REDEFINING BEING GREEN:

Upper Blackstone Pilots Advanced Biological Nutrient Recovery Using Algae

Alexandra Doody, P.E.
Jane Madden, P.E., BCEE
Mark Johnson, P.E.
Karla Sangrey, P.E.
Rick Johnson
Will Holm

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Agenda

- **UBWPAD Background**
- **Overview of ABNR™ Technology**
- **ABNR Pilot**
  - Planned Scope of Work
  - Results
  - Challenges Encountered
- **Additional Experiments**
  - Ammonia Addition
  - Influence of Source Water
- **What Have We Learned?**
- **Next Steps**

Upper Blackstone Water Pollution Abatement District (UBWPAD) WWTF

- **Serves greater Worcester, MA**
- **Designed for 45 mgd average daily flow; 160 mgd peak hour**
- **Construction of A^2/O process completed in 2012**

New NPDES Permit Limits Necessitate Tertiary Treatment

	2001 Permit	2012 Permit
Total Phosphorus (60-day rolling avg)		
Apr - Oct	0.75 mg/L	**0.1 mg/L**
Nov - Mar	Report	1.0 mg/L
Total Nitrogen (monthly average)		
May - Oct	Report	**5.0 mg/L**
Nov - Apr	Report	Report

- **Existing A^2/O process cannot meet 2012 permit limits**
- **Disadvantages of conventional tertiary P removal systems:**
  - Require addition of metal salt chemicals
  - Near edge of capabilities to meet 0.1 mg/L TP limit
  - Do not remove dissolved nitrogen species

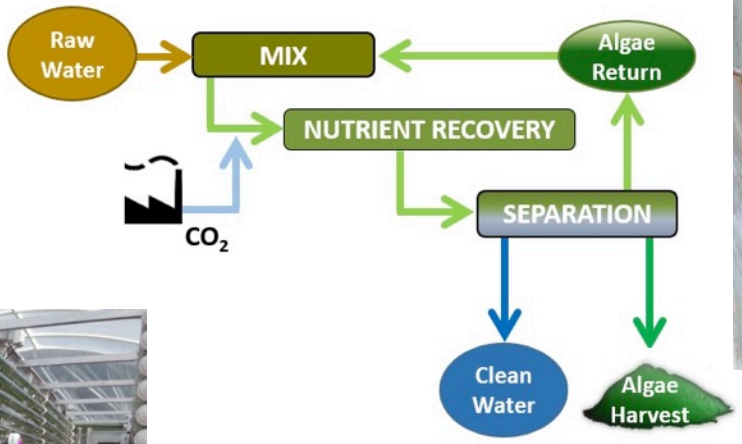
Innovative Technology: Advanced Biological Nutrient Recovery (ABNR™)

- Mimics natural algae growth but in a controlled environment
- Benefits:
  - Consumes CO_2
  - Releases O_2
  - No metal salt addition
  - Produces reuse quality effluent
  - Recovers nutrients in biomass with potential market value

