

Long-Term Ecological Responses to Alum Treatment in Spring Lake, Michigan

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Internal vs. External Phosphorus Loads

External Phosphorus Loading:

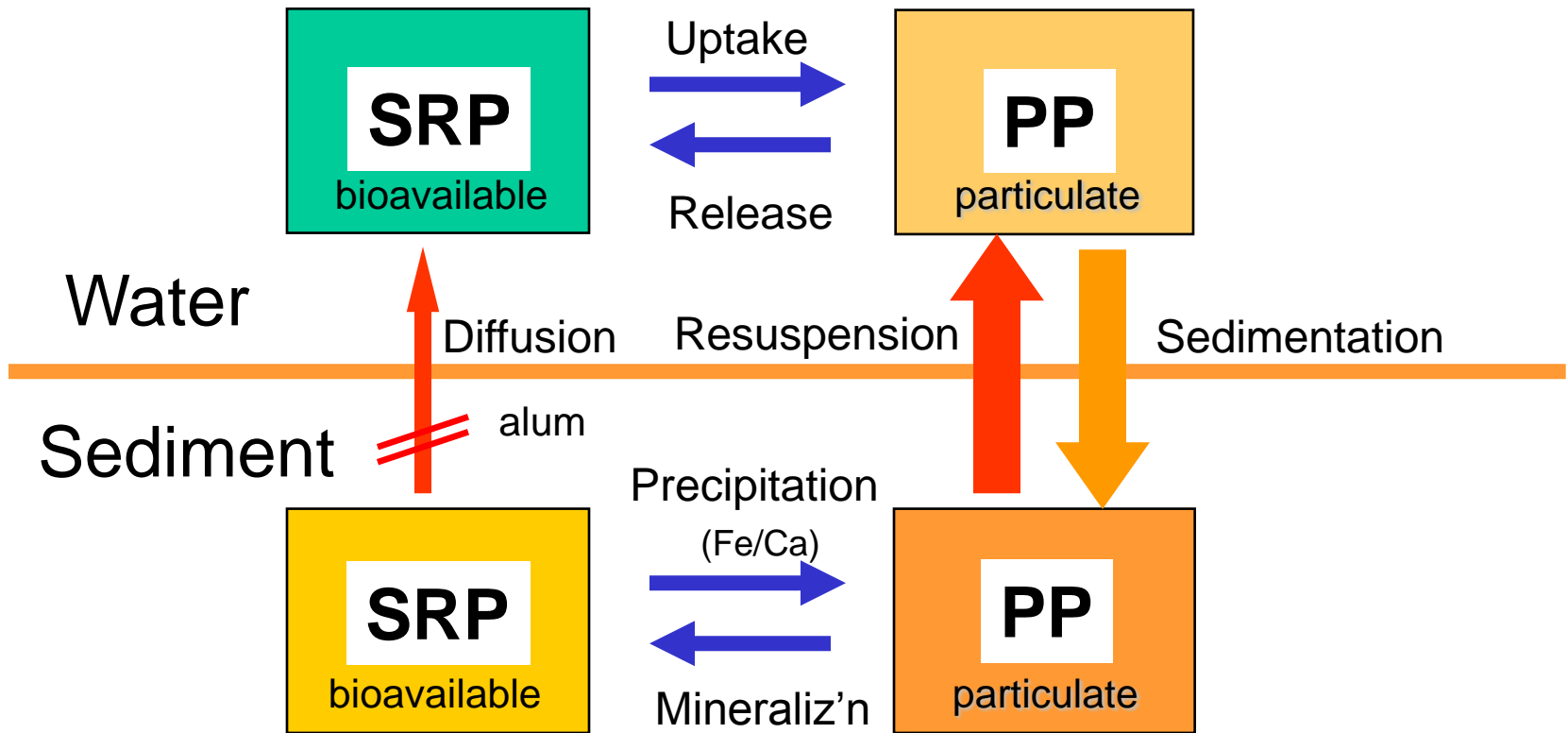
Phosphorus entering surface waters that originates outside the water body (watershed, atmosphere)

Internal Phosphorus Loading:

Release of P from sediments

- 1) diffusion of soluble phosphorus from sediments during periods of anoxia
- 2) resuspension-driven processes whereby soluble P is desorbed from particulate matter or released from the pore water

