Freshwater Harmful Algal Bloom (FHAB) Suppression through Solar-Powered Circulation (SPC)

H. Kenneth Hudnell[1], Christopher Jones[2], Bo Labesi[3], Vic Lucero[4] and Joseph Eilers[5]

[1] SolarBee, Inc., ; The University of North Carolina at Chapel Hill-Institute for the Environment; US Environmental Protection Agency, Neurotoxicologist, 1984-2007; 105 Serrano Way, Chapel Hill, NC 27517

[2] Des Moines Water Works, 408 Fleur Drive, Des Moines, IA 50321

[3] Palmdale Water District, 2029 E. Avenue Q, Palmdale, CA 93550

[4] City of Thornton, Thornton, CO, 80229

[5] SolarBee, Inc., 1900 NE 3rd St., Suite 106-279, Bend, OR 97701

Society of Environmental Toxicology and Chemistry

New Orleans, Louisiana

November 19-23, 2009

Overview

- **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 *et al.* (in press). Freshwater Harmful Algal Bloom (FHAB) Suppression with Solar-Powered Circulation (SPC). Harmful Algae.

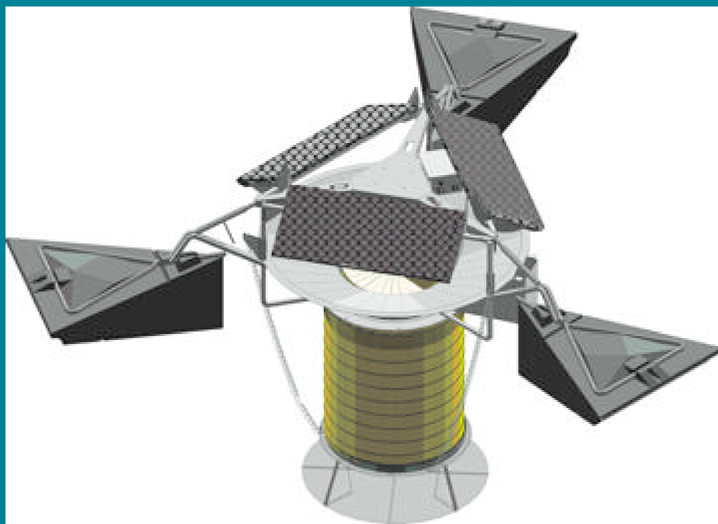
Ecological Approaches to FHAB Suppression

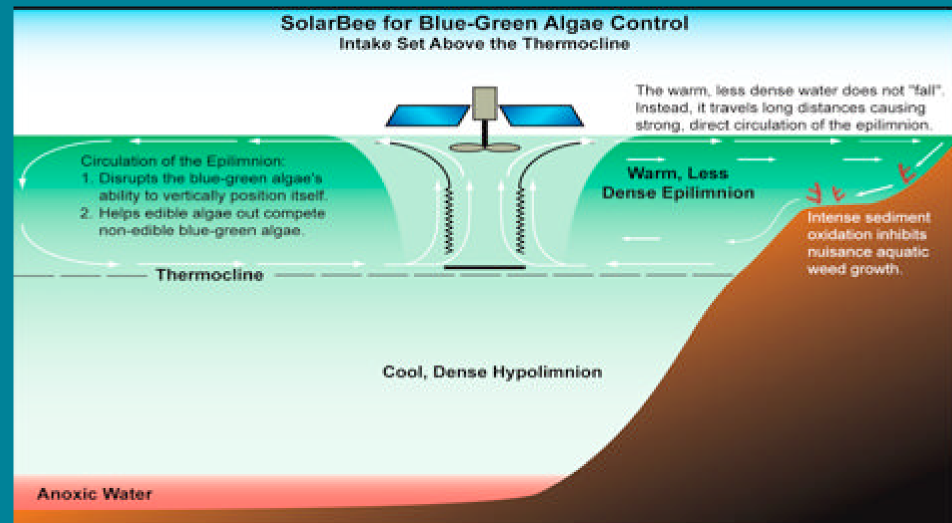
- **Factors that stimulate FHABs**
- **Sunlight**
  - **- Shading suppresses all photosynthetic organisms**
- **Temperature, increasing w/ Global Climate Change**
  - **- No near-term solutions**
- **Nutrient inputs, increasing w/ Global Climate Change**
  - **- Imperative to reduce non-point source runoff**
  - **- Should recapture & recycle nutrients, particularly P**
  - **- Long-term approach to FHAB control**
- **Quiescent or Stagnant waters, increasing w/ GCC**
  - **- Artificial circulation, a near-term, interim solution**
    - **- Solar-Powered Circulation (SPC)**

SolarBee

SPC Units

Only the Epilimnion is Circulated for FHAB Control





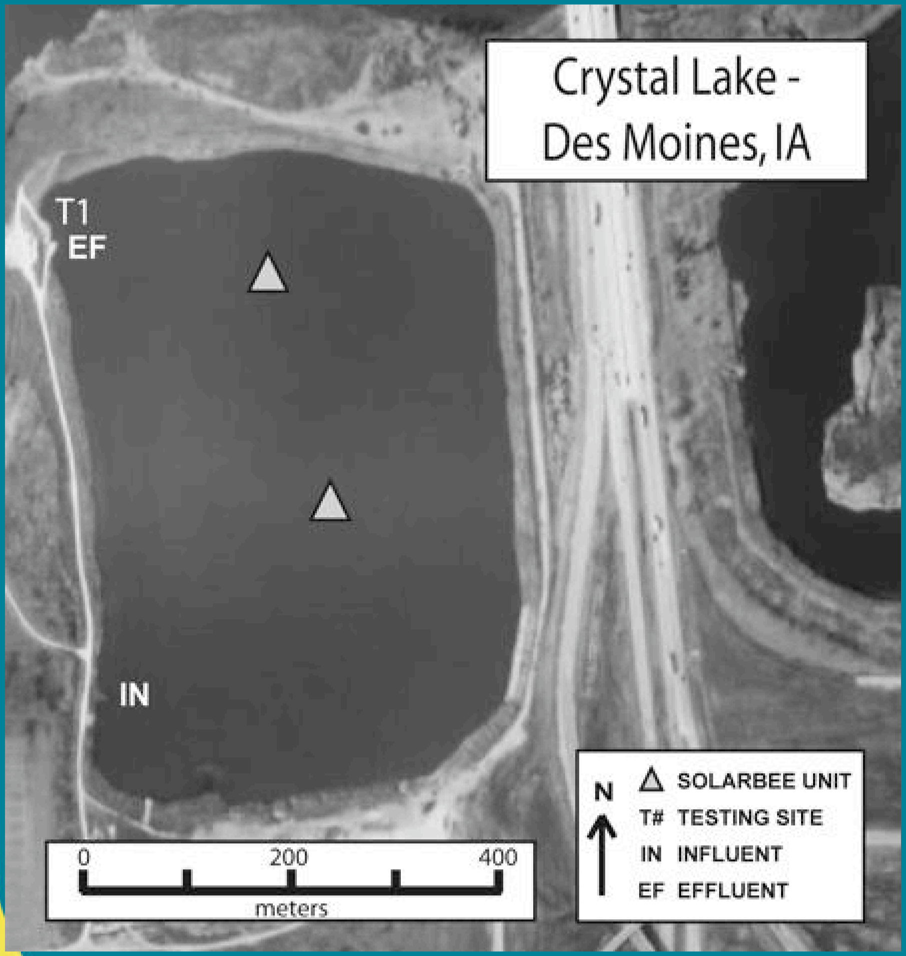
Three 80 watt solar panels; 18 Volt direct-drive motor & battery; Continuous day/night operation at 80 RPM; Near-laminar radial inflow; Non-turbulent outflow at surface; 10,000 GPM upflow, 35 acre spacing

