

# Optimization through Implementation of Automated Control Programs at NRRRF

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Raleigh Water

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# Topics for Today's Presentation

- Introduction / Background
  - Overview of NRRRF treatment process
  - Nutrient removal requirements
- Automation Control Strategies at NRRRF
  - Overview of strategies and objectives
  - Outcomes & benefits
  - Key take-aways
  - Next steps



# What “Smart Controls” are we discussing?

- Real-Time Process Control (RTPC) Programs

*ON-LINE ANALYZER RESULTS + PROCESS EQUATIONS → REAL-TIME SET POINTS*

- Potential Benefits
  - Assists in maintaining nutrient removal performance
  - Improve process efficiency
  - Reduce operational costs (chemicals & power)
  - Automate some routine decisions

# Introduction / Background



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# Neuse River Resource Recovery Facility

- Expanded to 75 mgd in October 2018
  - RTPC programs added as part of expansion project
- Planning for expansion to 90 mgd/105 mgd







# Nutrient Removal Requirements

- Annual Average, Load-Based TN Allocation
  - Current TN Allocation: 687,373 lbs/year
  - <3 mg/L TN at 75 mgd
- Quarterly average TP limit
  - 2.0 mg/L
- Monthly average NH<sub>3</sub>-N limits
  - 1.0 mg/L summer / 2.0 mg/L winter
- Stringent BOD<sub>5</sub> limits

# Real Time Process Control Strategies at NRRRF







# Real Time Process Control Programs

## DO / Ammonia-Based Aeration Control

Better match air demands to biological demand

Reduce blower demand and supplemental carbon demands

Feb 2018

## Load Based Equalization

Operate EQ basin based on target ammonia loads (vs flow)

Improve efficiency of biological process

Sept 2018

## Automated Chemical Feed (Carbon / Alum)

Use on-line nutrient sensors for real-time control of chemical dosages

Optimize chemical dosage rates

Nov 2018  
(Carbon)

## Clarifier Optimization Program

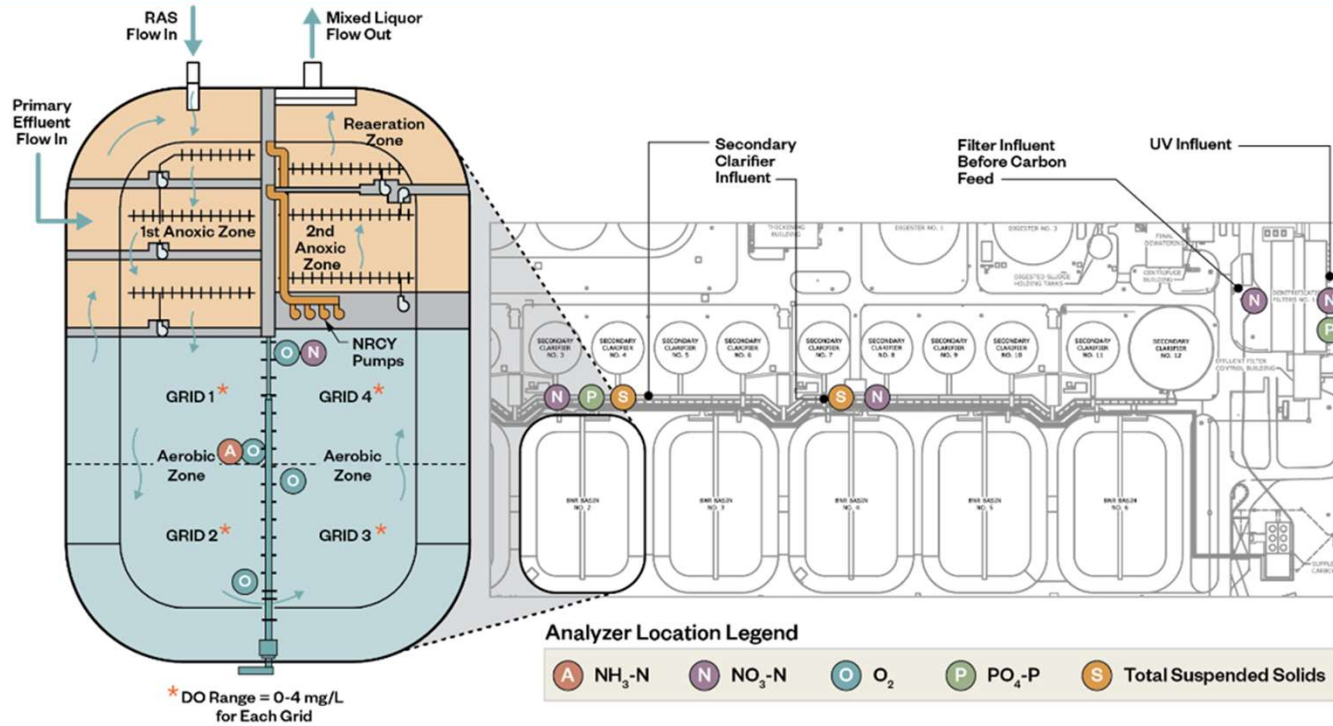
Use on-line MLSS analyzer for real-time solids loading rate

Real-time prompts for # of Clarifiers needed

Fall 2018



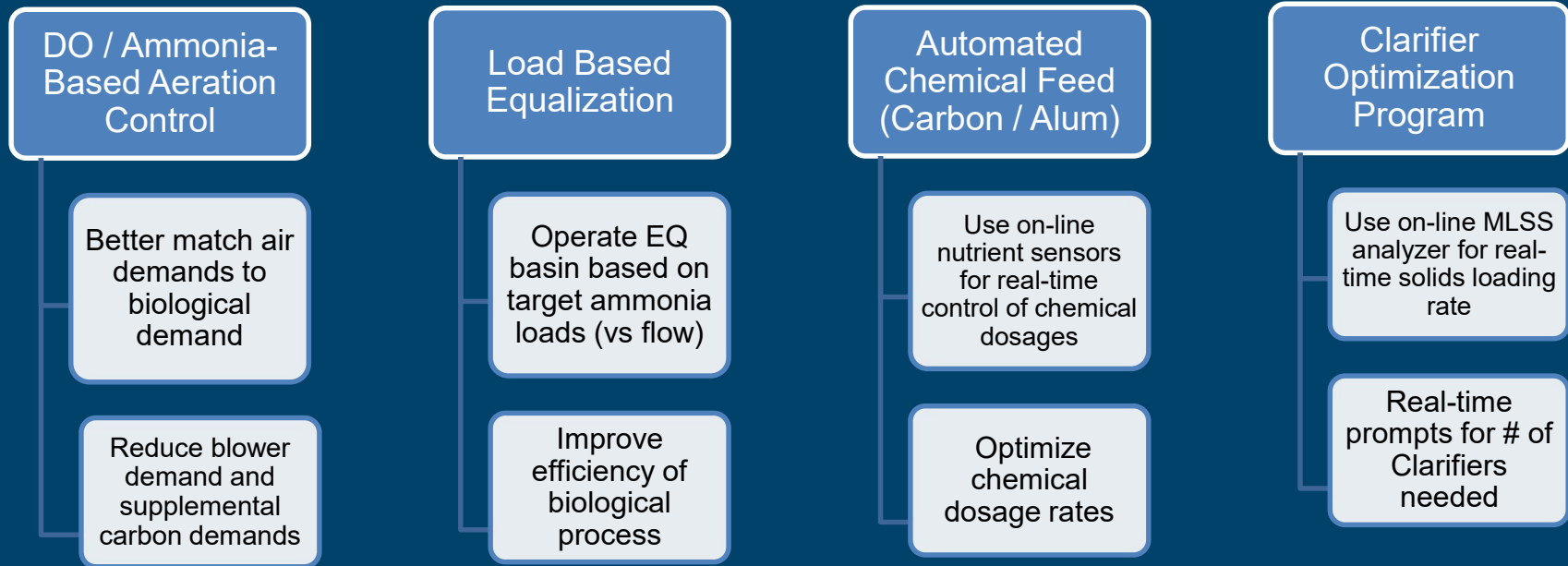
# RTPC Programs Rely on In-Situ Analyzers



