A Living Laboratory at Southern Illinois University: Remediation and Sustainable Science for Harmful Algal Blooms Following the 2016 Dredging of Campus Lake

Dr. Marj Brooks

Rachel Steiger

Illinois Lake Management Association 33nd Annual Conference

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Acknowledgements

- **<u>Physical Plant at Southern Illinois University:</u>** Scott Weber, Kevin Bame, David Tippy, Bret Dougherty, Andrea Palmer, Justin Harrell, Brad Dillard
- **<u>Sierra Club, Shawnee Chapter</u>**

SIU's Campus Lake:
A natural outdoor laboratory

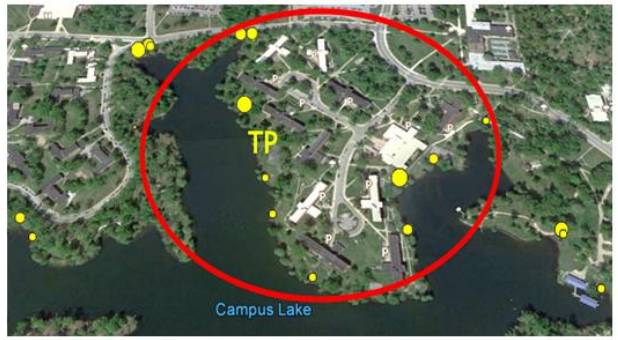
Problems:

- High nutrients
- High temperatures
- Low oxygen

Solutions:

- Remove or trap nutrients
- Cool the water
- Aerate the water
- Exercise and improve water quality

When Ecosystems Thrive, People Thrive

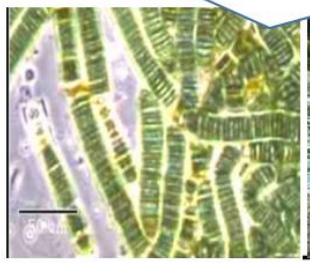


Savings Account ~50 Years of Nutrients in Wet Compost

New Income 2015 Phosphate

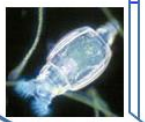
Increasing Temperatures

Low Flows = Low Oxygen



Blooms of Cyanobacteria Fed by Compost

Unbalanced Communities



Mostly Rotifers

Many Bluegill

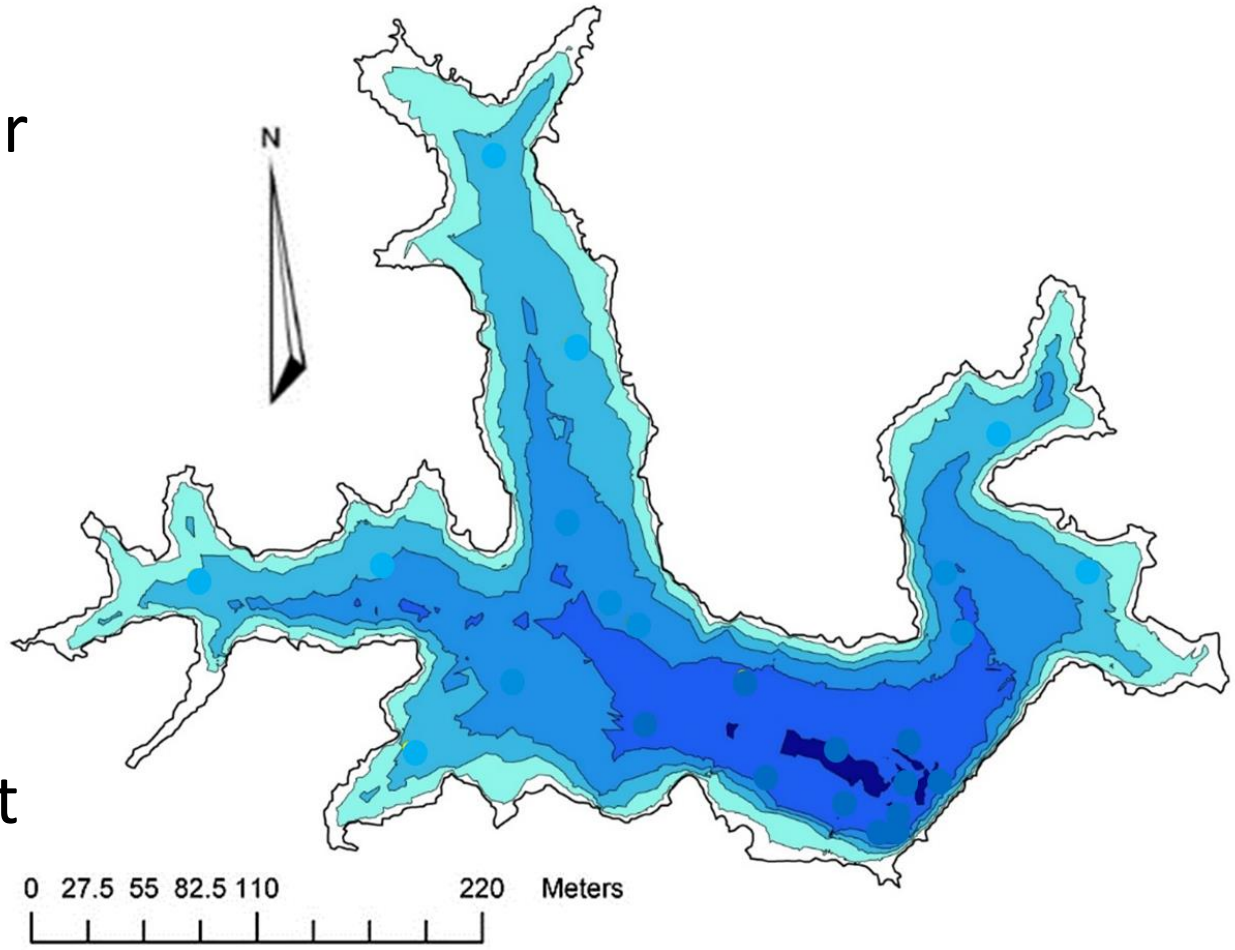
Odor & Health Hazards

→Fishing
→Boating
→Swimming

Small Sports Fish

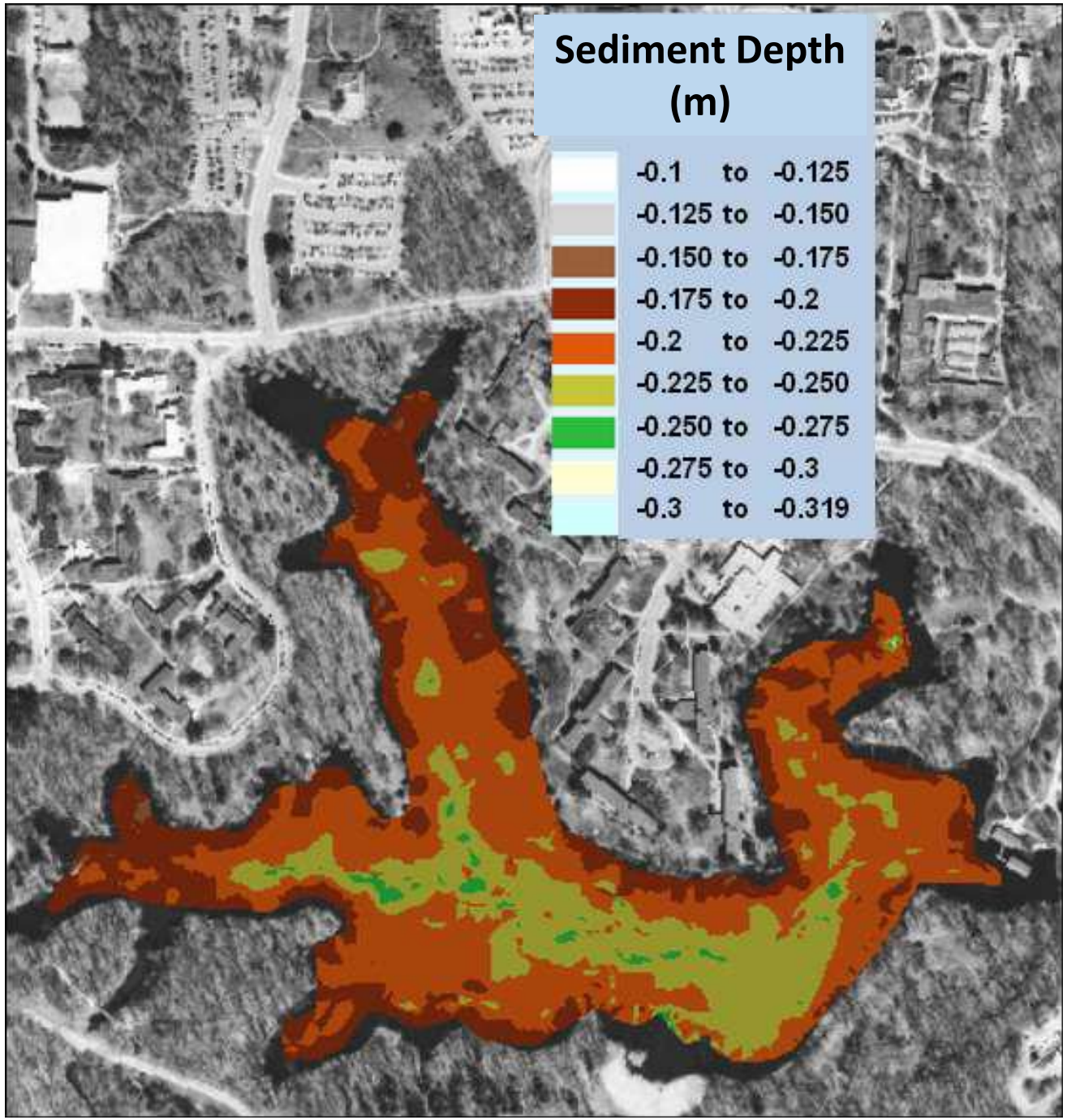
Basic facts about Campus Lake

- 40 acre lake
- Contains 104,272,320 gallons of water
- Total volume refreshes ~1.75 years
- The shoreline under consideration was 12,900 feet long
- Campus lake has an ***income*** of nutrients from 23 storm drains
- It also had a ***savings account*** of decaying algae—enough wet compost to maintain hyper-eutrophic conditions for 50 years

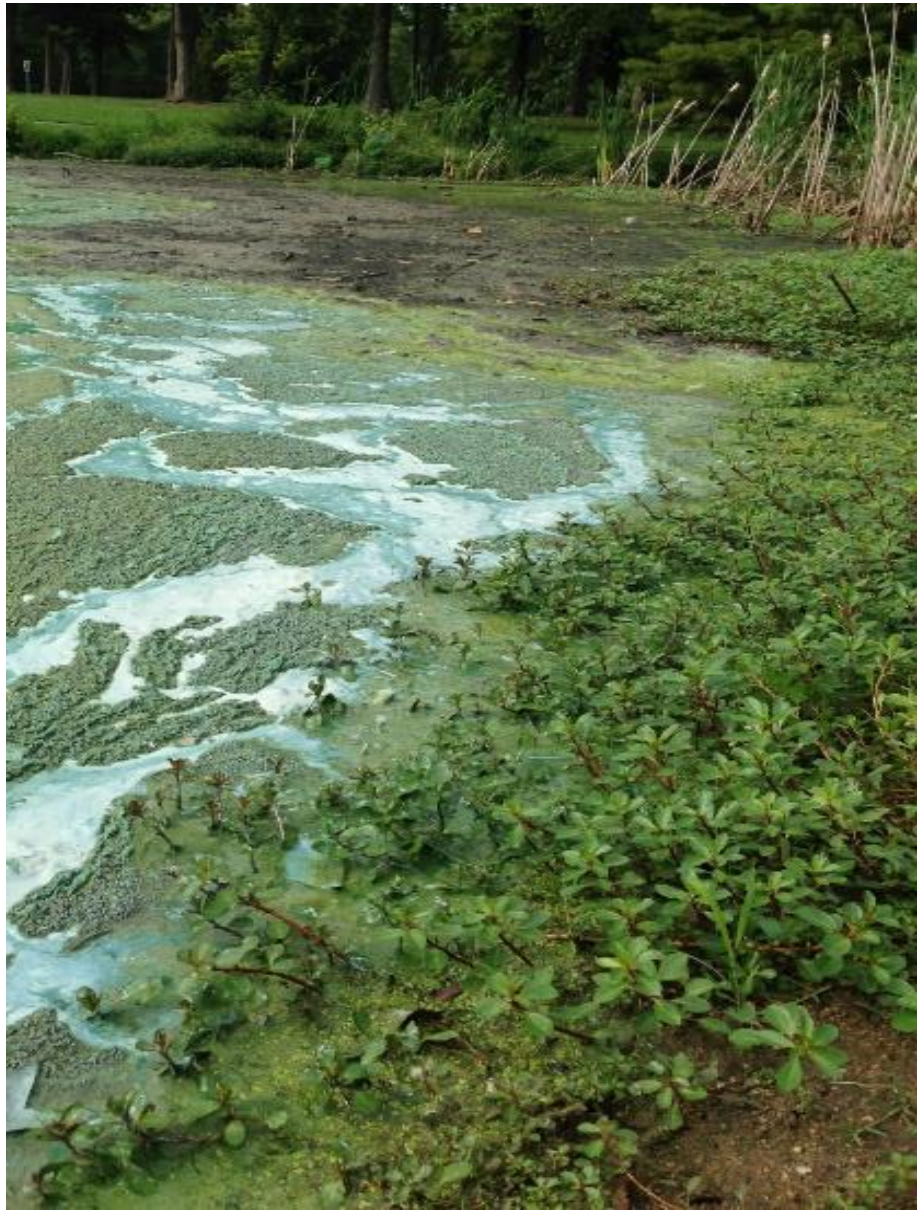


2011 Sediment Depths

Sediments are not deep, however, build up of detritus was significant.



