Membrane Filtration Pilot Scale Comparison: Direct Coagulation and DAF Pre-Treatment

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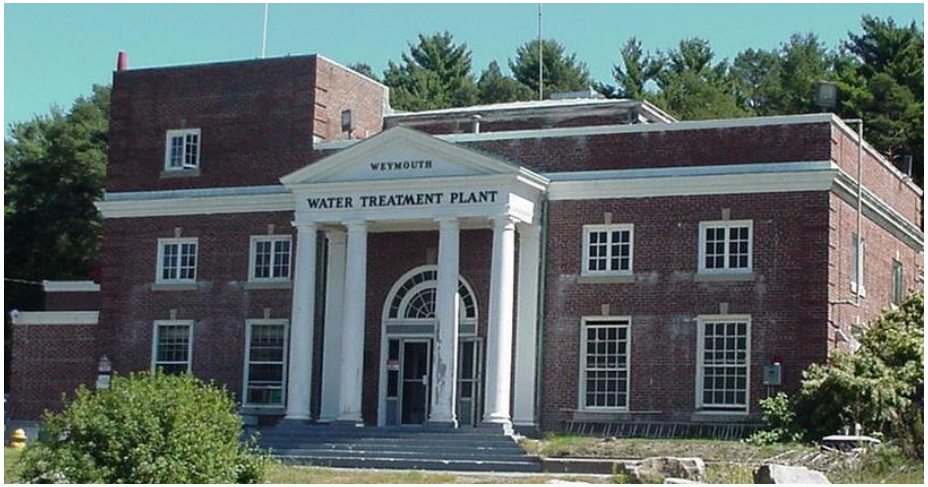
Presenter: **Stephen C. Olson, P.E.**
Sr. Project Manager

Presentation Outline

- **Project Background**
  - Town of Weymouth, Great Pond WTP
  - Water Quality
  - Pilot Study Overview
- **Pilot Study #1: Direct Coagulation**
  - Pilot Systems
  - Results and Conclusions
- **Pilot Study #2: DAF Pretreatment**
  - Pilot Systems
  - Results and Conclusions

Pilot Study Background Information



- **Town of Weymouth**
  - Population – 53,000
  - Number of Customers (15,800)
  - Average Demand – 4.3 MGD
- **Water Supply Source**
  - Surface Water - Great Pond
  - Safe Yield (3.5 MGD)
- **Existing Treatment**
  - Great Pond WTP – 6 to 8 MGD
  - Conventional Treatment
  - Year Built – 1935
  - Upgrades/Expansions – 1966, 1985, 1993, 2002, 2004
- **Project Goals**
  - Identify treatment options for new full scale facilities
  - Ability to meet existing and future proposed regulations
  - Flexible, reliable, dependable, cost effective.

Source Water Quality Assessment

"Great Pond is a seasonally variable low turbidity (1 NTU) surface water supply with low pH (5.5 to 6.5), low alkalinity (5 to 10 mg/L $CaCO_3$), moderate to high levels of natural organic matter (TOC: 5 to 12 mg/L), and trace levels of iron and manganese (above Secondary Standards)."

Great Pond Source Water Quality

		Historic	Winter Pilot 1	Summer Pilot 1	Summer Pilot 2	Winter Pilot 2
Temperature (°C)	Average	14.2	4.3	24.5	20.7	5.4
	Range	3.5 - 28.5	4 - 5	23 - 27	18- 23	4 - 7
pH (s.u.)	Average	6.4	6.15	6.6	6.7	6.4
	Range	5.5 - 6.9	5.8 - 6.3	6.2 - 6.8	6.3 - 7.2	6.1 - 6.8
Alkalinity (mg/L CaCO3)	Average	8.0	4.5	6.4	5.3	4.8
	Range	2 - 11	4 - 5	5 - 8	5 - 7	3 - 6
Turbidity (NTU)	Average	1.0	1.2	0.9	1.1	1.0
	Range	0.4 - 4.3	0.9 - 2.0	0.8 - 1.1	0.95 - 1.6	0.8 - 1.5
Color (s.u.)	Average	57	80	54	67	90
	Range	26 - 105	58 - 108	44 - 64	60 - 74	67 - 105
UV-254 (1/cm)	Average	0.27	0.34	0.25	0.28	0.40
	Range	0.18 - 0.33	0.32 - 0.36	0.23 - 0.27	0.27 - 0.29	0.38 - 0.41
TOC (mg/L)	Average	8.13	8.0	6.4	6.6	7.7
	Range	3.5 - 15	7.7 - 8.6	5.7 - 8.4	5.7 - 10.5	7.5 - 8.1
Fe (total) (mg/L)	Average	0.19	0.28	0.2	0.26	0.29
	Range	ND - 0.51	0.18 - 0.32	0.16 - 0.25	0.16 - 0.32	0.27 - 0.37
Mn (total) (mg/L)	Average	0.07	0.08	0.19	0.10	0.06
	Range	ND - 0.78	0.05 - 0.1	0.14 - 0.27	0.06 - 0.17	0.05 - 0.09
Algae (cells/L)	Average	300,000	NT	146,500	45,000	32,000
	Range	150,000 – 1,200,000	NT	64,000 – 820,000	45,000	32,000

Great Pond Pilot Study

Pilot Period	Piloting Duration
Pilot Study #1 Cold Water	January 21, 2005 – March 30, 2005
Pilot Study #1 Warm Water	July 21, 2005 – September 6, 2005
Pilot Study #2 Warm Water	August 3, 2005 – October 12, 2005
Pilot Study #2 Cold Water	December 5, 2005 – January 6, 2006

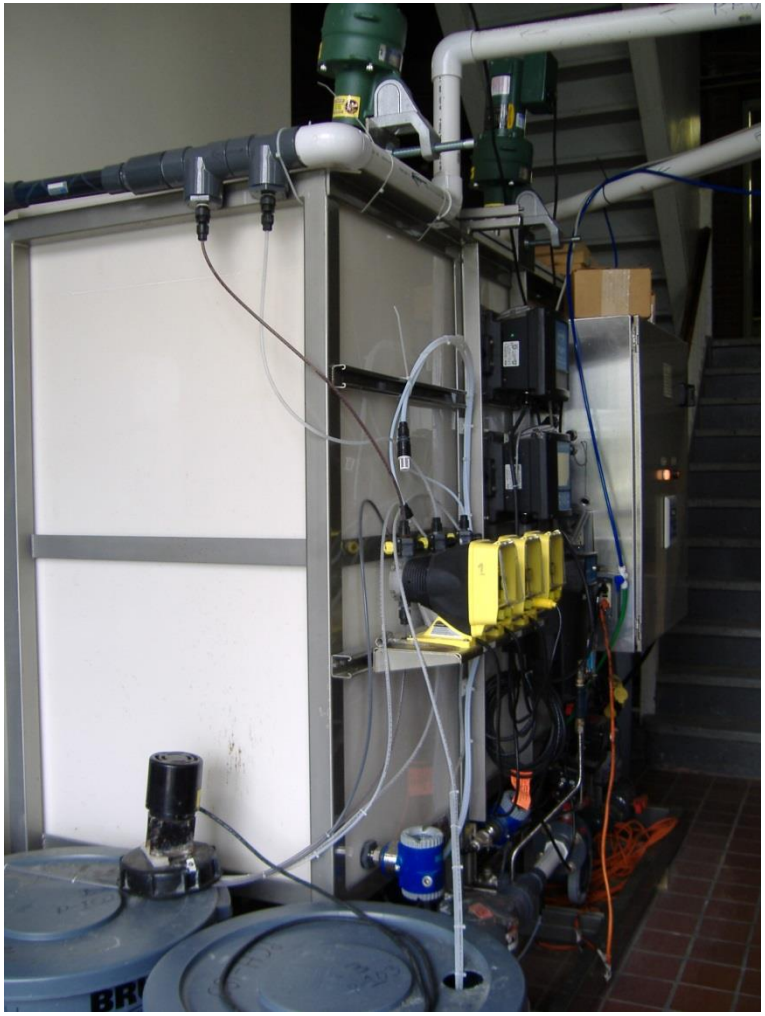
Membrane Systems Overview

- Pilot Study #1: Coagulation – Direct Membrane Filtration
- Pilot Study #2: DAF – Ozone – PAC Membrane Filtration

Membrane Filtration Systems

Membrane Vendors:	Zenon	USFilter	Pall
Membrane System, Pilot #1	ZeeWeed - 500	CMF-S S10V	Pall Microza MF
Membrane System, Pilot #2	ZeeWeed - 1000	CMF-S S10V+10	Pall Microza MF
Membrane Material	PVDF	PVDF	PVDF