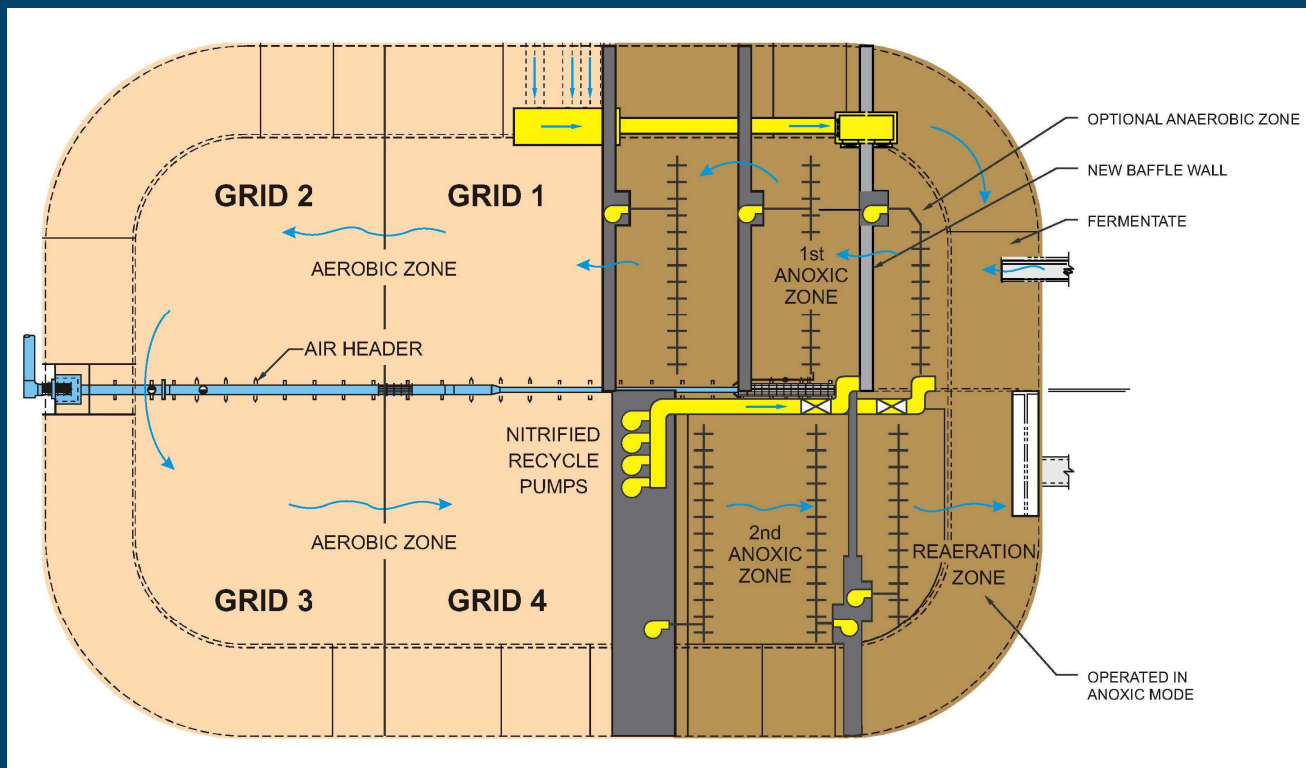
+ Primary Effluent NH<sub>3</sub>-N Probe



# Real Time Process Control Programs



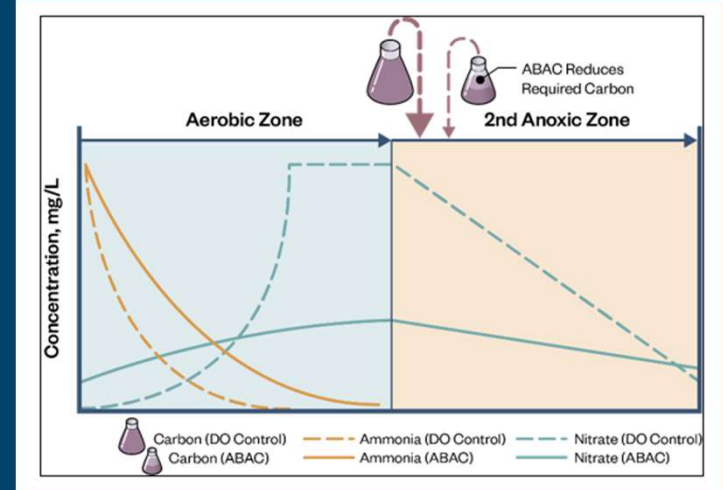
# Each Aeration Grid Has Own DO Control Zone





# Ammonia Based Aeration Control (ABAC)

- $DO = f(\text{target ammonia set point})$ 
  - Maintain minimum DO when ammonia < target
  - More air provided when ammonia > target
  - Achieve simultaneous nitrification and denitrification
  - Reduced energy and supplemental carbon requirements





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# Ammonia Load Based Equalization

- Maintain consistent load to BNR system
  - If (load > target) → FILL EQ
  - If (load < target) → EMPTY EQ
- If EQ is too full, load setpoint automatically increased
- Benefits
  - Reduces diurnal nitrogen load to BNR system
  - Reduces variability in required airflow
  - Improves process stability (more consistent operations)



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# Supplemental Carbon Feed Program

- Controls feed rate to filters and basins
  - Manual, flow-paced, or nutrient paced modes
- Use nutrient-paced mode in basins
  - Uses feedforward and feedback loop to match chemical addition to demand

Calculate nitrate load to anoxic zone

Enter desired nitrate concentration at end of anoxic zone

Calculate theoretical carbon needed

Pump initially set for calculated carbon demand

Compare setpoint and actual nitrate data, adjust pump speed as needed



# Alum Feed Program

- Manual, flow-paced, or nutrient paced mode
- Nutrient paced mode to maintain target Ortho-P setpoint
  - Secondary Clarifier channel and UV influent Ortho-P meters
  - Program accounts to time delay between meters and feed location at primary effluent
  - Feed-back only loop



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# Secondary Clarifier Guidance Program

- Purpose: to get feedback on number of secondary clarifiers to have in service for a given flow, SVI, MLSS, and RAS flow
- Equation developed using state point analysis results and multivariable linear regression

$$\text{Required Clarifier Surface Area} = -193,090 + 981 \times Q + 909 \times SVI - 530 \times Q_{ras} + 34.2 \times MLSS$$





# Secondary Clarifier Program Concept Overview

Select Variable to Solve for

- Q
- RAS
- SVI
- Small
- Large
- MLSS**

## Secondary Clarifier Guidance Program

Clarifiers in Service



### Key Performance Indicators

<b>100</b> mL/g SVI	<b>570</b> gpd/sf SOR
<b>45</b> mgd Flow	<b>25</b> mgd RAS flow
<b>25</b> lb/d/ft <sup>2</sup> SLR	<b>3500</b> mg/L MLSS