Site Selection

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

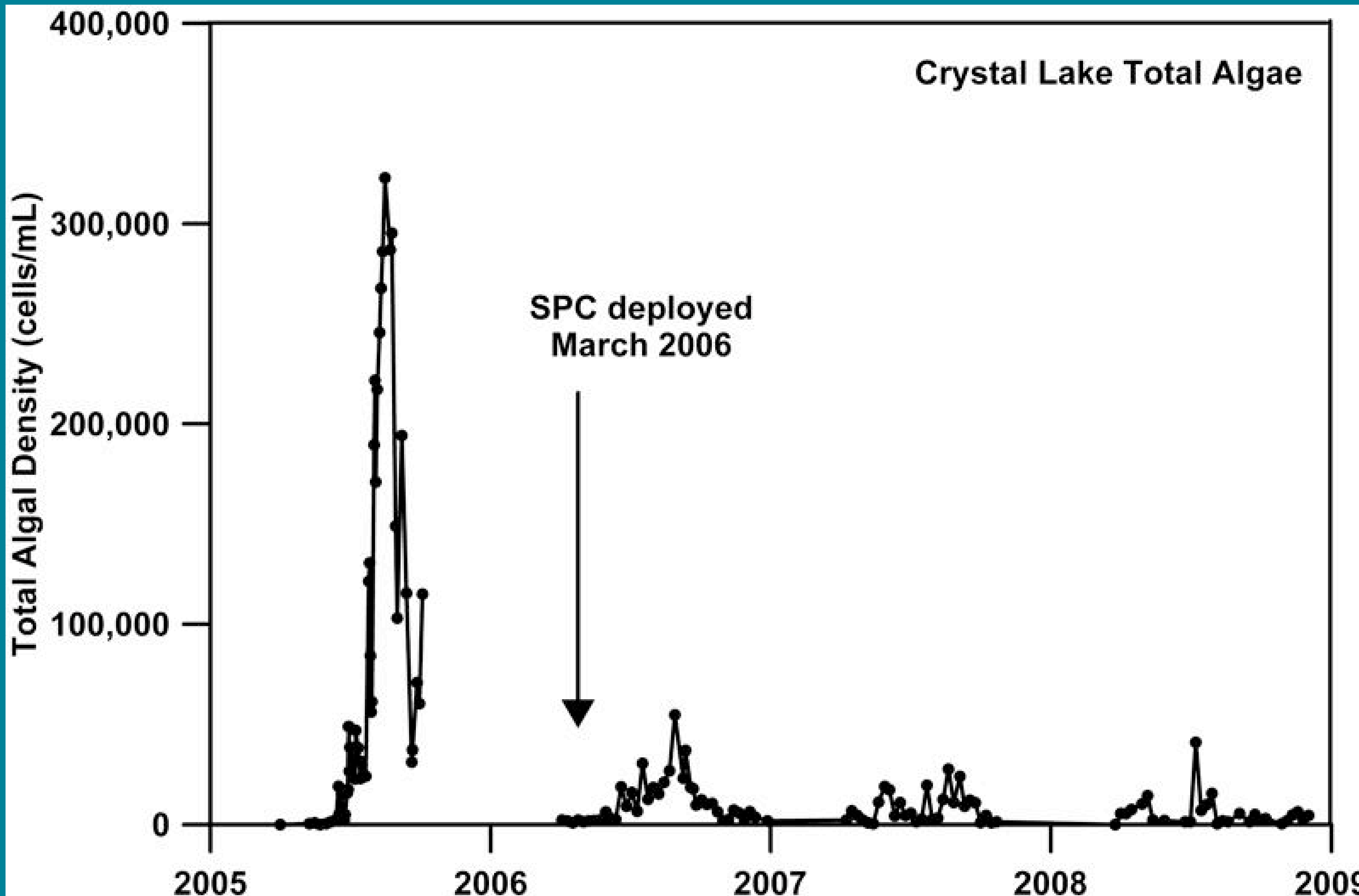
- SPC was deployed for epilimnetic circulation to suppress FHABs
- The whole water body was treated (surface area/SPC unit <16 ha)
- Water body personnel systematically assessed phytoplanktonic density
- Internal analytical methods were validated, standardized and consistent
- Densities of total plankton, 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

