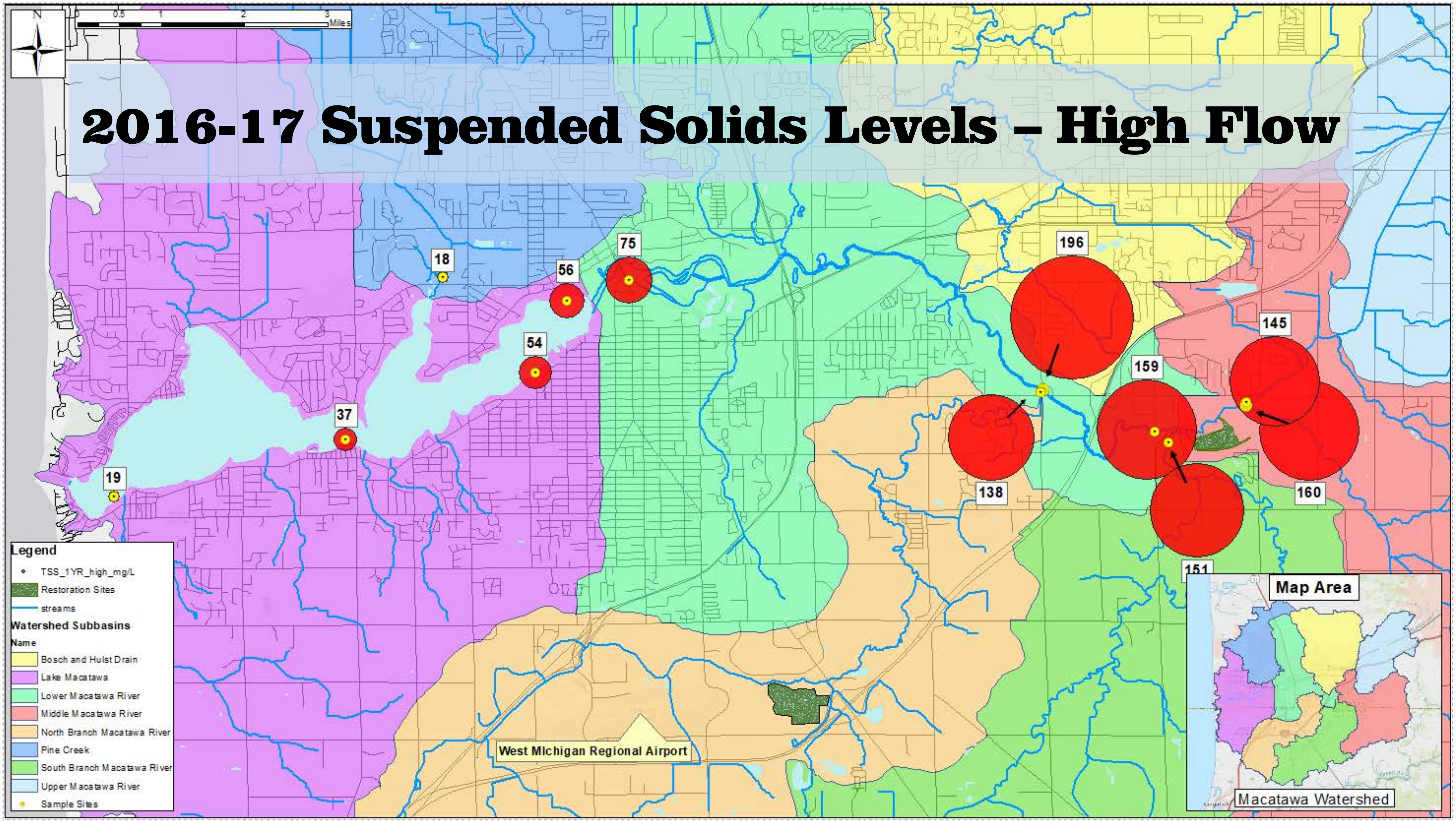

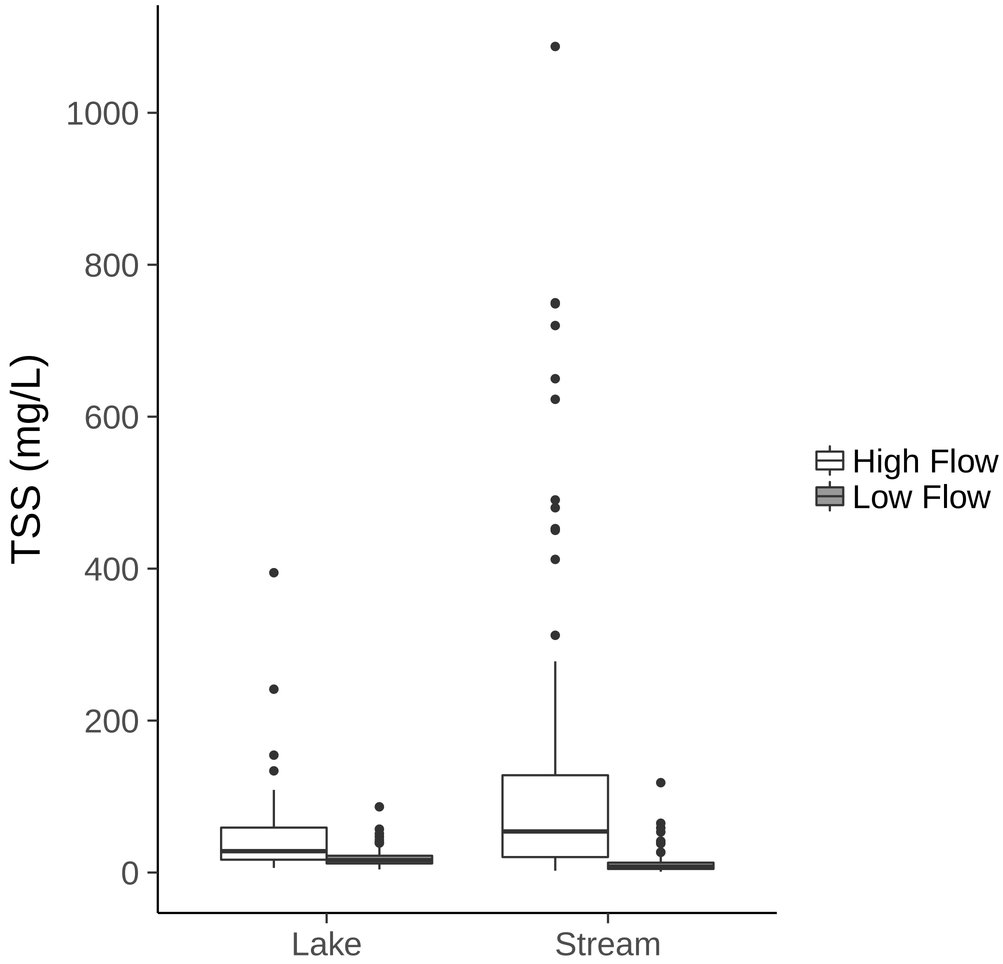

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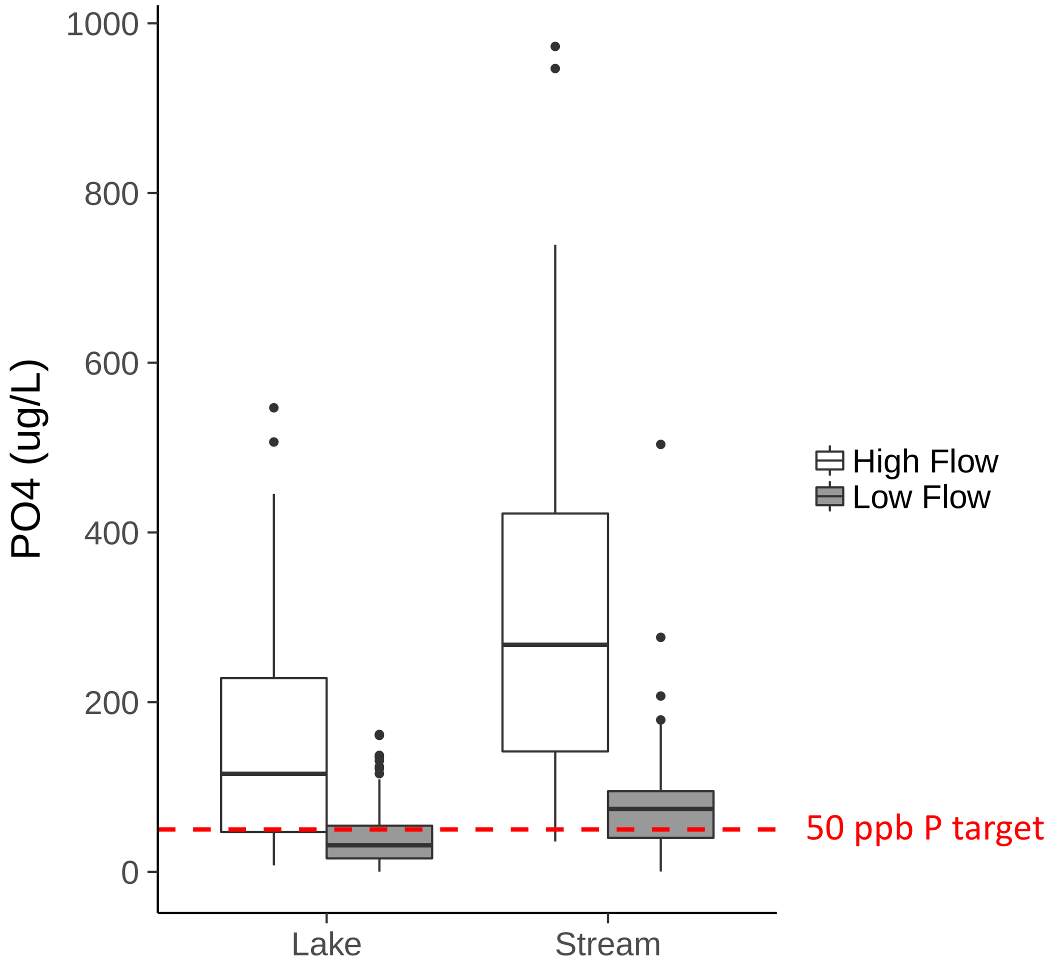

