NRRRF Instrumentation and Control Programs for Nutrient Removal Optimization

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LNBA / NRCA 2021 Annual Wastewater Training Workshop

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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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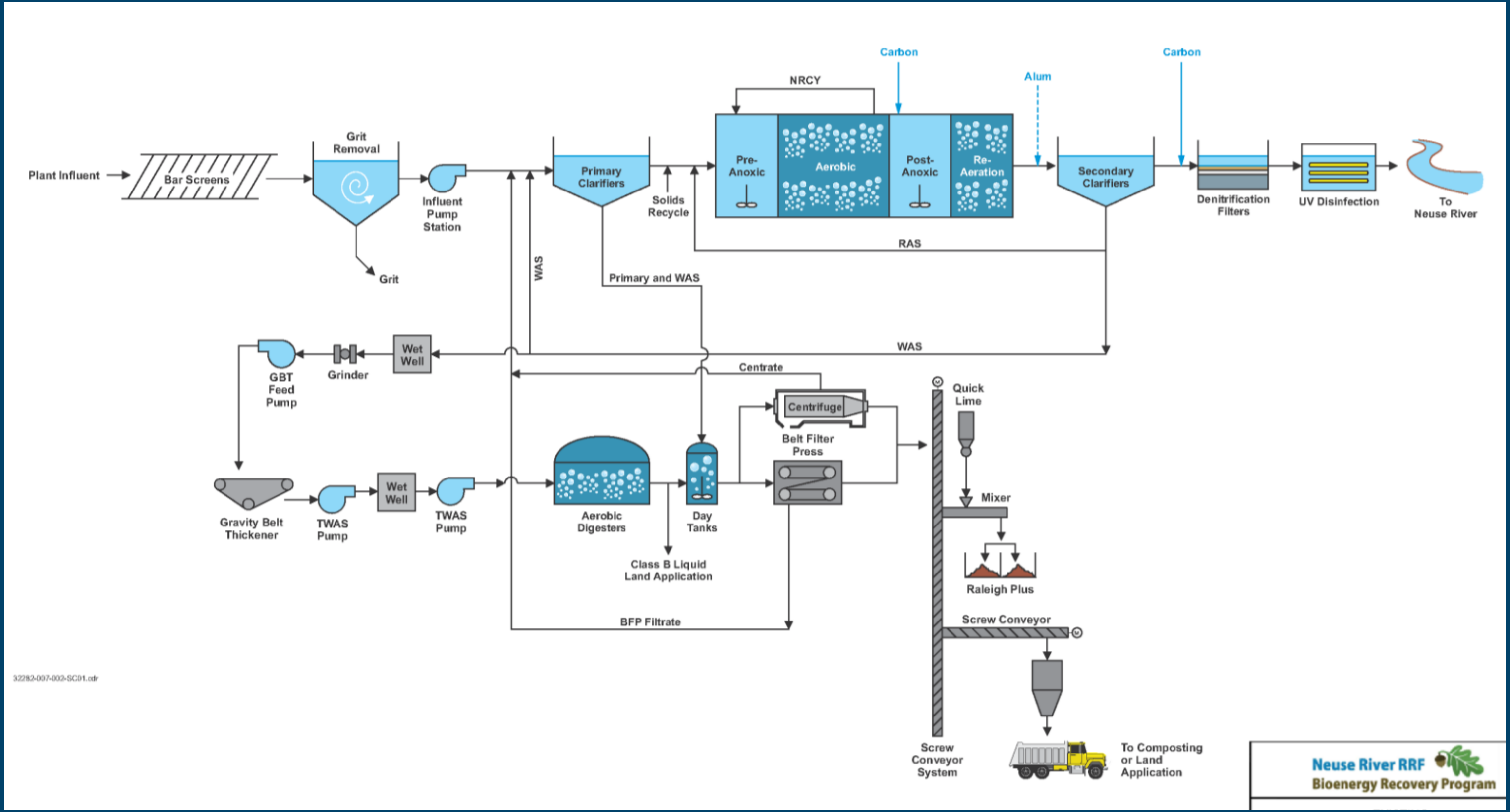
Neuse River Resource Recovery Facility

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

NRRRF Existing Process Flow Diagram



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_3-N limits
  - 1.0 mg/L summer / 2.0 mg/L winter
- Stringent BOD_5 limits

Real Time Process Control Strategies at NRRRF

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Real Time Process Control Programs

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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)

