Status Update on Spring Lake

Alan Steinman, Ph.D.

Allen and Helen Hunting Director
Annis Water Resources Institute-GVSU

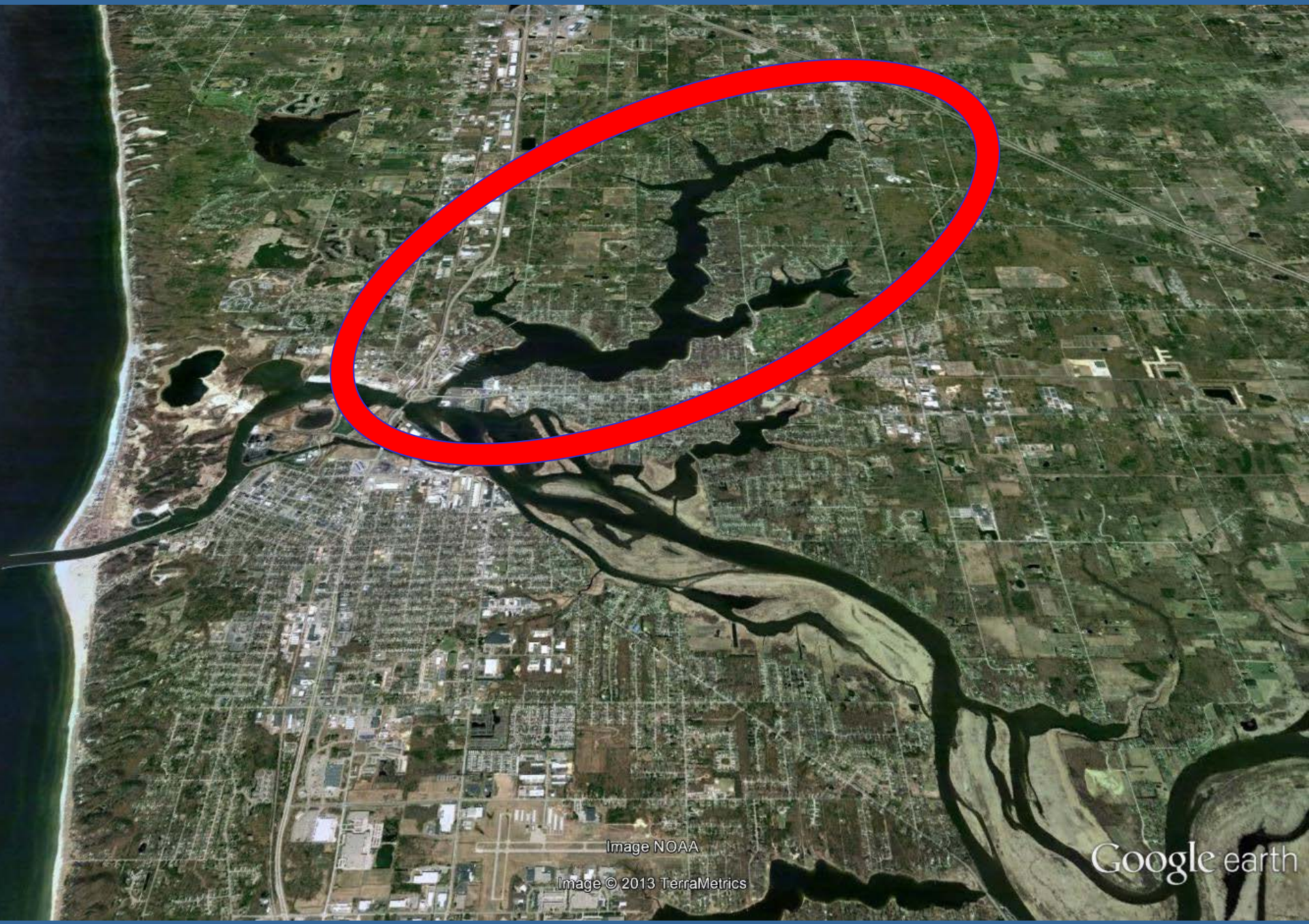
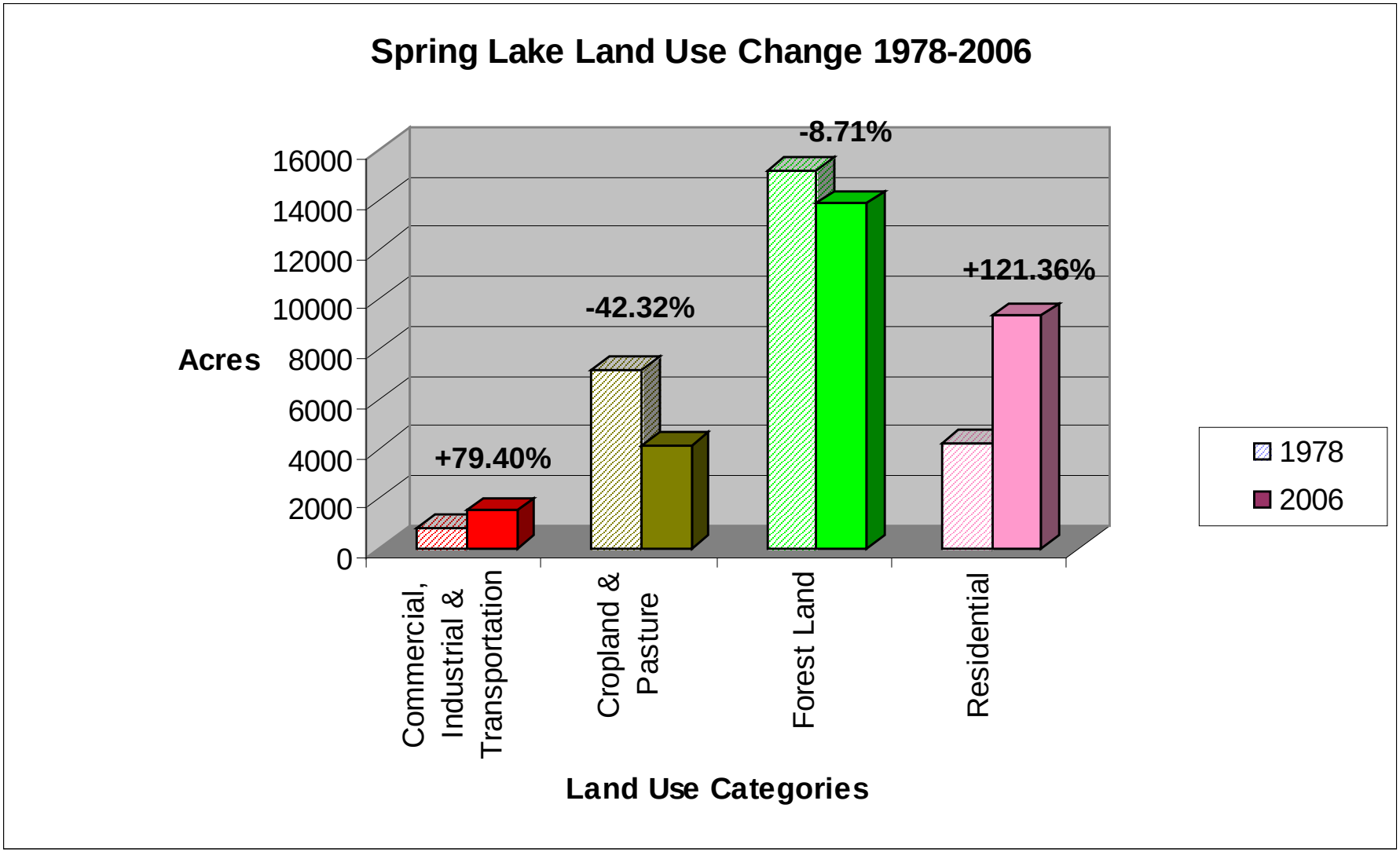


Image NOAA
Image © 2013 TerraMetrics
Google earth

Land Use Change Analysis



1978 Land Use and Cover

Legend

Land Use and Cover Description	Total Acres	%
Bare/sparsely vegetated	237	0.7
Commercial/industrial/transportation	838	2.5
Coniferous forest	3,267	9.7
Cropland and pasture	7,176	21.2
Deciduous forest	11,887	35.1
Emergent herbaceous wetlands	127	0.4
Herbaceous open land/grasslands	479	1.4
Mixed forest	0	0.0
Orchards/vineyards/other	598	1.8
Other agricultural land	13	0.0
Residential	4,221	12.5
Shrub/low-density trees	3,414	10.1
Urban/recreational grasses	286	0.8
Water	1,144	3.4
Woody wetlands	131	0.4

Data Sources:
1978 Land Use and Cover - Michigan Resources Information System (MIRIS): Michigan Department of Natural Resources, Land and Water Management Division

Base Information - Michigan Center for Geographic Information, Department of Information Technology, 2008

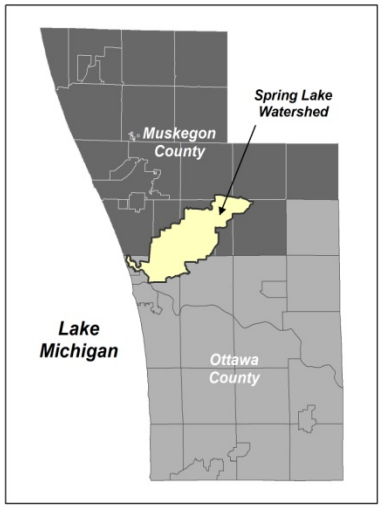
0 0.5 1 2 3 4 Miles

0 0.5 1 2 3 4 Kilometers

Information Services Center
Annis Water Resources Institute
Grand Valley State University

Map Prepared: March 2009

2006 Land Use and Cover



Legend

Land Use and Cover Description	Total Acres	%
Bare/sparsely vegetated	184	0.5
Commercial/industrial/transportation	1,504	4.4
Coniferous forest	2,643	7.8
Cropland and pasture	4,140	12.2
Deciduous forest	11,186	33.1
Emergent herbaceous wetlands	247	0.7
Herbaceous open land/grasslands	755	2.2
Mixed forest	5	0.0
Orchards/vineyards/other	834	2.5
Other agricultural land	214	0.6
Residential	9,343	27.6
Shrub/low-density trees	963	2.8
Urban/recreational grasses	523	1.5
Water	1,187	3.5
Woody wetlands	92	0.3

Data Sources:
2006 Land Use and Cover - AWRI-GVSU Updated using
2006 National Agricultural Imagery Program (NAIP) Digital
Orthophotograph with AWRI-GVSU 1992-97 Land Use and Cover Data

Base Information - Michigan Center for Geographic
Information, Department of Information Technology, 2008

0 0.5 1 2 3 4 Miles

0 0.5 1 2 3 4 Kilometers

Information Services Center
Annis Water Resources Institute
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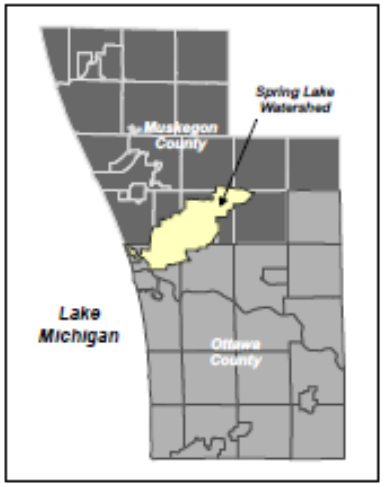
Map Prepared: March 2009