Reference Calculator  
(Click to Launch)

### Secondary Clarifier Evaluation

<b>6</b> No. 100' D Clarifiers in Service	<b>2</b> No. 160' D Clarifiers in Service	<b>87,000</b> Secondary Clarifier Surface Area in Service (ft <sup>2</sup> )
<b>Sufficient Clarifier Capacity</b> Clarifier Status		<b>53,000</b> Recommended Surface Area
<b>View Options</b> Clarifier Recommendations		

Q, mgd	45
RAS, mgd	25
SVI, L/g	120
Small Clarifier in Service	6
Large Clarifier in Service	2
<b>Maximum allowable MLSS under these Conditions, mg/L</b>	<b>4,100</b> mg/L

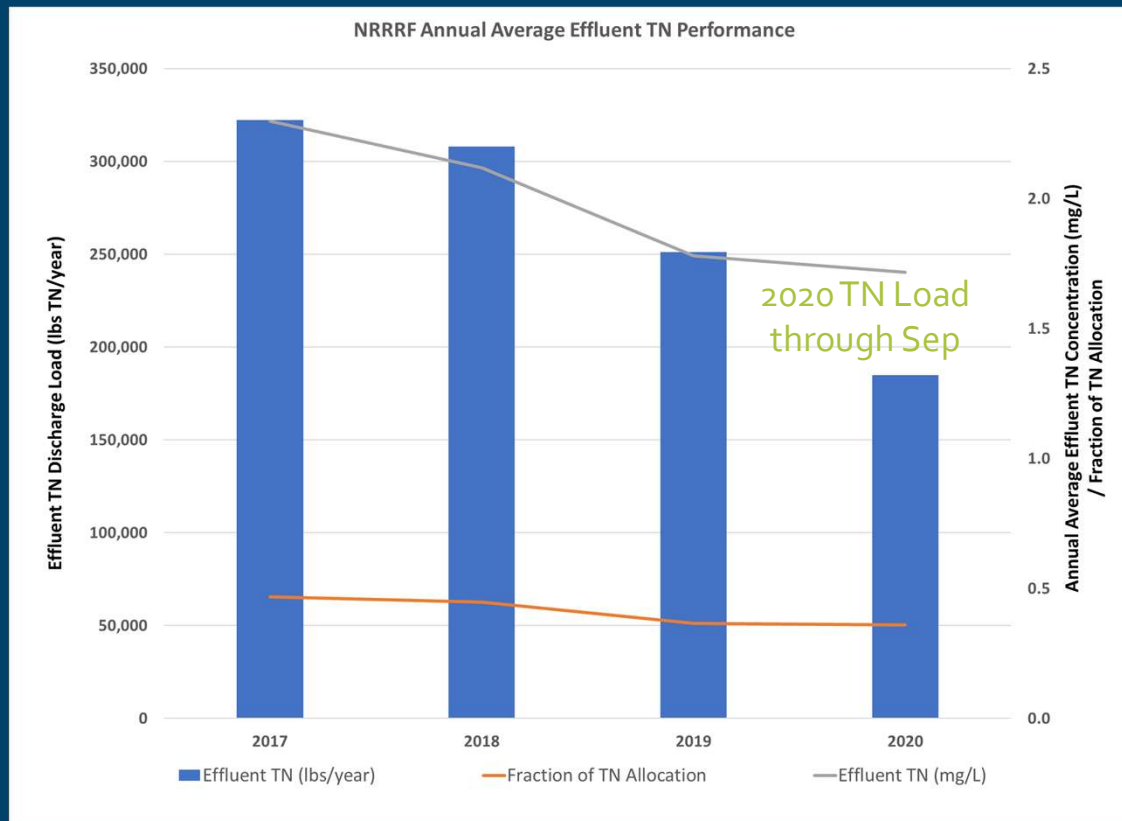
# Outcomes & Benefits



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# Reduced Effluent TN