Sediment-Water Interactions



Alum as a Management Tool

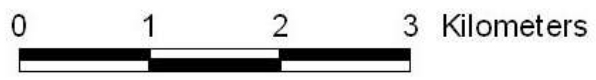
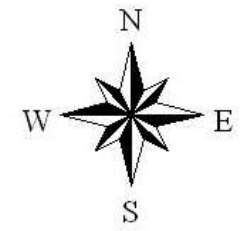
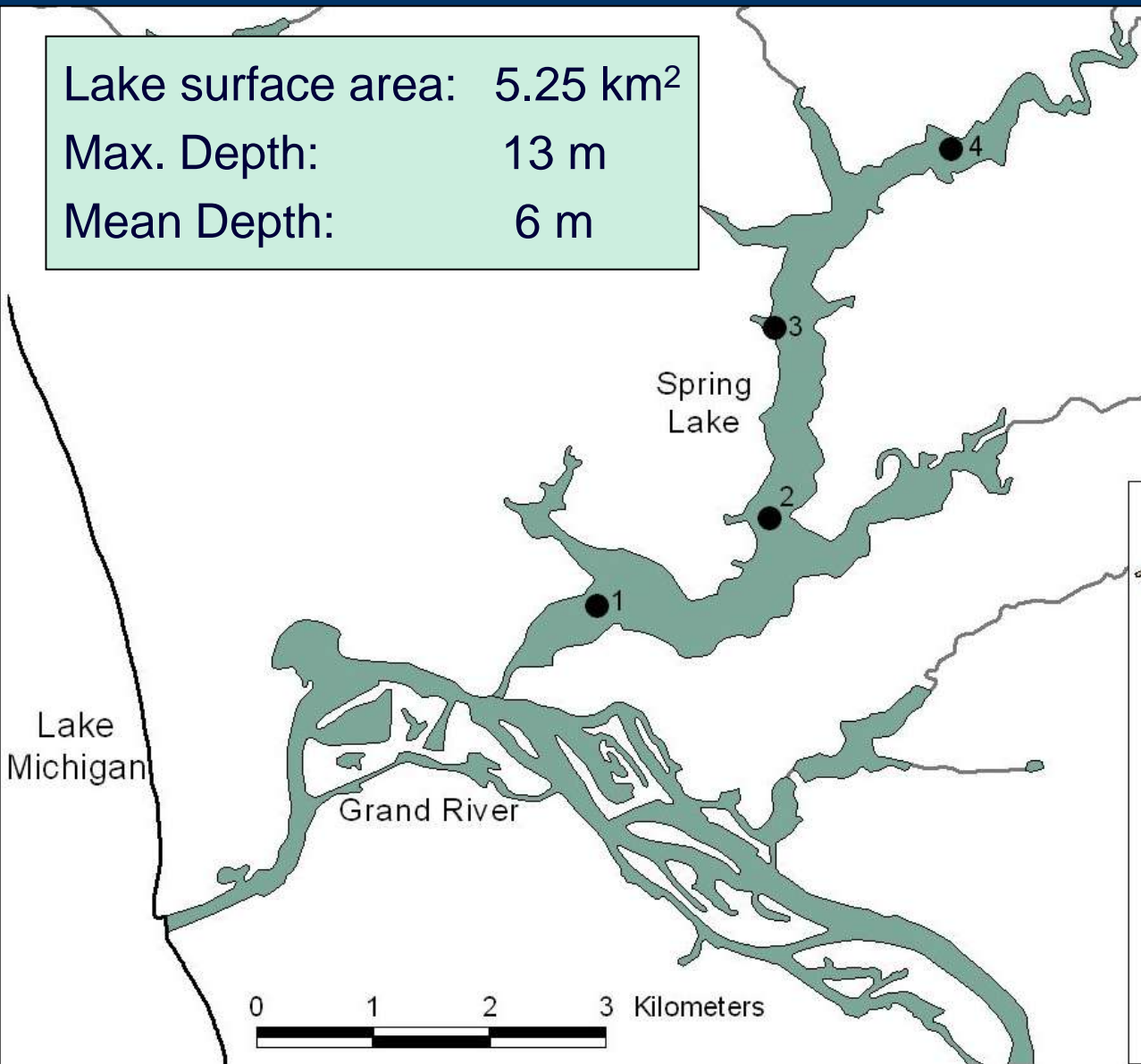
Highly effective P inactivation