Phosphate Levels

- Goal is under 50 ppb total P (70% reduction)
- Measuring PO_4^{2-} -- underestimates total P
- Low Flow Conditions
  - Lake Sites – generally **below** target
  - Stream Sites – generally **above** target for lake
- High Flow Conditions
  - **All** sites **above** target for lake
  - Increases by 2 to 4-fold at all sites compared to low flow conditions

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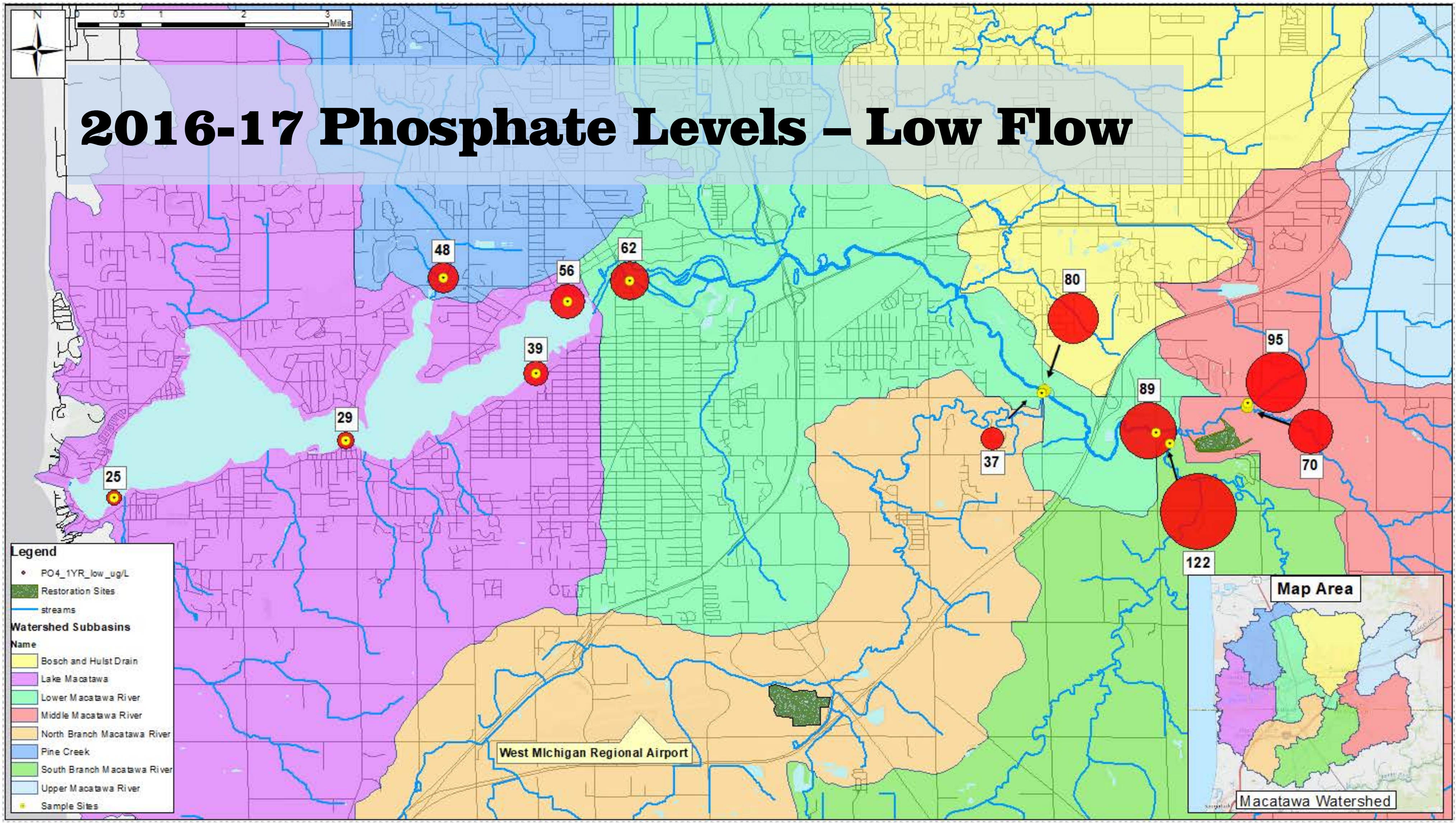
2016-17 Phosphate Levels – Low Flow



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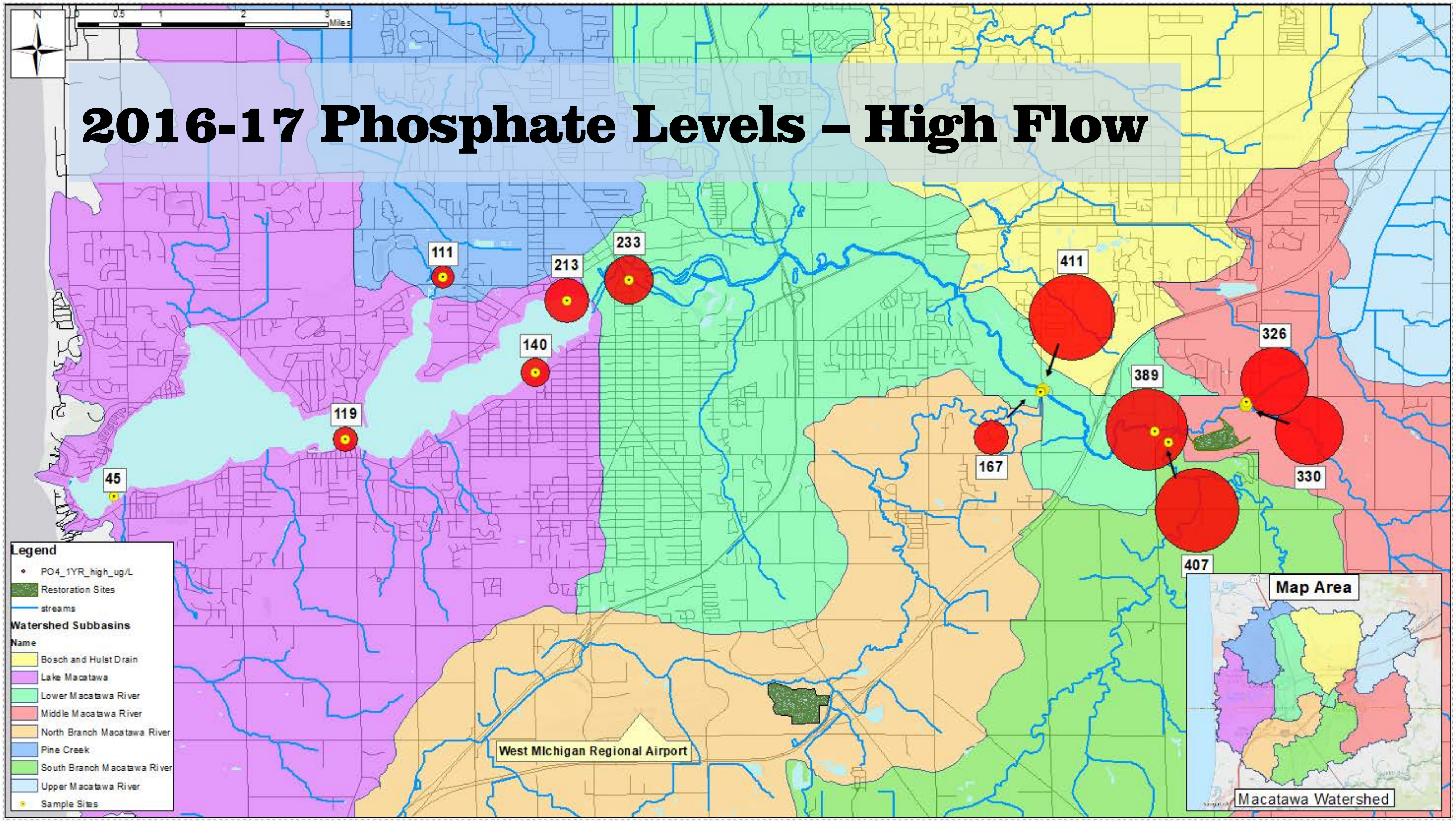