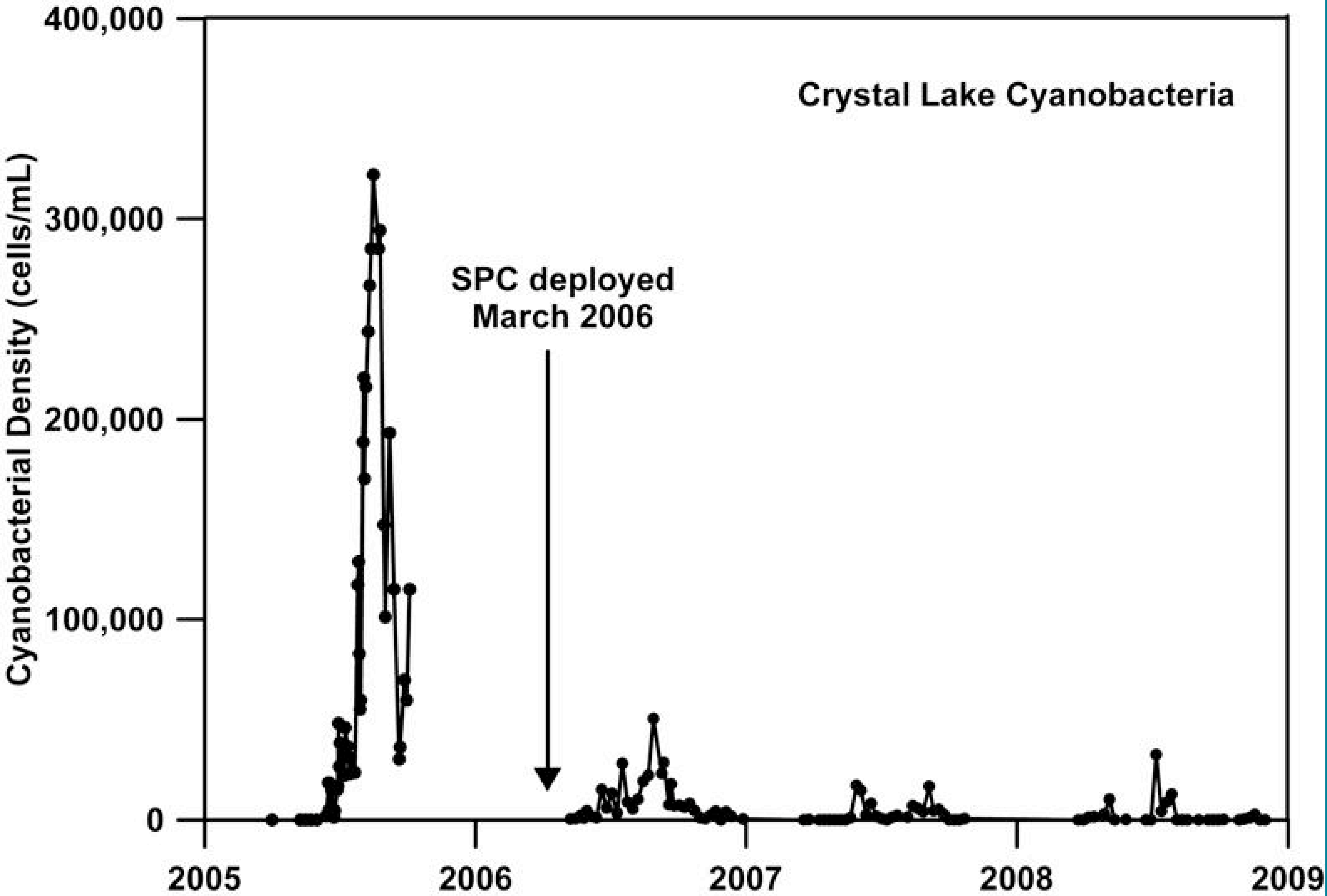


- 63 ac source water
  - 25 maximum depth
  - 10 ft mean depth
  - 7.9 ft SPC mean intake depth
  - 5 MGD mean input from Raccoon River
  - 40 day mean residence time
  - Total N reaches 18 mg/L
  - Total P reaches 8 mg/L
  - River seeds lake with FHAB cells
  - Taste & odor problems
  - Algaecides never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

