# Doing More with Less:  A Tale of Enhanced Biological Phosphorous Removal

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# Acknowledgement


1 Steve Broadbent – Cyclic Aeration Idea Back in 2007 Workshop

2 John Craigue and Steve Mancini – Woodard & Curran Operators


1 Nutrient Removal Biology

2 Wolfeboro WWRF

3 Biological Process Evaluation Objectives

4 Data Review & Sampling

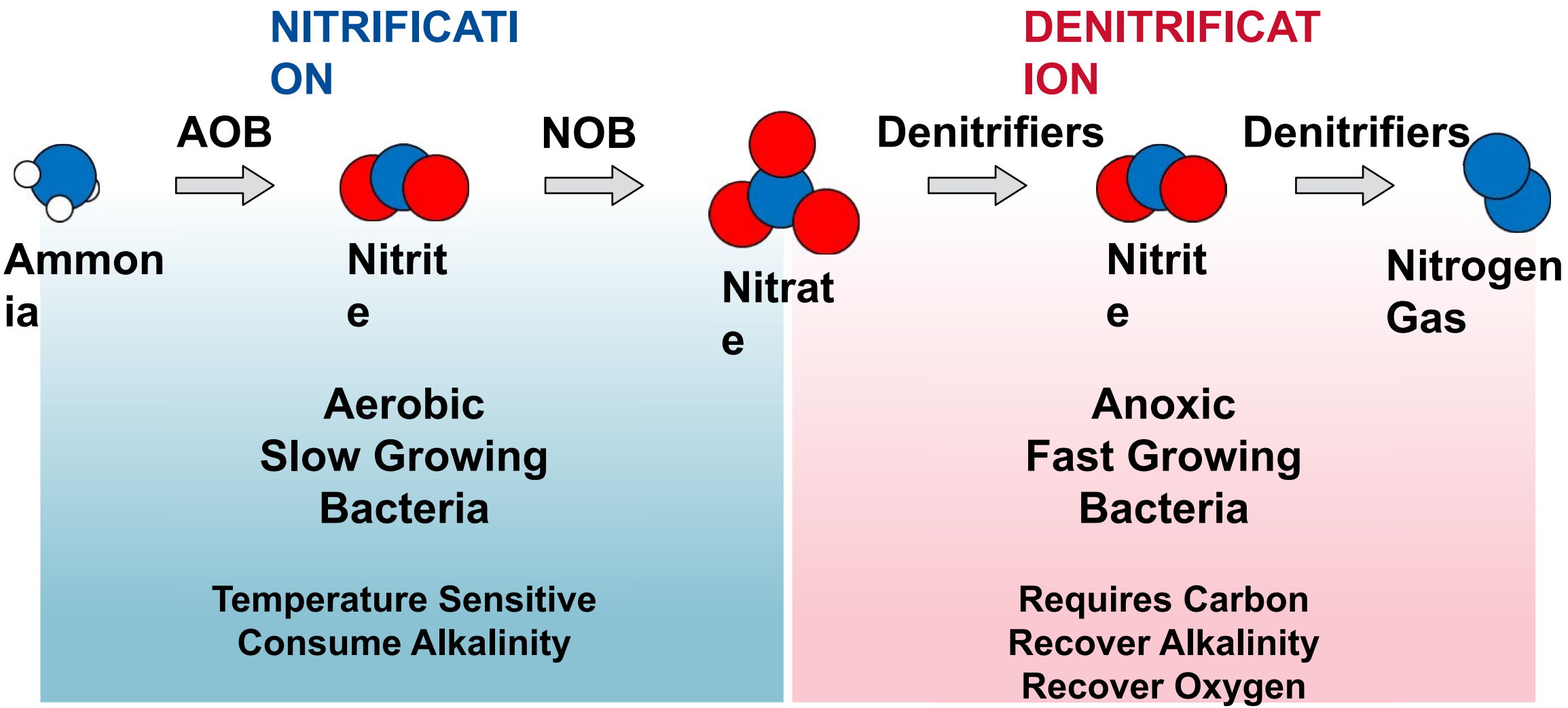
5 BioWin Model Development & Findings

6 Conclusions & Significance

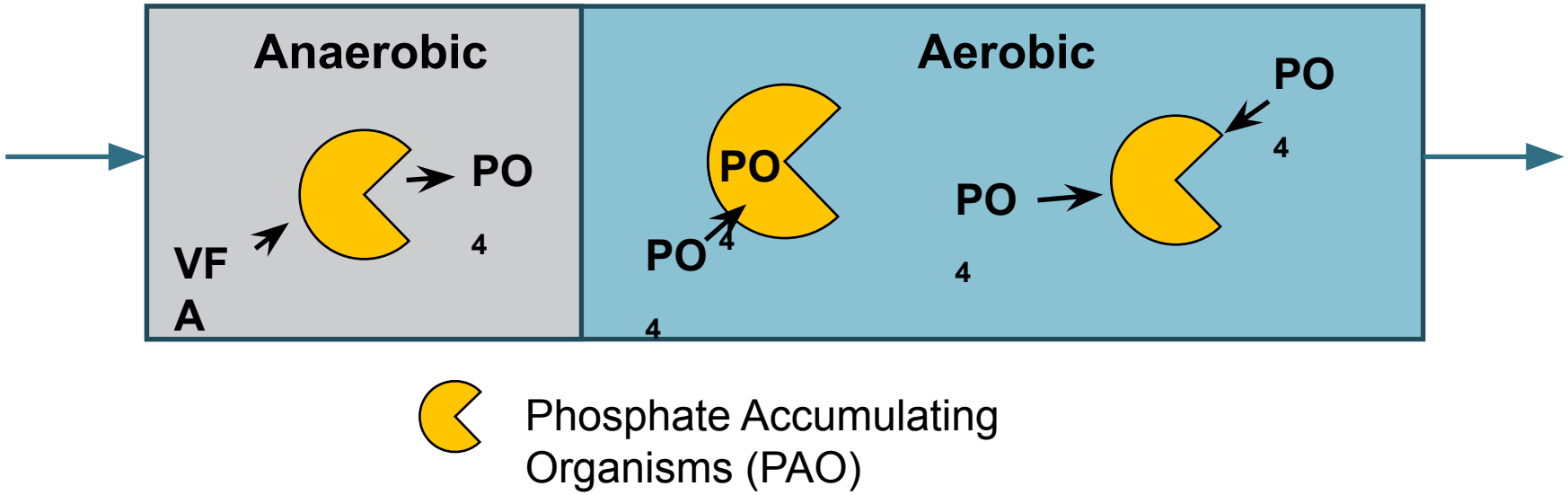