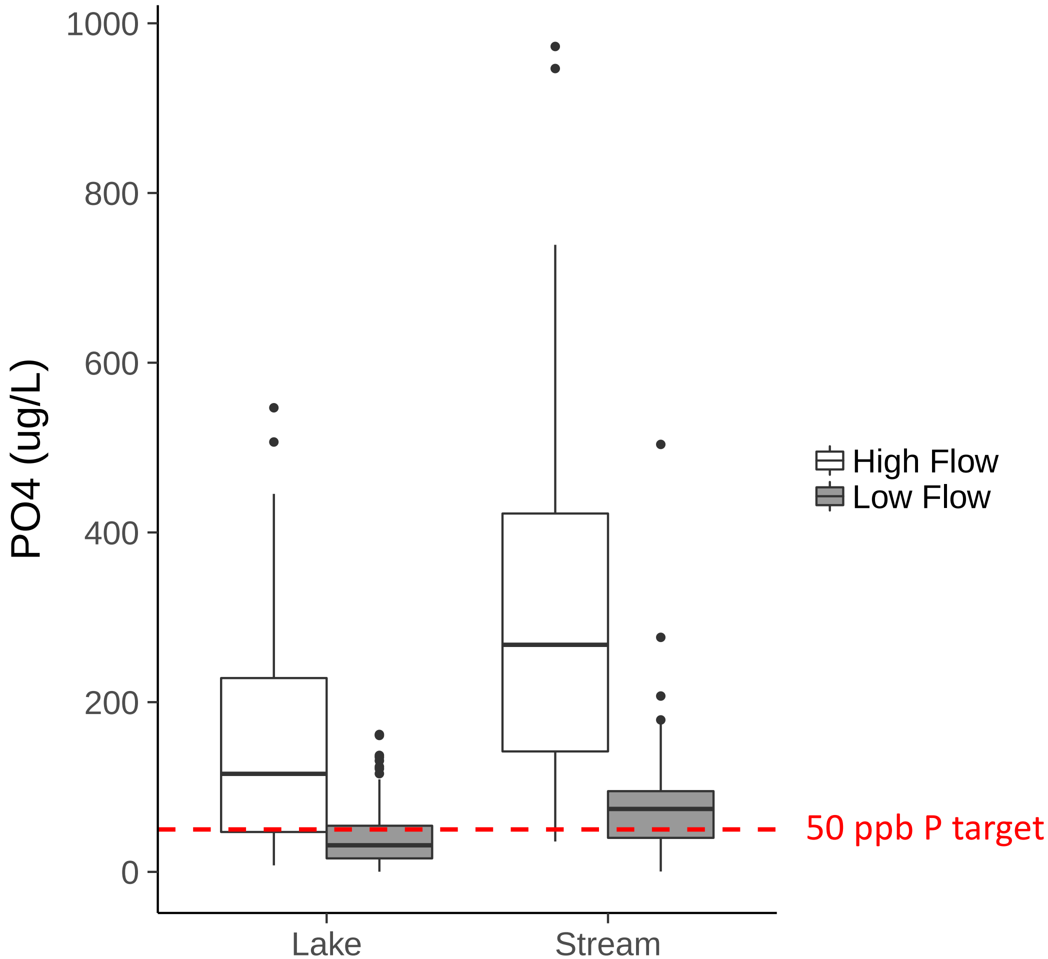

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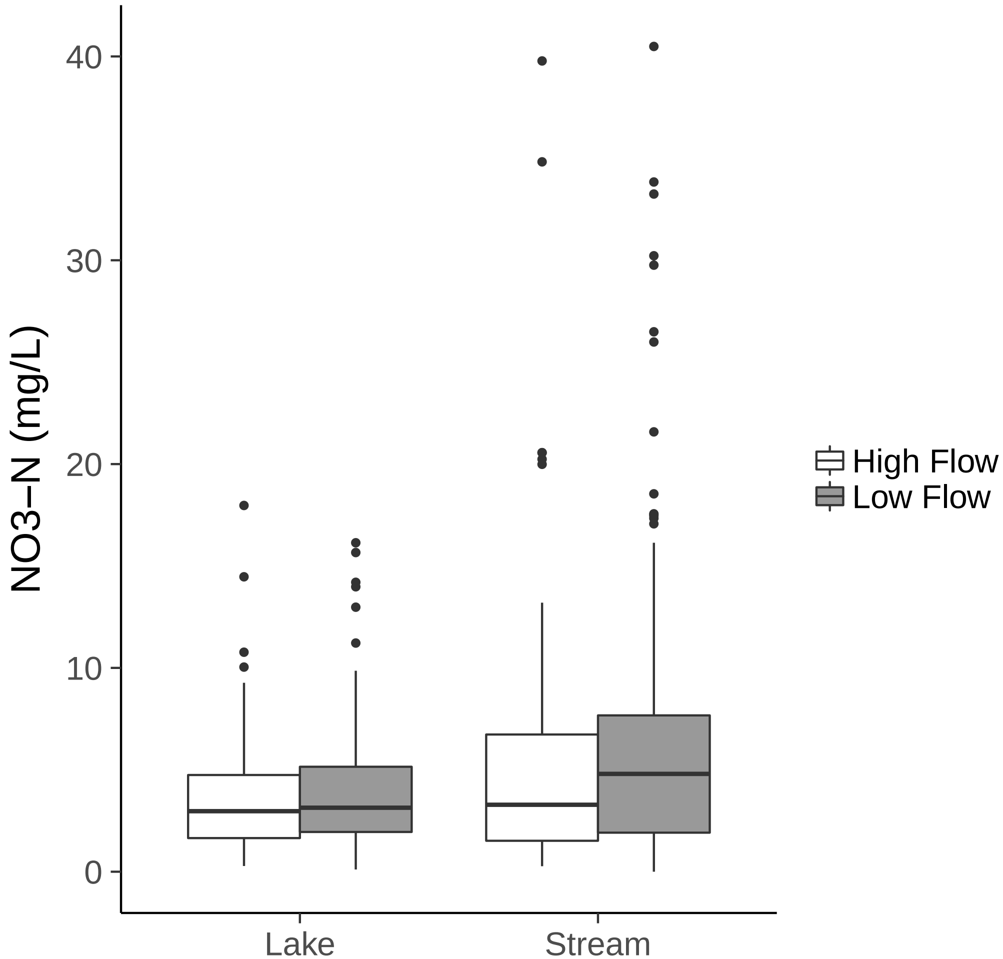

Nitrate Levels

- Drinking water regulated – below 10 ppm
- Not regulated for streams and lakes
- Low Flow Conditions **higher** in both lake and stream sites
- Outlier sampling events with high measured levels
- Can be limiting nutrient in cyanobacterial (algal) bloom formation

