Improving Wastewater Oxygenation & Mixing Efficiency with Solar Powered Circulation

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American Academy of Sciences
The Fifth International Conference on Environmental Science and Technology
Hilton Hotel, Houston, Texas, USA - July 12-16, 2010

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Overview

- The problem - mixing with aeration is inefficient
- U.S. EPA preliminary data
- The current study
  - The NHDES directed a 3 site study on Solar Powered Circulation (SPC) to reduce or eliminate the need for aeration to mix & oxygenate wastewater
  - Data collected 1 year pre-SPC & 2 years during-SPC
  - Effluent water quality, odor events, sludge buildup
- No pre- versus during-SPC water quality differences
- 37.5-88.5% drop in power use; 1.9-3.7 year payback

Journal submission:

A paper using these data and *entitled, Improving Wastewater Mixing and Oxygenation Efficiency with Solar Powered Circulation (SPC),* will be submitted for peer review to the journal, *Clean Technology & Environmental Policy,* immediately after this meeting

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The Problem

- Most wastewater treatment plants require mixing & oxygenation to increase organic-matter digestion rates
- WWTPs typically use grid-powered mechanical aerators to both mix & oxygenate the wastewater
- Mixing usually requires much more aeration than oxygenation
- This imbalance creates an operational inefficiency
  - Excessive grid-power consumption & expenditure
  - Increased greenhouse gas emissions

Preliminary Data

EPA United States Environmental Protection Agency

Auxiliary and Supplemental Power Fact Sheet: Solar Power

EPA 832-F-05-011, Office of Water, March 2005, Revised October 2007

- **Reviewed information from 4 WWTPs using SPC**
- **Concluded benefits include energy savings, & reduced odor, greenhouse gas emissions & biosolids**

Current Study

- Directed by the New Hampshire Department of Public Services

- Goal - Increase operational efficiency (reduce cost)

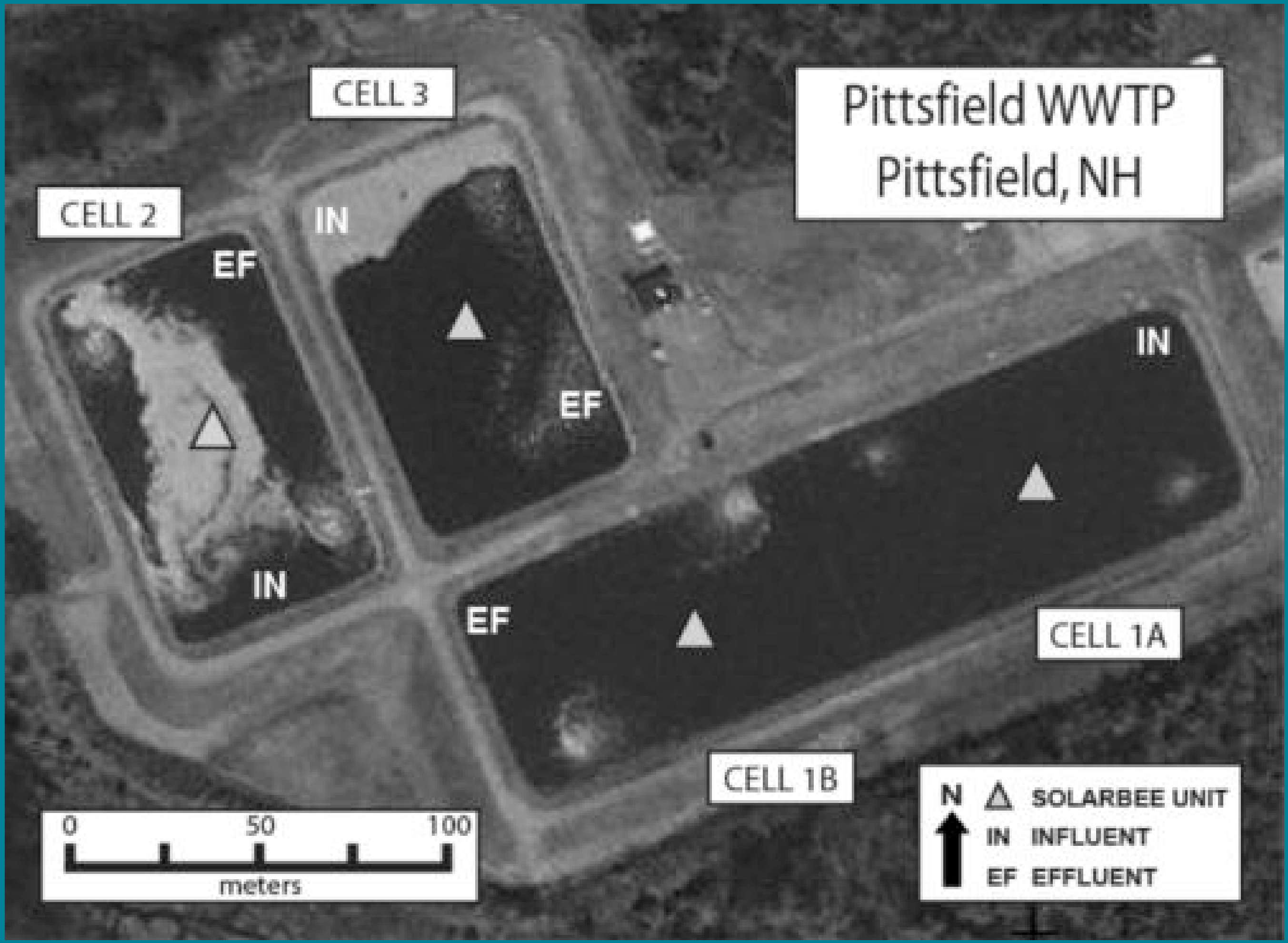
- Objectives
  - Reduce or eliminate grid-powered aeration
  - Maintain or improve effluent water quality

- Data collected by personnel at 3 NH WWTPs 1 year before and 2 years during SPC
  - Flow rate, total suspended solids (TSS), biochemical oxygen demand (BOD), ammonia, nitrate, odor, sludge
  - Electric grid power consumption & expenditures