# Nutrient Removal Review

# Nitrogen Removal Review



# Biological Phosphorus Removal

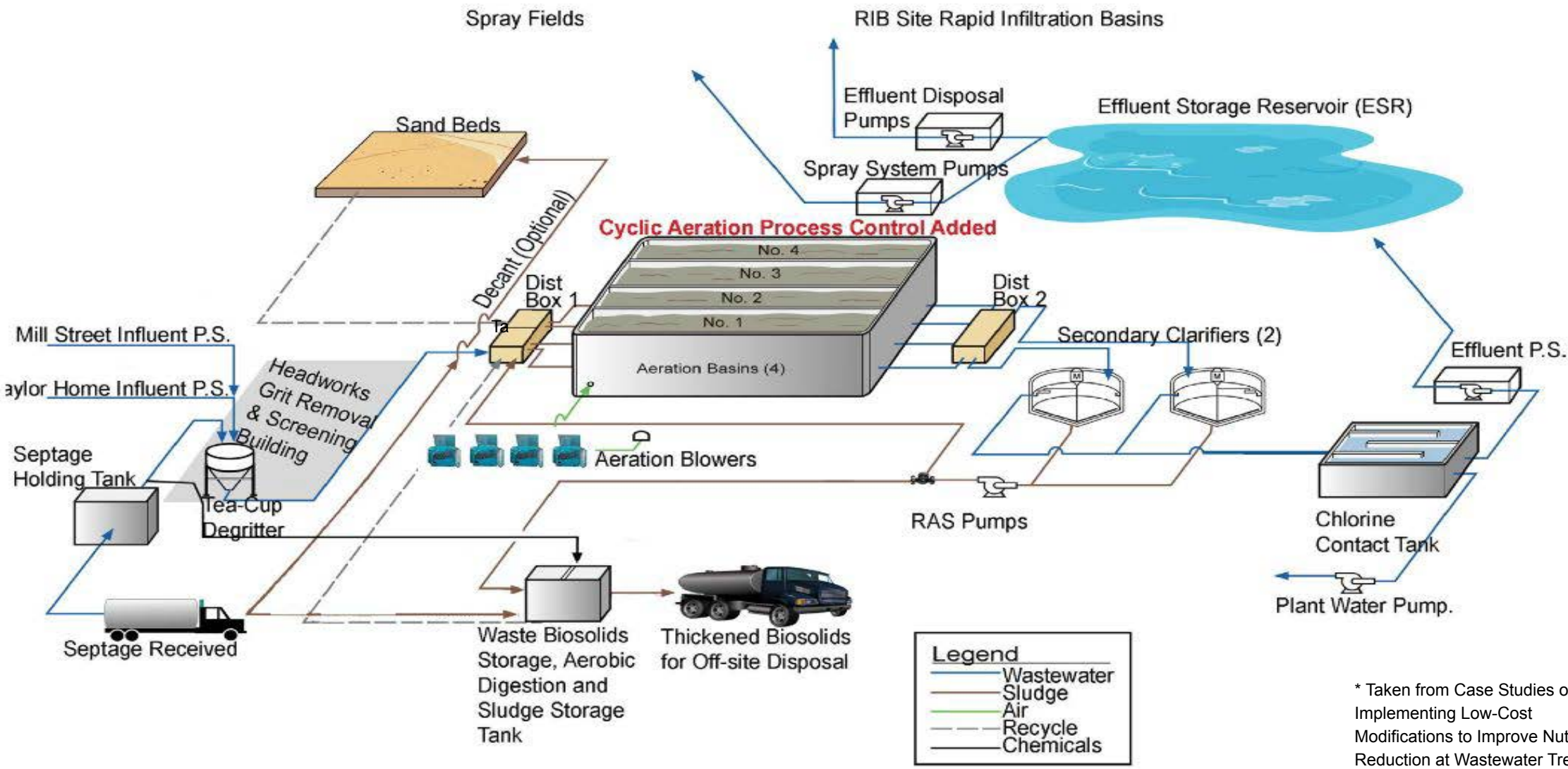



- Requires anaerobic zone followed by aerobic/anoxic zone
  - PAOs release $PO_4$ and take up VFAs in anaerobic zone
  - PAOs take up $PO_4$ in aerobic/anoxic zone
- Adequate supply of volatile fatty acids (VFAs) in anaerobic zone
- Oxygen and $NO_3$ returns disrupt anaerobic zone
  - Must avoid for stable Bio-P



# Wolfeboro Wastewater Treatment Facility

# Overview of Wolfeboro WWTF




* Taken from Case Studies on Implementing Low-Cost Modifications to Improve Nutrient Reduction at Wastewater Treatment Plants, EPA, 2015.

