

Climate Change Stimulates Freshwater Harmful Algal Blooms (FHABs): A Within Water-Body Management Solution

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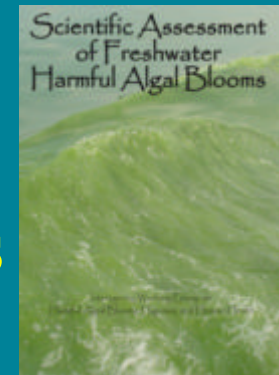
NALMS 19th Annual Southeastern Lakes Management Conference
Winston-Salem, North Carolina
May 5-7, 2010

Background



1

Freshwater Harmful Algal Blooms (FHABs)



2

The Interagency, International Symposium on Cyanobacterial HABs: ISOC-HAB



1 Hudnell HK [Ed.], 2008. *Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs*. Advances in Experimental Medicine and Biology, Vol. 619, 959 pp

2 Lopez CB, Jewett EB, Dortch Q, Walton BT, Hudnell HK, 2007. *Scientific Assessment of Freshwater Harmful Algal Blooms*. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Overview

- Water Quality, Eutrophication & FHABs
- FHAB Stimulatory Factors & Global Climate Change
- Solar Powered Circulation (SPC)
 - Planktonic Densities Before & During SPC
 - Crystal Lake, Des Moines, IA
 - East Gravel Lake 4, Thornton, CO
 - Lake Palmdale, Palmdale, CA
- Possible SPC mechanisms of FHAB Suppression
- Problematic Applications or Learning Experiences

Material from:

Hudnell (2010). The State of U.S. Freshwater Harmful Algal Blooms Assessments, Policy and Legislation. *Toxicon* 55:1024-1034.

Hudnell *et al.* (2010). Freshwater Harmful Algal Bloom (FHAB) Suppression with Solar-Powered Circulation (SPC). *Harmful Algae* 9:208-217.

Will We Have a Sustainable Supply of Usable Freshwater?

- 44% of river & stream miles, & 64% of lake & reservoir acres are impaired pursuant to section 305(b) of the U.S. Clean Water Act (EPA, 2009)
 - Flux of nutrients, toxic substances & pathogens to receiving waters
- 1972, 1st EPA Eutrophication Survey: 10-20% of all U.S. lakes & reservoirs eutrophic (Gakstatter & Malone, 1975)
- 2009, EPA Eutrophication Survey: 50+% of all U.S. lakes & reservoirs eutrophic/hypereutrophic (EPA, 2009)