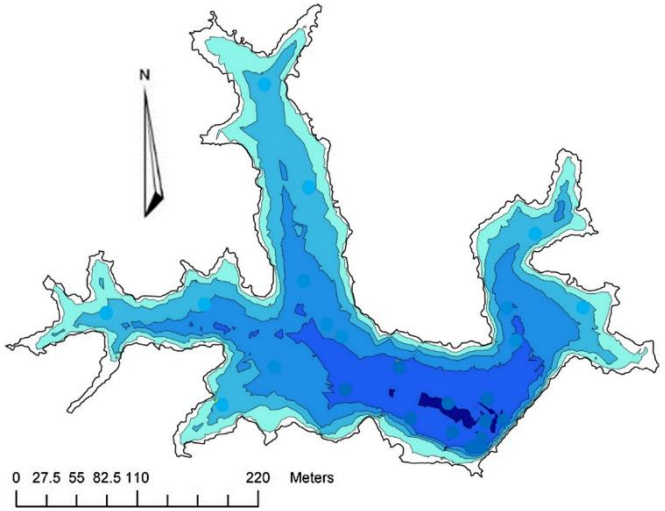
2015 Savings Account:



A conservative estimate of detritus was one cubic foot along the entire shoreline

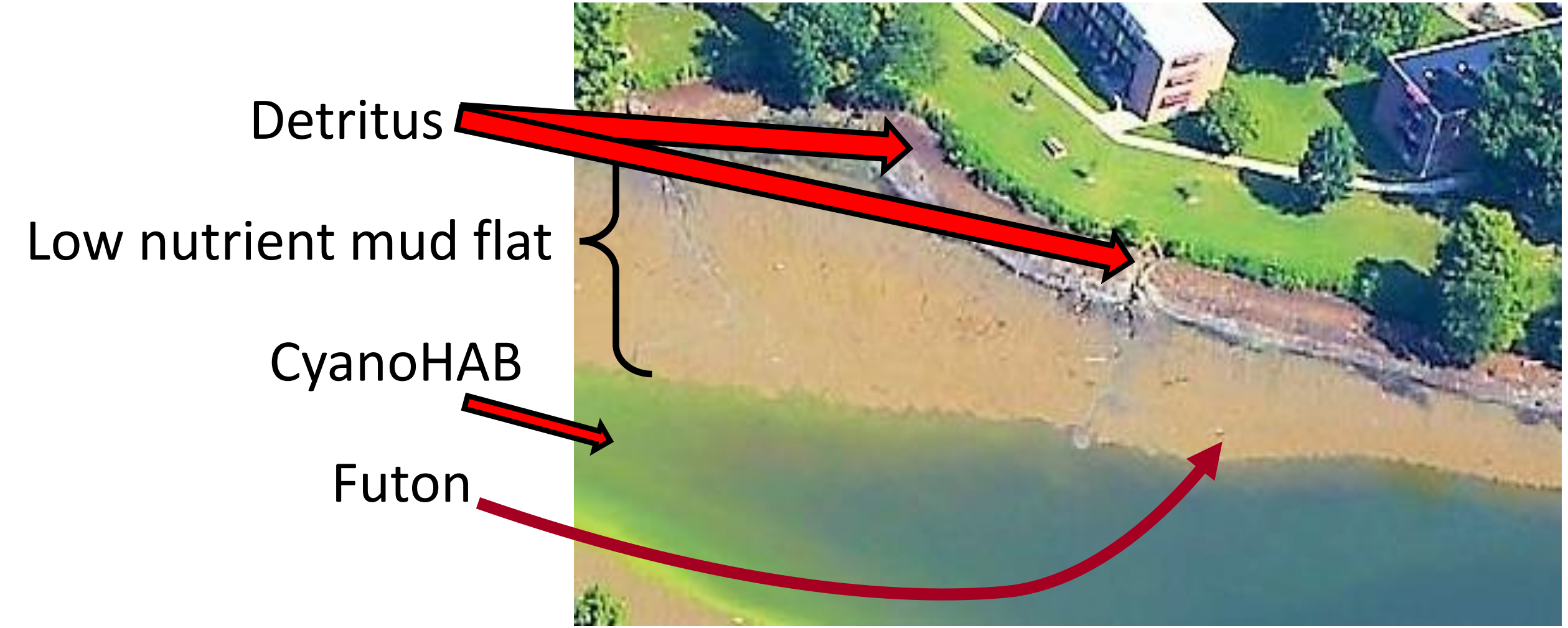
Stored nutrients in decaying algae and estimated time to flush Campus Lake naturally

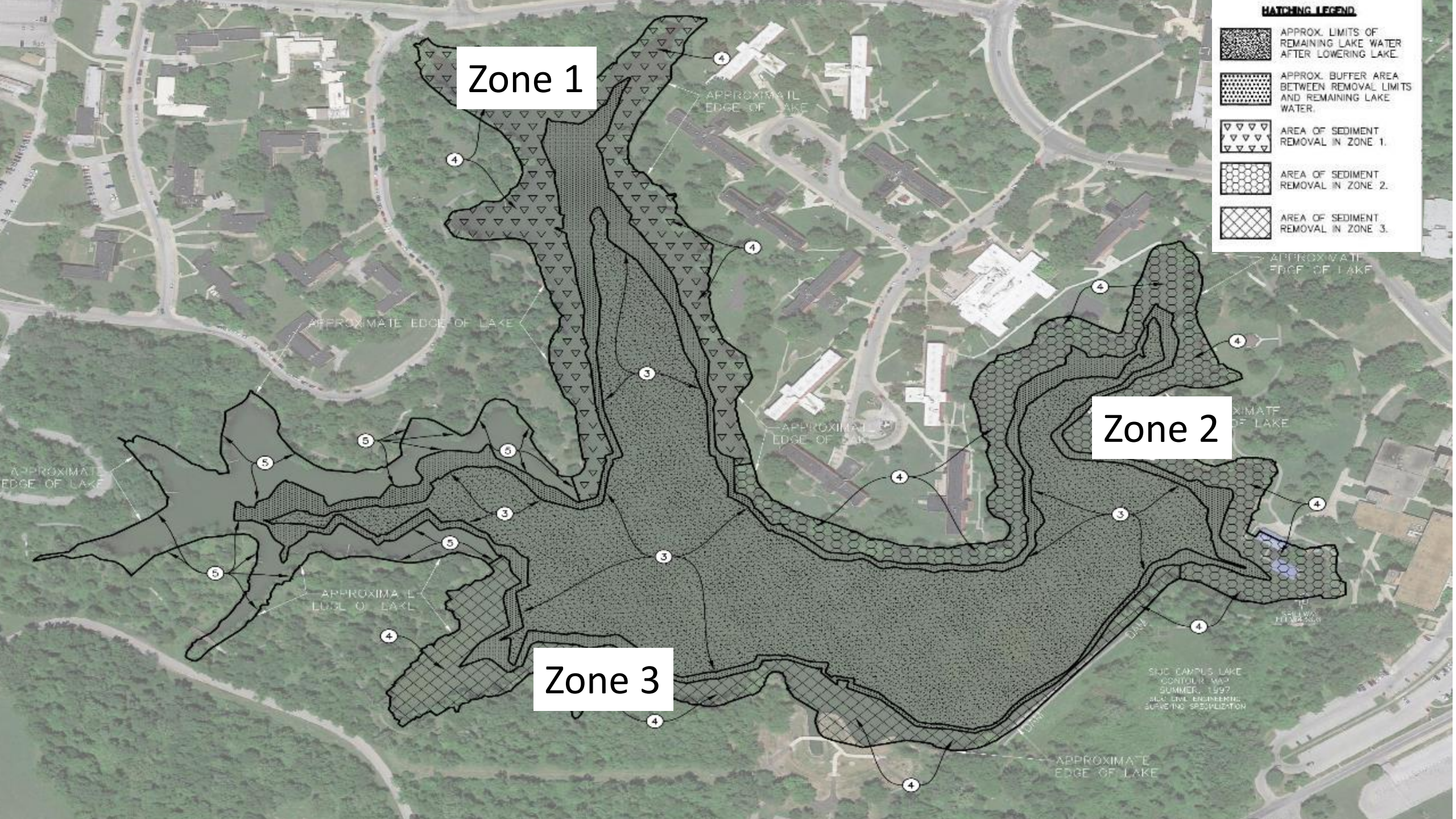
Scenarios	Best 1	Moderate 2	Worst 3
Estimated cubic feet of algae / linear foot of shoreline			



2016 Southern Illinois University invested $400,000
Lowered lake level and dredged detritus

Detritus, “wet compost” deposited at shoreline
Buoyant starch & lipid content

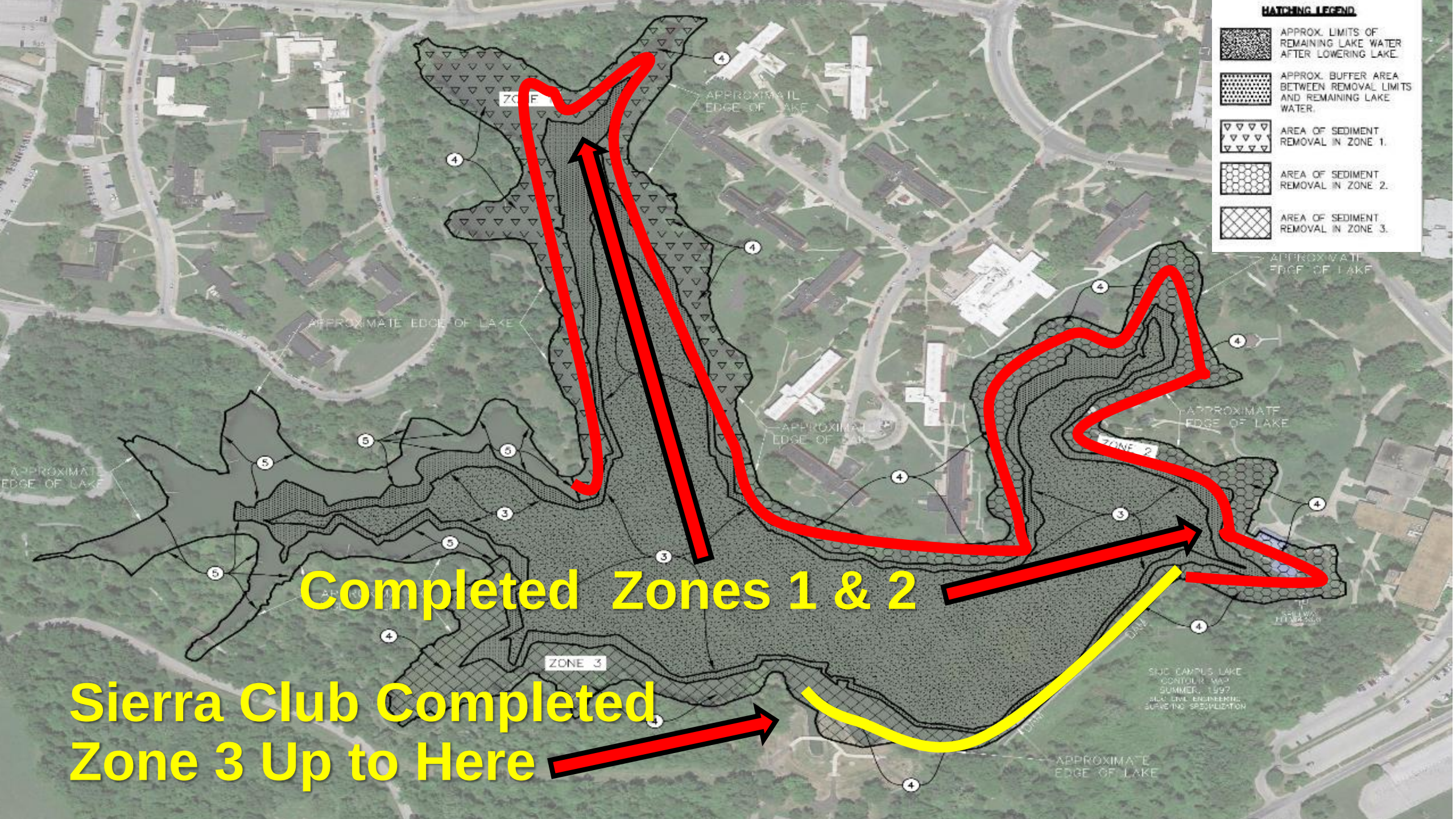



Zone 1
Zone 2
Zone 3
HATCHING LEGEND
APPROX. LIMITS OF REMAINING LAKE WATER AFTER LOWERING LAKE.
APPROX. BUFFER AREA BETWEEN REMOVAL LIMITS AND REMAINING LAKE WATER.
AREA OF SEDIMENT REMOVAL IN ZONE 1.
AREA OF SEDIMENT REMOVAL IN ZONE 2.
AREA OF SEDIMENT REMOVAL IN ZONE 3.
APPROXIMATE EDGE OF LAKE
SJSC CAMPUS LAKE
CONTOUR MAP
SUMMER, 1997