2016 Land Use and Cover - Partial Update



Muskegon County
Ottawa County

Muskegon County
Ottawa County

Stream Sampling Locations
Internal Loading Sample Locations
Bioassay Site

Legend

Land Use and Cover Description	Total Acres	%
Bare/sparsely vegetated	222	0.7
Commercial/industrial/transportation	1,646	4.9
Coniferous forest	2,498	7.4
Cropland and pasture	4,108	12.1
Deciduous forest	10,442	30.9
Emergent herbaceous wetlands	238	0.7
Herbaceous open land/grasslands	560	1.6
Mixed forest	1,162	3.4
Orchards/vineyards/other	791	2.3
Other agricultural land	288	0.9
Residential	9,106	26.9
Shrub/low-density trees	871	2.6
Urban/recreational grasses	476	1.4
Water	1,310	3.9
Woody wetlands	100	0.3

Data Sources:
2006 Land Use and Cover - AWRI-GVSU Updated using
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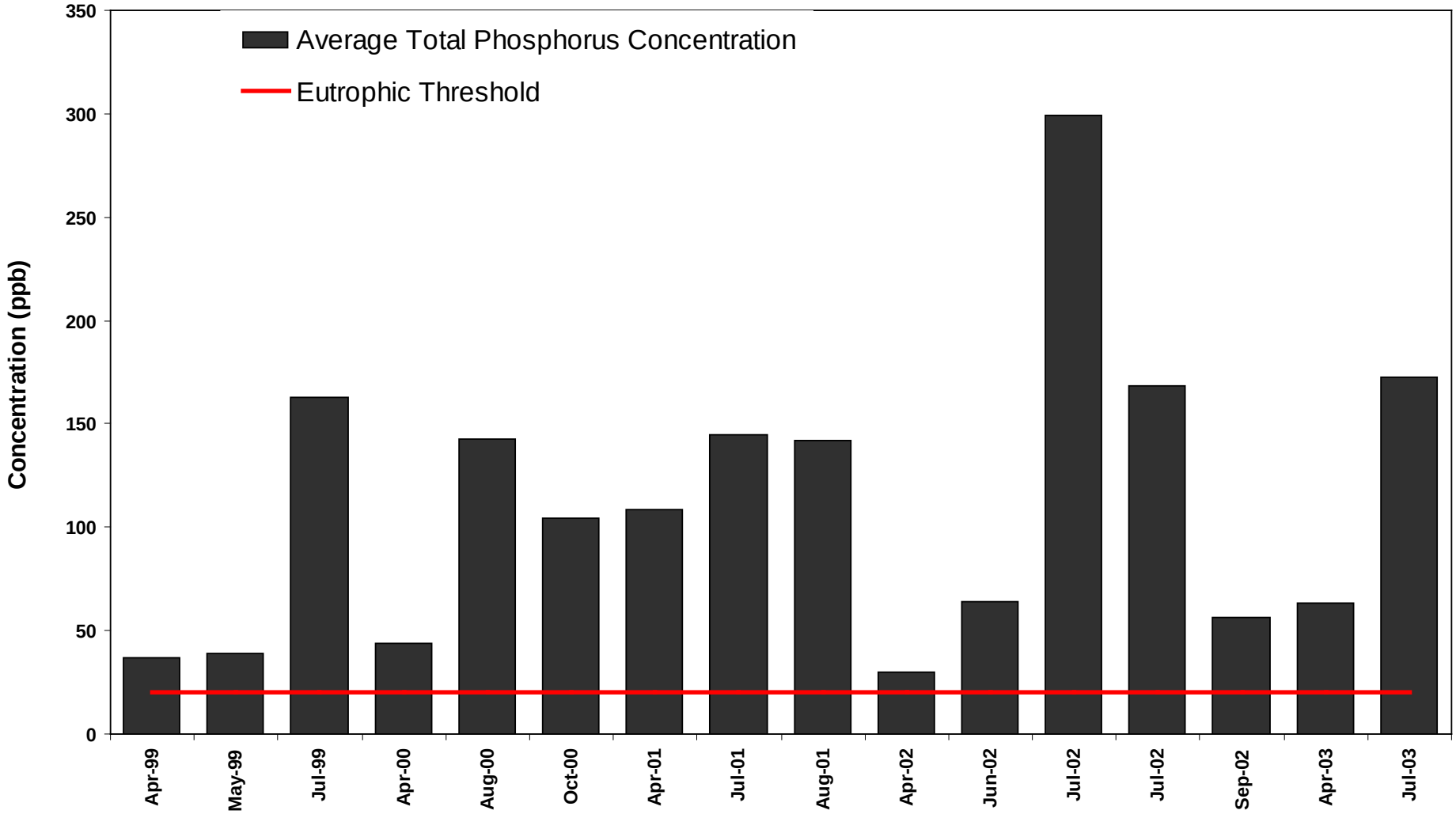
0 0.5 1 2 3 4 Miles
0 0.5 1 2 3 4 Kilometers

Lake Michigan

Information Services Center
Annis Water Resources Institute
Grand Valley State University