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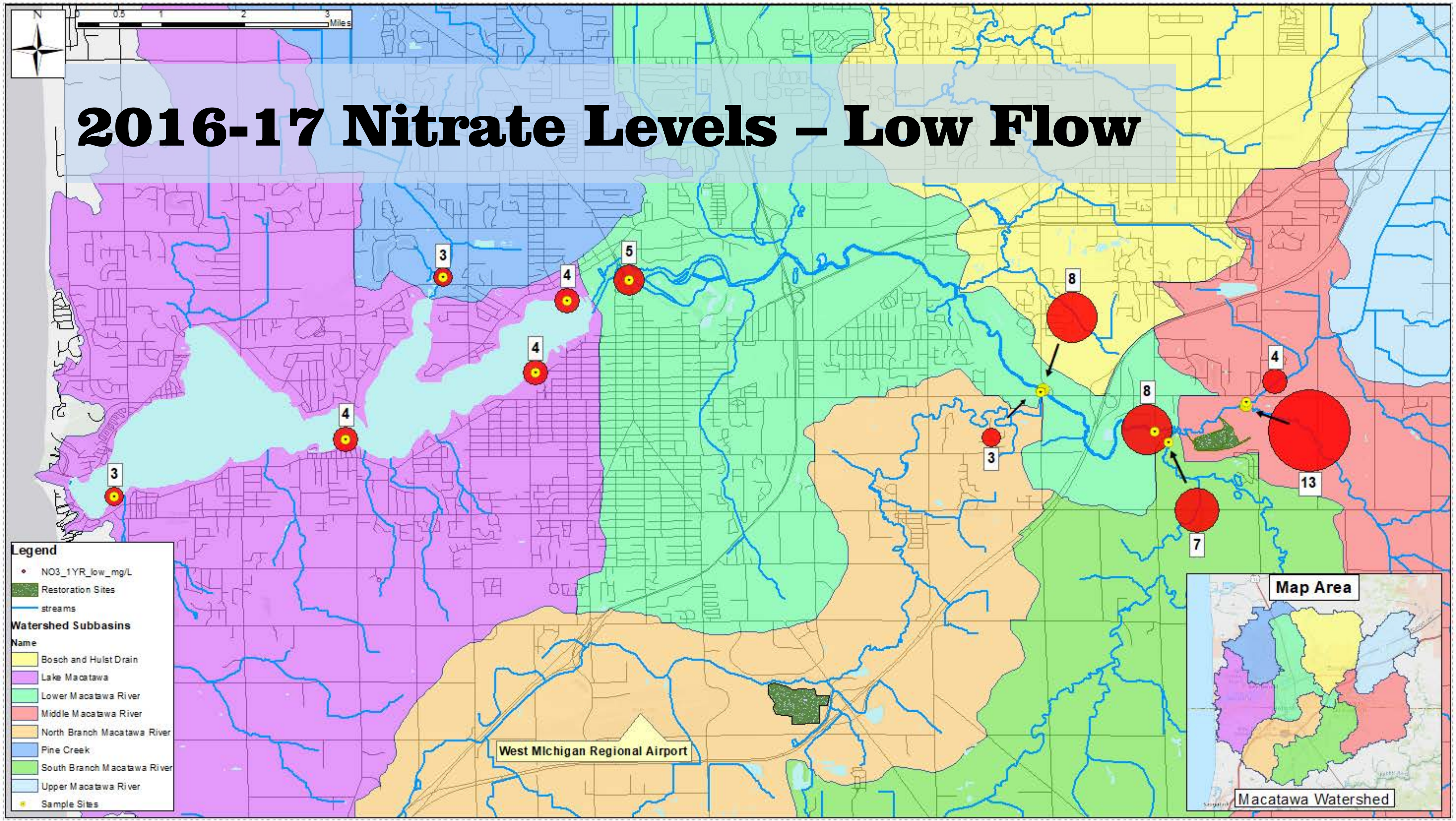
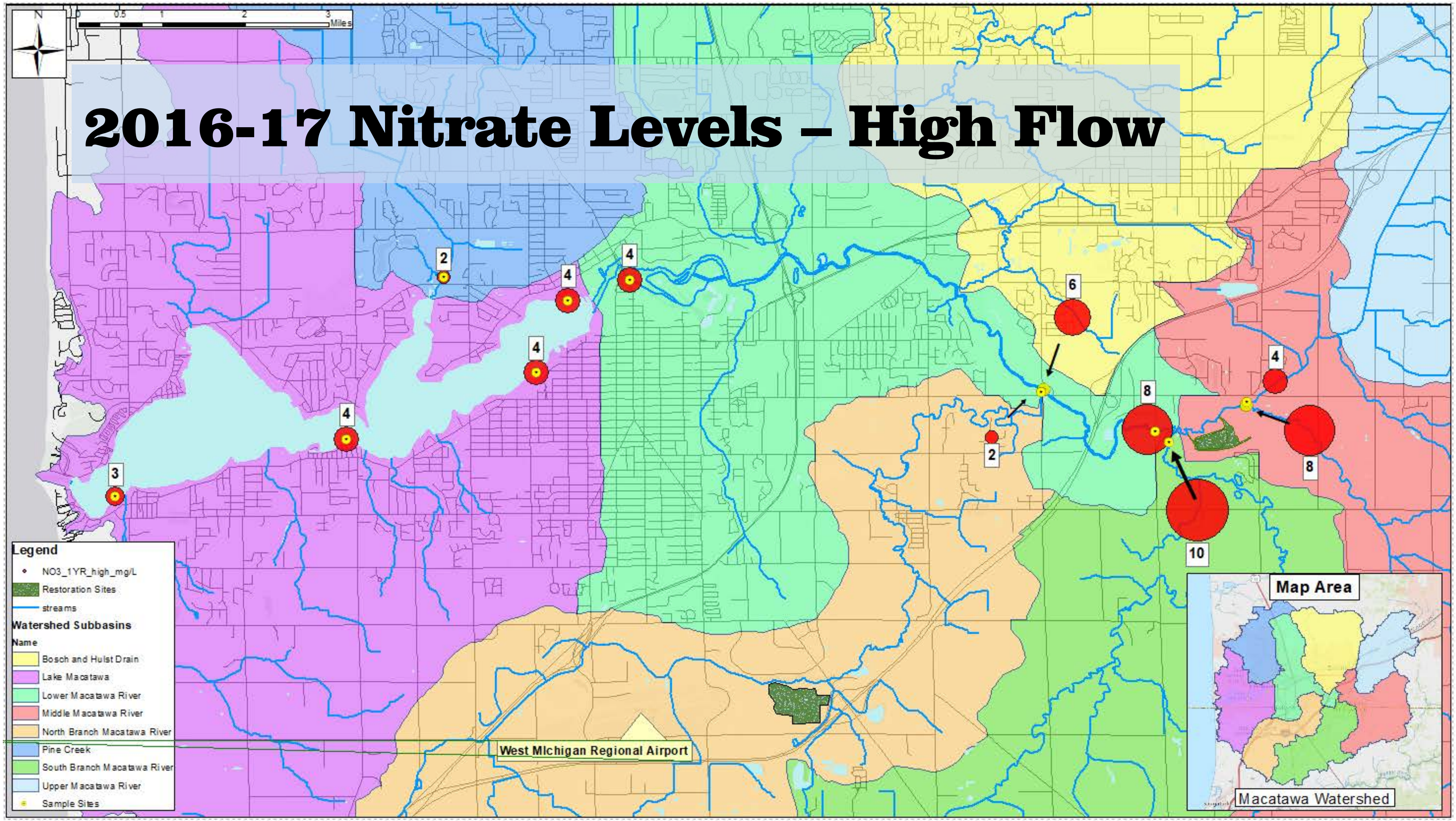
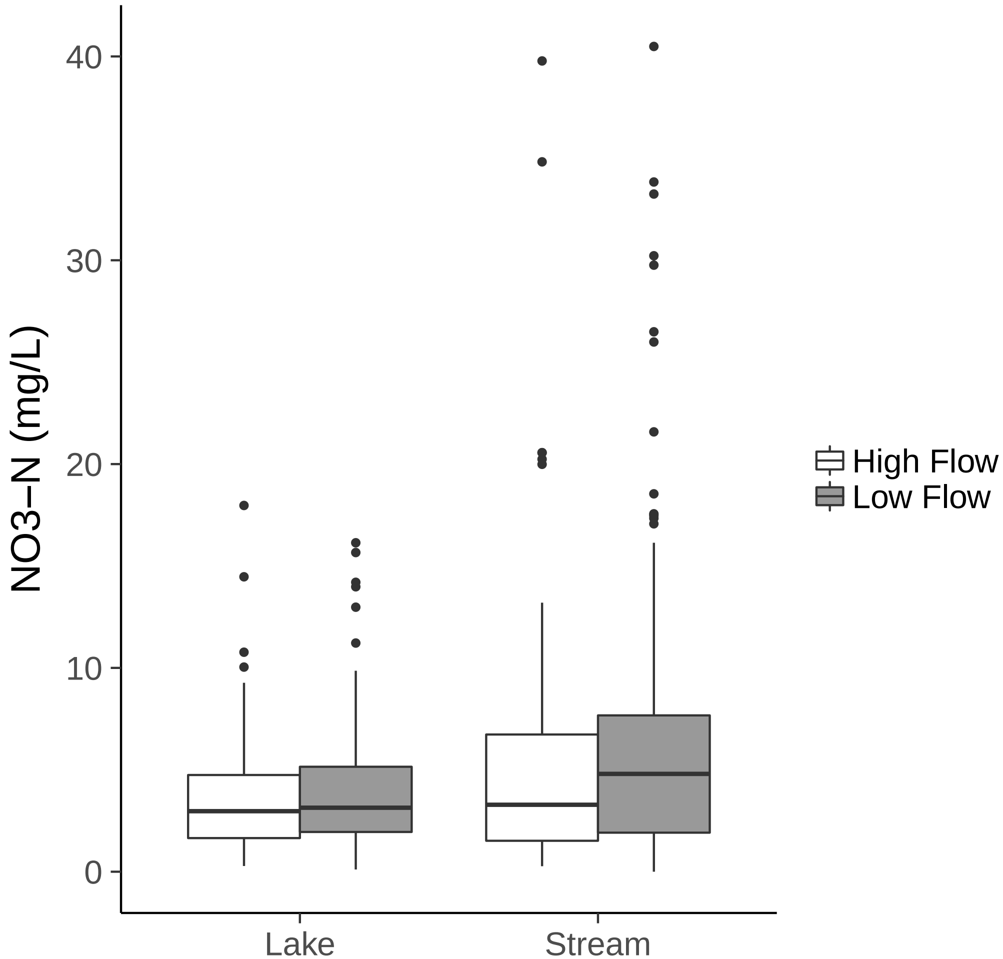
2016-17 Nitrate Levels – Low Flow





2016-17 Nitrate Levels – High Flow
N
0 0.5 1 2 3 Miles
2
4
4
4
4
3
6
4
8
8
2
10
Legend
NO3_1YR_high_mg/L
Restoration Sites
streams
Watershed Subbasins
Name
Bosch and Hulst Drain
Lake Macatawa
Lower Macatawa River
Middle Macatawa River
North Branch Macatawa River
Pine Creek
South Branch Macatawa River
Upper Macatawa River
Sample Sites
West Michigan Regional Airport
Map Area
Macatawa Watershed



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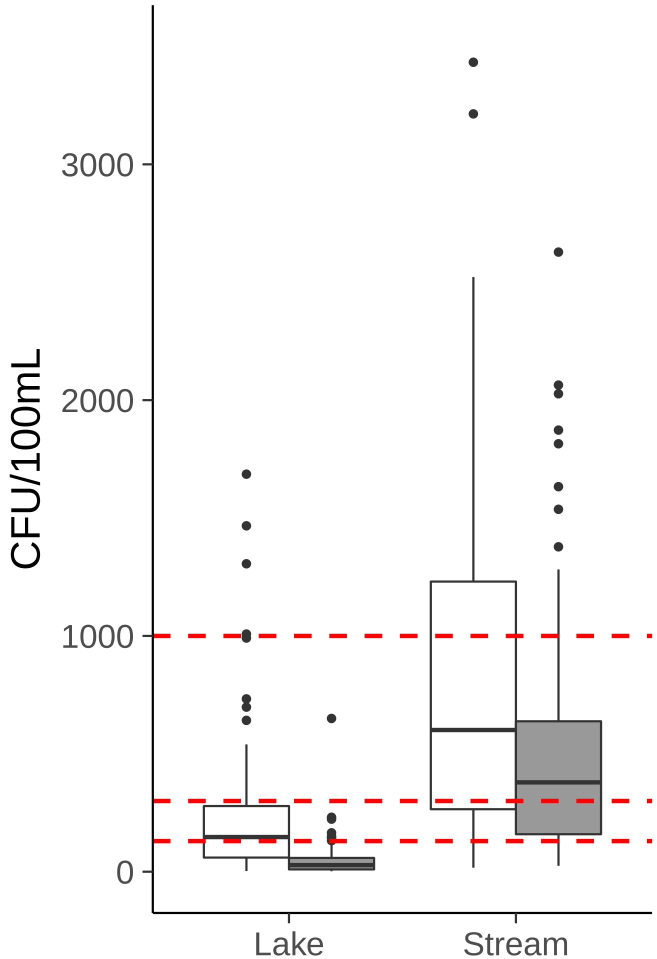

1000 CFU/100 mL –
Daily – partial body contact limit (All Year)

300 CFU/100 mL – Daily – total body contact limit (May to October)

130 CFU/100 mL – 30 Day geometric mean – total body contact limit

E. coli Counts

- Colony Forming Units (CFU)
- EPA Method 1603 (mTEC plate counts)
- Lake Sites generally **lower** than total body contact limit in high and low flow conditions – with exceptions
- Stream Sites generally **above** total body contact limit in high and low flow conditions – sometimes well above partial contact limit in high flow conditions