Crystal Lake Total Algal Densities

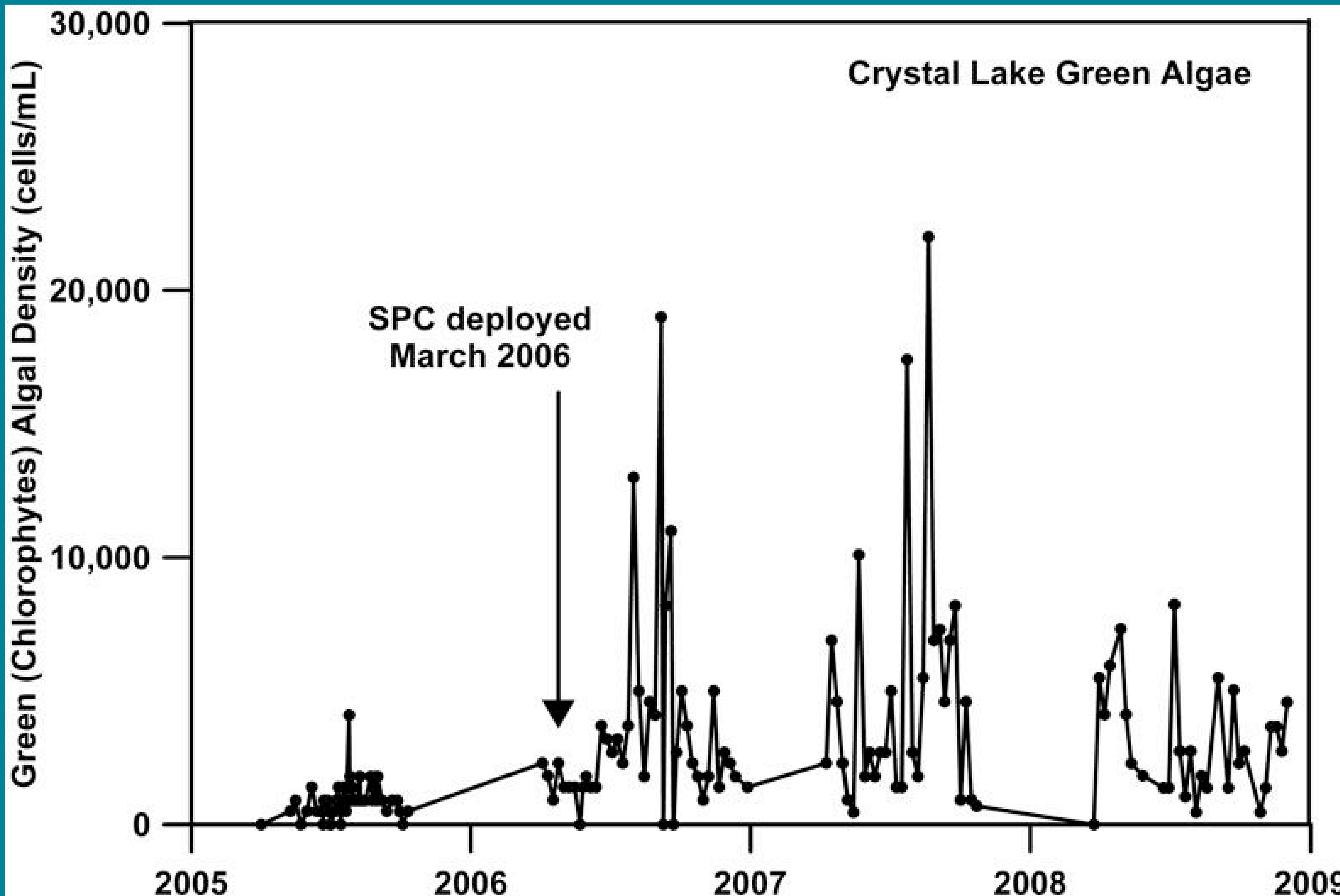


Crystal Lake Cyanobacterial Density



Algaecides never used

Crystal Lake Green Algal Densities



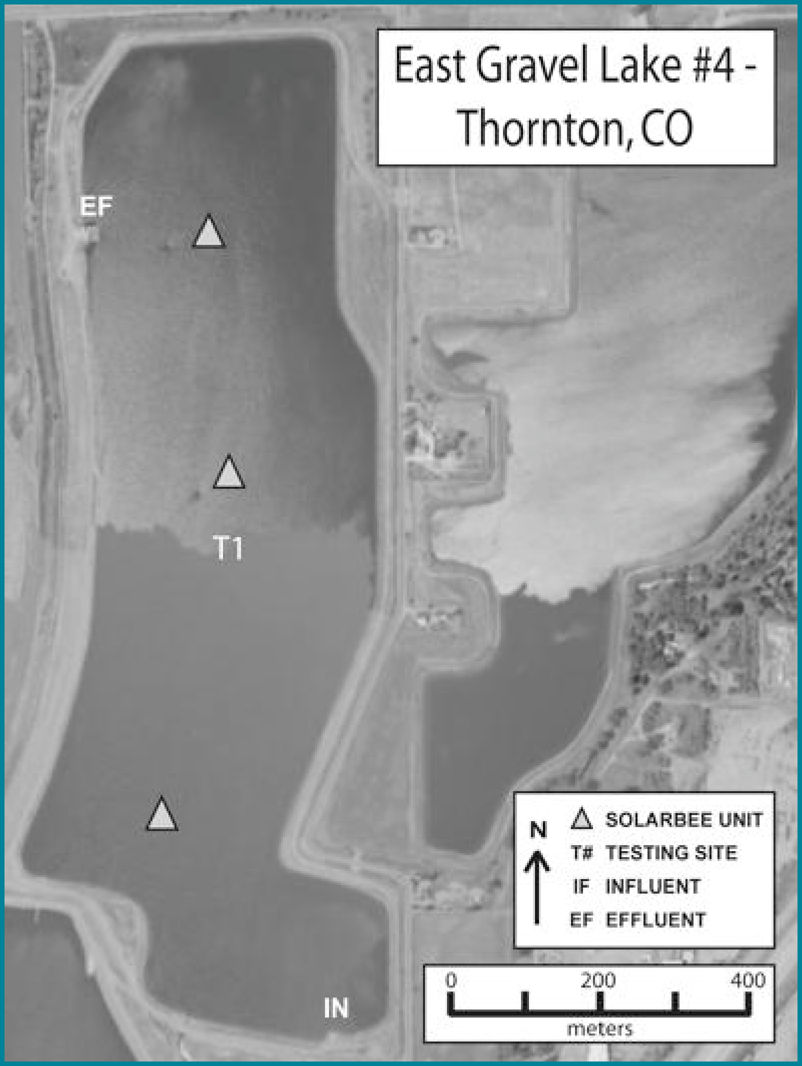
Crystal Lake Data Summary

- 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

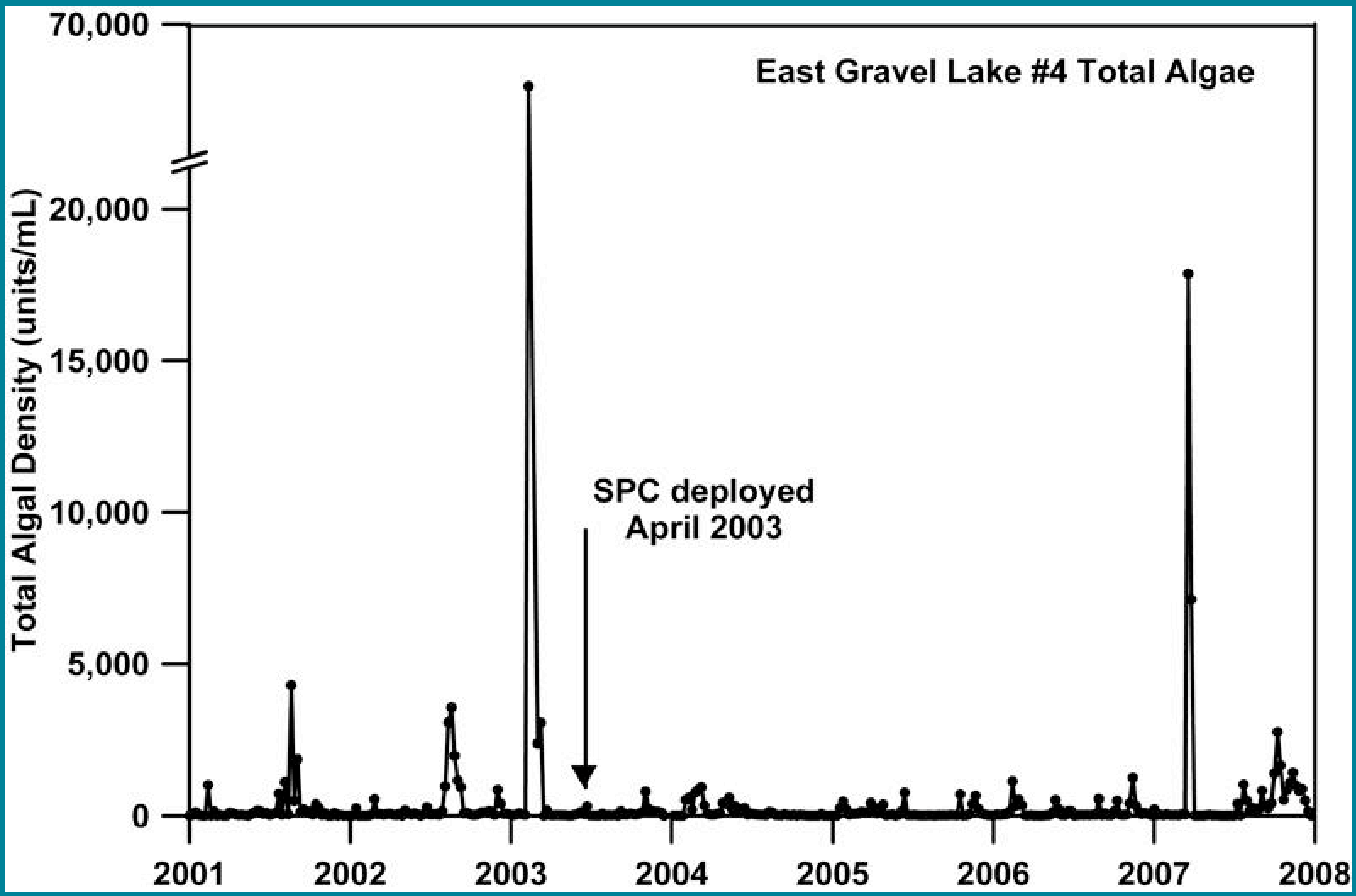
East Gravel Lake 4 (EGL 4)



