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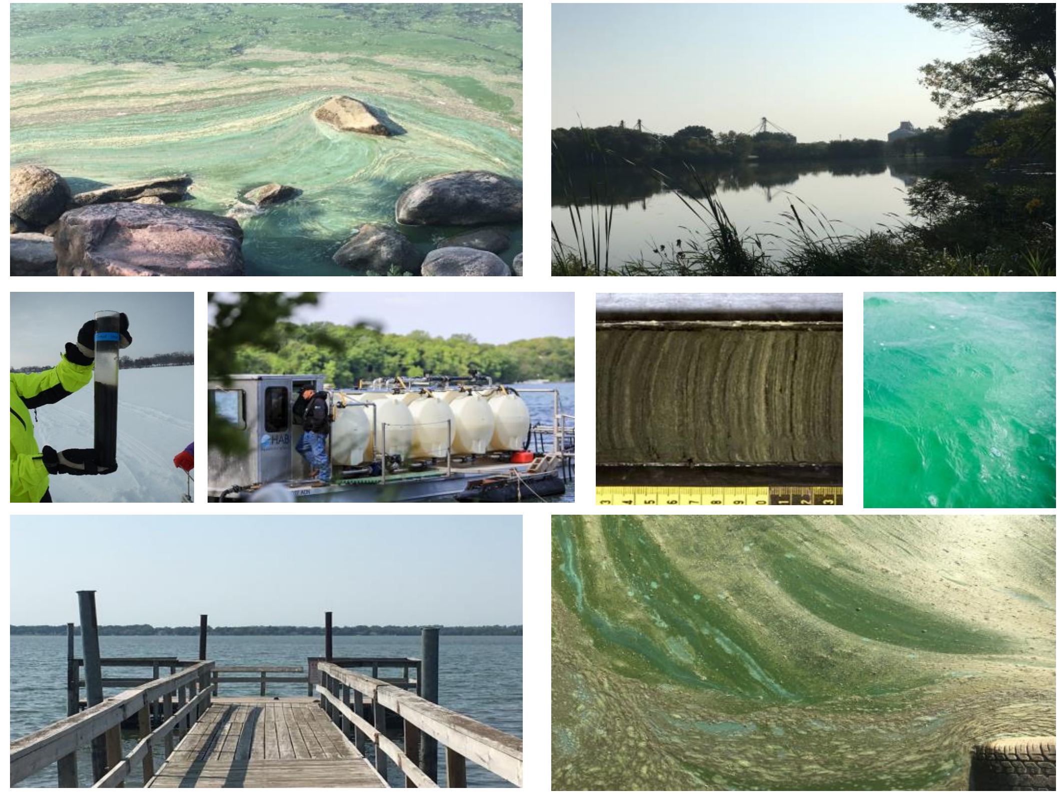
Responsive partner.
Exceptional outcomes.



Why is Watershed Phosphorus Loading so Stubbornly Persistent?

Joe Bischoff
Bill James, UW-Stout

June 14, 2018

WENCK

EAGAN

RILEY PURGATORY BLUFF CREEK
WATERSHED DISTRICT

CITY OF Chanhassen Minnesota

MINNEHAHA CREEK
WATERSHED DISTRICT
QUALITY OF WATER, QUALITY OF LIFE
50TH ANNIVERSARY
Est. 1967

UNIVERSITY OF WISCONSIN
STOUT
WISCONSIN'S POLYTECHNIC UNIVERSITY

EDEN PRAIRIE
LIVE • WORK • DREAM

Shingle Creek
West Mississippi

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PRESENTATION OBJECTIVES

Overview of Watershed Phosphorus Cycle

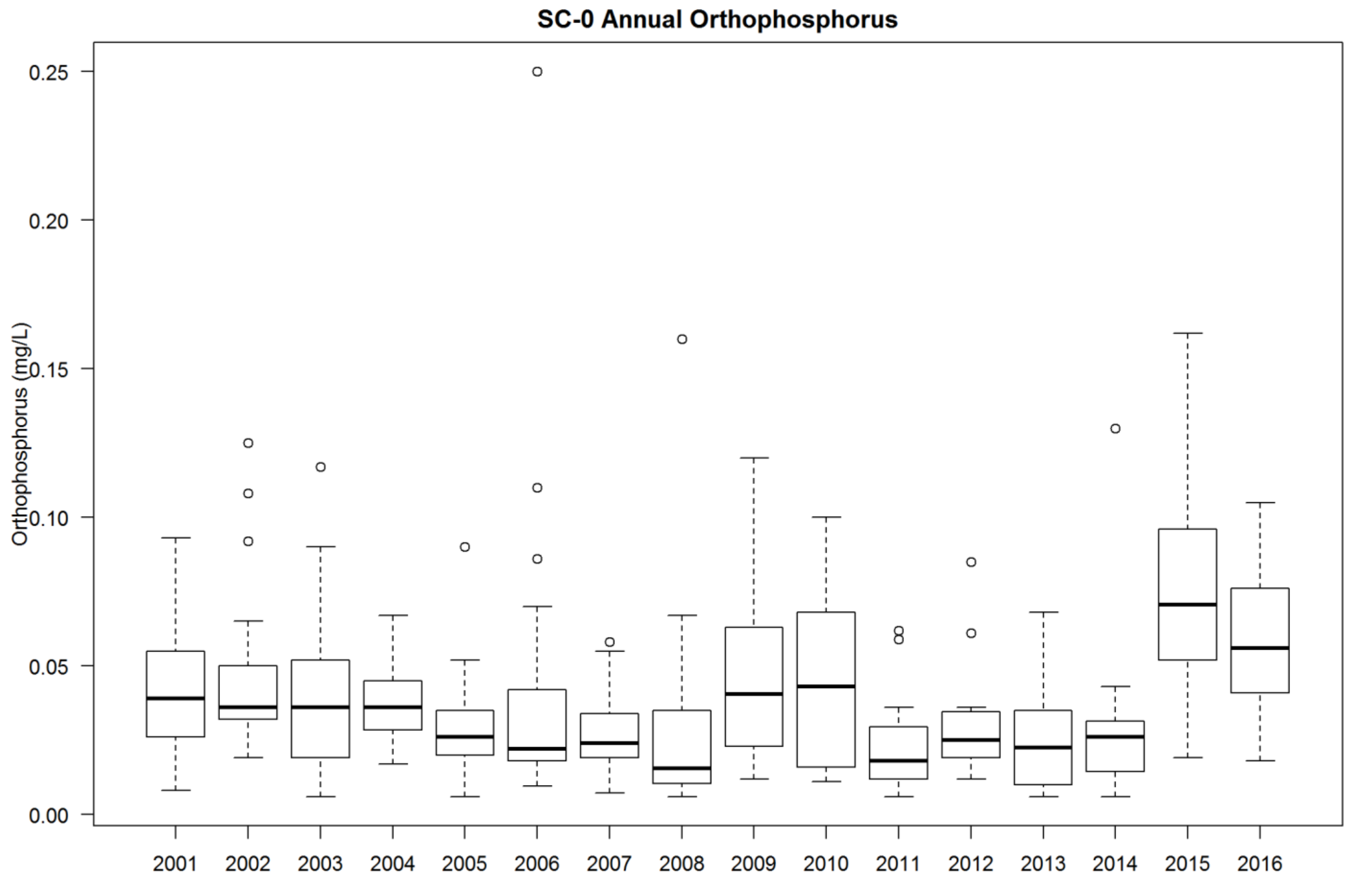
- Sources and management

Constructed Ponds and Stormwater Wetlands as Phosphorus Sinks

- General design
- Sediment phosphorus burial and release
- Implications for watershed phosphorus loading

Understanding and Managing Watershed Sediment Phosphorus Pools

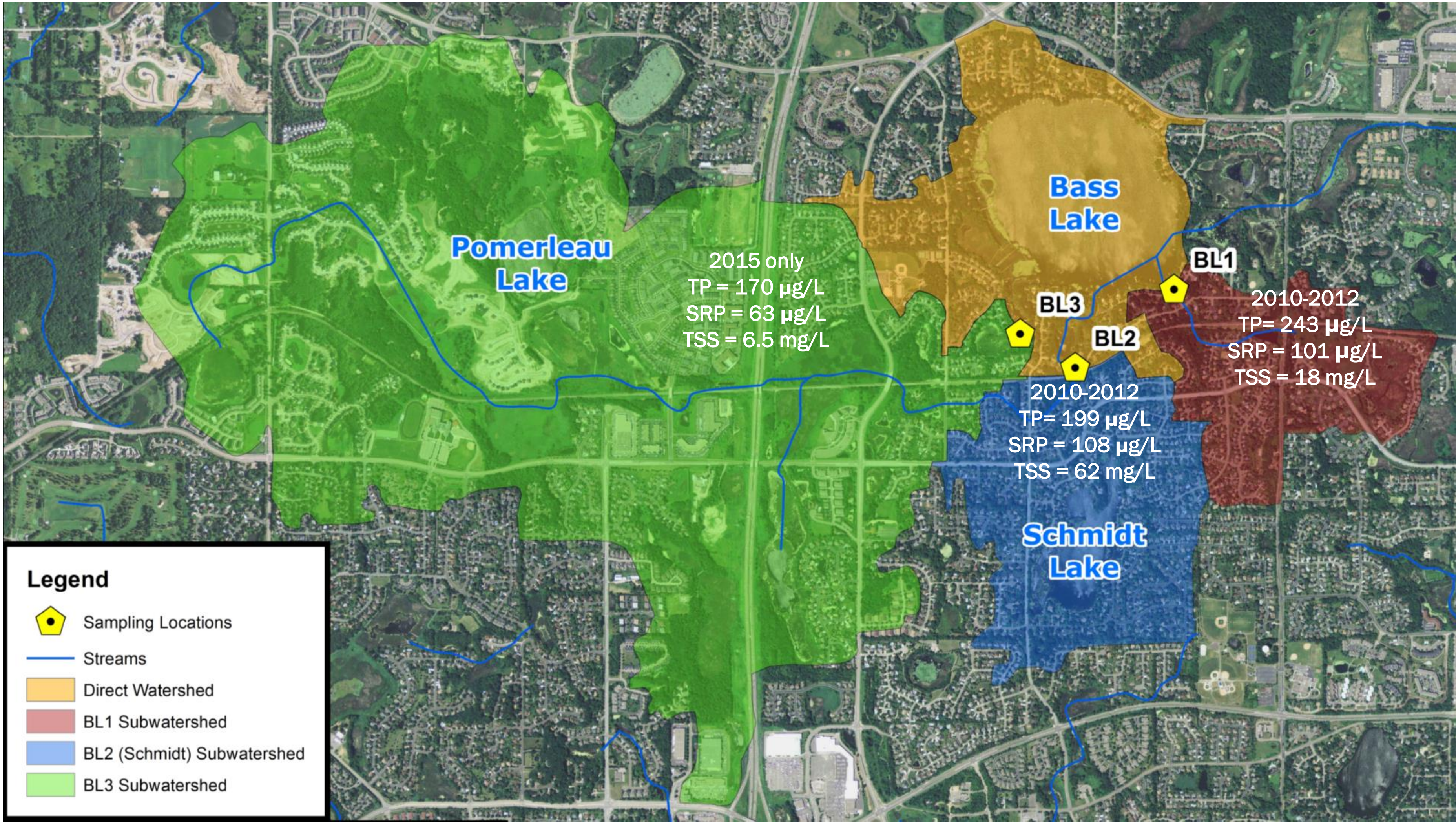
- Modeling approaches for identifying sediment P sources
- Management approaches for sediment P sources



Shingle Creek Watershed Management Commission

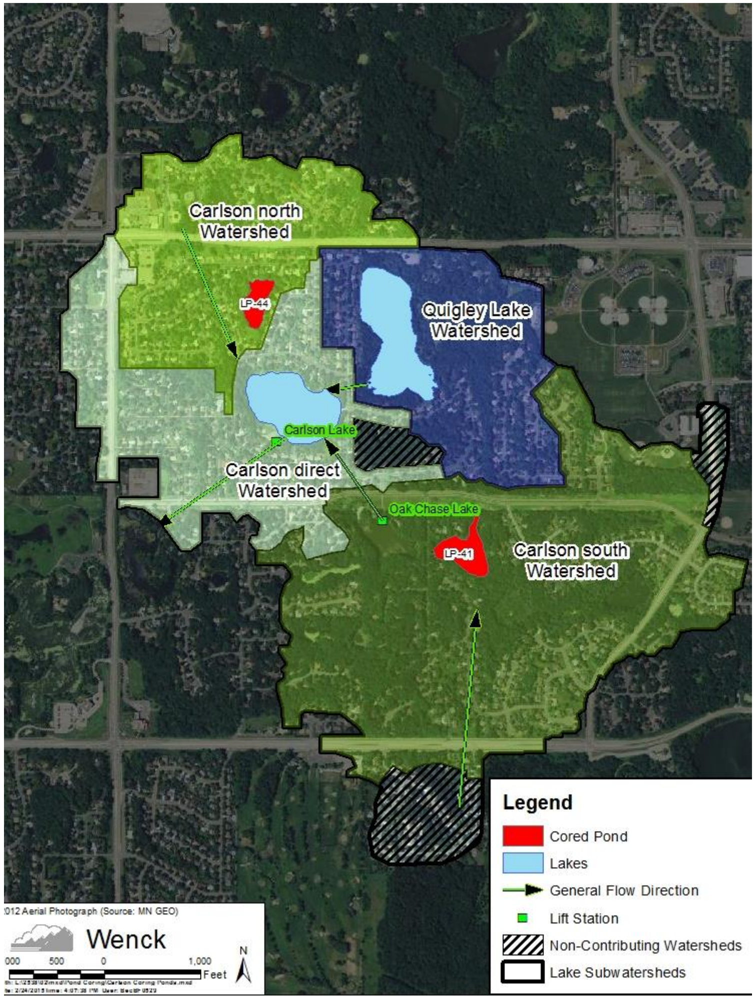
- Since 2005, $12 million invested in water quality projects
- Municipal retrofits, $2.7M
- MNDOT and County water quality projects, $2M

