Green Lake Alum Treatment – Dose for a Decade

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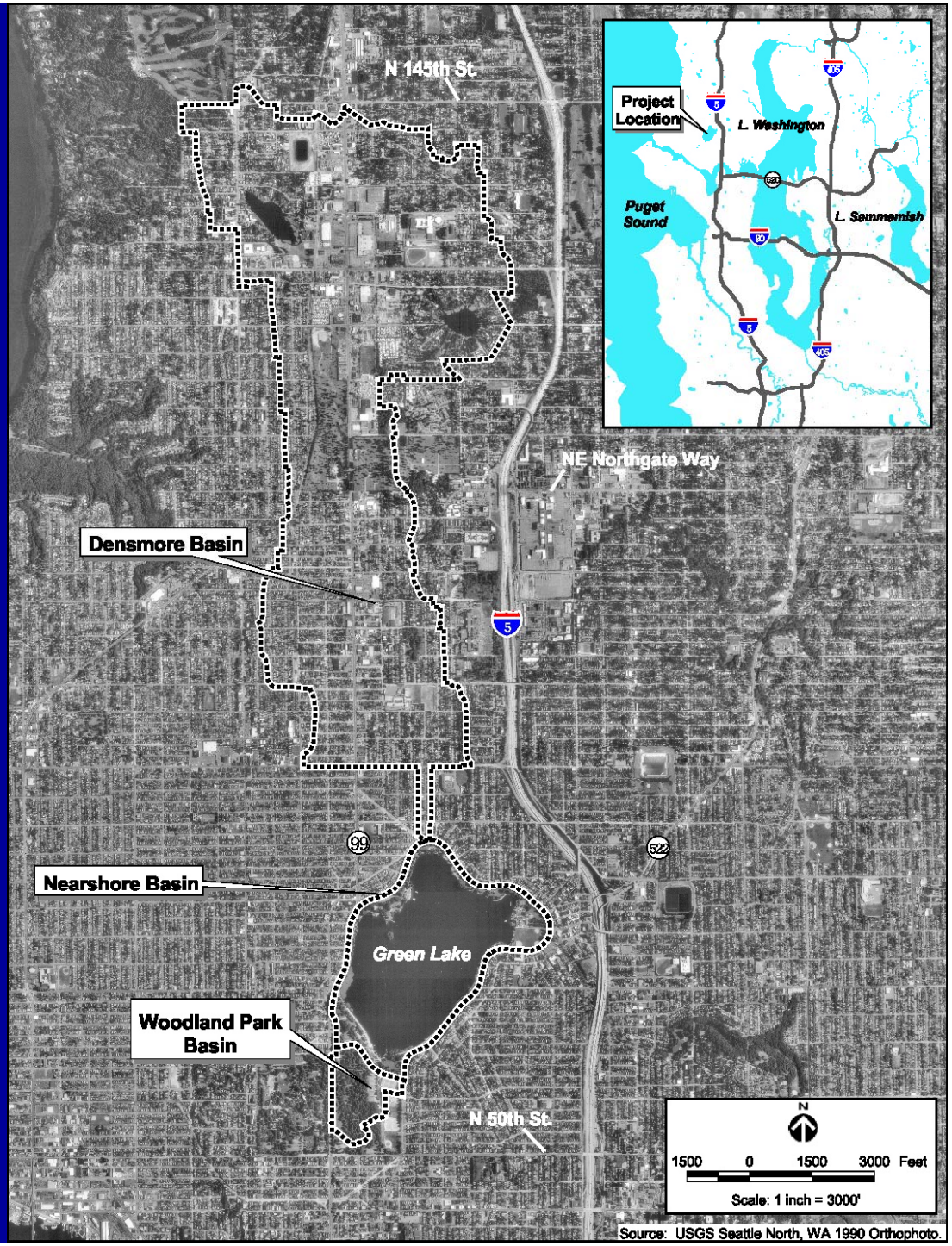
Presentation Outline

- Watershed and lake characteristics
- Historical lake problems
- Early solutions, studies, and plans
- 1991 alum treatment
- 2004 alum treatment
- Alum treatment effectiveness
- Sediment and stormwater studies

Watershed

- Urban land use
- Drainage is diverted to combined sewer
- < 50 percent of stormwater is from the Densmore basin



Lake

- 104 ha (259 acres)
- 4.5 km shoreline
- 3.9 m mean depth
- 9.1 m max. depth
- 2.6 to 5.0 years residence time

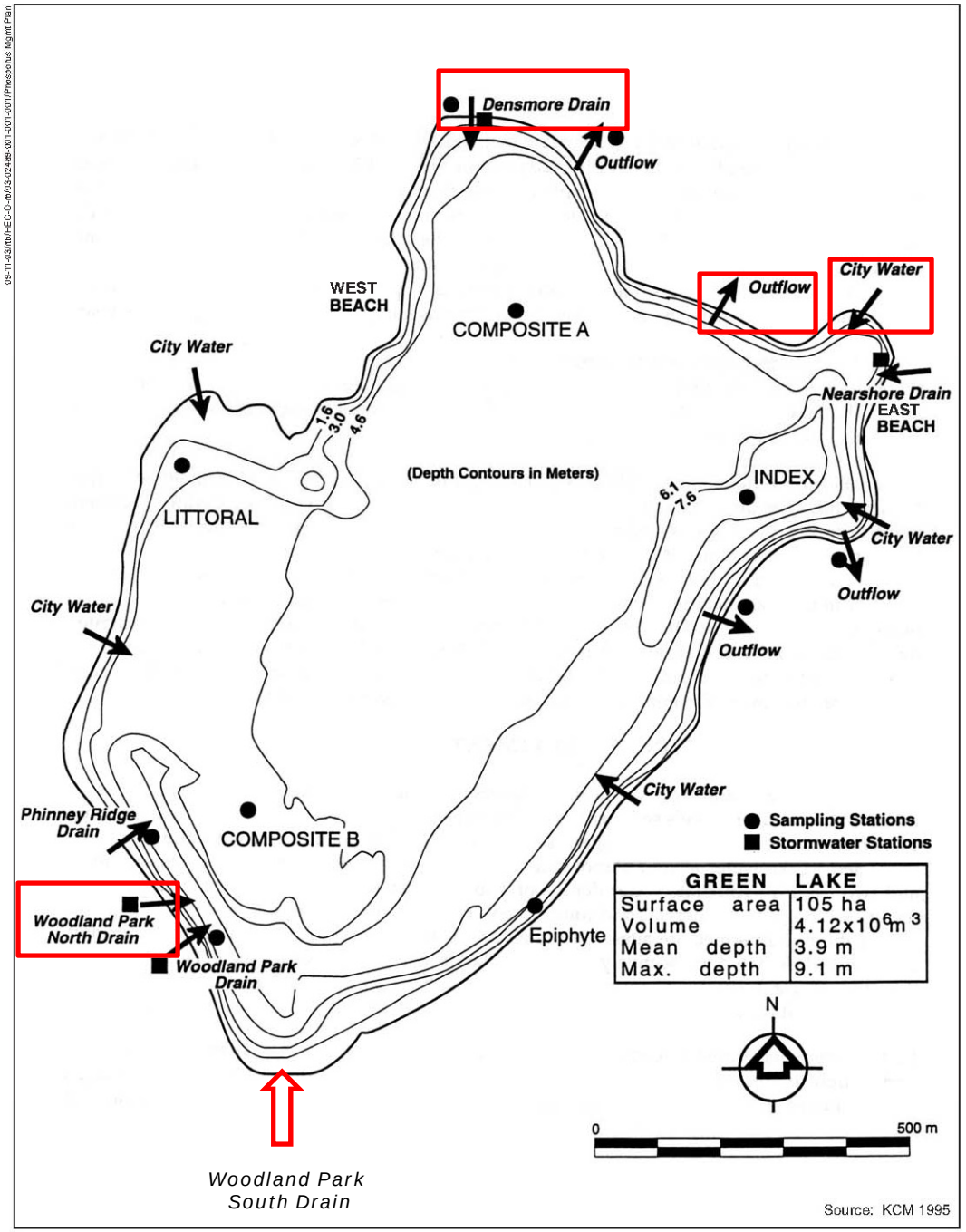


Figure 2. Locations of historical sampling stations in Green Lake.