Pall – Direct Pressure MF

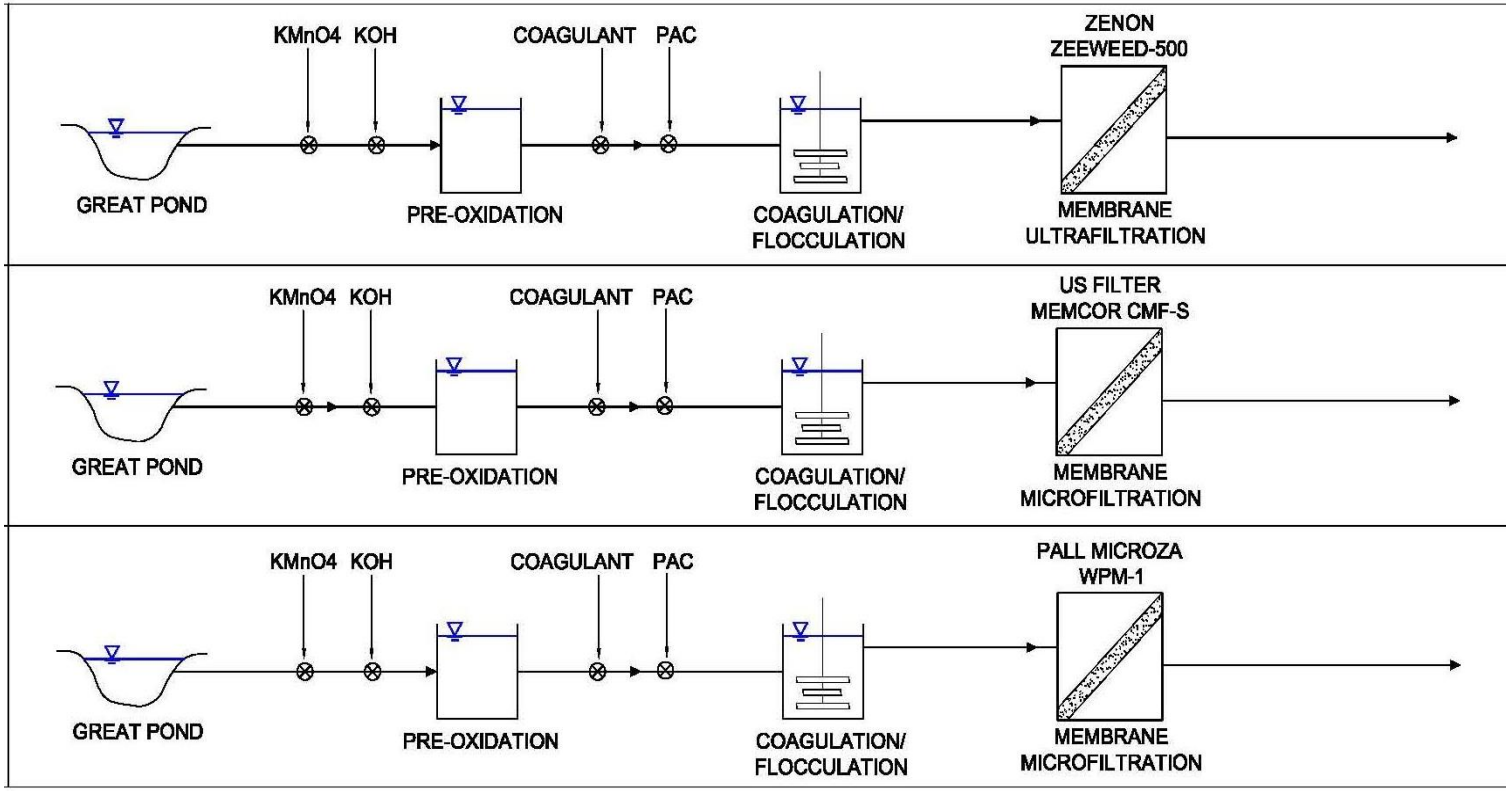


US Filter/Memcor – Submerged MF

Zenon – Submerged UF

Pilot Study #1 Technologies

Coagulation – Direct Membrane Filtration



Pilot #1: Results & Operating Conditions

Pretreatment

Process	Chemical	Dose	Reaction Time	pH
Pre-Oxidation	Potassium Permanganate	0.8 mg/L	3 to 6 minutes	6.9 – 7.2
Coagulation	Polyaluminum Chloride	75 mg/L	15 seconds	6.2 – 6.8
Carbon Absorption	PAC	20 mg/L	3 to 6 minutes	NA
Flocculation	NA	NA	3 to 6 minutes	6.2 – 6.8

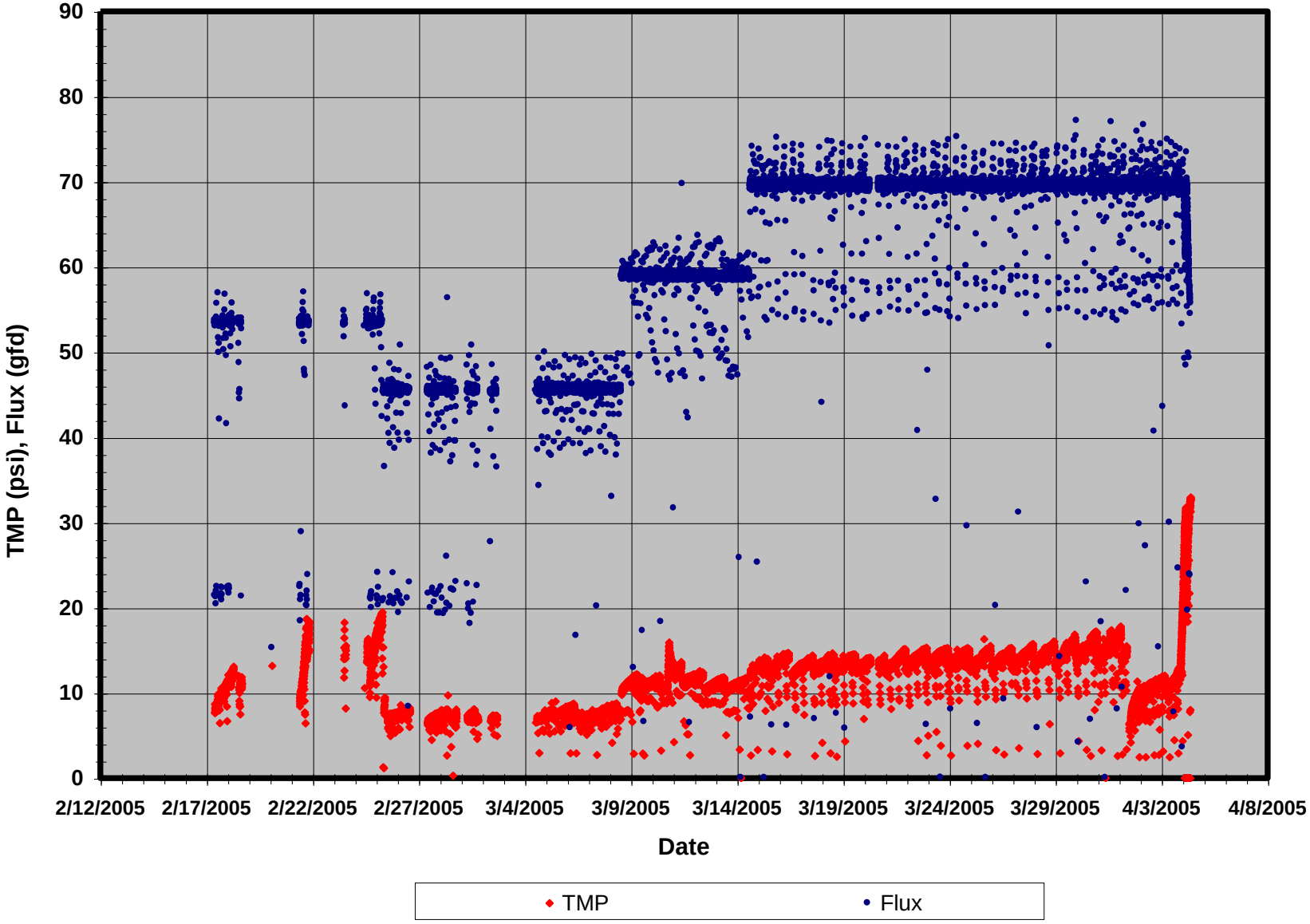
Membrane Filtration

Membrane Parameters	Zenon	USFilter	Pall
Trial Membrane Flux (gfd)	25 - 32	25 - 31	40 – 70
Recommended Membrane Flux (gfd)	32	25	40
Average TMP (psi)	4 – 7	4 – 8	5 – 15
Backwash Frequency (minutes)	15	20	15
Chemical Maintenance Wash	Chlorine	Chlorine & HCl	Chlorine
Chemical Wash Frequency	Weekly	Daily	Daily
Recirculation Flow	0	0	10% - 20%
Average Recovery	92%	95%	95.5% - 97%