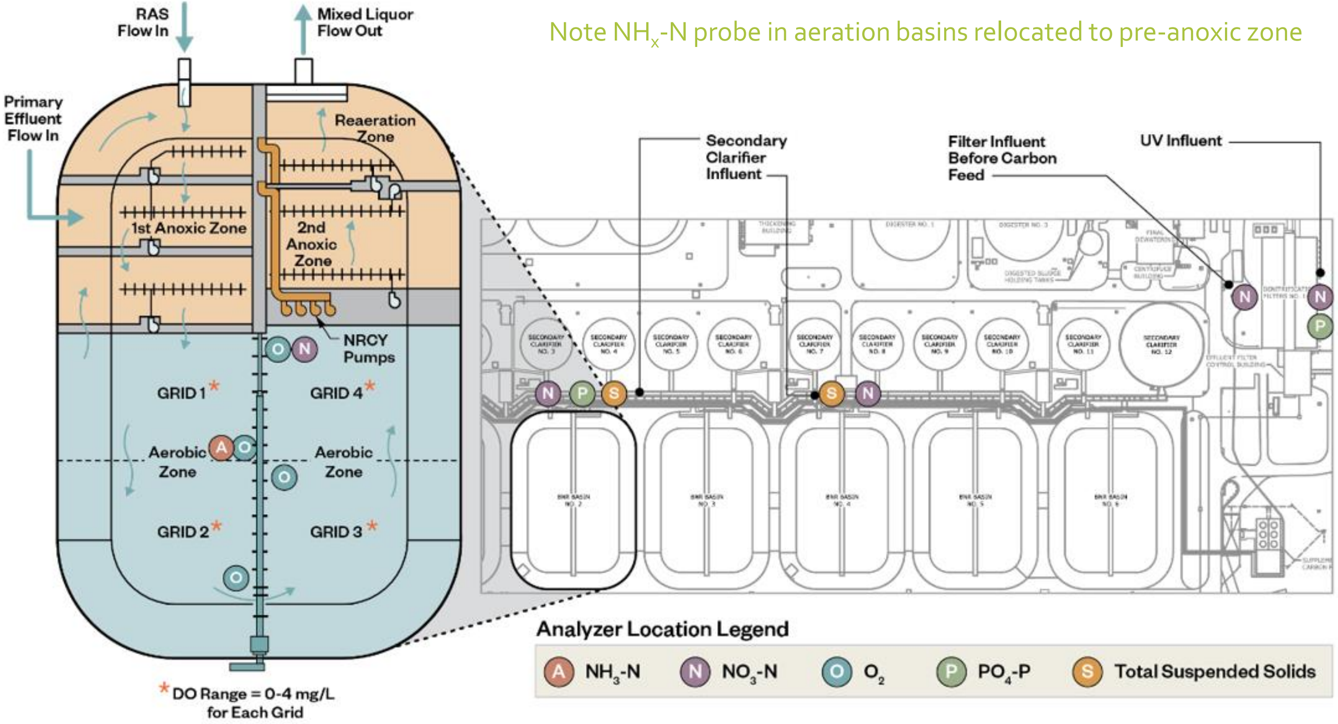
Clarifier Optimization Program

- 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

Note NH_x-N probe in aeration basins relocated to pre-anoxic zone



+ Primary Effluent NH_3-N Probe

RTPC Sensor Summary

Constituent Monitored	Number / Type of Instruments	Control Program
Dissolved Oxygen	24 DO (optical) probes (20 active)	Zone Based DO control
Ammonia-N	7 ISE probes (6 active); 1 wet chemistry analyzer with filtration	Load Based EQ (1) ABAC (5)
Nitrate-N	6 nitrate probes (UV absorption)	Carbon feed
Ortho-P	2 OP wet chemistry analyzers with filtration	Alum feed
Total Suspended Solids (TSS) / MLSS	2 TSS probes (infrared)	Secondary clarifier optimization