Lake Problems

- Water quality complaints since 1916
- Cyanobacteria bloom odors and toxicity
- High internal phosphorus load
- High waterfowl phosphorus load
- Lack of natural drainage
- Eurasian watermilfoil invasion in 1980s

1960s Solutions

- Dilute with surplus city water
- Dredge nutrient-rich sediments

1981 Diagnostic Study

- Phosphorus is the growth-limiting nutrient
- Internal phosphorus loading accounts for 21% of the annual P load and 88% of the summer P load

1980s Plans

- Dilute with ground water (high P)
- Dilute with Lake Washington (no permit)
- Build a treatment plant (too expensive)
- Treat with aluminum sulfate (alum)

1990 Restoration Program Goals

- Summer total phosphorus < 30 µg/L (revised to < 25 µg/L)
- Summer Secchi depth > 2.5 meters (> 8.2 feet)

1990 Restoration Program

- Buffered alum treatment
- Stormwater treatment and diversion
- Dilution with surplus city water
- Harvest Eurasian watermilfoil
- Control Canada geese
- Public education and lake monitoring
- (Plant 150 tiger musky in 2000)
- (Plant 777 grass carp in 2001)

1991 Alum Treatment

- Applied liquid alum and sodium aluminate buffer in 2:1 ratio
- Calculated dose by alkalinity method to maintain pH above 6.0
- Recommended dose of 13.7 mg Al/L
- Applied 8.6 mg Al/L dose

1991 Treatment Results

- **Water quality improved and met goals for 3 to 5 years**
- **Eurasian watermilfoil growth continued**

Cyanobacteria Blooms Returned

Green Lake Summer 1999:

0.6 – 32 ug/L microcystin
by Seattle University

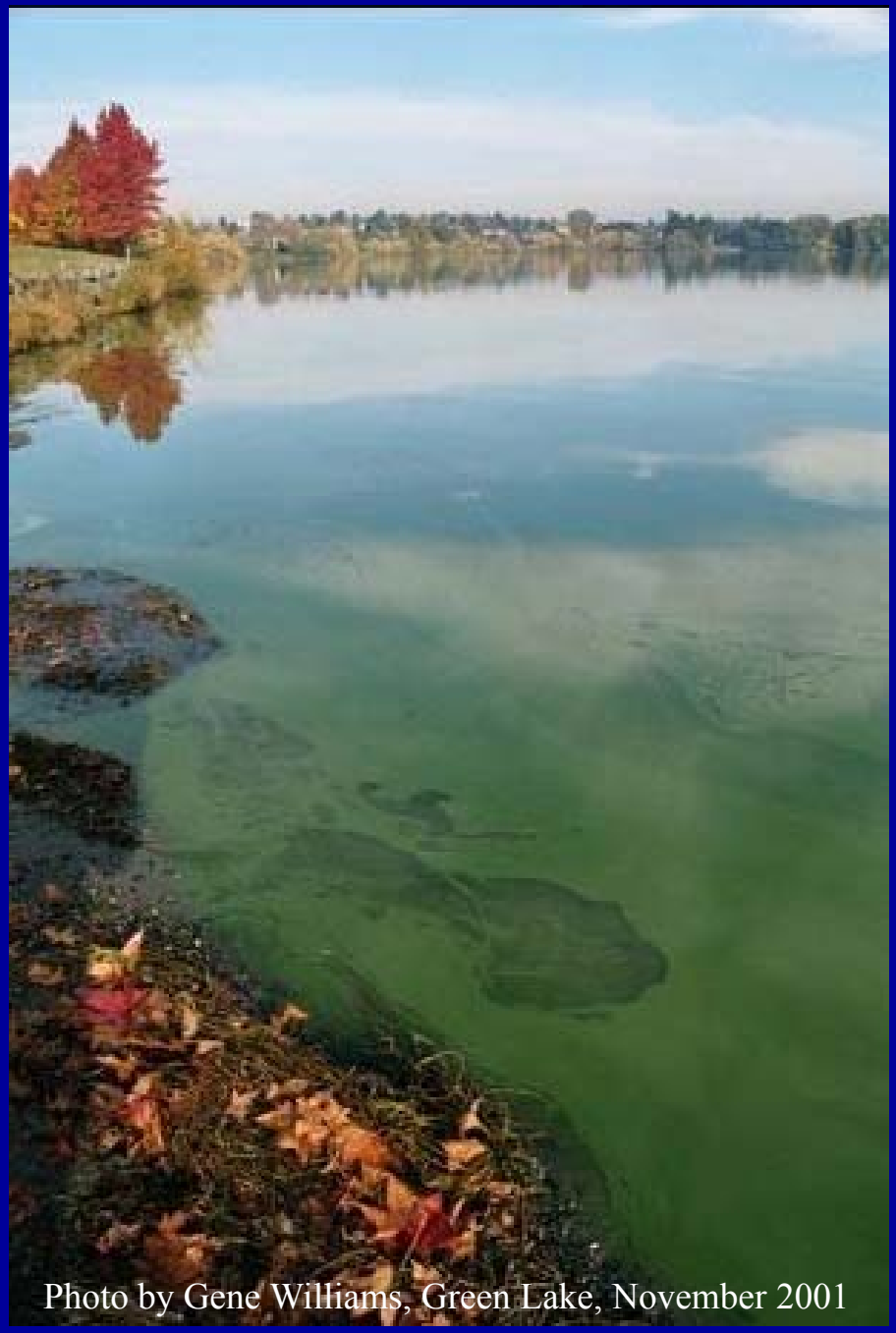
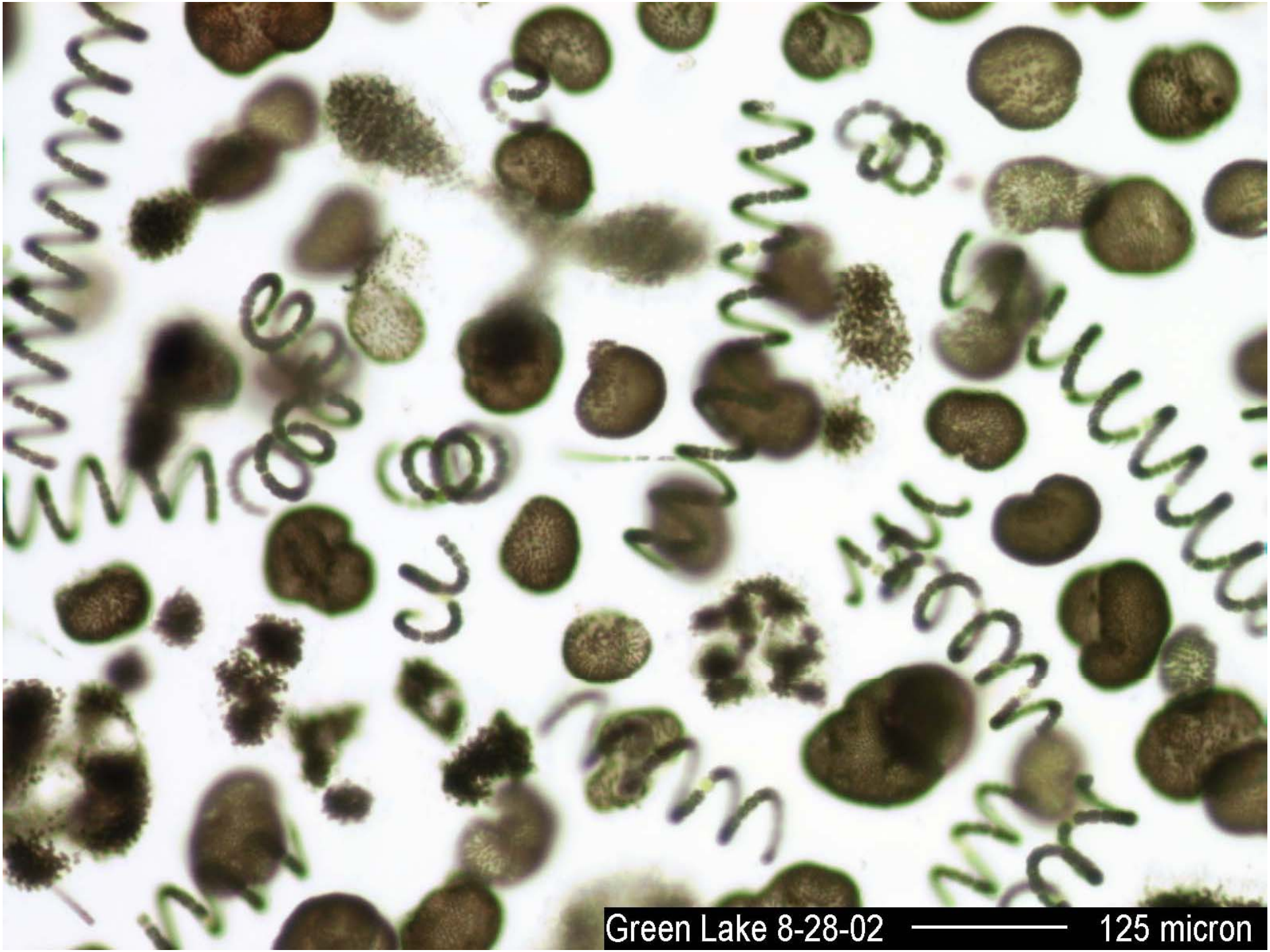