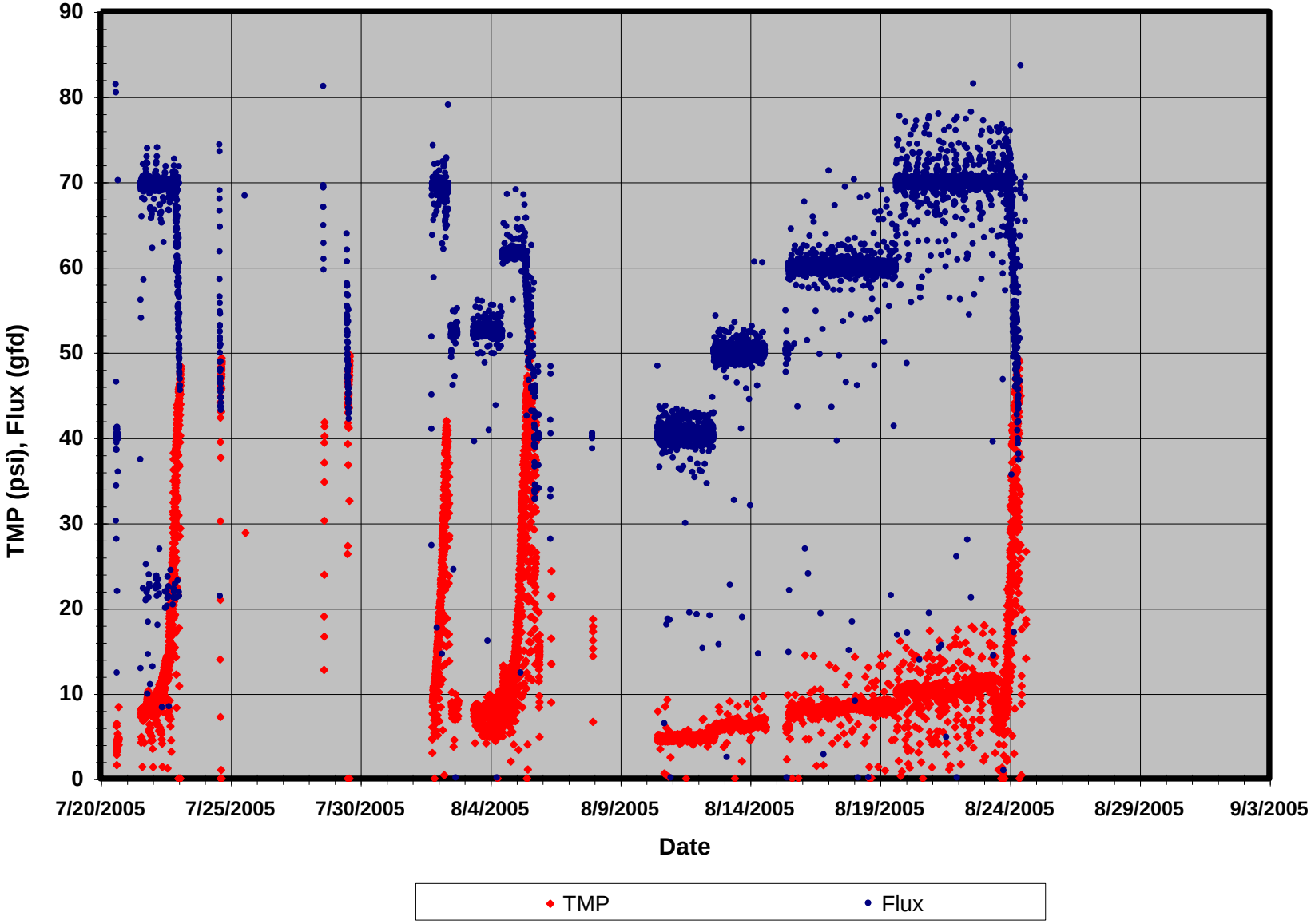
Pilot #1: Feed Water Summary

- Turbidity
  - 3 to 5 NTU (just coagulant)
  - 5 to 15 NTU (with PAC)
- Particle Counts
  - > 10,000 particles/100 mL
- Precipitated Metals
  - Iron: 0.1 to 0.3 mg/L
  - Manganese: 0.1 to 0.2 mg/L
  - Aluminum: 0.5 to 0.6 mg/L
- Algae
  - Summer levels > 100,000 cells/L

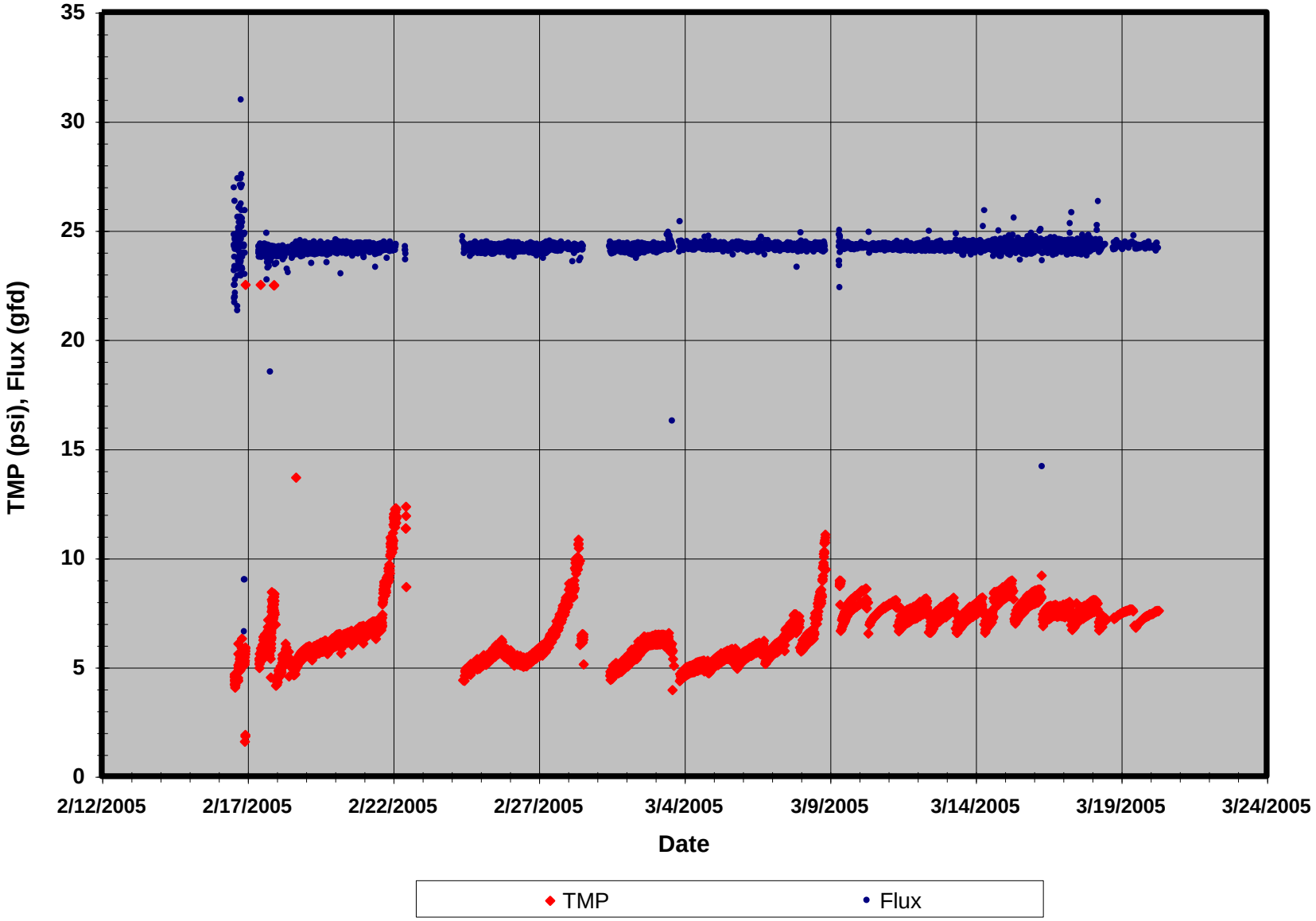
Town of Weymouth
Great Pond Pilot Study #1 (Cold Water)
Operational Results: Pall Microza