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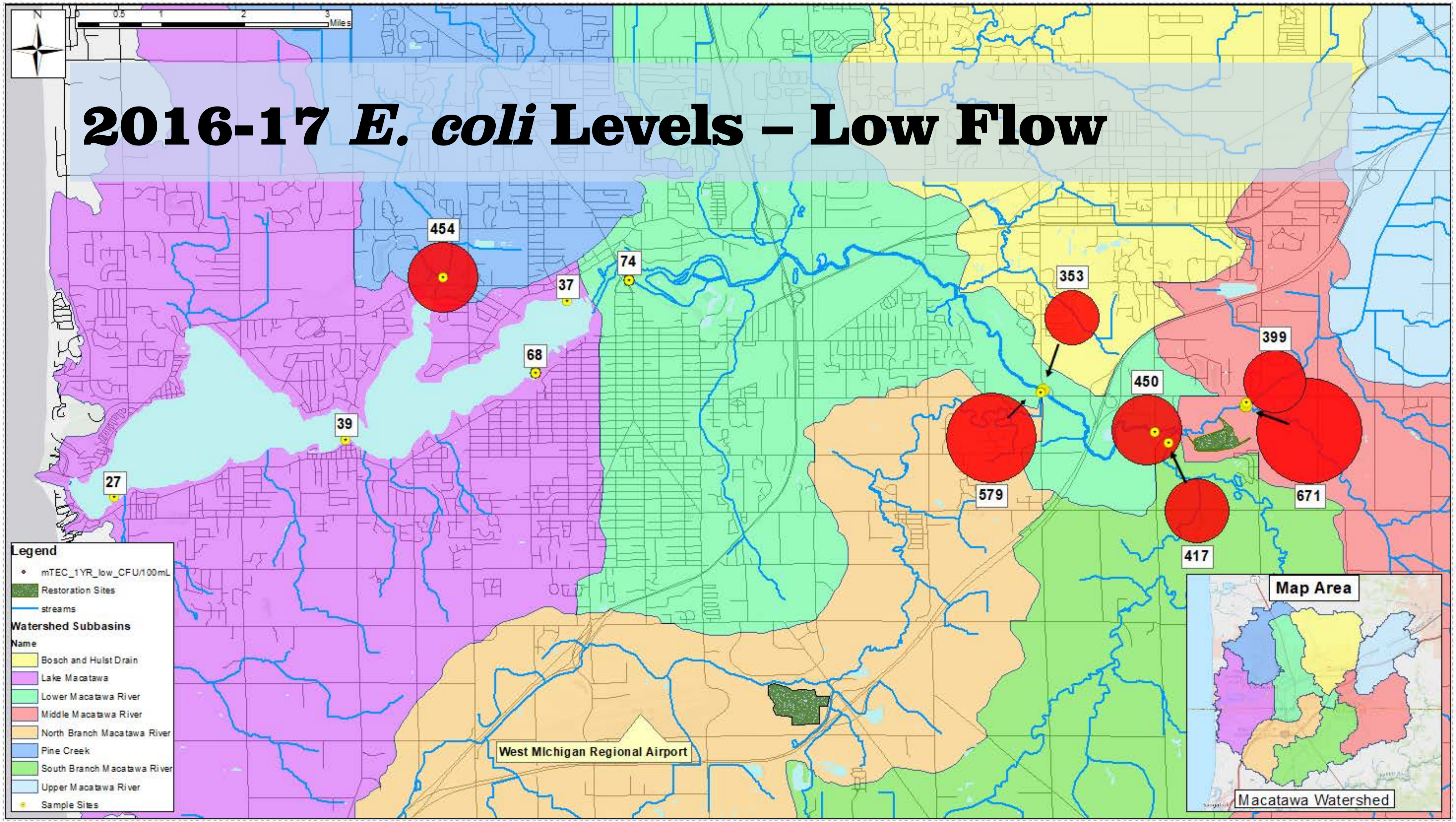
2016-17 *E. coli* Levels – Low Flow



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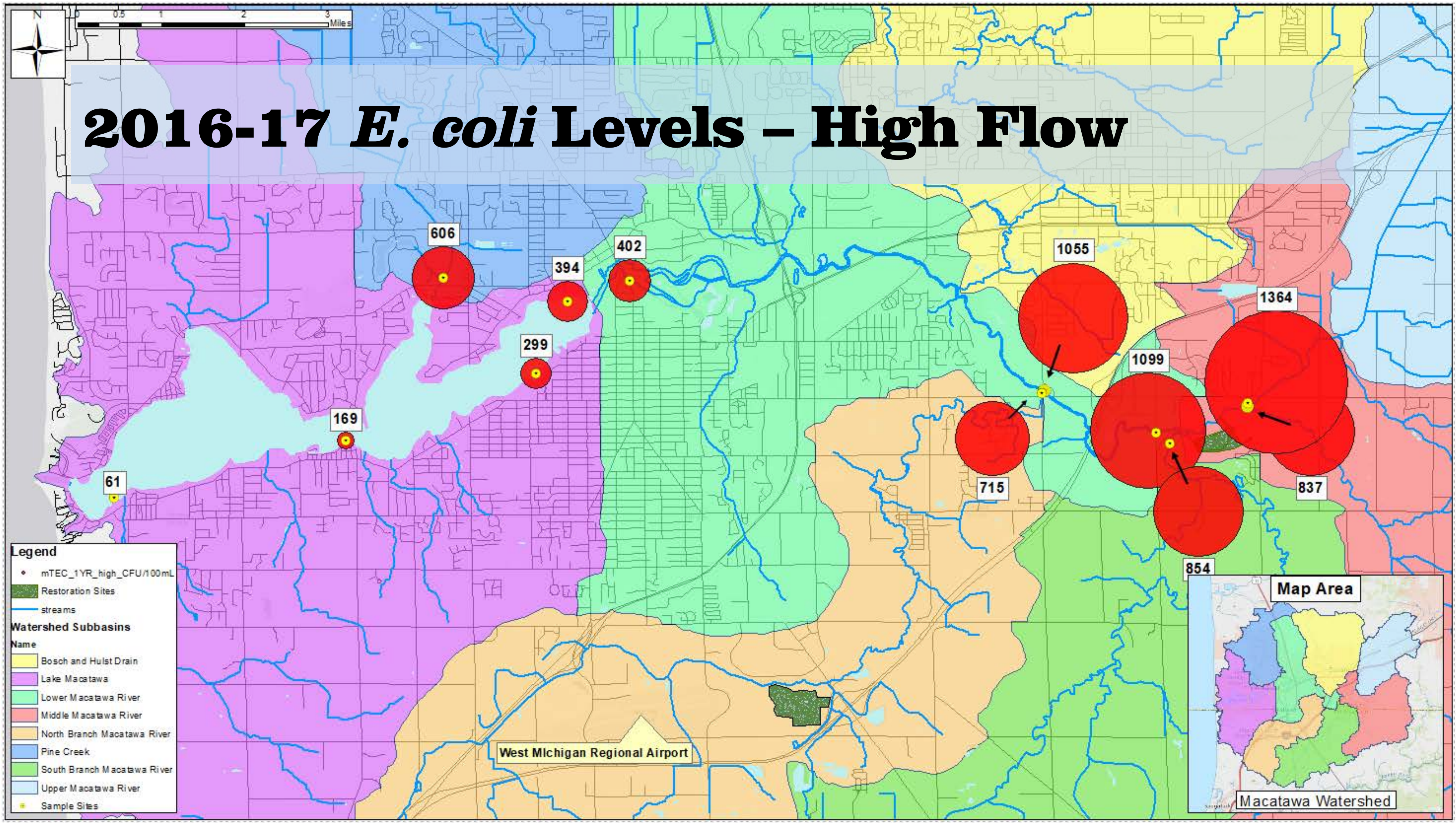

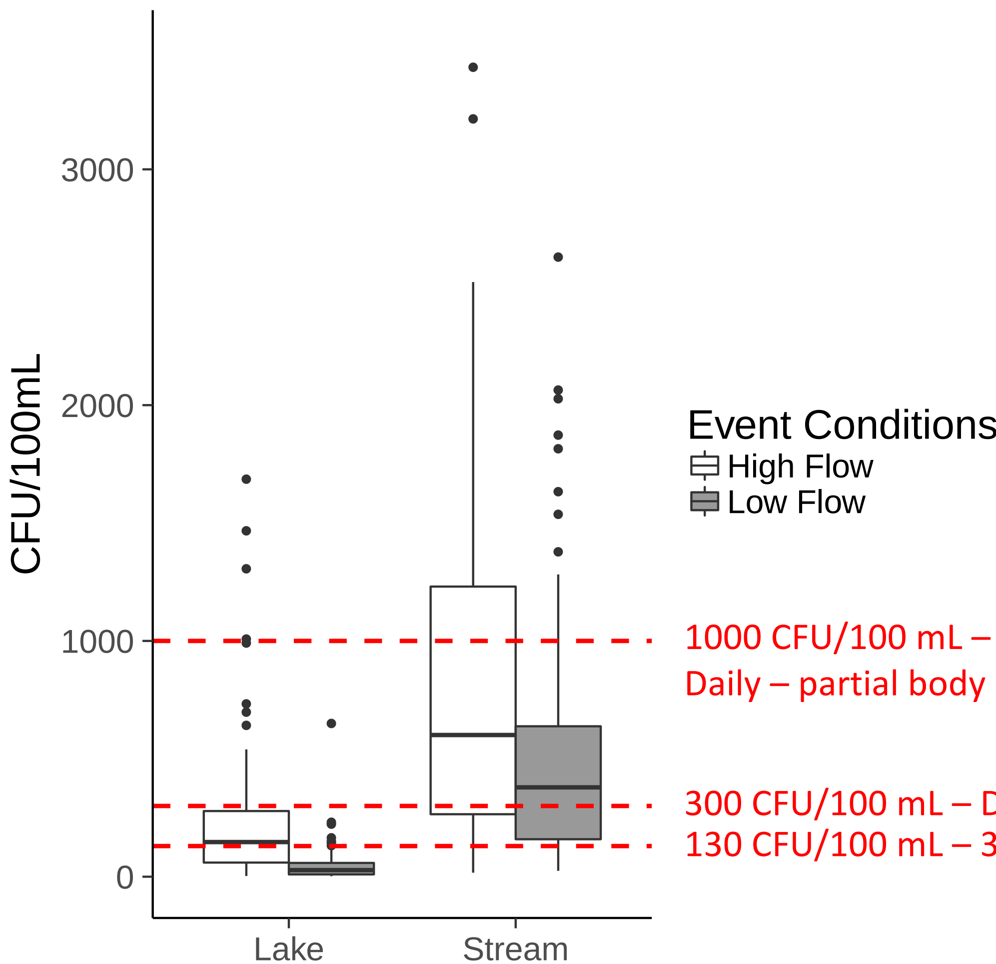

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DEQ Contacts Permits Online Services Programs Locations MI.gov

DEQ Department of Environmental Quality

Search

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WATER

- Great Lakes
- Drinking Water
- Lakes & Streams
  - Aquatic Nuisance Control
  - Water Quality Monitoring
  - Lakes & Streams Protection
  - Marinas
  - Related Links
- Wetlands
- MiWaters
- Permits
- Wastewater
- Water Management

DEQ / WATER / LAKES & STREAMS / WATER QUALITY MONITORING

Michigan's Statewide *E. coli* Total Maximum Daily Load

Contact: Molly Rippke 517-284-5547

Get the latest updates - subscribe to receive TMDLs and Integrated Reporting (Clean Water Act Sections: 303d, 305b, and 314) emails.