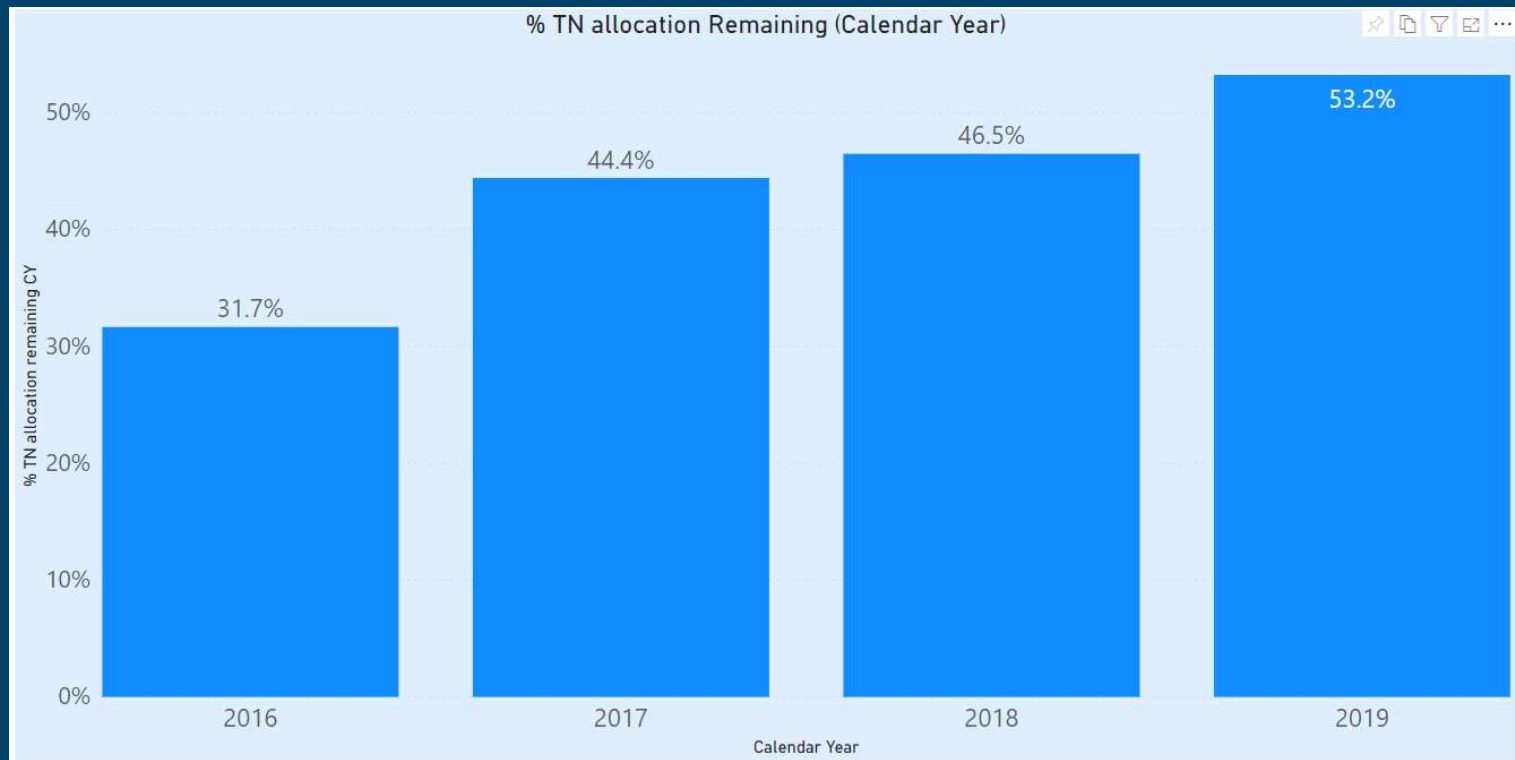
2004 – 2018 Avg:  
2.4 mg/L

2019 Avg:  
1.78 mg/L

2020 Avg (thru Sep):  
1.72 mg/L



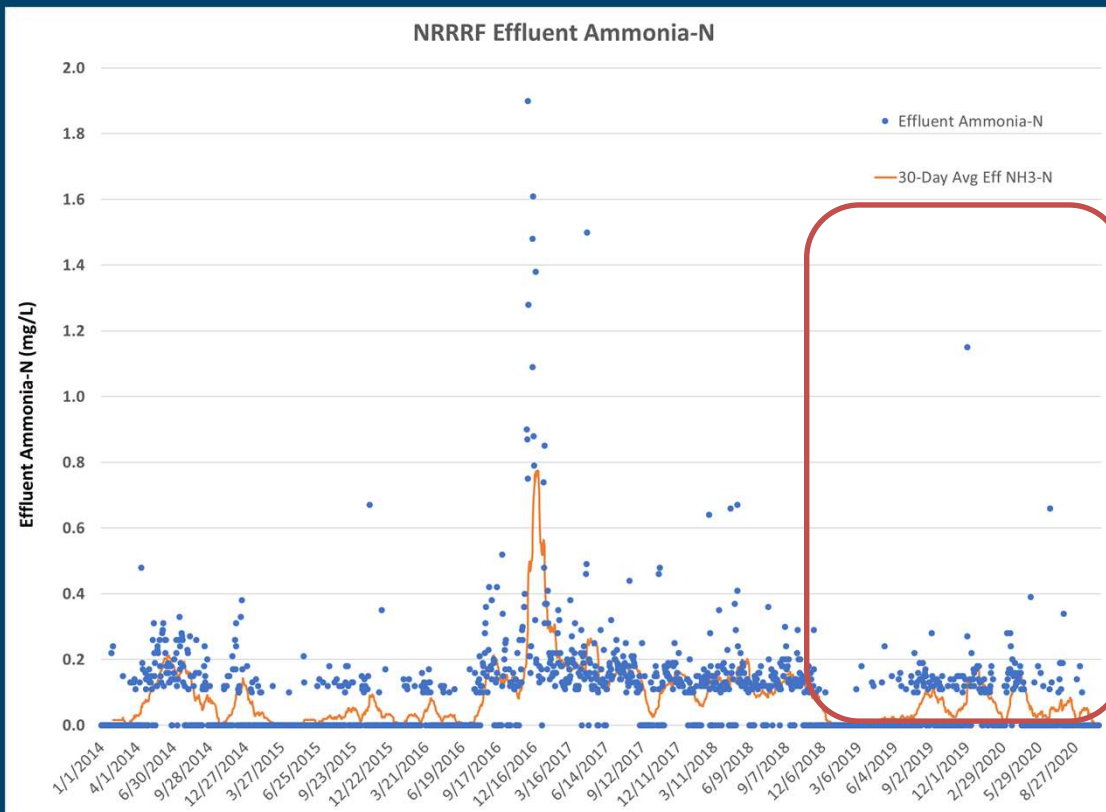
# % TN Allocation Remaining w/ Debit







# Improved Process Stability

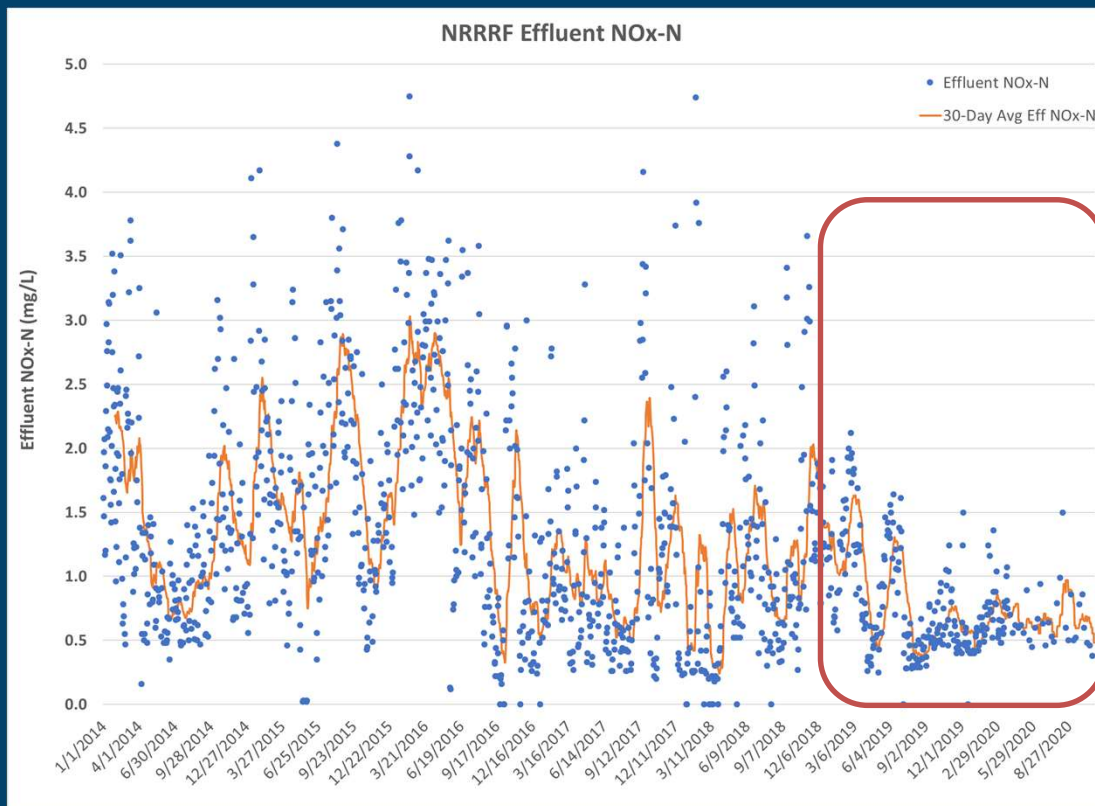


2004 – 2017 Avg:  
0.1 mg/L

2019 - 2020 Avg:  
0.05 mg/L



# Improved Process Stability



2004 – 2017 Avg:  
1.5 mg/L

2019-2020 Avg:  
0.8 mg/L



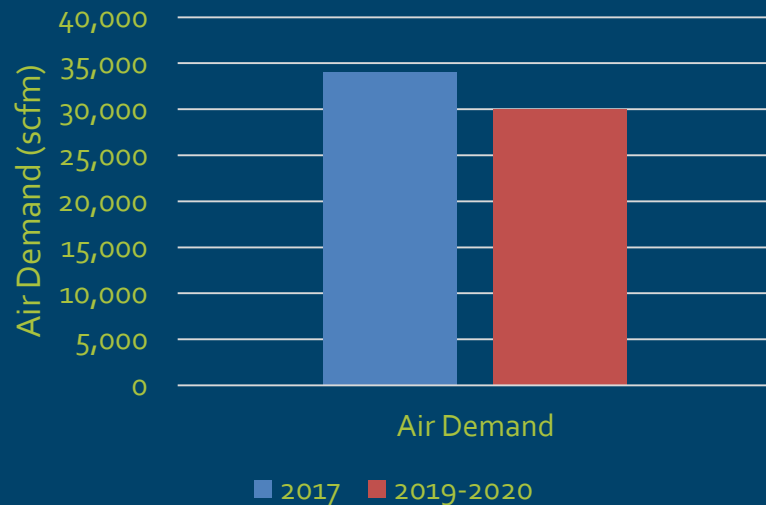
Variable	Avg.	Max.	Peaking Factor
NH <sub>3</sub> Load into Basins	12,990	13,360	1.0
NH <sub>3</sub> Load to Primary Effluent Distribution Box	12,982	15,360	1.2