Town of Weymouth
Great Pond Pilot Study #1 (Warm Water)
Operational Results: Pall Microza



Town of Weymouth
Great Pond Pilot Study #1 (Cold Water)
Operational Results: US Filter CMF-S



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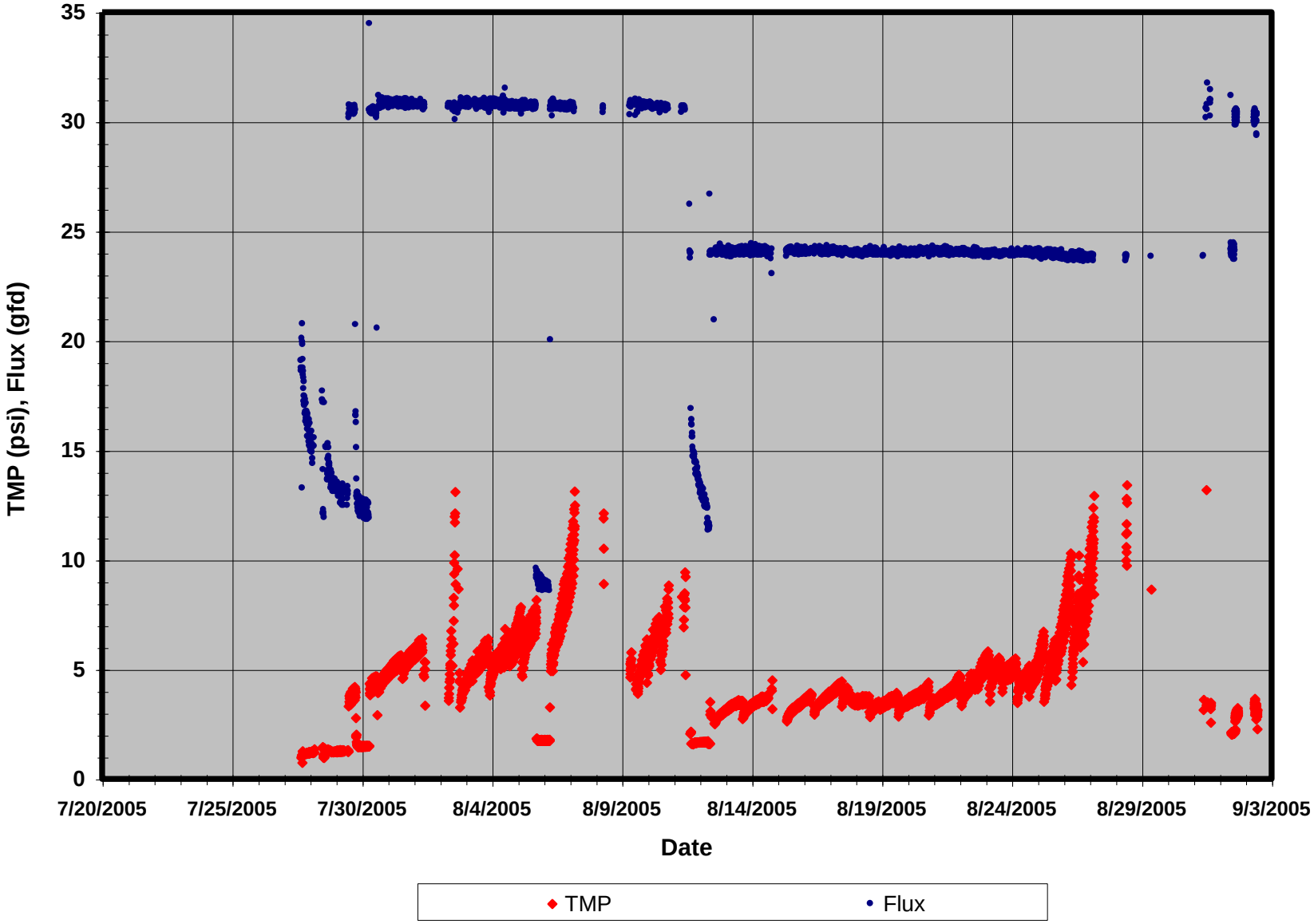
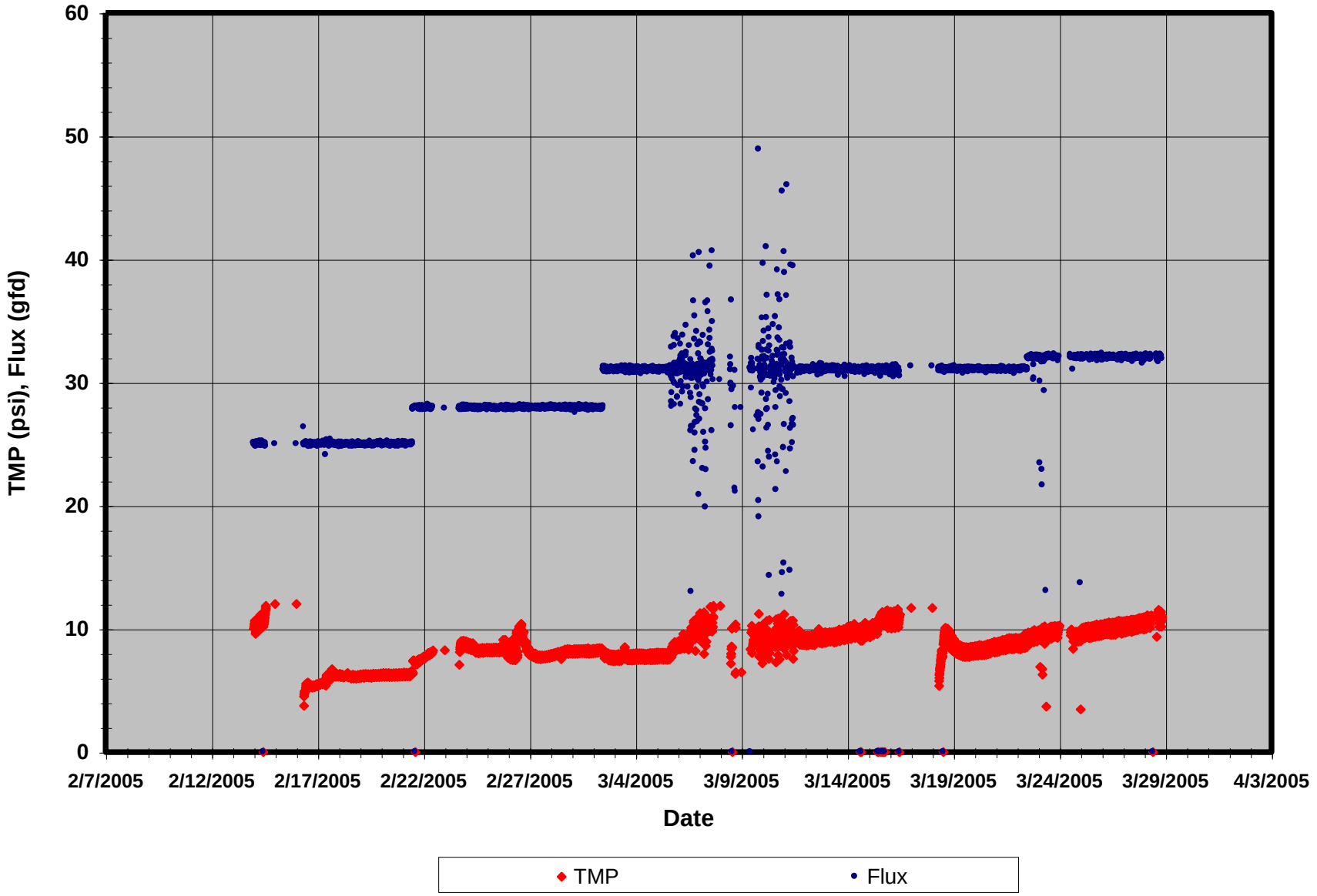
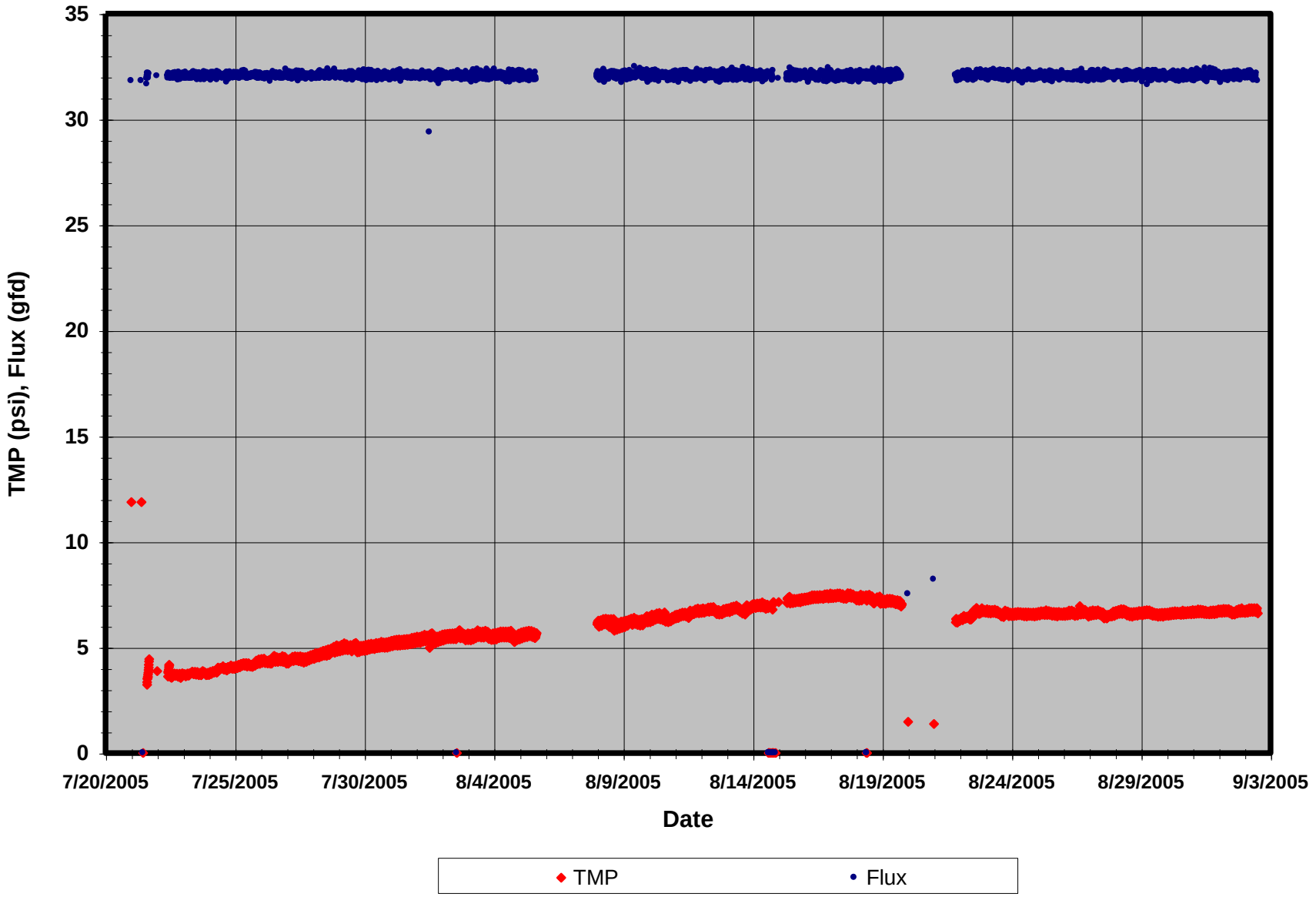