Eutrophic → Harmful Algal Blooms

NATURAL FORCES

HUMAN ACTIVITIES

Habitat Alteration & Environmental Pollutants

Ocean

ECOSYSTEMS

Estuary

Fresh Water

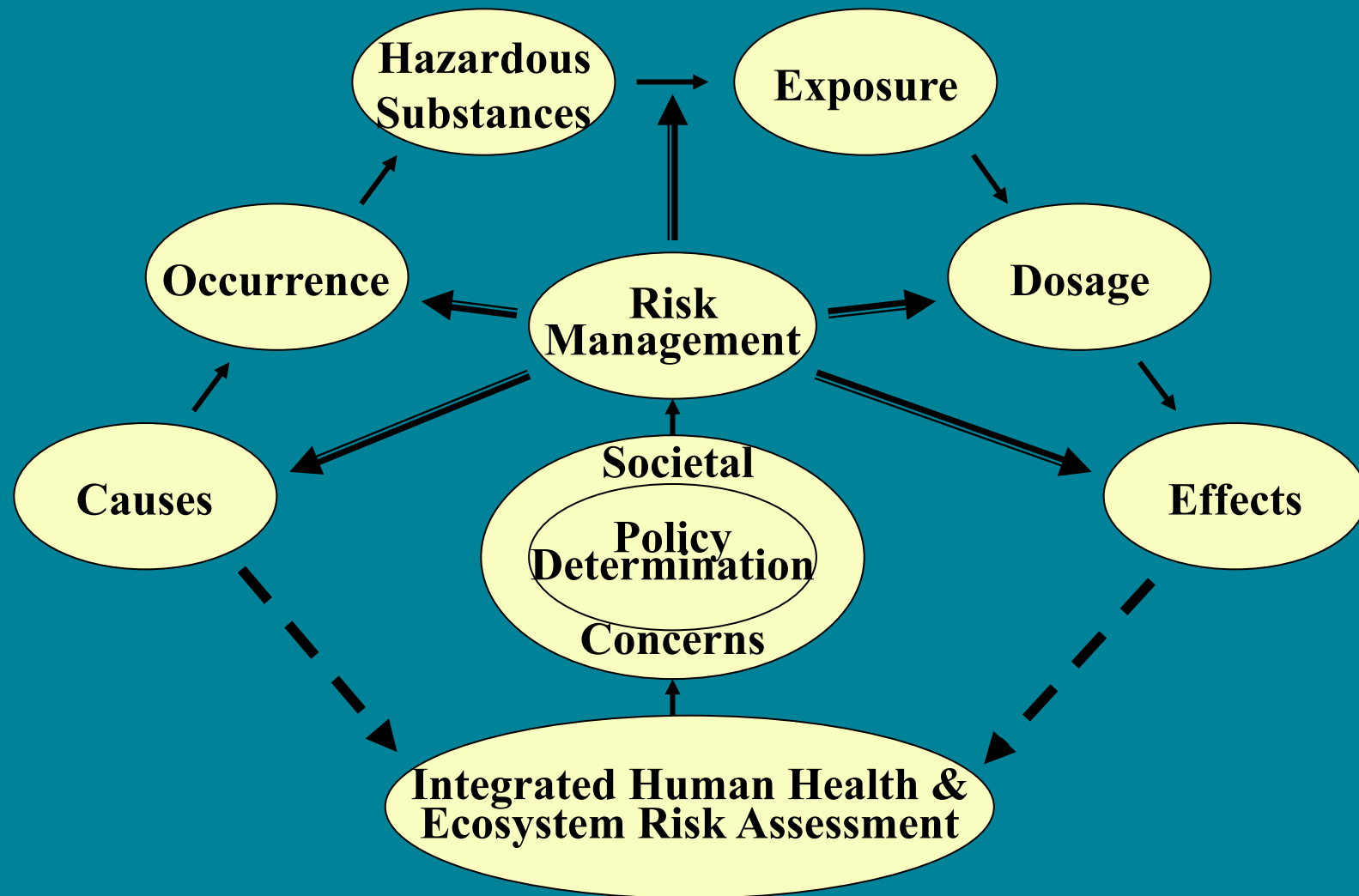
Land

Ecosystem Sustainability

TOXIGENIC CYANOBACTERIA

Human & Animal Health

Systems Approach: FHAB Risk Management



**EPA declined to voluntarily establish
FHAB research & control program**

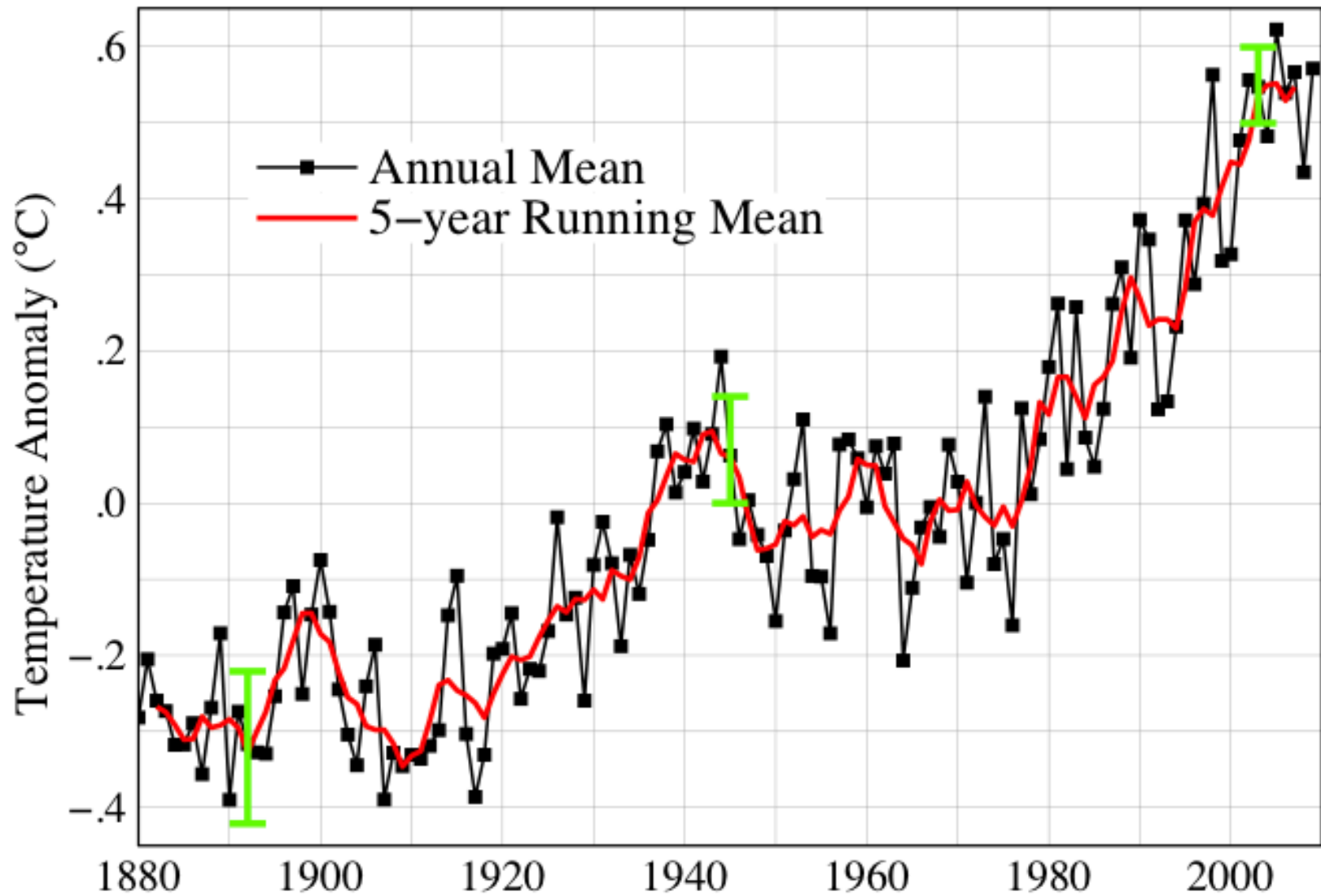
FHAB Stimulatory Factors & Global Climate Change (GCC)

- Sunlight - for photosynthesis - No GCC effect

FHAB Stimulatory Factors & Global Climate Change (GCC)

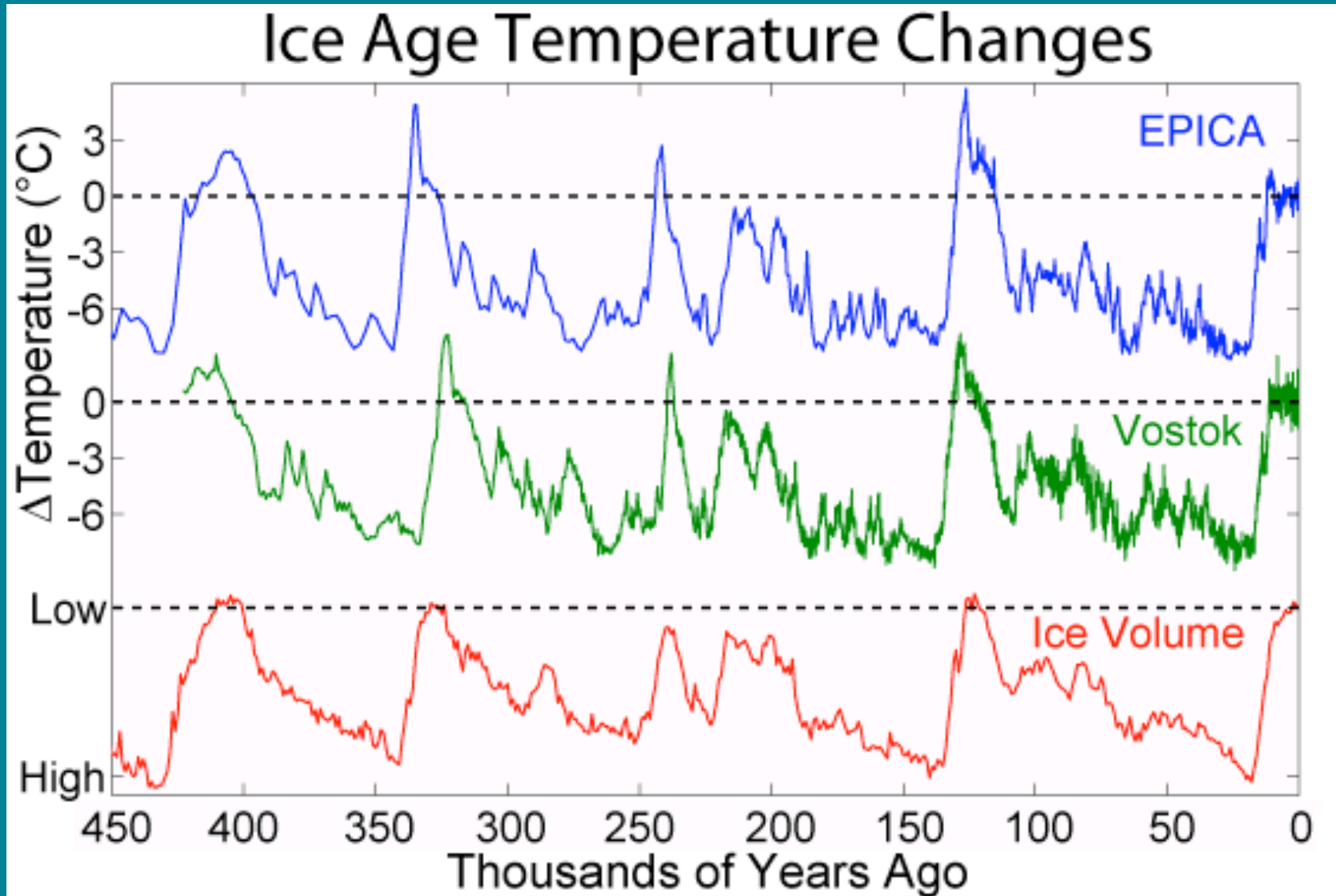
- Sunlight - for photosynthesis - No GCC effect
- Temperature: Best $> 28^{\circ}\text{C}$ - Increased by GCC
 - Increasing incidence, prevalence & durations

Global Land–Ocean Temperature Index



NASA Goddard Institute for Space Science, April 2010

Based on oxygen isotope ratios in ocean cores



Lisiecki & Raymo (2005) *Paleoceanography* 20:1003

FHAB Stimulatory Factors & Global Climate Change (GCC)