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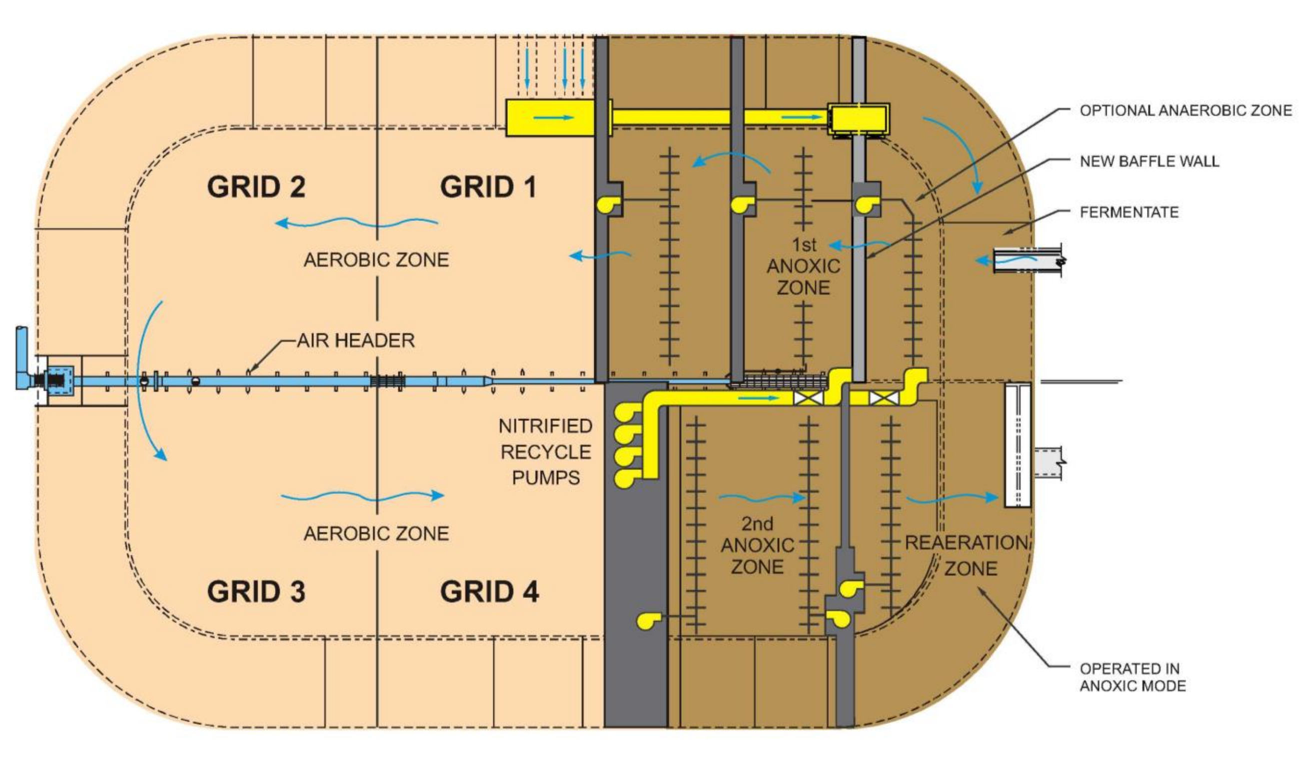
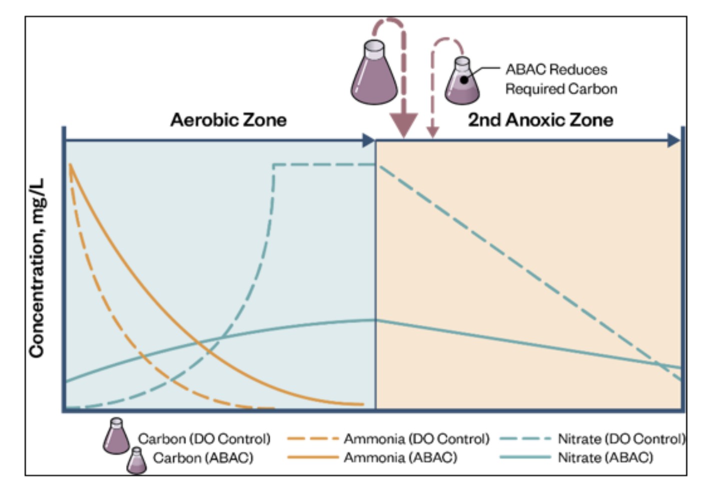
Each Aeration Grid Has Own DO Control Zone



Ammonia Based Aeration Control (ABAC)

- DO = f(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



Real Time Process Control Programs

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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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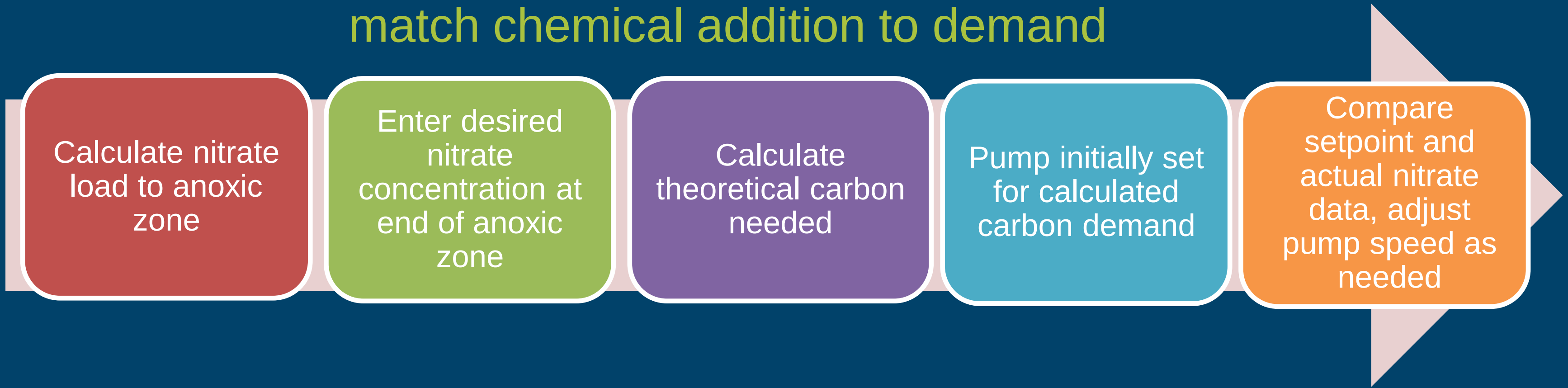
Supplemental Carbon Feed Program