Study Sites - Pittsfield, NH

<u>Pre-SPC</u>

Lagoons with 65 kW fine bubble blower system

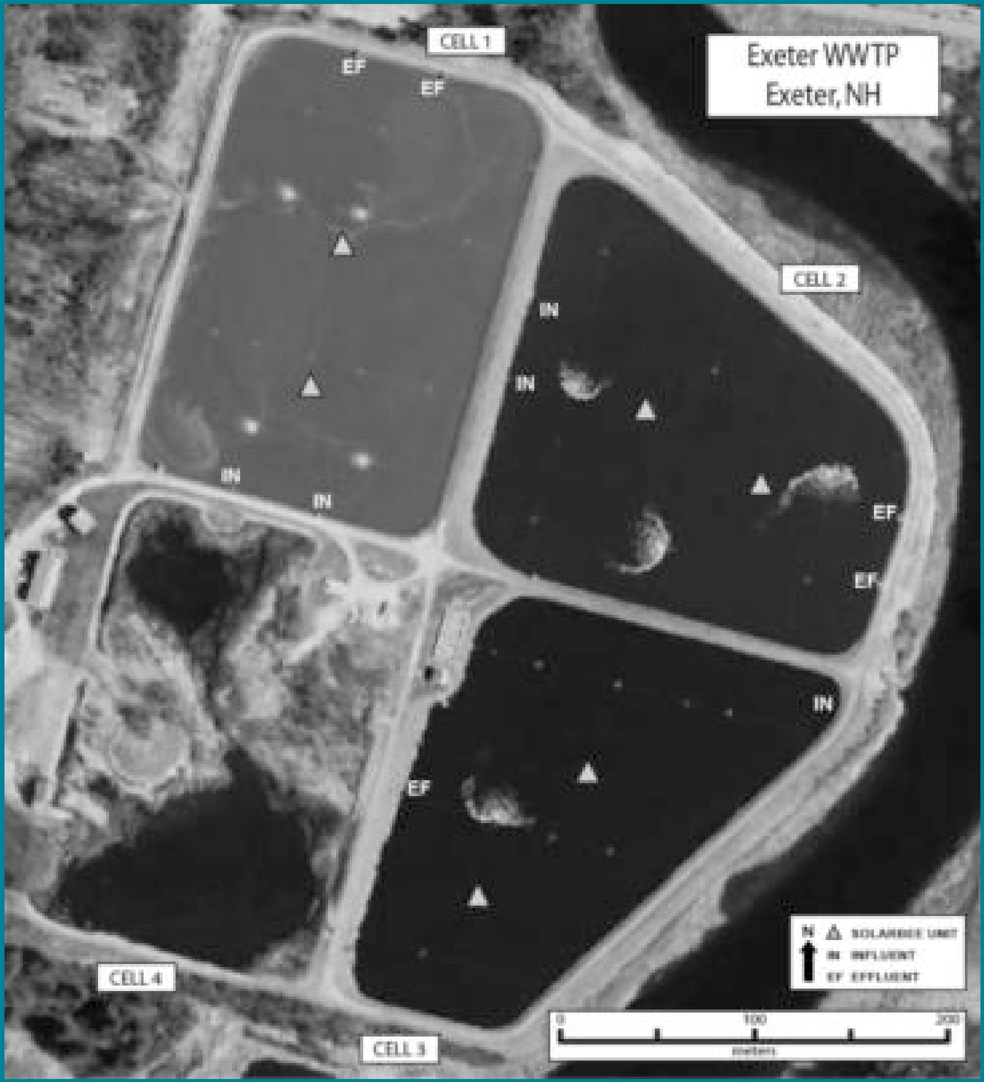


Secondary treatment plant using aerated lagoons

Study Sites - Exeter, NH

Pre-SPC

Lagoons with 272 kW fine bubble blower system



Secondary treatment plant using aerated lagoons

Study Sites - Rochester, NH

Pre-SPC

Lagoons with 116 kW fine bubble blower system

During-SPC

Converted to equalization basins also receiving sludge, raw septage, backwash & raw sewage

Activated sludge, advanced tertiary-treatment plant

Table 1. Location, Cell & Treatment Parameters

	Exeter			Pittsfield				Rochester	
	Cell 1	Cell 2	Cell 3	Cell 1a	Cell 1b	Cell 2	Cell 3	Cell 1	Cell 2
Surface Area (km^2)	0.036	0.034	0.034	0.0054	0.0054	0.0053	0.0053	0.046	0.028
Operating Depth (m)	2.59	2.59	2.59	3.35	3.35	3.35	3.35	2.13	2.13
Operating Volume (km^3)	$6.19x10^{-5}$	$5.87x10^{-5}$	$5.12x10^{-5}$	$1.17x10^{-5}$	$1.17x10^{-5}$	$1.16x10^{-5}$	$1.16x10^{-5}$	$6.86x10^{-7}$	$4.17x10^{-7}$
Influent Depth (m)[a]	1.22	V[a]	V[a]	3.25	3.25	3.25	3.25	1.52	1.52
Effluent Depth (m)[a]	1.52	1.2	1.2	3.00	3.00	3.00	3.00	V[b]	V[b]
Discharge Method[a]	C	C	C	C	C	C	C	C/I[c]	C/I[c]
Detention Time (days)	8.2	7.8	6.8	6.16	6.16	6.12	6.12	47	47
# SPC Units	2	2	2	1	1	1[d]	1[d]	3	2
Surface Area km^2/SPC unit	0.018	0.017	0.017	0.0054	0.0054	0.0053	0.0053	0.015	0.014
Mean Intake Depth (m)	1.37	1.52	1.52	1.21	1.12	0.76	1.5	0.61	0.61
Water Volume Circulated (km^3)	$3.27x10^{-5}$	$3.44x10^{-5}$	$3.00x10^{-5}$	$4.23x10^{-6}$	$3.91x10^{-6}$	$2.65x10^{-6}$	$5.19x10^{-6}$	$3.23x10^{-7}$	$4.18x10^{-8}$
Water km^3 Circulated/SPC unit (km^3)	$1.64x10^{-5}$	$1.72x10^{-5}$	$1.50x10^{-5}$	$4.23x10^{-6}$	$3.91x10^{-6}$	$2.65x10^{-6}$	$5.19x10^{-6}$	$1.39x10^{-8}$	$2.08x10^{-8}$
SPC Circulation Rate (km^3/day)	$5.5x10^{-5}$	$5.5x10^{-5}$	$5.5x10^{-5}$	$5.5x10^{-5}$	$5.5x10^{-5}$	$1.36x10^{-5}$	$1.36x10^{-5}$	$5.5x10^{-5}$	$5.5x10^{-5}$
Total Circulation Rate (km^3/day)	$1.1x10^{-4}$	$1.1x10^{-4}$	$1.1x10^{-4}$	$5.5x10^{-5}$	$5.5x10^{-5}$	$1.36x10^{-5}$	$1.36x10^{-5}$	$1.65x10^{-4}$	$1.1x10^{-4}$
Turnover Duration (days)[e]	0.30	0.31	0.27	0.08	0.07	0.19	0.38	0.003	0.0004