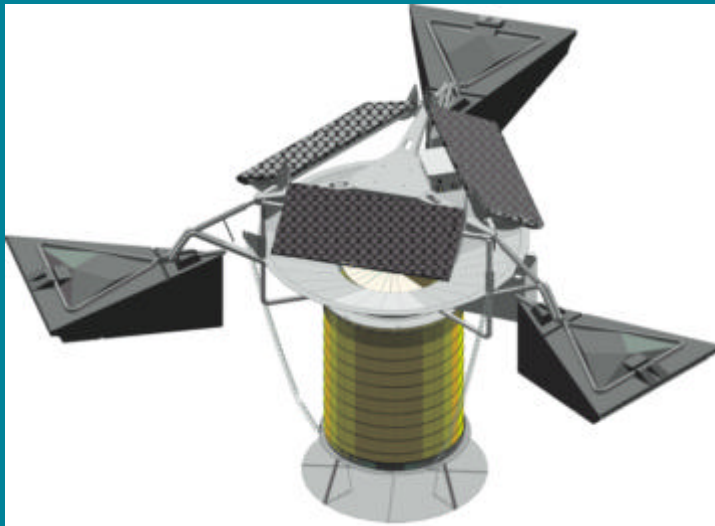
- **Sunlight:** for photosynthesis - No GCC effect
- **Temperature:** Best $> 28^{\circ}$ C - Increased by GCC
 - Increasing incidence, prevalence & durations
- **Nutrients:** growth & reproduction - Increased by GCC
 - More frequent & severe storms & floods
 - Watershed & land use management policies have proven to be inadequate
 - Each receives over \$5B/yr of Federal funds, & much more in state and local funding

FHAB Stimulatory Factors & Global Climate Change (GCC)

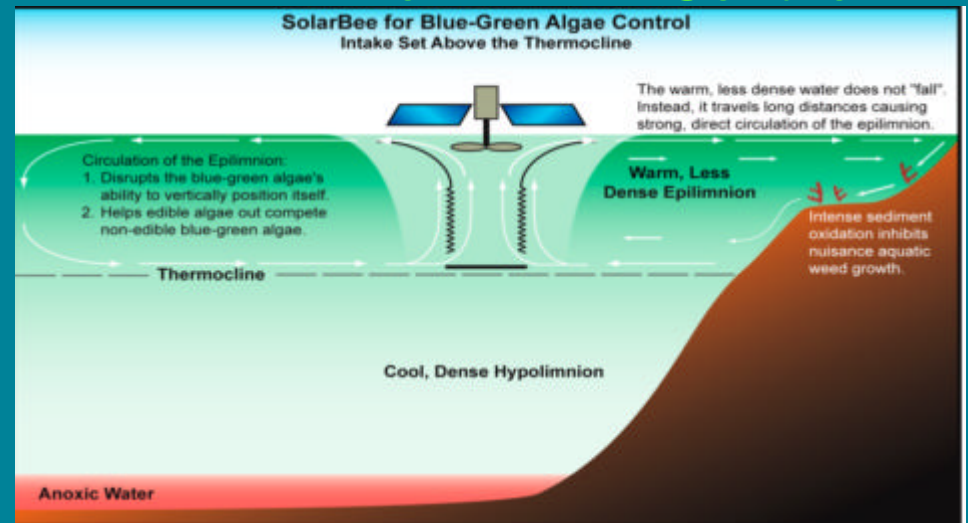
- **Sunlight:** for photosynthesis - No GCC effect
- **Temperature:** Best > 28° C - Increased by GCC
 - Increasing incidence, prevalence & durations
- **Nutrients:** growth & reproduction - Increased by GCC
 - More frequent & severe storms & floods
 - Watershed management inadequate
- **Quiescent, stagnant water:** outcompete other plankton
 - Increased by GCC
 - More frequent & severe droughts
 - Within water-body management needed

Solar Powered Circulation An Ecological Solution

Only Epilimnion Circulated for FHAB Control



SPC Unit



Three 80 watt solar panels; 18 Volt direct-drive motor & battery;
Continuous day/night operation at 80 RPM; Near-laminar radial inflow; Non-turbulent outflow at surface; 10,000 GPM upflow, 35 acre spacing

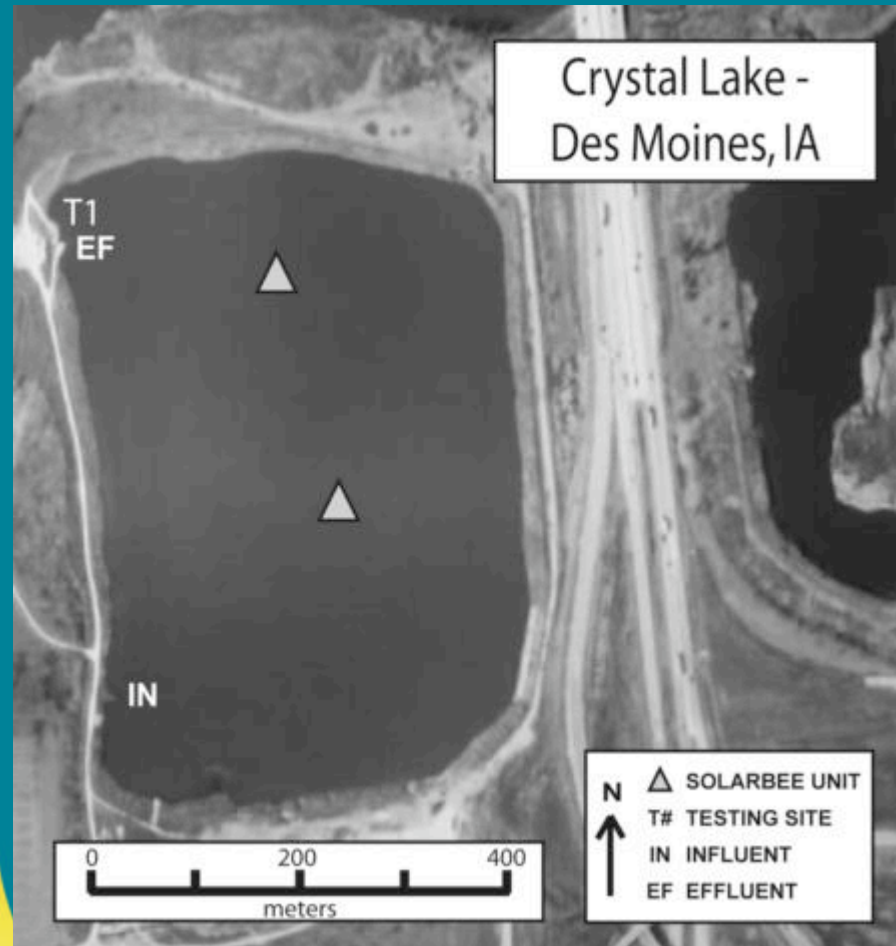
Long Distance Circulation

Site Selection

➤ March 2007, Survey sent to 1st 121 SPC users - 121/83/64: 50 FHAB control, Epilimnetic SPC