# Biological Process Evaluation Objectives

- Understand the process
  - Existing flow and load conditions
- Examine Alternatives
- Tool for the Future



# Data Review and Supplemental Sampling


# Data Analysis

- Preliminary Data Review
  - Influent characterization
  - Aeration tank and secondary clarifier process information
  - Monthly operating reports
  - Effluent and effluent storage pond
- Supplemental Sampling and Testing
  - Influent VFA characterization
  - Aeration tank profiling

# Influent Characterization

- 10 yrs of data evaluated
- 3 years used for statistical analysis
- Medium to high strength municipal wastewater

| Parameter | Average | Max Month | Max Day |
|---|---|---|---|
| Flow (gpd) | 290,000 | 390,000 | 550,000 |
| TSS (mg/L) | 420 | 430 | 11,000 |
| BOD5 (mg/L) | 250 | 350 | 2,100 |
| $NH_3$-N (mg/L) | 26 | 35 | 56 |
| TKN (mg/L) | 41 | 55 | 180 |
| Orthophosphate-P (mg/L) | 2.2 | 3.3 | 14 |
| TP (mg/L) | 9.9 | 20 | 130 |

# Plant Operation and Performance

- Summary of operation
  - SRT of ~10 days in summer and ~20 days in winter
  - Cyclic aeration
    - ~60 min air-on and ~45 min air off
    - Adjusted based on conditions
  - RAS rate of ~70-100%
- Summary of performance
  - Effluent consistently meets NPDES permit limits
  - Occasional spikes in effluent ammonia

| Secondary Effluent Parameter | NPDES Permit | Average |
|---|---|---|
| CBOD5 (mg/L) | 30 | 11 |
| TSS (mg/L) | 30 | 8.2 |
| Total Nitrogen (mg/L) | 10 | 3.6 |
| Total Phosphorus (mg/L) | - | 0.8 |

# Supplemental Sampling

- Understand environmental conditions created by cyclic aeration in flow-through basins
- Twice daily for one-week
- DO, pH, oxidation-reduction potential, nitrate, and orthophosphate
- Measured along the length of the basin during air on and air off cycles.

# Supplemental Sampling – Influent Volatile Fatty Acids (VFAs)

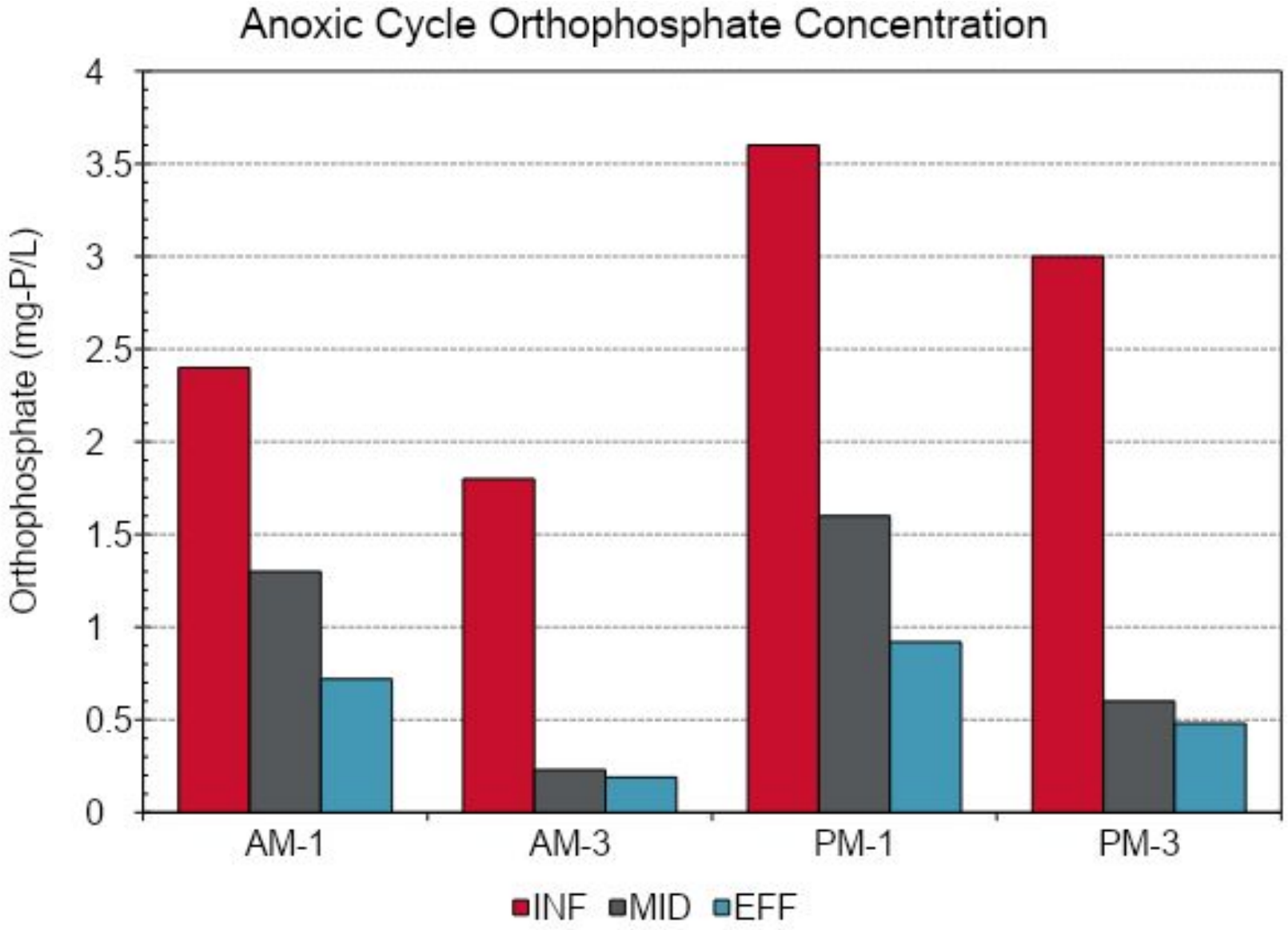
## Influent VFAs in mg/L-COD

| Date | 6/14/2021 7:15 | 6/15/2021 7:20 | 6/16/2021 7:20 | 6/17/2021 7:25 | 6/18/2021 7:15 | Average |
|---|---|---|---|---|---|---|
| Acetic Acid | 29.2 | 24.1 | 28.9 | 38.5 | 51.2 | 34.4 |
| Propionic Acid | 9.7 | 8.5 | 16.2 | 15.7 | 26.3 | 15.3 |
| **Total** | **39.0** | **32.6** | **45.1** | **54.2** | **77.5** | **49.7** |