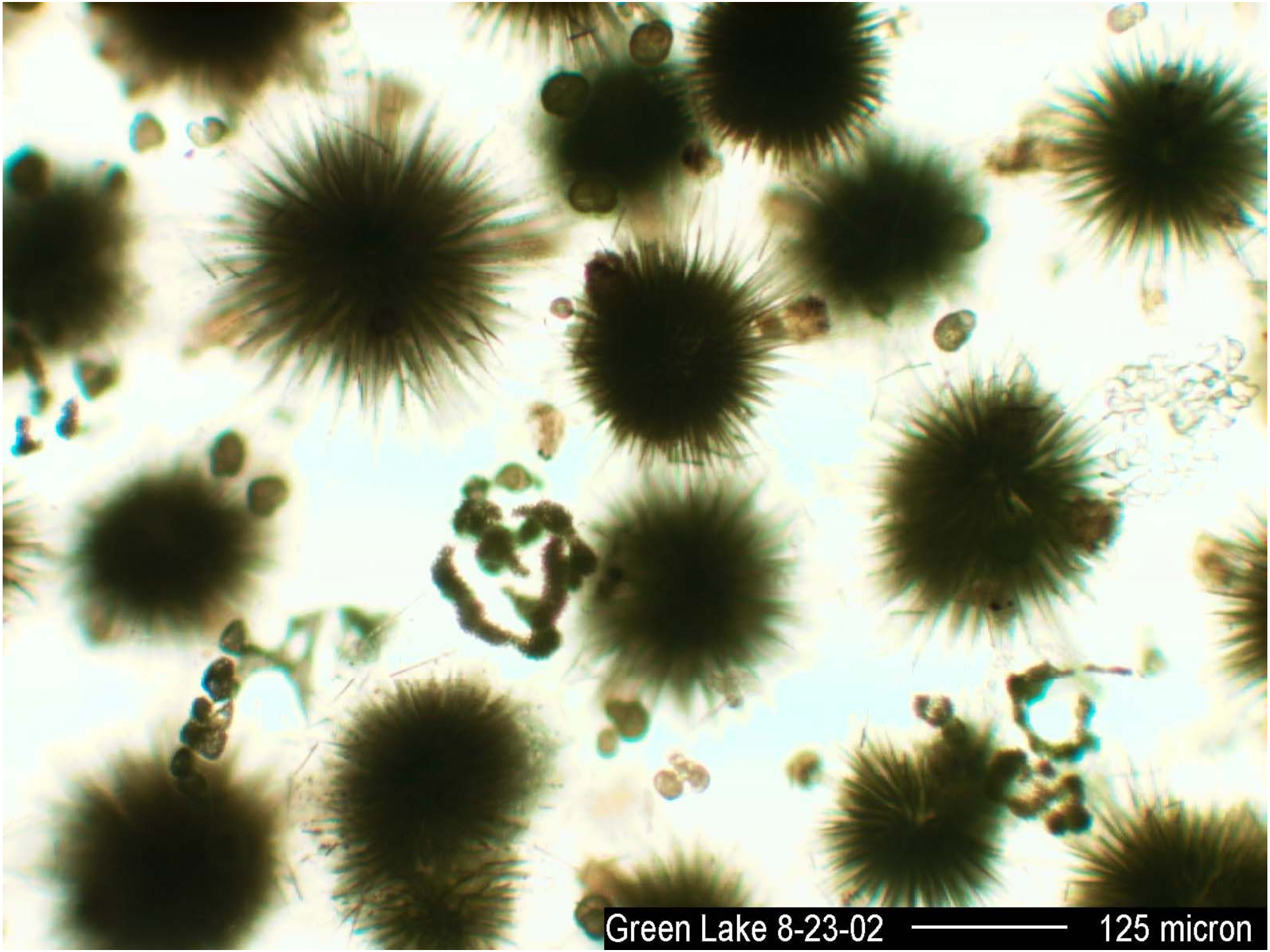
Photo by Gene Williams, Green Lake, November 2001

Swimming beaches were closed in summers of 2002 and 2003 due to high microcystin concentrations (up to 100 ug/L).