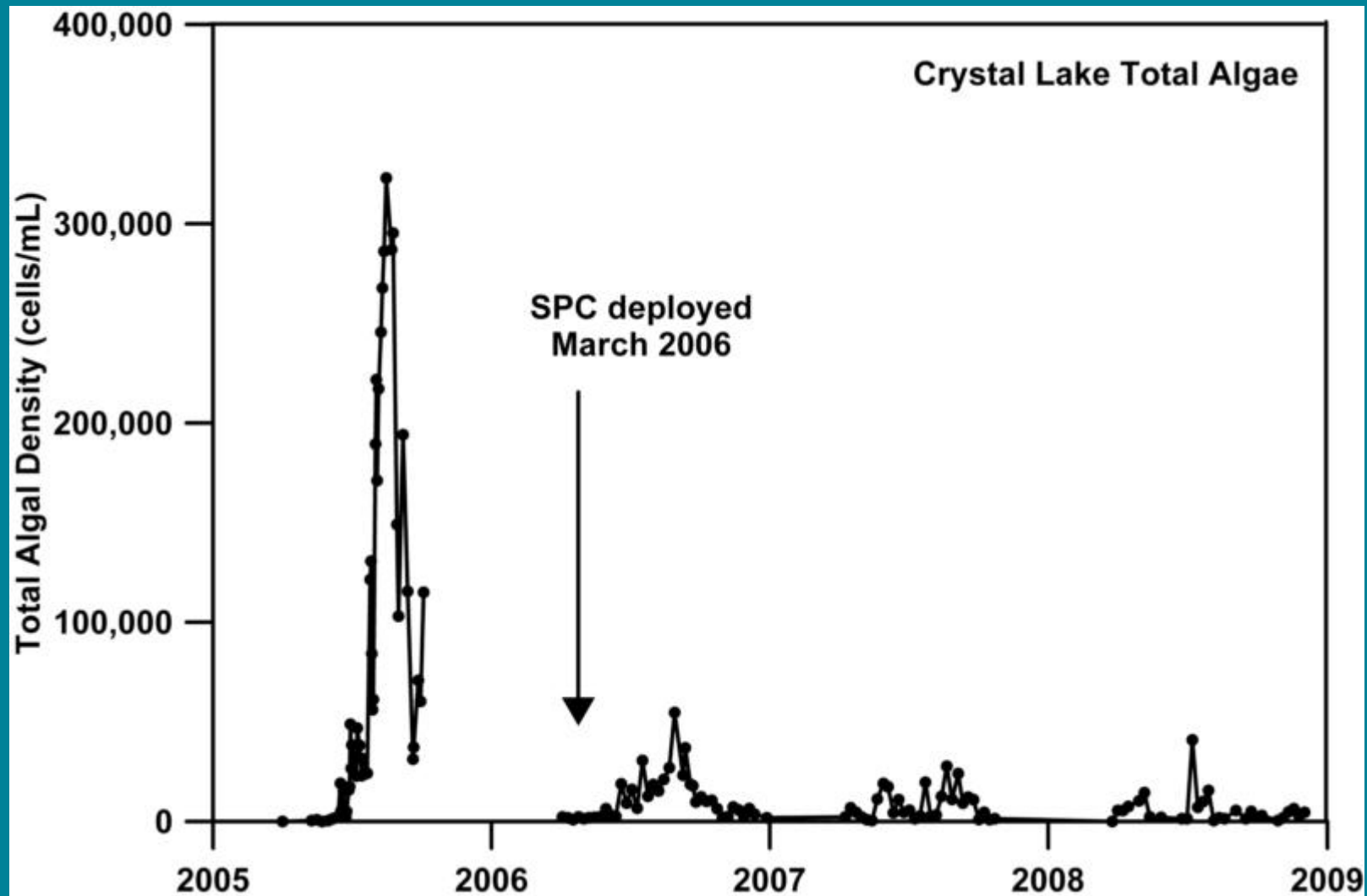
- SPC was deployed for epilimnetic circulation to suppress FHABs
- The whole water body was treated (surface area/SPC unit <16 ha)
- Water body personnel systematically assessed phytoplanktonic density
- Internal analytical methods were validated, standardized and consistent
- Densities of total plankton, cyanobacteria and green algae were available
- Phytoplankton data were available \geq one spring-fall season pre-SPC
- Phytoplankton data were available \geq one spring-fall season during SPC

Crystal Lake

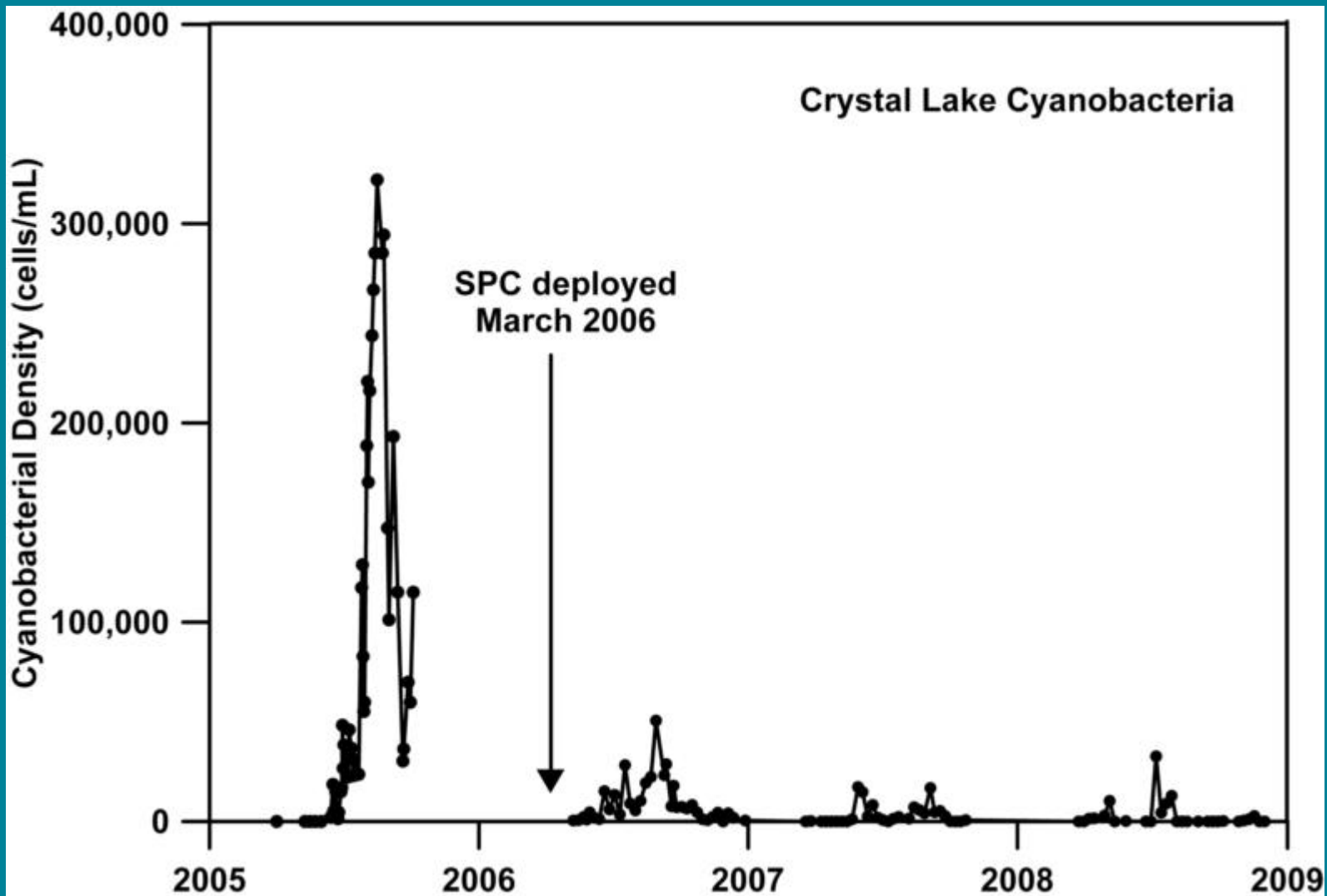


- 63 ac source water
- 25 maximum depth
- 10 ft mean depth
- 7.9 ft SPC mean intake depth
- 5 MGD mean input from Raccoon River
- 40 day mean residence time
- Total N reaches 18 mg/L
- Total P reaches 8 mg/L
- River seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides never used**