When a water quality standard is exceeded, the Federal Clean Water Act requires Michigan to address pollution issues with either a Total Maximum Daily Load (TMDL) or by fixing the problem through other means. For some issues, a remedy is already in progress to reduce pollution. This is not the case for *E. coli* across the state. This TMDL will provide a framework for restoration of water quality.

Routine testing has shown *E. coli* levels in many areas are above the standard. These levels increase the risk of illness upon contact or incidental ingestion of the water. Given the extent of this problem, and the multitude of potential sources, a statewide approach will be more effective and more efficient at addressing this issue. To learn more, please visit the *E. coli* in Surface Waters website.

Long term solutions to bacterial problems can only be accomplished through a collaborative approach. In addition to its work on effective National Pollutant Discharge Elimination System (NPDES) permit requirements and corrective actions on illegal sources, the MDEQ is looking for assistance from landowners, local health departments, conservation districts, other state and local agencies, and environmental groups to focus voluntary improvements in areas where nonpoint sources are a problem. Please see our Guide for Homeowners to find out how you can help reduce *E. coli* contamination of our rivers, lakes and beaches.

Google Search Term: michigan deq e coli
Also see "E. coli in Surface Waters" web page

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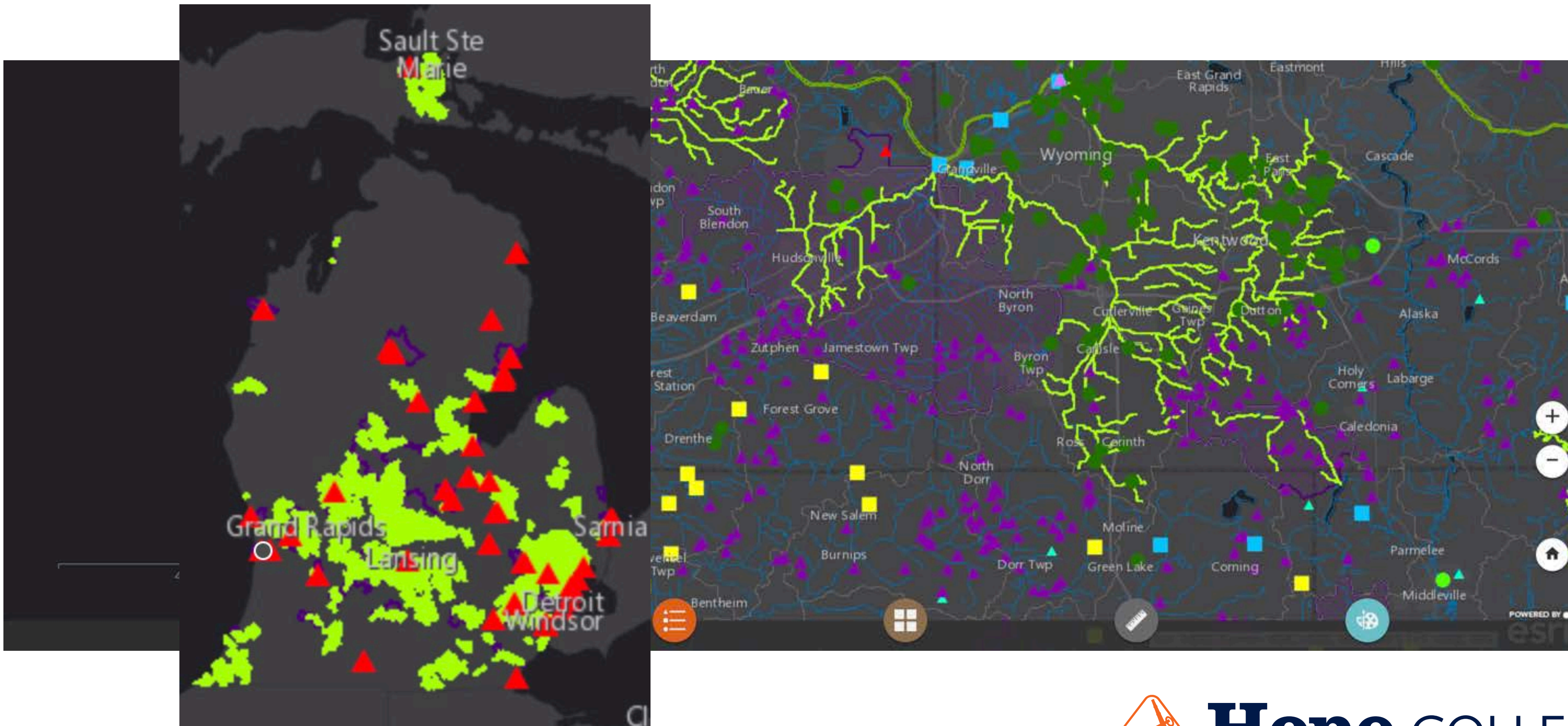
MDEQ Interactive Map – *E. coli* TMDL



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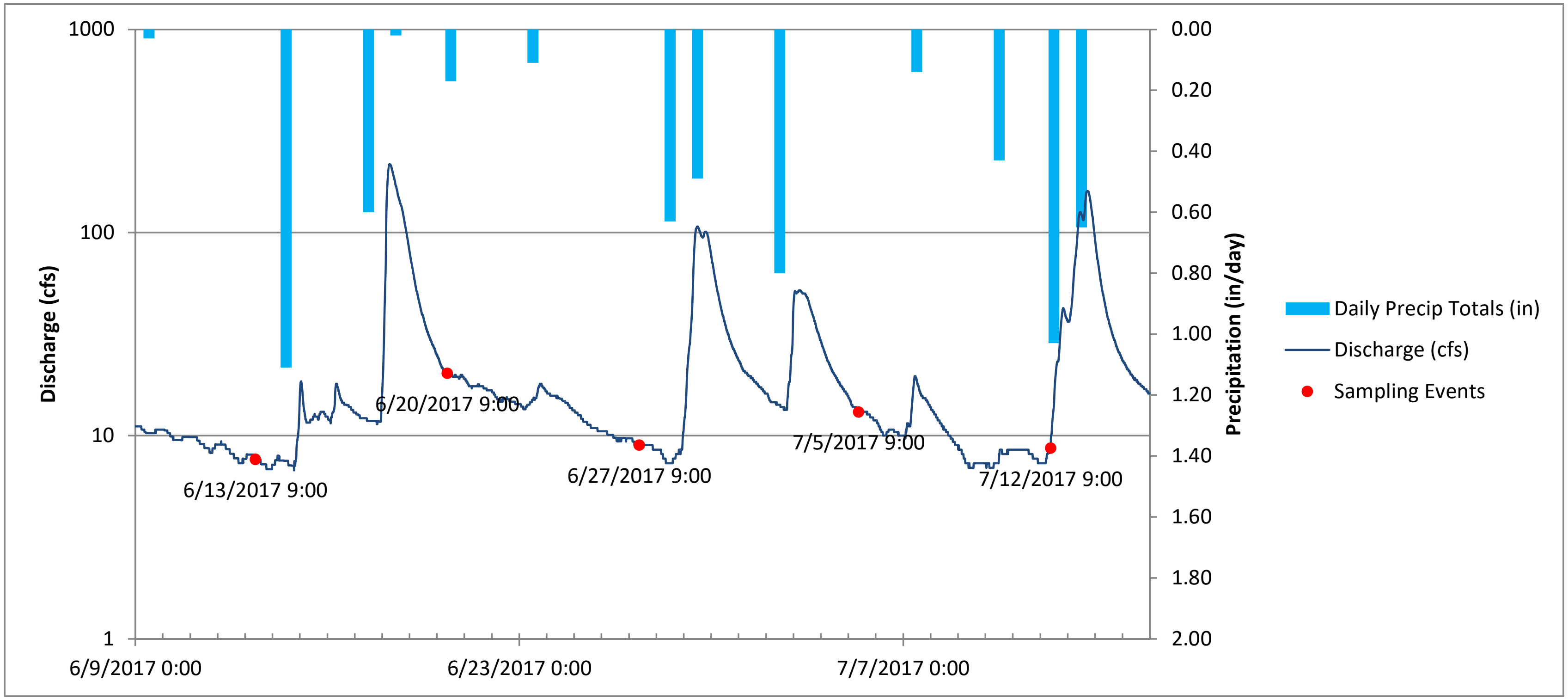
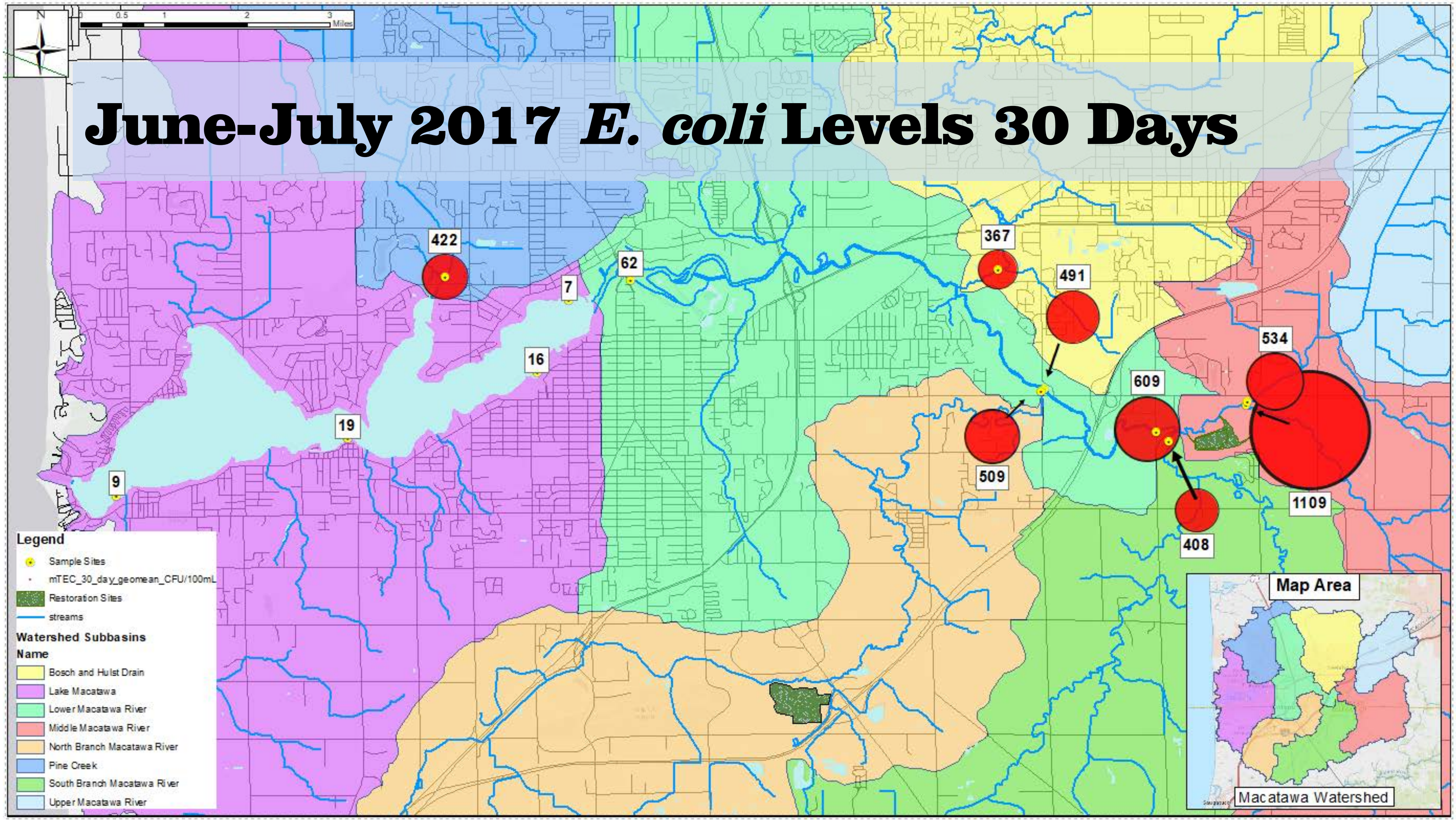
Weekly Sampling – June/July 2017