Beginning 24 October 2016
HITACHI
HITACHI

Unstable organics above dry mud flat

Sierra Club Tackles the Compost


HATCHING LEGEND
APPROX. LIMITS OF REMAINING LAKE WATER AFTER LOWERING LAKE.
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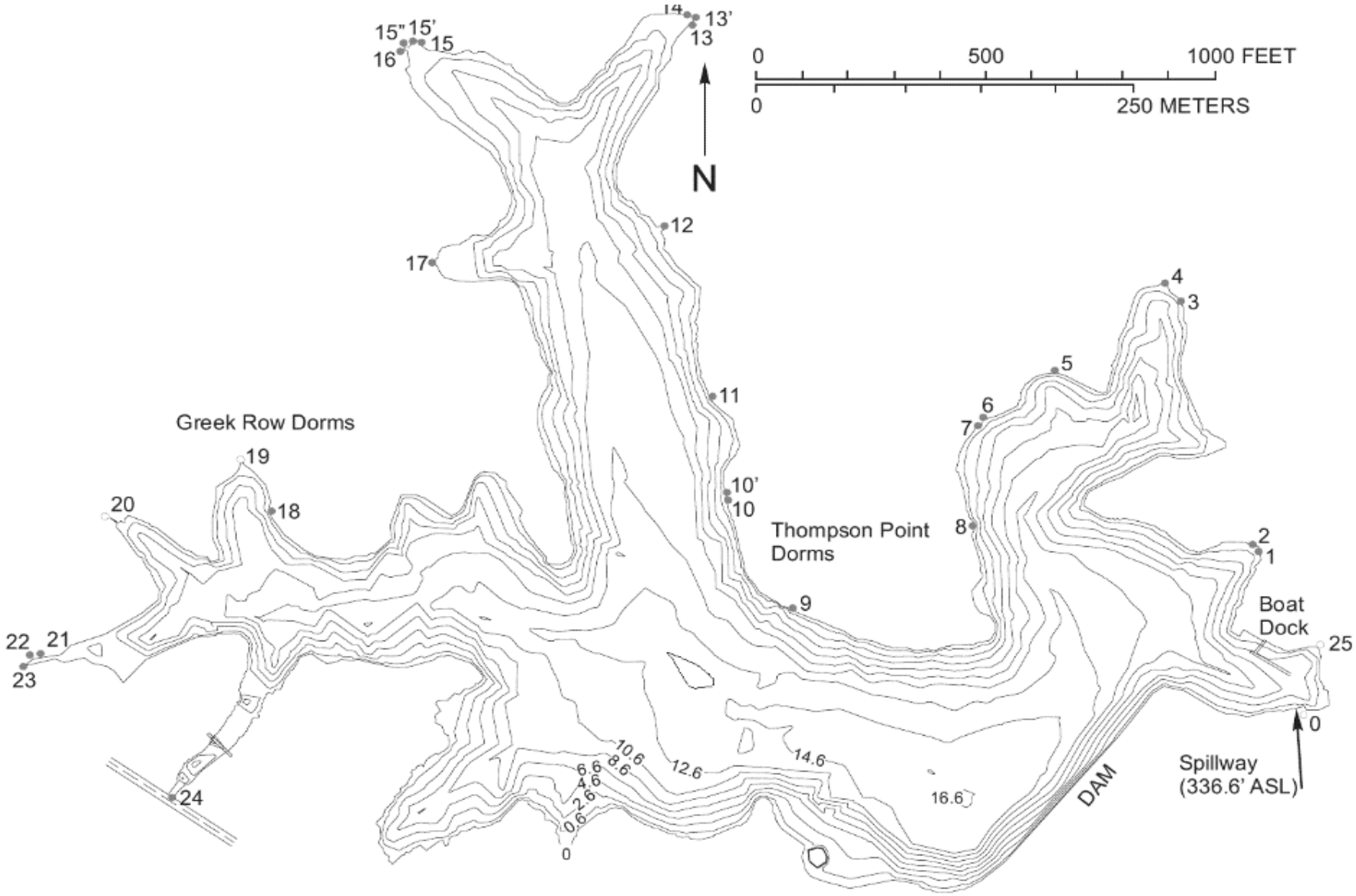
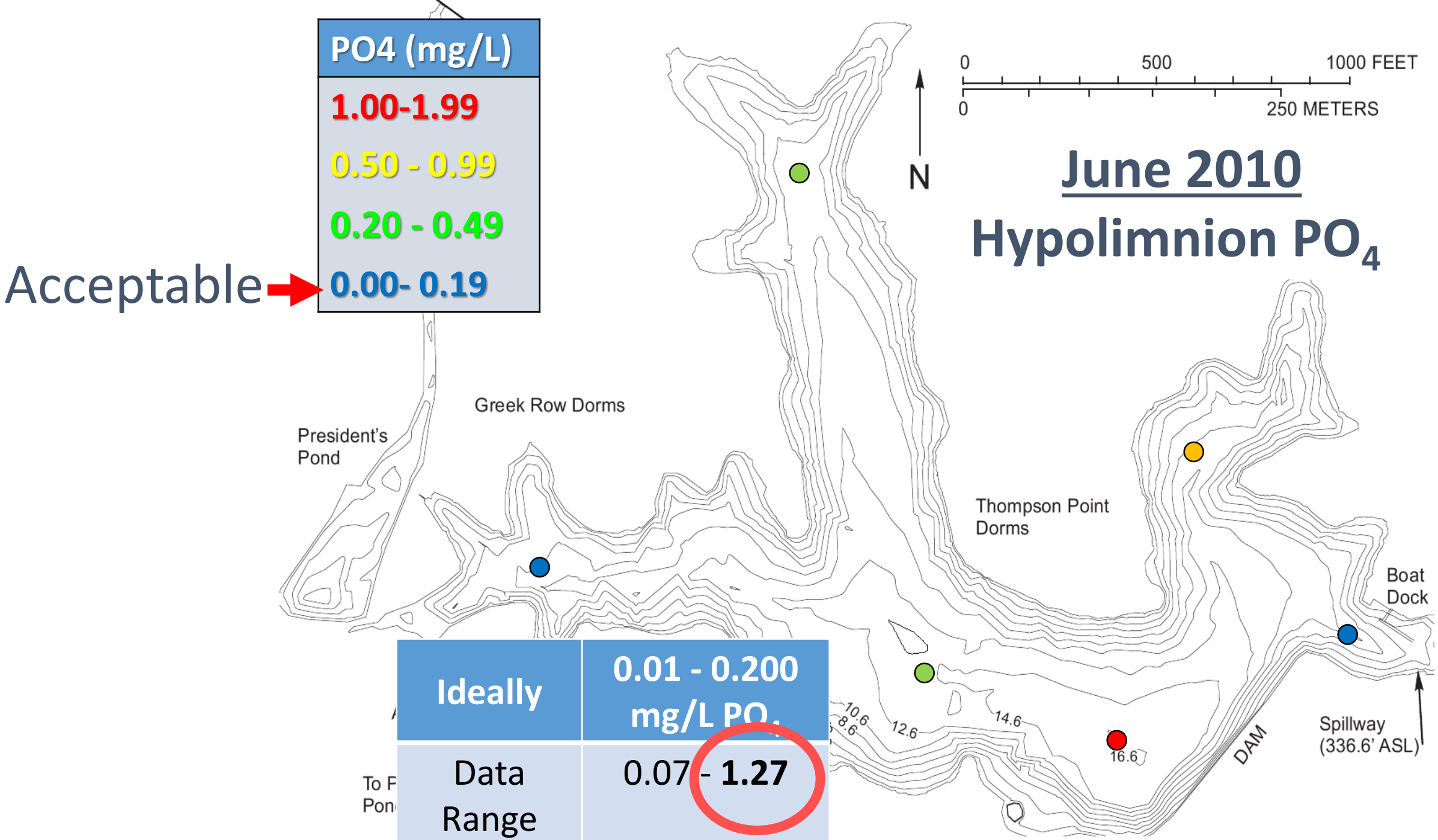
AREA OF SEDIMENT REMOVAL IN ZONE 1.
AREA OF SEDIMENT REMOVAL IN ZONE 2.
AREA OF SEDIMENT REMOVAL IN ZONE 3.
ZONE 3
ZONE 2
APPROXIMATE EDGE OF LAKE
Completed Zones 1 & 2
Sierra Club Completed Zone 3 Up to Here

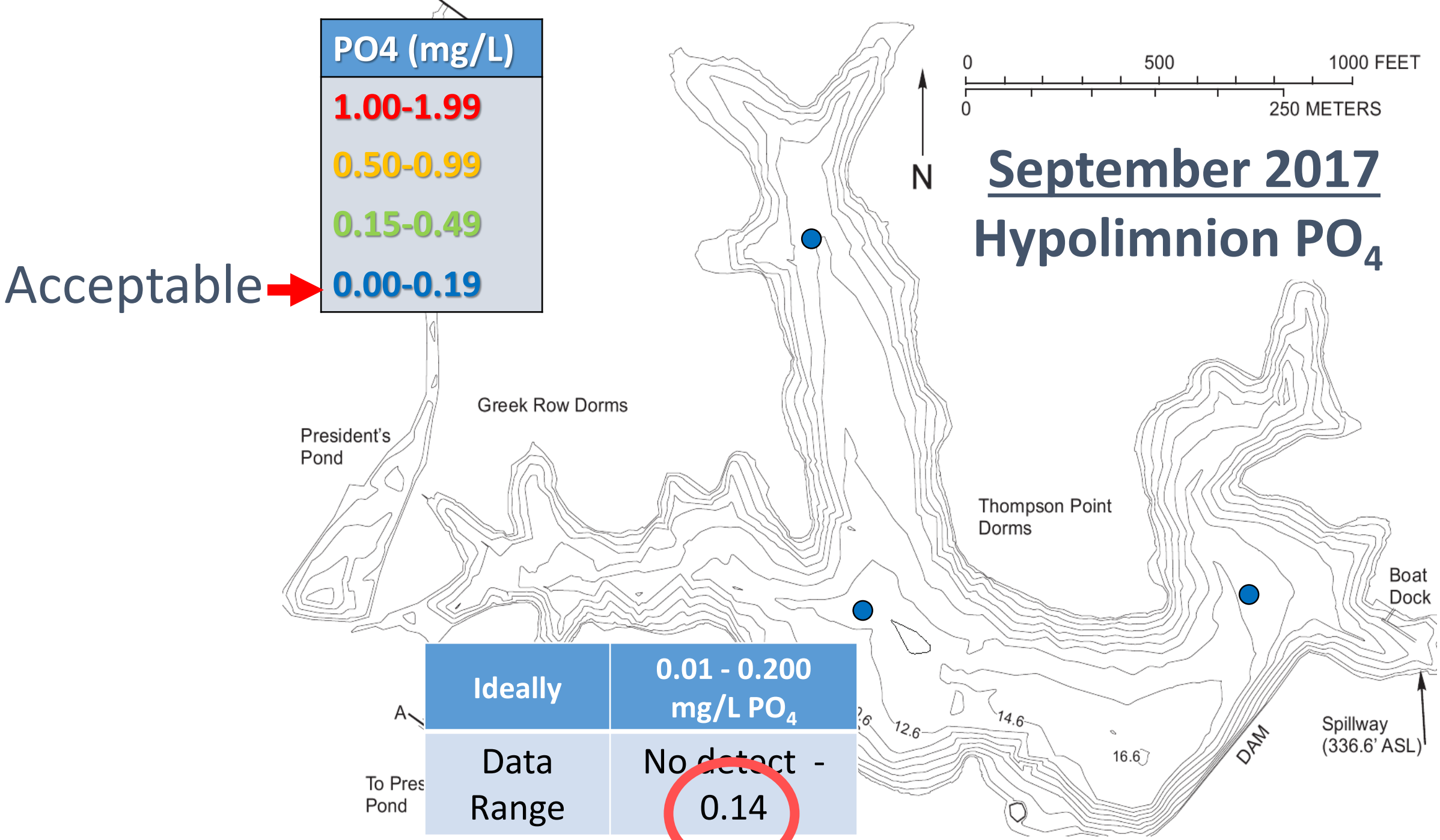

23,240 tons removed

Where did the spoils go?