THE PROBLEM



Bass Lake
Pomerleau Lake
Schmidt Lake
2015 only
TP = 170 µg/L
SRP = 63 µg/L
TSS = 6.5 mg/L
BL1
BL2
BL3
2010-2012
TP= 243 µg/L
SRP = 101 µg/L
TSS = 18 mg/L
2010-2012
TP= 199 µg/L
SRP = 108 µg/L
TSS = 62 mg/L
Legend
Sampling Locations
Streams
Direct Watershed
BL1 Subwatershed
BL2 (Schmidt) Subwatershed
BL3 Subwatershed

WATERSHED PHOSPHORUS MANAGEMENT
THE TRADITIONAL STORMWATER PARADIGM



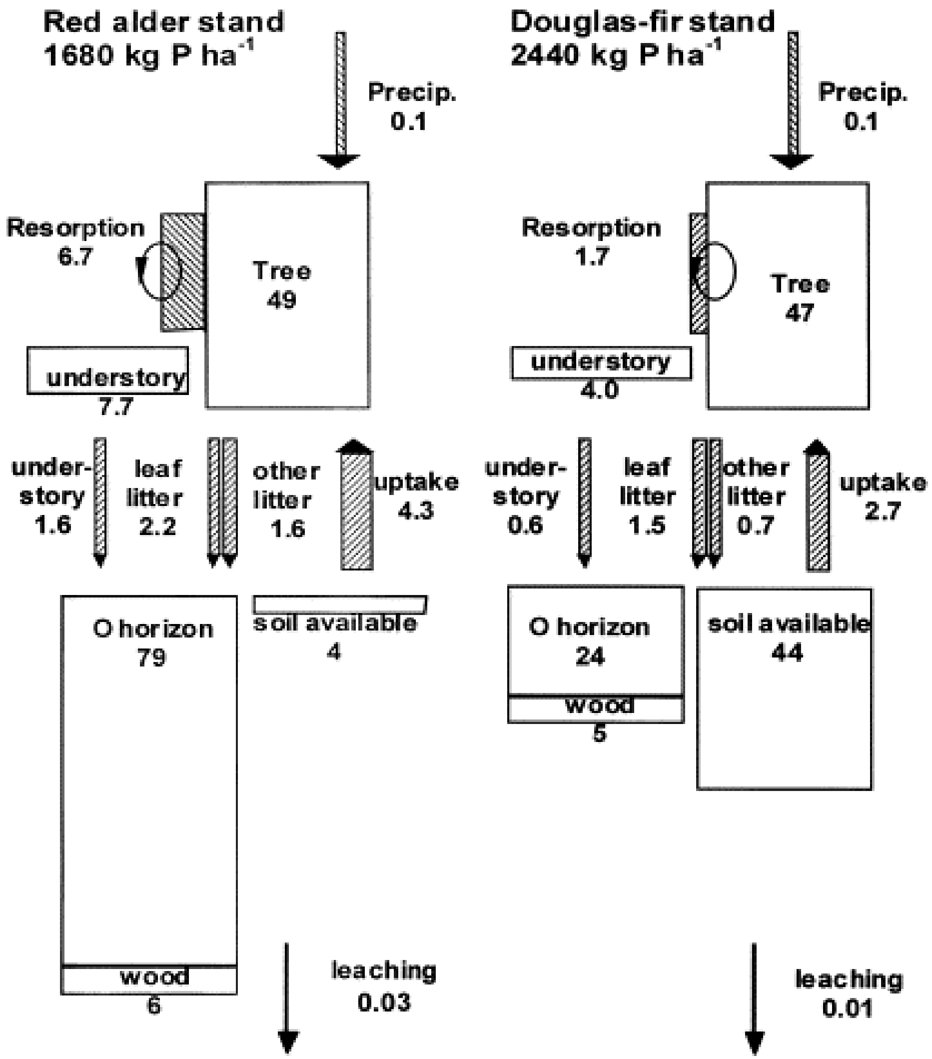
Phosphorus Source Management

- Phosphorus fertilizer ban
- Homeowner best practices
  - Grass clippings, runoff management
- Street sweeping

Provide phosphorus sinks in the watershed

- Constructed ponds to settle particulate phosphorus
- Wetlands to settle and adsorb phosphorus
- Rain gardens and biofilters

POOLS AND FLUX OF WATERSHED P



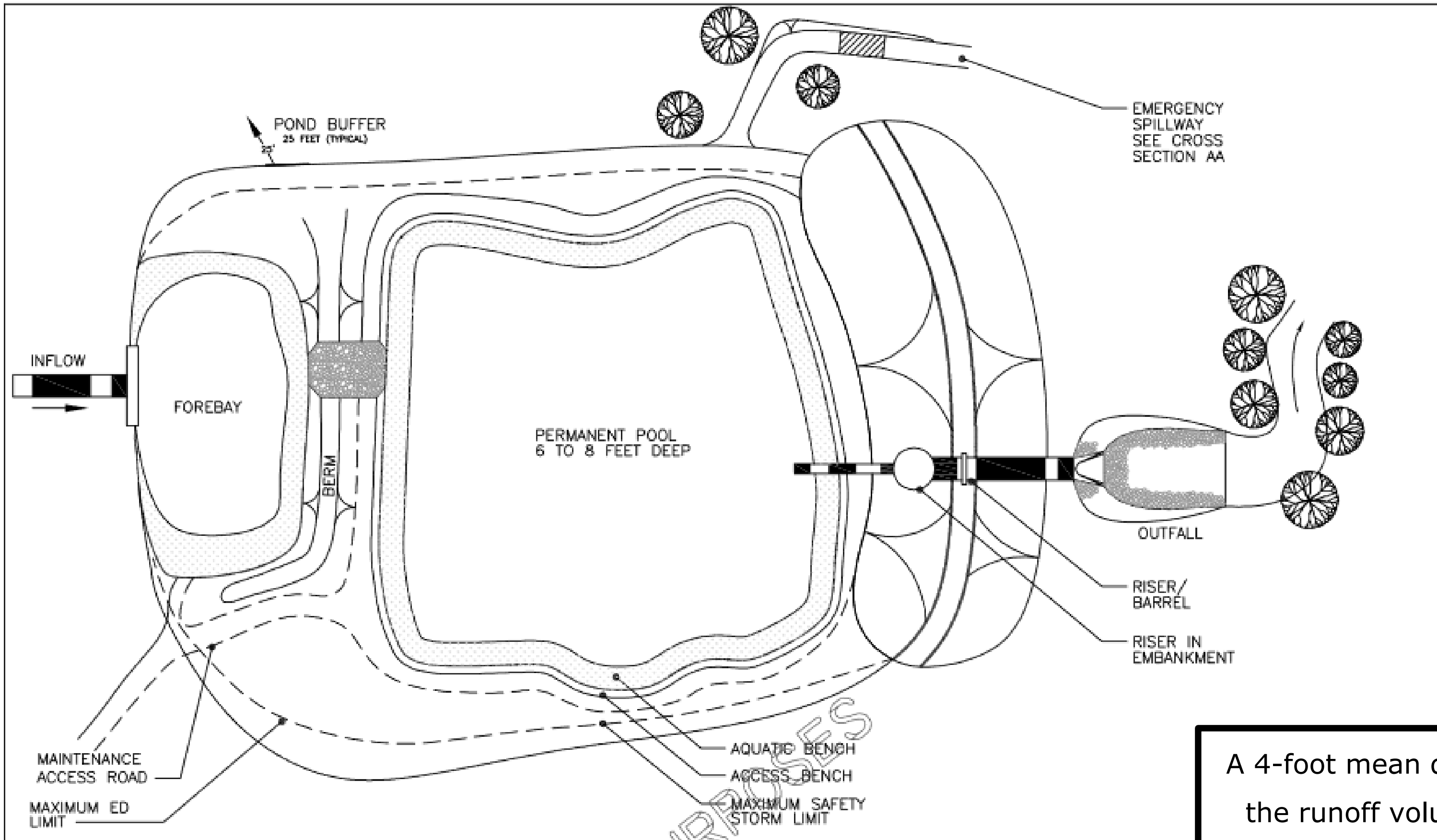
Pools

- Soils
- Wetlands
- Pond and lake sediments
- Vegetation

Flux

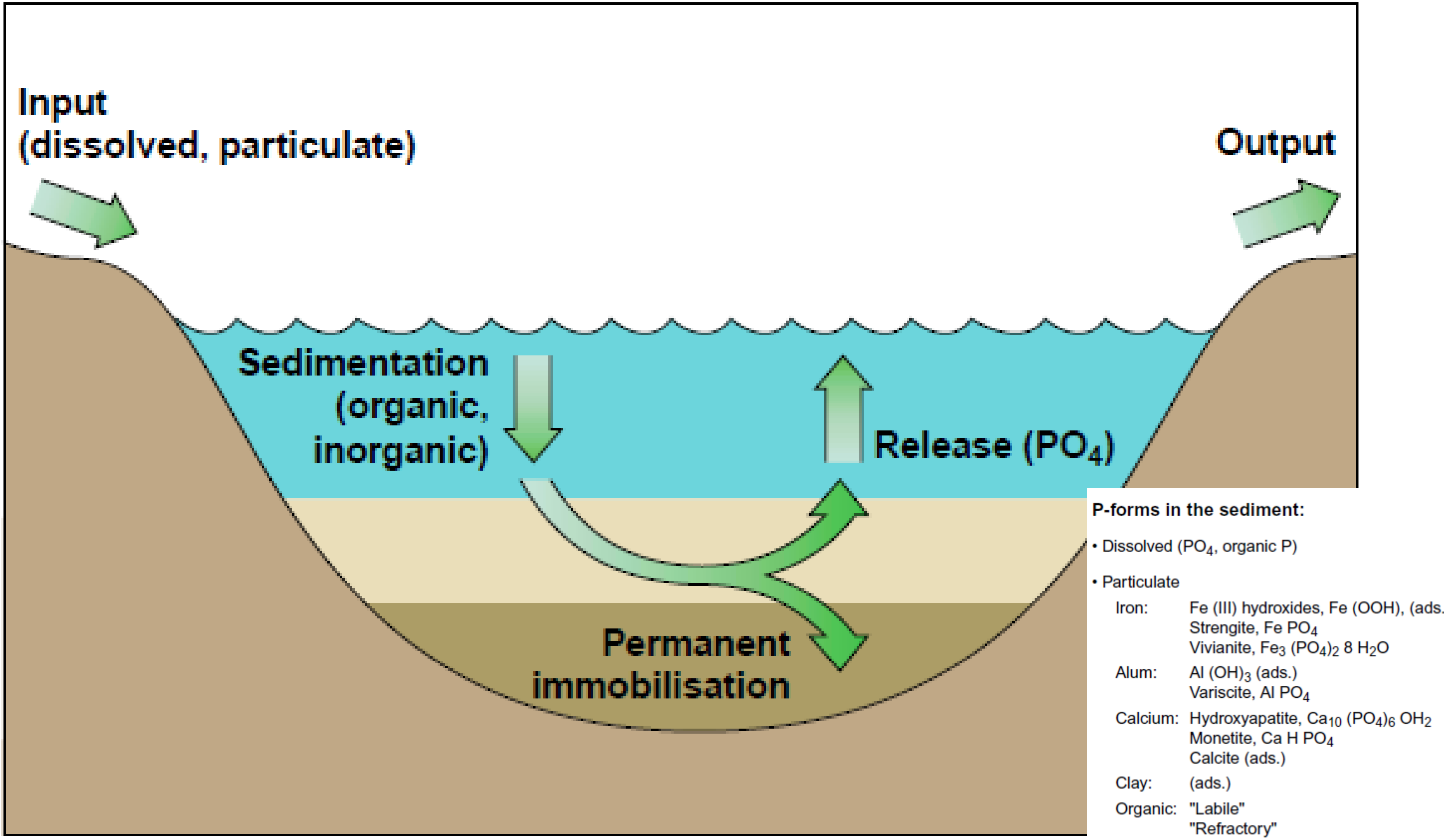
- Agricultural export
- Mass loading in surface waters
- Microbial release
- Fertilizer application