- Formation of insoluble precipitate
- Al(OH)₃ floc adsorbs P

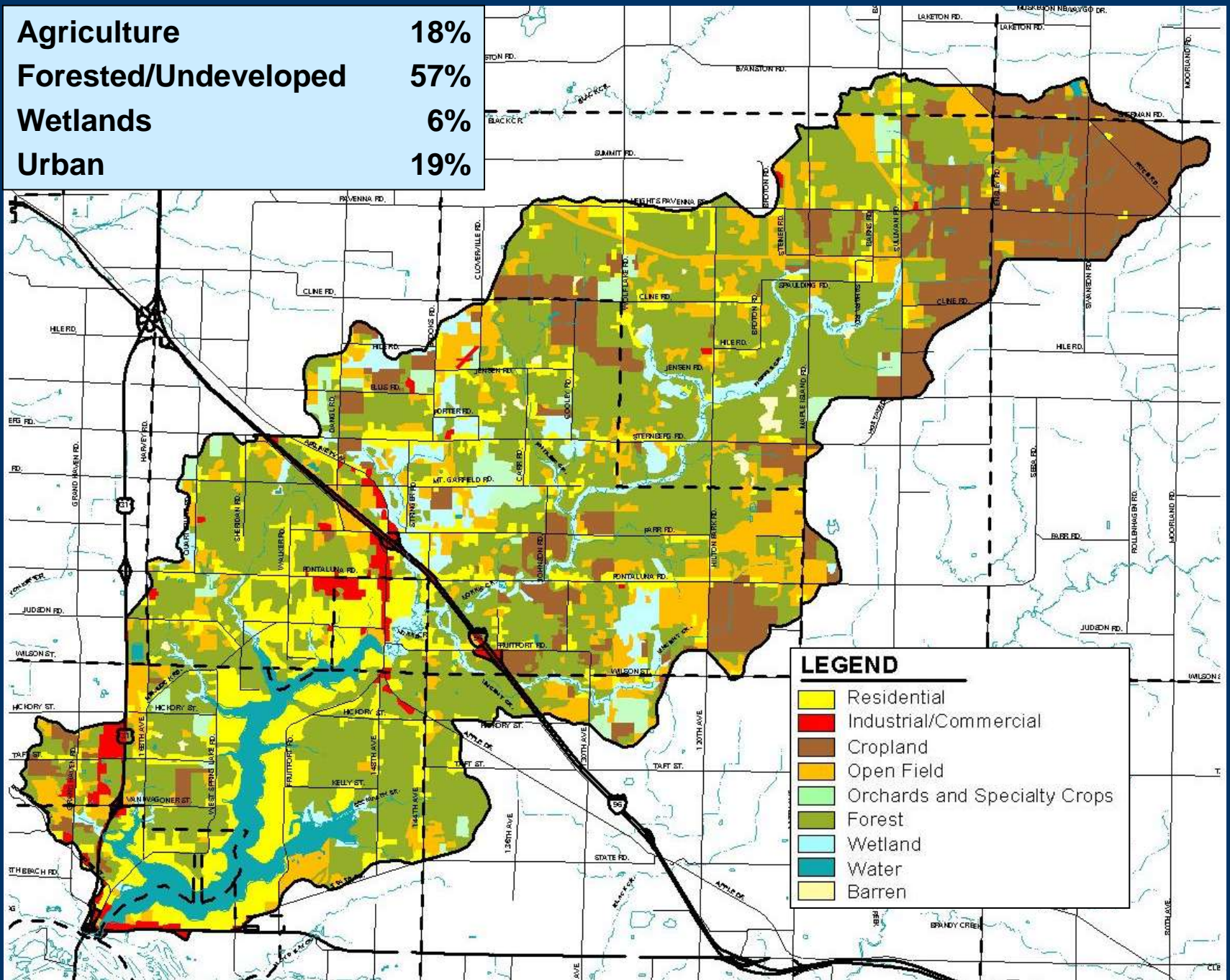
Longevity of treatment varies

- 4-20 years?
- Simultaneous control of external loading is essential

Lake surface area: 5.25 km²
Max. Depth: 13 m
Mean Depth: 6 m



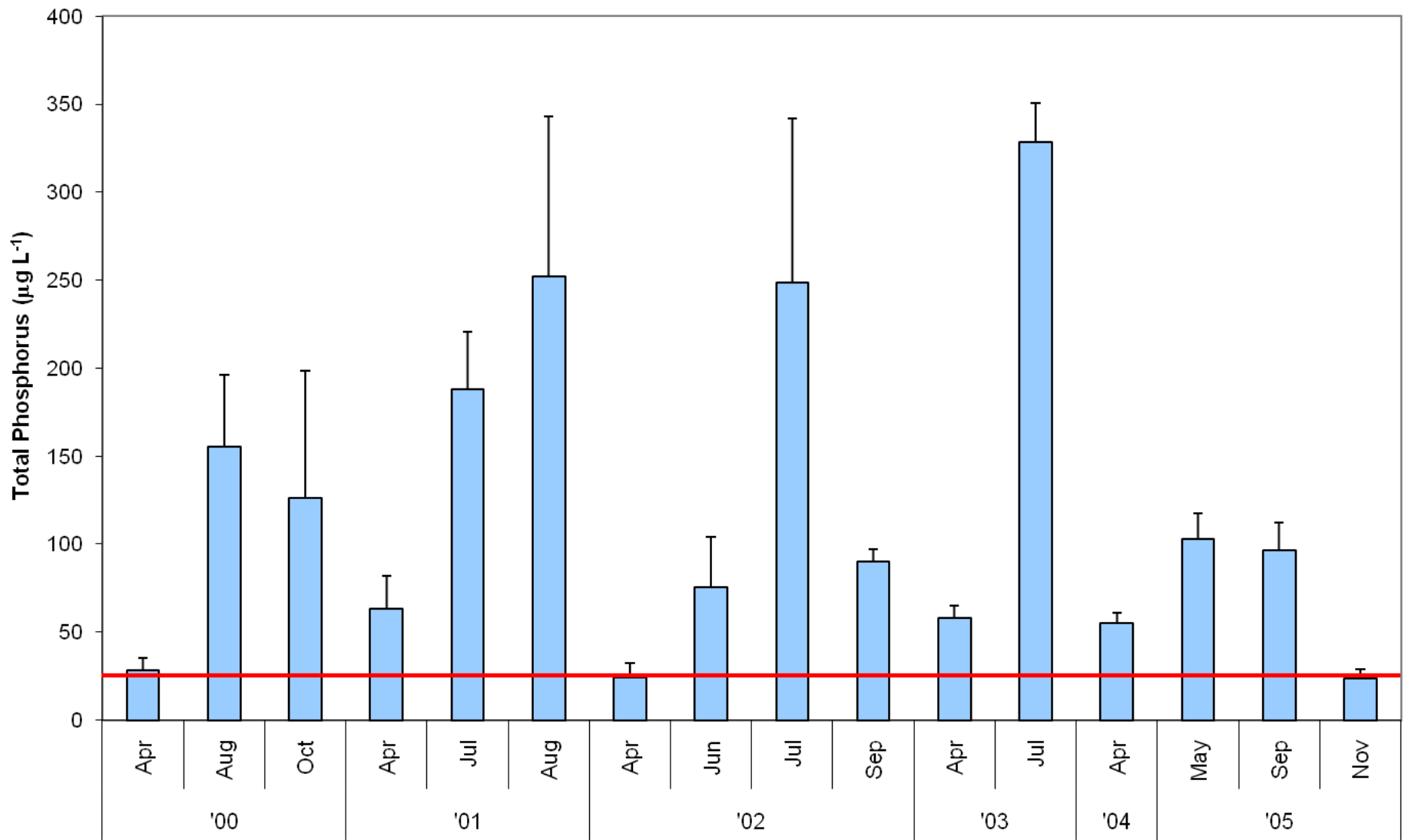
Agriculture	18%
Forested/Undeveloped	57%
Wetlands	6%
Urban	19%



LEGEND

	Residential
	Industrial/Commercial
	Cropland
	Open Field
	Orchards and Specialty Crops
	Forest
	Wetland
	Water
	Barren