- 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



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

Real Time Process Control Programs

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Secondary Clarifier Guidance Program

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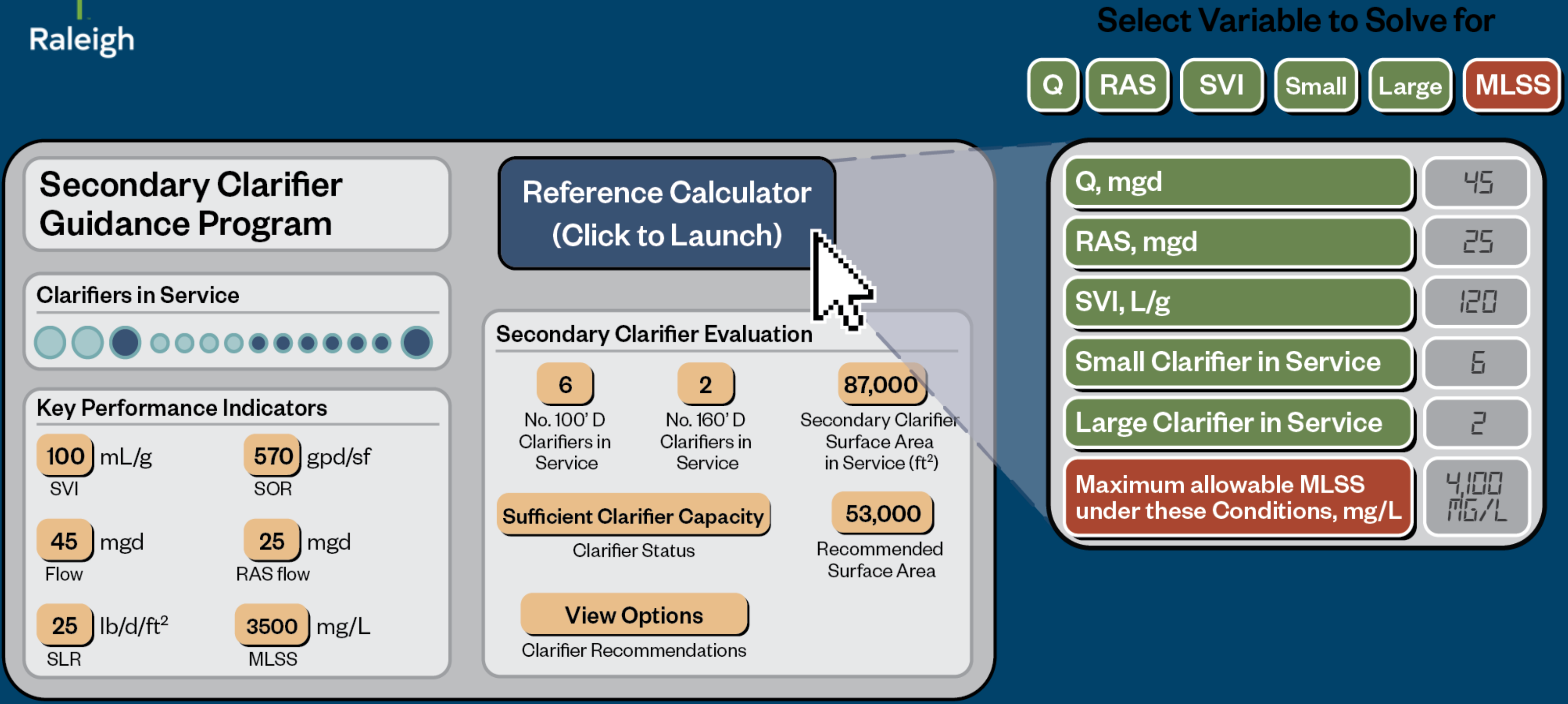
- Purpose: to get feedback on number of secondary clarifiers to have in service for a given flow, SVI, MLSS, and RAS flow
- Equation developed using state point analysis results and multivariable linear regression