STANDARD CONSTRUCTED POND DESIGN



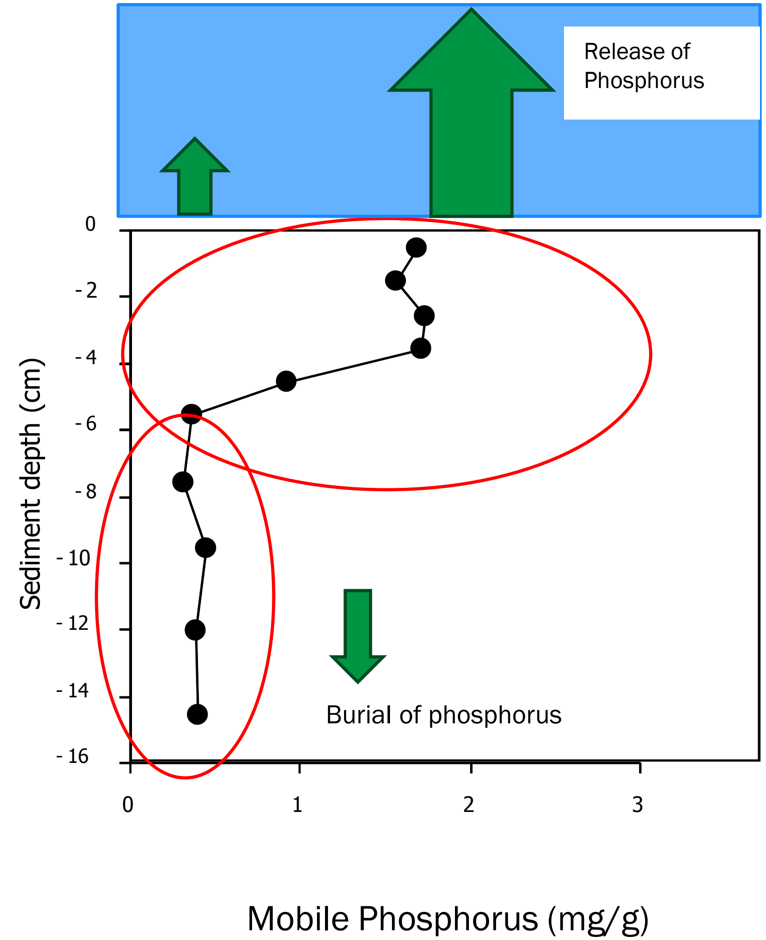
A 4-foot mean depth and volume equal to the runoff volume from a 2.5-inch, 24-hour rainfall event over the watershed, or 1800 cubic feet per acre of drainage to the basin, or 3600 cubic feet per acre of drainage area for enhanced phosphorus removal.

SEDIMENT PHOSPHORUS CYCLE



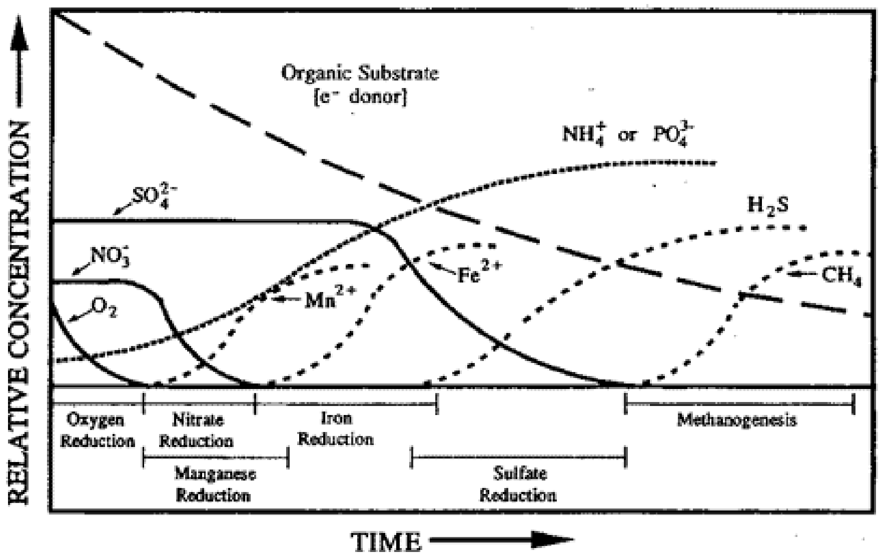
Sondergaard et al. 2001

What is Causing Sediment Phosphorus Release?



Sediment Redox Reactions

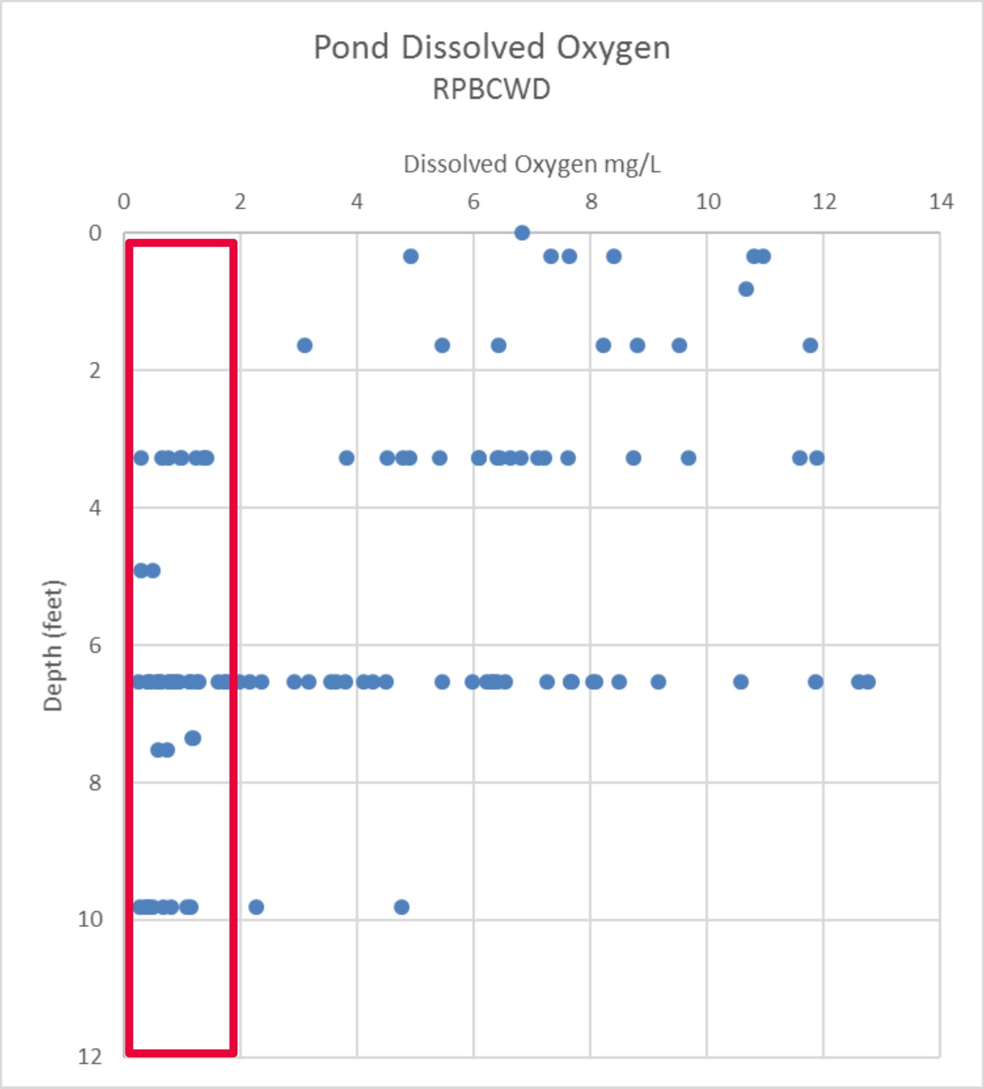
Anoxic Conditions



ANOXIA IN STORMWATER PONDS AND WETLANDS

Pond Monitoring

- 6 stormwater ponds and wetlands in Chanhassen and Eden Prairie
- Monitored May through August
- Anoxia observed as shallow as 3 feet in ponds