- 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

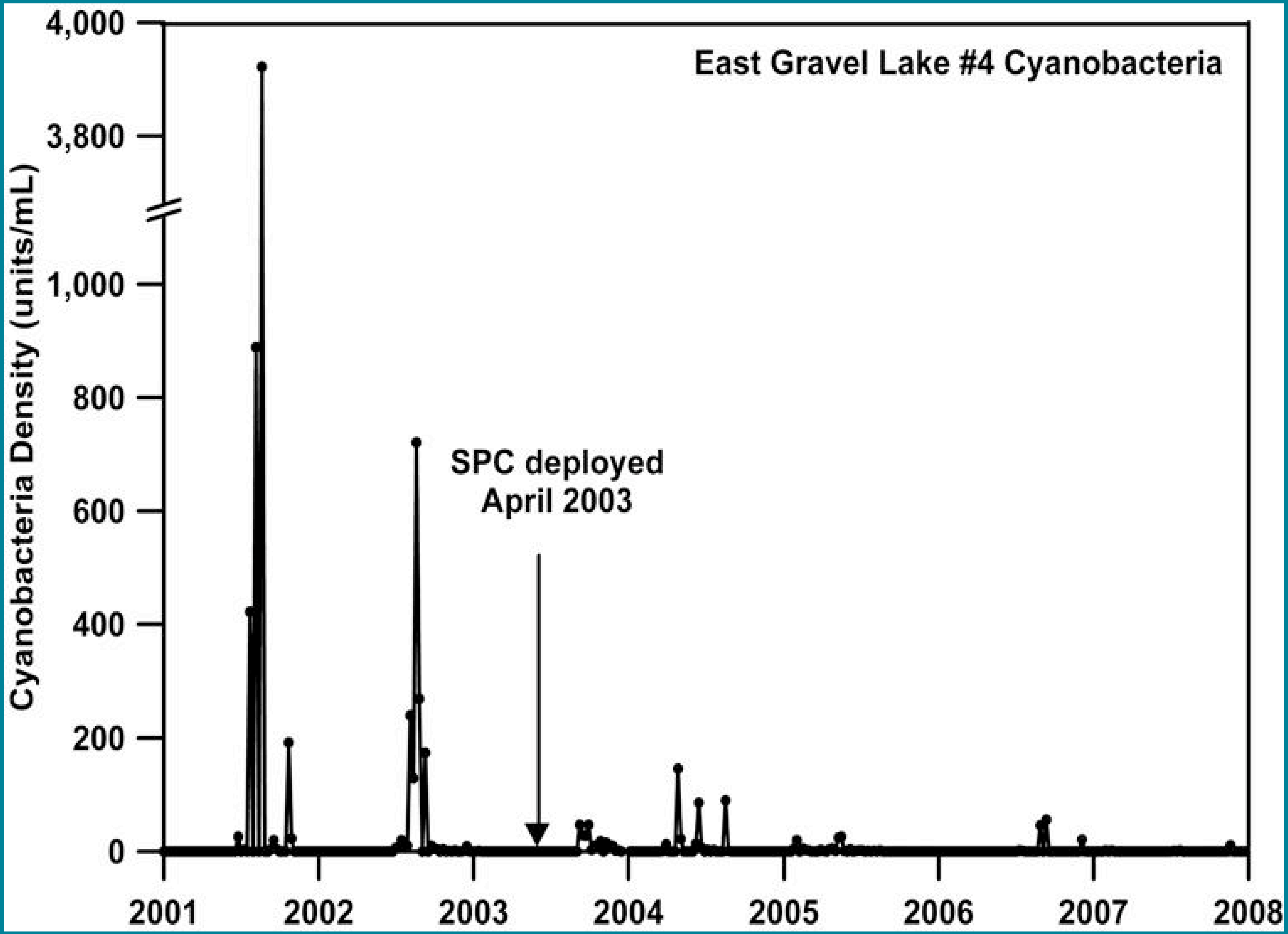
SolarBee

EGL 4 Total Algal Densities



SolarBee

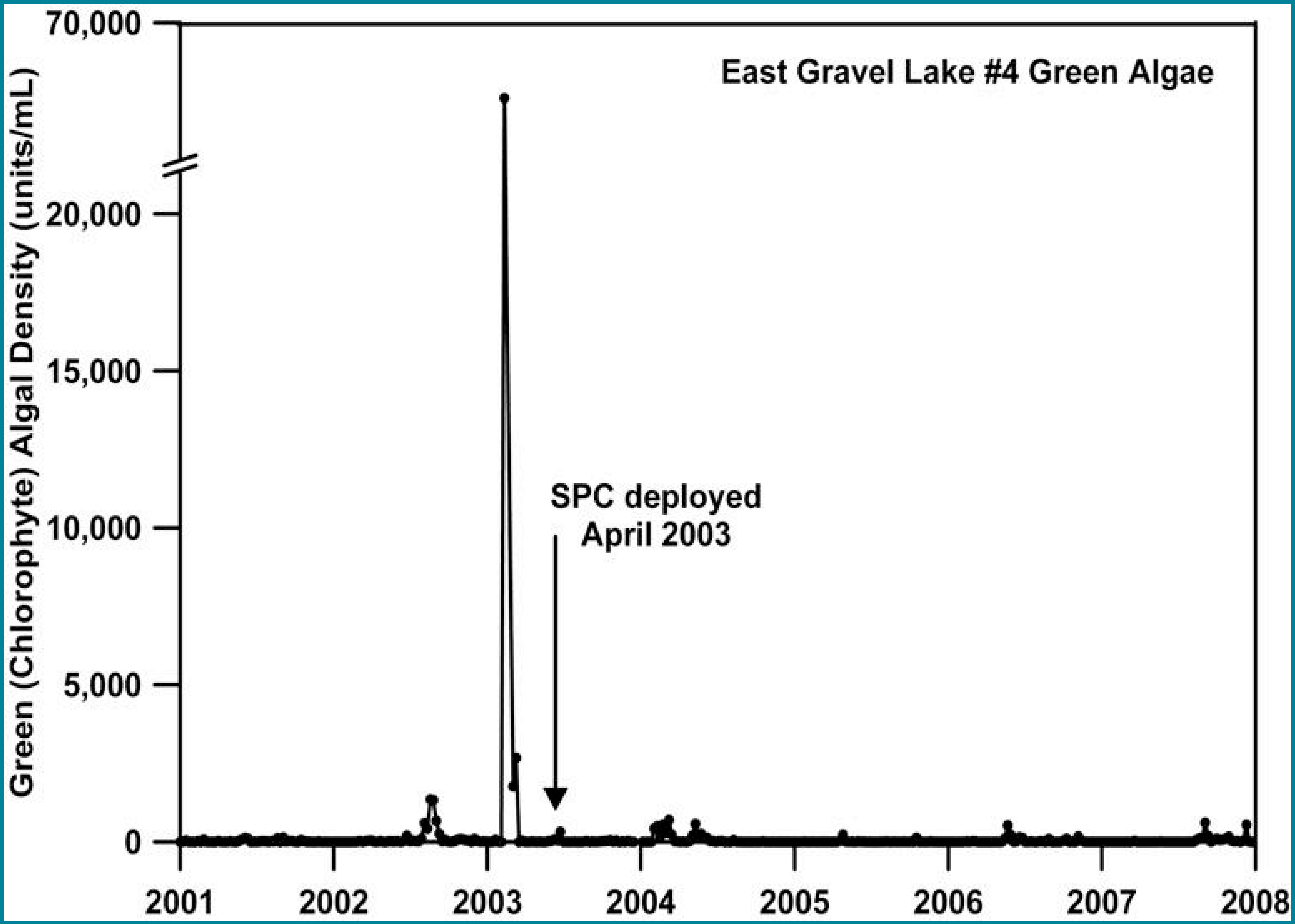
EGL 4 Cyanobacterial Densities



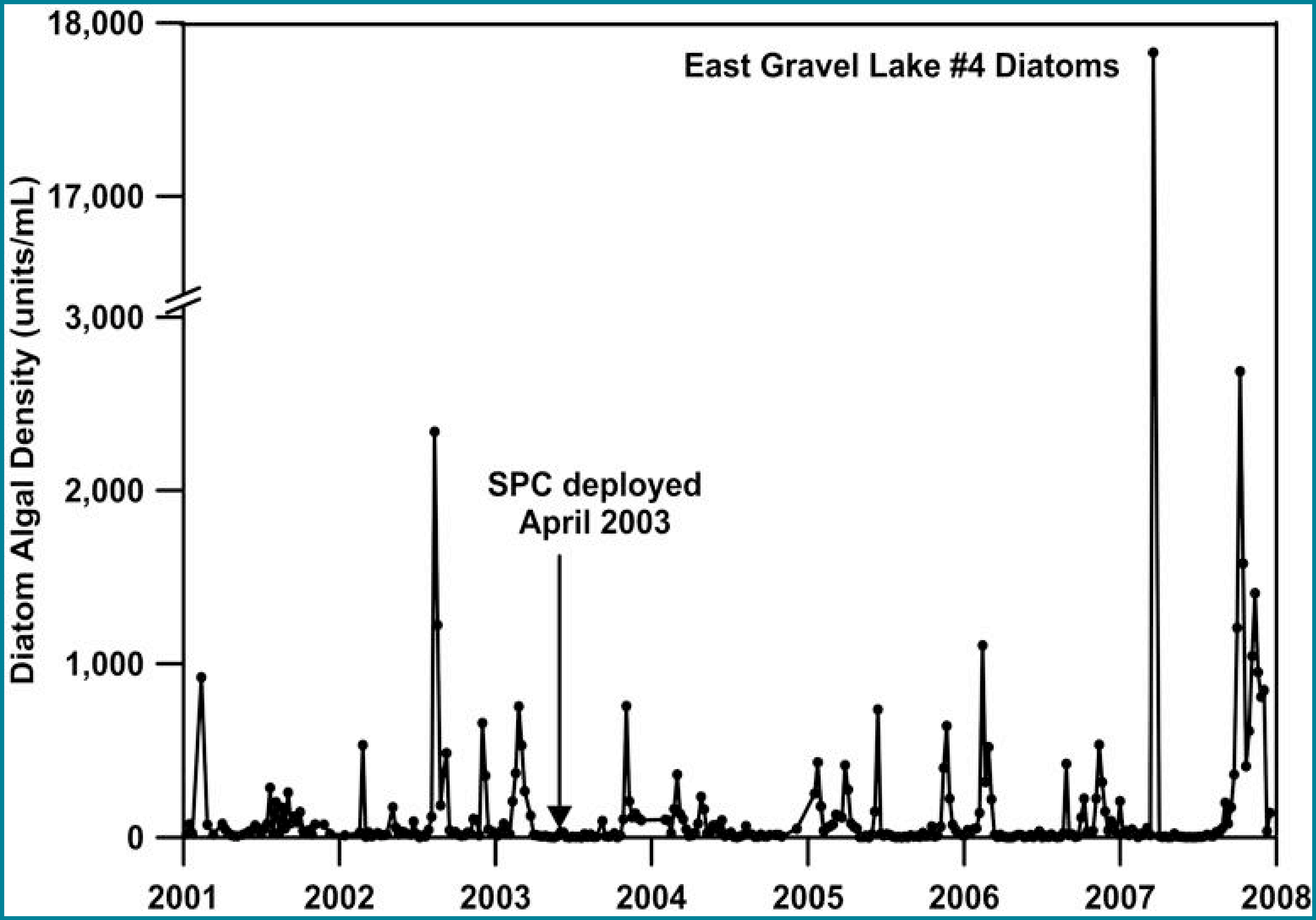
Algaecide usage: 1-2/mth pre- to 1-2/yr during-SPC

SolarBee