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

Secondary Clarifier Program Concept Overview



Outcomes & Benefits

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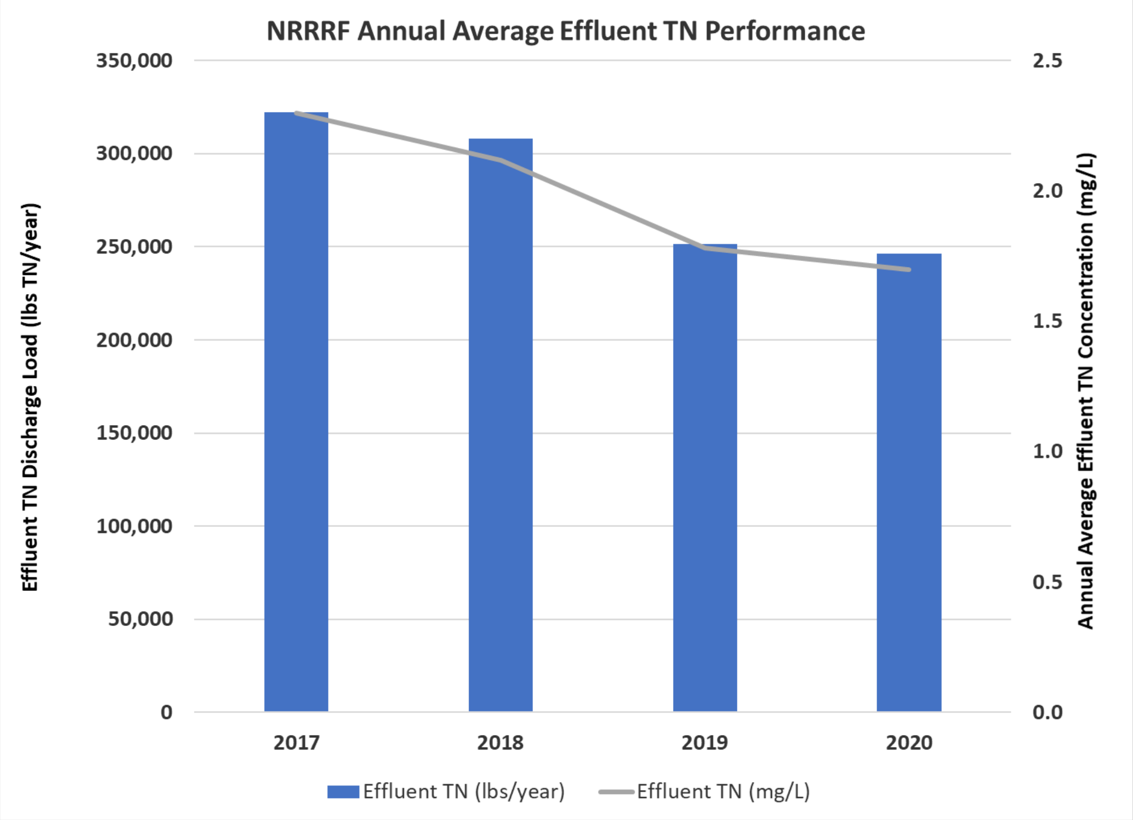
Reduced Effluent TN