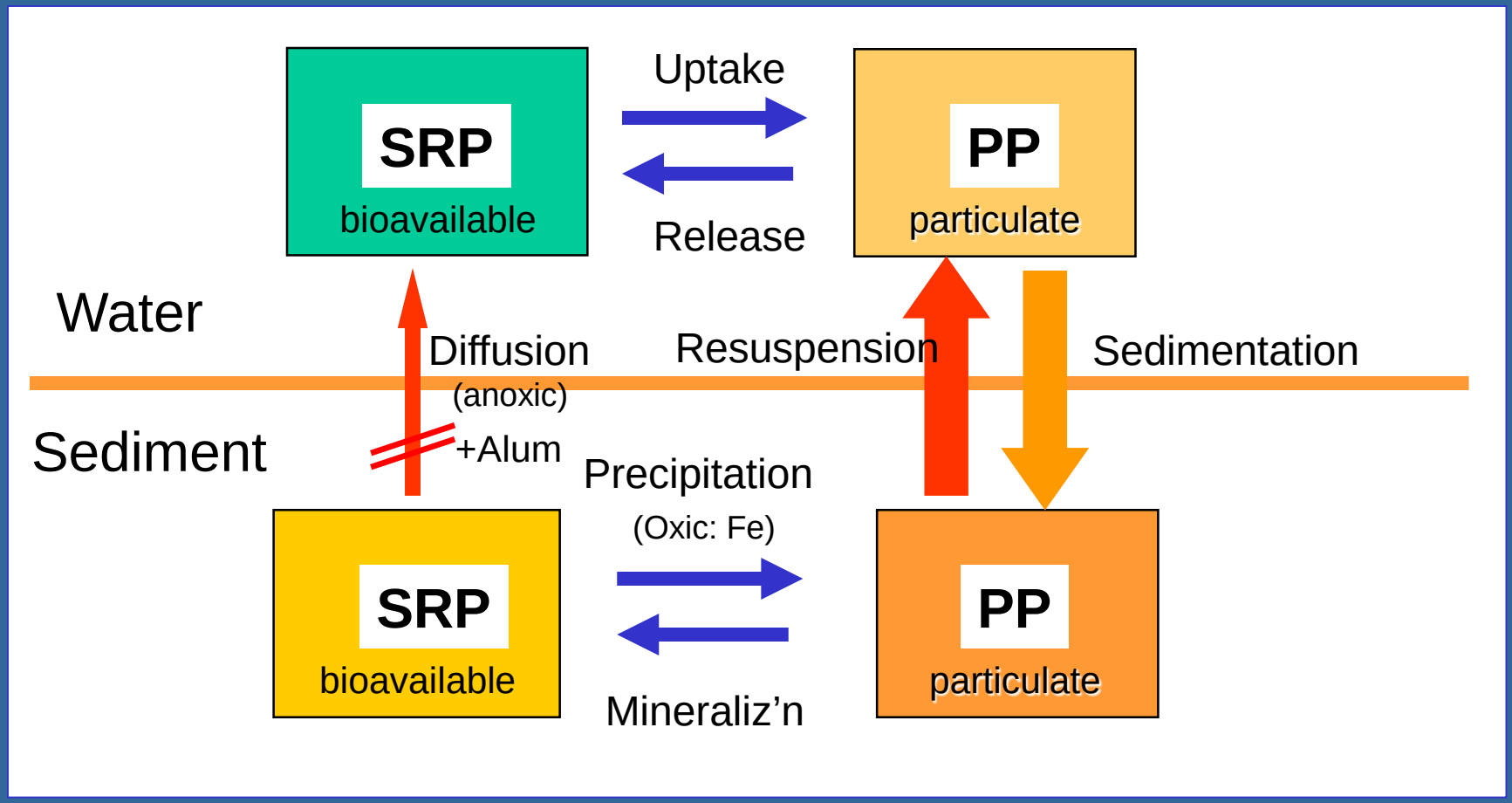
Map Prepared: November 2017

Total Phosphorus: Spring Lake



Data: Progressive AE

Sediment-Water Interactions



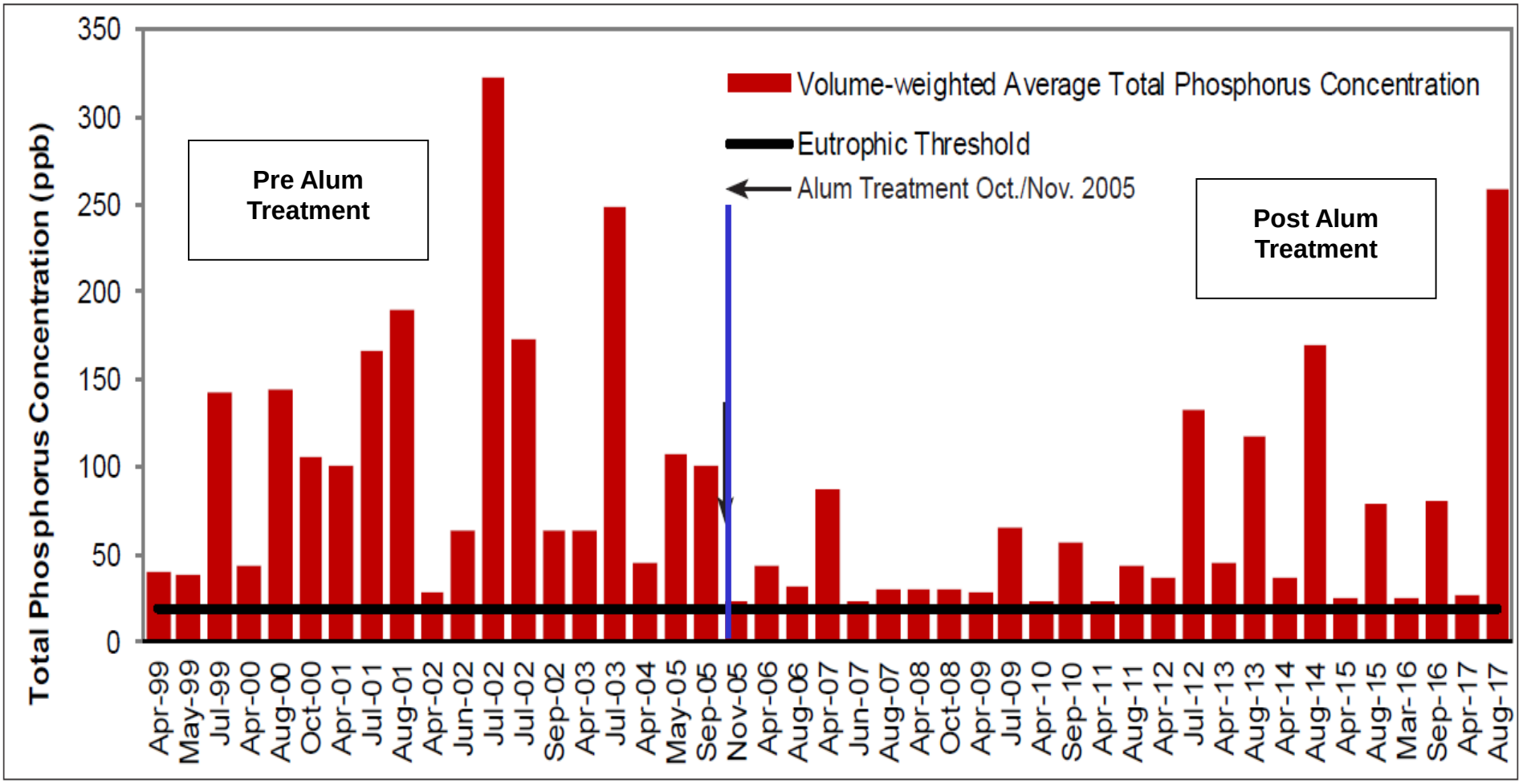
Alum Application

- Application date: Oct—Nov, 2005
- Total application: 1,163,00 gallons
- Surface application using spray nozzles
- Treatment area: ~2.4 km^2 (~46%)
- Treatment dose: ~80 g Al/m^2