Total Phosphorus: Spring Lake



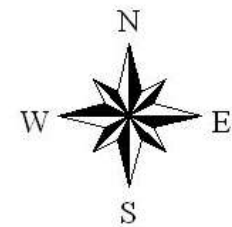
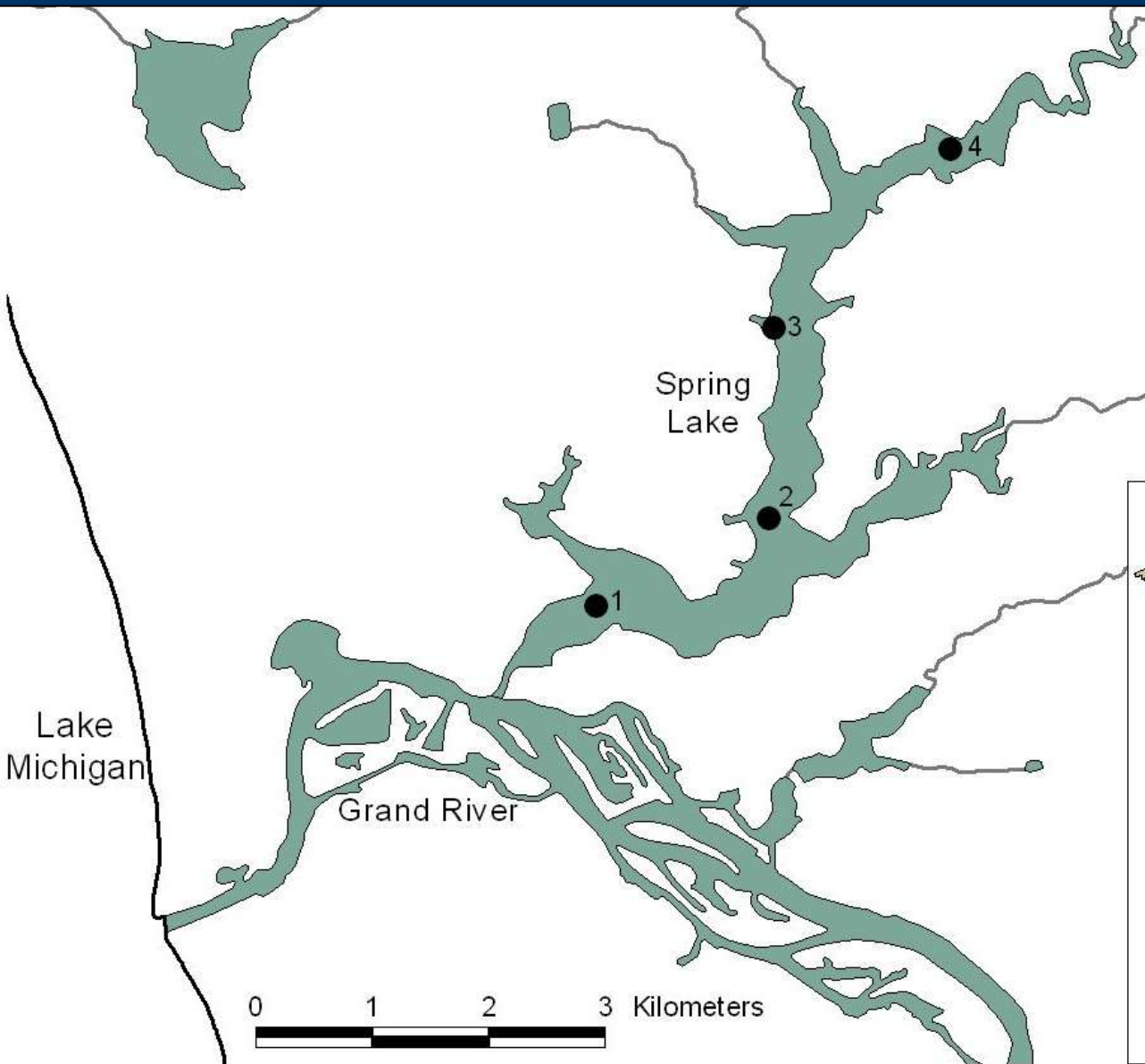
Source: Progressive AE

Objectives:

Experiment 1: 2003-2004

Before field application of alum

- Compare internal vs external P loading rates
- Determine the effectiveness of alum in reducing internal P loading
- Based on lab studies, assess whole-lake alum application