EAGAN STORMWATER WETLAND JP-5

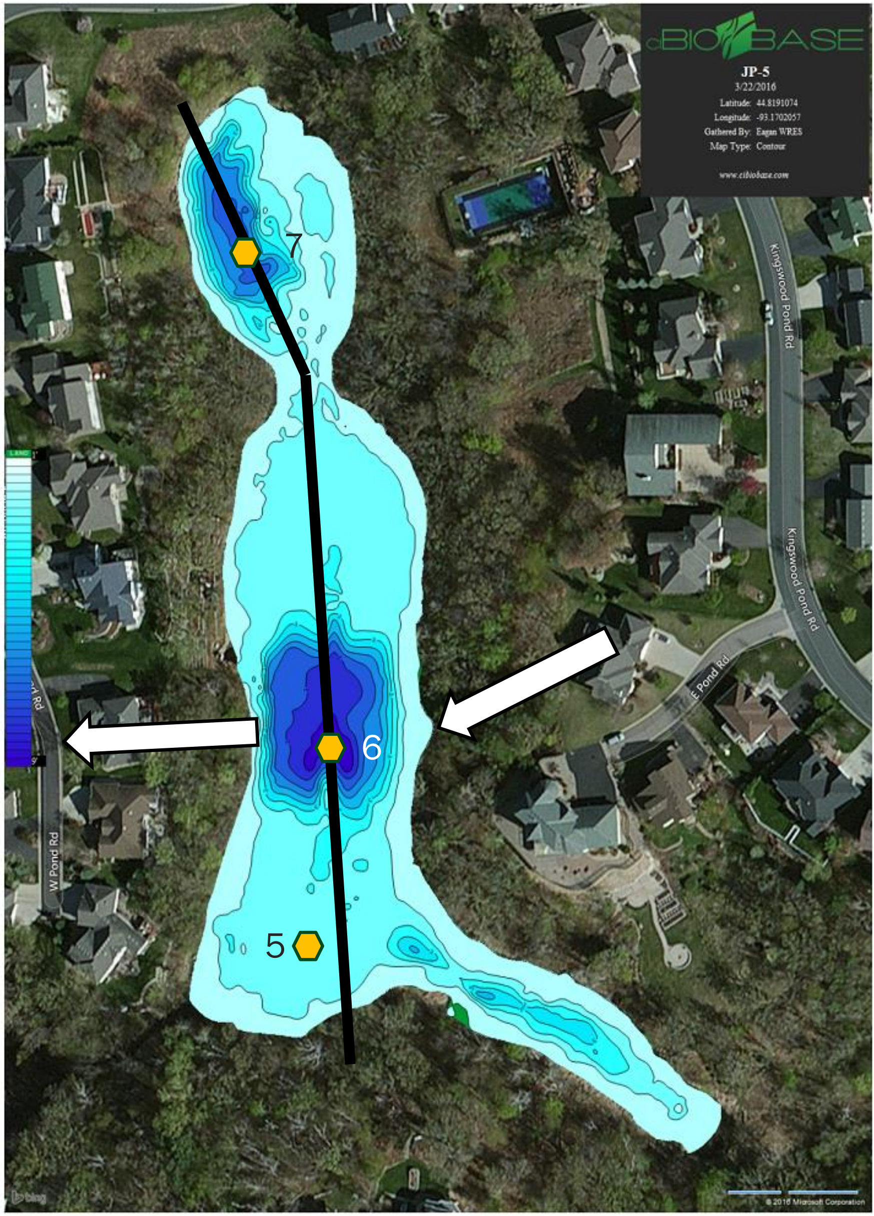
Receives discharge from Fish Lake

Discharges to Blackhawk Lake

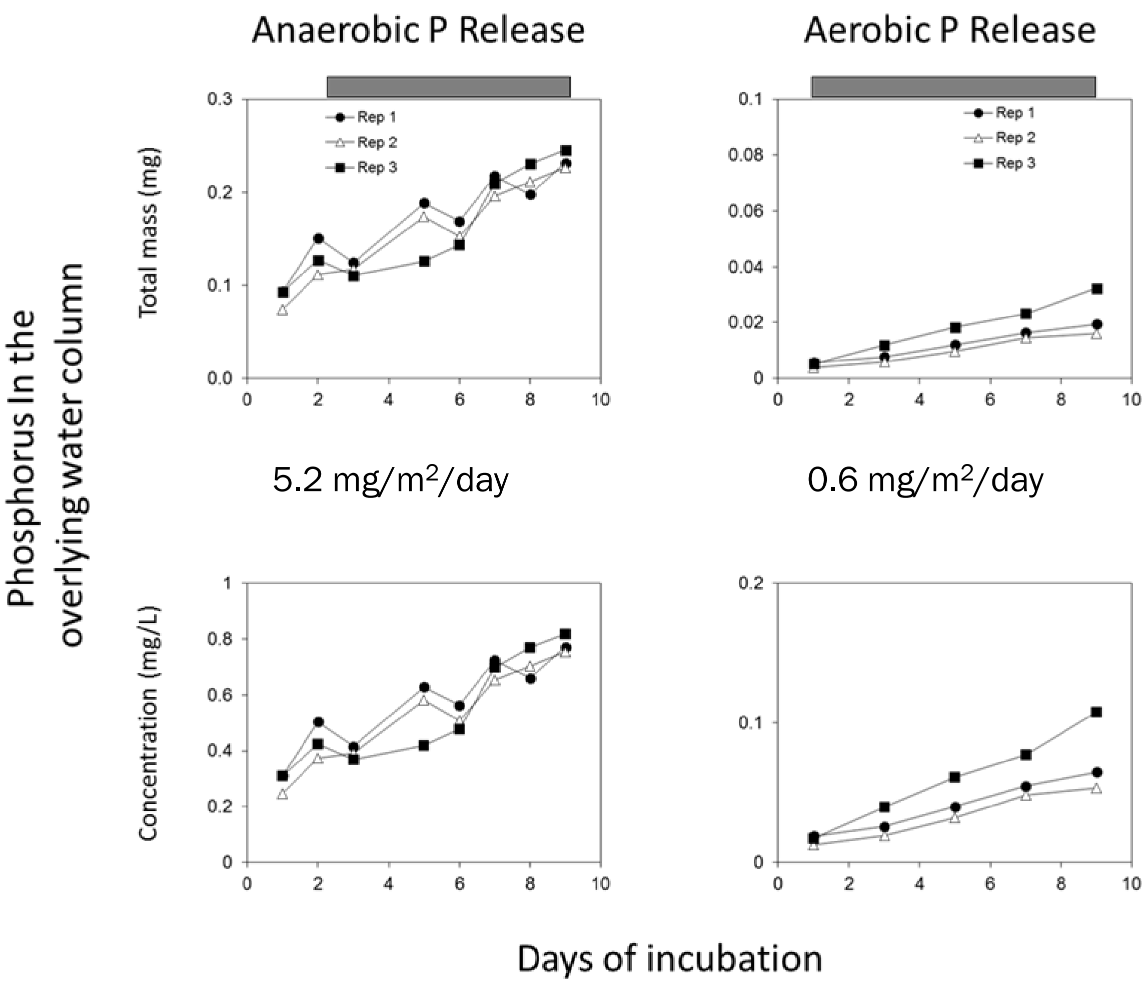
Pond is undersized

Max depth of 8 feet

Concerned adding phosphorus to discharge and inadequately treating watershed runoff

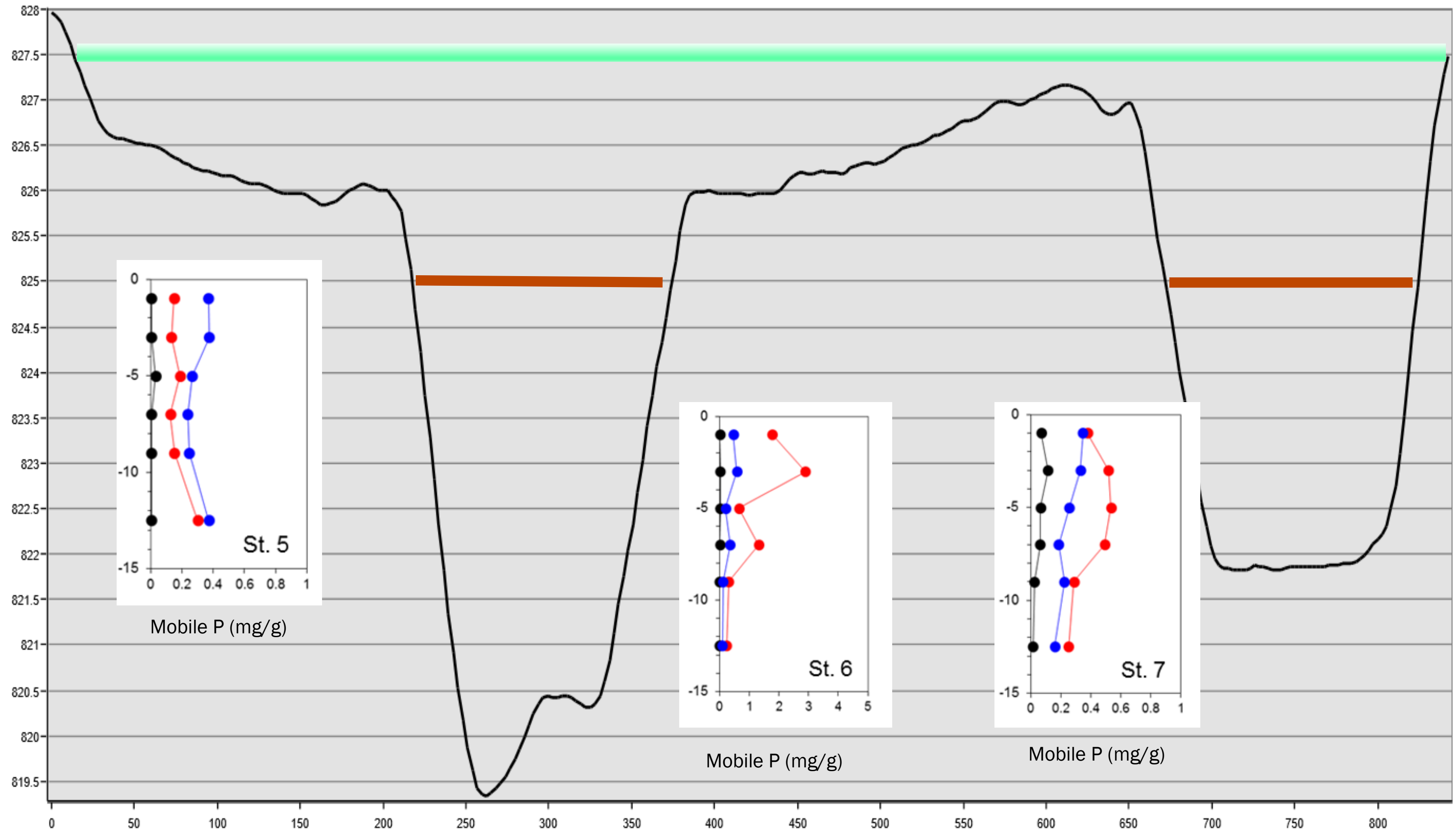


Pond JP 5 station 6



POND/STORMWATER WETLAND JP-5

CITY OF EAGAN



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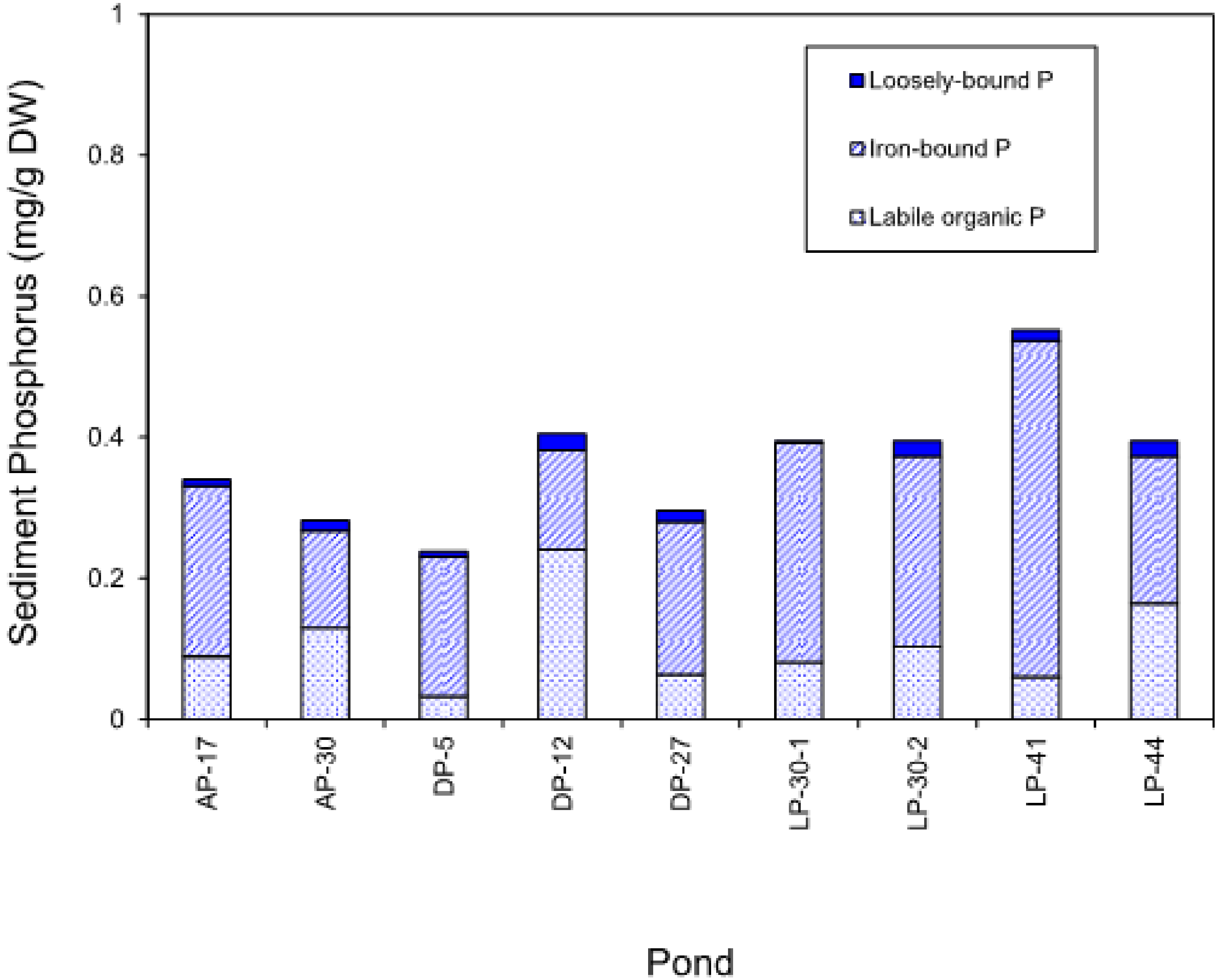
URBAN POND SEDIMENT CHEMISTRY
CITY OF EAGAN