Milfoil Die-off Fueled Cyanobacteria Blooms

Photo by Gene Williams, Green Lake, November 2001


Green Lake 8-28-02
125 micron


Green Lake 8-23-02
125 micron

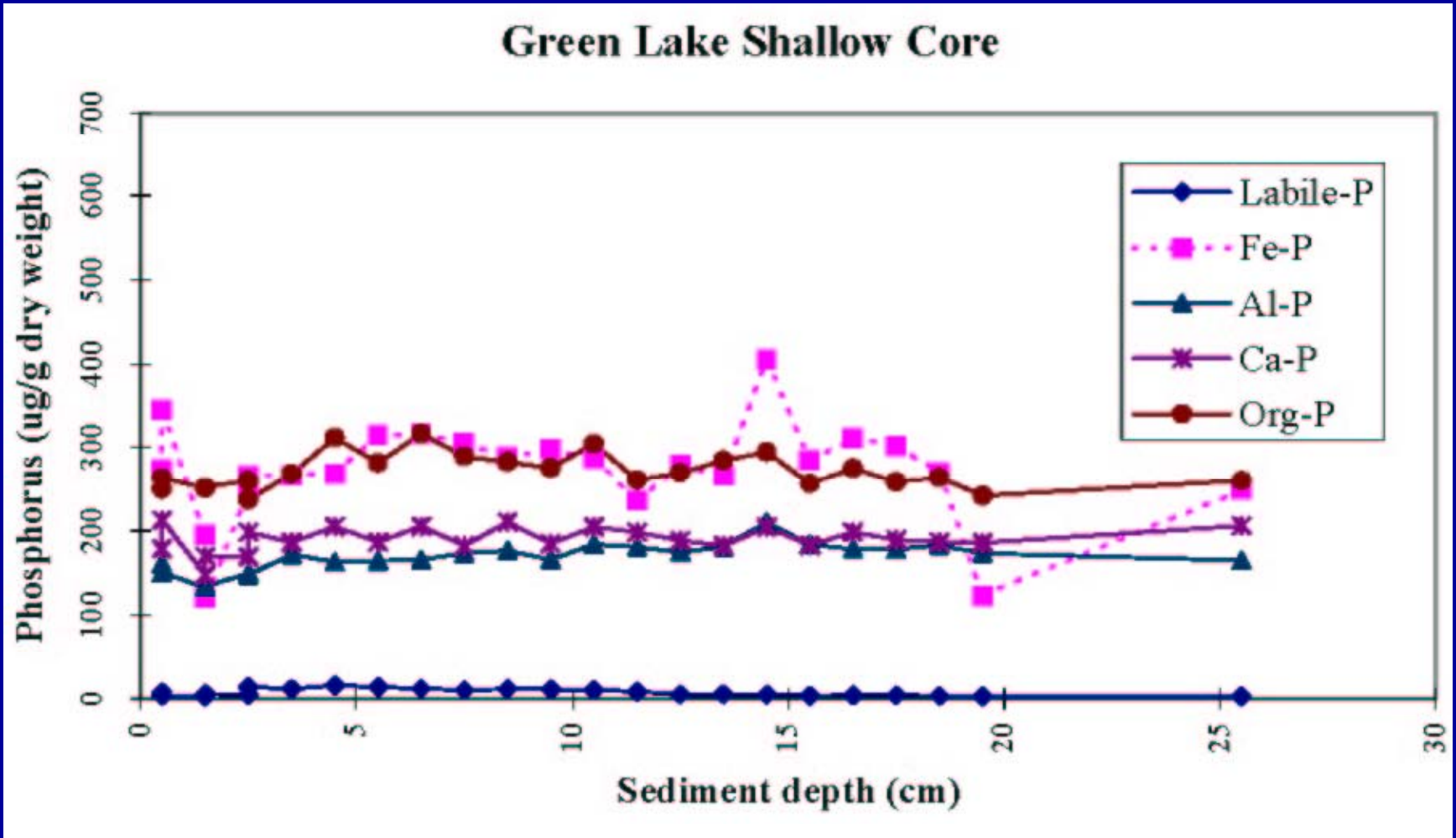
2003 Alum Treatment Study

- Summarize data collected since 1995
- Review alum literature
- Calculate alum dose
- Conduct jar tests (twice)
- Prepare specifications and cost estimate
- Prepare integrated phosphorus management plan for NPDES permit

Alum Dose Calculation

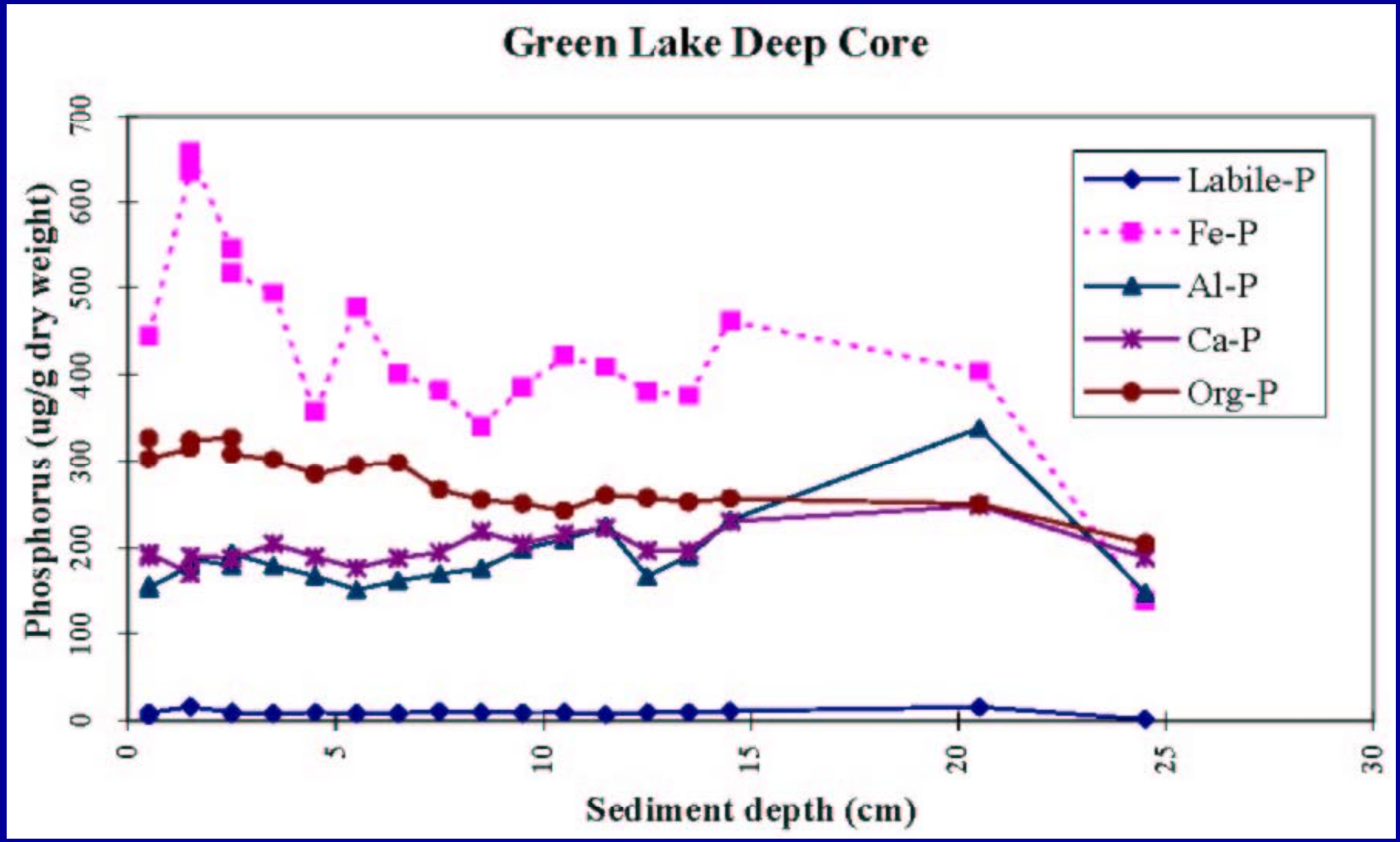
1. Alkalinity Method
2. Internal Loading Method
3. Sediment Phosphorus Method

Sediment Phosphorus Profile at Station A



Collected in 1998 for alum-treated lake study by Emil Rydin

Sediment Phosphorus Profile at Index Station



Collected in 1998 for alum-treated lake study by Emil Rydin

Sediment Phosphorus Method

- Bind mobile phosphorus in sediment (mean Fe bound + labile P = 370 µg/g)
- 20 cm sediment depth
- 10 % binding efficiency
- Estimate 18 mg Al/L for sediment phosphorus
- Add 6 mg Al/L for water column phosphorus
- Use 2:1 alum to sodium aluminate by volume

2004 Alum Treatment Specifications and Cost

- **Apply in January – March 2004 (no plants)**
- **Apply 632 tons (234,000 gallons) alum and 373 tons (117,300 gallons) sodium aluminate**
- **Adjust rate with depth using sonar and GPS for 24 mg Al/L dose throughout lake (>5 ft depth)**
- **Estimate up to 21 days for treatment (actual 15)**
- **Estimate total cost of $ 1.5 million (actual ~1)**