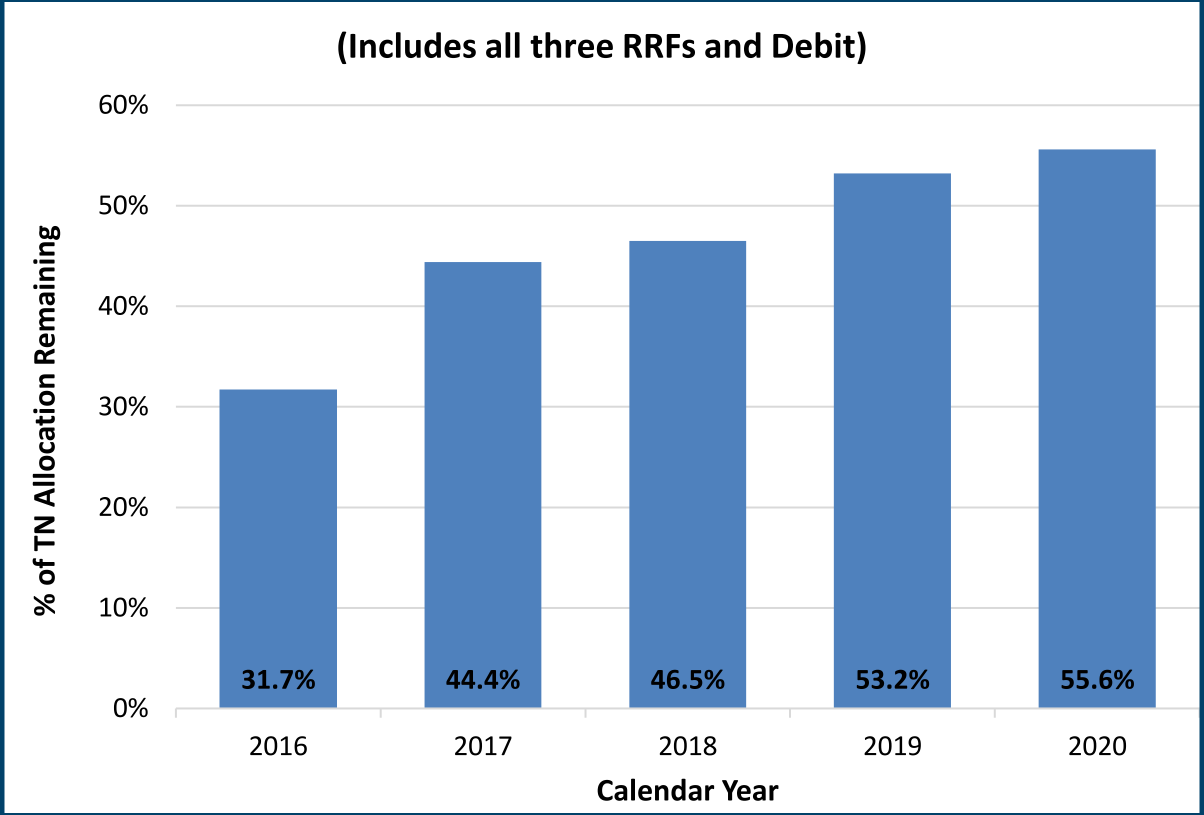


2004 – 2018 Avg:
2.4 mg/L

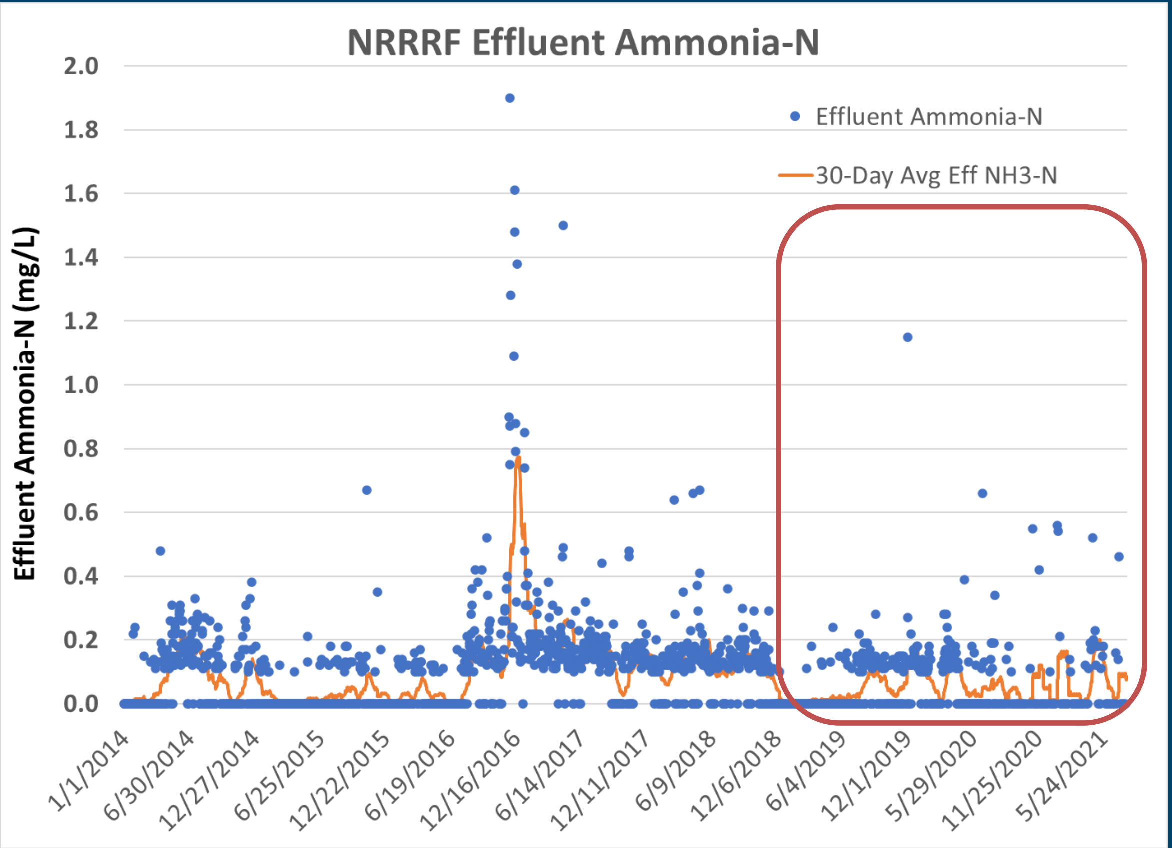
2019 Avg:
1.78 mg/L

2020 Avg:
1.70 mg/L

% TN Allocation Remaining w/ Debit



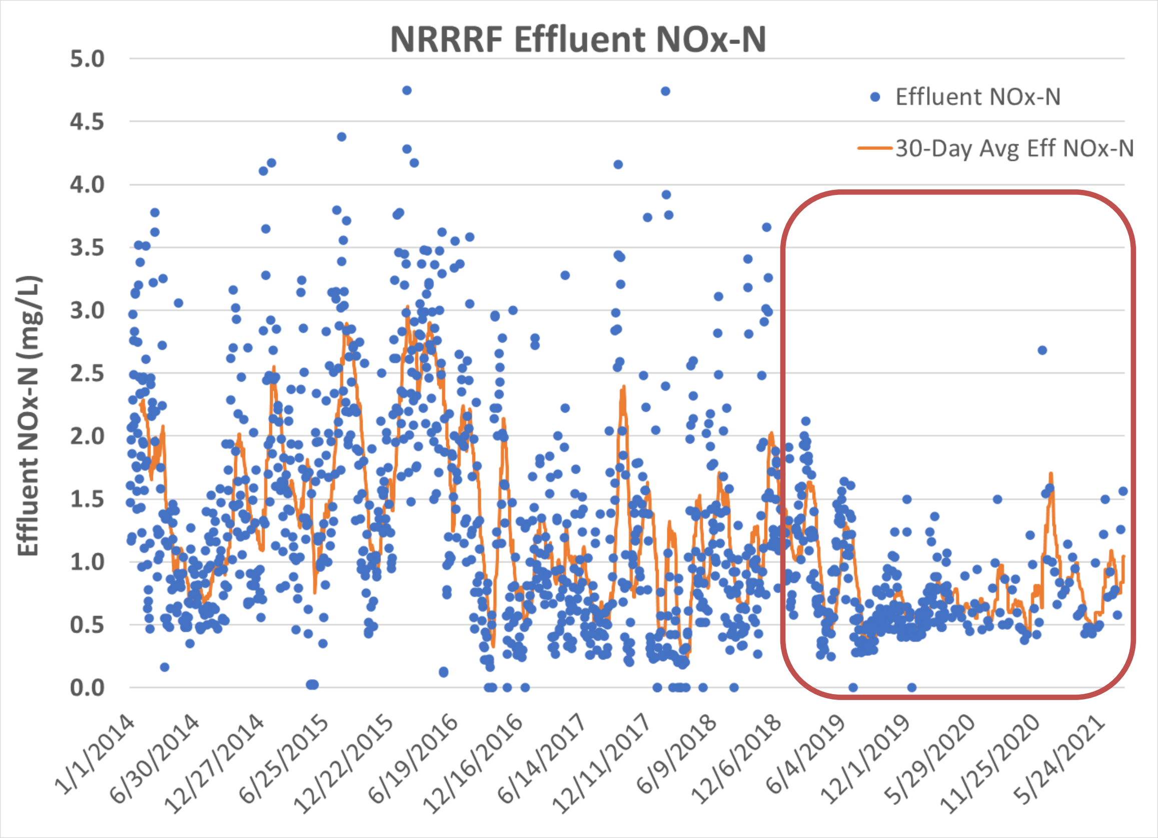
Improved Process Stability