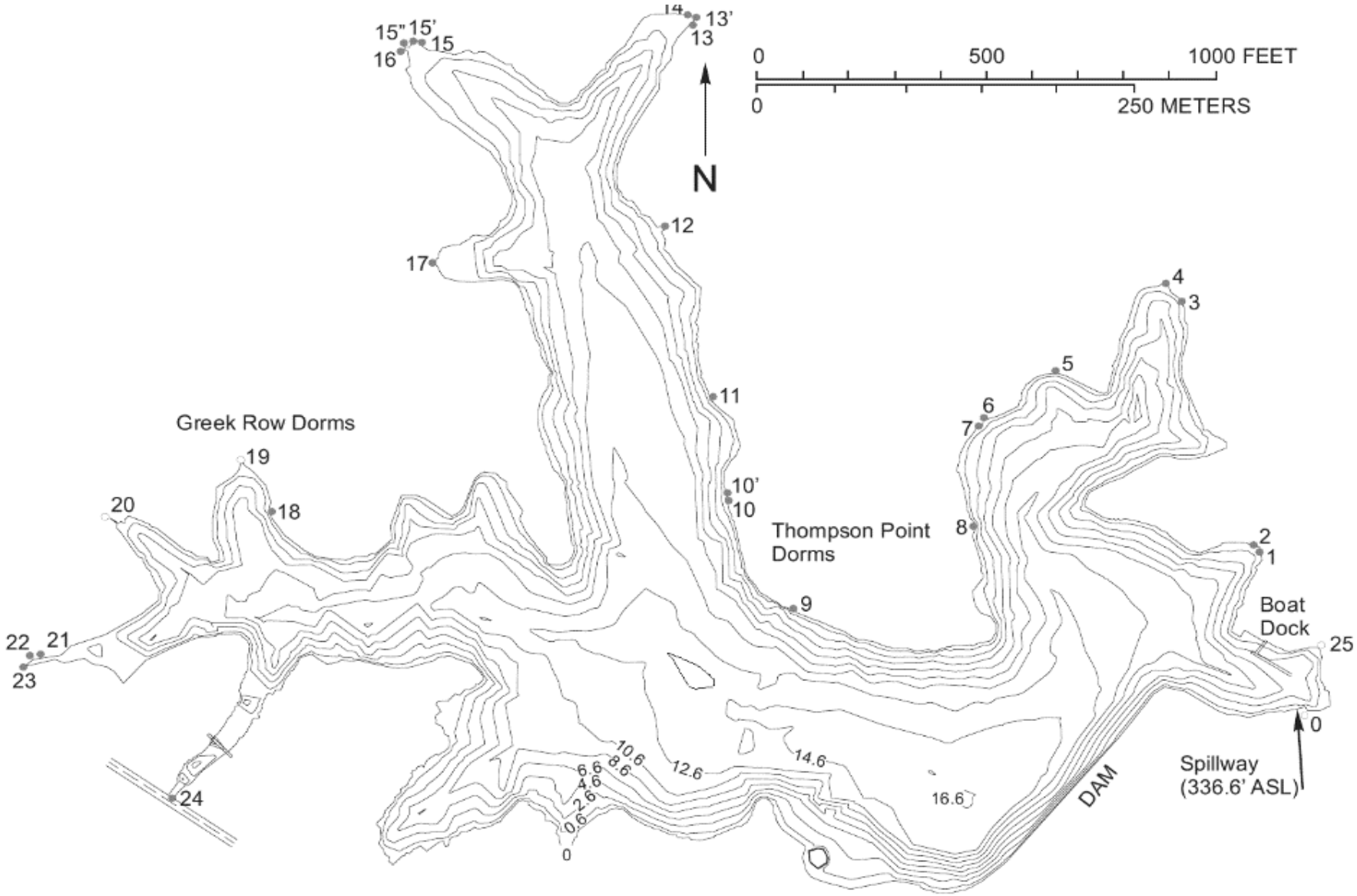
Results: Benefits of dredging shown in water column



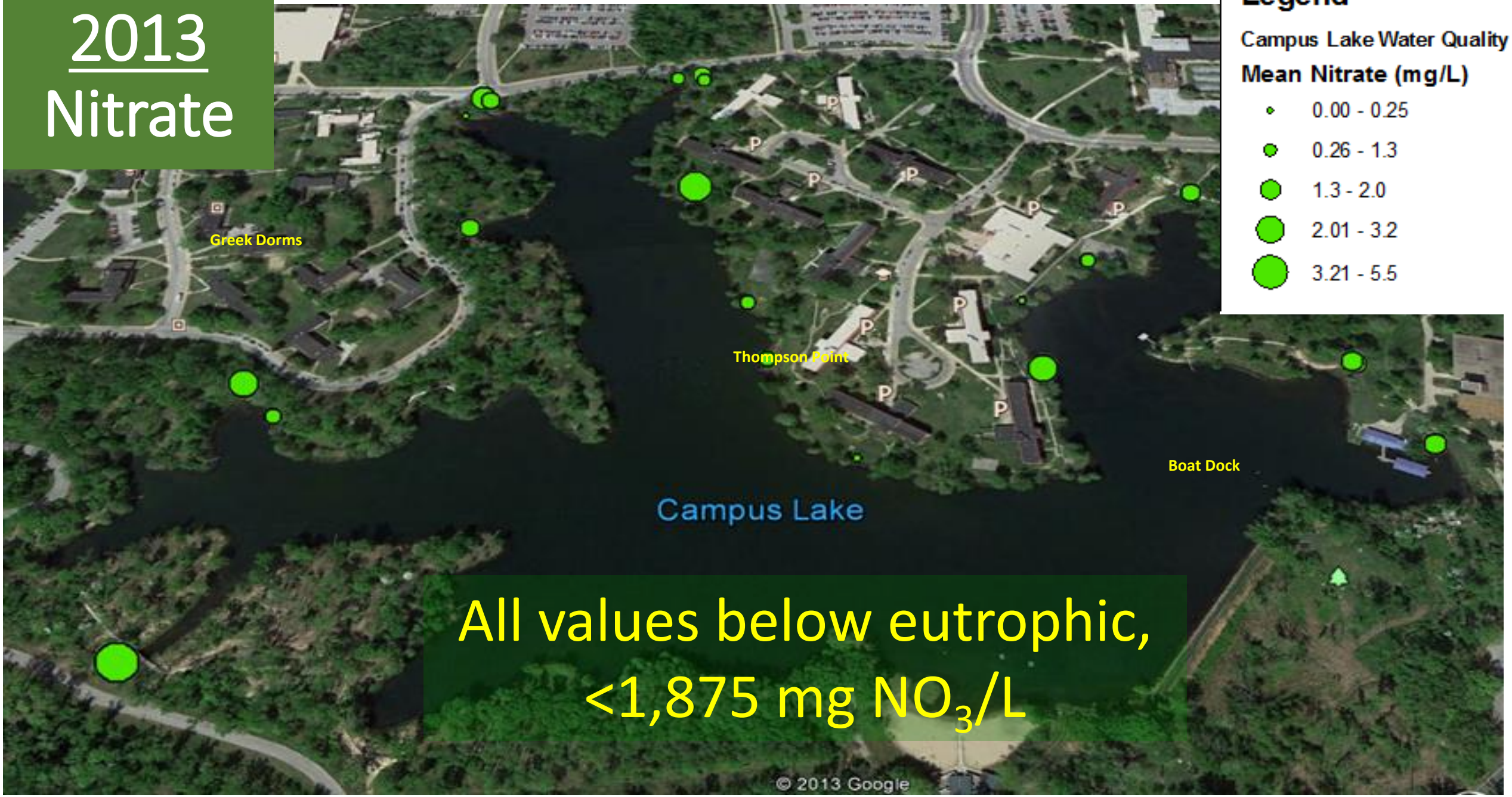

PO4 (mg/L)
1.00-1.99
0.50 - 0.99
0.20 - 0.49
0.00- 0.19
Acceptable
0
500
1000 FEET
0
250 METERS
N
June 2010
Hypolimnion PO4
Greek Row Dorms
President's Pond
Thompson Point Dorms
Boat Dock
Spillway (336.6' ASL)
DAM
10.6
8.6
12.6
14.6
16.6
Ideally
0.01 - 0.200 mg/L PO4
Data Range
0.07 - 1.27


PO4 (mg/L)
1.00-1.99
0.50-0.99
0.15-0.49
0.00-0.19
Acceptable
0
500
1000 FEET
0
250 METERS
N
September 2017
Hypolimnion PO4
Greek Row Dorms
President's Pond
Thompson Point Dorms
Boat Dock
Spillway (336.6' ASL)
DAM
12.6
14.6
16.6
To Pres Pond
Ideally
0.01 - 0.200 mg/L PO4
Data Range
No detect - 0.14

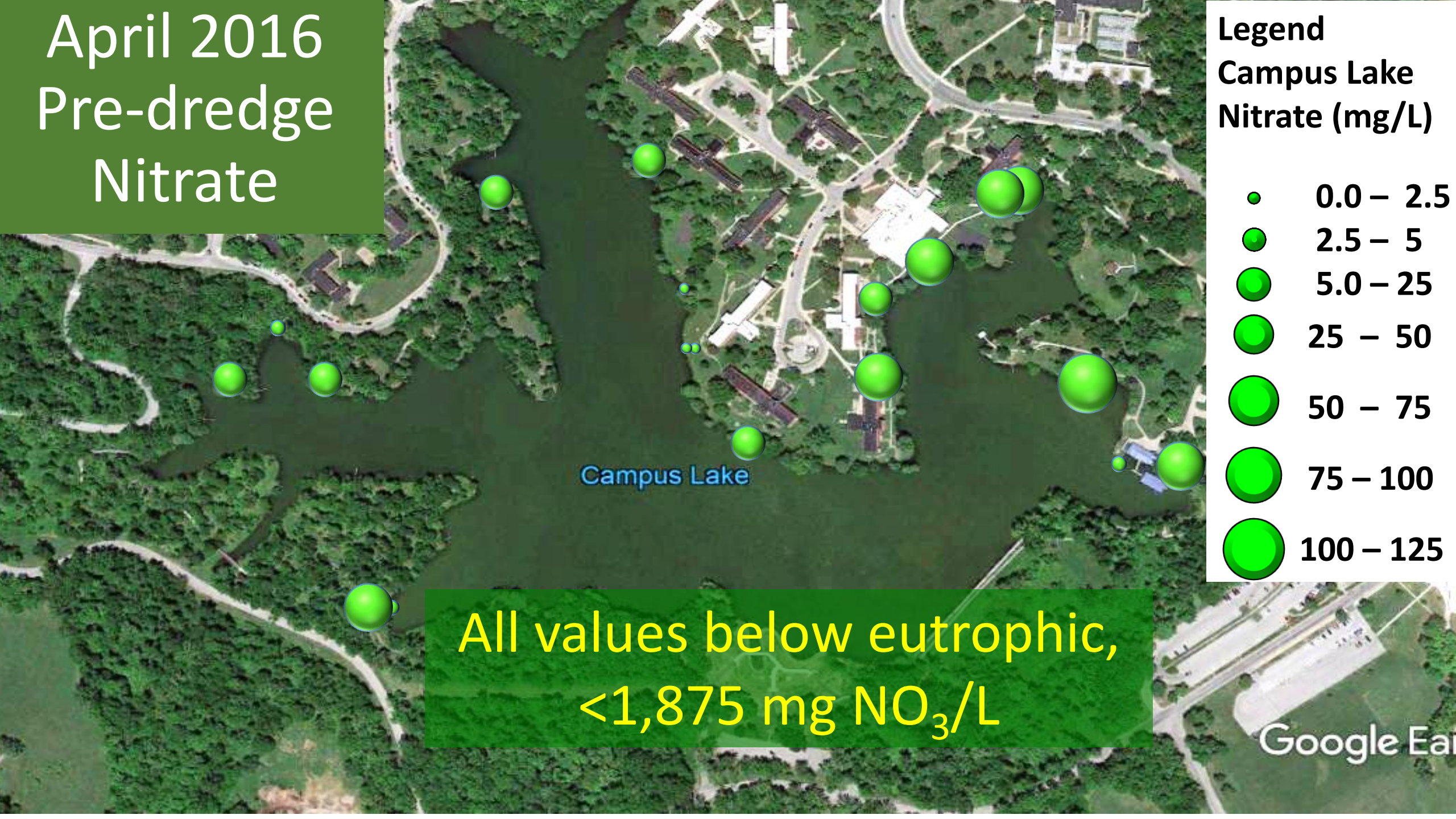
Ongoing concern: Income from storm drains