Crystal Lake Total Algal Densities

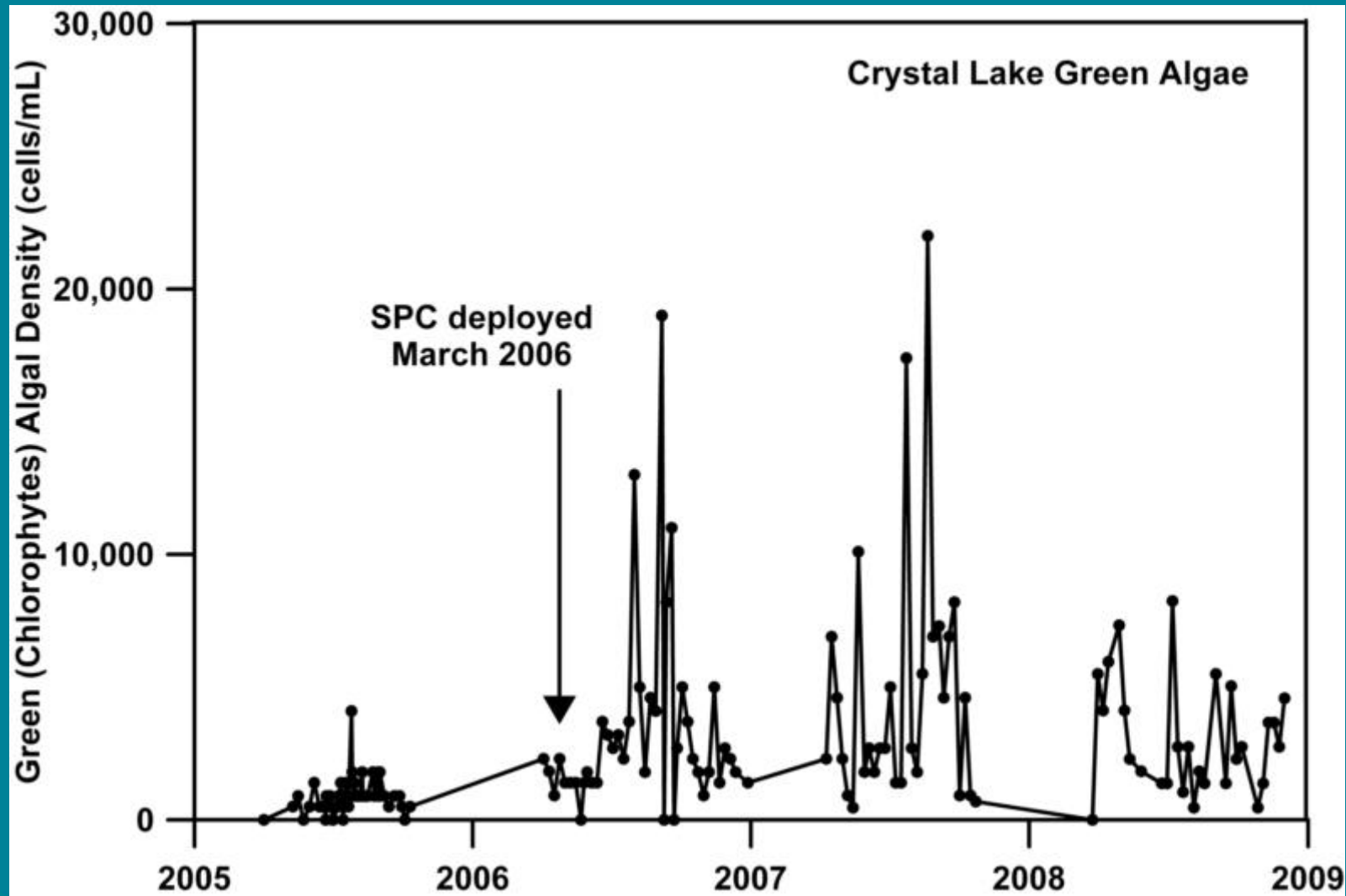


Crystal Lake Cyanobacterial Density



Algaecides never used

Crystal Lake Green Algal Densities



Crystal Lake Data Summary

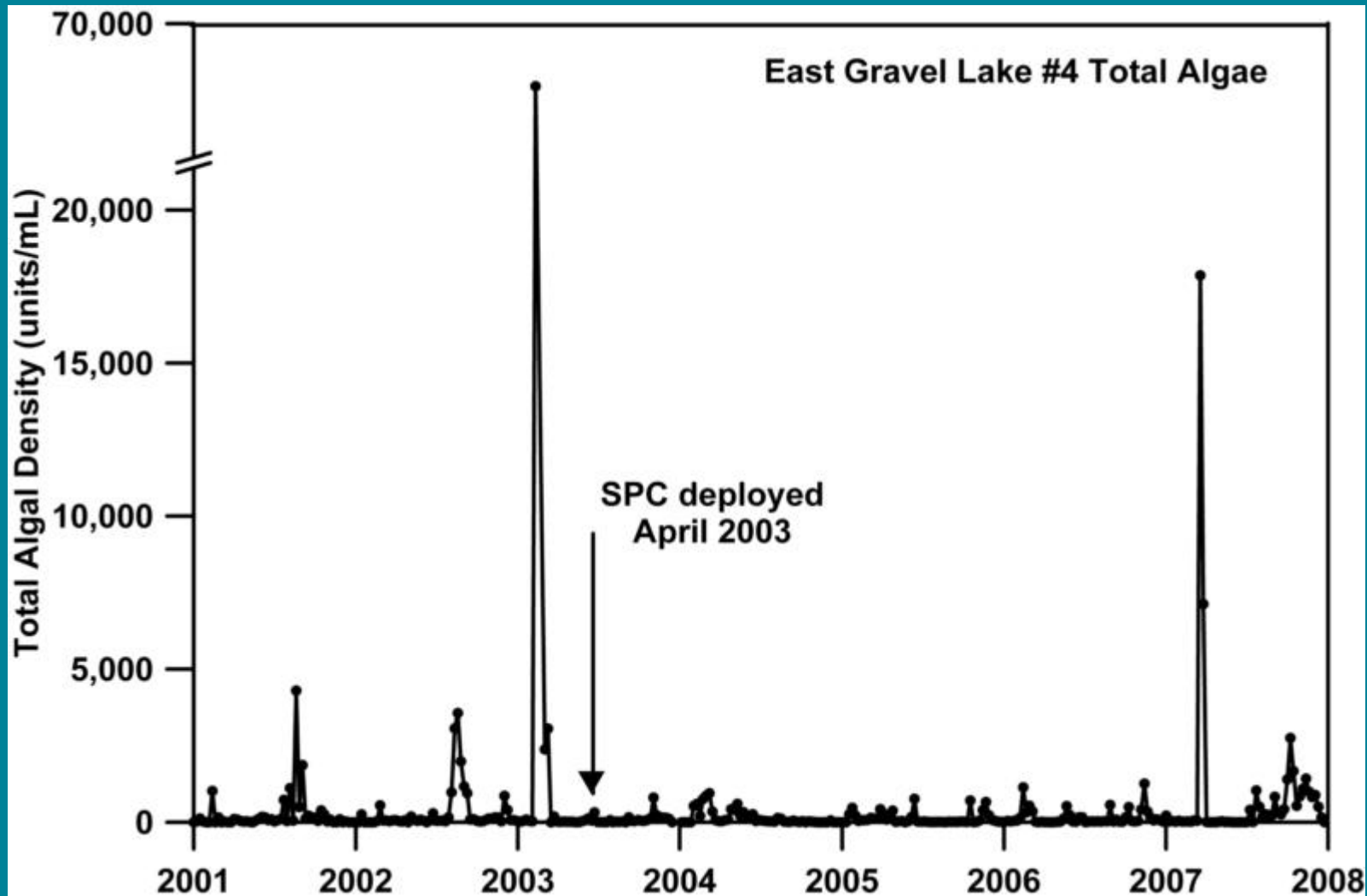
- High densities of total algae were dominated by cyanobacteria prior to SPC
- Total algal & cyanobacterial densities decreased significantly during SPC
 - Indication that FHAB suppression strengthened over time
- Green algal densities increased significantly during SPC

East Gravel Lake 4 (EGL 4)