ABNR Pilot at Upper Blackstone: 11-gpm with Secondary Effluent Feed Water

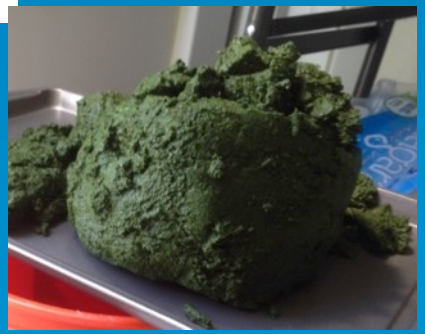
Pre-Filtration and Mix Tank

Membrane Separation Tank



CO_2 Addition and Photobioreactor with LED Lights

Harvested Algae



ABNR Pilot Scope of Work

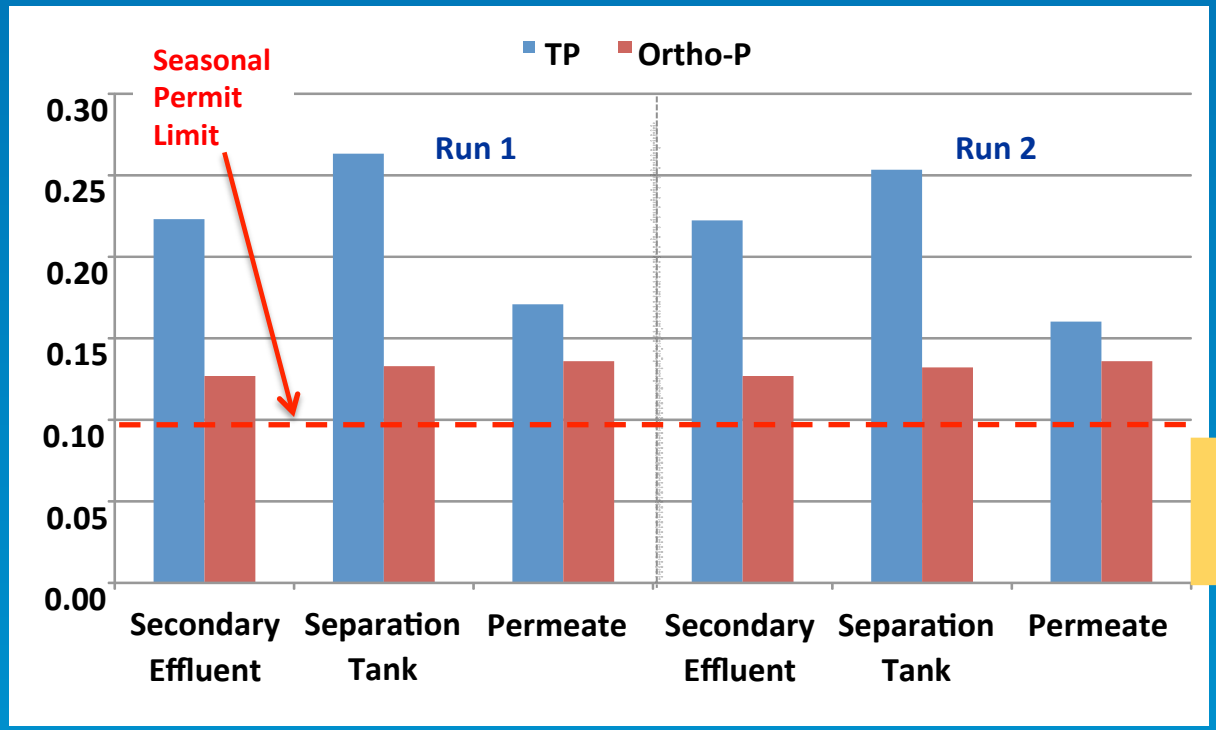
- ***6 weeks planned:*** 2 wks set-up + 4 wks data collection

- ***Sampling protocol:***
  - 24-hr composites of pilot influent (secondary effluent) and pilot effluent (permeate)
  - Third-party lab analysis

- ***Key success criteria:***
  1. Demonstrate TP < 0.05 mg/L in continuous flow operation
  2. Confirm performance of membrane separation
  3. Determine all consumables required

Control Tests for Phosphorus June 2014

- Operated ABNR without algae inoculant to demonstrate effect of membranes:

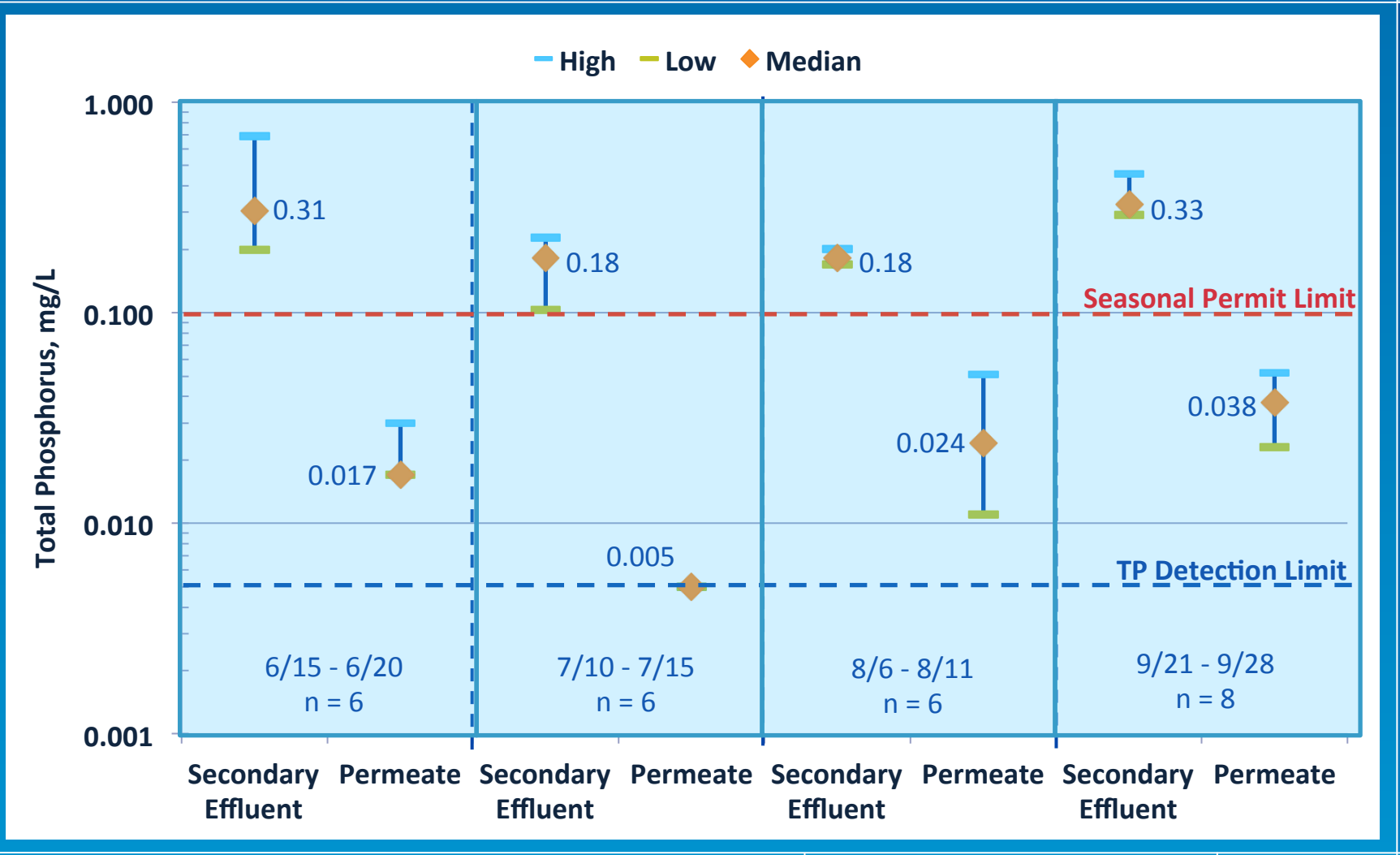


Membranes alone cannot remove dissolved P

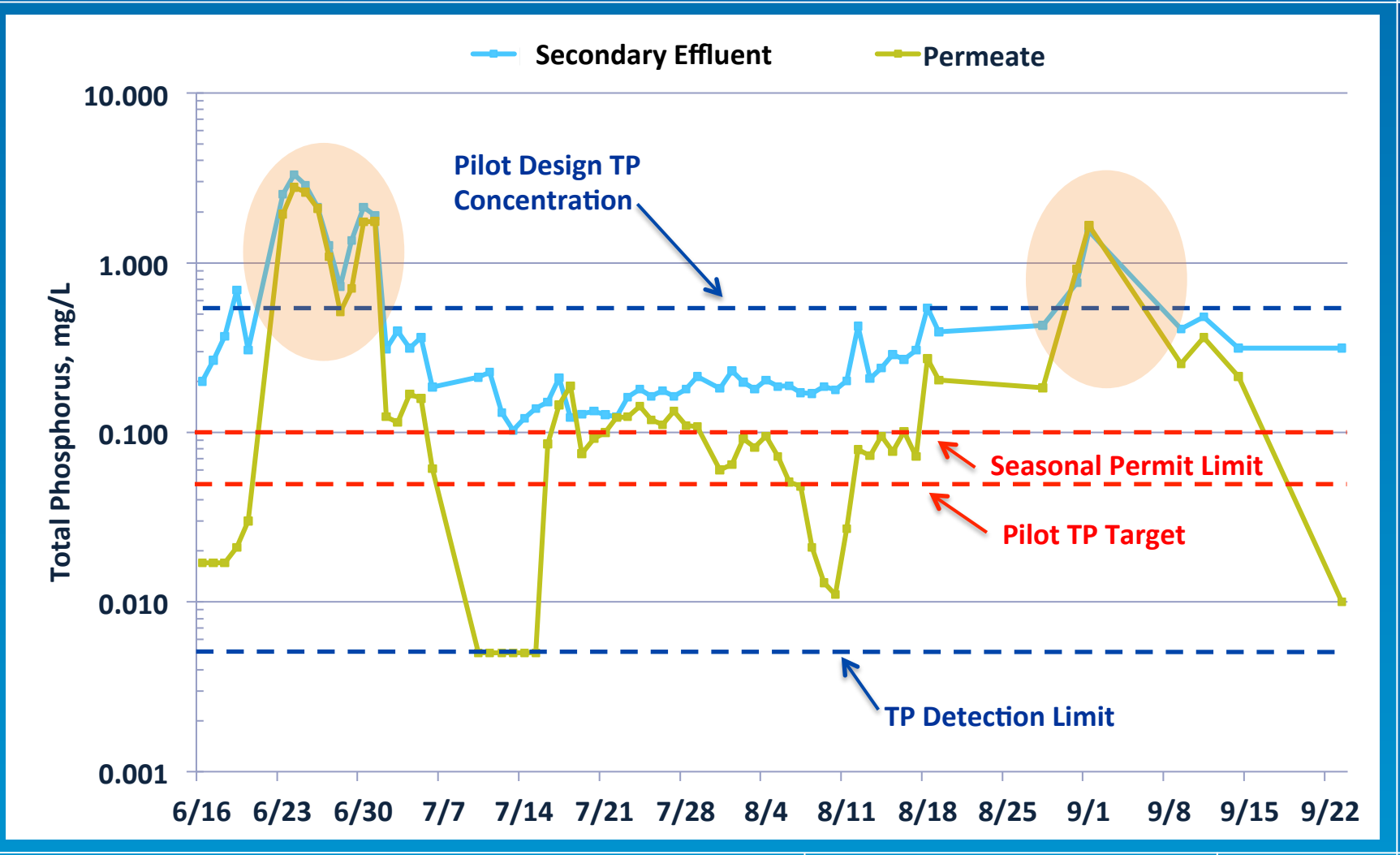
Seeding the Pilot
June 2014

Recirculation mode to build up algae to target density (400-500 mg/L TSS)

TP Performance During Stable Operation June to September 2014



All Pilot Influent and Effluent TP Data June to September 2014



Challenges Encountered

- **EBPR process upsets upstream of pilot**
  - TP concentration exceeded design capacity of pilot
- **Filamentous algae competition with desired species (*Scenedesmus*)**