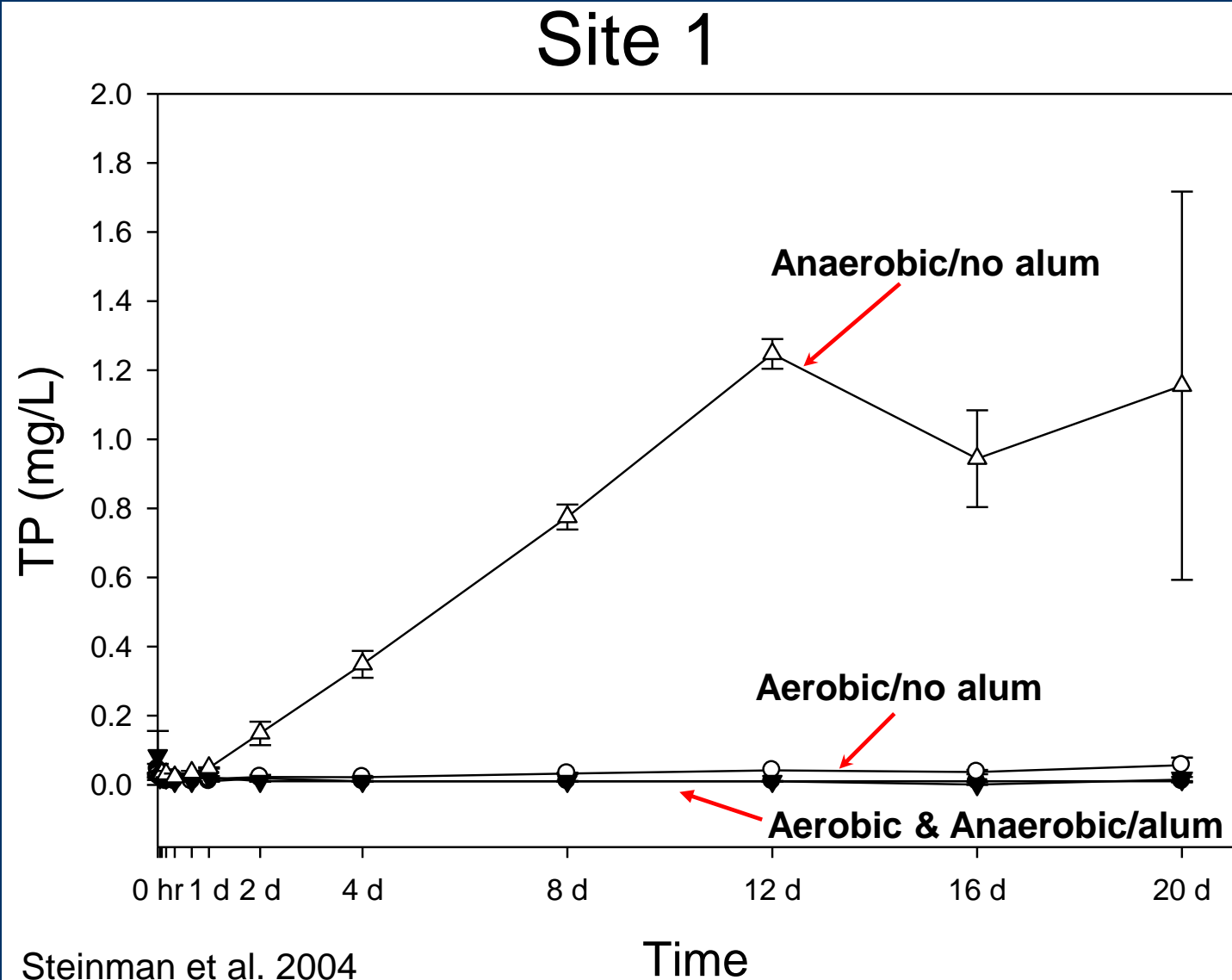




		Alum	No Alum
Redox	N ₂ (anaerobic)	Alum-N ₂	No Alum-N ₂
	O ₂ (aerobic)	Alum-O ₂	No Alum-O ₂



TP Release from Sediment Cores

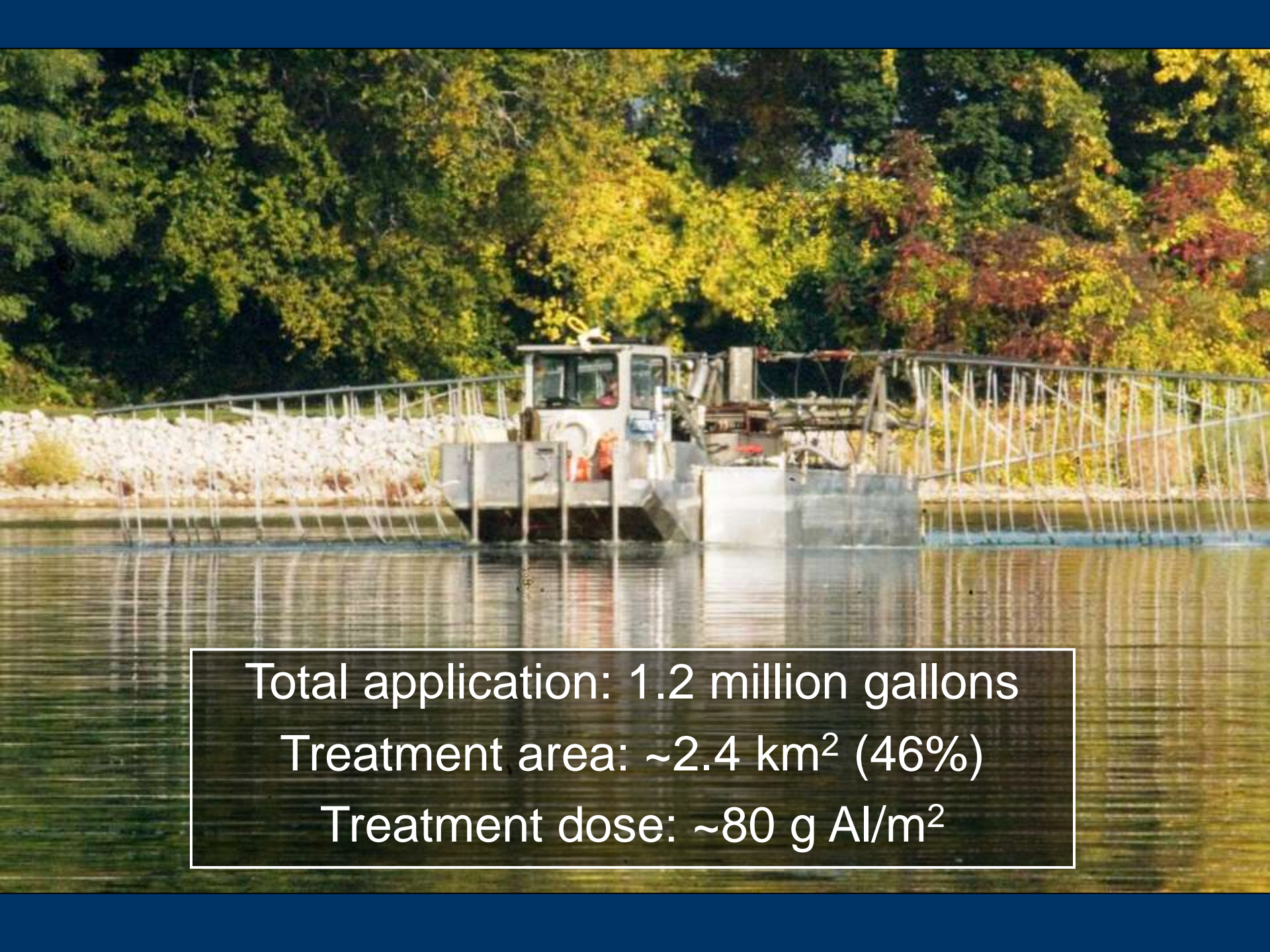


TP Load Estimates

External Load*	2.2-4.7 tons yr ⁻¹
Mean Internal Load**	2.7-6.4 tons yr ⁻¹
Internal:Total Load **	55-67%