Treatment Barge

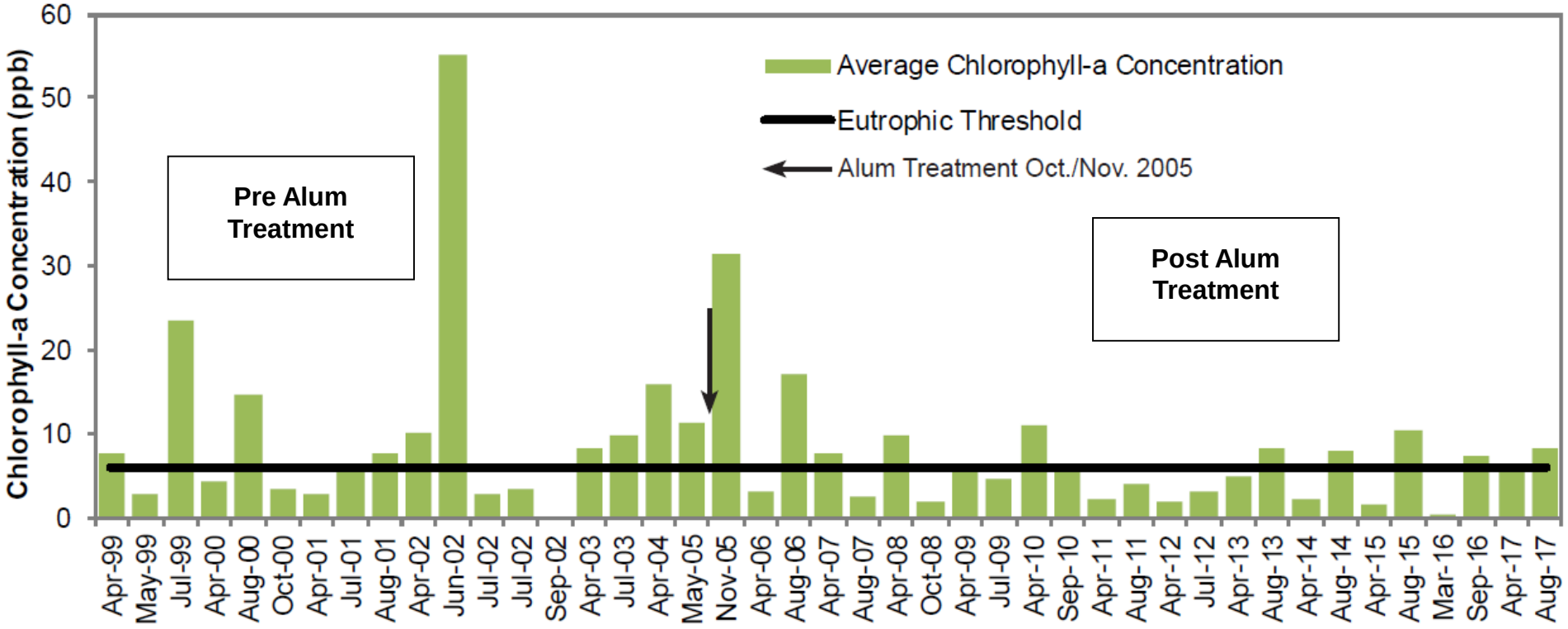
Photo Credit: Progressive AE

Spring Lake Phosphorus Concentrations

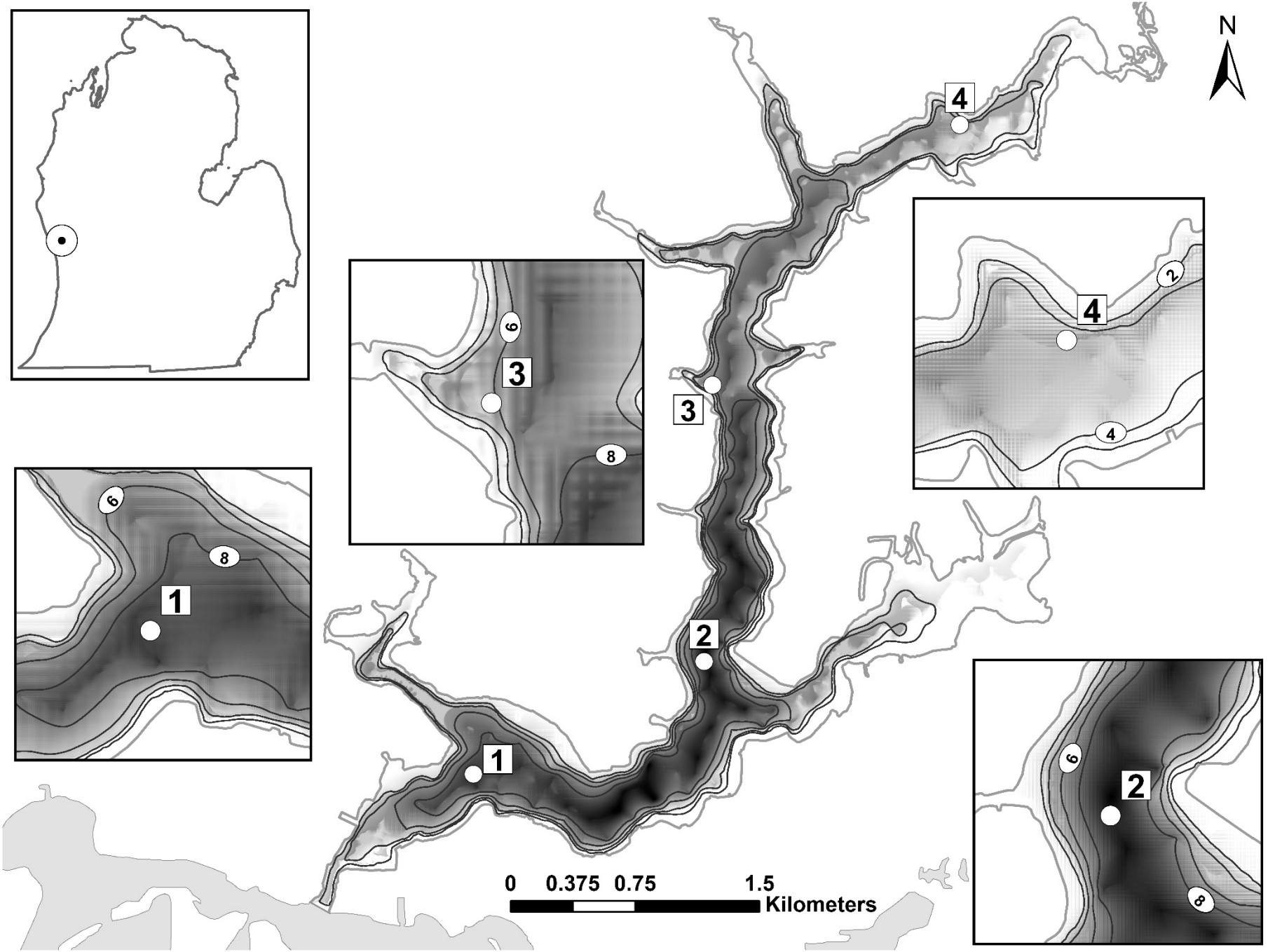


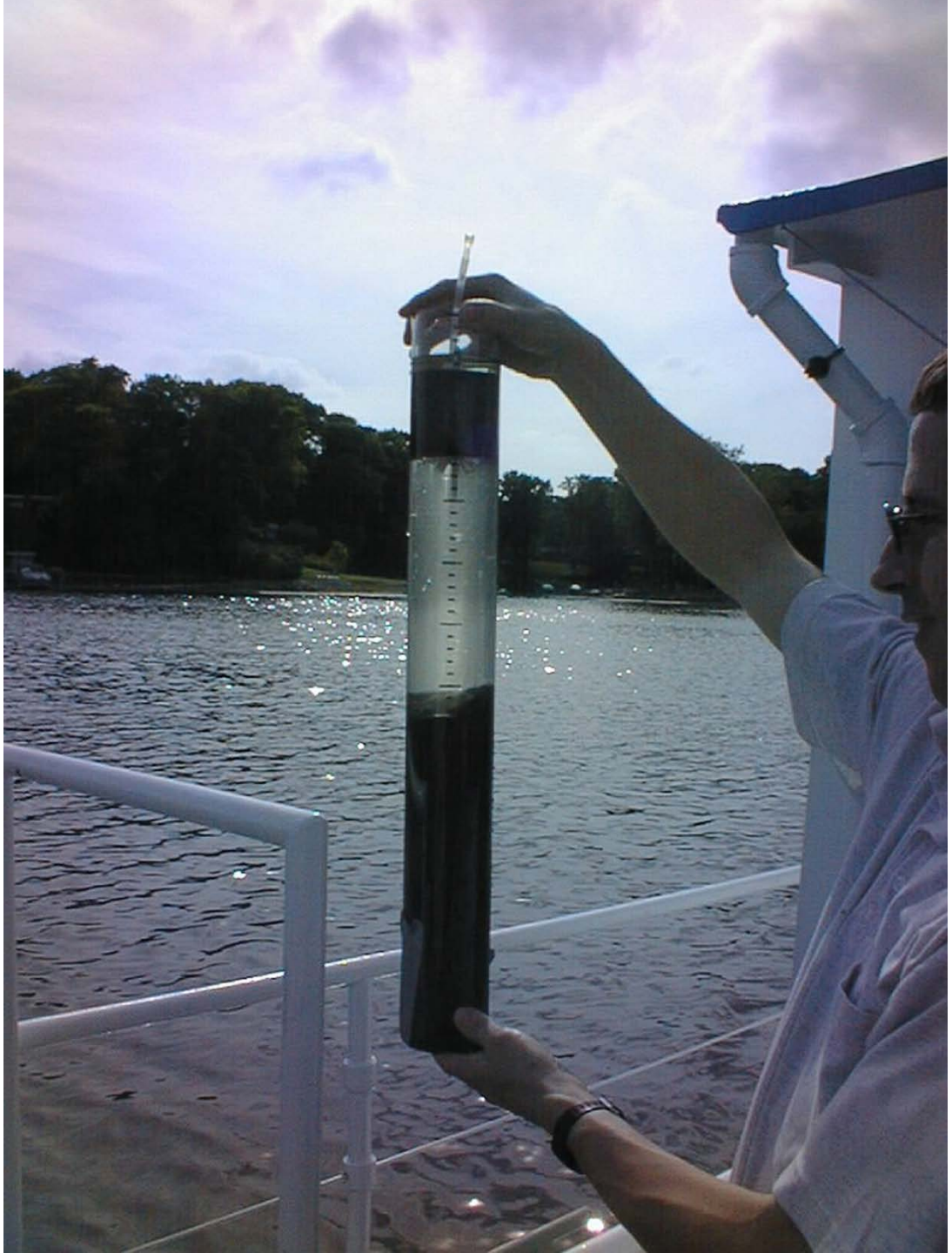
Data: Progressive AE

Spring Lake Chlorophyll *a* Concentrations



Data: Progressive AE


N
4
3
2
1
6
8
9
4
2
0 0.375 0.75 1.5
Kilometers

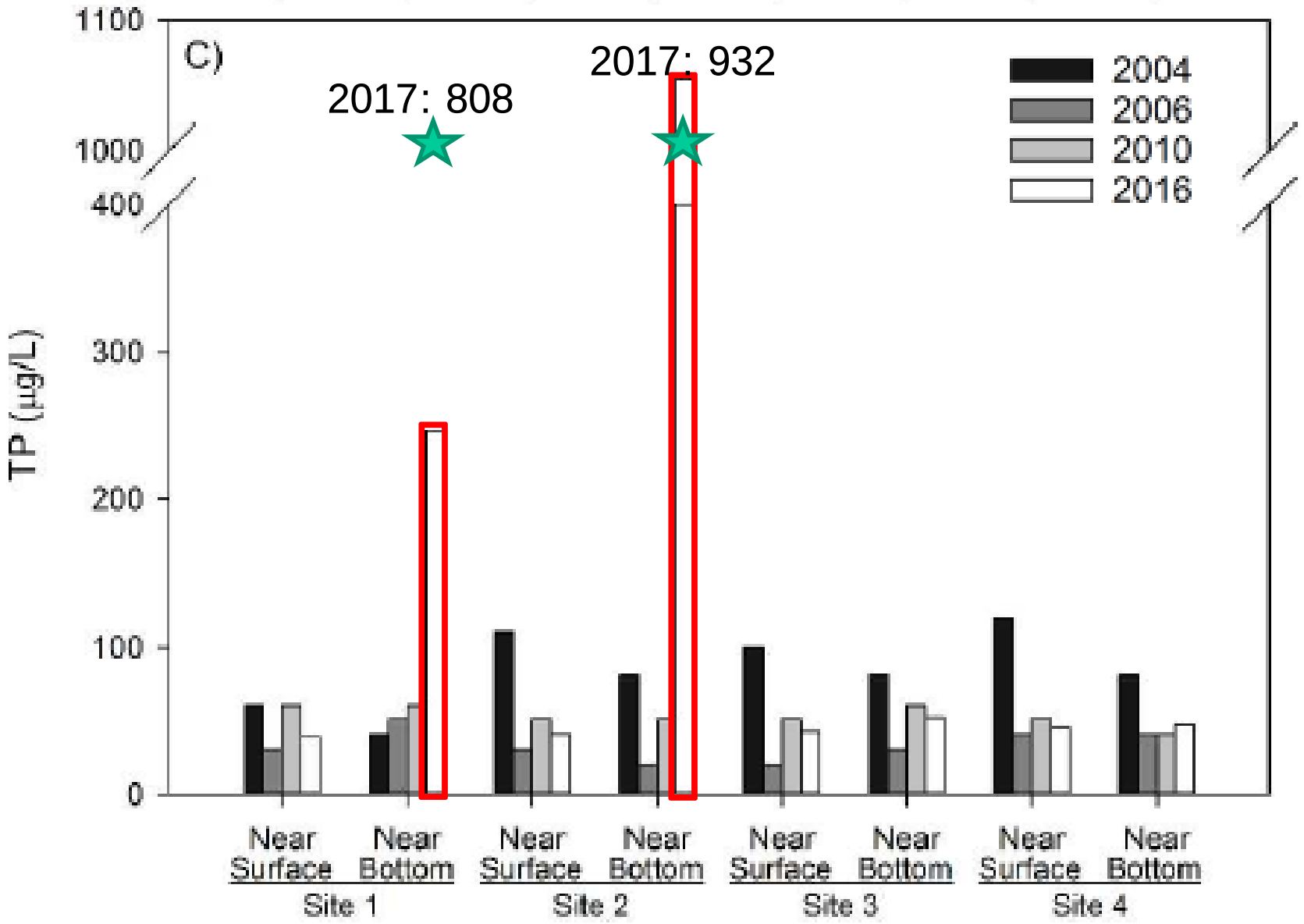


Mean TP Flux Rates (mg P/m^2/d)

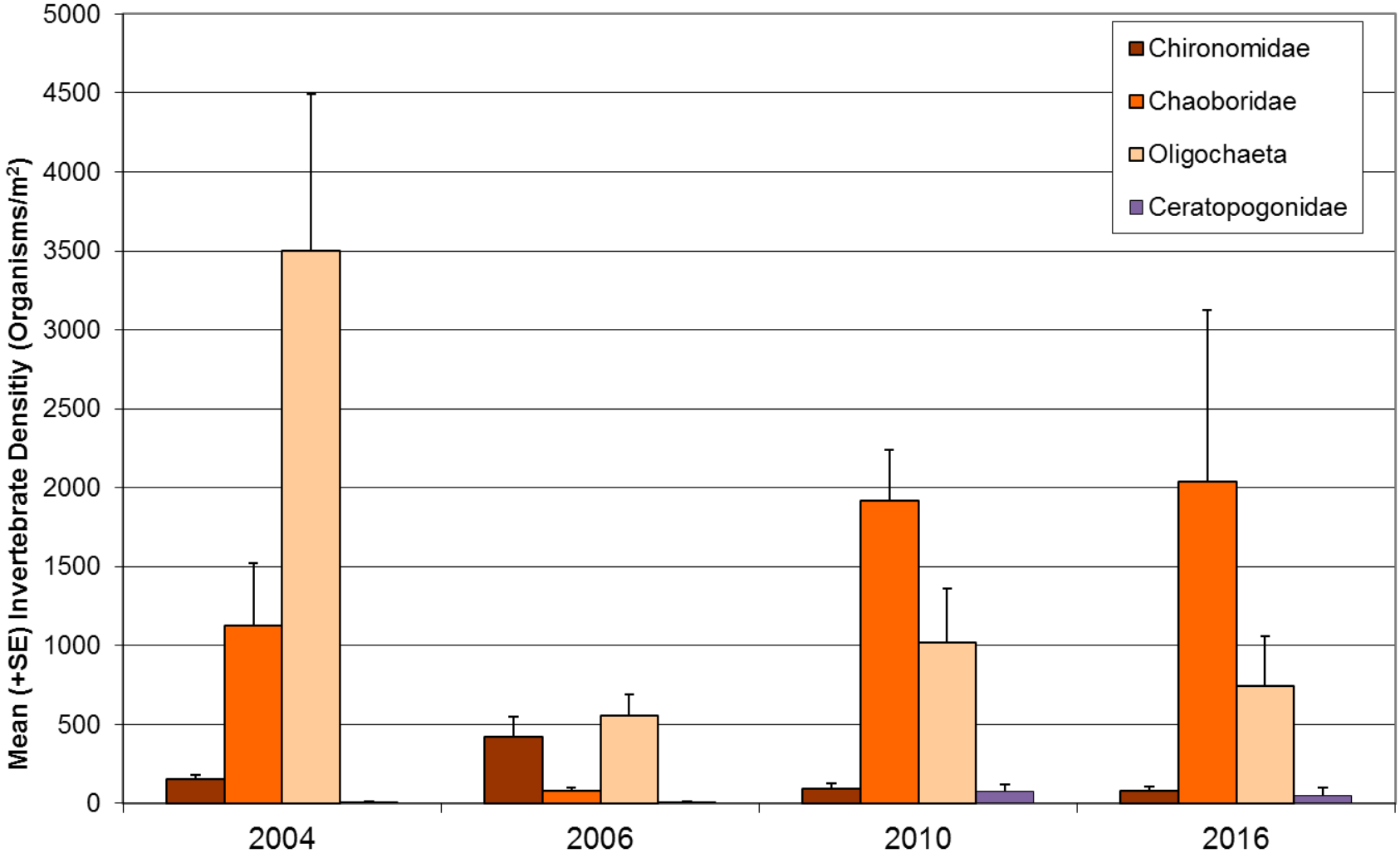
2003 (pre-alum)	2006 (post-alum)	2010 (5 yr post-alum)	2016 (11 yr post-alum)
17.97	0.41	1.14	1.25

Steinman and Ogdahl (2012)
Steinman et al. (In Press)