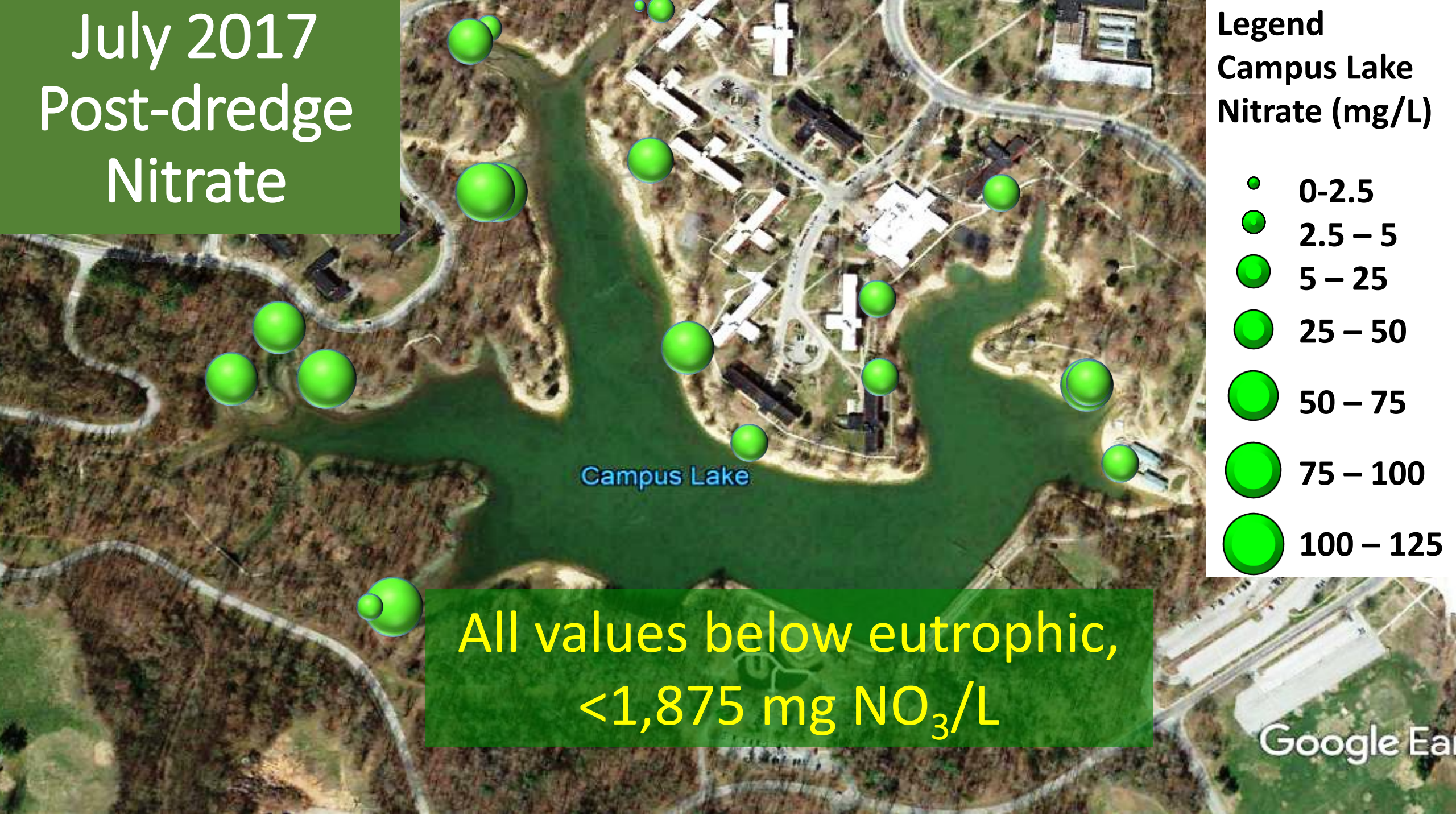


2013 Nitrate

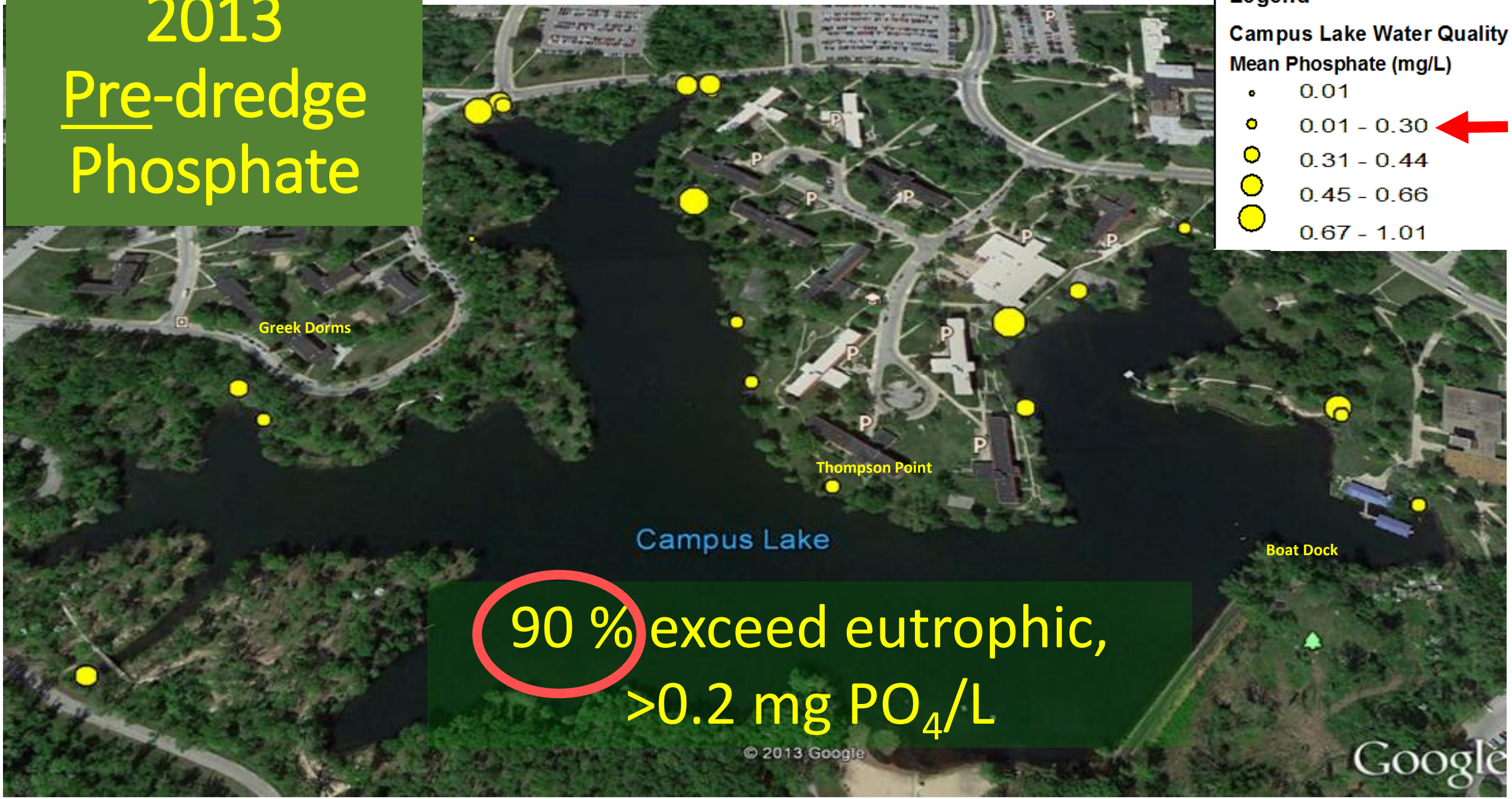


All values below eutrophic, <1,875 mg NO_3/L

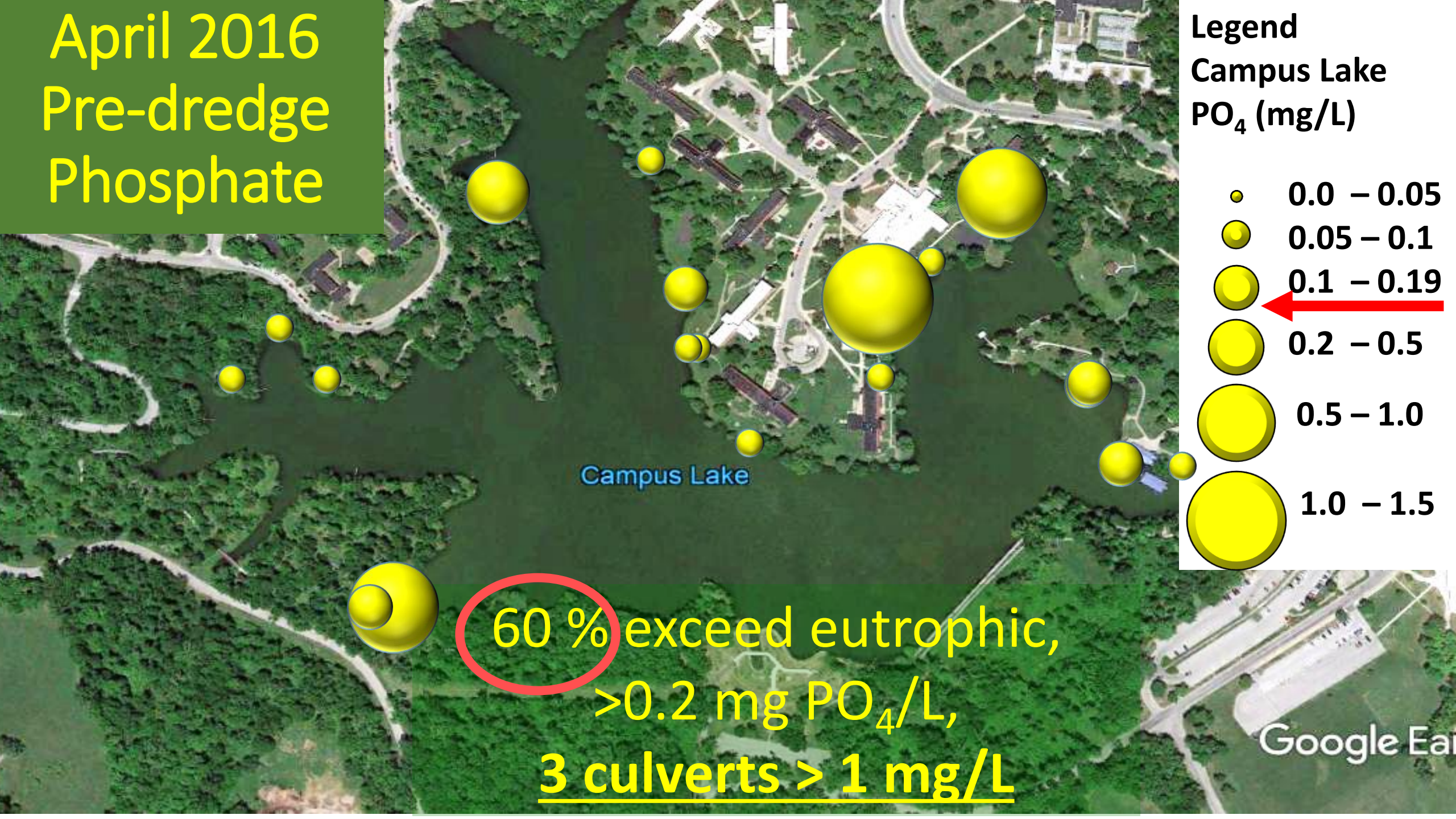

April 2016
Pre-dredge
Nitrate
Legend
Campus Lake
Nitrate (mg/L)
0.0 – 2.5
2.5 – 5
5.0 – 25
25 – 50
50 – 75
75 – 100
100 – 125
Campus Lake
All values below eutrophic,
<1,875 mg NO_3/L
Google Ea


July 2017
Post-dredge
Nitrate
Legend
Campus Lake
Nitrate (mg/L)
0-2.5
2.5 – 5
5 – 25
25 – 50
50 – 75
75 – 100
100 – 125
Campus Lake
All values below eutrophic,
<1,875 mg NO_3/L
Google Ea

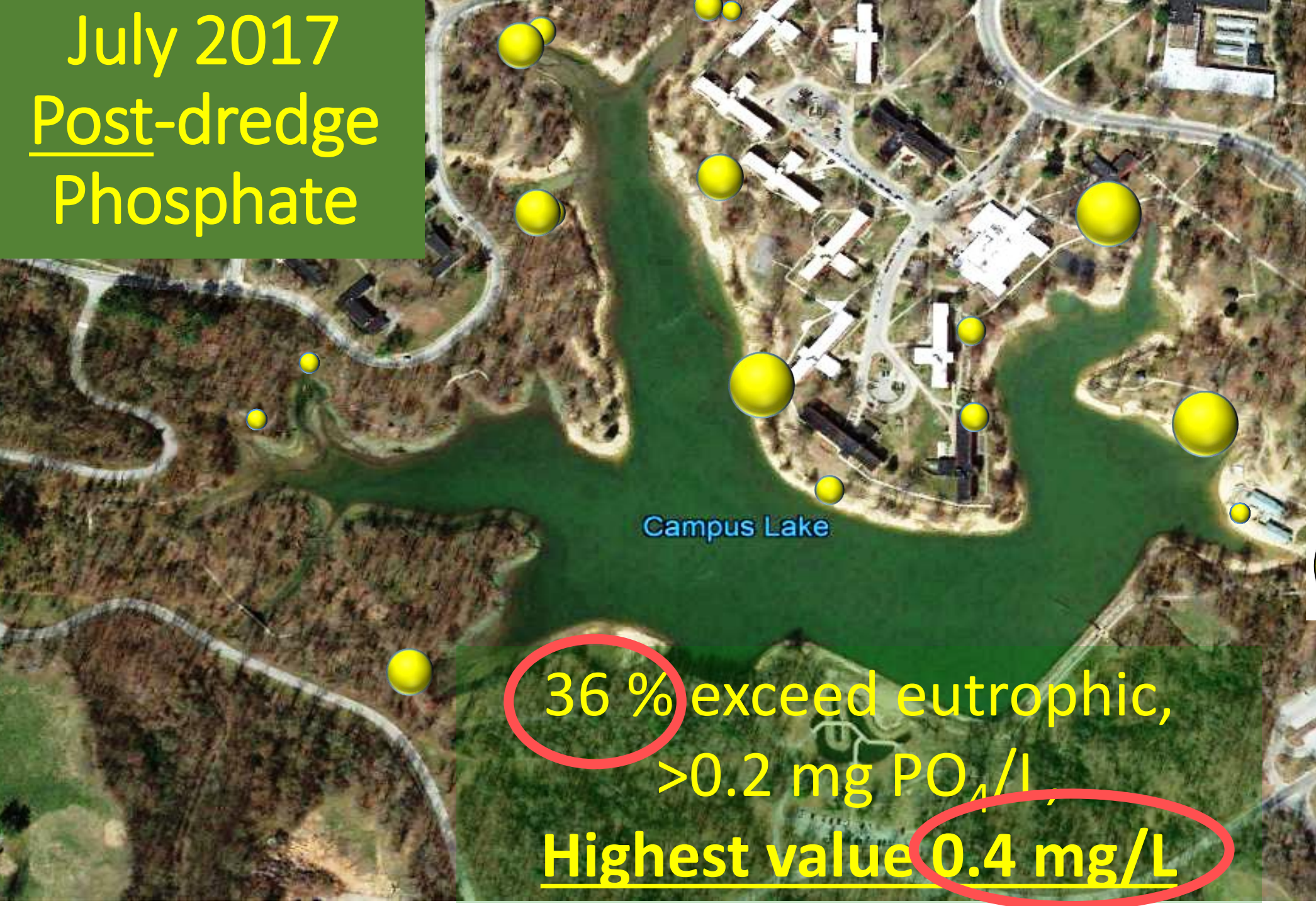
2013 Pre-dredge Phosphate



90 % exceed eutrophic, >0.2 mg PO_4/L


April 2016
Pre-dredge
Phosphate
Legend
Campus Lake
PO_4 (mg/L)
0.0 – 0.05
0.05 – 0.1
0.1 – 0.19
0.2 – 0.5
0.5 – 1.0
1.0 – 1.5
Campus Lake
60 % exceed eutrophic,
>0.2 mg PO_4/L,
3 culverts > 1 mg/L
Google Ea