Town of Weymouth
Great Pond Pilot Study #1 (Cold Water)
Operational Results: Zenon ZeeWeed-500
TMP (psi), Flux (gfd)
60
50
40
30
20
10
0
2/7/2005
2/12/2005
2/17/2005
2/22/2005
2/27/2005
3/4/2005
3/9/2005
3/14/2005
3/19/2005
3/24/2005
3/29/2005
4/3/2005
Date
TMP
Flux

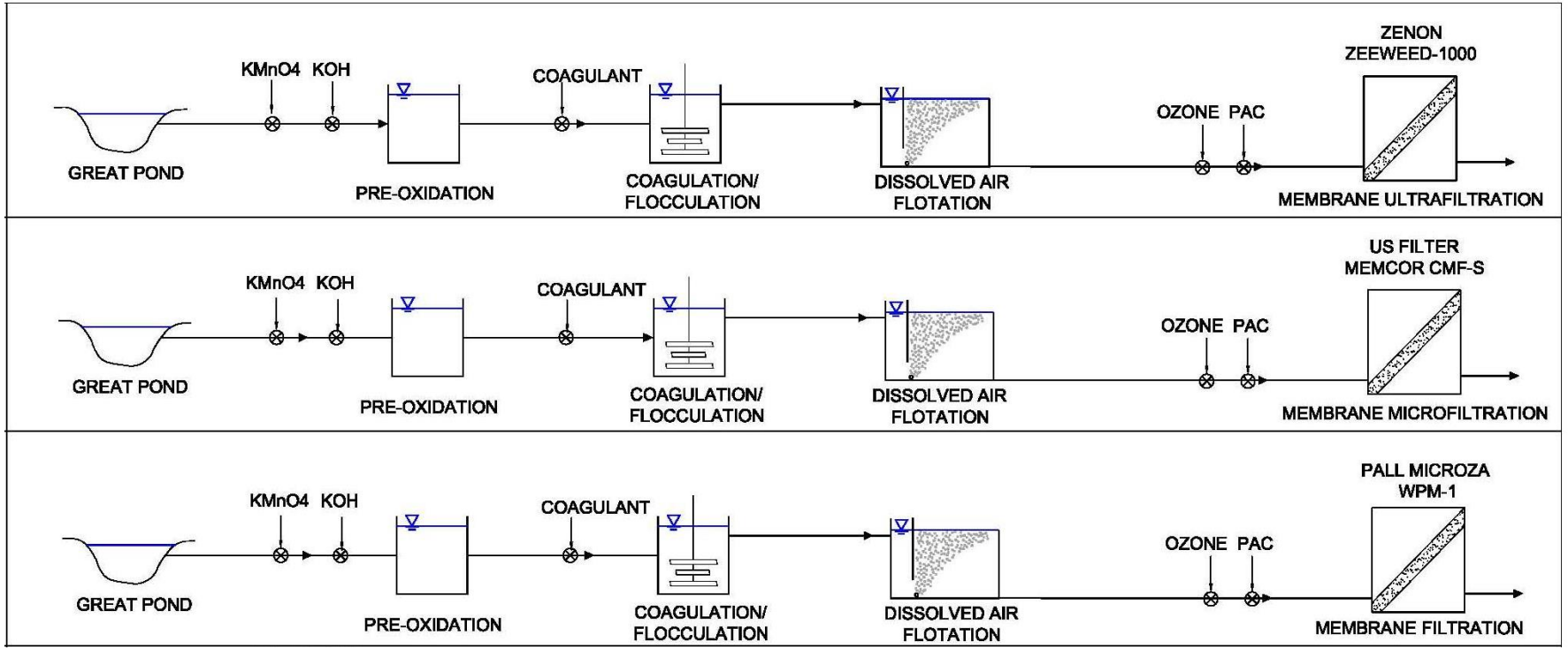

Town of Weymouth
Great Pond Pilot Study #1 (Warm Water)
Operational Results: Zenon ZeeWeed-500
TMP (psi), Flux (gfd)
35
30
25
20
15
10
5
0
7/20/2005
7/25/2005
7/30/2005
8/4/2005
8/9/2005
8/14/2005
8/19/2005
8/24/2005
8/29/2005
9/3/2005
Date
TMP
Flux

Pilot Study #1: Summary & Conclusions

- Algae presented operating problems with Pall system (direct pressure) and US-Filter system (submerged).
  - XR flow and reduced flux improved operations for Pall
  - Reducing flux and daily chemical washes (chlorine and acid) improved operations for US Filter
- Zenon system (ZeeWeed-500) did not experience operating problems in the presence of algae.
  - Tank drain operation
- Introduction of PAC improved TMP
- Rapid increase in TMP with loss of coagulant feed