*Lauber 1999

**Steinman et al. 2004



Total application: 1.2 million gallons

Treatment area: $\sim 2.4 \text{ km}^2$ (46%)

Treatment dose: $\sim 80 \text{ g Al/m}^2$

Objectives:

Experiment 2: 2006

1 year after alum treatment

- Measure short-term internal P release rates
- Evaluate the short-term ecological effects

Experiment 3: 2010

5 years after alum treatment

- Measure long-term internal P release rates
- Evaluate the long-term ecological effects

Maximum TP Release Rates (mg P m⁻² d⁻¹) - Anaerobic Cores -

Site	Pre-alum*	1 y after**	5 y after
1	29.54		
2	17.33		
3	13.33		
4	11.67		

* Steinman et al. 2004

** Steinman and Ogdahl 2008

Maximum TP Release Rates (mg P m⁻² d⁻¹) - Anaerobic Cores -

Site	Pre-alum*	1 y after**	5 y after
1	29.54	0.33	
2	17.33	0.88	
3	13.33	0.49	
4	11.67	-0.05	

* Steinman et al. 2004

** Steinman and Ogdahl 2008

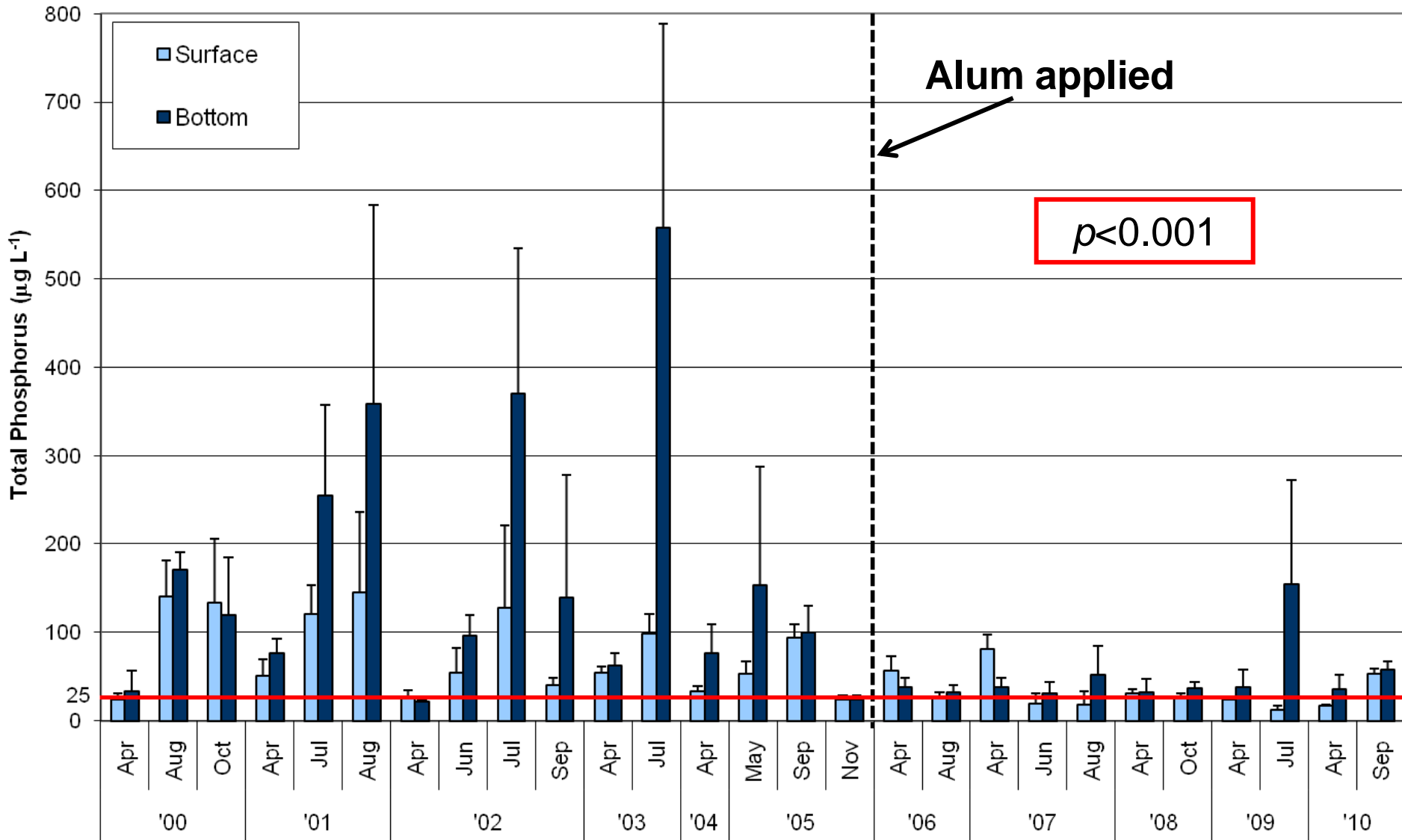
Maximum TP Release Rates (mg P m⁻² d⁻¹) - Anaerobic Cores -

Site	Pre-alum*	1 y after**	5 y after
1	29.54	0.33	2.81
2	17.33	0.88	1.68
3	13.33	0.49	2.33
4	11.67	-0.05	2.25