- VFA concentrations within typical range
- VFA to average BOD ratio is higher than industry standards
- May indicate fermentation in the collection system

# Supplemental Sampling - Nutrients

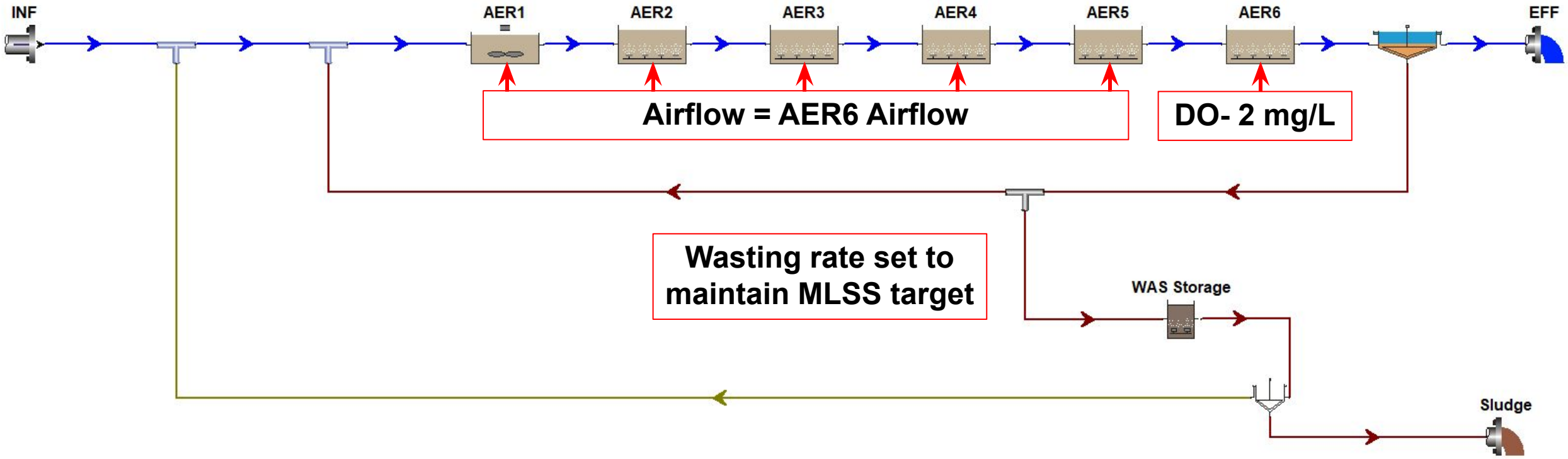
- DO and ORP
  - Data erratic and difficult to interpret
  - Very low DO even during air-on cycles
- Non-detectable nitrate for all samples
- Orthophosphate release during anoxic cycle