Pilot Study #2 Technologies

DAF Clarification – Ozonation – Membrane Filtration



Pilot #2: Results & Operating Conditions

Pretreatment

Process	Chemical	Dose	Reaction Time	pH
Pre-Oxidation	Potassium Permanganate	0.8 mg/L	2 to 4 minutes	7.0 – 8.0
Coagulation	Polyaluminum Chloride	75 to 120 mg/L	30 seconds	5.8 – 6.5
Flocculation	NA	NA	10 to 20 minutes	5.8 – 6.5
DAF	Loading Rate	Recycle Rate	pH	
	6 to 16 gpm/sf	10 to 12 %	5.8 – 6.5	
Ozonation	Applied Dose	Reaction Time	pH	
	2 to 3 mg/L	3 to 5 minutes	5.6 – 6.3	
PAC	Applied Dose	Reaction Time	pH	
	15 to 20 mg/L	2 to 3 minutes	5.6 – 6.3	

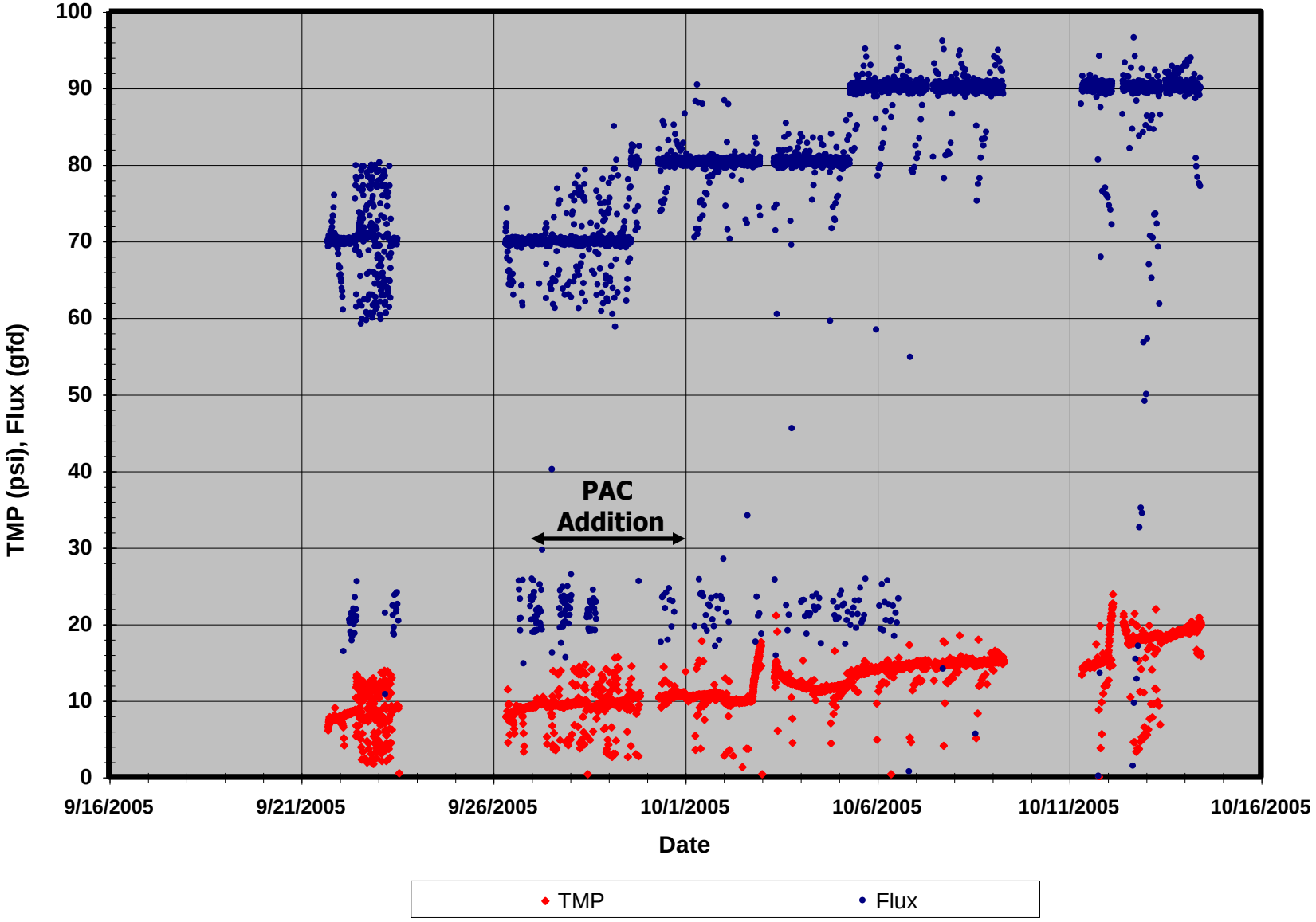
Membrane Filtration

Membrane Parameters	Zenon	USFilter	Pall
Trial Membrane Flux (gfd)	32 – 50	30 - 60	70 – 90
Recommended Membrane Flux (gfd)	50	40	80
Average TMP (psi)	2 – 7	5 - 10	10 – 20
Backwash Frequency (minutes)	26	30	25
Chemical Maintenance Wash	None	HCl & Citric Acid	Chlorine
Chemical Wash Frequency	None	Daily	Daily
Recirculation Flow	0	0	10%

Pilot #2: Feed Water Summary

- Turbidity
  - 0.4 to 1.0 NTU (DAF/O_3)
  - 5 to 10 NTU (DAF/O_3/PAC)
- Particle Counts
  - < 100 particles/100 mL (DAF/O_3)
  - > 10,000 particles/100 mL (DAF/O_3/PAC)
- Precipitated Metals
  - Iron < 0.04
  - Manganese < 0.04
  - Aluminum < 0.1 (summer); < 0.02 (winter)
- Algae
  - <1,000 cells/L

Town of Weymouth
Great Pond Pilot Study #2 (Warm Water)
Operational Results: Pall Microza