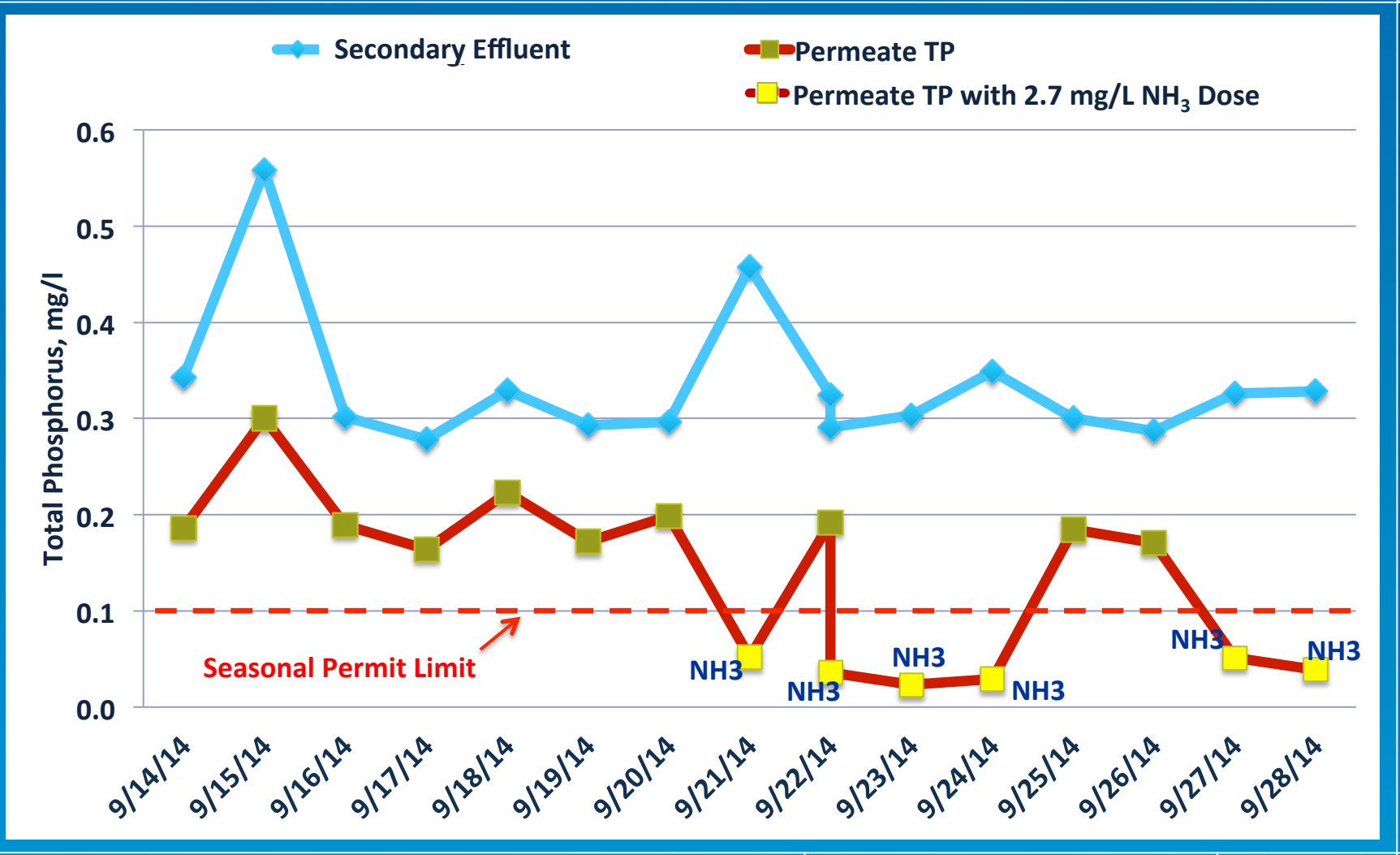
Spirogyra ***Oedogonium***

VS

Scenedesmus

- **Inadequate nitrogen availability in late summer**
  - Need about 6-8 parts of N for every 1 part of P uptake