C=Continuous, I=Intermittent, NA=Not Available, V=Variable

[a] Weir gate – 0.61-3.0 m from bottom

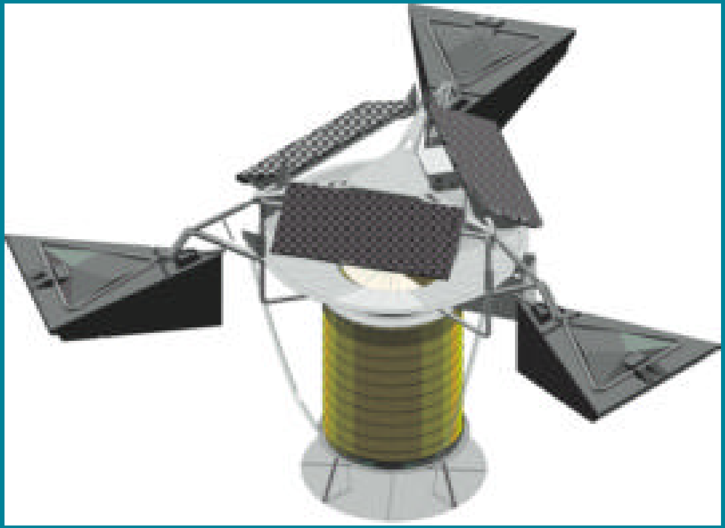
[b] 3 sluice gate – top 0.61-1.52 m, middle 1.52-2.44 m, bottom 2.44-3.52 m from surface

[c] Spring & fall continuous at 3,271 m^3/d, Winter & summer intermittent at mean 818 m^3/d

[d]All SPC units were SB10000 models except SB2500 models indicated by a superscript d

[e] The duration required for the SPC units to circulate all the water between the surface and mean intake depth one time