2004 Alum Treatment


2004 Alum Treatment

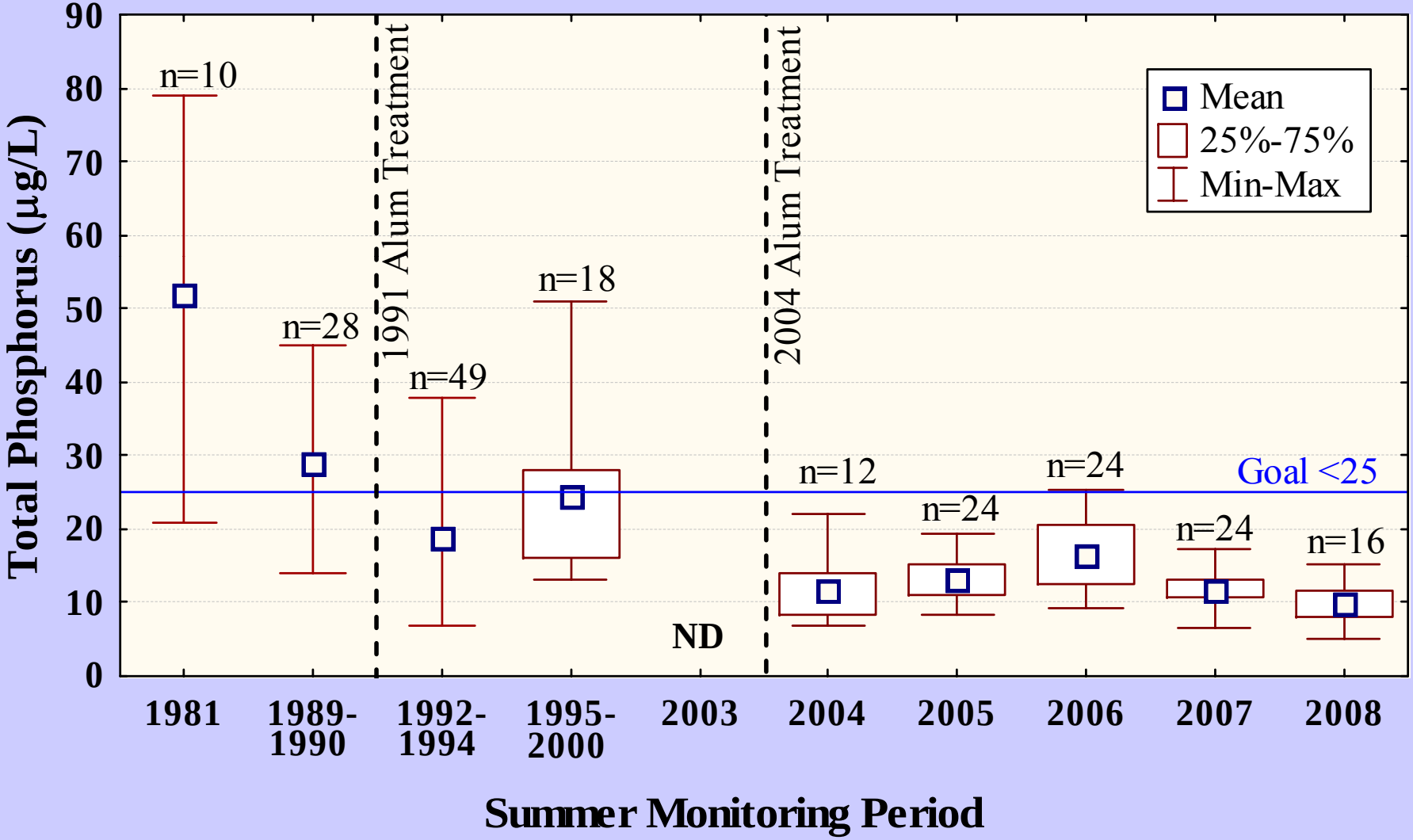
2004 Alum Treatment Impacts

	7 Days Before	15 Days During	2 Days After	14 Days After
pH	7.5	6.8 - 7.7	6.9	7.5
Alkalinity (mg/L)	33	19 - 34	18	17
Total Al (ug/L)	131	--	401	128
Diss. Al (ug/L)	9	--	29	43
Total P (ug/L)	16	--	5	14
Chl. *a* (ug/L)	5.3	--	0.9	3.6
Secchi (m)	2.5	1.8 - 6.8	5.4	2.9

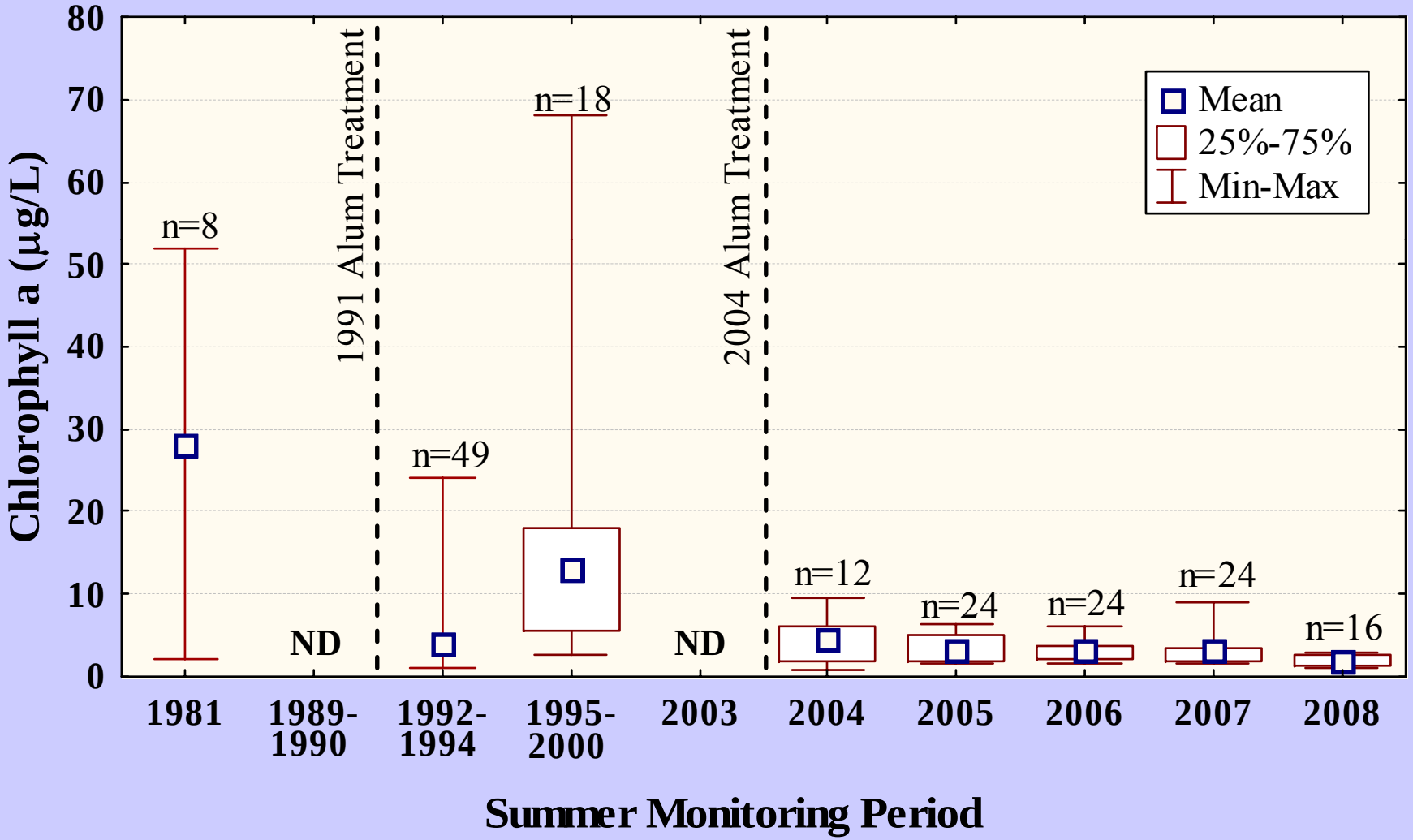
Alum Treatment Effectiveness: Summer Mean Values of Trophic State Parameters