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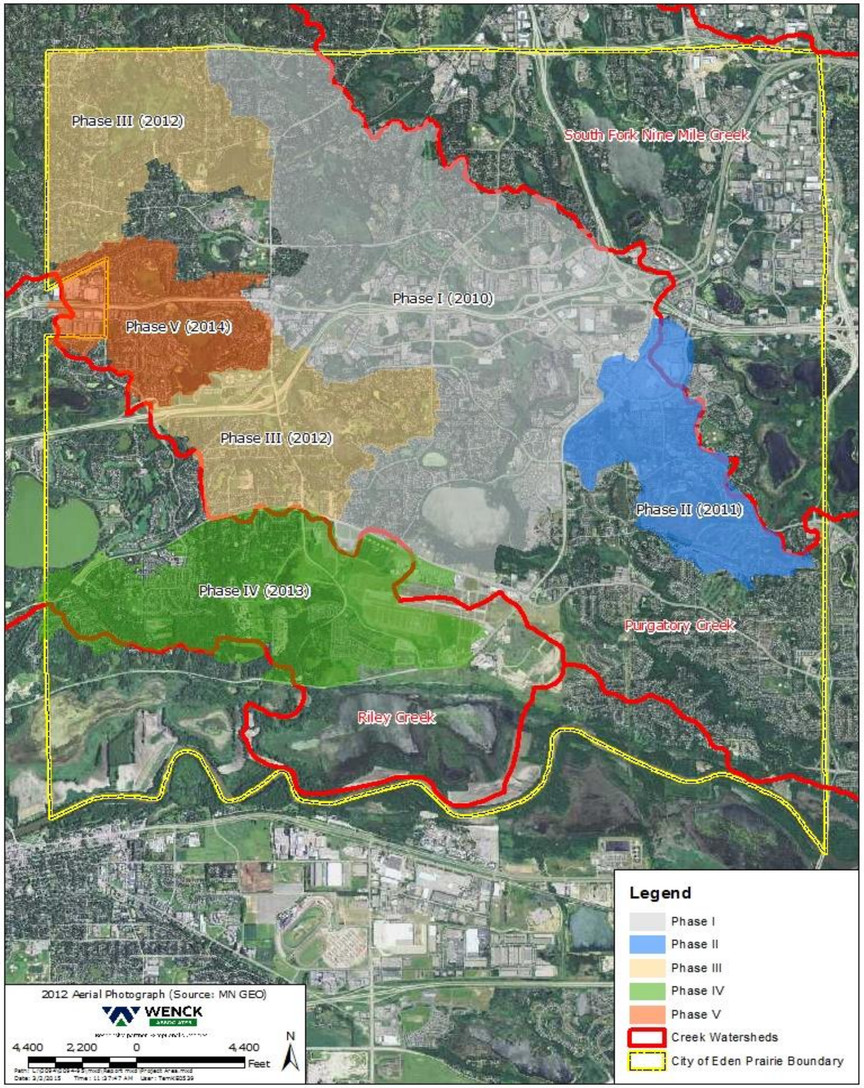
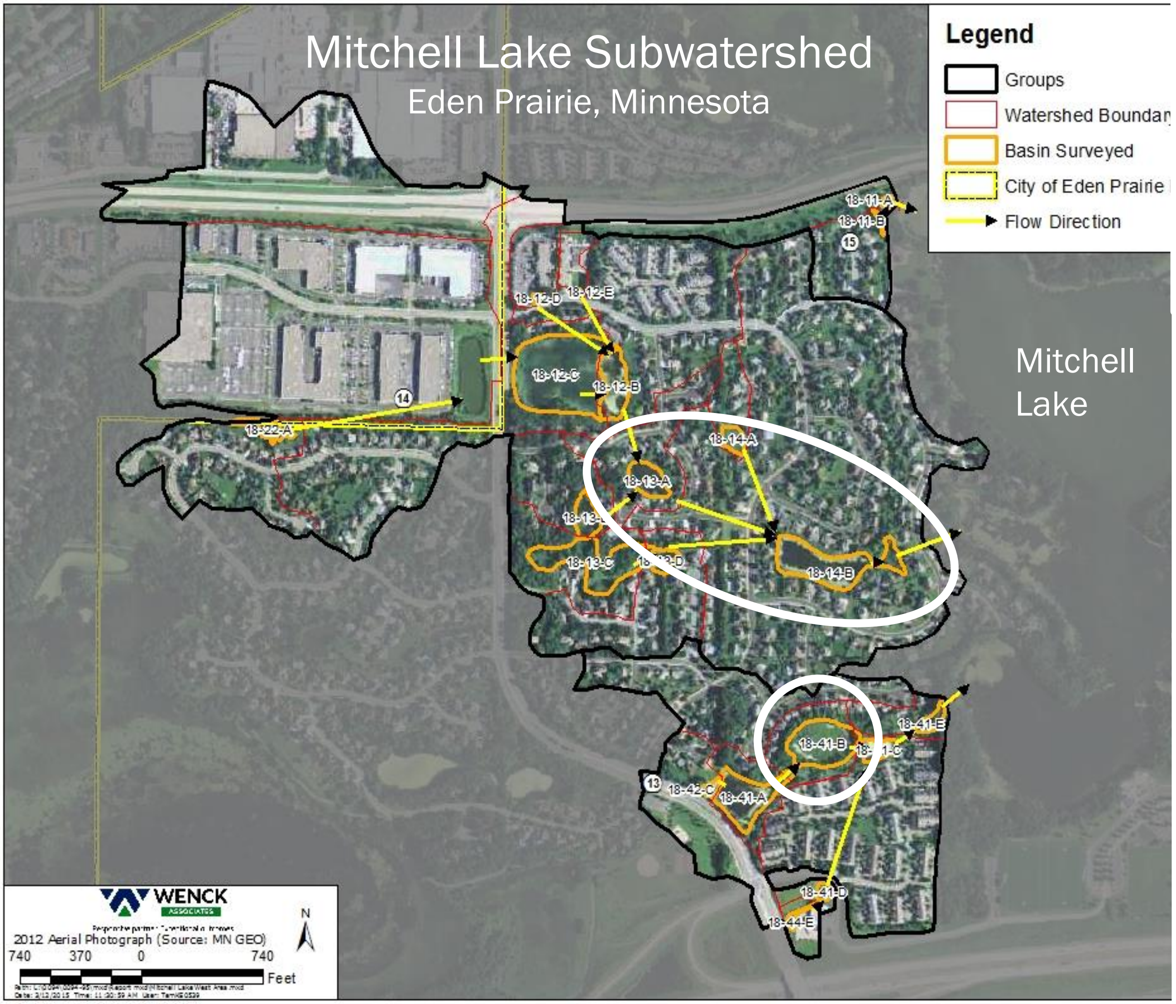
POND INSPECTION PROGRAM

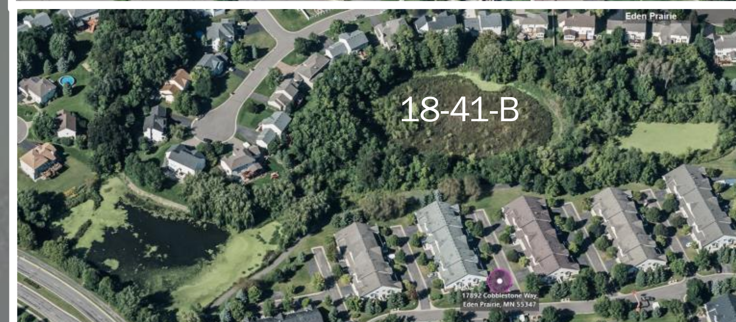
EDEN PRAIRIE, MINNESOTA



- MS4 Permit requires annual inspection of stormwater ponds
  - Identify those with maintenance issues
  - ***Identify ponds that are losing dead storage and settling effectiveness***
  - Identify critical ponds in treatment train
- Over 1,400 stormwater ponds and wetlands
  - Mix of private and public ownership
- Almost $1,000,000 in inspection costs

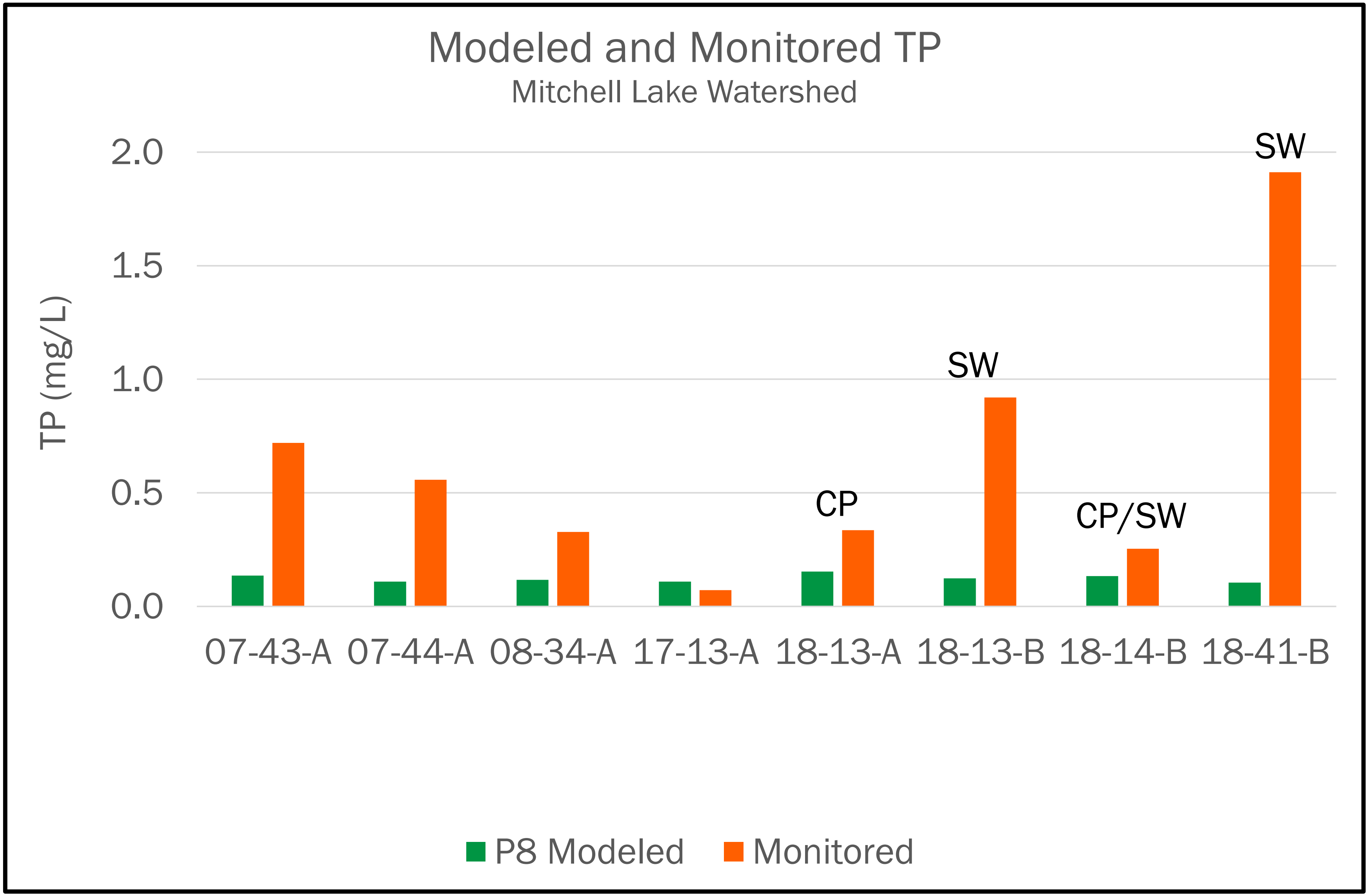

Mitchell Lake Subwatershed
Eden Prairie, Minnesota
Legend
Groups
Watershed Boundar
Basin Surveyed
City of Eden Prairie
Flow Direction
Mitchell
Lake
18-11-A
18-11-B
18-12-D
18-12-E
18-12-C
18-12-B
18-22-A
18-14-A
18-13-A
18-14-B
18-13-C
18-41-B
18-41-E
18-42-C
18-41-A
18-41-D
18-44-E
WENCK
2012 Aerial Photograph (Source: MN GEO)
740 370 0 740
Feet
N


18-14-B


18-41-B


18-13-A

WENCK

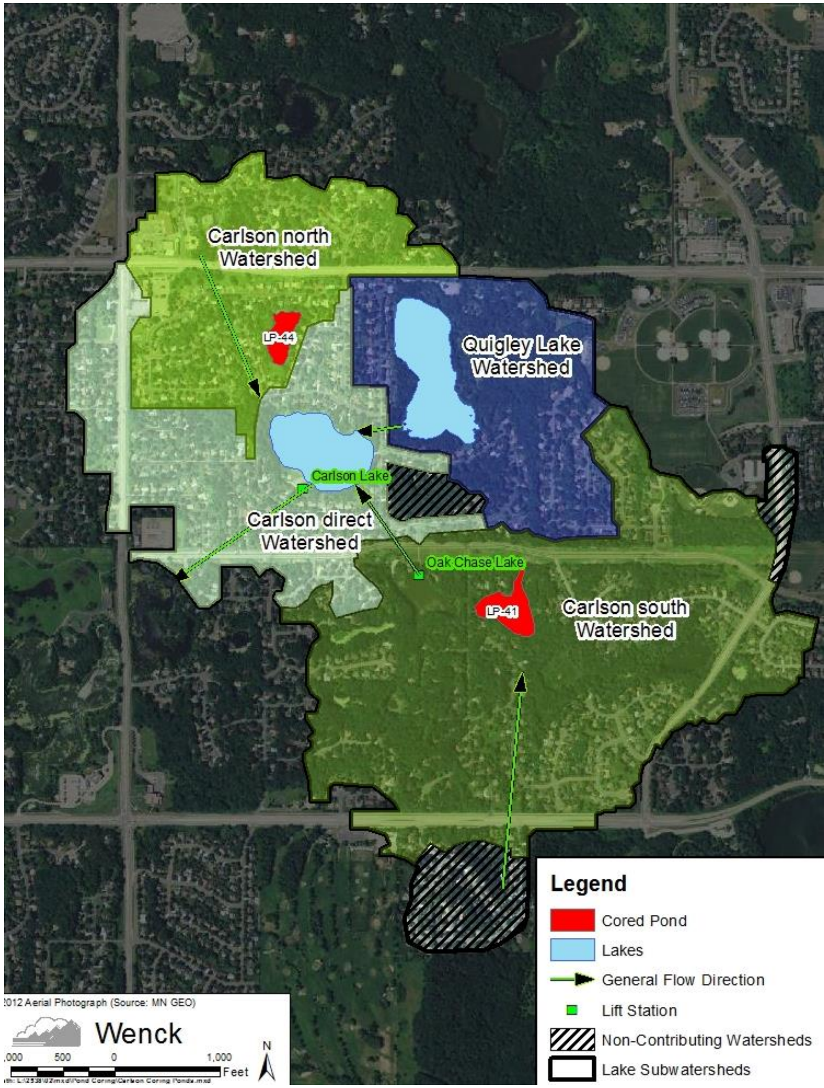


Modeled and Monitored TP
Mitchell Lake Watershed
TP (mg/L)
2.0
1.5
1.0
0.5
0.0
SW
SW
CP
CP/SW
07-43-A
07-44-A
08-34-A
17-13-A
18-13-A
18-13-B
18-14-B
18-41-B
P8 Modeled
Monitored

ASSESSMENT APPROACHES
MODELING CONSIDERATIONS

City of Eagan Ponds	LP-41	LP-44
Pond Area (acres)	4.8	2.4
Pond P release (lbs/yr) [1]	9.7	4.9
Pond TP Sedimentation (lbs/yr) [2]	8.6	6.5
Sediment Redox P (pounds)	728	33
Sediment Mobile P (pounds)	1,295	227