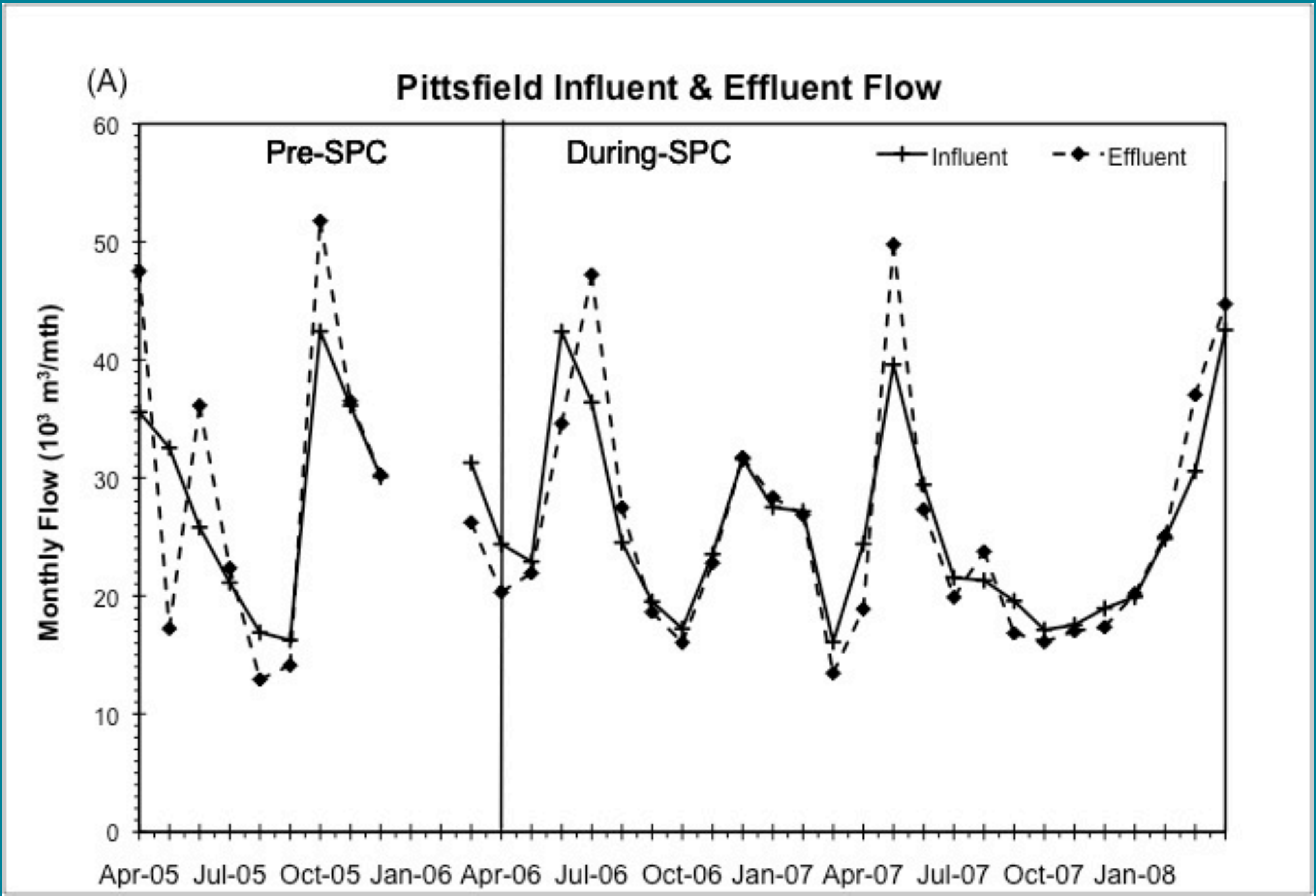
Solar Powered Circulation



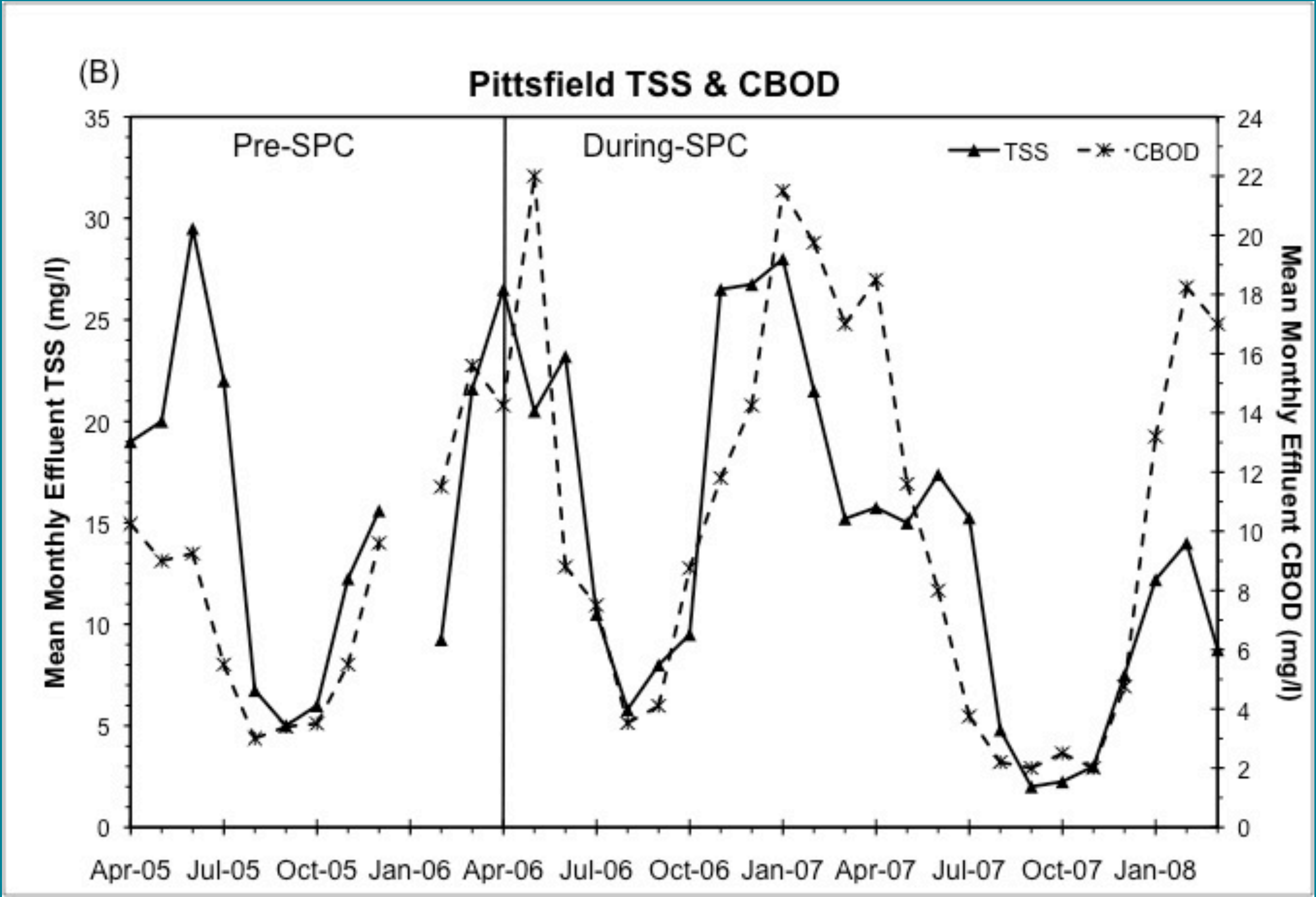
Pittsfield site

- 316 Stainless steel construction
- Three foam filled HDPE pontoons
- Two HDPE coated concrete mooring blocks
- Three 80 watt solar panels
- 18 Volt direct-drive motor & battery
- Continuous day/night operation at 80 RPM
- 3 ft diameter thermoplastic rubber intake hose, length adjustable
- Stainless plate suspended 1 ft below hose intake
- Near-laminar radial inflow
- 10,000 GPM upflow
- Non-turbulent outflow at surface