July 2017 Post-dredge Phosphate

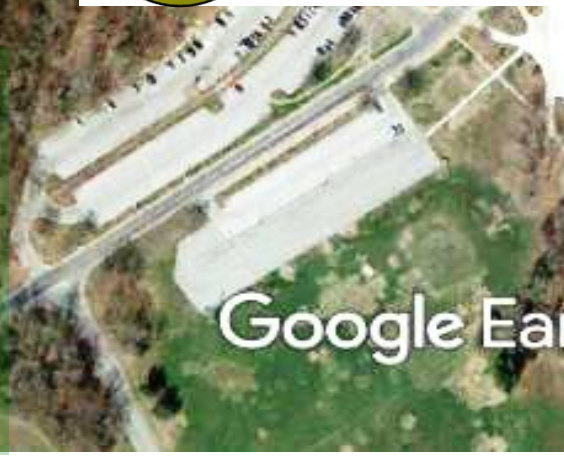


Legend
Campus Lake
PO_4 (mg/L)

- 0-0.05
- 0.05 – 0.1
- 0.10 – 0.19
- 0.20 – 0.5
- 0.50 – 1
- 1 – 1.5

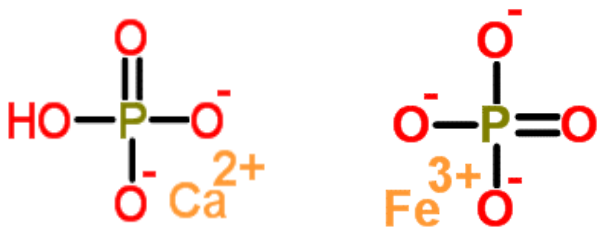
36 % exceed eutrophic,
>0.2 mg PO_4/L

Highest value 0.4 mg/L



Next steps: Inhibit CyanoHAB growth, limit N & P

- **Aerate**
  - In the water column, Lake contains 40 x more Fe and Ca than required to bind all PO_4



  - But that sequestration is seasonal

- **Cool**

One calorie cools
1 gram of H_2O by 1 °C

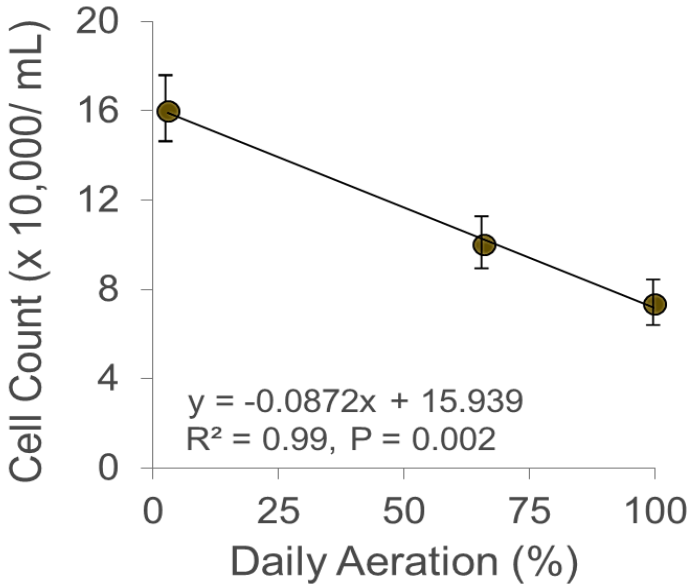
  - 540 calories of heat loss
    gram H_20 evaporation
  - Heat loss / one liter is can cool 180 L by 3 °C
  - 3 °C cooling from 27 to 24 °C can slow cyanobacterial growth by 25%.

Impair Cyanos

Impair Cyanos

Next steps: Inhibit CyanoHAB growth

- **Aerate**

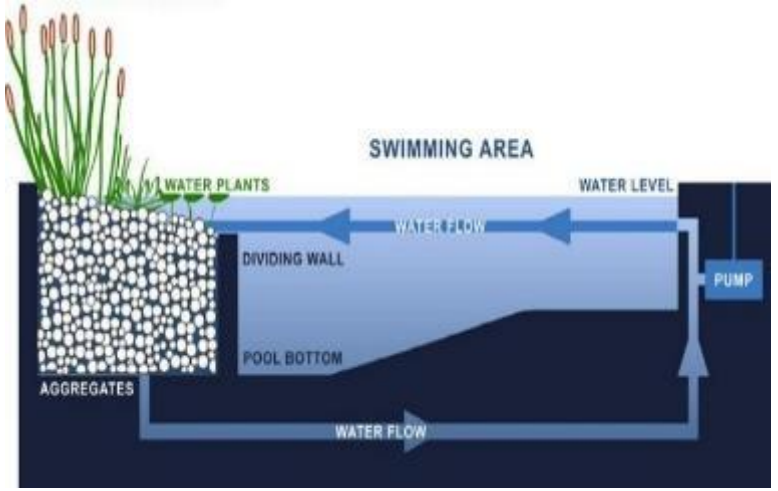


- Cell counts dropped by 54% in 1 week, 16:8 h light:dark photoperiod, constant 30 ºC
- Why?
- **Aeration inhibits N_2 fixation**

Impair Cyanos

Impair Cyanos

- **Wetlands & Swimming Areas**



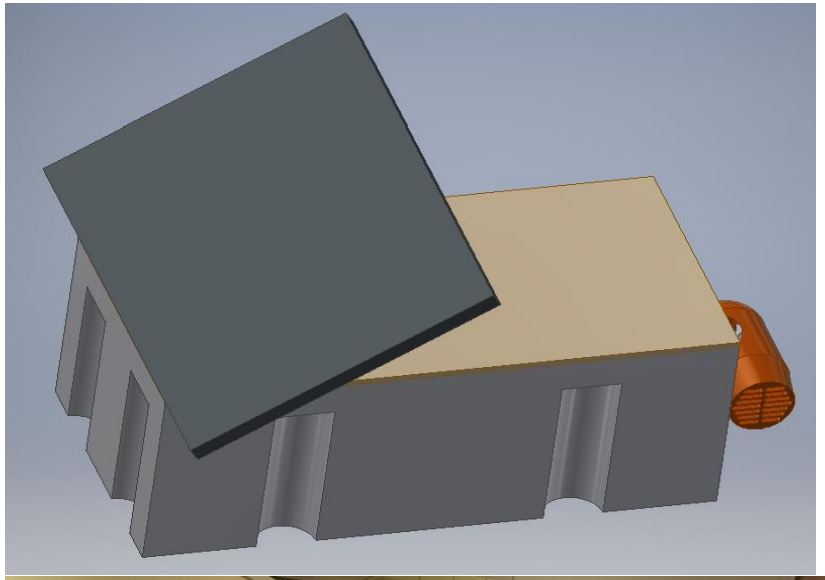
- 2 x 9 m wetland can remove
- 2 kg NO_3 per day
- 125 kg of organic carbon→ future detritus

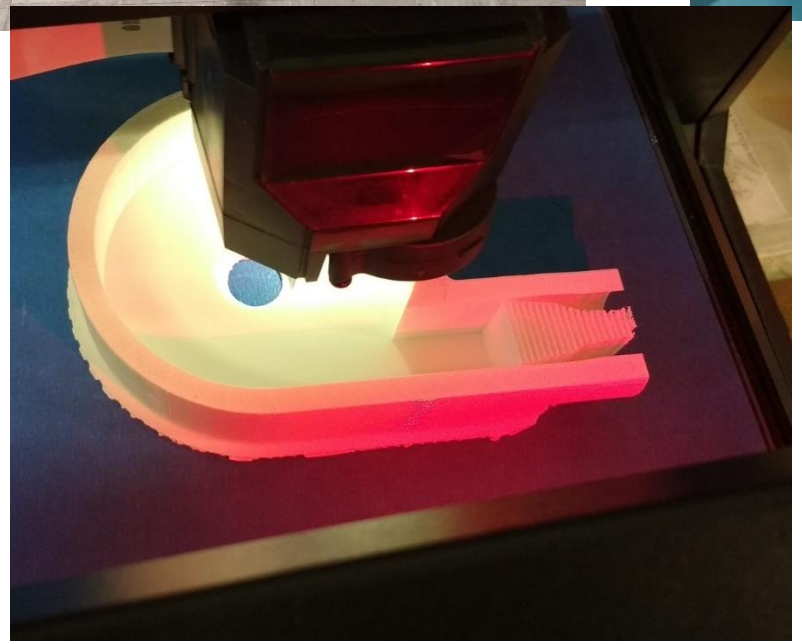
Eco-Recreation Projects Underway:
Solar fountains, Pedal-powered water cannons

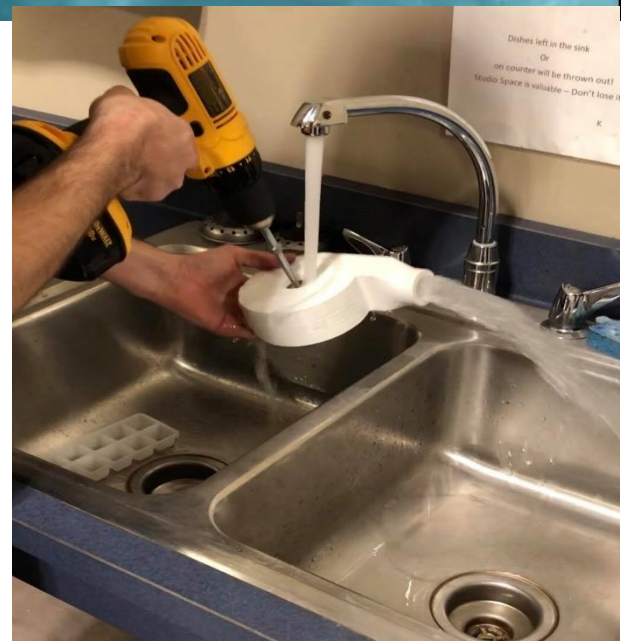
Kayaking beside a fountain in Barrie, Ontario
(no photo credit. https://www.tripadvisor.ca/)

Watering with pedal power at the PermaPai agriculture project in Pai, Mae Hong Son province of northern Thailand
(https://permapai.wordpress.com/2013/03/08/bicycle-pump-power/)

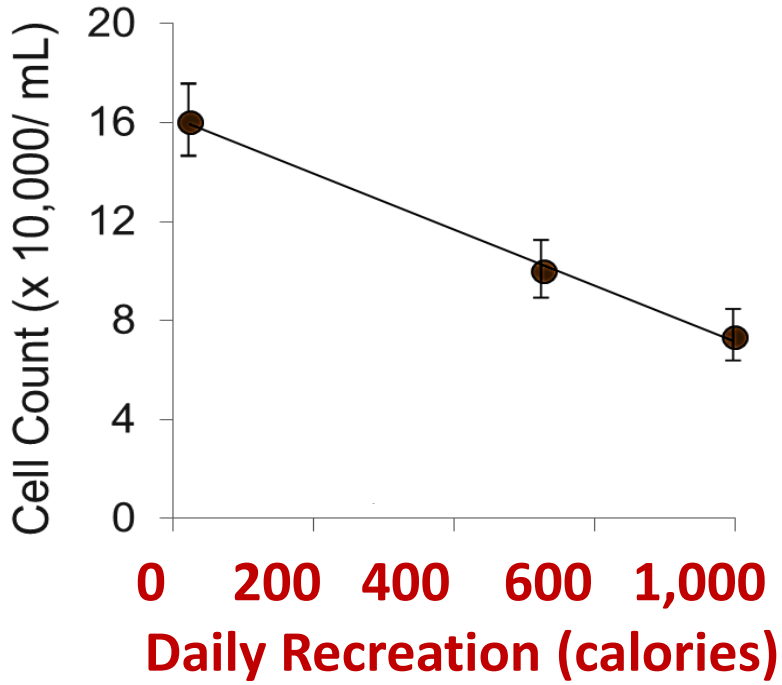
Prototypes: Solar fountains, Pedal water cannons







Potential Eco-Rec Project:
Phone and “Fitbit” apps that link cardio **directly** to …
→lake health



Campus Lake is My Workout Partner

Innovative aspects of Sustainable Eco-Recreation

Innovative aspects of Sustainable Eco-Recreation

- Methods to control harmful algae are well known but... Now, directly linked to human health
- Uses sustainable solar, wind, or human power
- Uses natural ecology, no chemicals
- Experiential learning incorporates theory and research into action
- Empowers students to learn, serve, and succeed

$400K investment yielded $1M donation from the Becker Family for Boathouse Renovation

Summary

- **<u>Dredging results:</u>** Water column P lowered by 90% to below 0.2 mg/L
- **<u>Storm drain results:</u>**
- Decrease in P from storm drain from 90% to 34% of drains above eutrophic limit
- Total storm drain input of P halved from 7 mg/L to 3.2 mg/L across the lake
- Intensive analysis underway

—Shameless plug

See Rachel Steiger's poster

FUNDED BY THE STUDENT GREEN FEE
SIU SOUTHERN ILLINOIS UNIVERSITY CARBONDALE SUSTAINABILITY


Questions?