*Reduced Peak Loads to Aeration Basin*

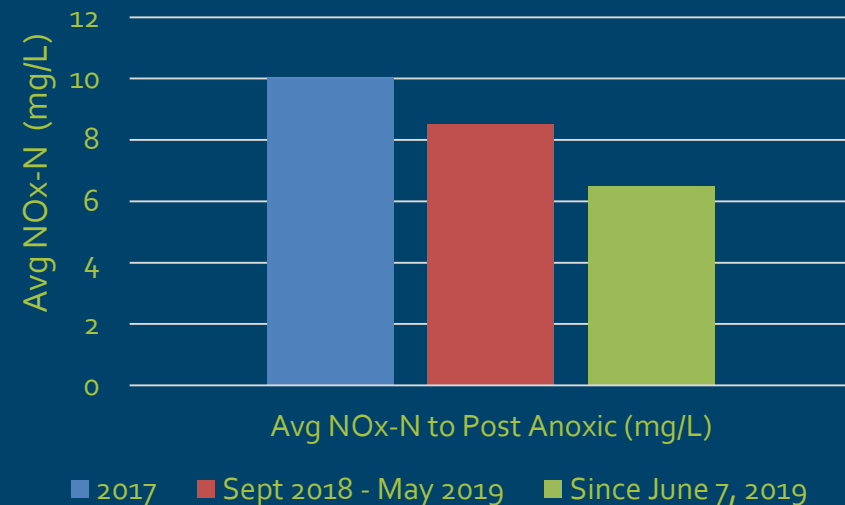


# Reduced Air Demands / More SND

## NRRRF Basin Air Demands



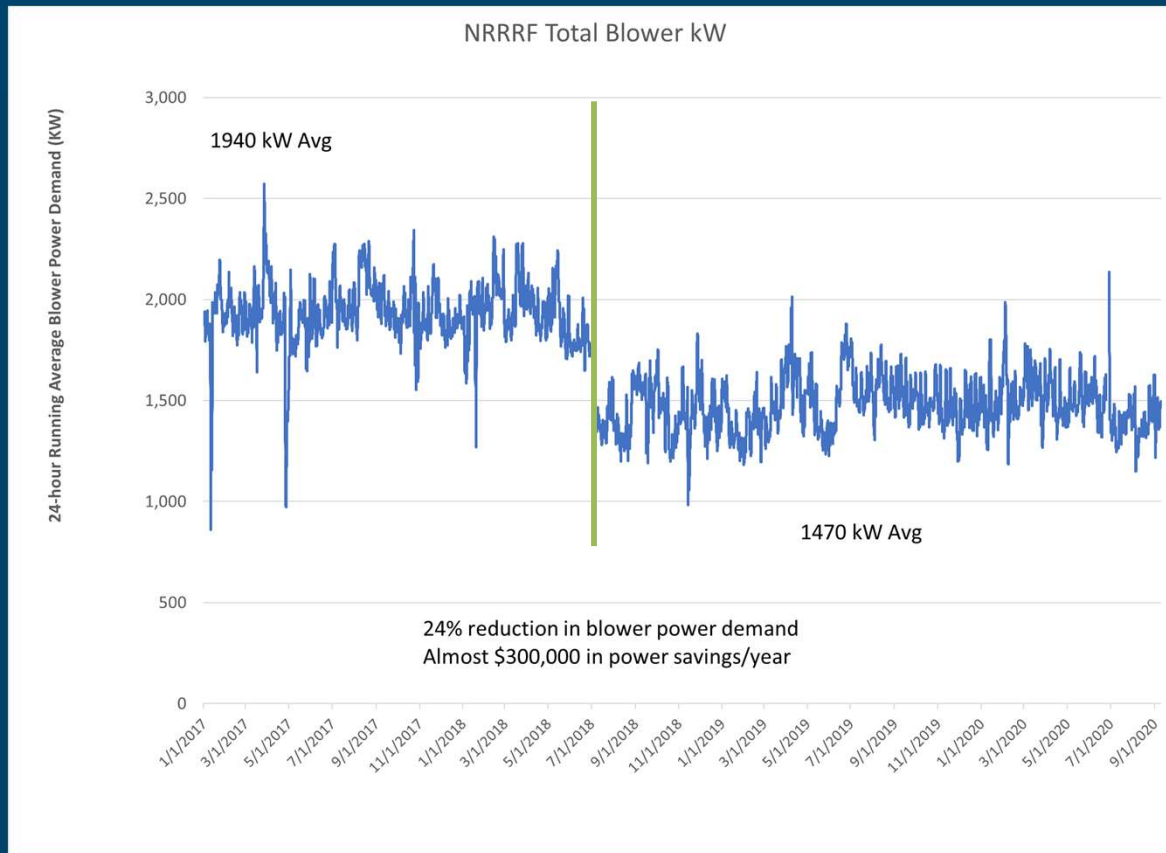
## Nitrates to Post Anoxic Zone



Avg SVI: 80 mL/g



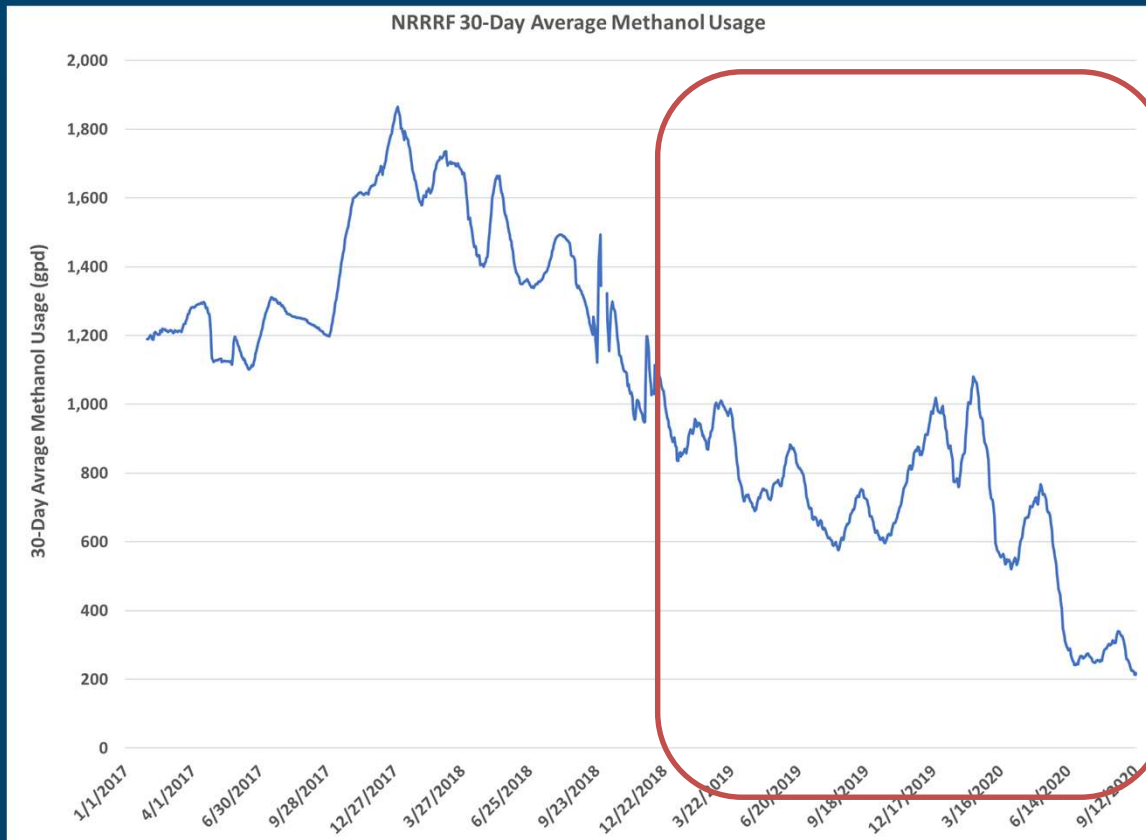