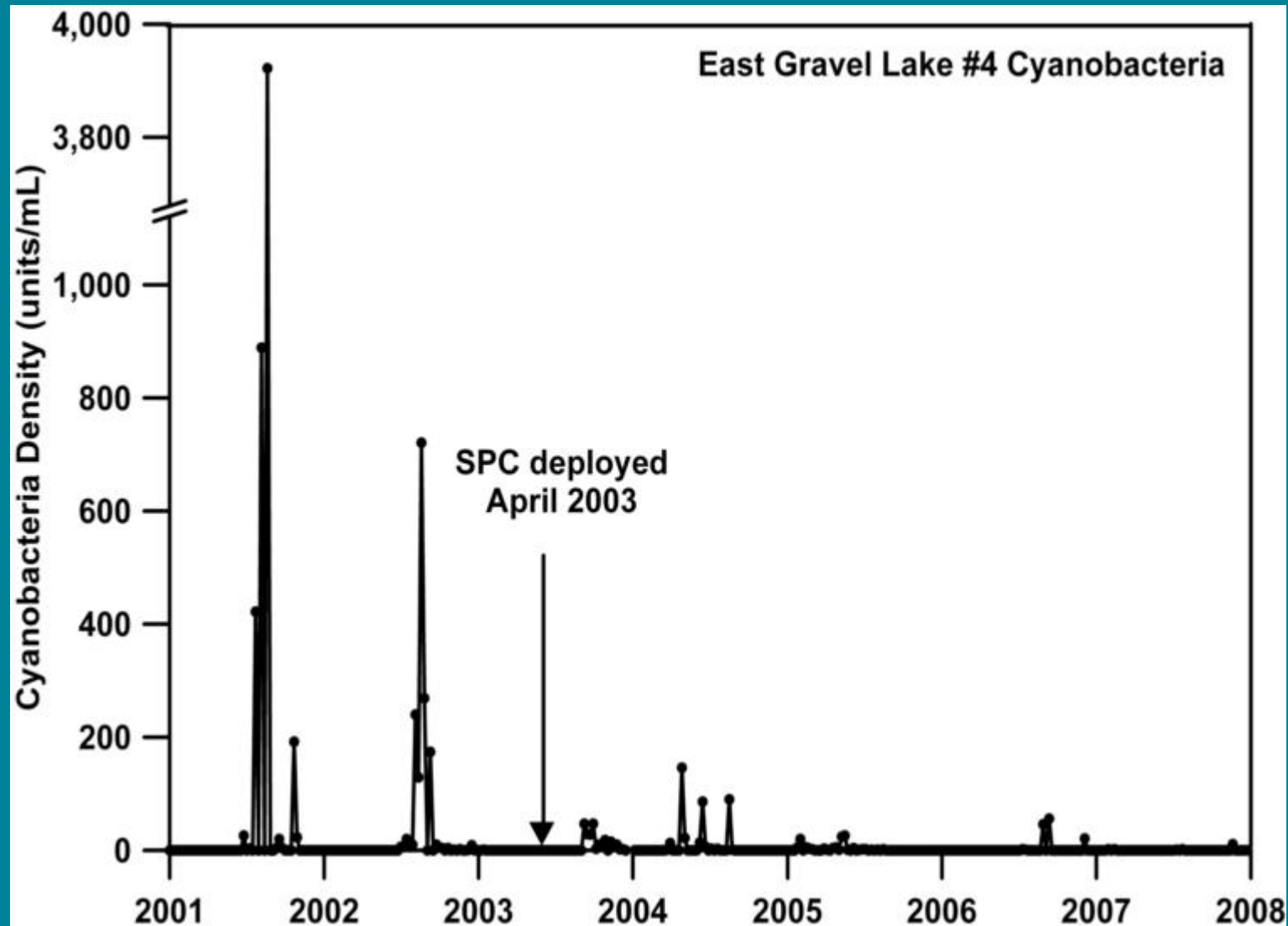


- 115 ac source water
- 35 maximum depth
- 25 ft mean depth
- 22-14.1 ft mean SPC intake depth
- 3.4 MGD mean input from Burlington Ditch (carries Denver effluent)
- 270 day mean residence time
- Nitrate reaches 10 mg/L
- Total P reaches 1.3 mg/L
- Ditch seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides used**