Total Phosphorus: 2004-2016



Spring Lake Invertebrate Densities



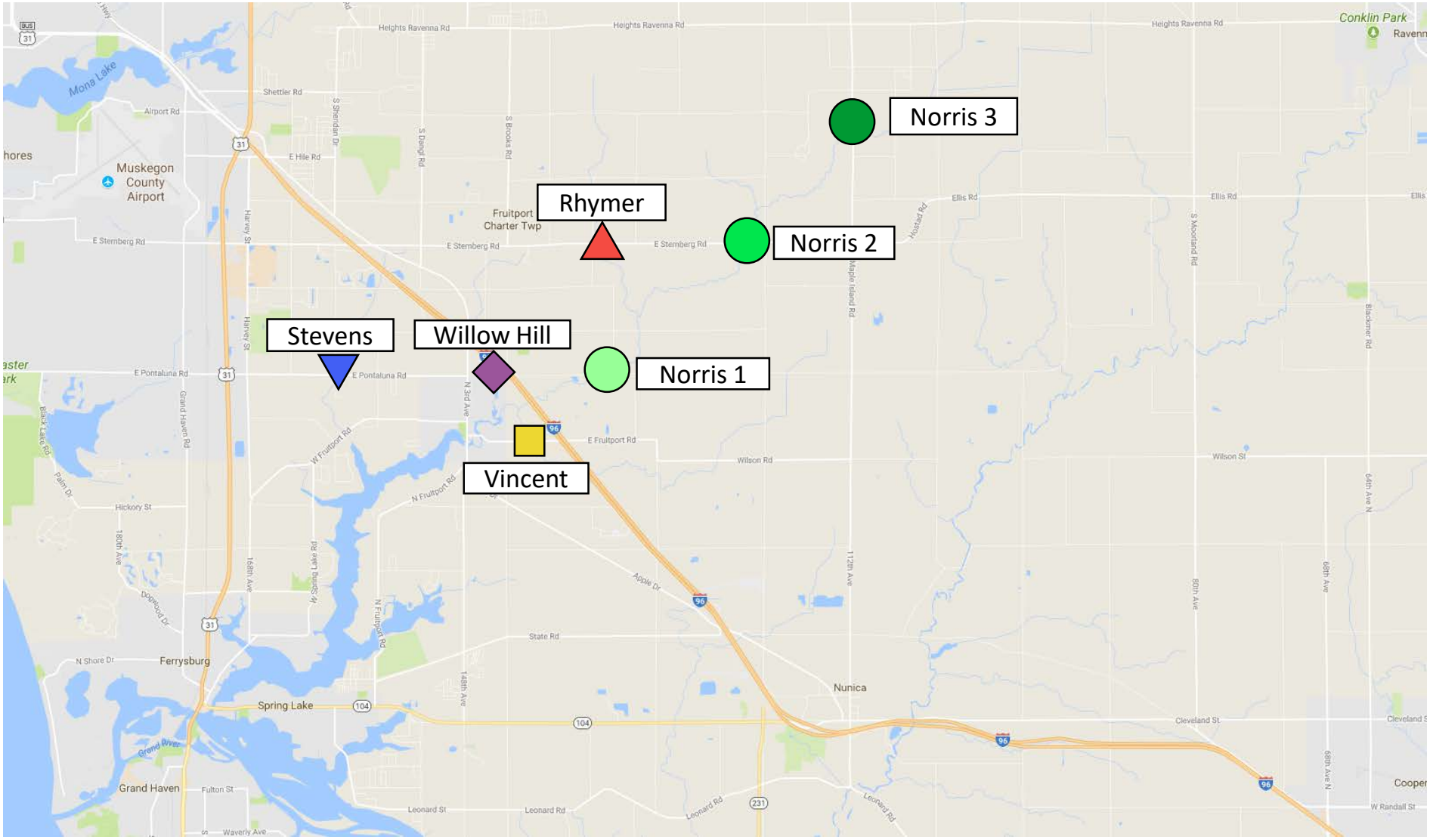
2017 Studies

1) Baseflow and Storm Flow Watershed Monitoring (2017-2018)

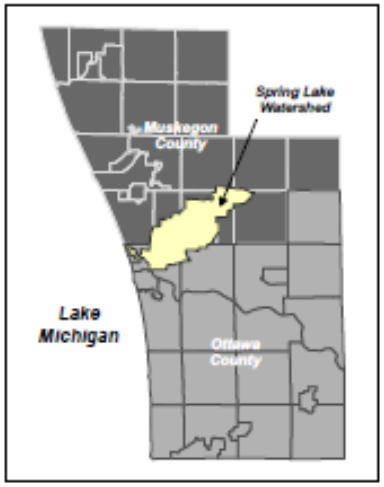
2) Microcystin Monitoring (2017)

3) Nutrient Bioassay (2017)

Baseflow and Storm Flow Watershed Monitoring: 2017-2018



2016 Land Use and Cover - Partial Update



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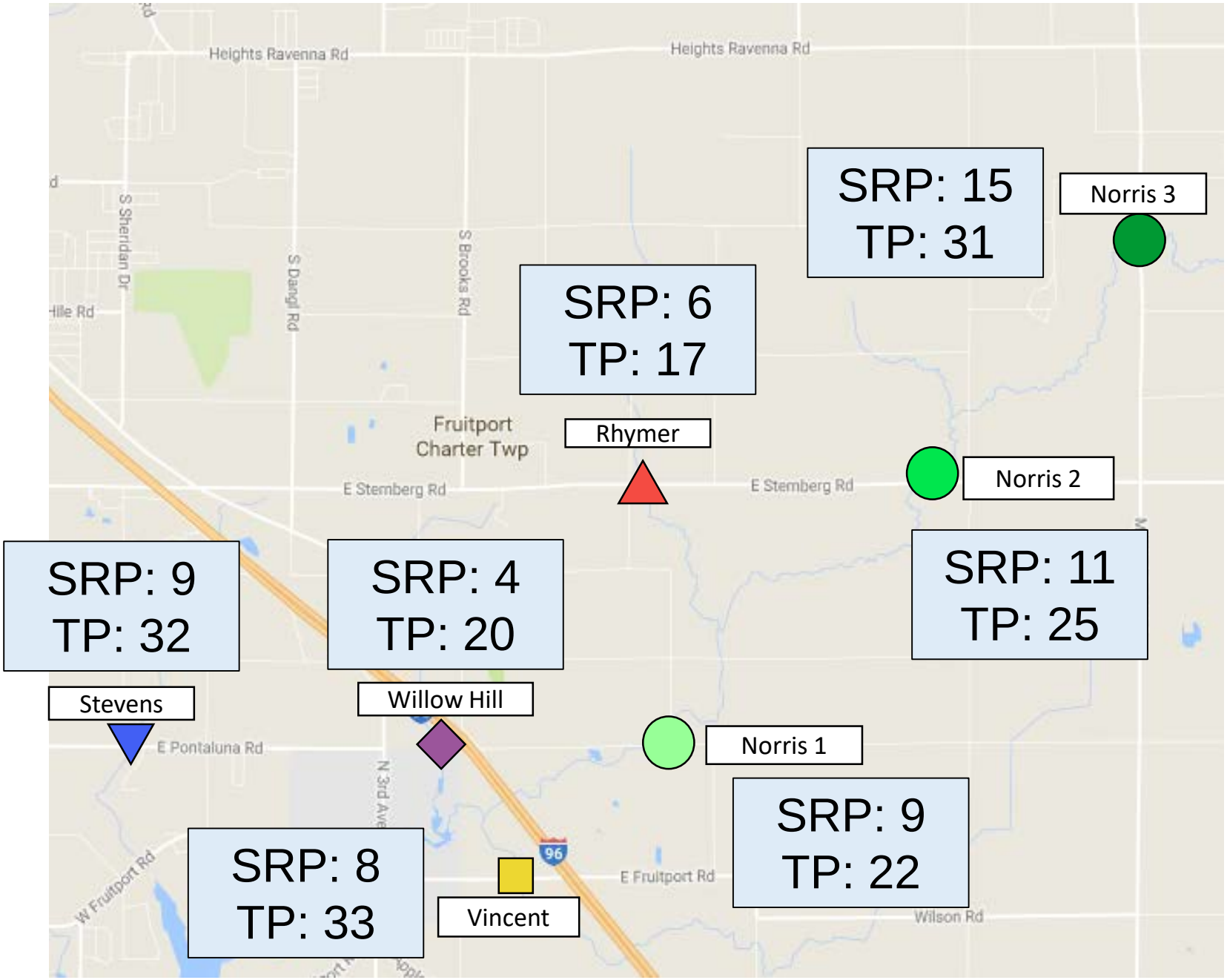
Lake Michigan

Grand Valley State University
Robert B. Annis Water Resources Institute

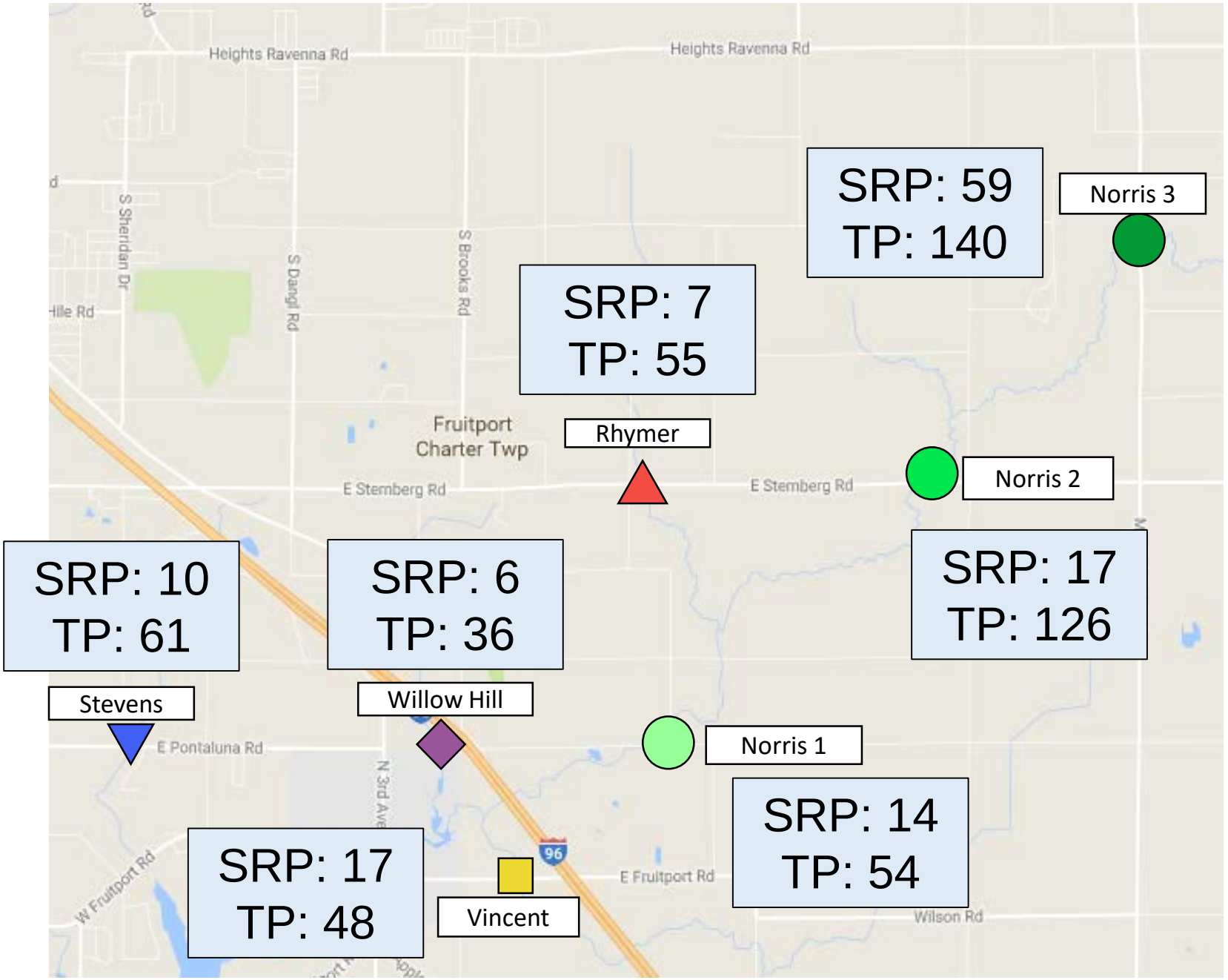
Information Services Center
Annis Water Resources Institute
Grand Valley State University