[1] Assumes release of 5 mg/m^2/day and 45 days anoxia
[2] 2008-2012 average using PondNet



City of Eagan, MN has over 1,200 Stormwater wetlands and constructed ponds over 34.5 square miles

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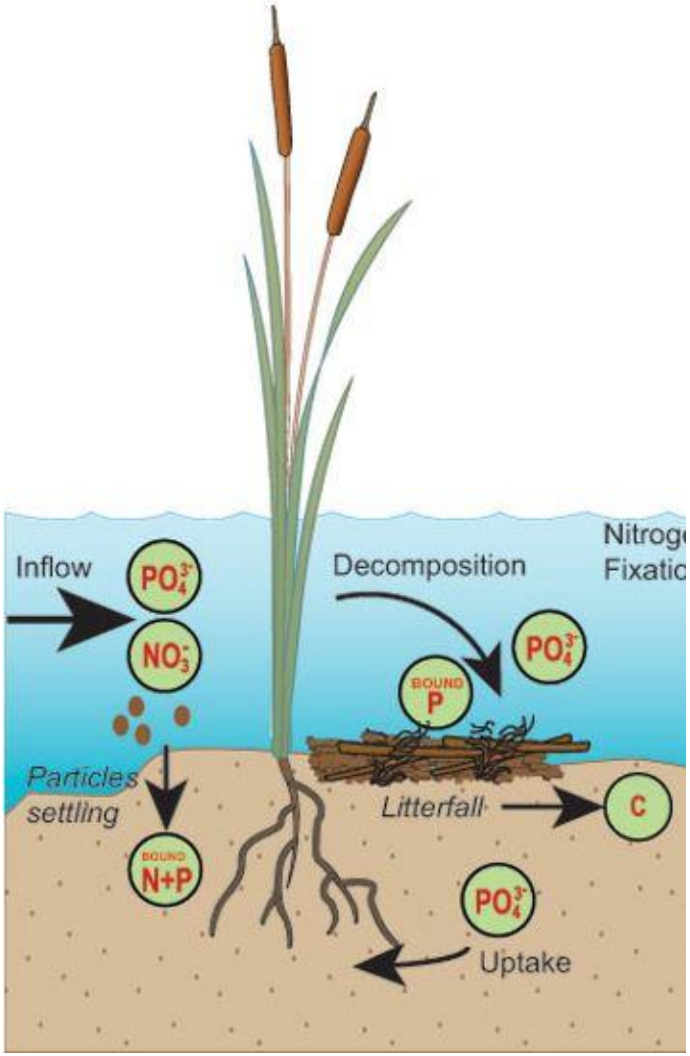
FACTORS IMPACTING PHOSPHORUS CYCLING

Wetlands remove incoming phosphorus through:

- Adsorption to soils
- Assimilation by wetland plants
- Settling of particulate phosphorus

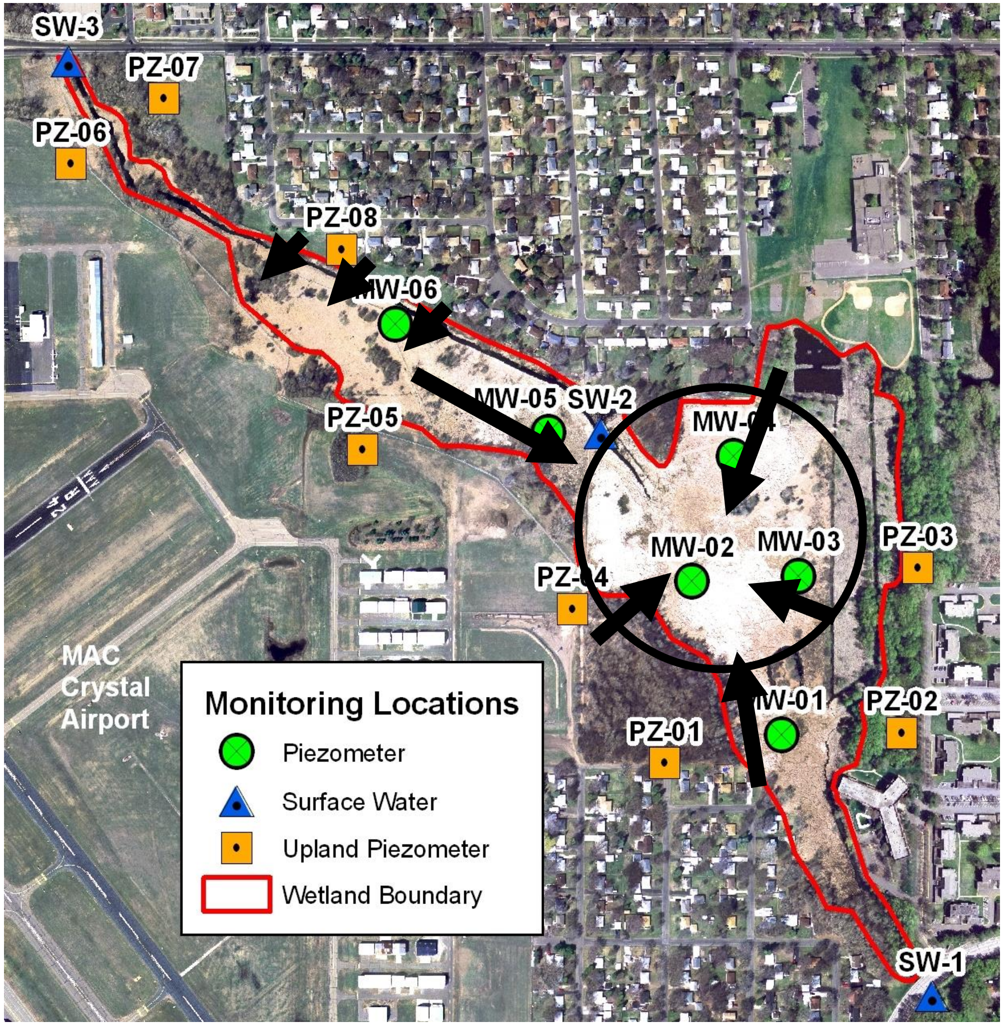
Wetlands export phosphorus through:

- Organic matter decay
- Desorption from particulate material



WETLAND 639 SHINGLE CREEK WATERSHED

- Drawdown speeds up mineralization, organic P transformed into inorganic
- When wetland is flooded, ferric iron reduces to soluble ferrous iron and is released
- Solution: keep water in the wetland by managing outlet and releasing only short-contact runoff from the upper wetland



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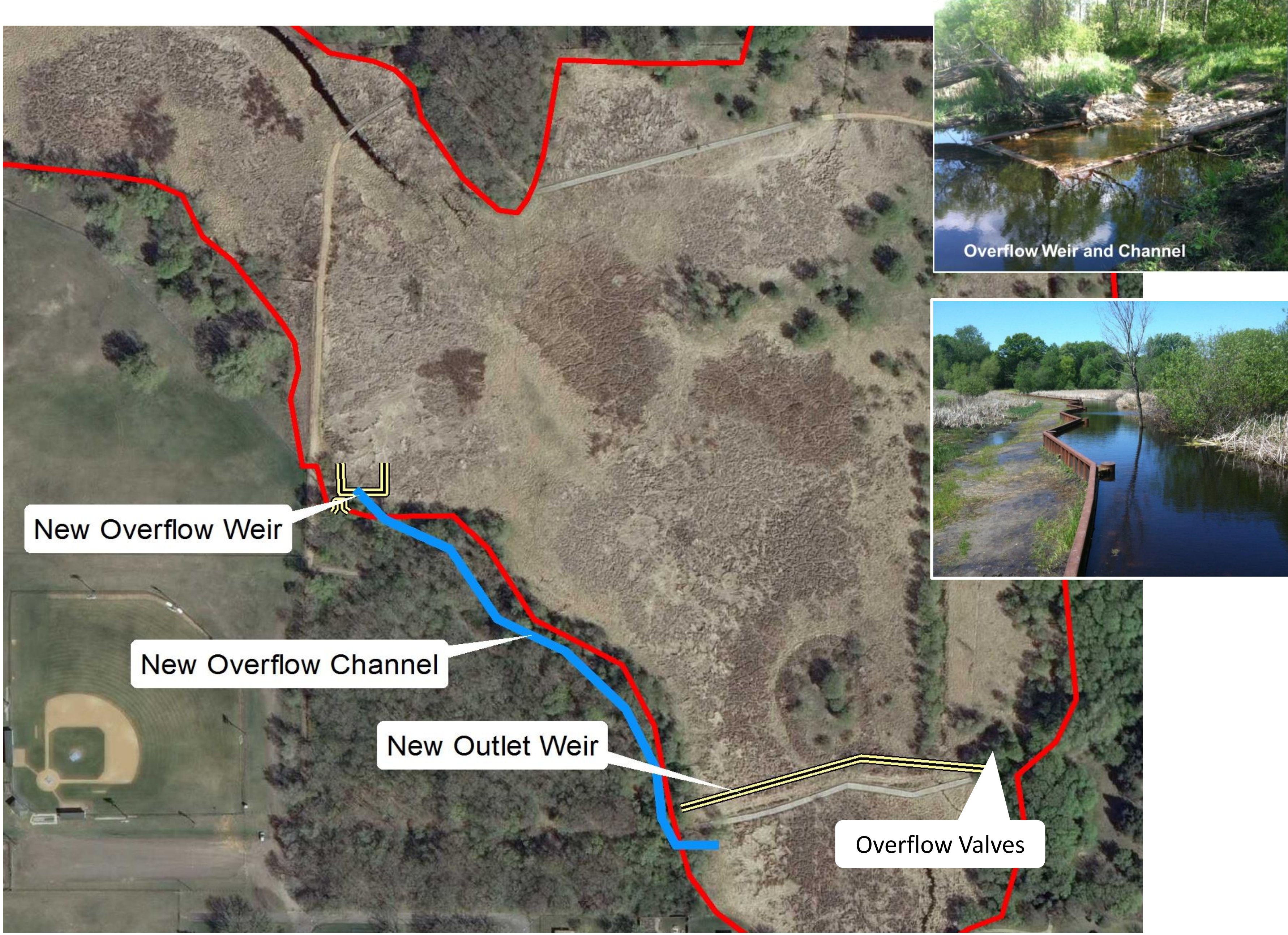
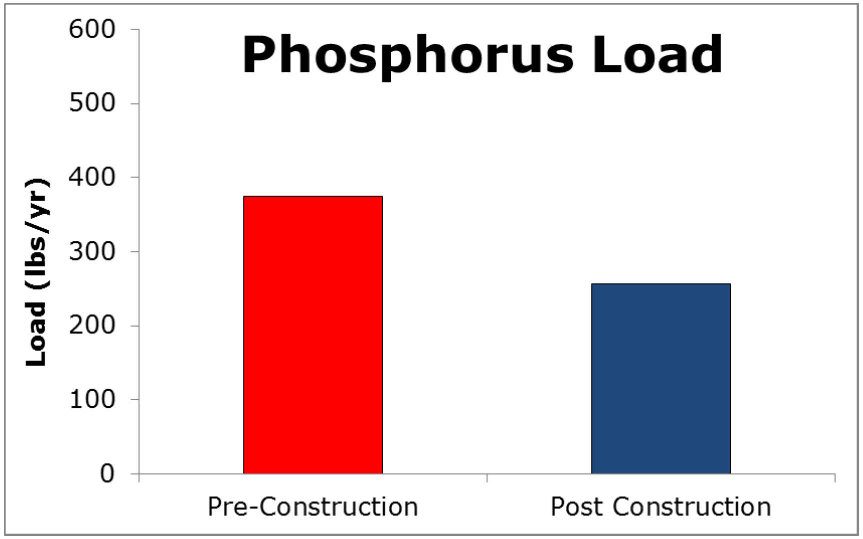
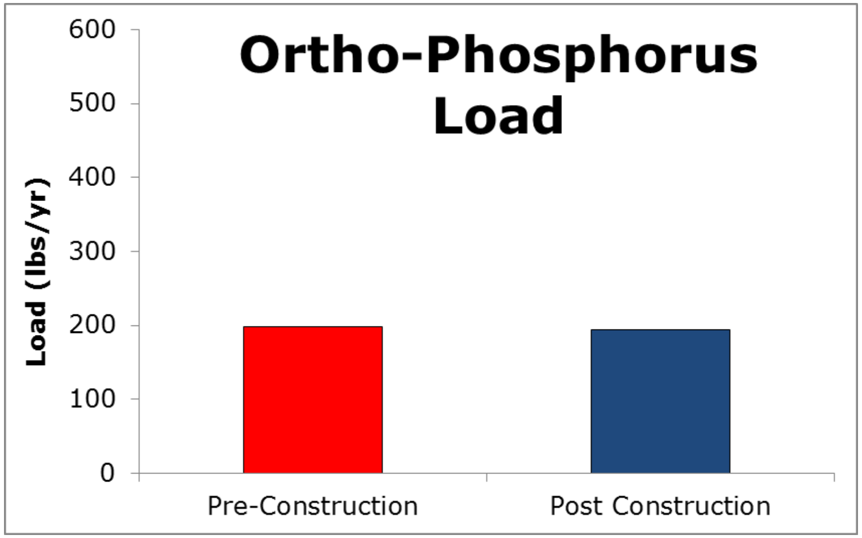