EGL 4 Total Algal Densities

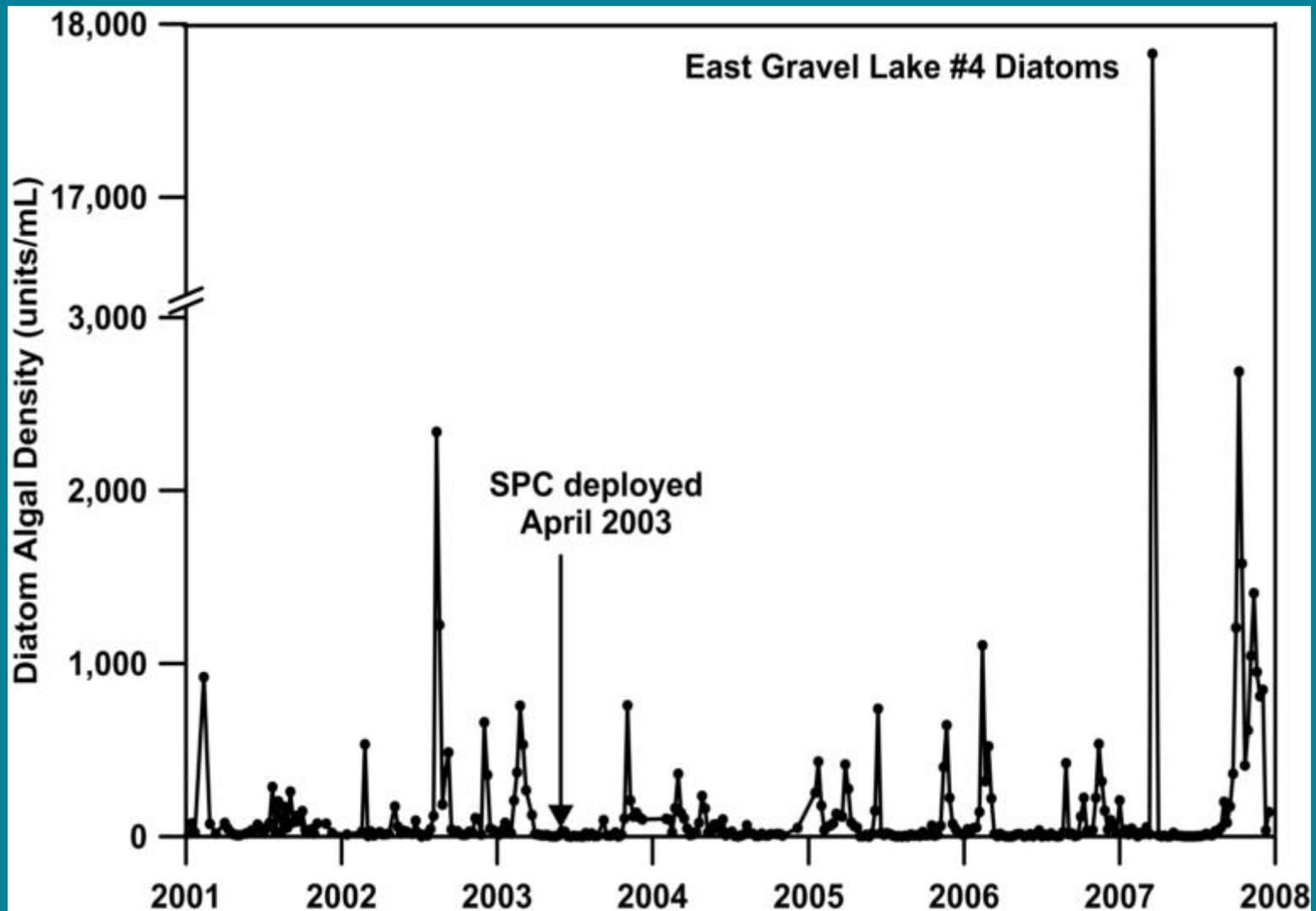


EGL 4 Cyanobacterial Densities



Algaecide usage: 1-2/mth pre- to 1-2/yr during-SPC

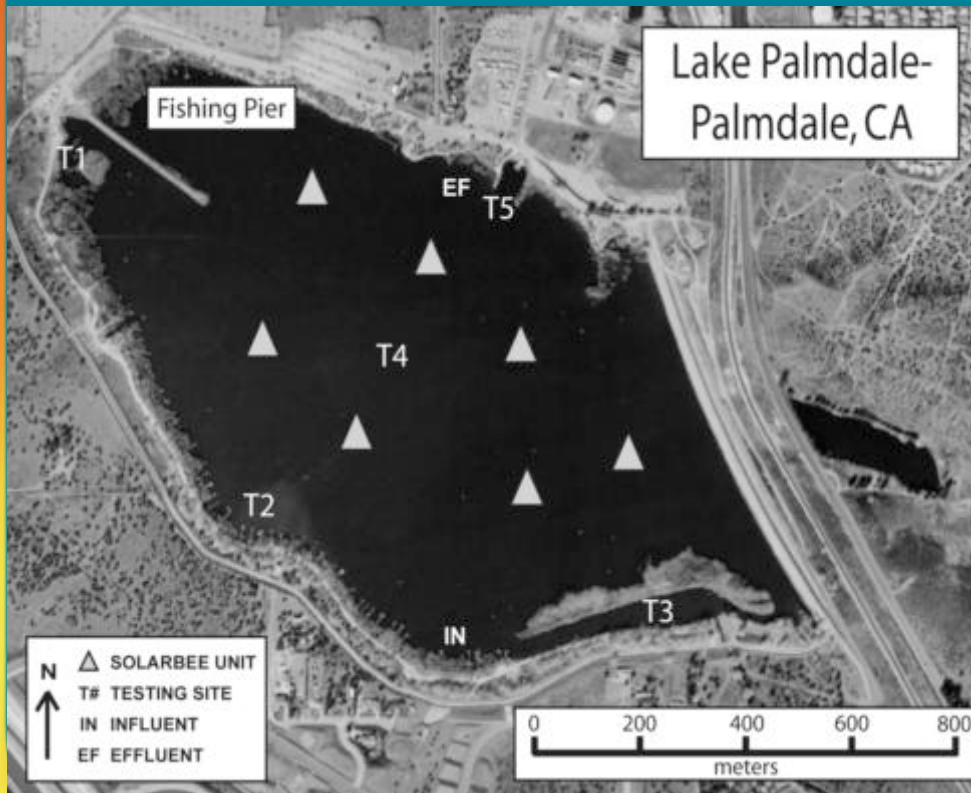
EGL 4 Diatom Densities



EGL 4 Data Summary

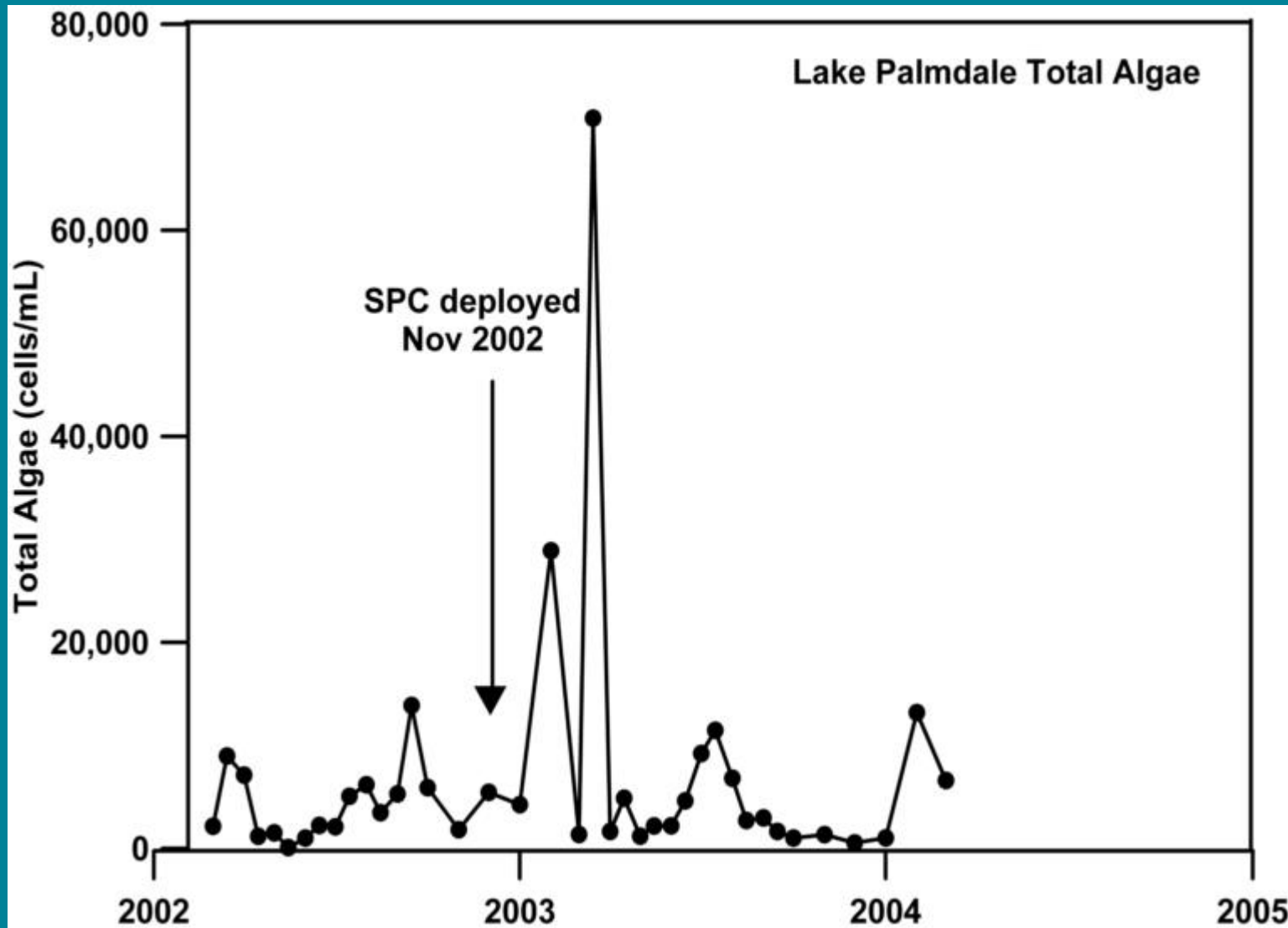
- High densities of total algae were dominated by cyanobacteria prior to SPC
- Total algal & cyanobacterial densities decreased significantly during SPC
 - Indication that FHAB suppression strengthened over time
- Little change in green algal density
- Diatom densities increased significantly during SPC
- Algaecide applications declined from 1-2/mth to 1-2/yr during SPC

Lake Palmdale



- 234 ac source water
- 25 maximum depth
- 18 ft mean depth
- 15.1 ft mean SPC intake depth
- 14.2 MGD mean input from California Aqueduct
- 270 day mean residence time
- Nitrate reaches 6 mg/L
- Total P reaches 0.22 mg/L
- Aqueduct seeds lake with FHAB cells
- Taste & odor problems
- **Algaecides used**