# Reduced Blower Demands



Since July 2018  
reduced to one  
blower for typical  
operations



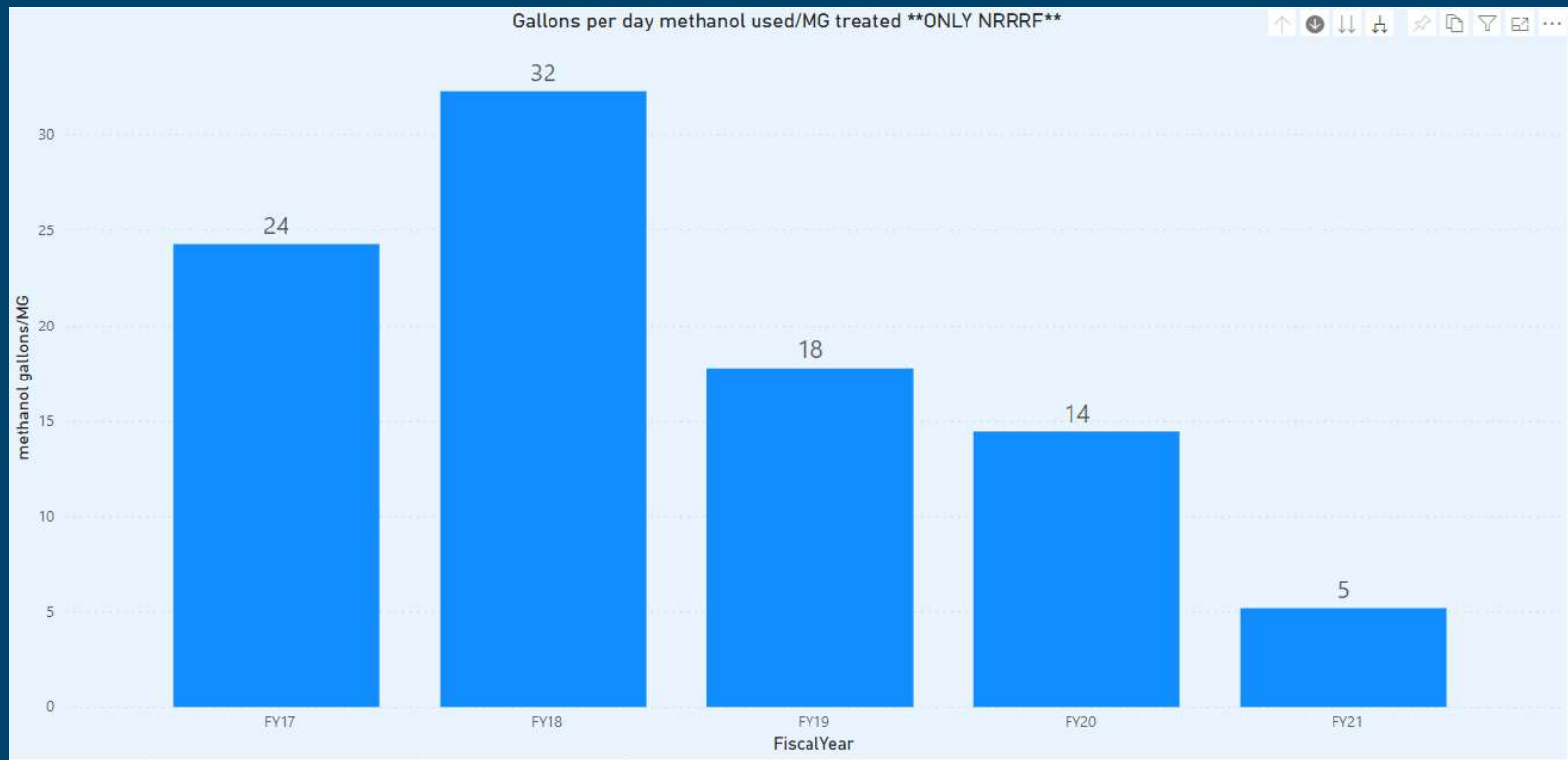
# Reduced Methanol Usage



- Avg usage reduced from 1,300 gpd (2017) to < 650 gpd (2019 - 2020)
- >50% methanol usage reduction
- Avg of \$275,000 in chemical savings / year at \$1.10/gal