Town of Weymouth
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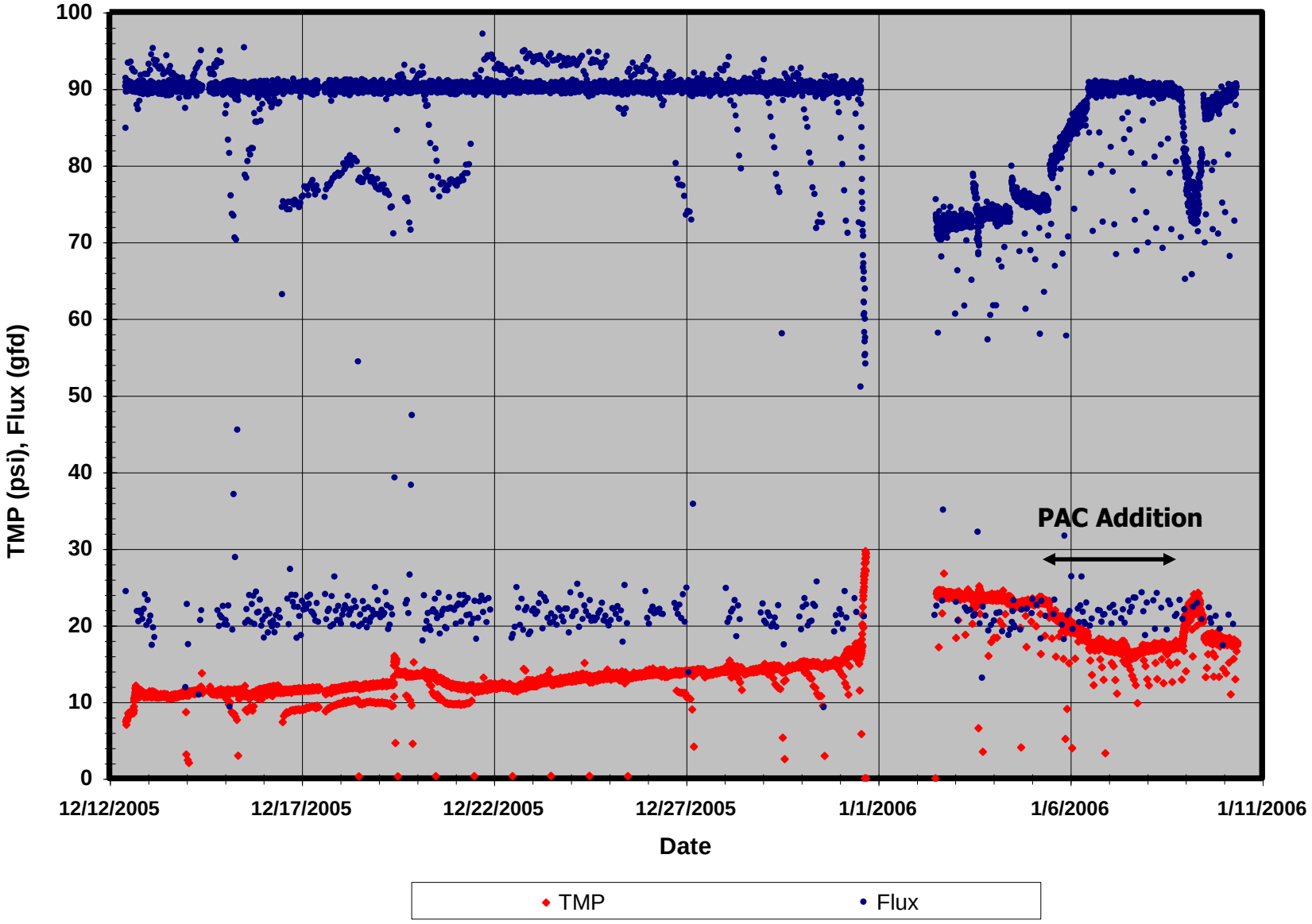
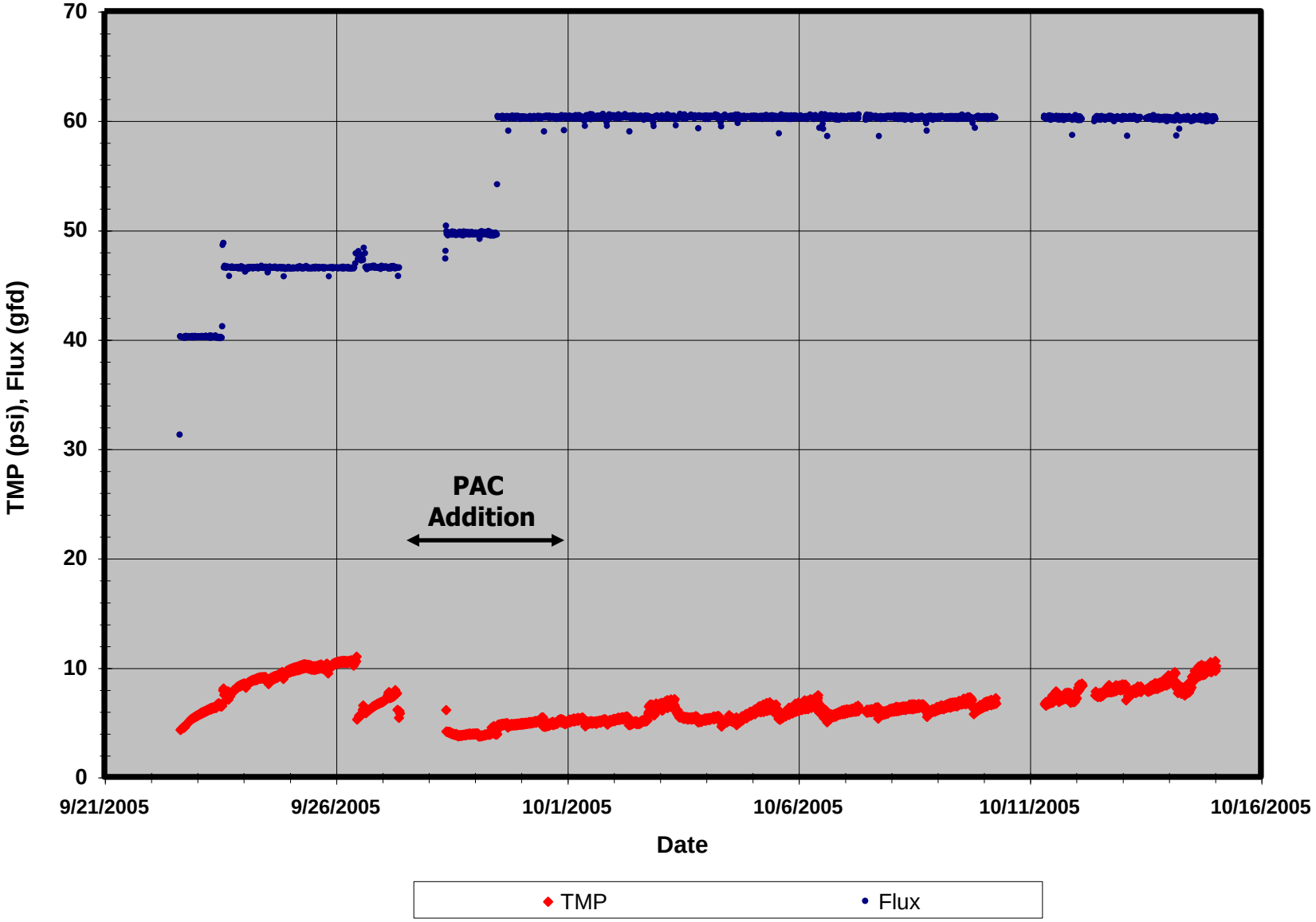
Operational Results: Pall Microza



Town of Weymouth
Great Pond Pilot Study #2 (Warm Water)
Operational Results: US Filter CMF-S