Pittsfield - Flow Rate



Pittsfield - TSS & CBOD



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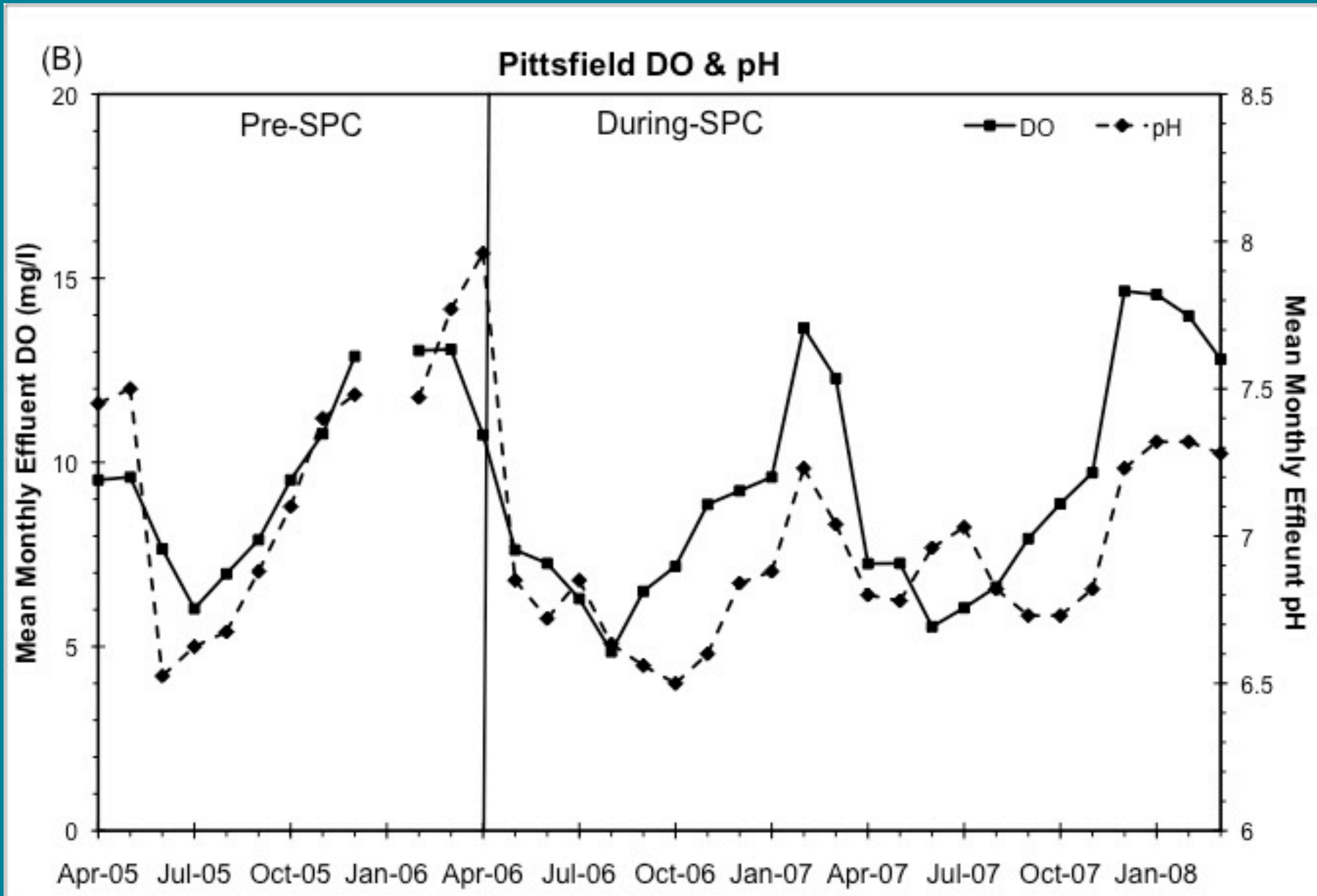
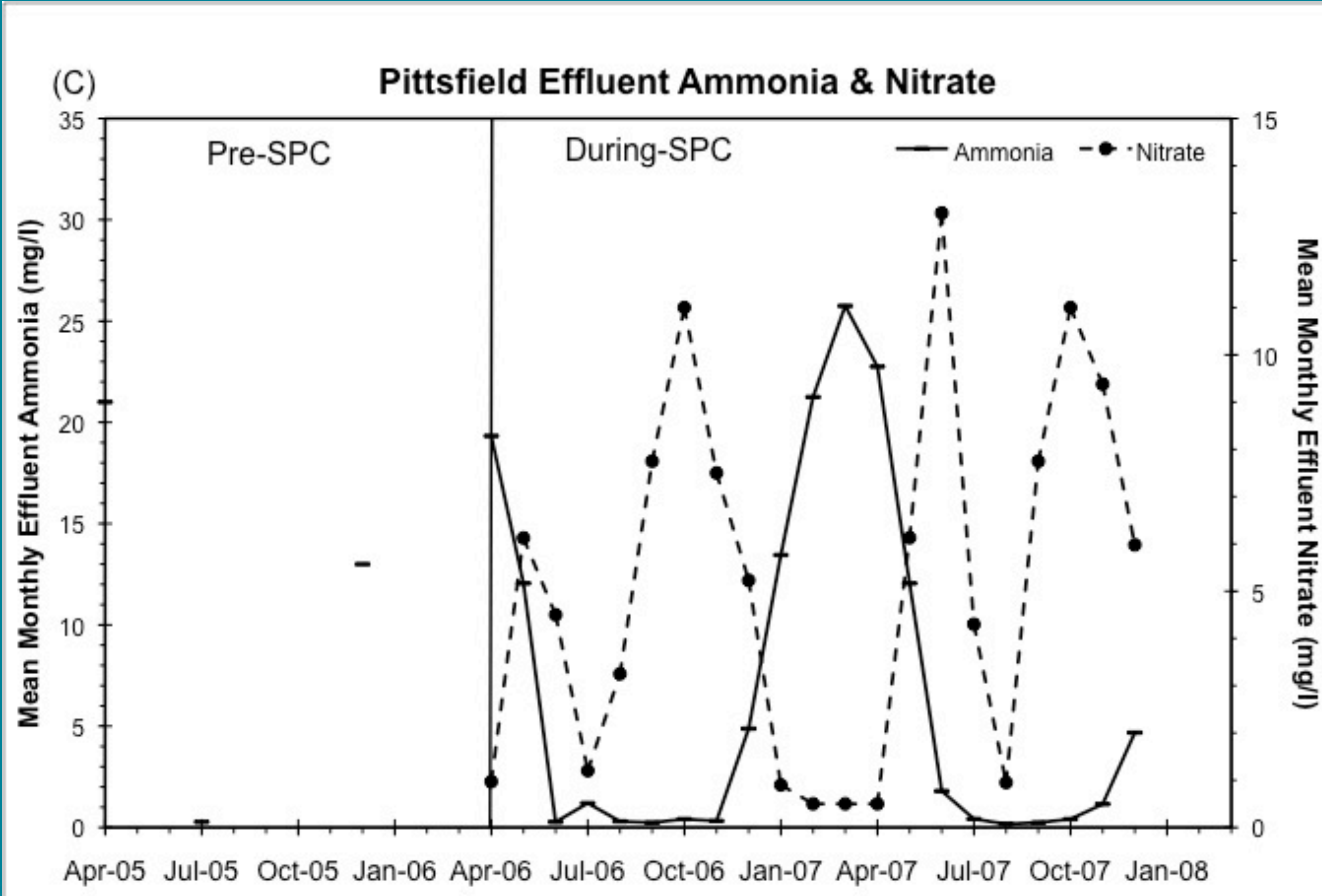
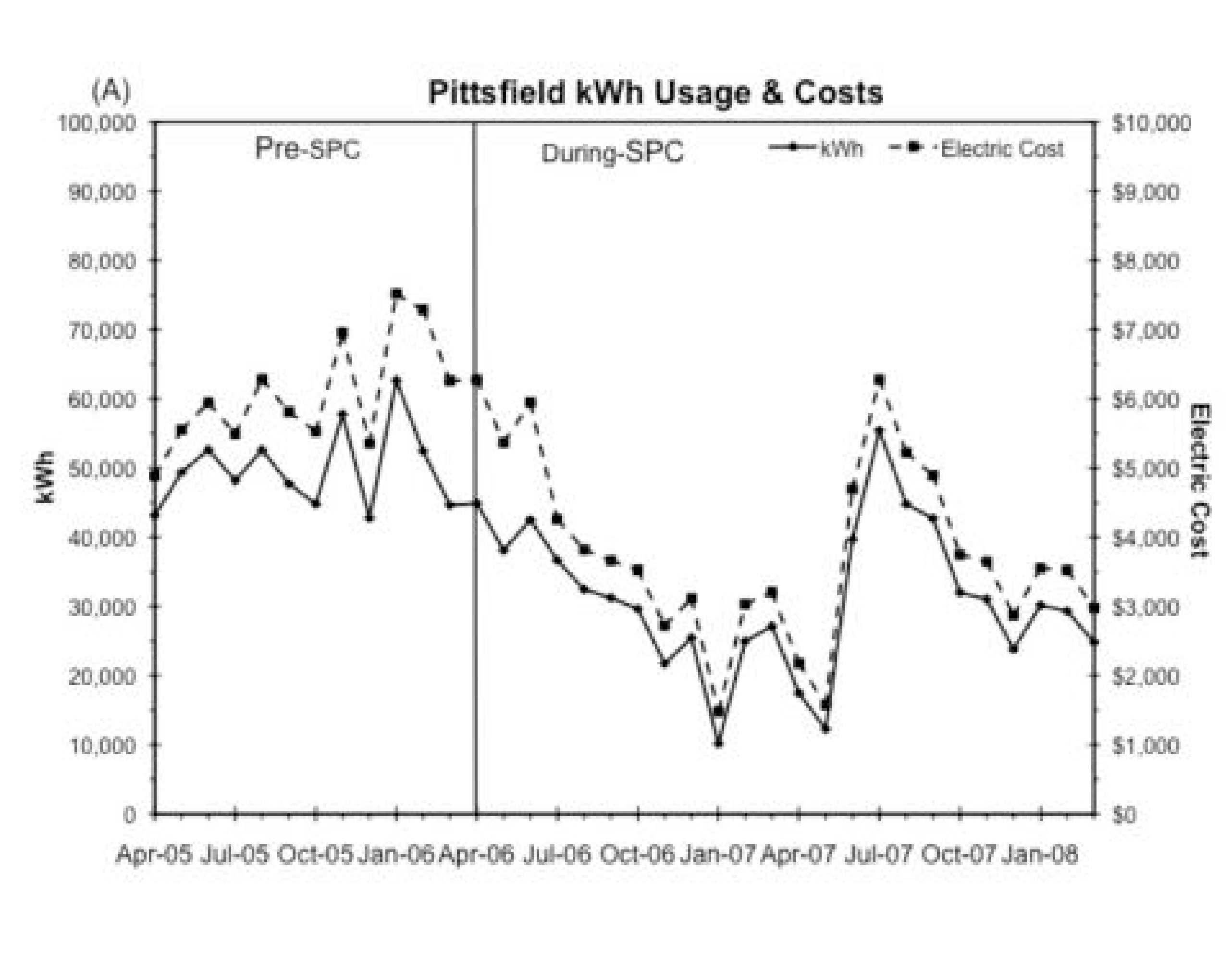
Pittsfield - DO & pH