Lake Palmdale Total Algal Densities



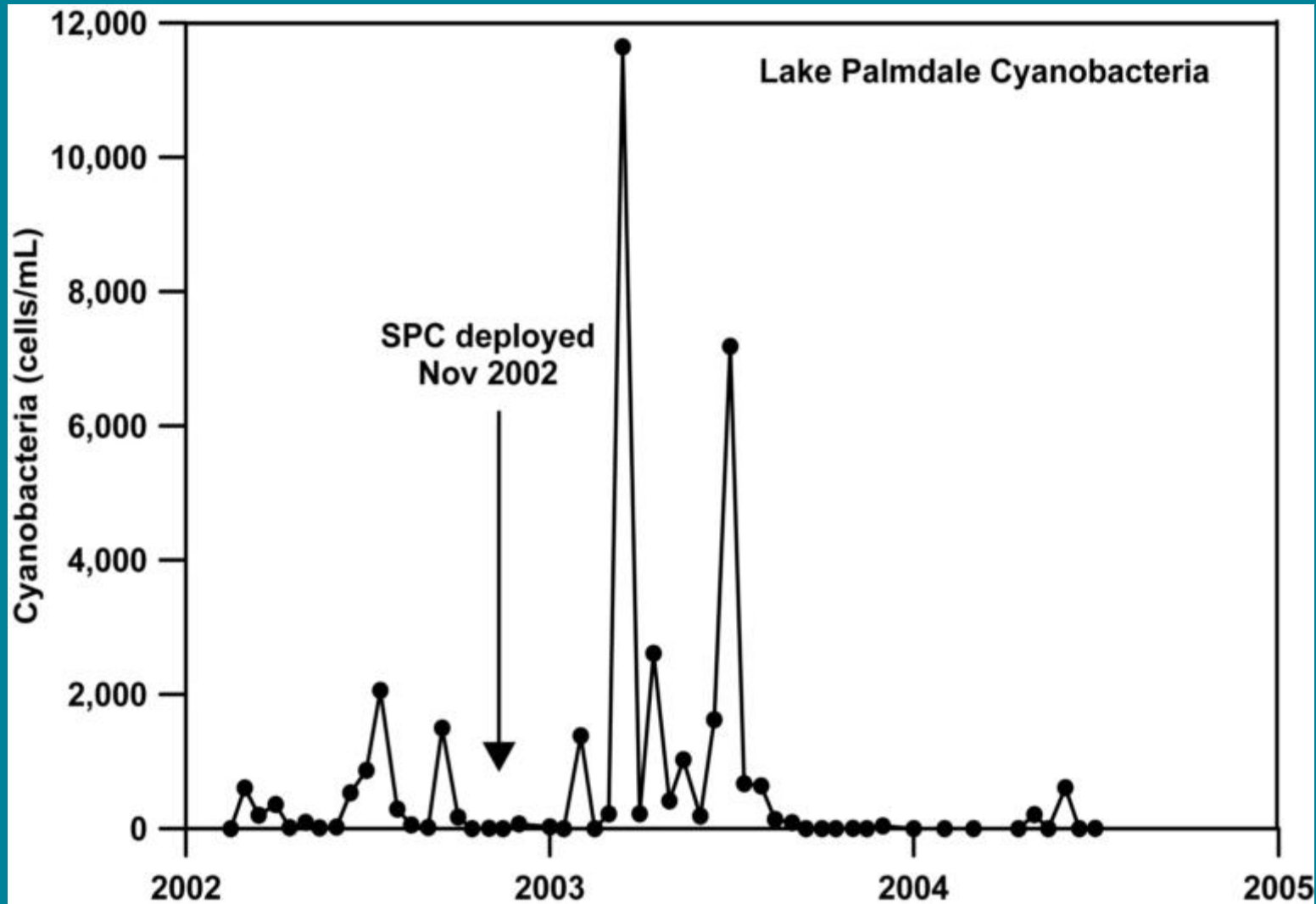
26,070 kg

3,922 kg

3,753 kg

CuSO₄

L Palmdale Cyanobacterial Densities



26,070 kg

3,922 kg

3,753 kg

CuSO₄

Lake Palmdale Data Summary

- Total algal mean density significantly higher during SPC
- Large FHAB during 1st year of SPC, cyanobacterial density significantly lower in 2nd year than pre-SPC
- No significant change in green algal or diatom densities during SPC
- Zooplankton densities increased significantly during SPC
- Algaecide usage declined by approximately 85% during SPC

Possible Mechanisms

- **Disruption of cyanobacterial buoyancy control**
 - Non-optimal positioning for light & nutrients
- **Distribution of non-motile cyanobacterial pathogens**
 - Cyanophage (viruses), cell lysing bacteria, fungi
- **Distribution of non-motile beneficial algae & bacteria**
 - Higher reproduction rates, limit available nutrients
- **Enhance iron oxidation rate, making it less available**
 - Cyanobacteria require much iron more than others
- **Promote zooplankton & grazing**

May be multifactorial or vary with conditions

Problematic Applications or Learning Experiences

- **Small, shallow (< 1 m) aquaculture ponds**
 - High fish density & nutrient levels, low zooplankton density
- **Other small, shallow ponds, particularly when adjacent to wetlands that seed cyanobacteria**
- **Lakes with residence time < 5 days and frequent seeding from inflows**
- **Some partial-lake applications**
 - High nutrient & seeding rate, leeward side of prevailing wind, photic zone beyond thermocline

SPC is an Ecologically-based, Sustainable Approach to FHAB Suppression

Thank You!

Please Consider Joining the Informal Coalition for Improved FHAB Federal Research & Control Legislation (FHAB ACT)

Now Folded into the HABHRCA Reauthorization

<http://www.FreshwaterHABlegislation.com>

<http://www.CleanWaterAmericaAlliance.org/index.php>

Reservoirs & Treatment

	Crystal Lake	EGL 4	Lake Palmdale
Algaecides Used	No	Yes	Yes
Surface Area (km ²)	0.26	0.47	0.89
Max Depth (m)	7.6	10.7	7.6
Mean Depth (m)	3.0	7.6	5.5
Water Volume (km ³)	7.65x10 ⁻⁴	3.53x10 ⁻³	4.90x10 ⁻³
Water Mean Residence Time (days)	40	270	91
Data Collection Period	March-December 2005-2008	January-December 2001-2007	January-December 2002-2004
SPC Initiation Date	March 2006	April 2003	November 2002
# SPC Units	2	3	6-7 ^a
Surface Area km ² /SPC unit	0.13	0.16	0.15-0.13 ^a
Mean Intake Depth (m)	2.4	6.7-4.3 ^b	4.6
Water Volume Circulated (km ³)	6.1x10 ⁻⁴	3.1x10 ⁻³ -2.0x10 ^{-3b}	4.1x10 ⁻³
Water km ³ Circulated/SPC unit	3.05x10 ⁻⁴	1.04x10 ⁻³ -6.67x10 ^{-47b}	6.82x10 ⁻⁴ -5.85x10 ^{-4a}
SPC Circulation Rate (km ³ /day)	5.5x10 ⁻²	5.5x10 ⁻²	5.5x10 ⁻²
Total Circulation Rate (km ³ /day)	0.11	0.17	0.33-0.39 ^a
Turnover Duration (days) ^c	5.6	19.0-12.2 ^b	12.4-10.6 ^a

^a A seventh SPC unit was installed in June 2003

^b Water intake depths were varied as the reservoir surface elevation and water clarity varied over time

^c The duration required for the SPC units to circulate all the water between the surface and mean intake depths one time

Pre- v During-SPC Data Summary

	Total Algae	Cyanobacteria	Green Algae	Diatoms	Zooplankton
Crystal Pre	86,302_{+13,834}	85,447_{+13,799}	871₊₉₀	NA	NA
Crystal Post	8,668₊₉₇₂	5,161₊₅₂₄	3,665₊₃₈₀	NA	NA
EGL 4 Pre	1,796₊₈₆₂	72₊₄₁	1,534₊₈₅₀	135₊₃₀	NA
EGL 4 Post	306₊₈₇	3.9₊₁	45₊₈	232₊₈₆	NA
Palmdale Pre	4,228₊₈₄₈	426₊₁₄₈	1,528₊₄₂₃	2,216₊₇₆₉	169₊₅₆
Palmdale Post	7,977_{+2,449}	967₊₄₄₆	888₊₂₁₄	4,436_{+2,211}	984₊₂₇₂

Numbers are means + standard errors of the means; NA = not available

Units are cell/mL at Crystal and Palmdale, and units/mL at EGL 4

Bolded values are statistically significant at $p < 0.05$; Between-site comparisons are inappropriate

Algaecides were never used at Crystal, whereas copper sulfate usage declined by 85% at Palmdale and from 1-2/mth to 1-2/yr at EGL 4 after SPC initiation

SPC provides an Ecological Approach to FHAB Suppression