1. Total Phosphorus
2. Chlorophyll *a*
3. Secchi Depth

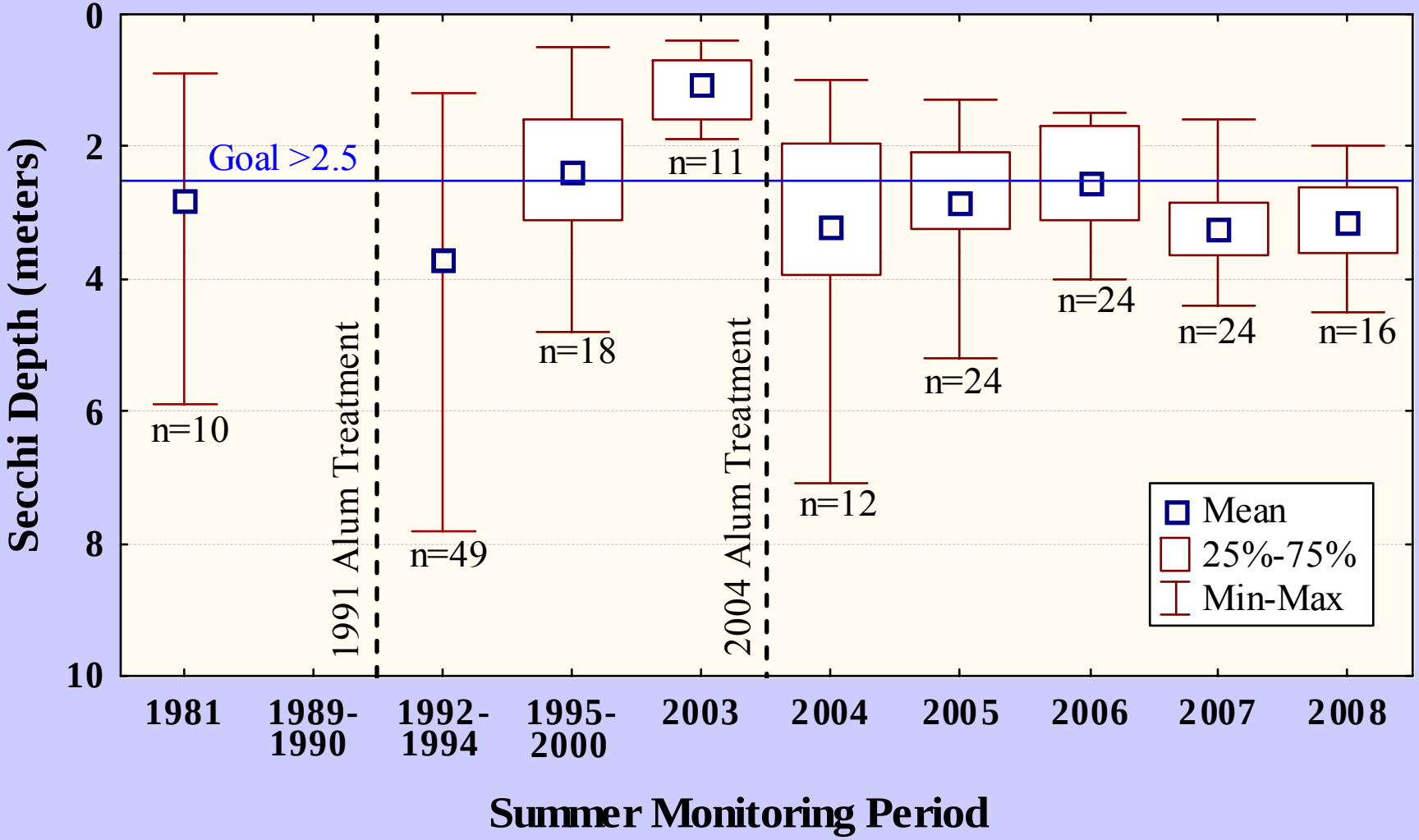
Green Lake Total Phosphorus



Green Lake Chlorophyll *a*



Green Lake Secchi Depth



Post-Treatment Sediment Study

- Collect 1 sediment core each from 4 locations 6 months after 2004 treatment
- Analyze 1 cm segments for P fractions and total aluminum by Rebecca Dugopolski (UW) and Emil Rydin at Uppsala University, Sweden
- Compare results to 1998 pre-treatment results and to results for other alum treated lakes in western Washington

Sediment Study Conclusions

- Ratio of Al added to Al-P formed >100 in Green Lake sediments, versus 10 in other alum treated lakes in Washington
- 70 percent of available P was transformed to Al bound P in Green Lake sediments
- Alum will control internal P loading and meet restoration goals for a decade…….. or more if stormwater P loading is reduced.

2004 Woodland Park Stormwater Study

- Concern:
  - Reduced alum treatment longevity due to high phosphorus concentrations in park runoff
- Study Objectives:
  - Track sources of phosphorus and fecal coliform bacteria (on 303d list)
  - Evaluate existing stormwater treatment facilities built in 1992
  - Identify new stormwater treatment facilities.

Stormwater Monitoring Sites

South Woodland Subbasin

- Station 1 (South Outfall)
- Station 2 (South Midstream)
- Station 3 (South Upstream)

North Woodland Subbasin

- Station 4 (North Outfall)
- Station 5 (North Midstream)
- Station 6 (North Upstream)