Sigma plot of nutrients in water column over time.

Sustainable Eco-Recreation Designed by Students



<u>Possible Projects:</u>

- Fountain maze as an obstacle course for paddle boarders
- Shoreline swimming pool with wetland water treatment

<u>Benefits:</u>

- Renewable Energy
- Inter-disciplinary Experiential Education
- Career Building. Tiered funding tied to meeting deadlines, outreach, team-building
- Produce sustainable answers to a worldwide environmental problem
- New Patents and Products → Think Burton snowboards.

2013 Data

	Summer (µg/L)	Late Fall (µg/L)	Limit between "Low" to "Moderate" nutrients as NO_3, PO_4, or NH_3 (µg/L)	How many multiples of limit
Nitrate (NO_3)	500	11,000	1,356	8
Phosphate (PO_4)	521	1,825	31	**58**
Ammonia (NH_3)	900	250	119	8

Nutrient levels in some areas of the lake were ~10 to ~60 times higher than concentrations that support moderate algal growth in lakes.

Eco-Recreation Projects: Solar fountains, Pedal water

Kayaking through a fountain in Barrie, Ontario (https://www.tripadvisor.ca/)

Watering with pedal power at PermaPai agriculture project in Pai, Mae Hong Son province, Thailand (https://permapai.wordpress. com/2013/03/08/ bicycle-pump-power/)

<u>Wetlands.</u> <u>Each day, a 2 x 9 m wetland can:</u>

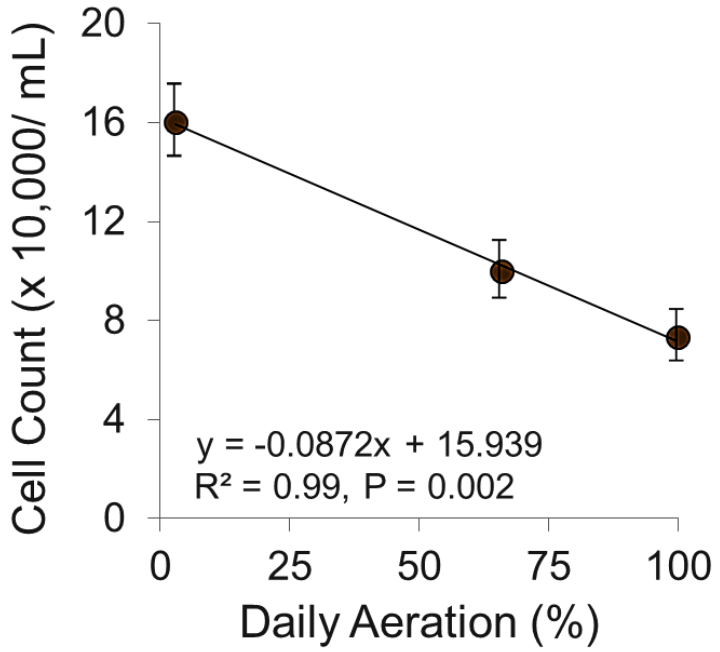
- Prevent wet compost
  →Remove 12 kg (27 pounds) of organic carbon
  →Remove 2 kg (4 ½ pounds) of nitrate
- **Great habitat for young fish**
- **<u>Only harvesting plants removes phosphorus</u>**

Eco-Rec Projects: Obstacle course

Kayaking or paddling through a obstacle course of fountains → aerate & cool

Water cannons battles over wetlands using pedal power →aerate, cool,& remove nutrients

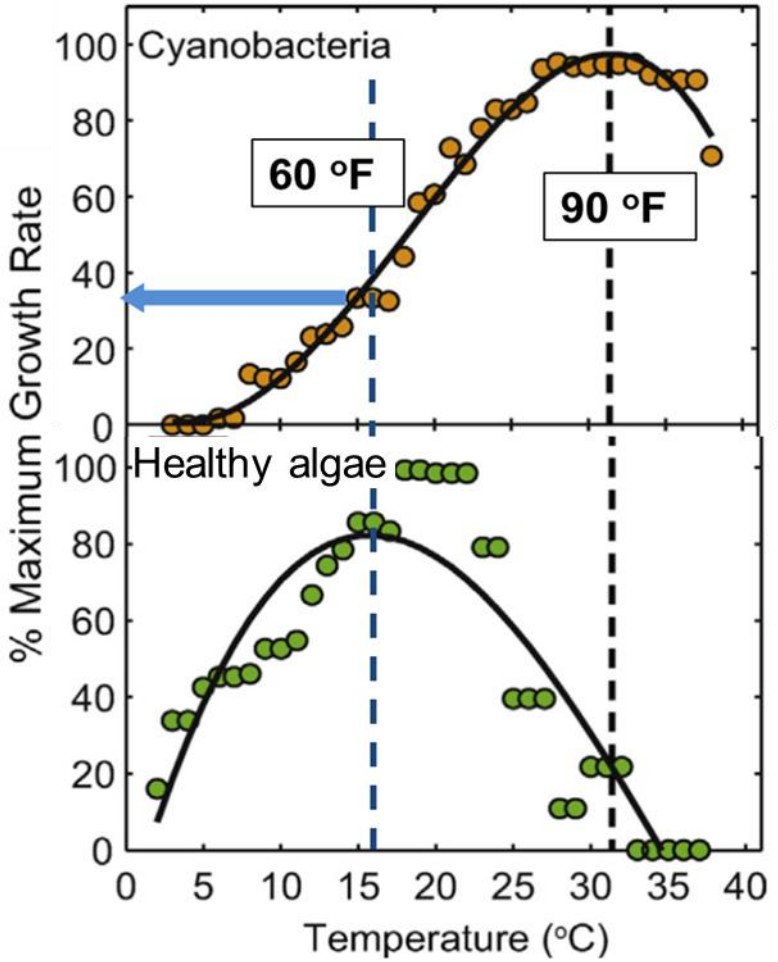
The science:
Benefits of cooling and aeration



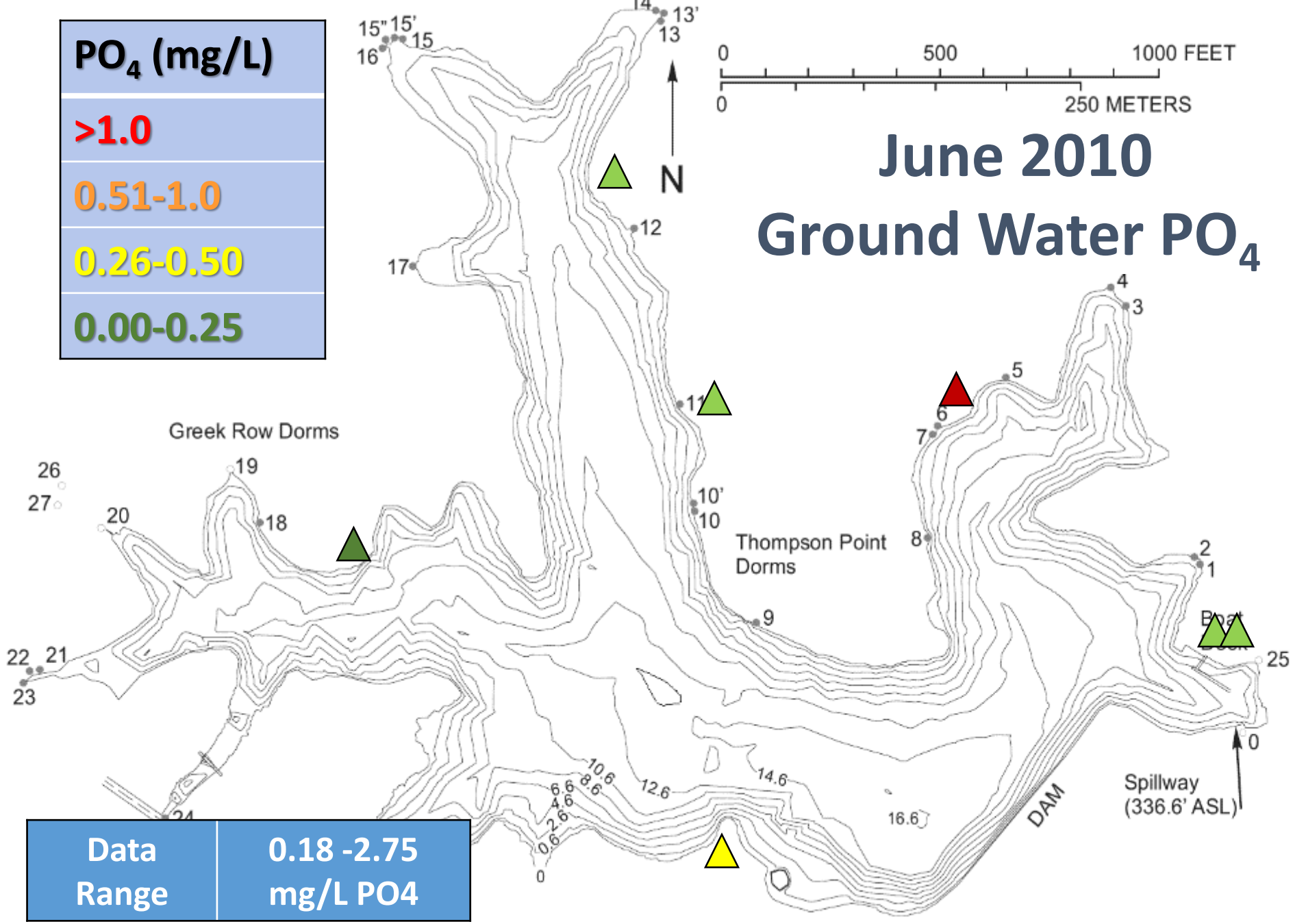
When aerated day and night with an aquarium bubbler, cyanobacteria cannot use nitrogen from the air. Cell counts dropped 54% after one week at 30 ºC (86 ºF) (M. Brooks, unpublished data).

540 calories of heat are lost when 1 gram of water evaporates

For every liter evaporated, 540,000 calories of heat is lost. That's enough to cool two 40-gallon aquariums from 86 to 71 ºF.

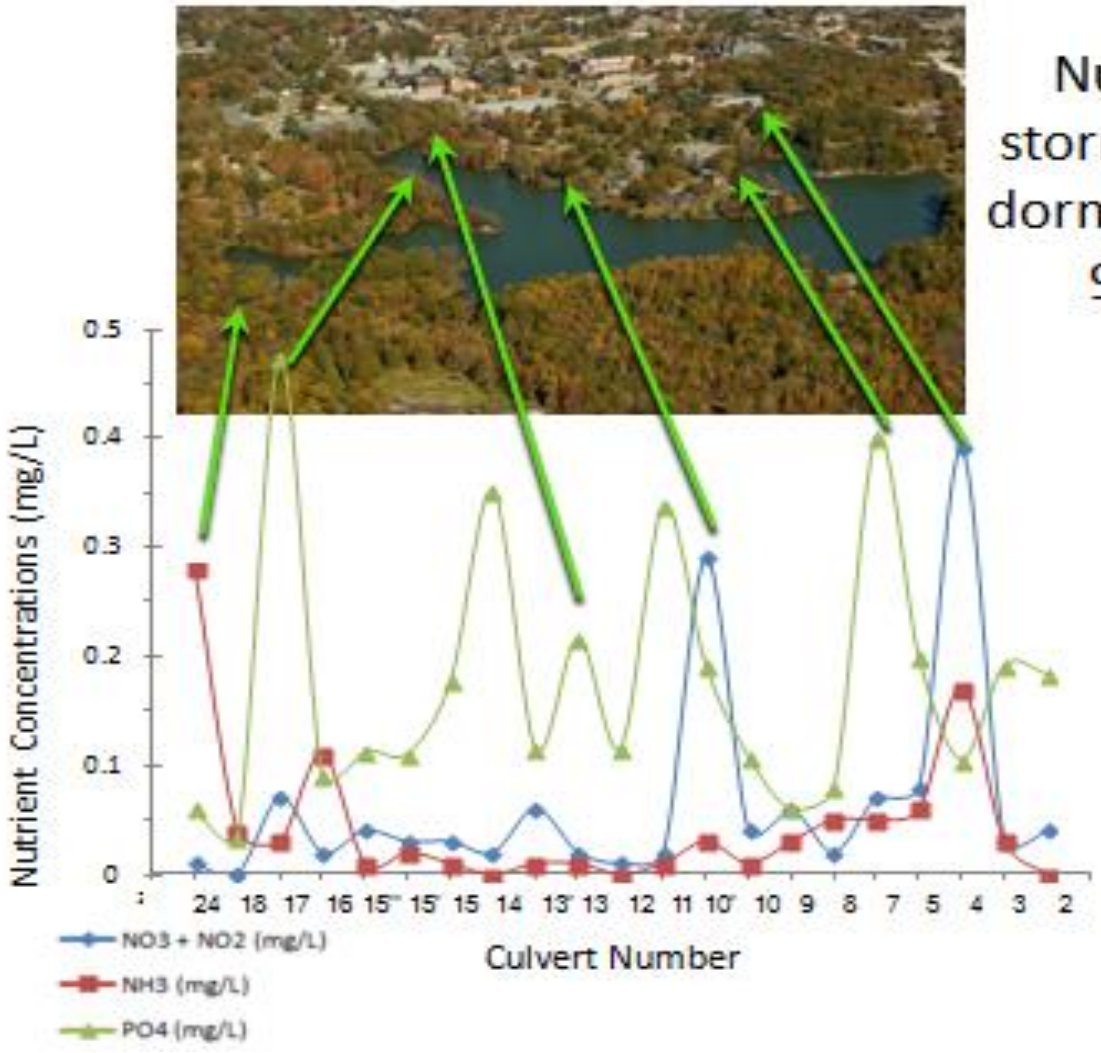


Blue arrow shows that cyanobacteria have a 35% growth rate at cool temperatures where healthy algae grow at 90% of their maximal rate (Paerl et al. 2016. Harmful Algae 54:213-222**).**