EGL 4 Green Algal Densities



EGL 4 Diatom Densities



EGL 4 Data Summary

- **High densities of total algae were dominated by cyanobacteria prior to SPC**

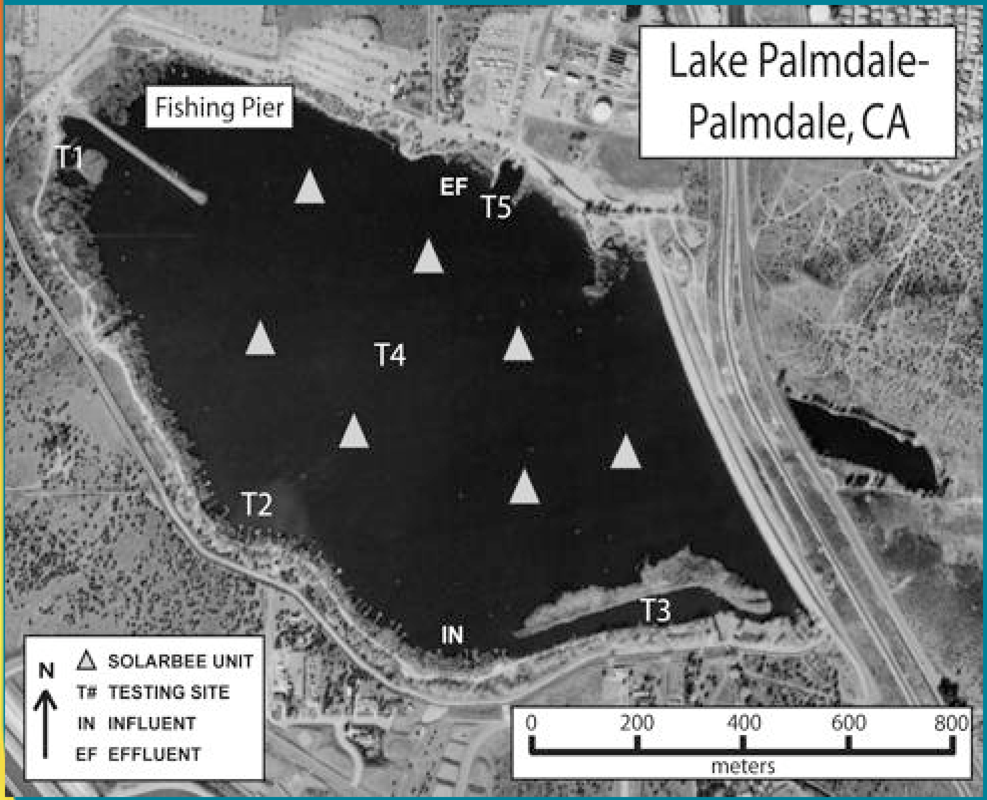
- **Total algal & cyanobacterial densities decreased significantly during SPC**
  - Indication that FHAB suppression strengthened over time