Map Prepared: November 2017

Baseflow Mean P Concentrations (June-Oct) in µg/L

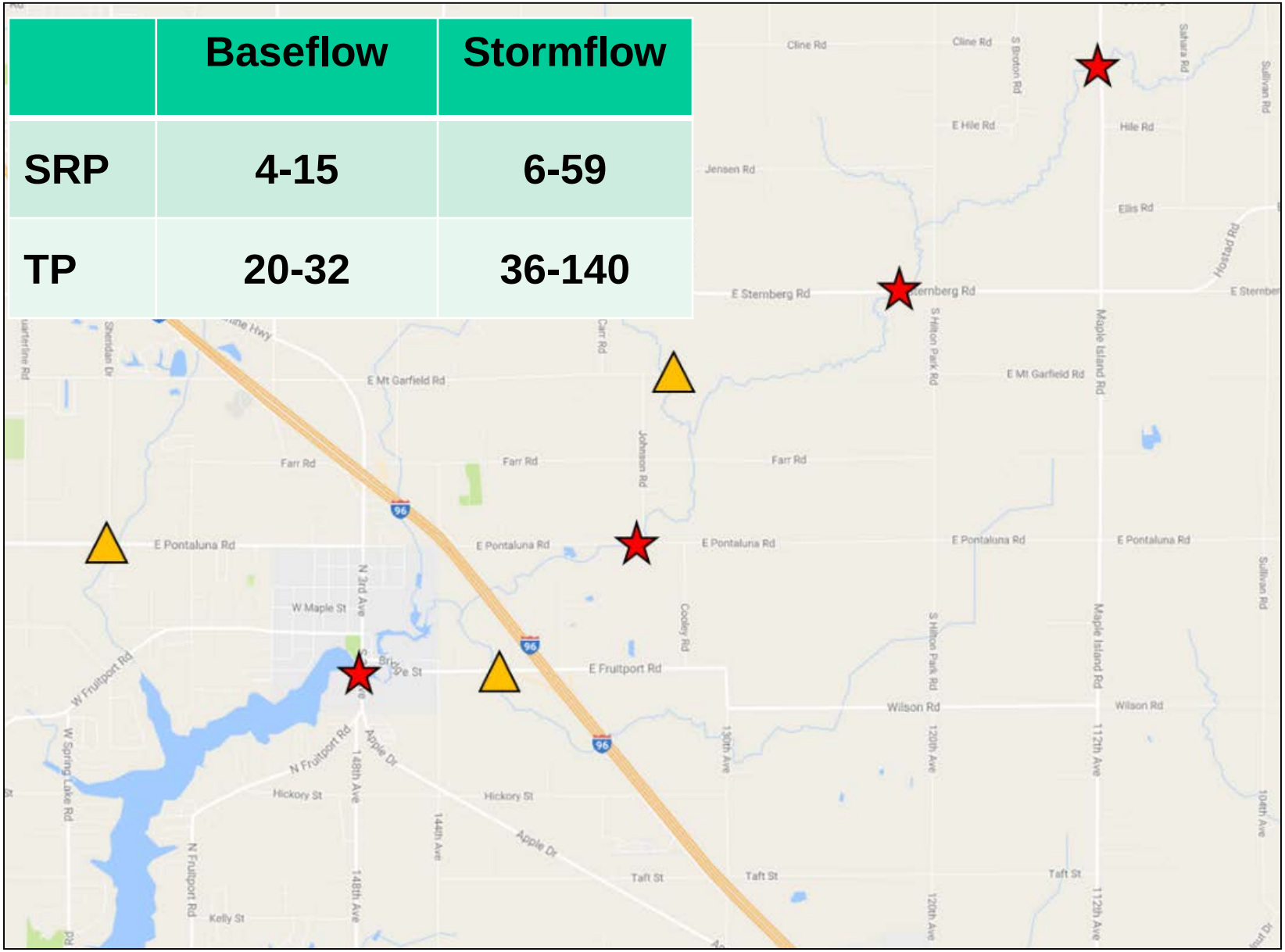


Stormflow Mean P Concentrations (June-Oct) in µg/L



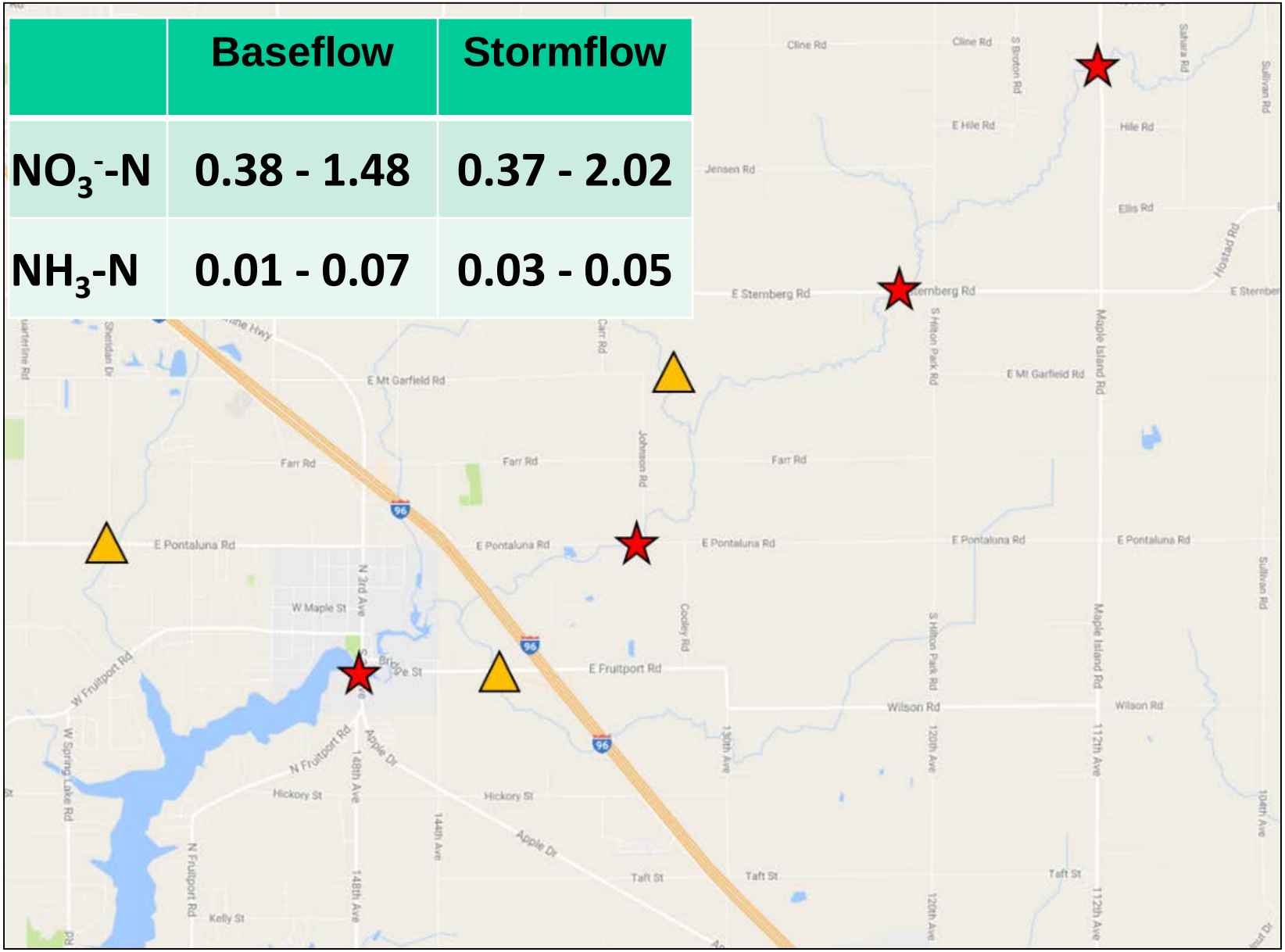
Baseflow and Storm Flow P Concentrations (µg/L)

	Baseflow	Stormflow
SRP	4-15	6-59
TP	20-32	36-140



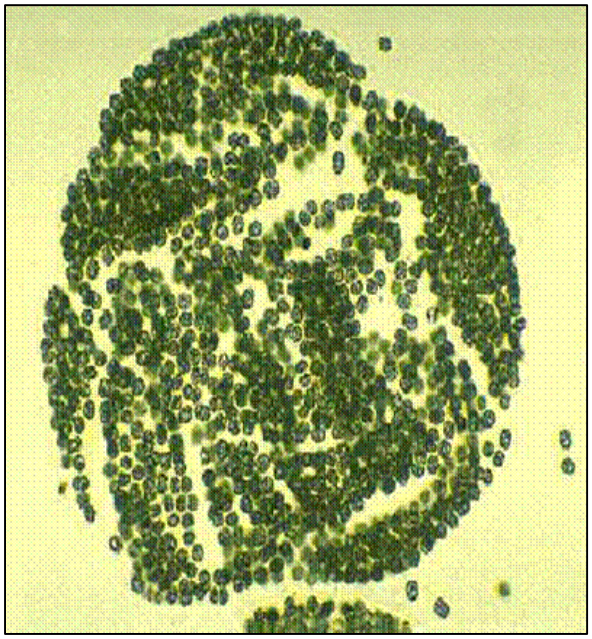
Baseflow and Storm Flow N Concentrations (mg/L)

	Baseflow	Stormflow
NO_3^--N	0.38 - 1.48	0.37 - 2.02
NH_3-N	0.01 - 0.07	0.03 - 0.05



Microcystin Monitoring

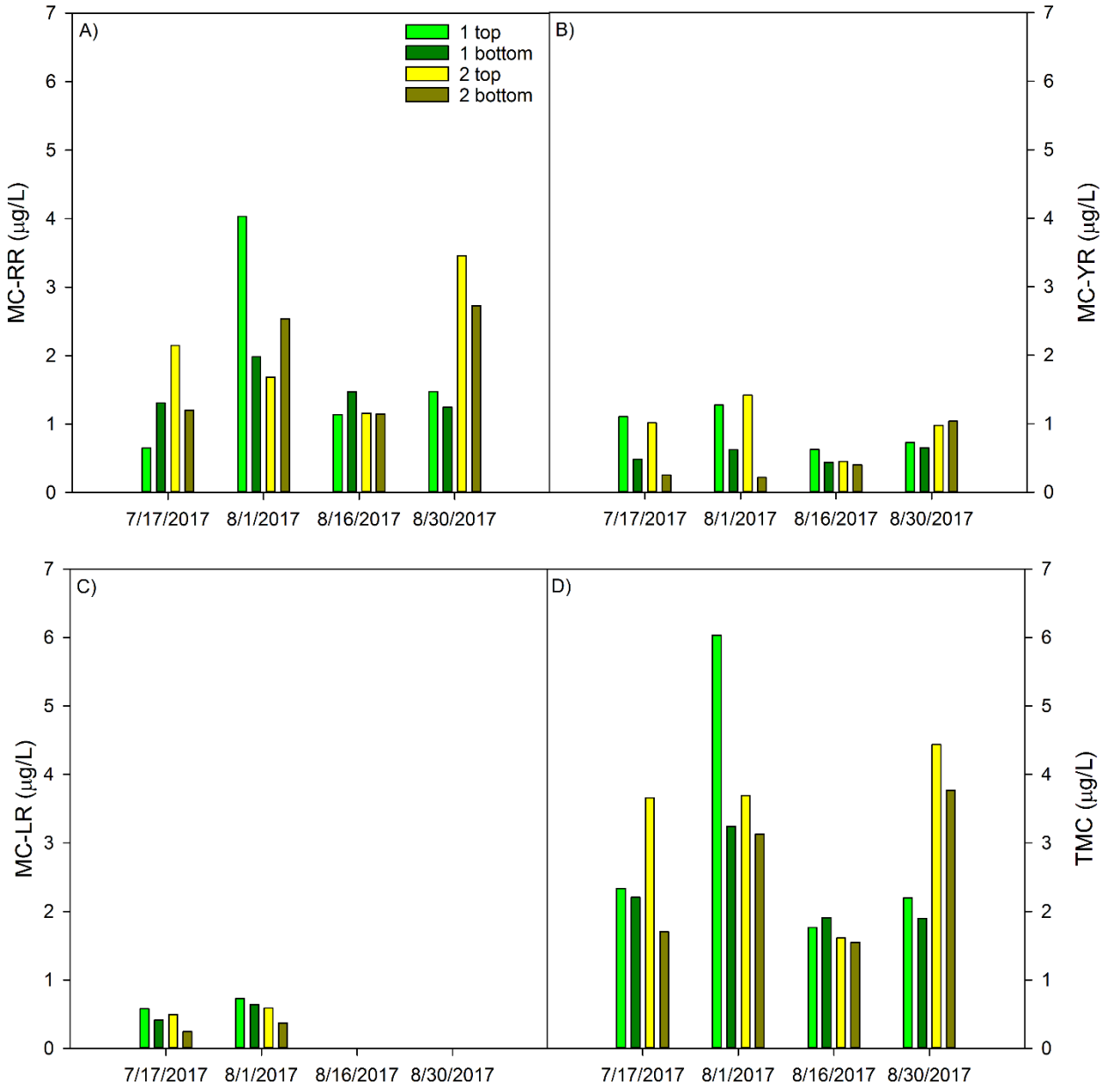
Microcystin is the most common cyanotoxin produced by HABs → hepatoxin and tumor promotor.