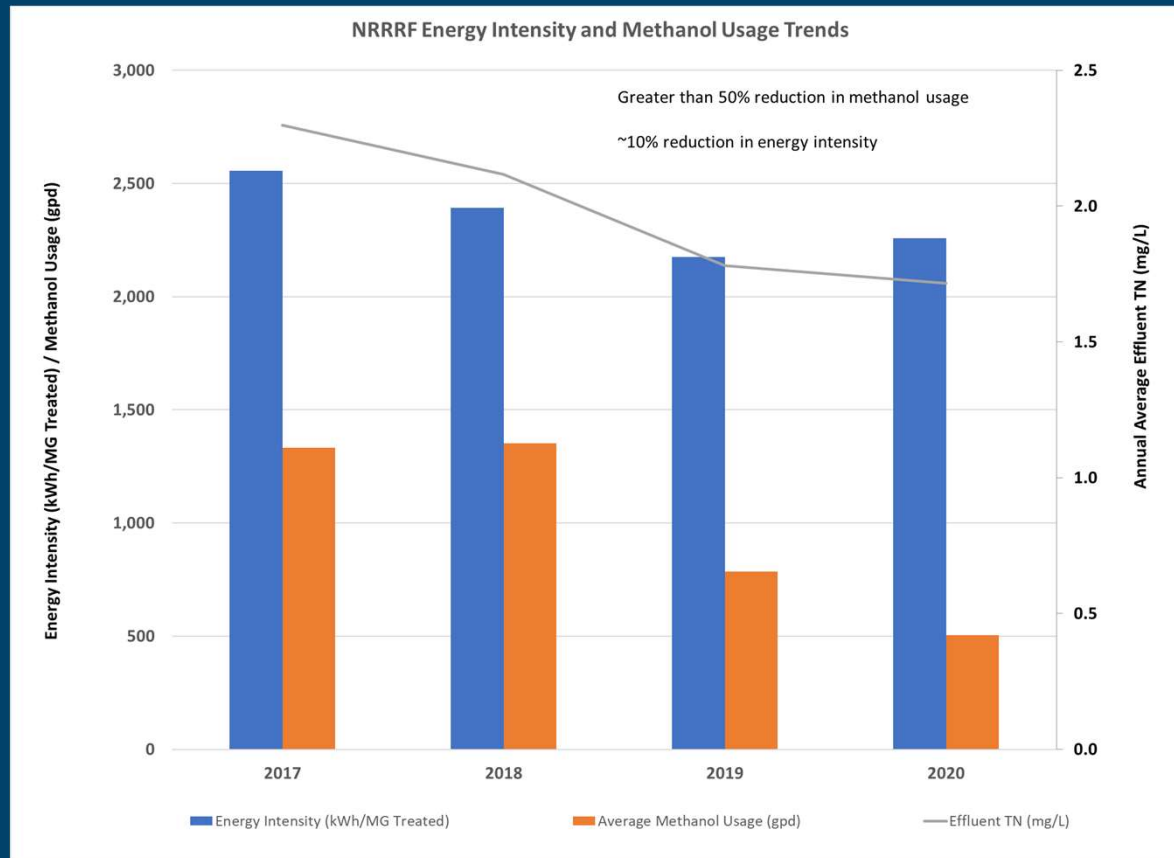


# Gallons Methanol / MG Treated





# Energy Intensity and Methanol Usage Trends







# Conclusions

- “Smart Controls” at NRRRF are producing tangible benefits
  - Reduced effluent TN concentration
  - Improved process stability
  - Reduced supplemental carbon demand
  - Reduced energy demand
- Very much a collaborative RRF team effort to recognize and maintain benefits
  - Step-wise implementation of different programs
  - Routine upkeep of on-line instrumentation
  - Routine monitoring of data and tweaking of program setpoints



## Next Steps

- Development of real-time flow prediction program as the next step in data-driven decision making
- Evaluation of low-ammonia chemical analyzer for better ABAC controls



# Acknowledgements



- Nathan Howell
- Mike Stevens
- Lisa Joseph
- Wendy Gresham

The Hazen logo features the word "Hazen" in a bold, dark blue, serif font, centered within a white rectangular box.

**Hazen**

- Victoria Boschmans
- Katya Bilyk

# Thank you!

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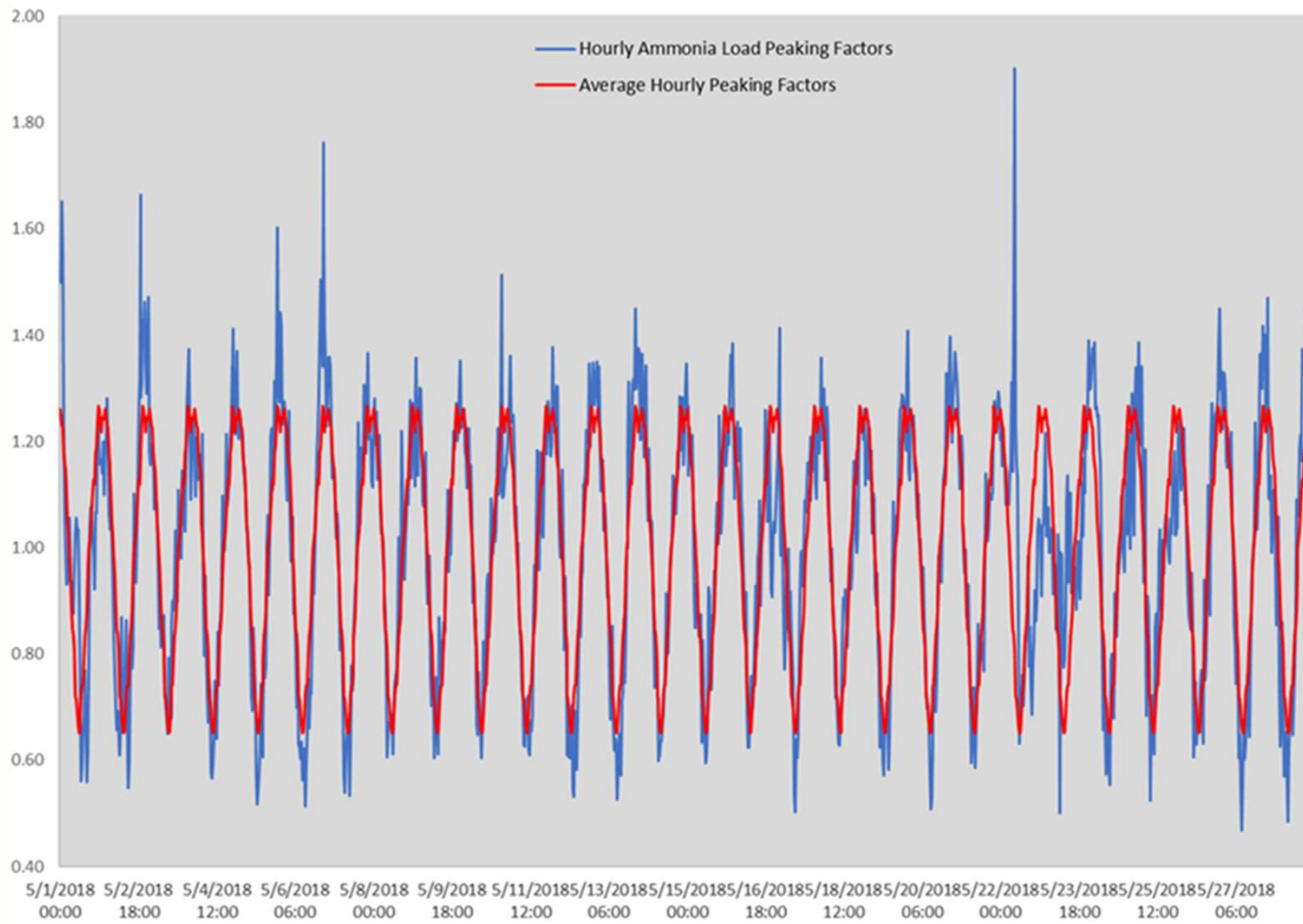
## ABAC Key Take Aways / Lessons Learned

- Challenges with ISE probes
  - Drifting with low ammonia concentrations in aeration basins
  - EPS build-up on probes in aeration basins
- Moved ISE probes from Zone 3 to Zone 1
  - Continued challenges with drifting (especially during summer)
- Pilot tested feed forward strategy with ISE probes in pre-anoxic zone
  - Less EPS build-up on probes
  - Better probe reliability
  - DO stays low during lower influent ammonia load periods and increased when loads are highest
  - Lose on-line feedback for ammonia



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PEDB Ammonia Bi-Hourly Peaking Factors (removed extreme outliers)





## Load Based EQ - Key Take Aways / Lesson Learned

- Changes historical diurnal EQ pattern
- More frequent cleaning
- More frequent calibration