New Overflow Weir
New Overflow Channel
New Outlet Weir
Overflow Valves
Overflow Weir and Channel

POST CONSTRUCTION OUTFLOW MONITORING

Time	Annual Flow [acre-ft/yr]	TP Load [lbs/yr]	Ortho-P Load [lbs/yr]
Pre-Construction	501	374	198
Post Construction	366	257	194
Reduction	135	**118**	4

****TP Reduction Goal = 300 lbs/yr**





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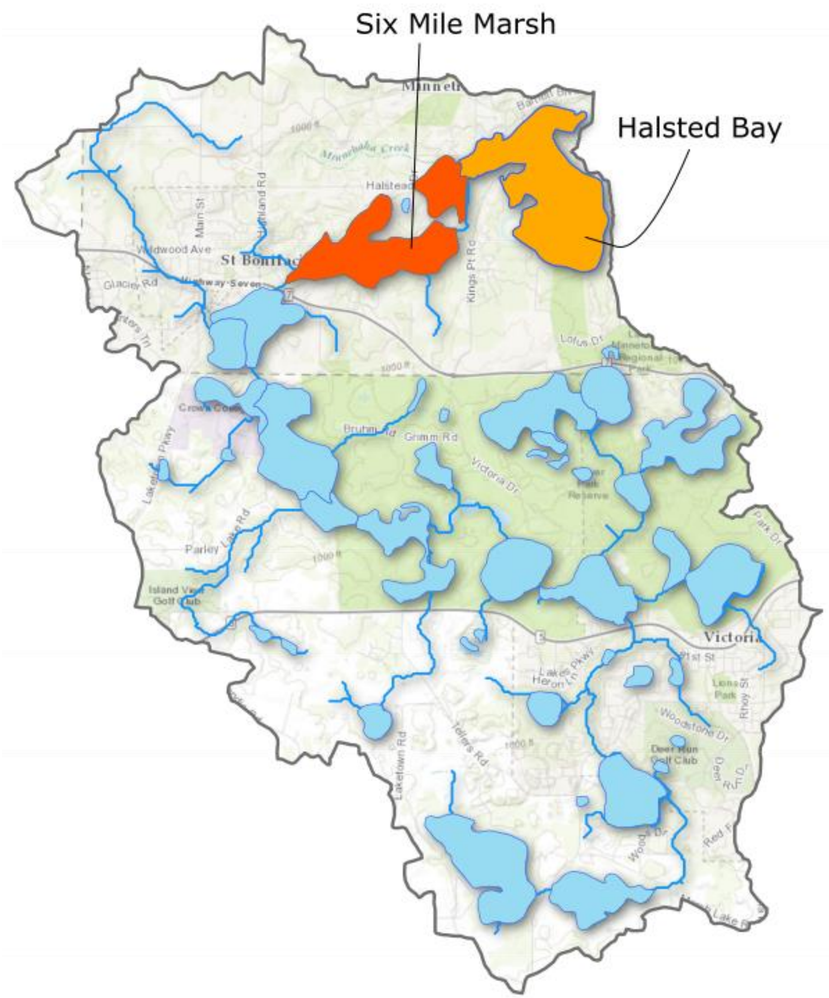
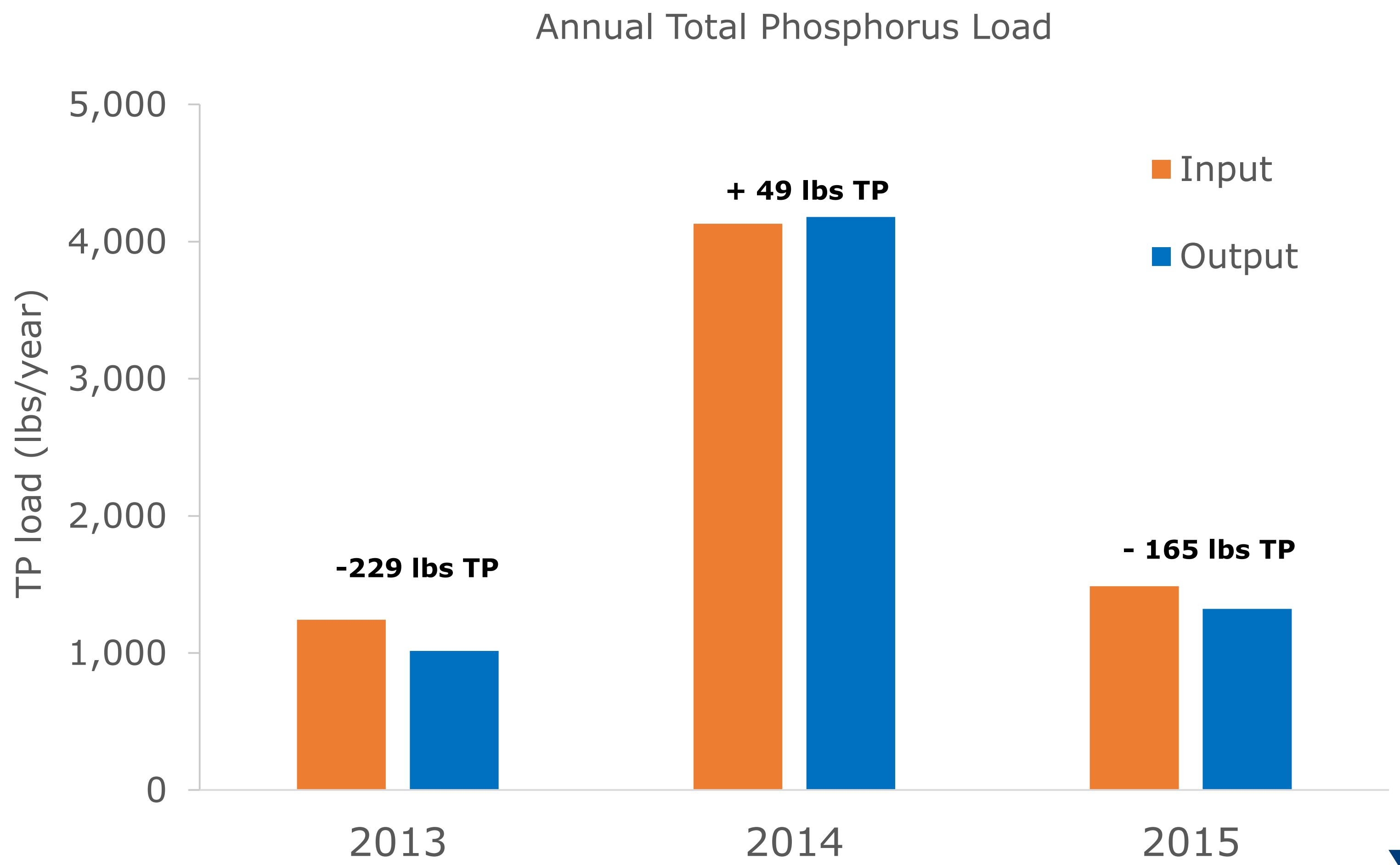
SIX MILE MARSH AND SIX MILE CREEK

- Six Mile Marsh is a ditched wetland that lies between the headwaters of Minnehaha Creek and Halsted Bay
- Six Mile Marsh was anecdotally identified as a potential source of phosphorus in 2013
    - Little data to support position



SIX MILE MARSH RESULTS



- Six Mile Marsh is removing 115 pounds of TP per year
- Analysis seems to confirm that wetlands improve water quality

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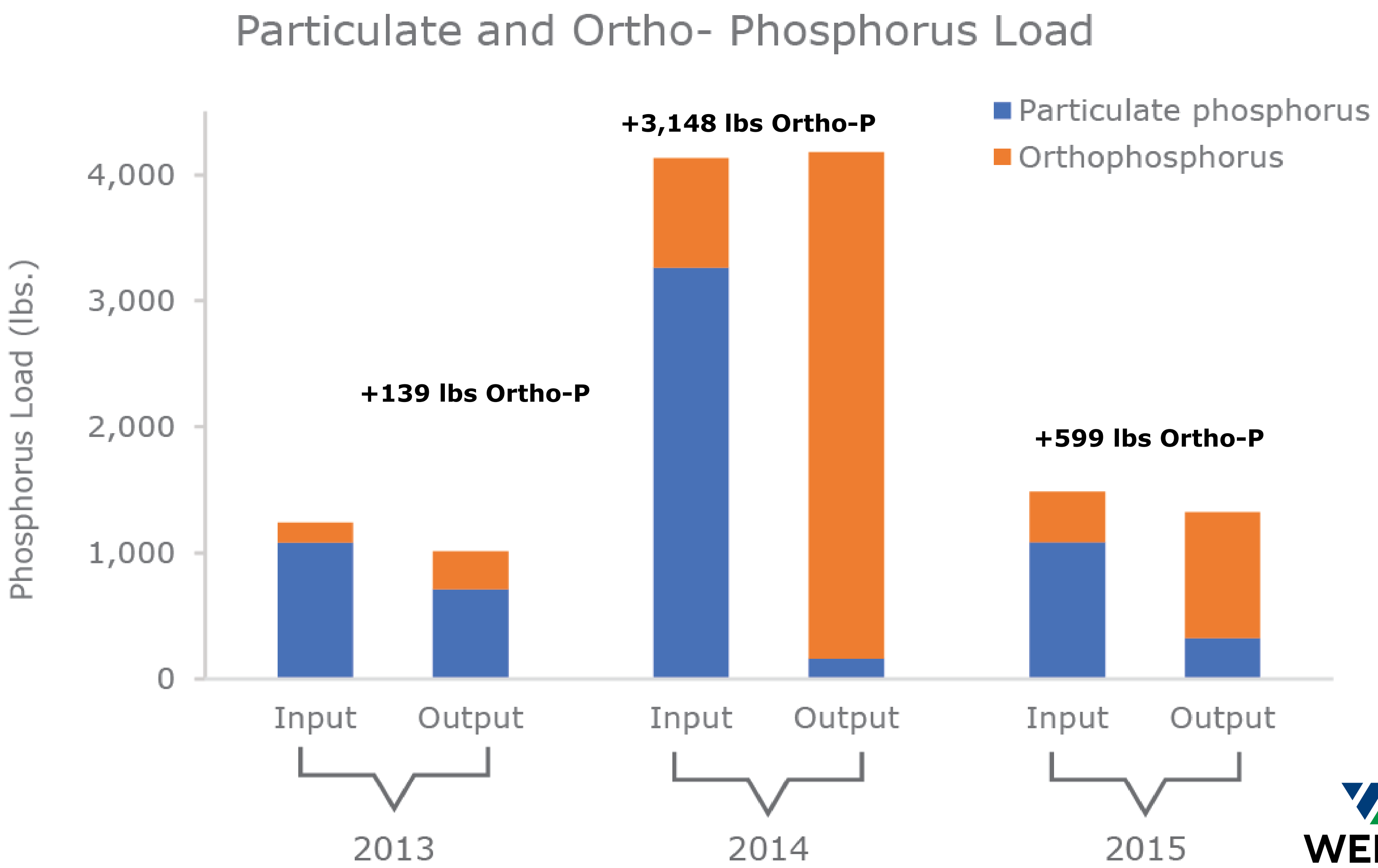
PARTICULATE AND ORTHO-P ANALYSIS