Pittsfield - Ammonia & Nitrate



Pittsfield - kWh Usage & Cost



Reductions during SPC

kWh = 18,712/mth
=224,540/yr
= 37.5%

Cost = $2,256/mth
=$27,068/yr
= 37.2%

Pay back period
= 3.7 yrs

All 3 Sites

- No NPDES violations occurred during SPC
- No odor events during SPC
  - Maintaining 1-2 mg/l DO in the top 0.5-1 m oxidized toxic hydrogen sulfide to odorless sulfate
- Little or no sludge accumulation during 2 years of SPC
  - CO_2, acids, alcohols & then CH_4 are formed & emitted to air during sludge digestion. SPC stimulates green algae that consume CO_2 during photosynthesis, increasing pH and improving the function of CH_4 forming anaerobic bacteria in the sludge & slurry.
  - SPC eliminated the neuston layer of lipids & proteins, increasing CH_4 & CO_2 emissions

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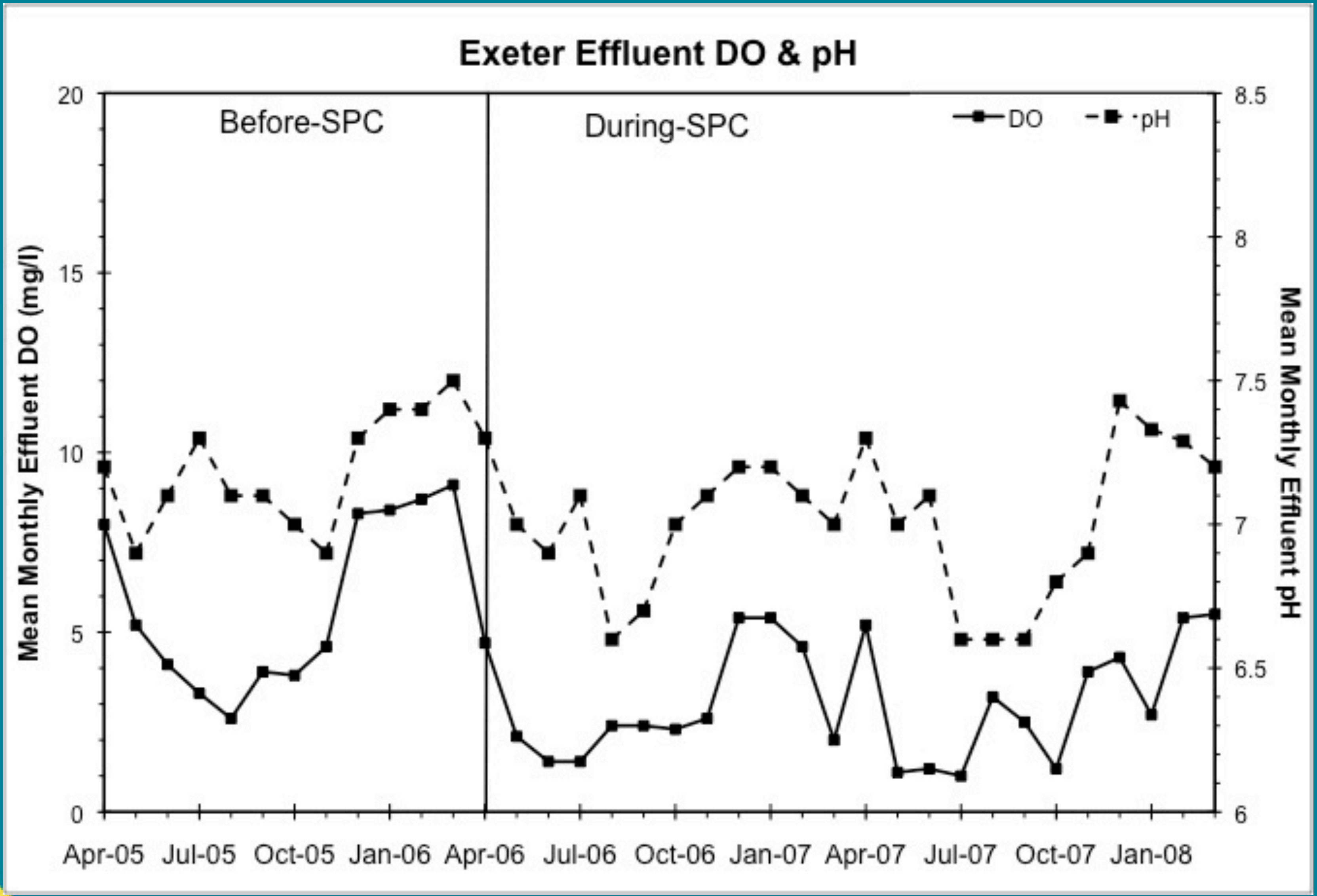
Exeter Results