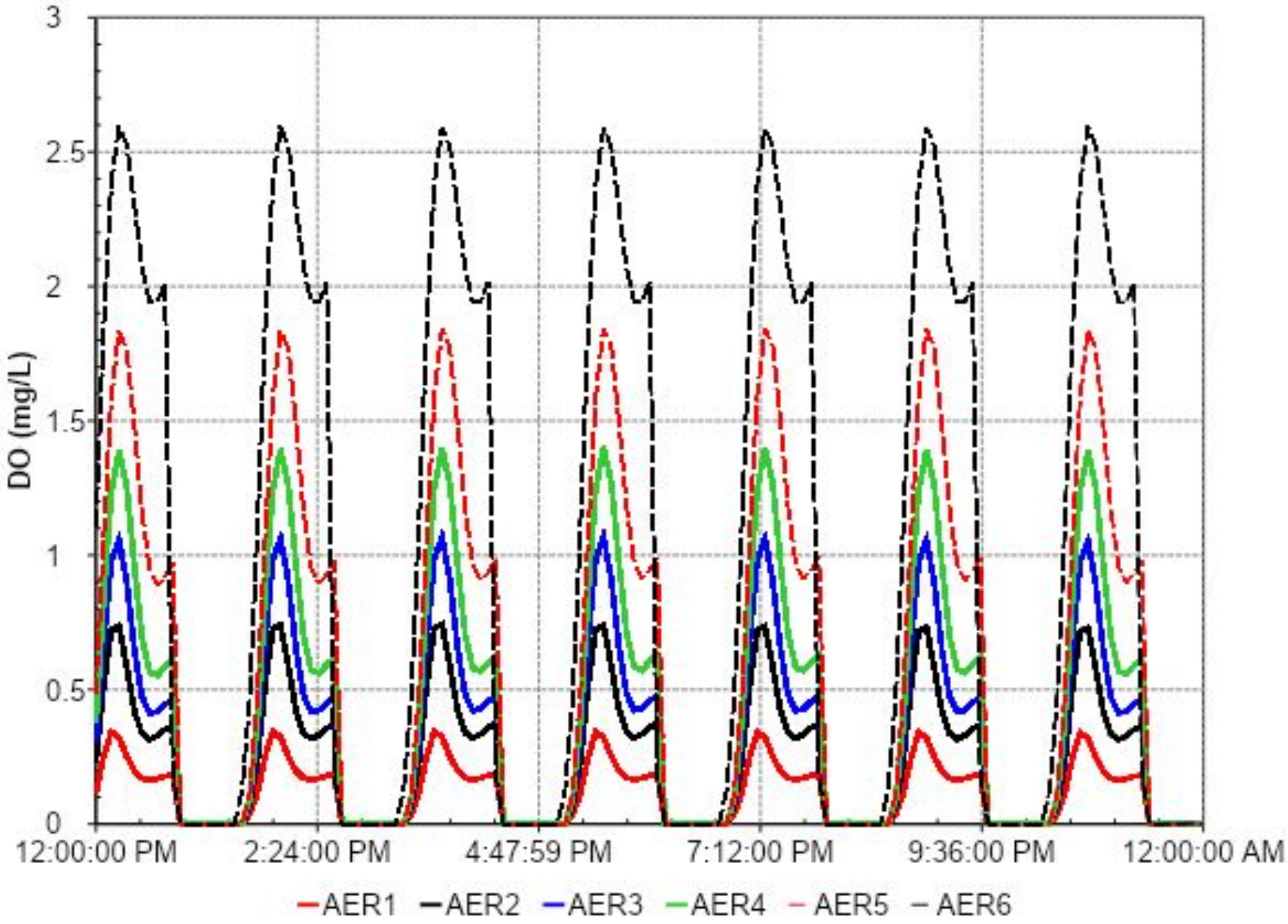
# BioWin Model Development and Findings

# BioWin Model Development

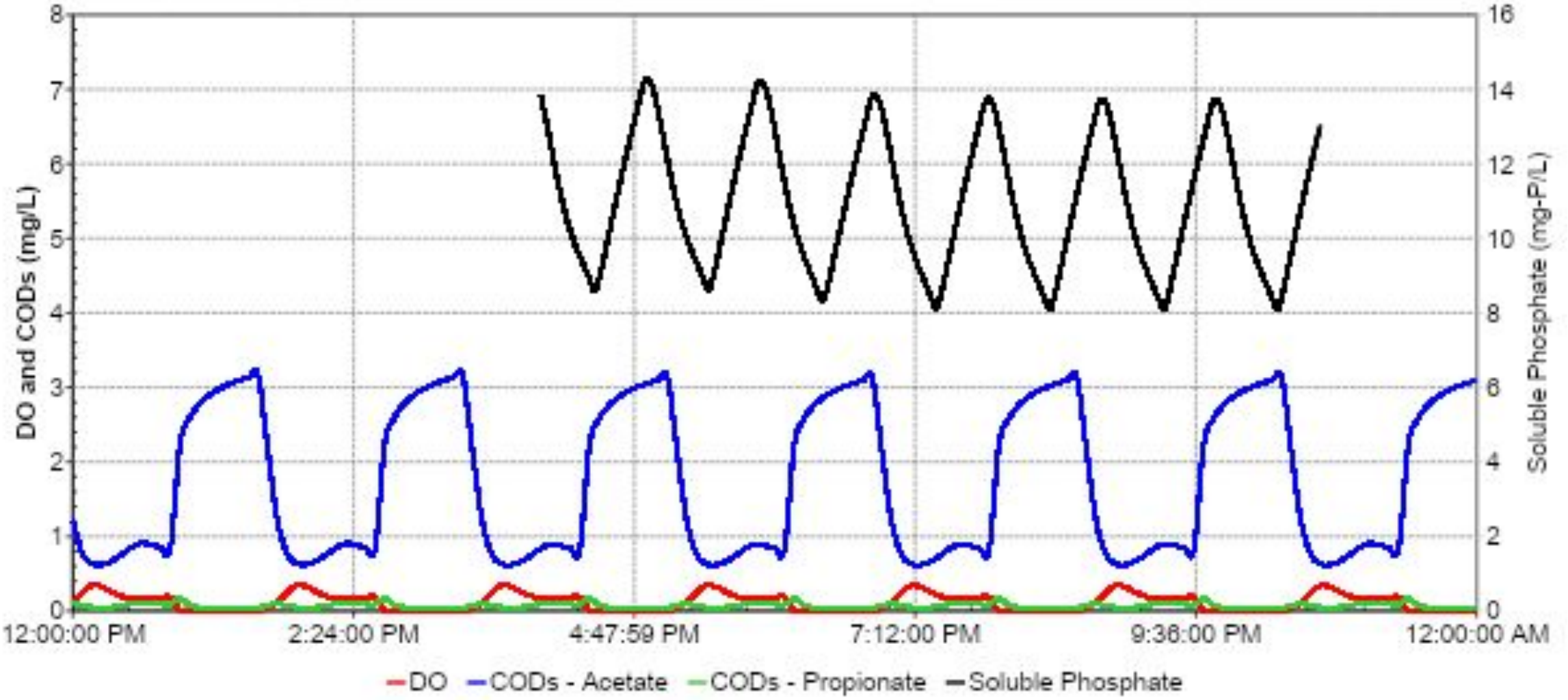


# Predicted DO Profile

- DO profile along length of tank.
- Low air demand at effluent end
  - Low BOD
  - Better oxygen transfer
- Airflow not adequate to hit DO target in most of tank
  - DO probe location at effluent end