Densmore Basin

- Densmore outfall

Stormwater Study Design

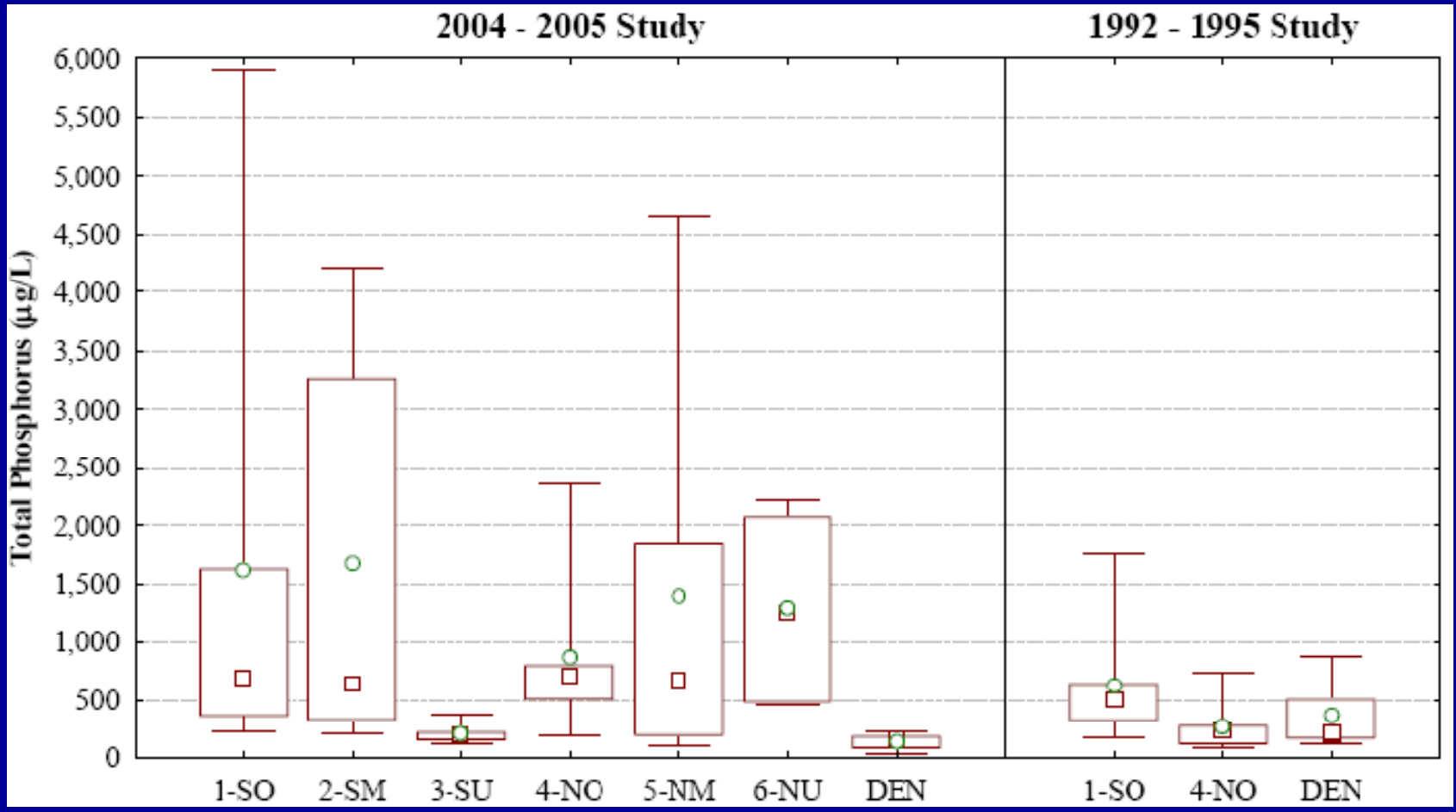
- 6 grab samples per station
- 4 storm events (Nov. – Dec. 2004)
- Measure:
  - Discharge rate
  - Total suspended solids (TSS)
  - Total phosphorus (TP)
  - Total dissolved phosphorus (TDP)
  - Fecal coliform bacteria
- Also measure wood chip pile inflow/outflow in January 2005 storm
- Perform genetic fingerprinting of 60 E. coli isolates from collected samples.