Additional Experiments: Ammonia Addition September 2014



Additional Experiments: Influence of Source Water November 2014 – January 2015

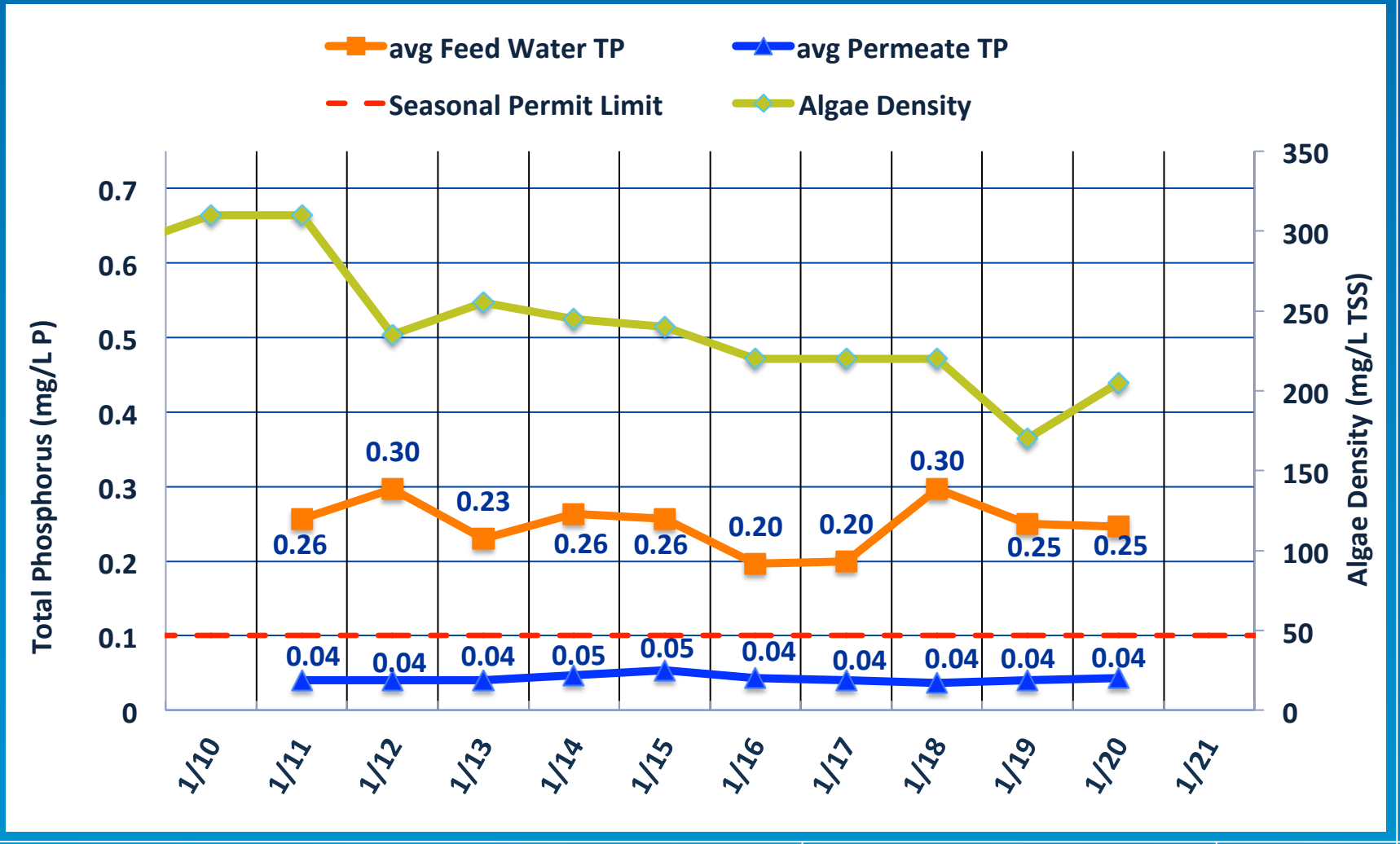
Objective:

To study whether the source of incoming water to the pilot had an influence on TP removal/recovery performance

Results and Status:

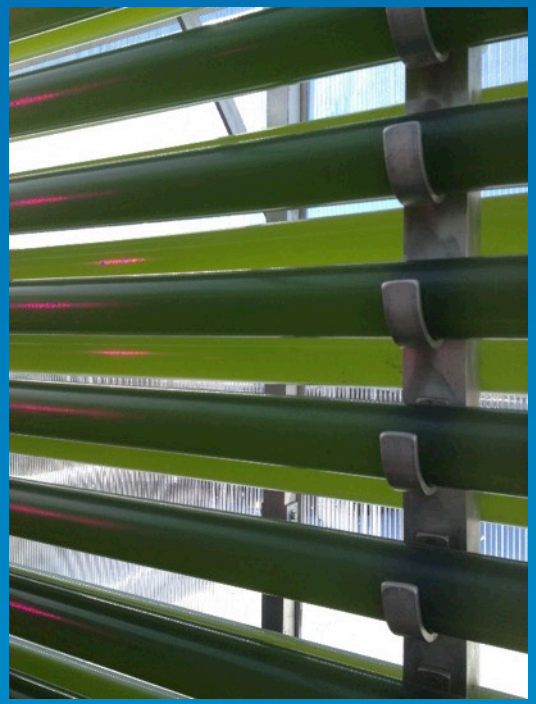
1. Baseline: City Water
   - 40+ days of stable and predictable performance
2. Outfall Water
   - In progress
   - 14+ days of performance at TP < 0.05mg/L (and counting…)
   - Using alternate membrane cleaning procedures

Additional Experiments: Influence of Source Water Outfall Water Results



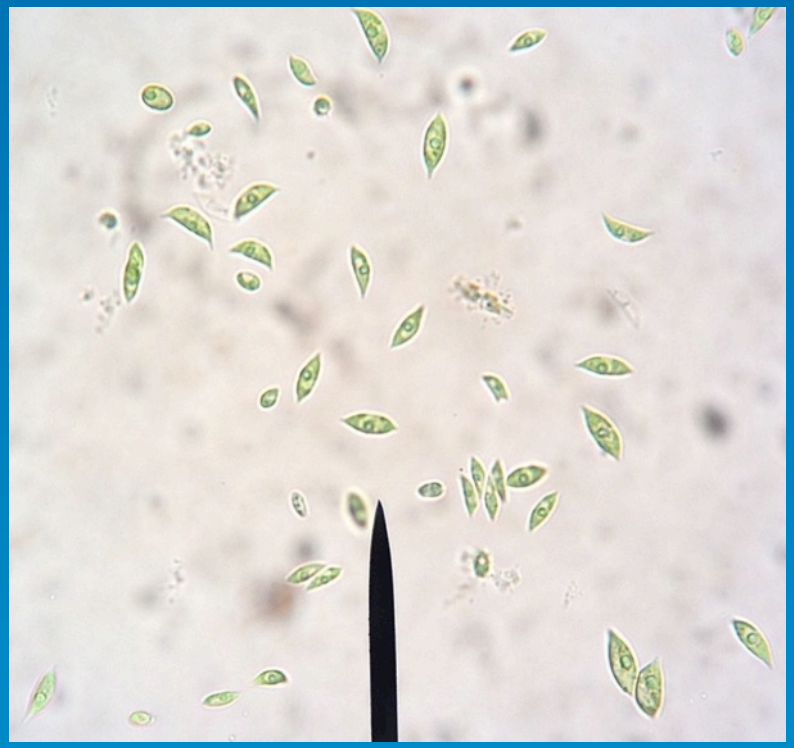
What Have We Learned?

1. Similar to any suspended growth biological process, ABNR can be subject to upsets
2. Membranes can produce reuse quality effluent, but alone cannot achieve permit compliance
3. Sub-systems, including separation, require further optimization
4. The compelling potential benefits warrant further investigation & development



Next Steps

- Complete outfall water experiment
- Optimize separation process
- Evaluate full-scale technical and economic considerations
- If competitive, continue pilot for complete permit season



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  CDM Smith

Questions?