# Phosphorus Removal - Inlet End Anaerobic Zone



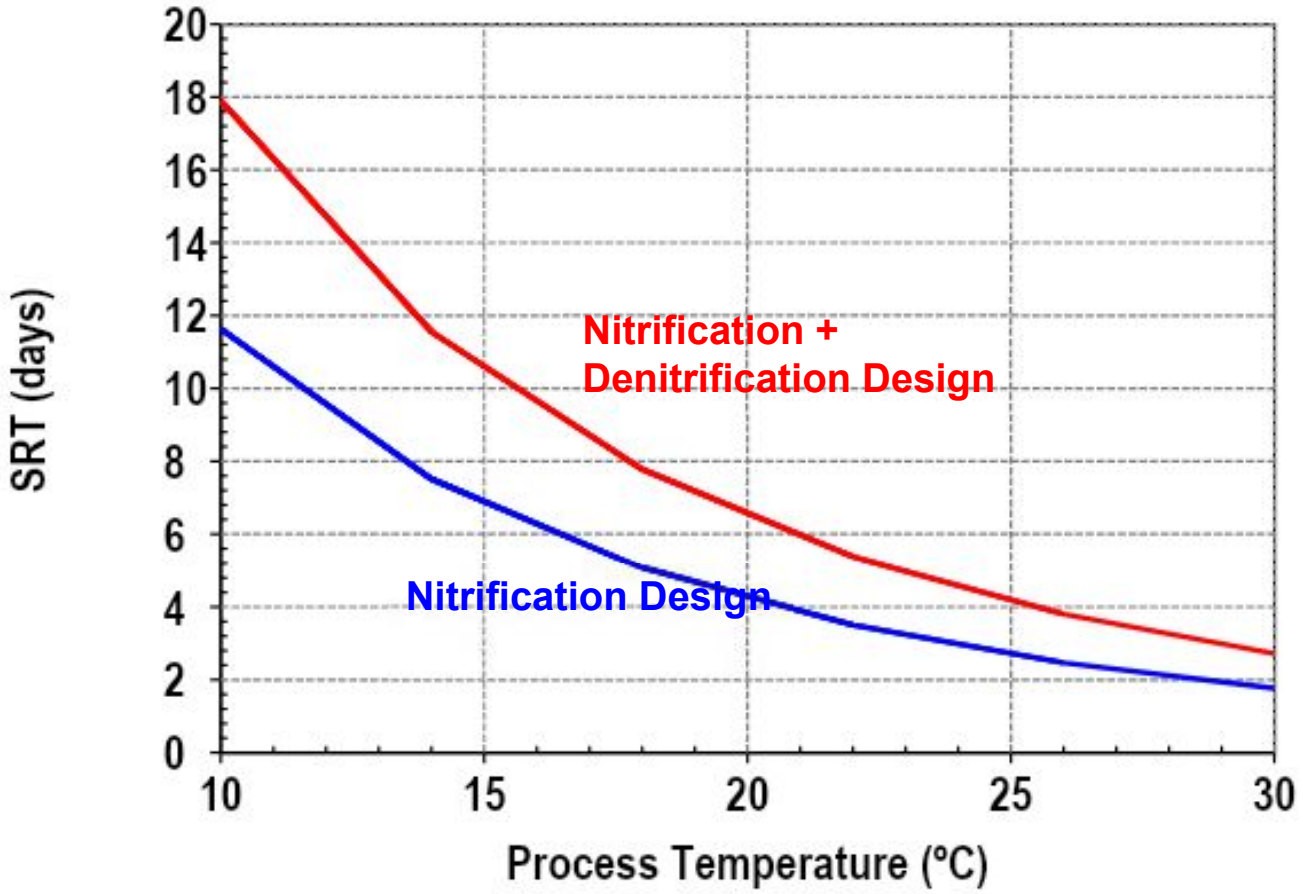

Anaerobic zone created to facilitate P release and VFA formation

# Conclusions and Significance

- Conclusions
  - Flow-through cyclic-aeration can sustain both biological nitrogen reduction and EBPR
  - Aeration control using a DO probe at the effluent end of the basin caused anaerobic conditions at the influent end of the basin as predicted by the process model
  - High influent VFA concentration likely bolster EBPR at this facility
- Significance
  - Small WWTPs may be able to achieve EBPR in flow-through cyclic-aeration process potentially saving capital costs in basin expansion.
- Future
  - Keep doing more with less
  - Keeping the bugs happy