June-July 2017 *E. coli* Levels 30 Days



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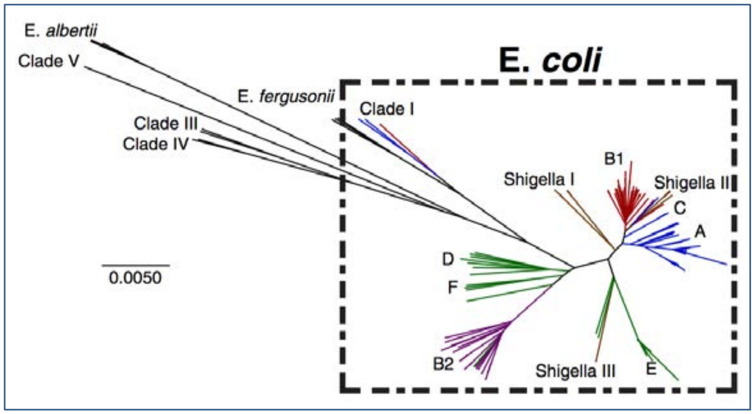
Not All *E. coli* Are Created Equal

- Model organism for microbiology, genetics and molecular biology
- Commensal organism in animal guts
- Pathogenic Strains – gastrointestinal, UTIs, food poisoning, many classifications (e.g., EPEC, ExPEC, EHEC, ETEC, EAEC, EIEC, UPEC, APEC)
- Used in routine water quality monitoring – EPA and State Guidelines
- Thousands of publically sequenced genomes
  - Vast majority are from clinical sources
  - Highly diverse genus with respect to genome content
  - Evidence for adaptation to secondary environments (e.g., soil, water)
  - Is *E. coli* a good organism to use as proxy for sewage contamination of water resources?



Kaas RS, et al. 2012. BMC Genomics **13**:577.

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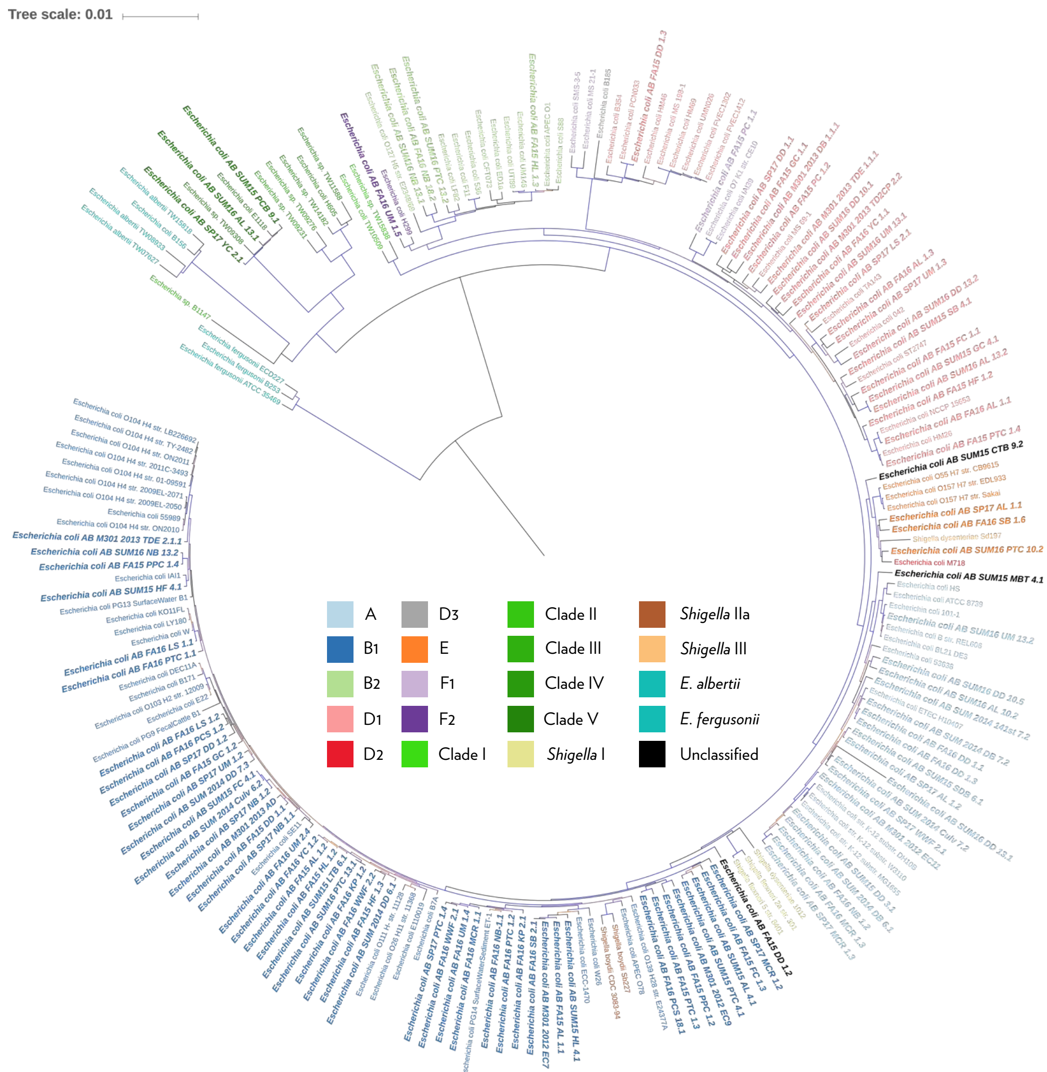

- Family Tree of *E. coli*
- 104 watershed strains
- 97 reference strains
    - Environmental
    - Commensals
    - Laboratory
    - Pathogens
- Watershed
    - All subgroups found
    - 46% group B1 – found often in water
    - Present year round

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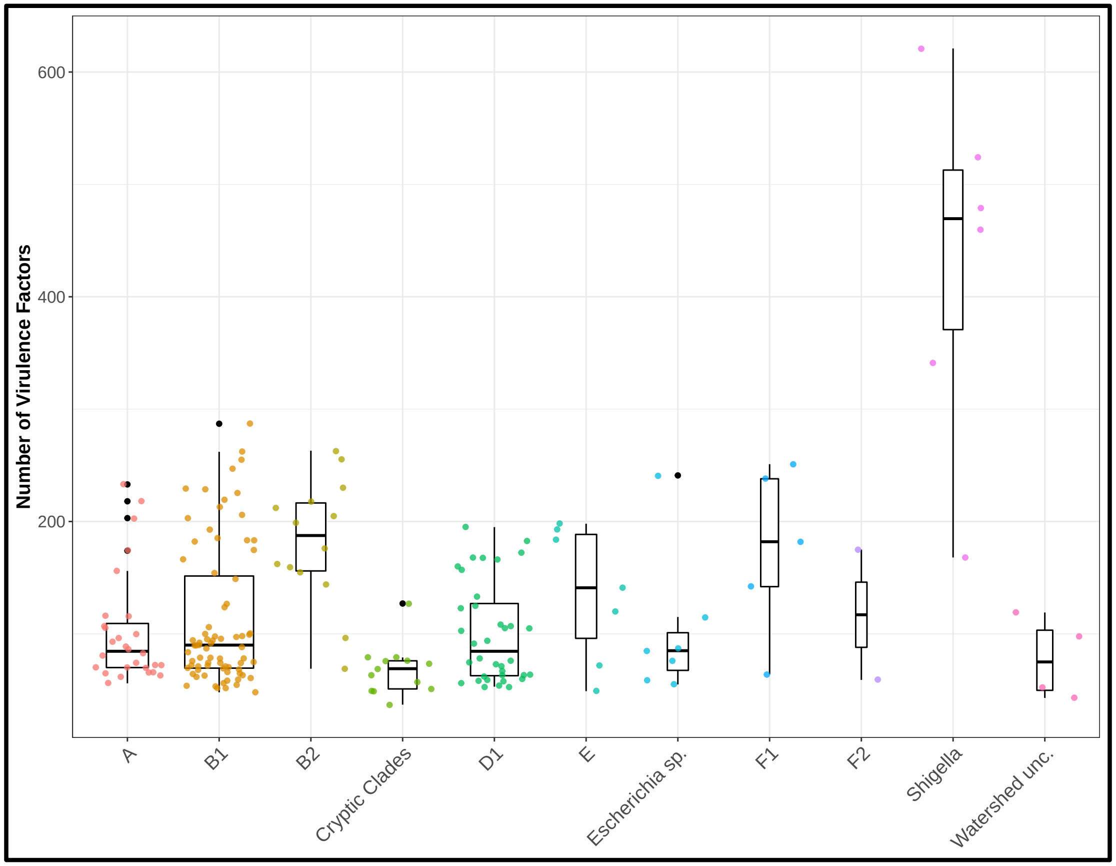
Virulence Factors Summary by Phylogroup