Stormwater Sampling

South Outfall

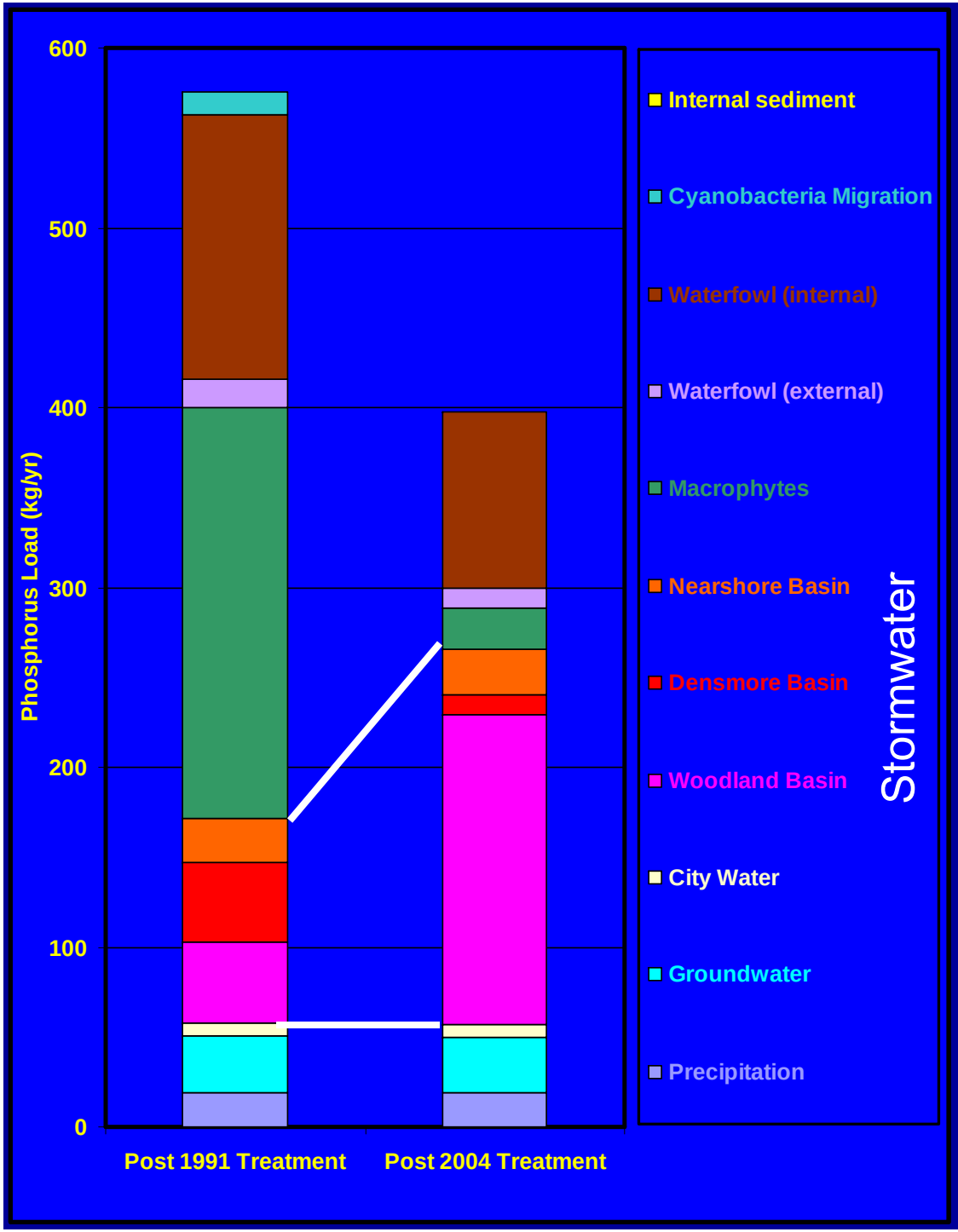
Park Runoff

Stormwater Phosphorus Concentrations



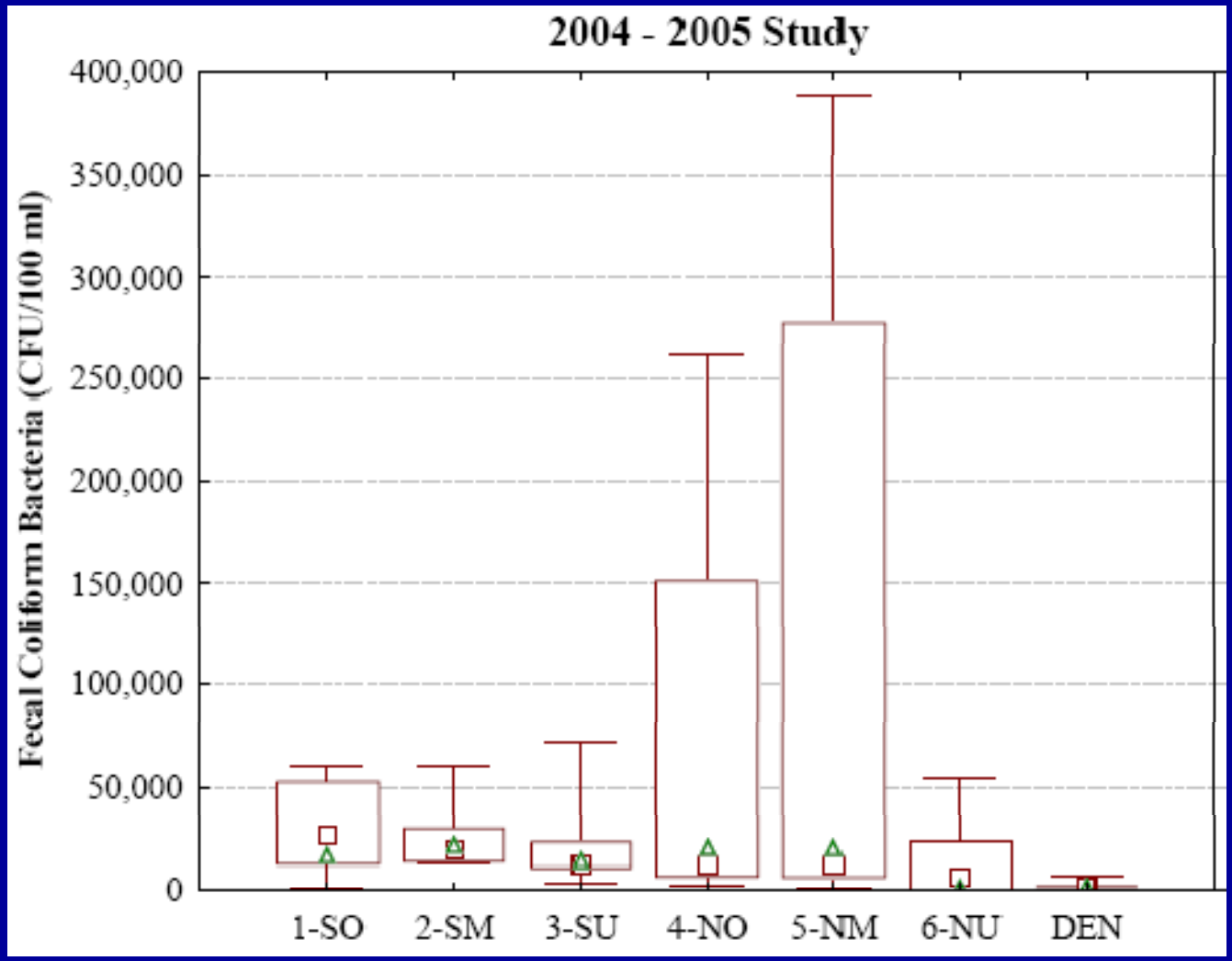
Stormwater Phosphorus Conclusions

- Very high TP at Woodland Park outfalls (1,615 and 874 µg/L at south and north) compared to Densmore outfall (142 µg/L) and lake goal (<25 µg/L).
- Woodland Park outfall TP increased 66% and Densmore outfall TP decreased 24% since 1995.
- High proportion of TP is dissolved (45%) due to wood chip pile.
- No TSS or TP removal by dirt field sediment vault .
- Wood chip pile increased TP from 1,066 to 21,100 µg/L in forest runoff.

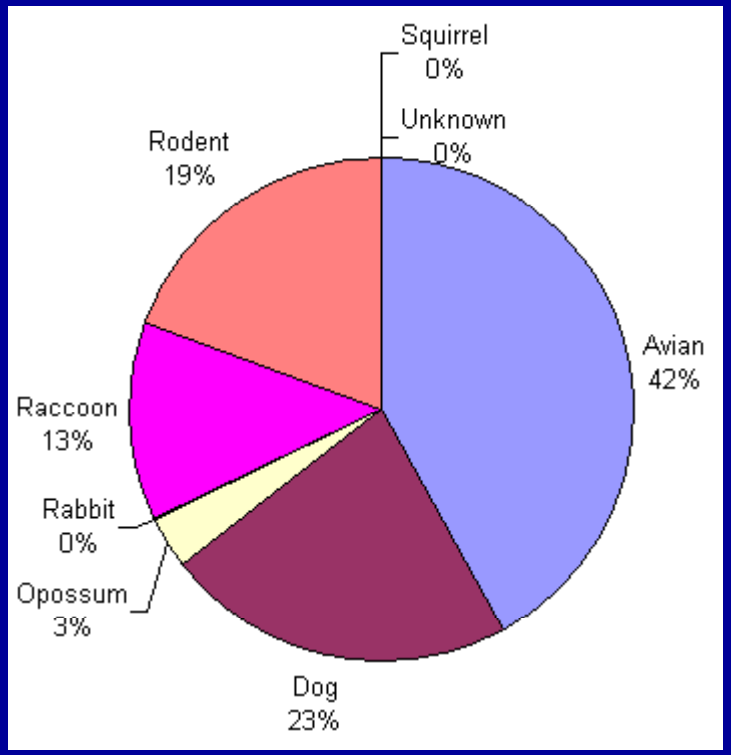


Green Lake Post-treatment Annual Phosphorus Loads (kg)

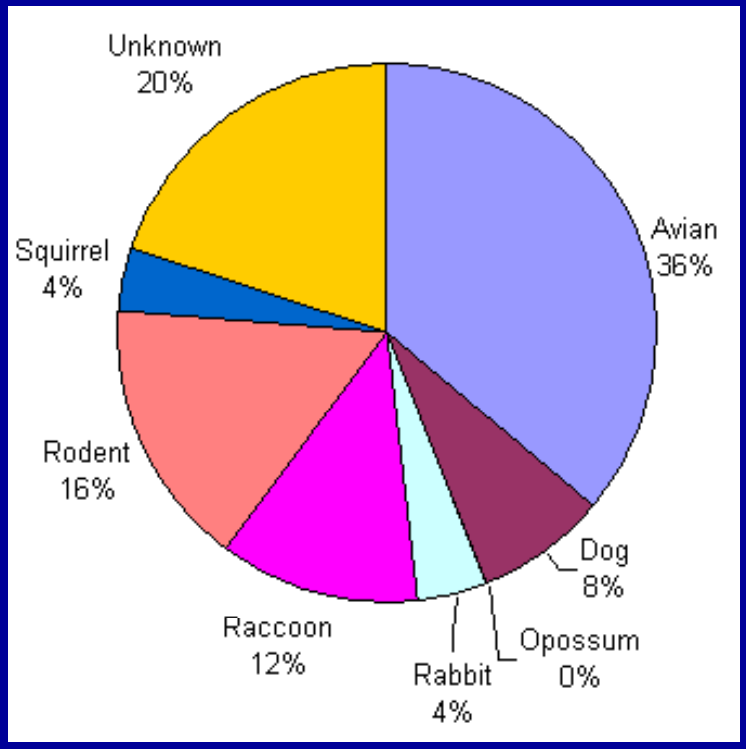
Stormwater Fecal Coliform Bacteria Concentrations



Stormwater *E. coli* Bacteria Sources



Upstream South Subbasin
(Station 3)



Downstream South Subbasin
(Station 1)

Stormwater Bacteria Conclusions

- Very high fecals at South Outfall (>16,000) and North Outfall (>20,000) compared to Densmore (>1,600) and standard (<50).
- Wood chip pile is the major source of fecal coliform bacteria (>60,000), but >90 % were *Klebsiella.*
- Most common sources include birds, rodents, and dogs, but no humans observed.

Stormwater Pollutant Sources and Recommended Controls

Pollutant Source:	Recommended Control:
Wood chip pile	Removed
Dirt soccer fields:	Convert to sport turf and clean vault
Unpaved parking lot:	Regrade with pervious pavement
Paved roads and parking lots	Street sweep
Grass playfields and golf course	No phosphate fertilizer; apply BMPs
Dirt storage piles	Apply BMPs
Wooded ravine erosion	Curb road and clean catch basins
Off-leash dog park	Plug catch basin and infiltrate runoff

Remove Wood Chip Pile

Convert Dirt Soccer Fields to Synthetic Turf

Green Lake lunar eclipse, fall 2003 photo by Gene Williams

Control external phosphorus sources to protect your alum investment

Questions?