PO4 (mg/L)
>1.0
0.51-1.0
0.26-0.50
0.00-0.25
0
500
1000 FEET
0
250 METERS
N
June 2010
Ground Water PO4
Greek Row Dorms
Thompson Point Dorms
Boat
Spillway
(336.6' ASL)
DAM
Data Range
0.18 -2.75 mg/L PO4

Nutrient hotspots around Campus Lake

2010 Data



Nutrients from storm drains under dorms & Greek Row 9 Sept 2010

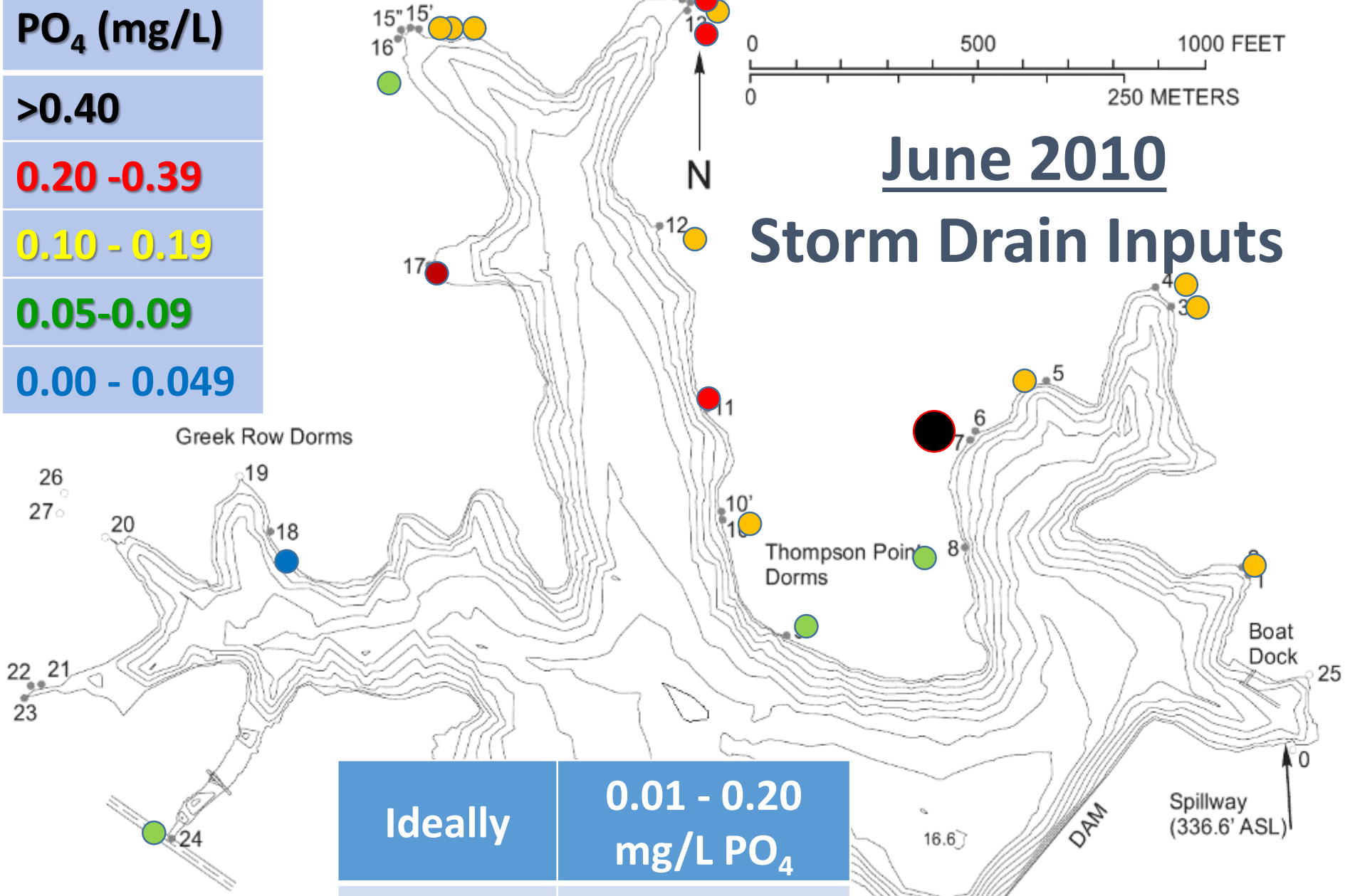
Brooks et al. 2013. Phase II Implementation: Report for Campus Lake, Jackson County, Illinois, Illinois Environmental Protection Agency. Illinois Clean Lakes Program

June 2010

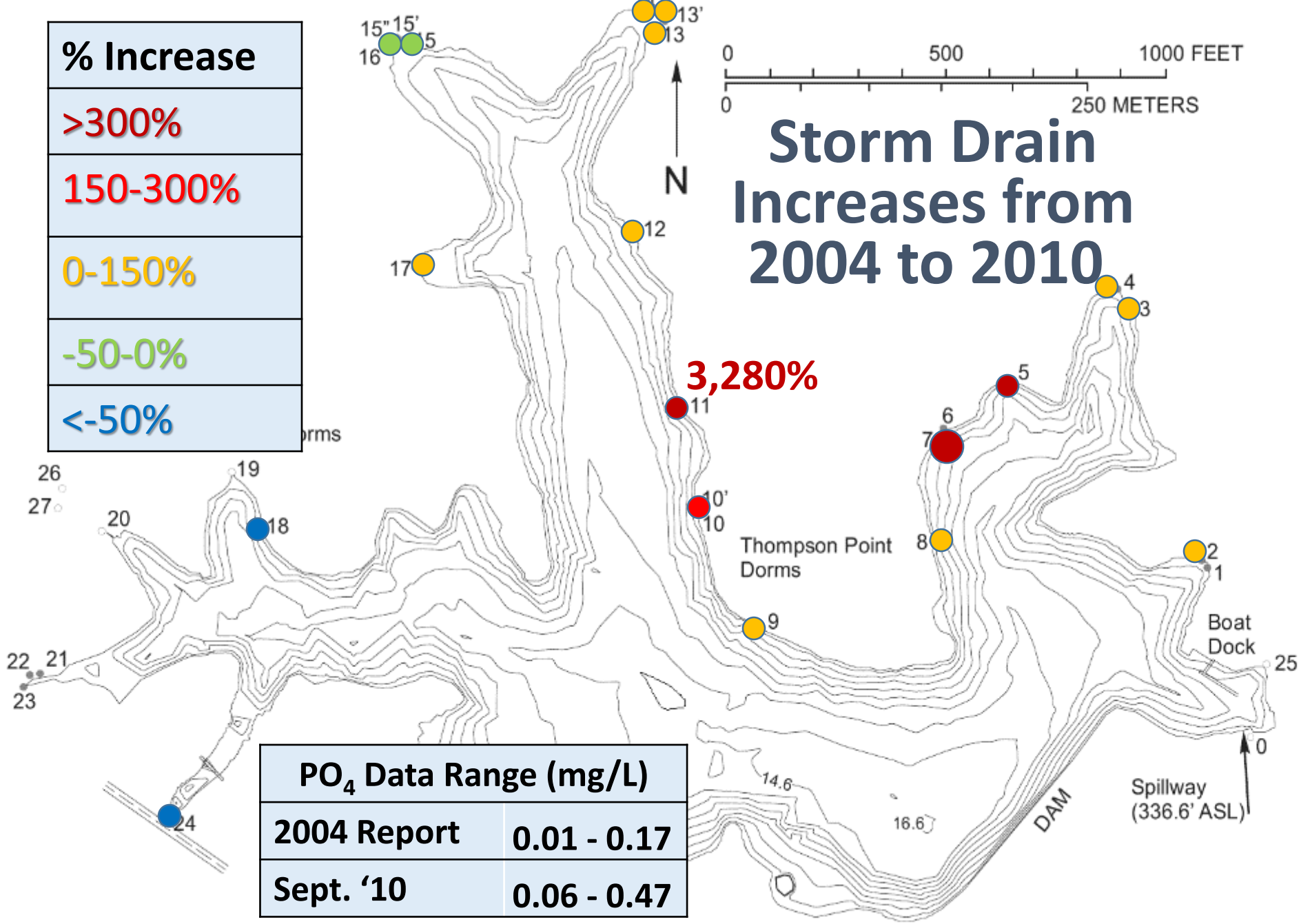
Storm Drain Inputs

PO_4 (mg/L)
>0.40
0.20 -0.39
0.10 - 0.19
0.05-0.09
0.00 - 0.049

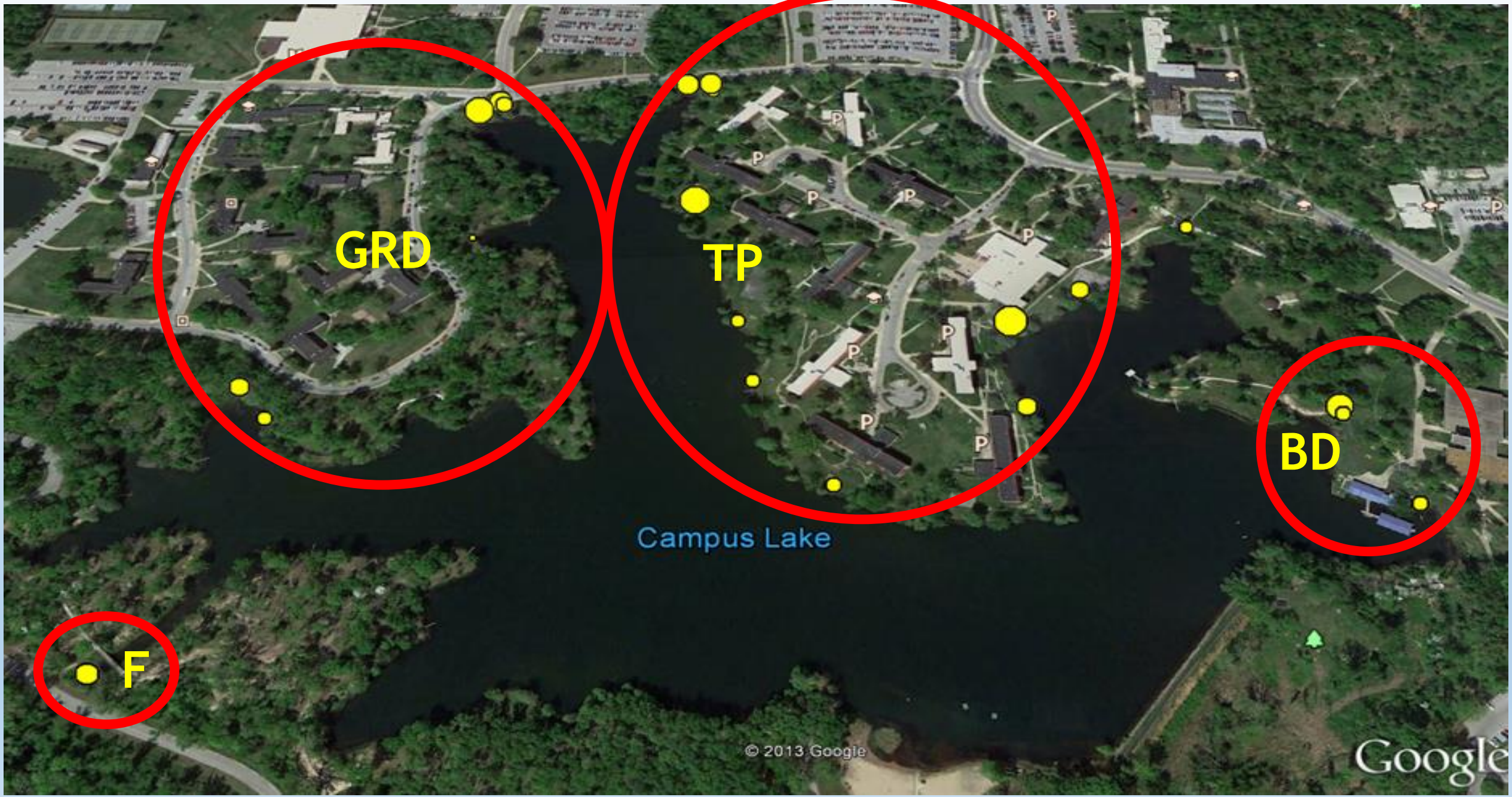
Acceptable →



Ideally	0.01 - 0.20 mg/L PO_4
Data Range	0.06 - 0.47



Brooks et al 2013 compared to Muchmore et al. 2004. Phase I diagnostic / feasibility study of Campus Lake, Report to the Illinois EPA


GRD
TP
BD
F
Campus Lake
© 2013 Google
Google