WHO standards:

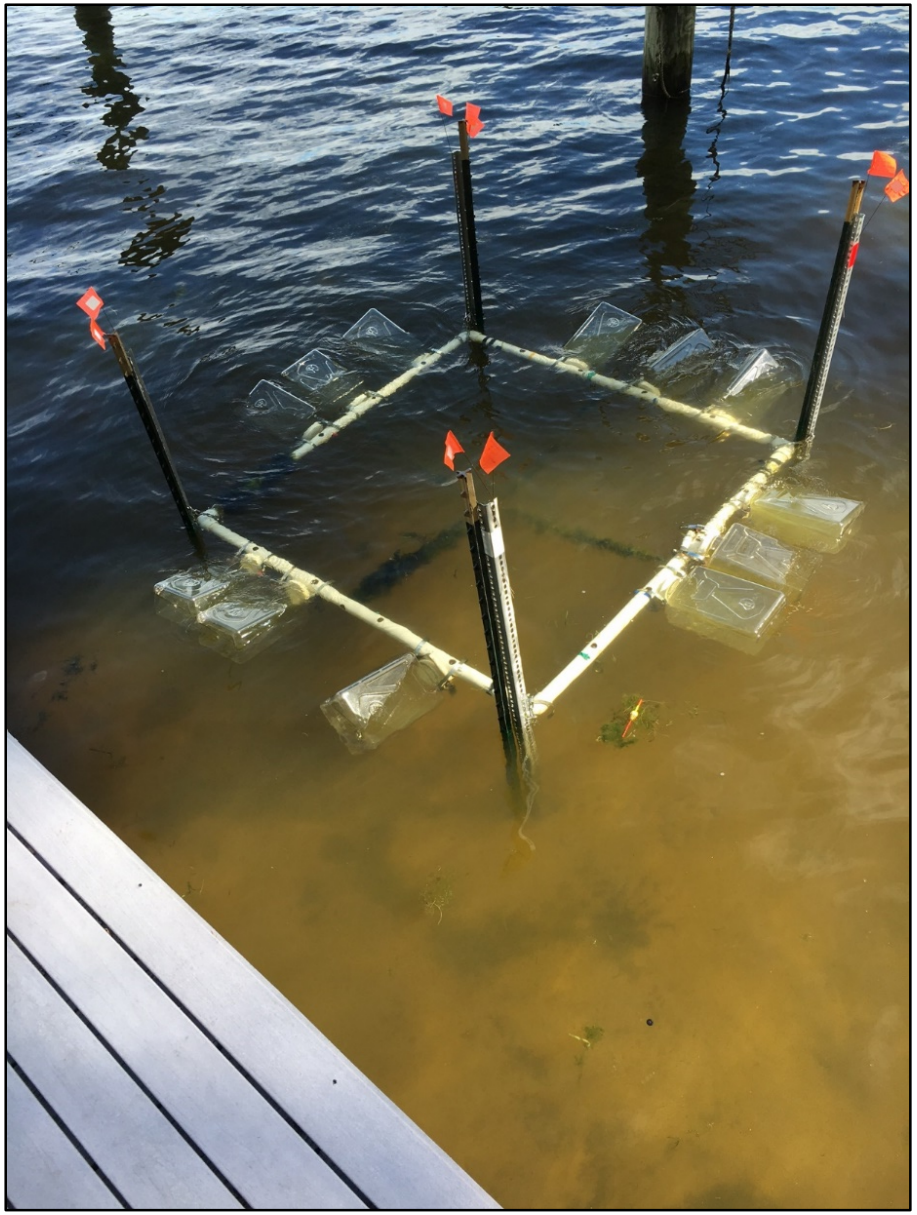
- drinking water: 1 µg/L
- recreational: 20 µg/L