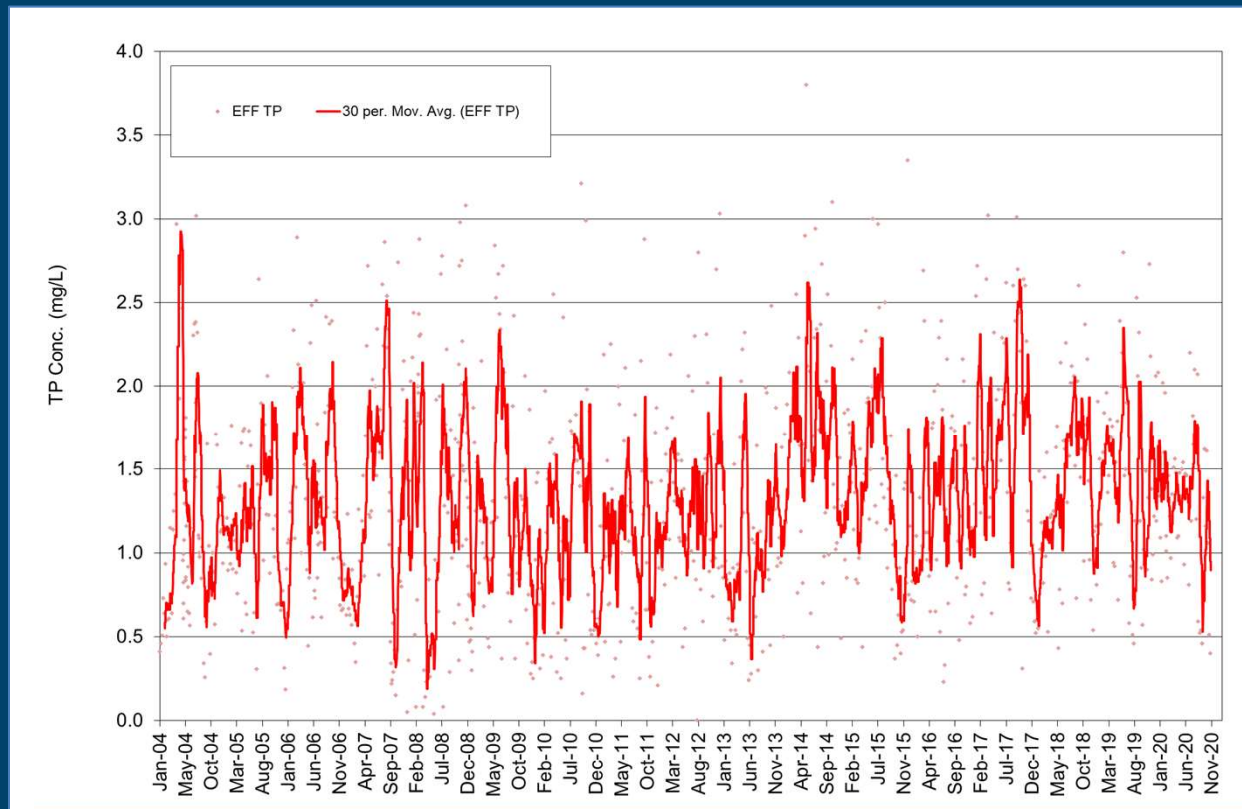


## Alum Program Key Take Aways / Lesson Learned

- Long time lag between dosage point and measurement point affects program effectiveness
- During testing had difficulty achieving consistent target OP when running in nutrient paced mode
- Have converted back to manual set point for alum feed rates
- Feed forward dosage strategy based on primary effluent OP readings would eliminate time lag issues



# NRRRF Effluent TP Historical Trend



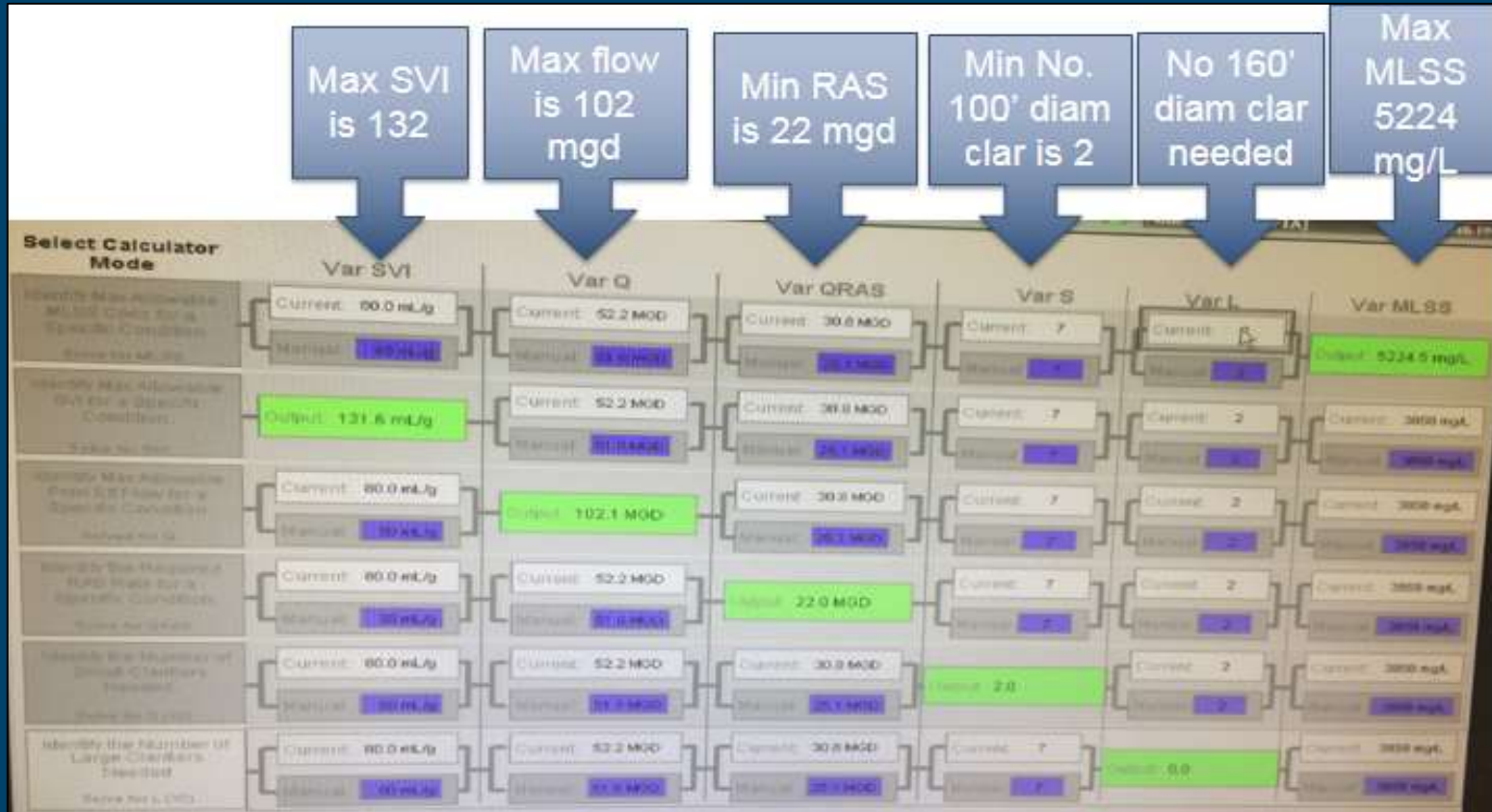


## SC Program - Key Take Aways / Lesson Learned

- Very tangible and quickly realized reduced carbon usage from this program
- Added in maximum pump feed rates to prevent overfeeding
- Feed rates can go up during high flow events
- Additional methanol reductions may also be attributed to ammonia-based EQ and ABAC.



# Secondary Clarifier Program Example





## Clarifier Program - Key Take Aways / Lesson Learned

- Real time solids loading rate is helpful reference for optimizing dry weather number of clarifiers in service
- Recognize we will typically have a high safety factor from predicted failure point
- Program is helpful reference guide during wet-weather operations when experience very high flows