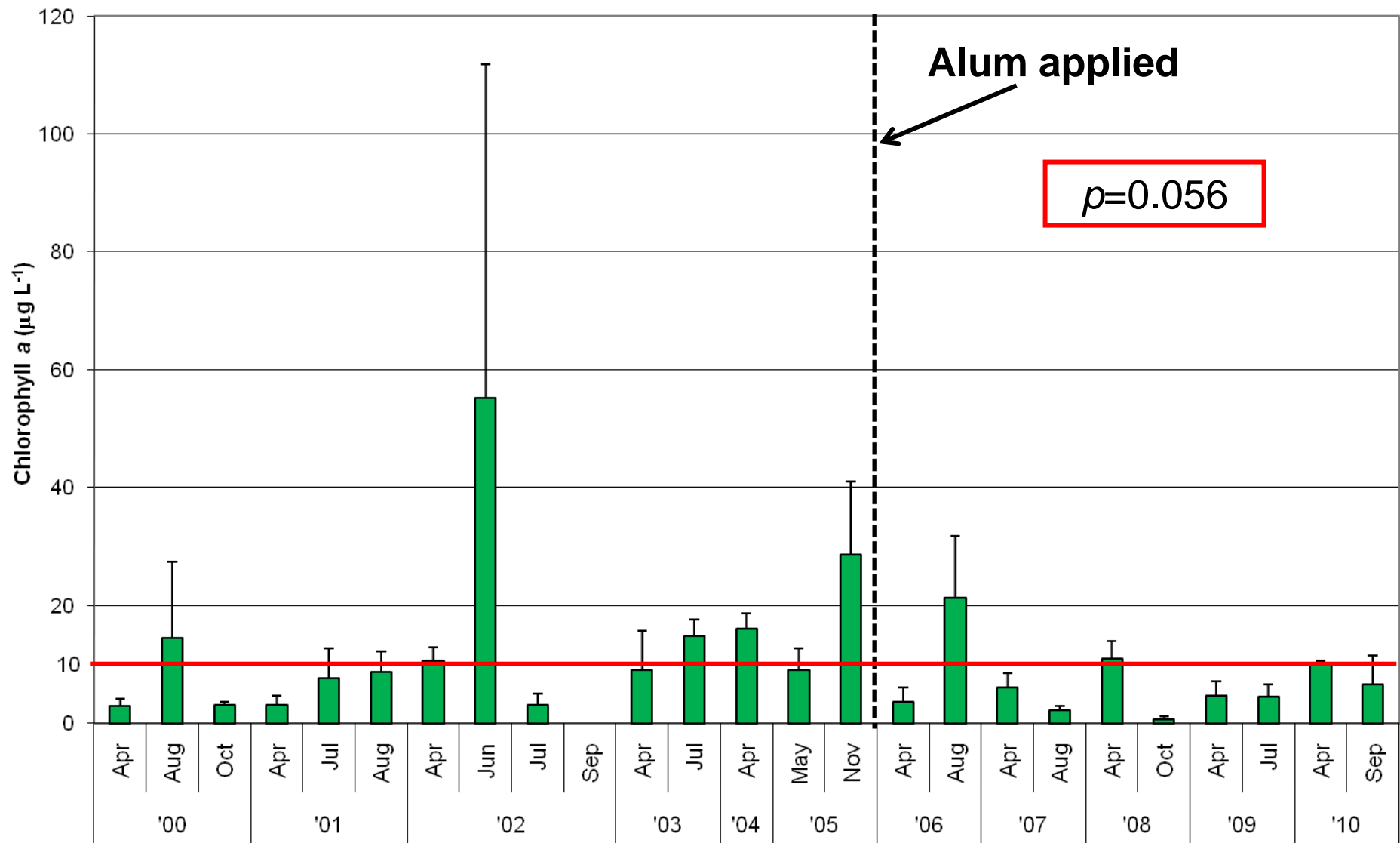
* Steinman et al. 2004

** Steinman and Ogdahl 2008

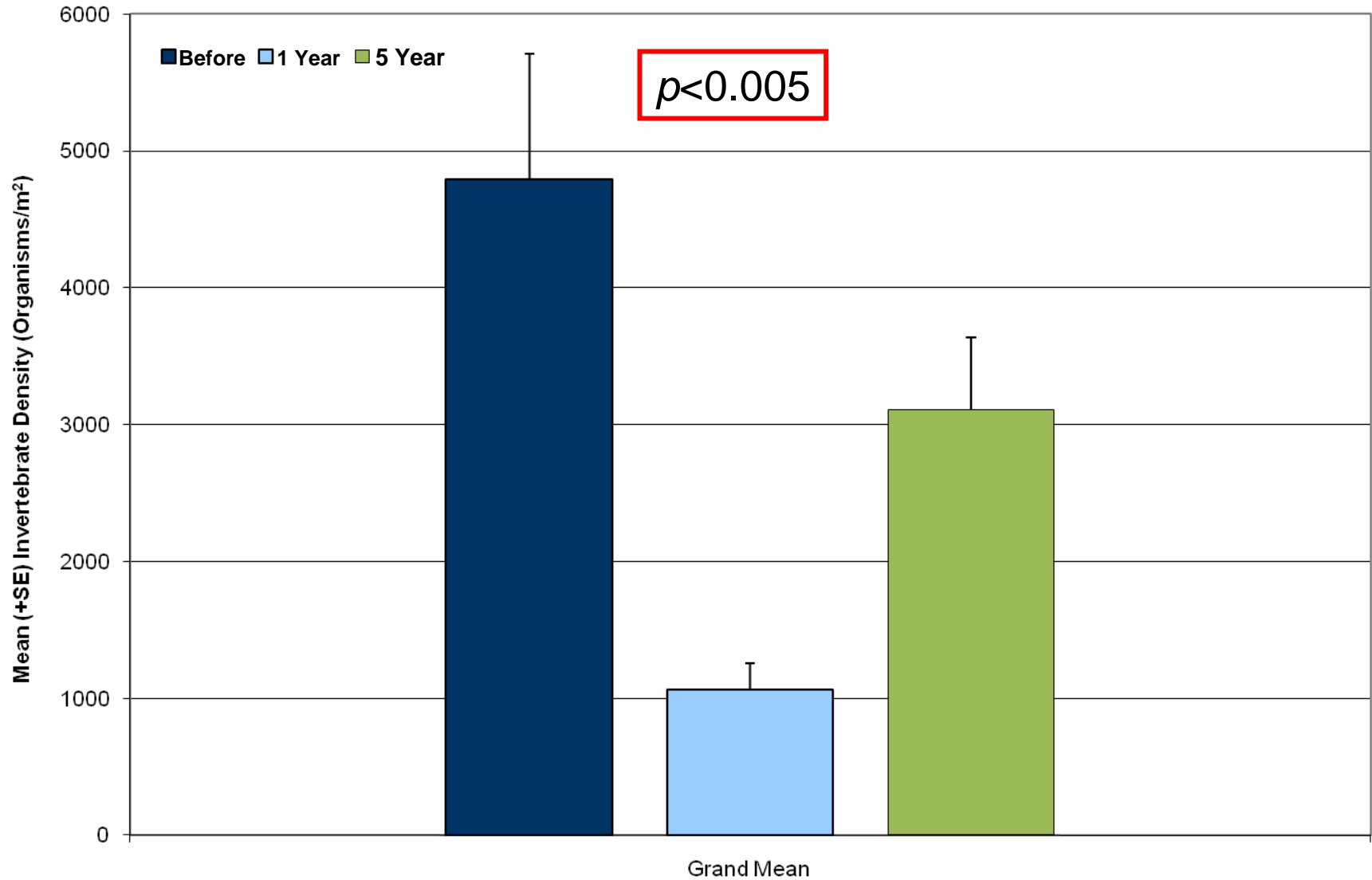
Total P: Before vs. After Alum



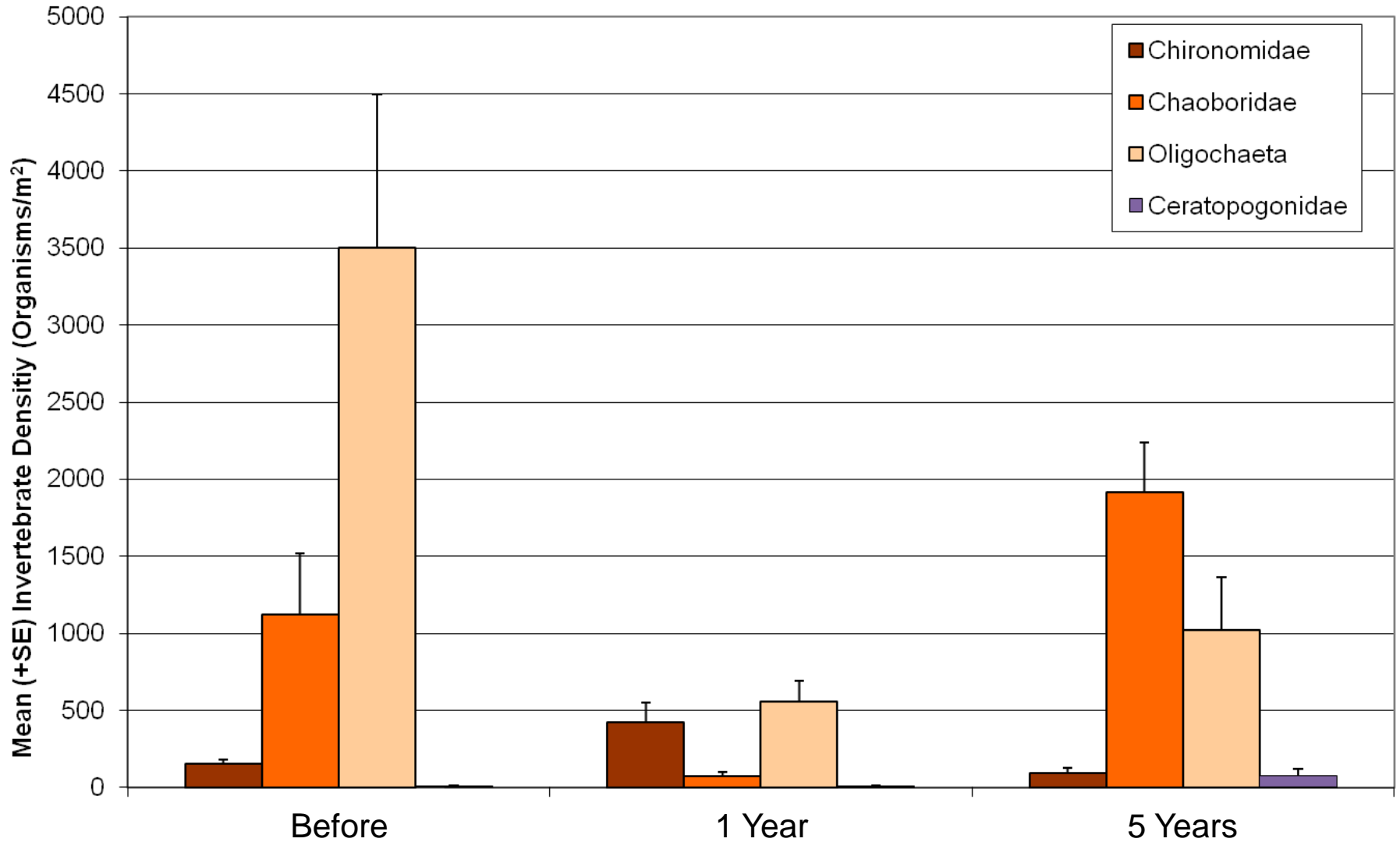
Chlorophyll a: Before vs. After Alum



Invertebrate Density: Before vs. After Alum



Invertebrate Community Composition



Conclusions

- The invertebrate community has recovered from the decline observed 1 year after treatment
- Alum continues to be highly effective at reducing sediment P release rates, but its efficacy is beginning to decline
- Water column P remains sufficiently high to fuel algal biomass at or above eutrophic levels
- Control of external sources of P is essential for further improvements in the lake and continued success of the alum treatment

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