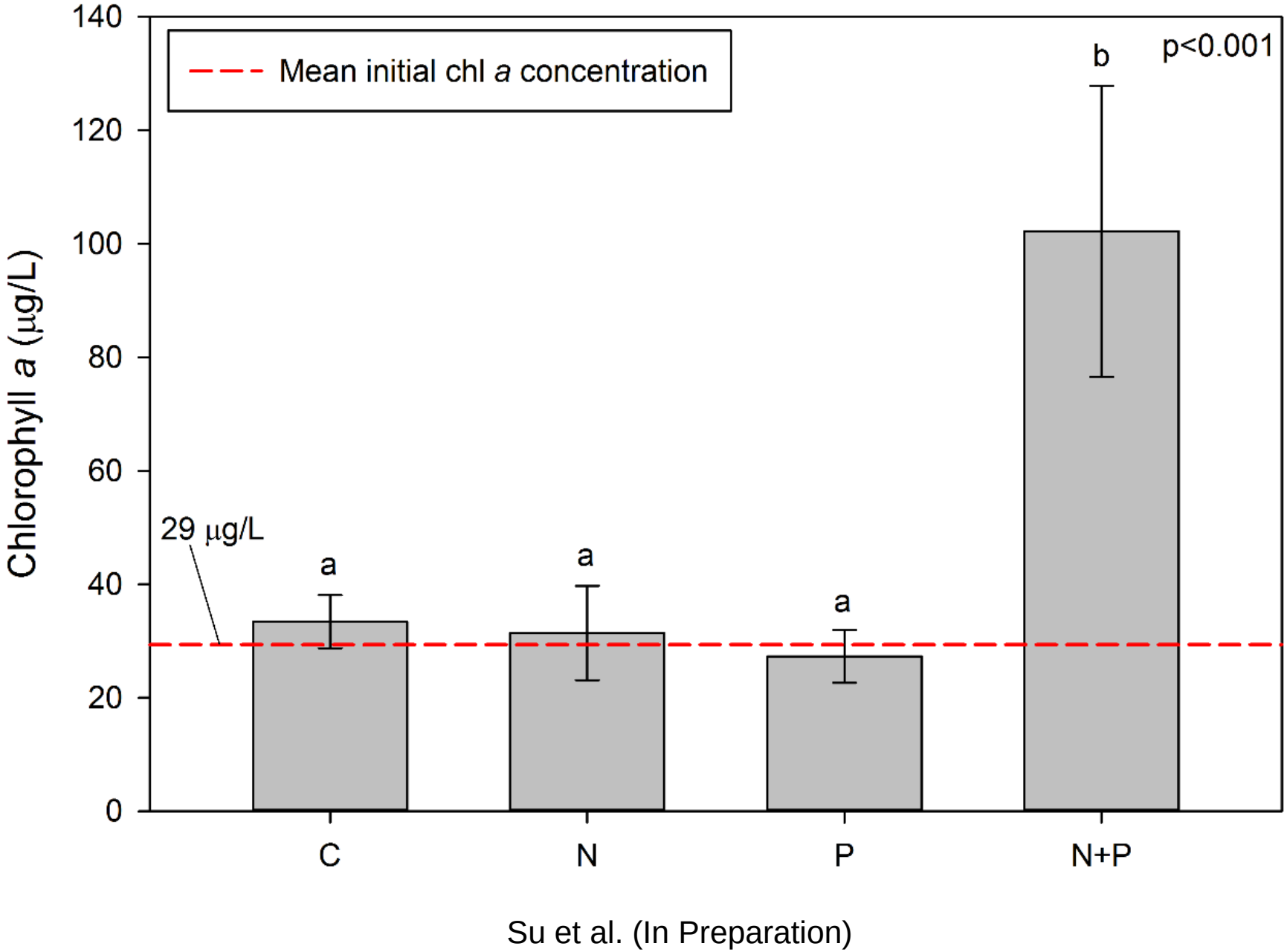
Microcystin Monitoring: 2017



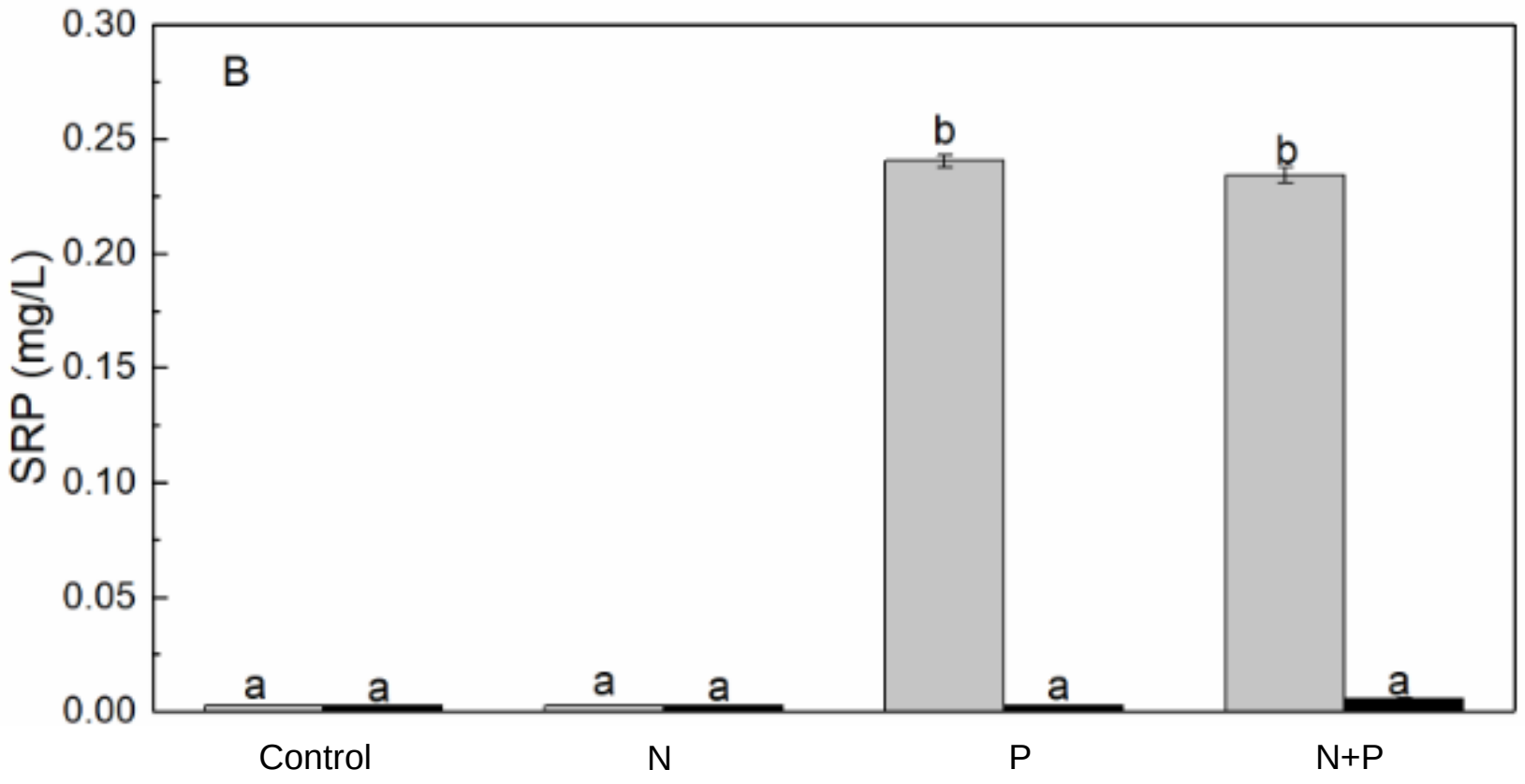
Nutrient Bioassay

- 4 treatments:
  - Control
  - Nitrogen alone
  - Phosphorus alone
  - N+P
- 3 replicates/treatment
- 7-day incubation
- Measure Δ in nutrients, Chl-*a*, and microcystins



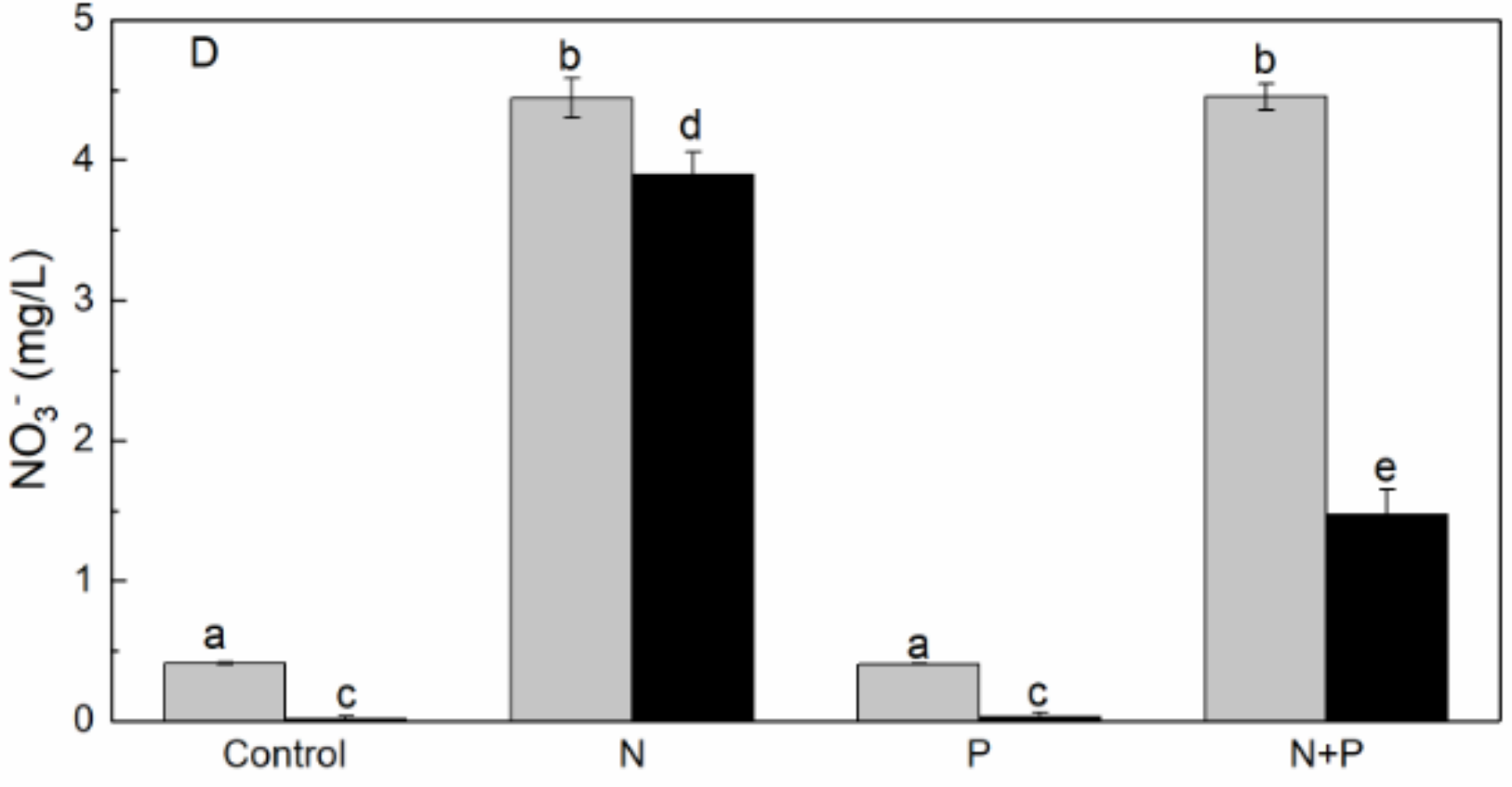

Mean initial chl a concentration
p<0.001
Chlorophyll a (μg/L)
140
120
100
80
60
40
20
0
29 μg/L
a
a
a
b
C
N
P
N+P
Su et al. (In Preparation)

Change in Bioavailable Phosphorus



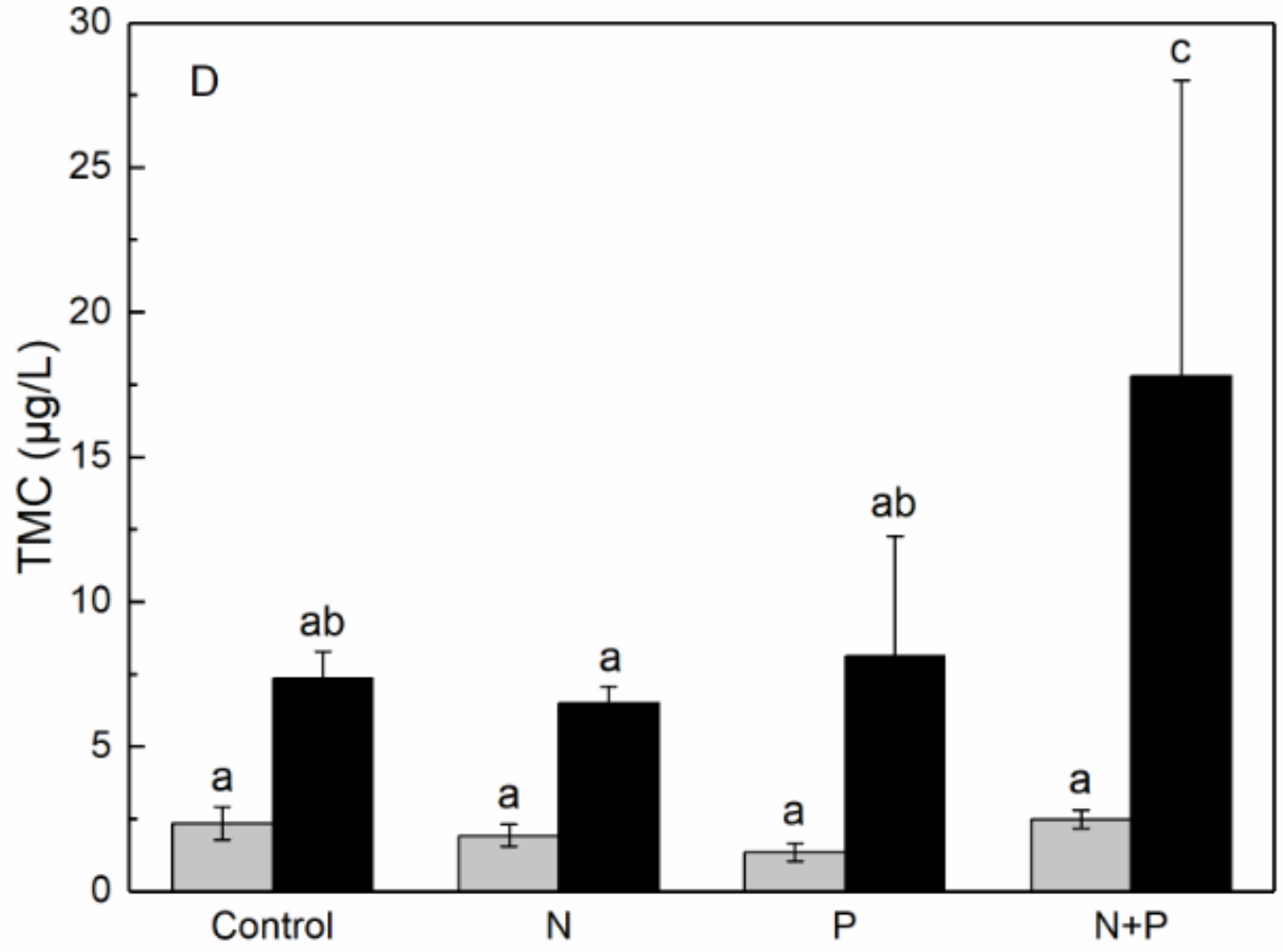
Su et al. (In Preparation)

Change in Nitrate



Su et al. (In Preparation)

Change in Total Microcystins



Su et al. (In Preparation)

Downing and McCauley (1992) found that N limitation is significantly more frequent in lakes with:

1) low ambient TN: TP (TN: TP mass ratio ≤ 14)
Spring Lake TN:TP = 23 (2017 data)

2) TP > 30 µg/L
Spring Lake: 50.4 µg/L (2017 data)

- Some indication of N limitation present

Downing and McCauley (1992) *Limnology and Oceanography* 37: 936-945.

Summary

- Alum application has worked well for more than 10 yr
- Efficacy starting to wane at deeper sites; continued monitoring recommended
- Algae appear to be primarily limited by P but secondarily limited by N
- External loading reductions plausible next step

Acknowledgements

Funding: Spring Lake – Lake Board; MI Sea Grant

Colleagues:

- Progressive AE (Tony Groves, Pam Tyning)
- AWRI (Mike Hassett, Maggie Oudsema, Brian Scull, Rick Rediske, Kurt Thompson, Xiaomei Su, Mary Ogdahl)