- **Large spike in green algal density just before SPC responsible for significant decrease during SPC**

- **Diatom densities increased significantly during SPC**

  - **Algaecide applications declined from 1-2/mth to 1-2/yr during SPC**

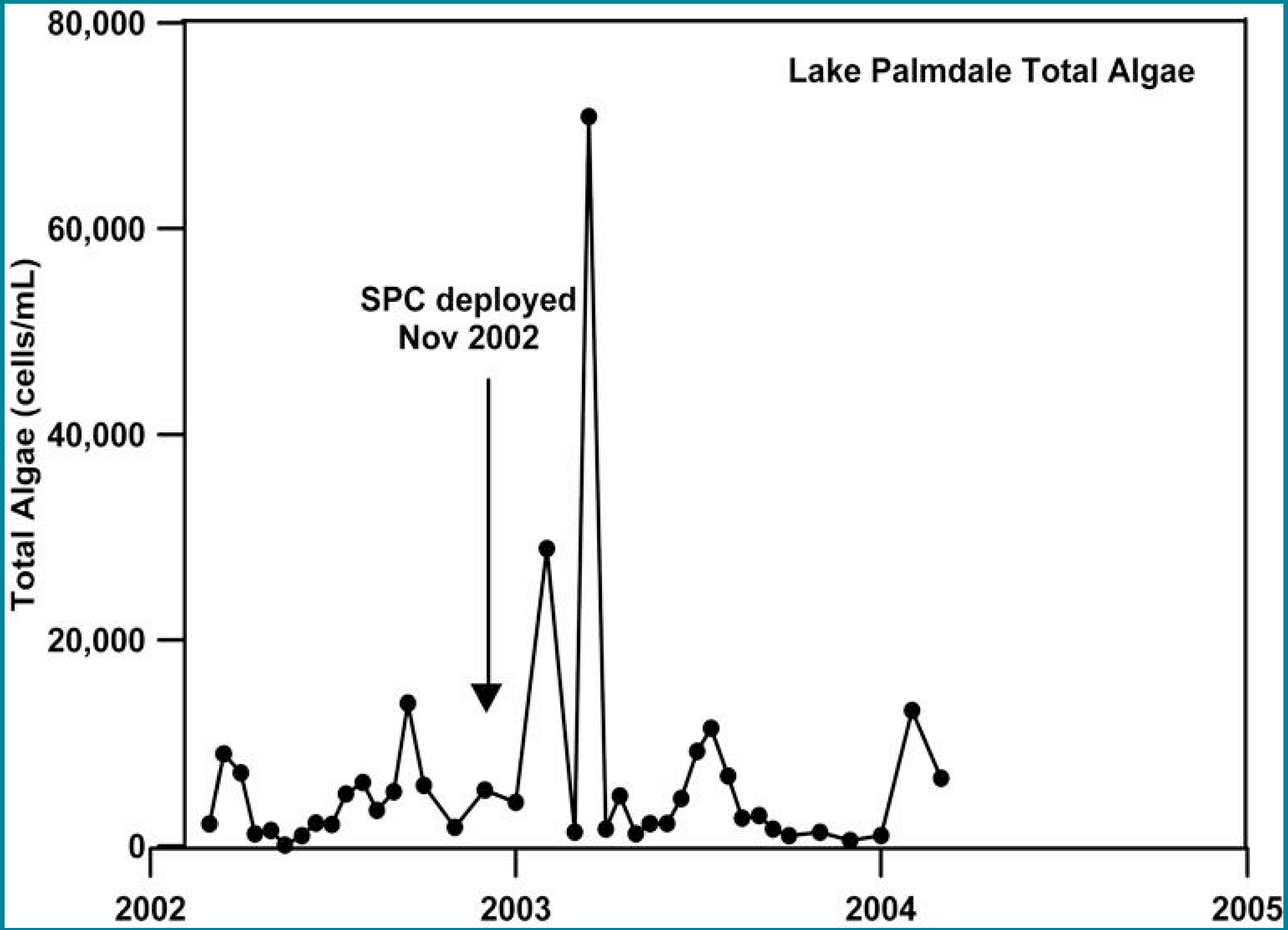
Lake Palmdale



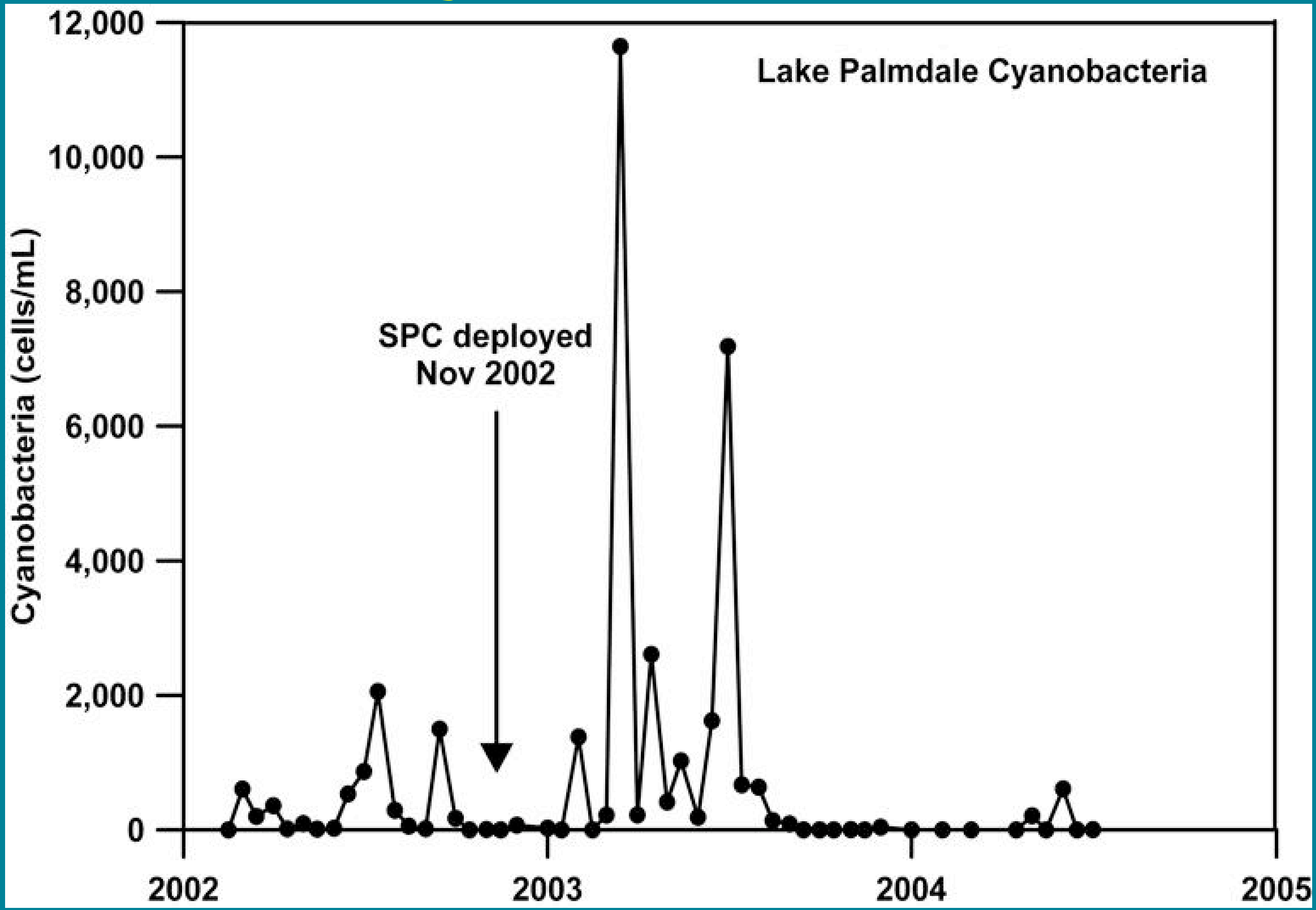
- 234 ac source water
  - 25 maximum depth
  - 18 ft mean depth
  - 15.1 ft mean SPC intake depth
  - 14.2 MGD mean input from California Aqueduct
  - 270 day mean residence time
  - Nitrate reaches 6 mg/L
  - Total P reaches 0.22 mg/L
  - Aqueduct seeds lake with FHAB cells
  - Taste & odor problems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