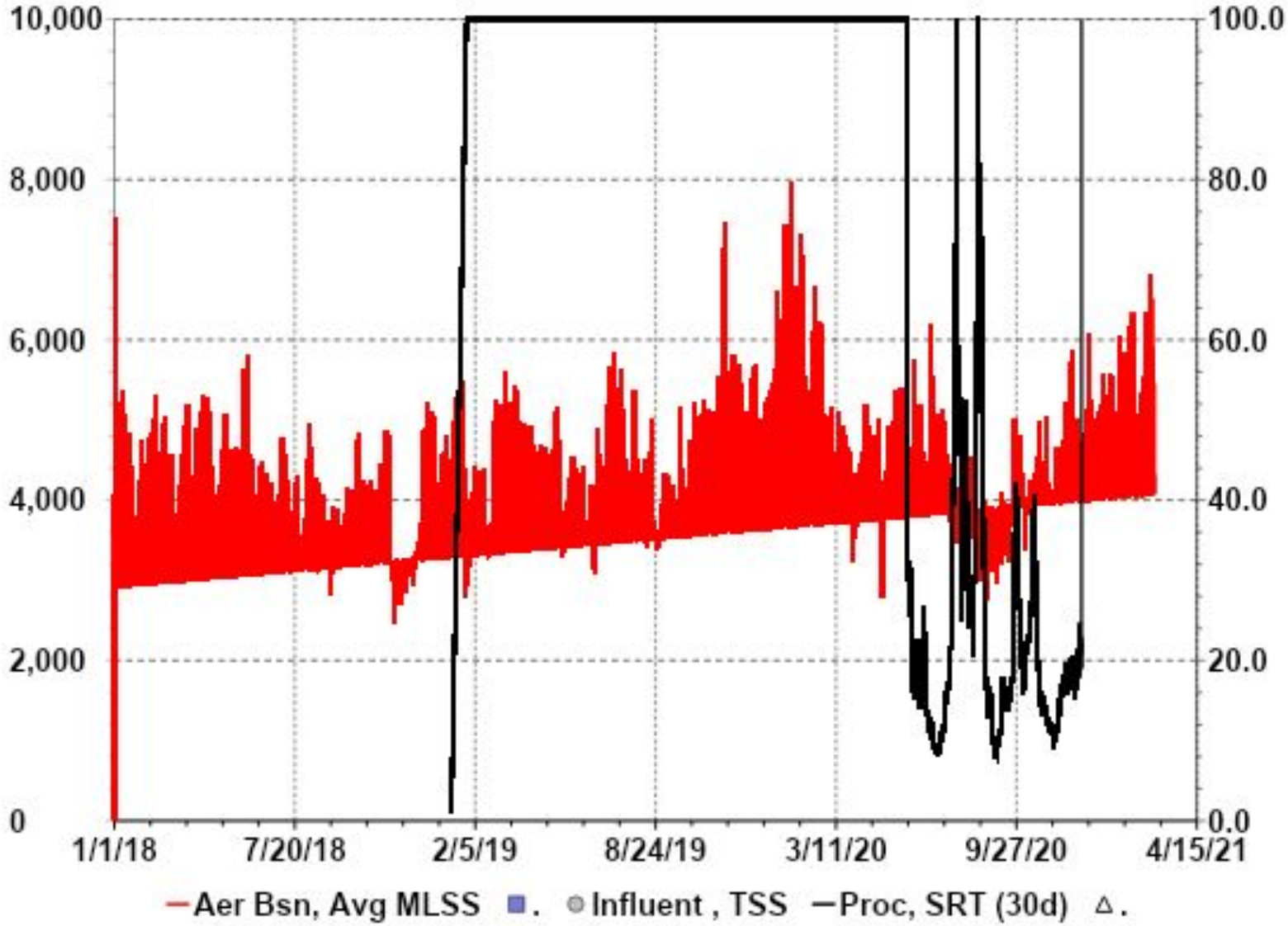
# Nitrogen Removal and SRT

- Nitrification and denitrification requires longer SRTs than only nitrification.
- Cold weather in Wolfeboro requires high SRTs.



# Process Evaluation

- Relatively high MLSS compared to industry standards.
- SRT spikes correspond to all basins being online (not actual 100 day SRT).
- Average SRT of 23 days



# Secondary Effluent and Effluent Storage Pond (ESP)

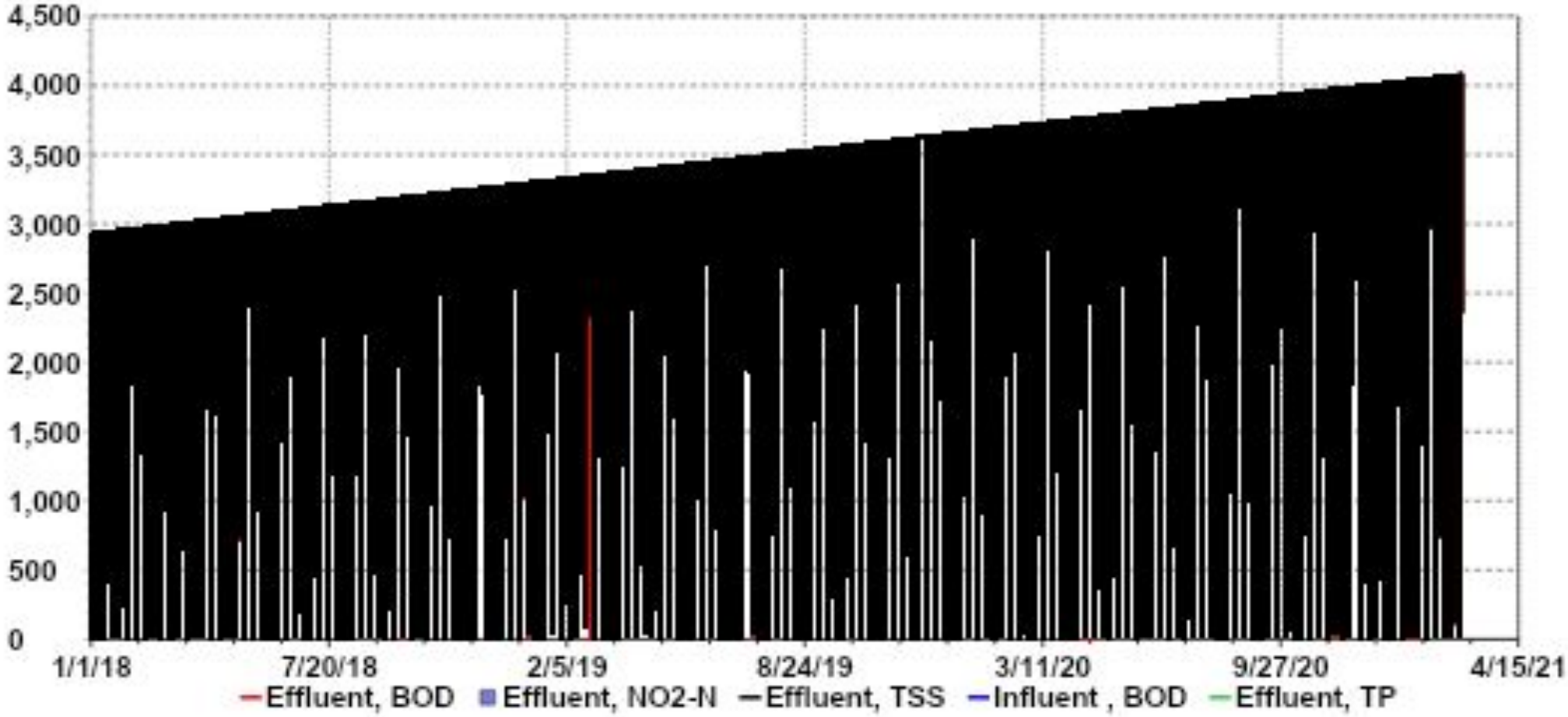
- CBOD5 and TSS effluent values comply with NPDES permit
- Max day ESP effluent ammonia greater than NPDES permit
- Low effluent TP indicative of enhanced biological phosphorus removal (EBPR)