Alex Doody, P.E. (TX), LEED AP

CDM Smith

DoodyAT@cdmsmith.com

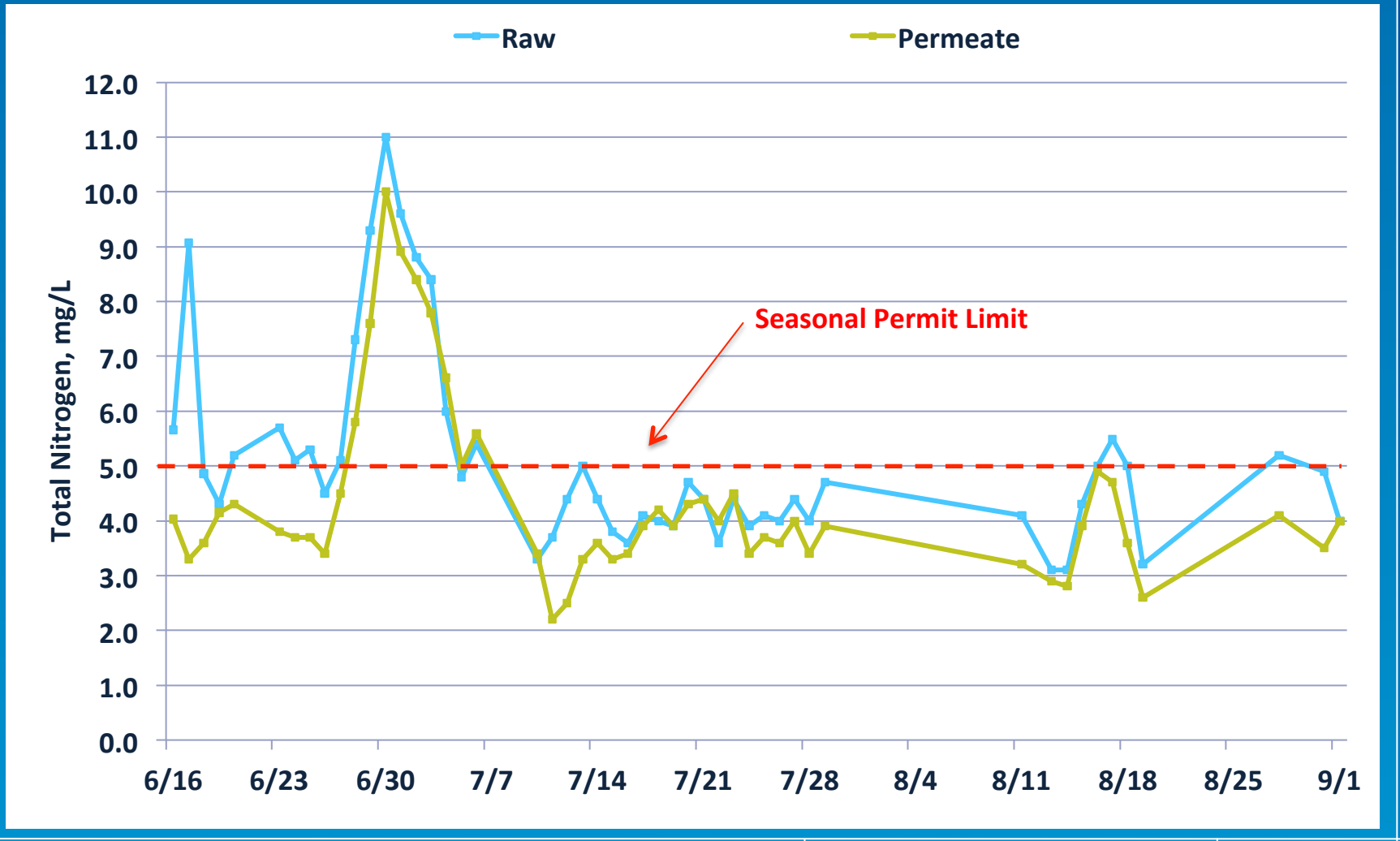
Additional Slides to Review if Time Permits

Bench-Scale Nutrient Recovery Test on Upper Blackstone Secondary Effluent

- Single grab sample collected on May 2013
- Results obtained from 3rd party independent lab
- N:P ratio in the sample collected adequate for low-level P removal (6-8 is good)

Constituent	Units	Raw Clearas	Treated Clearas
Ammonia	mg/l	0.16	0.02
BOD	mg/l	2	Non Detect
NO2/NO3	mg/l	4.28	0.36
TKN	mg/l	0.9	Non Detect
TN	mg/l	5.18	0.36
TP	mg/l	0.11	0.01
TDS	mg/l	450	306
TSS	mg/l	Non Detect	Non Detect

Pilot Influent and Effluent TN Concentrations June to September 2014



Microscopic Analysis of Culture When Nutrient Uptake is Not Optimal