SolarBee

Lake Palmdale Total Algal Densities

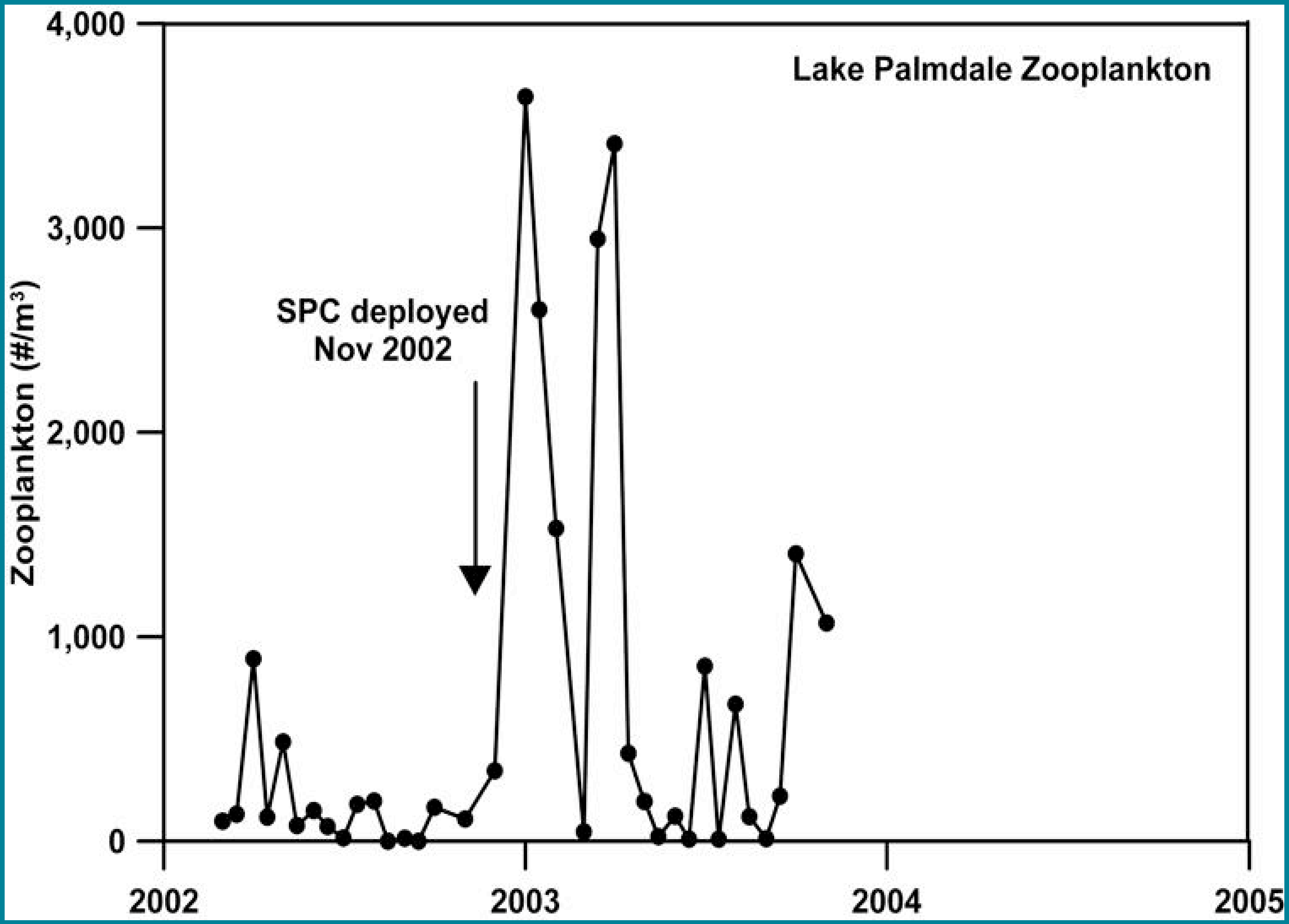


L Palmdale Cyanobacterial Densities



Algaecide usage (lbs/yr): 2002-57,490; 2003-8,647; 2004-8,274; approximately an 85% decrease

Lake Palmdale Zooplankton Density



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

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 $p \leq 0.05$; 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

Possible Mechanisms

- Promotion & distribution of cyanobacterial pathogens
  - Cyanophage (viruses) &/or cell lysing bacteria
- Promotion of beneficial algae & bacteria
  - Higher reproduction rates, limit available nutrients
- Disruption of cyanobacterial buoyancy control
  - non-optimal positioning for light & nutrients
- Promote zooplankton & grazing, other

May be multifactorial

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

Thank You!

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

http://www.FreshwaterHABlegislation.com

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)	$6.1x10^{-4}$	$3.1x10^{-3}$-$2.0x10^{-3}$[b]	$4.1x10^{-3}$
Water km^3 Circulated/SPC unit	$3.05x10^{-4}$	$1.04x10^{-3}$-$6.67x10^{-4}$7[b]	$6.82x10^{-4}$-$5.85x10^{-4}$[a]
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