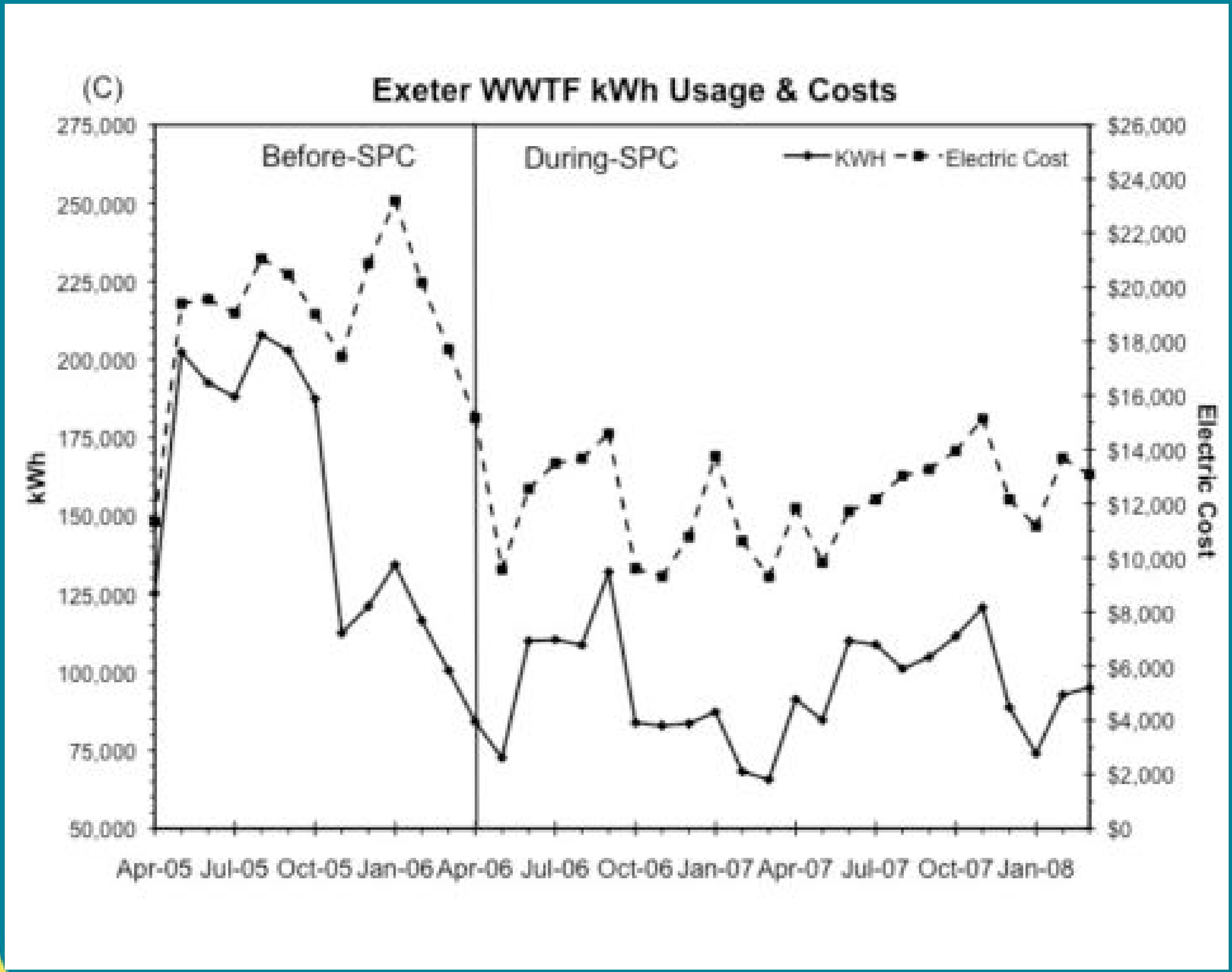
- **No statistically significant differences between Pre-SPC & During-SPC study periods in the following parameters (During-SPC mean values shown)**
- **Effluent flow rate (60.6±21.2 x 10^3 m^3/mth)**
- **TSS (12.7± mg/l)**
- **BOD (12.0±4.7 mg/l)**
- **pH (7.2±0.2 su)**
- **Ammonia (9.9±4.9 mg/l)**
- **Nitrate not measured**

Exeter DO



Exeter Effluent DO & pH
Before-SPC
During-SPC
DO
pH
Mean Monthly Effluent DO (mg/l)
Mean Monthly Effluent pH
20
15
10
5
0
8.5
8
7.5
7
6.5
6
Apr-05 Jul-05 Oct-05 Jan-06 Apr-06 Jul-06 Oct-06 Jan-07 Apr-07 Jul-07 Oct-07 Jan-08