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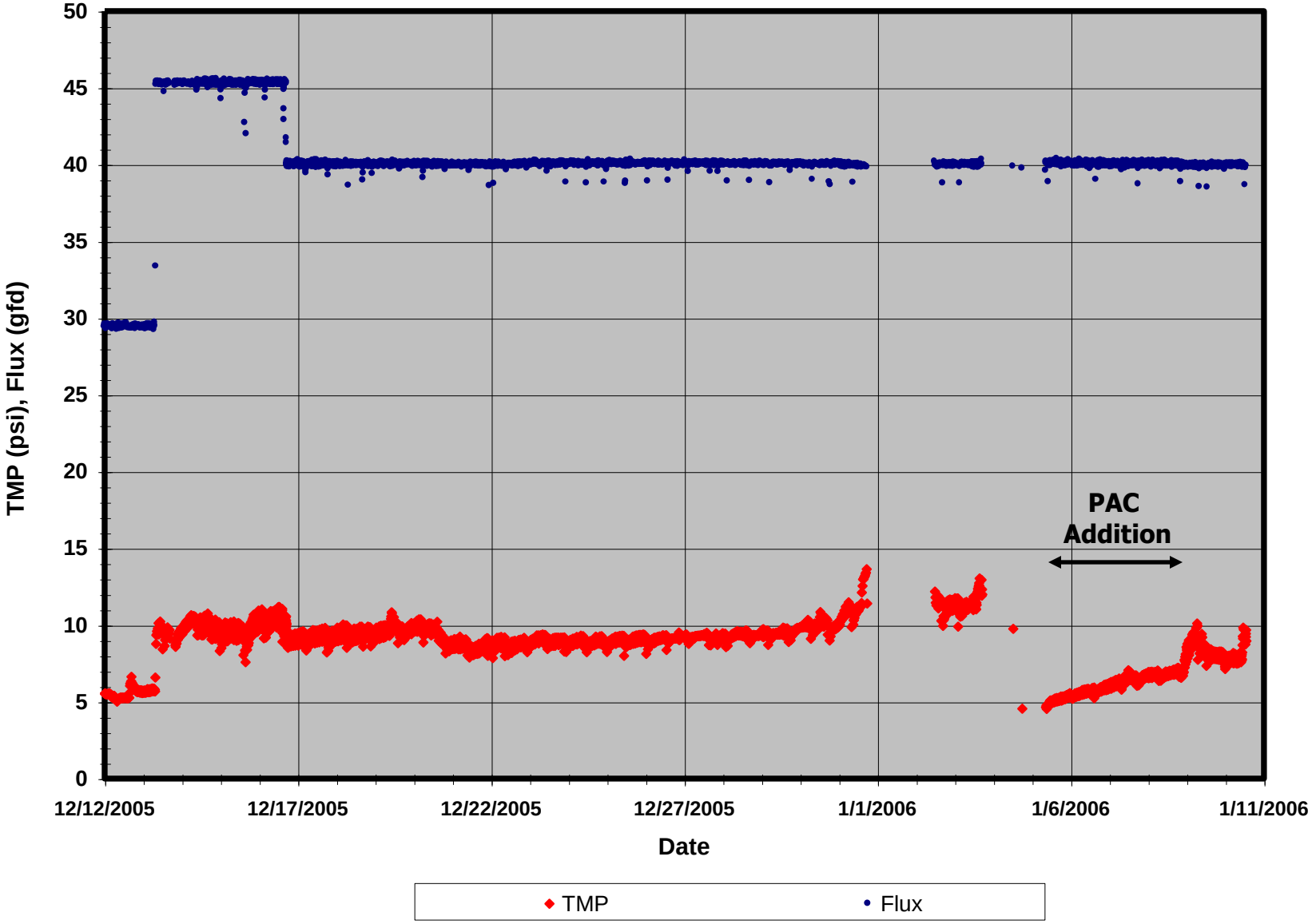
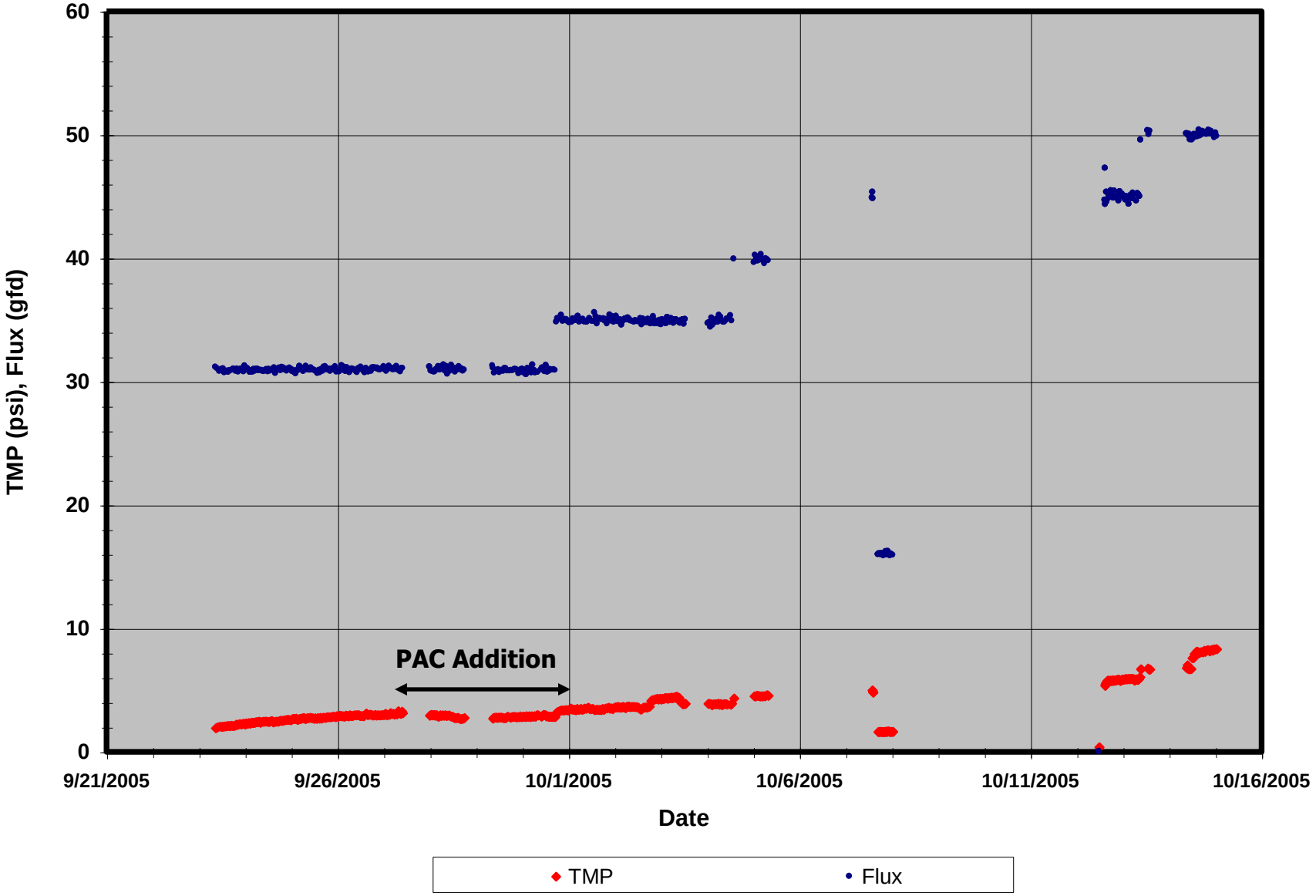
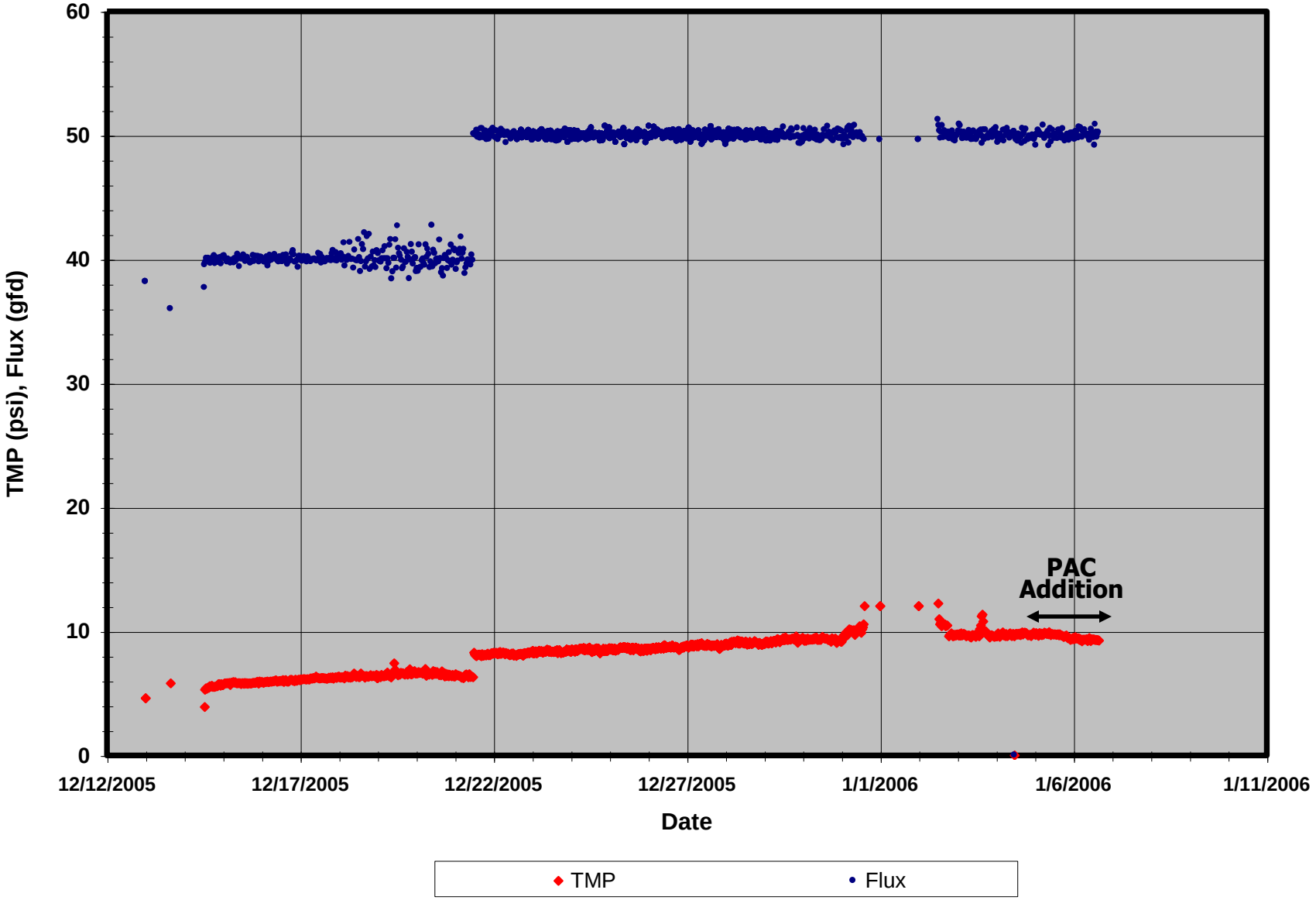
Great Pond Pilot Study #2 (Cold Water)
Operational Results: US Filter CMF-S



Town of Weymouth
Great Pond Pilot Study #2 (Warm Water)
Operational Results: Zenon ZeeWeed-1000



Town of Weymouth
Great Pond Pilot Study #2 (Cold Water)
Operational Results: Zenon ZeeWeed-1000



Pilot Study #2: Summary & Conclusions

- The presence of algae in the source water did not affect membrane operations (DAF pretreatment).
- Greater flux rates were achieved with pretreatment (DAF).
- Introduction of PAC improved TMP and NOM removal.
- No short term deleterious affects of ozone observed.
- Rapid increase in TMP with loss of coagulant feed

Acknowledgements

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Questions?

Stephen C. Olson