- Virulence Factor Database (VFDB)
- PATRIC ([www.patricbrc.org)](http://www.patricbrc.org) specialty gene interface
- Groupings include reference and watershed strains
- Average number of VFs for major groups of *Escherichia* and *Shigella* vary significantly (ANOVA)
  - ***Shigella*** significantly higher than all other groups ($p < 0.01$)
  - **Phylogroup B2** significantly higher than phylogroups A, B1, D1 and cryptic clades ($p < 0.01$)
  - **Phylogroup F1** significantly higher than cryptic clades ($p < 0.05$)

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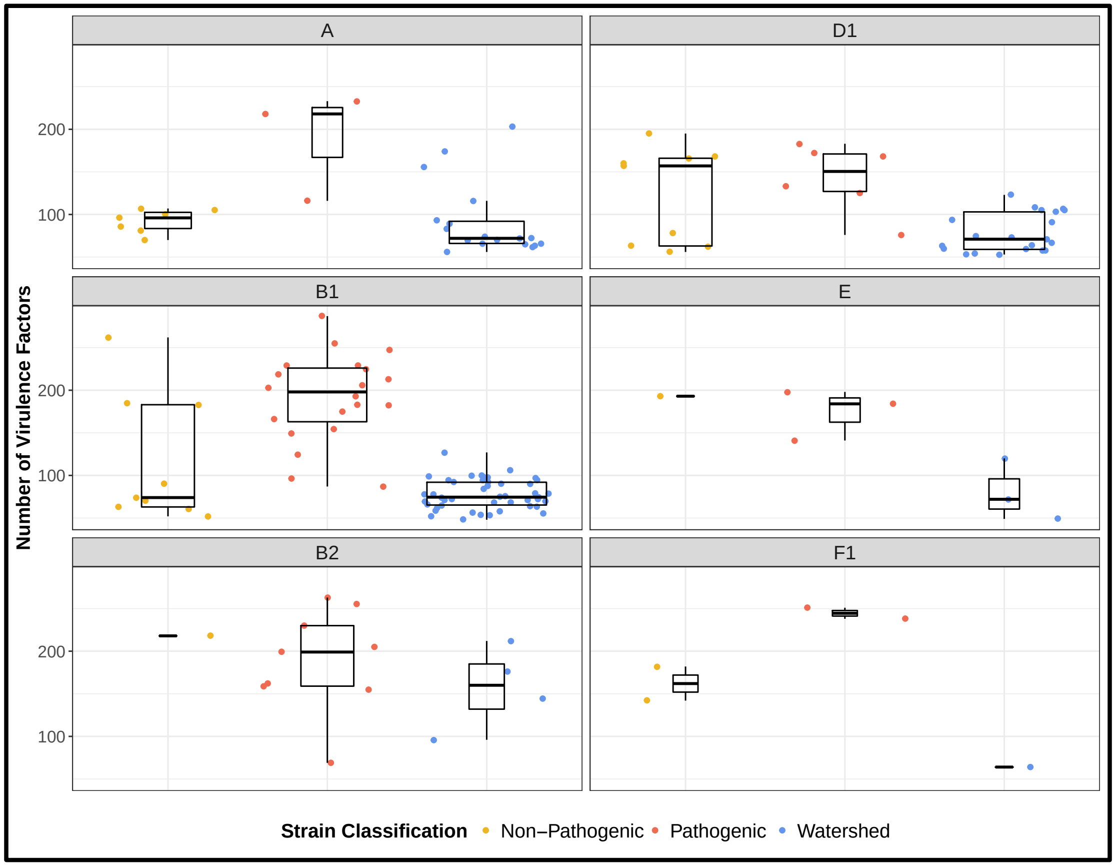
Virulence Factors Summary by Strain Classification



- Virulence Factor Database (VFDB)
- PATRIC (www.patricbrc.org) specialty gene interface
- Subgrouping of All Strains
  - Reference Pathogenic Strains
  - Reference Non-Pathogenic Strains
  - Watershed Strains
- Significant differences in average number of VFs for groups (ANOVA)
  - **All phylogroups combined** ($p < 0.01$)
  - **Phylogroup B1** pathogenic higher than both non-pathogenic and watershed ($p \ll 0.001$)
- **Phylogroup A Watershed Strain Outliers** – functions of VFs enriched in same categories as for known pathogen reference strains

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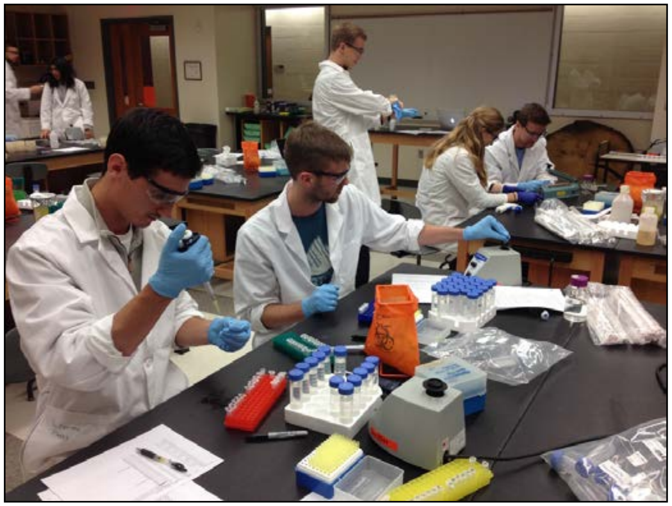

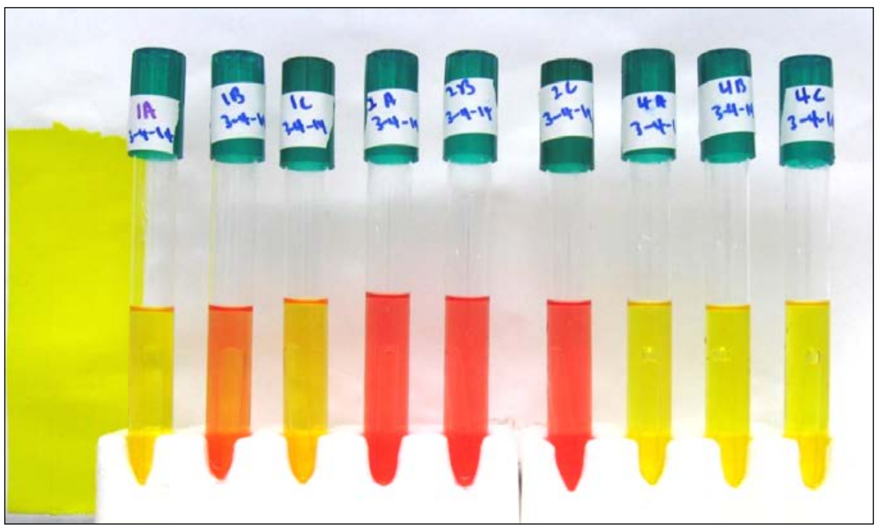

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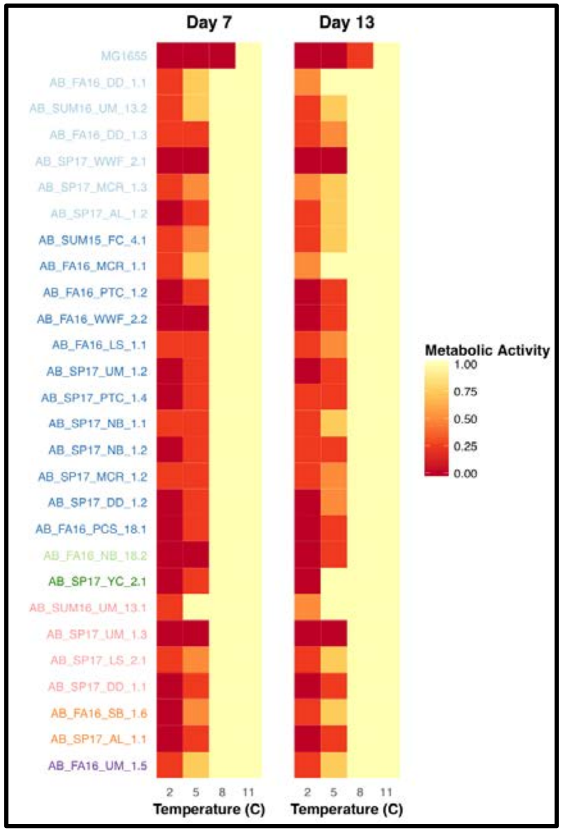
Physiological Adaptation? Cold Metabolism



Fermentation Day 13	2°C (# of strains)	5°C (# of strains)	8°C (# of strains)	11°C (# of strains)
No Change	12	3	0	0
Weak	12	9	1	0
Weak Acid	**4**	4	0	0
Acid	0	8	0	0
Strong Acid	0	**4**	27	28

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Hope College students since Fall 2015 – Over 120

Hamilton High School Stream School – 30 students

Holland Christian High School Winterim Internships – 3 students

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Acknowledgements

Project Clarity
Travis Williams; Dan Callam; Lynn Kotecki

Naber Family; Koostra Family

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Dr. Brent Krueger; Dr. Michael Pikaart; Dr. Graham Peaslee
Dr. Catherine Mader; Sarah Harvin

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Hope College Departments of Biology and Chemistry
Hope College Day1 Program

Hope College Day1 Watershed Students and TAs 2015-17
Hope College Microbiology Students and TAs 2014-17

Marian Schmidt; Michelle Berry