Exeter - kWh Usage & Cost



<u>Reductions during SPC</u>

kWh = 62,896/mth
=754,753/yr
= 40.0%

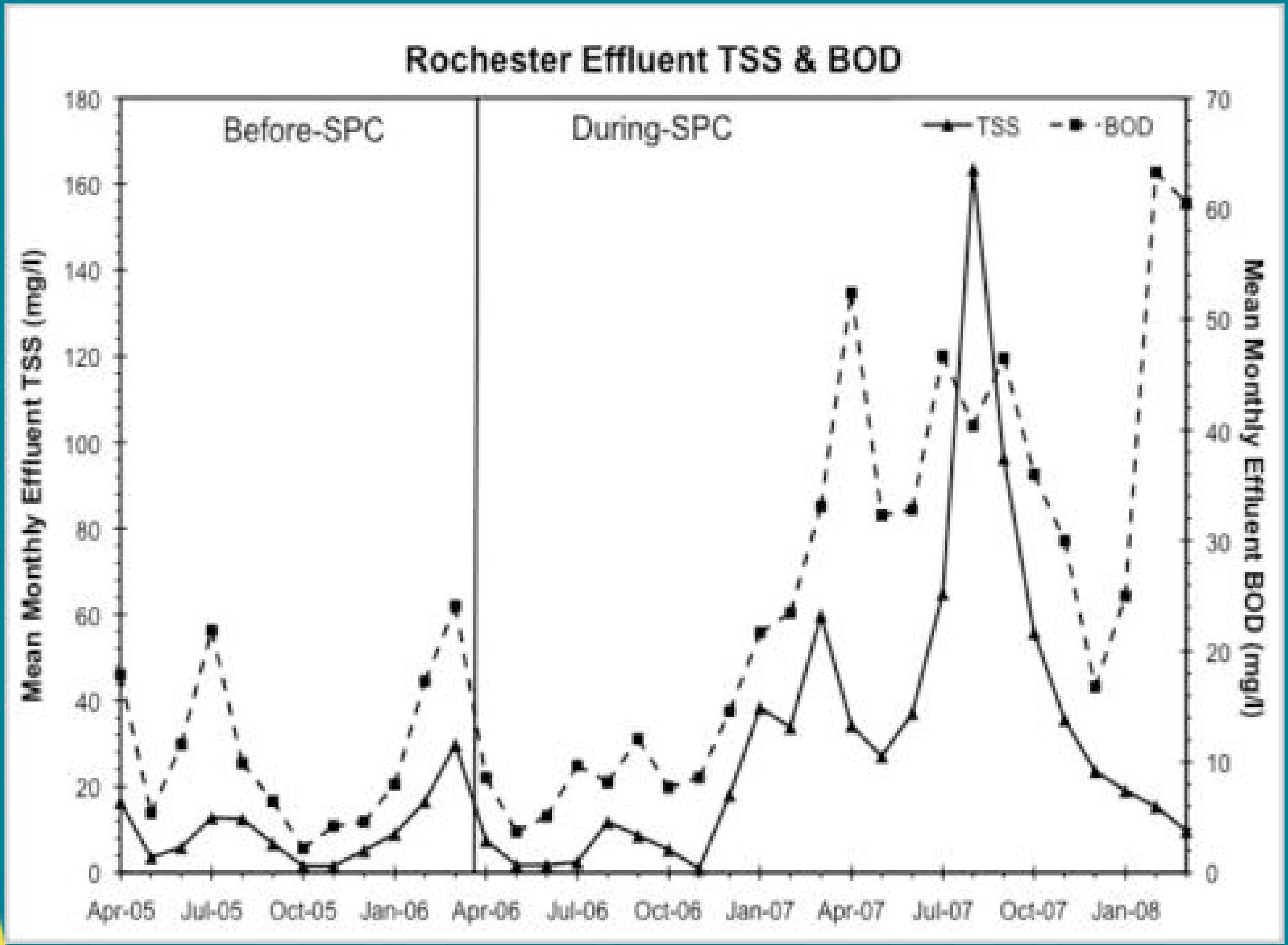
Cost = $6,876/mth
=$82,513/yr
= 36.0%

<u>Pay back period</u>
= 2.9 yrs

Rochester Results

- **No statistically significant differences between Pre-SPC & During-SPC study periods in the following parameters (During-SPC values shown)**
  - **Aerated lagoons converted to equalization basins**
- **Effluent flow rate (712.1$\pm$294.2 m^3/mth)**
- **DO (4.3$\pm$2.4 mg/l)**
- **pH (7.5$\pm$0.2 su)**
- **Ammonia (16.7$\pm$8.8 mg/l)**
- **Nitrate not measured**

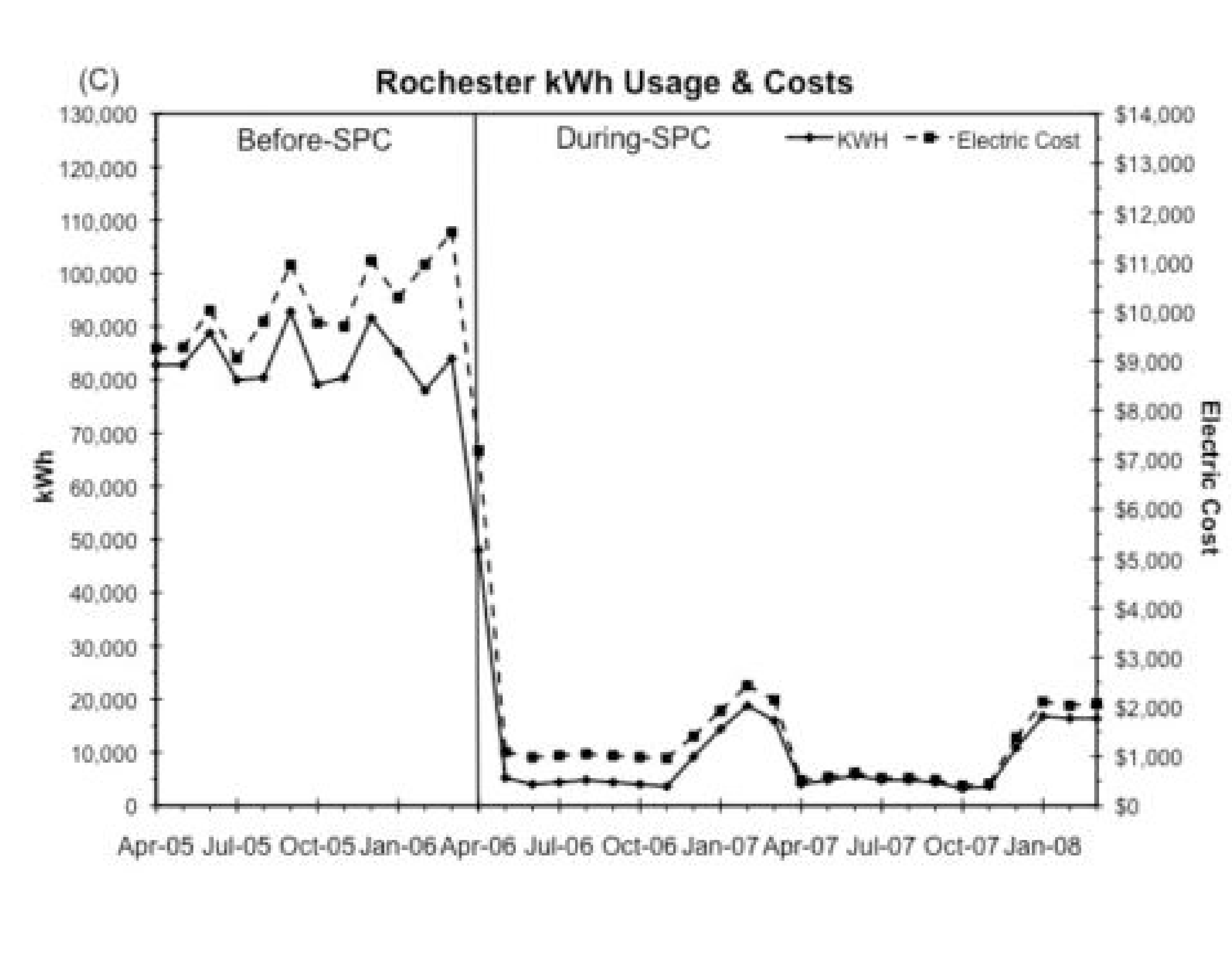
Rochester TSS & BOD



TSS & BOD increased significantly during SPC due to the conversion from aerated lagoons to equalization basins

Cell 2 reductions in TSS & BOD ranged from 30-40% before effluent transferred to anaerobic cells

Rochester - kWh Usage & Cost



Reductions during SPC

kWh = 74,150/mth
=889,803/yr
= 88.5%

Cost = $8,722/mth
=$104,658/yr
= 86%

Pay back period
= 1.9 yrs

Conclusions

- Operational efficiency was increased by replacing some or all electrical grid-powered aeration at 3 WWTPs with SPC
- Effluent water quality was maintained, odor events were avoided, & sludge buildup was minimized
- Electrical grid-power consumption decreased by 37.5-88.5%
- Electrical grid-power expenditure decreased by 36-86%
- Payback periods ranged from 1.9-3.7 years
  - Long term operating expense reductions indicated by 25 yr unit lifetime & low maintenance needs

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Thank You!

I'm happy to take any questions