| Parameter | NPDES Permit | Average | Max Month[1] | Max Day[2] |
|---|---|---|---|---|
| **Secondary Effluent** | | | | |
| CBOD5 (mg/L) | - | 11 | 18 | 64 |
| TSS (mg/L) | - | 8.2 | 14 | 68 |
| Ammonia-N (mg/L) | - | 3.0 | 8.1 | 17 |
| Total Nitrogen (mg/L) | - | 3.6 | 4.0 | 8.8 |
| Total Phosphorus (mg/L) | - | 0.8 | 1.6 | 4.6 |
| **Effluent Storage Lagoon** | | | | |
| CBOD5 (mg/L)[3] | 30 | 7.6 | 10 | 55 |
| TSS (mg/L)[3] | 30 | 9.5 | 17 | 33 |
| Ammonia-N (mg/L) | 5 | 1.9 | 3.5 | 12 |
| Total Nitrogen (mg/L) | 10 | ND | ND | ND |
| Total Phosphorus (mg/L) | - | 0.8 | 1.1 | 4.3 |

1. Max month based on the 91.7th percentile.
2. Max day based on the 99.7th percentile.
3. CBOD5 and TSS limits are average monthly values.

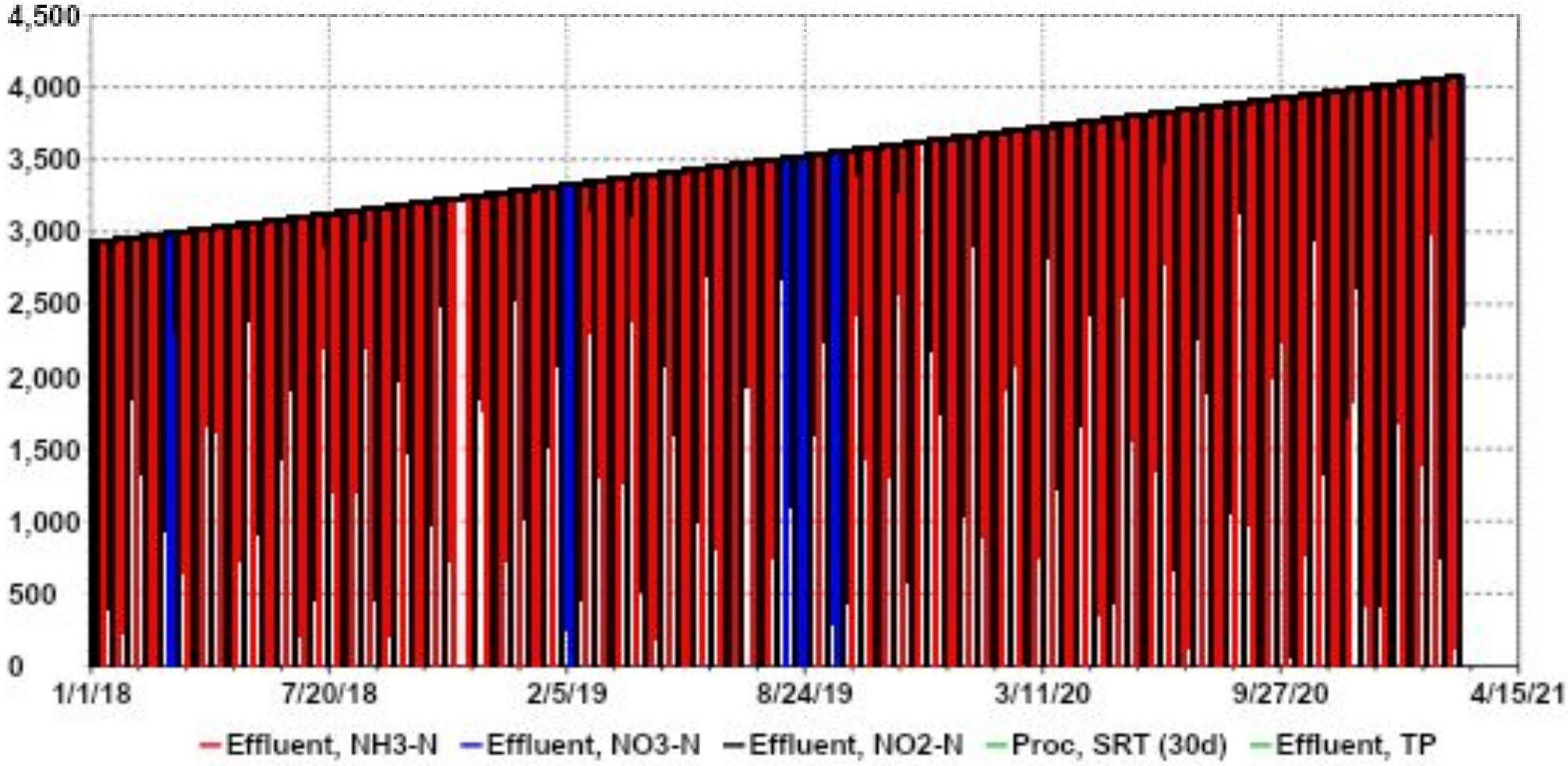
ND: Data not provided.

# Process Performance




Spike in effluent BOD and effluent TSS corresponds to high influent loading and increased F:M ratio.

# Process Performance




- Spikes in effluent NH3-N and NO3-N (typically in summer months)
- Consistently low NO2-N concentrations indicate complete nitrificaton