2004 – 2017 Avg:
0.1 mg/L

2019 - 2021 Avg:
0.05 mg/L

Improved Process Stability



2004 – 2017 Avg:
1.5 mg/L

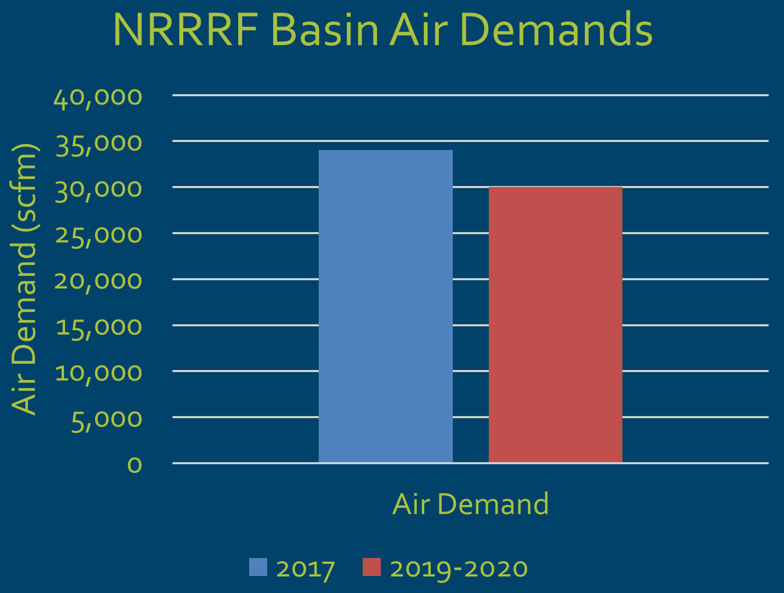
2019-2021 Avg:
0.8 mg/L

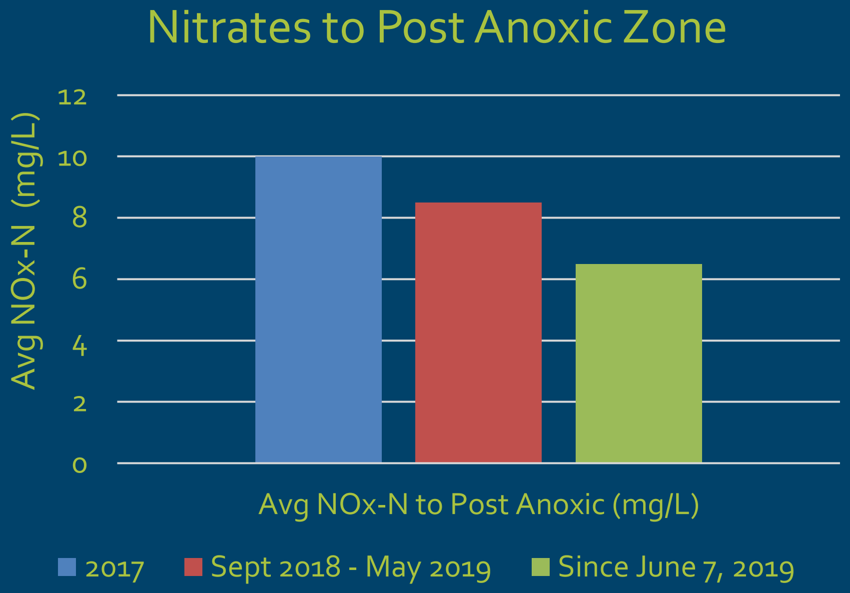
Variable	Avg.	Max.	Peaking Factor