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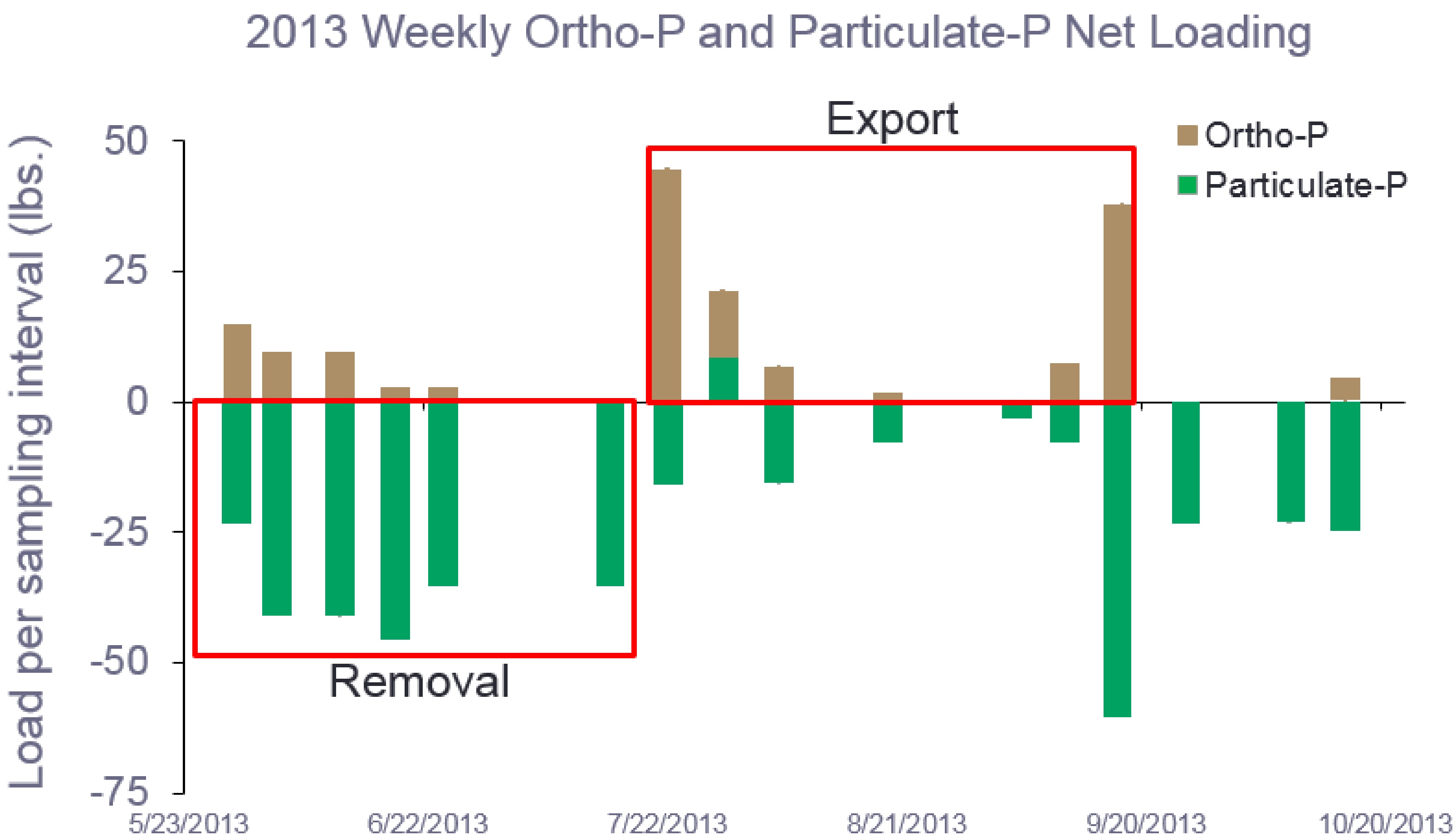

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The particulate P settles in the spring and ortho-P is released primarily in the warmer months (July-September)

MANAGEMENT OF P RELEASE IN STORMWATER PONDS

Sediment Excavation and Disposal

- Increase dead storage to improve settling
- Remove high phosphorus sediments

Sediment Phosphorus Inactivation

- Aluminum, iron, lanthanum

Dissolved Oxygen Management

  - Eliminate anoxic release of sediment P

SEDIMENT REMOVAL AND DISPOSAL

Basin ID	Estimated Excavation Costs	Priority	TP Reduction	Cost per pound P removal
			(lb/yr)	$
14-43-A	$69,000	Medium	0.3	$7,667
14-34-A	$81,000	High	1.4	$1,929
24-33-A	$110,000	High	0.9	$4,074
24-33-C	$195,000	Medium	0.8	$8,125

- Excavation for improved settling efficiency
  - Increase dead storage to improve settling to remove additional particulate P
  - Excavation and disposal are typically expensive
    - Contaminated sediments must be landfilled
  - Limited by wetland regulations in stormwater wetlands

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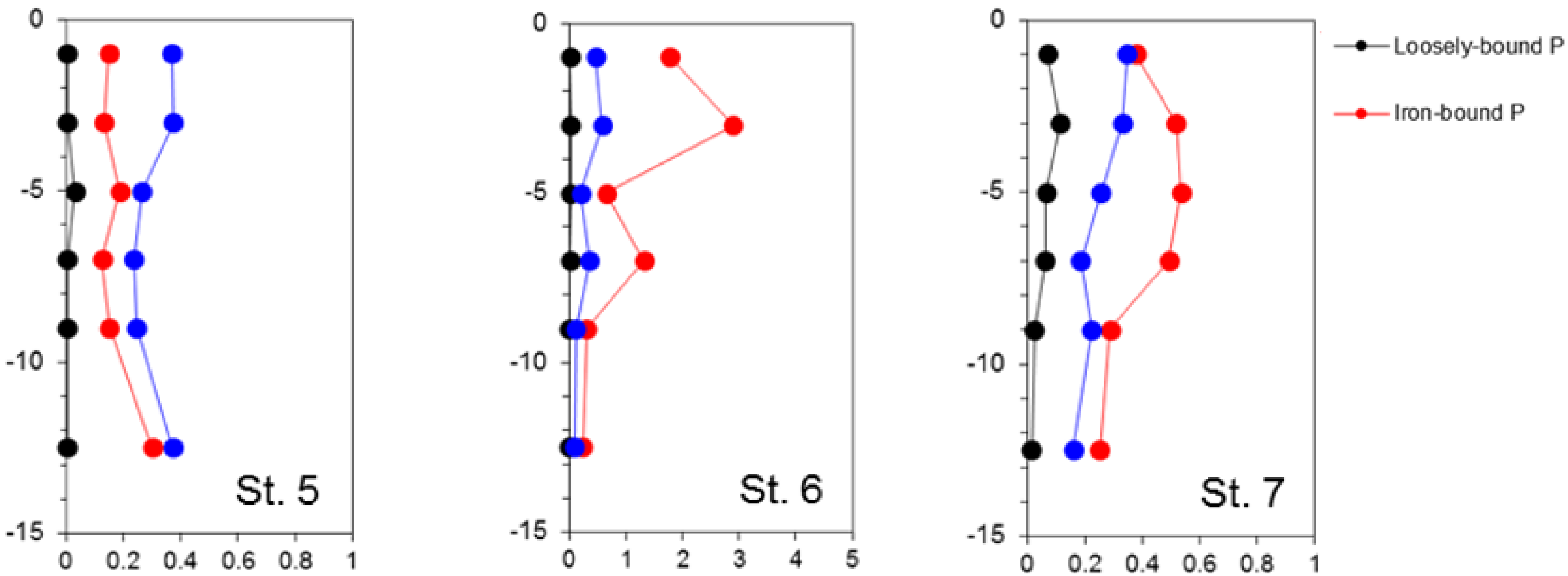
EXCAVATION FOR PHOSPHORUS CONTROL



Mobile P (mg/g)

SEDIMENT PHOSPHORUS INACTIVATION

Aluminum Sulfate (liquid)

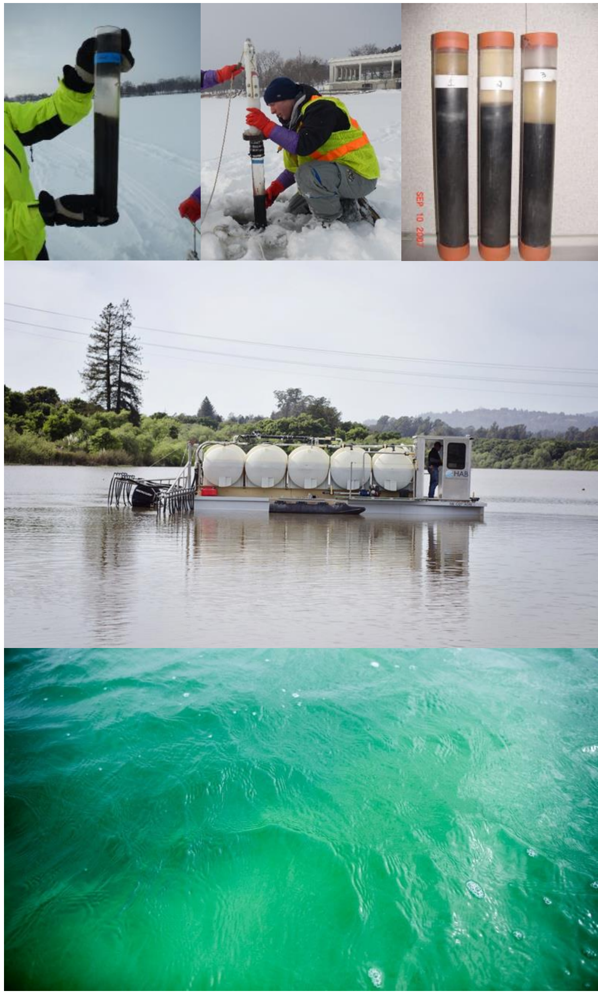
- Dissolves in water to form aluminum hydroxide and sulfate
- Aluminum hydroxide is a white solid that settles out of the water column

Permanently binds phosphorus in the sediments

Aluminum phosphate complexation ($Al(OH)_3PO_4$)

- Very stable in the environment
- Not sensitive to anoxia (low oxygen)

Alum has been used in hundreds of lakes throughout the world to reduce P cycling



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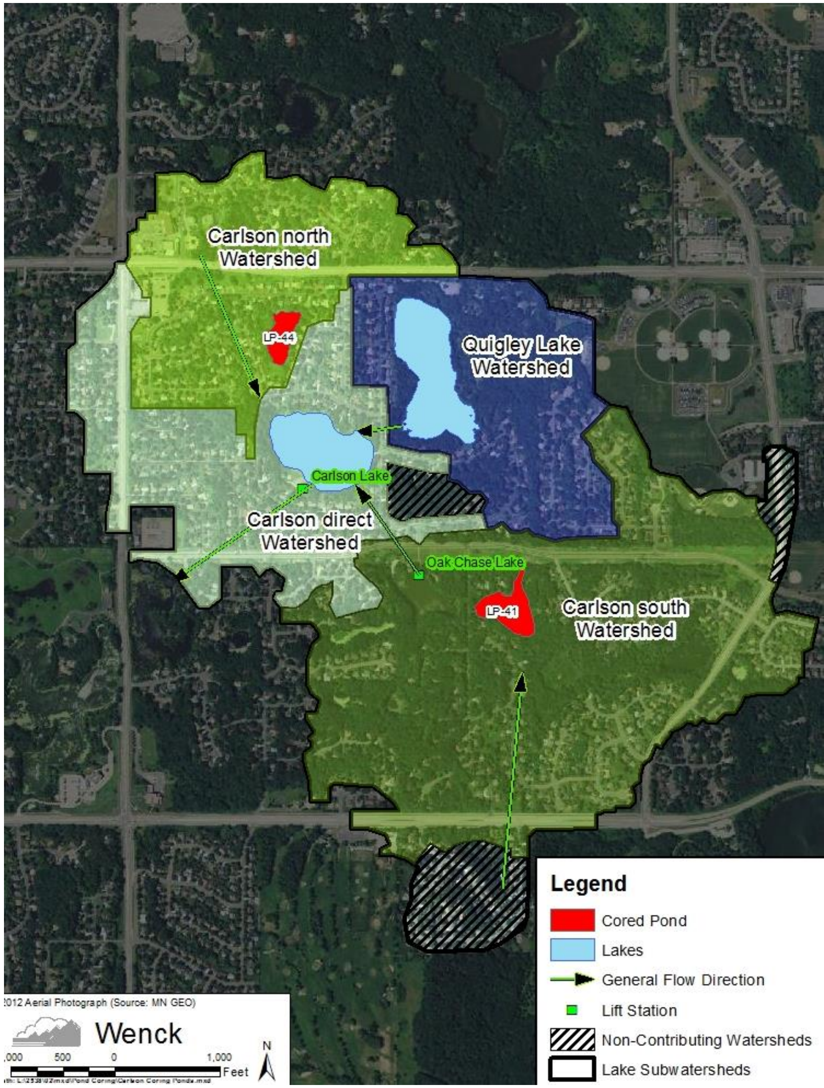
Sediment Mobile P (pounds)	1,295	227
Alum Inactivation Cost[3]	$137,000	$39,000
Alum Treatment Frequency[4] (years)	6	16
Cost ($ per treatment)	$10,000	
Cost ($ per 30 year life cycle)	$187,000	$59,000

[1] Assumes release of 5 mg/m^2/day and 45 days anoxia
[2] 2008-2012 average using PondNet
[3] Based on inactivating 90% of mobile P in top 5 cm
[4] Assumes 43% and 23% of settled TP is mobile P respectively and minimum dose of 50 g Al/m^2



IRON ENHANCED SAND FILTERS

SUMMARY

Stormwater ponds and wetlands are potential sources of phosphorus

- Offsetting watershed phosphorus BMPs
- Transformers of P: settling particulate P, releasing dissolved P
- Release is driven by anoxia and sediment mobile phosphorus

Quantifying watershed wide sediment phosphorus pools and dissolved oxygen dynamics is critical

- Good sediment and DO data is invaluable
- Mobile phosphorus in pond and wetland sediments
- Anoxia as the driver of P release

Standard maintenance techniques are not cost effective or feasible in most cases

- Sediment removal is expensive, limited by wetland regulations and does not address P release

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QUESTIONS?

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