NH_3 Load into Basins	12,990	13,360	1.0
NH_3 Load to Primary Effluent Distribution Box	12,982	15,360	1.2

Reduced Peak Loads to Aeration Basin

Reduced Air Demands / More SND

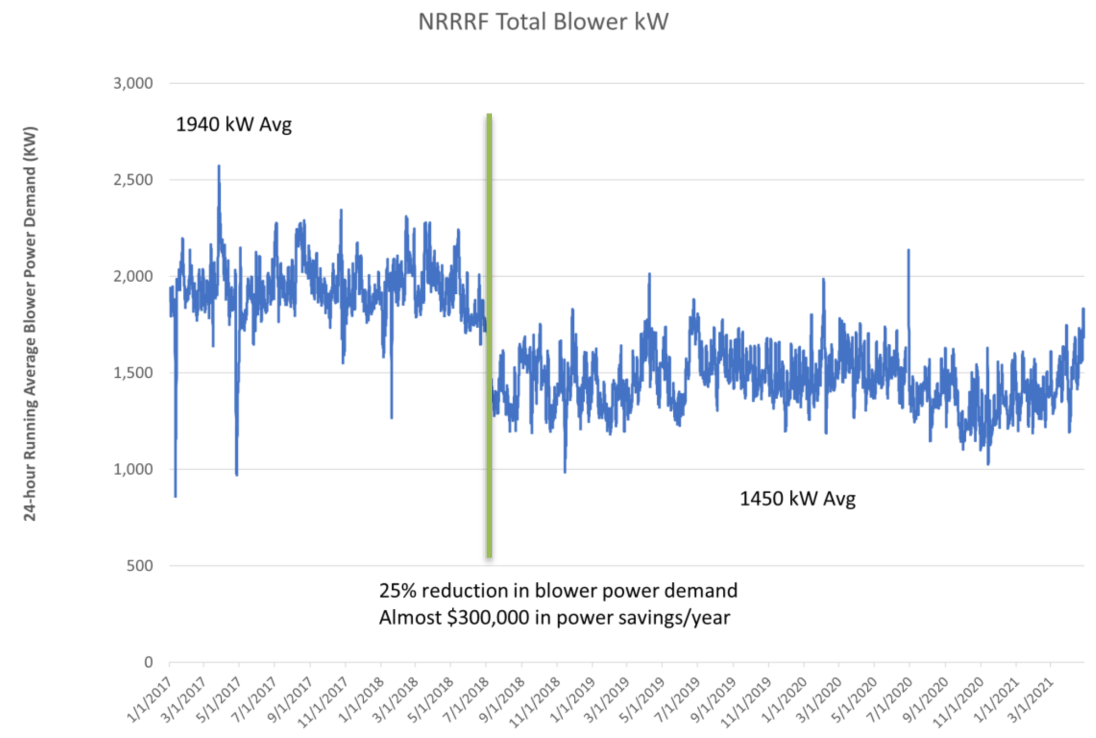
(Averages through October 2020)





Avg SVI: 80 mL/g

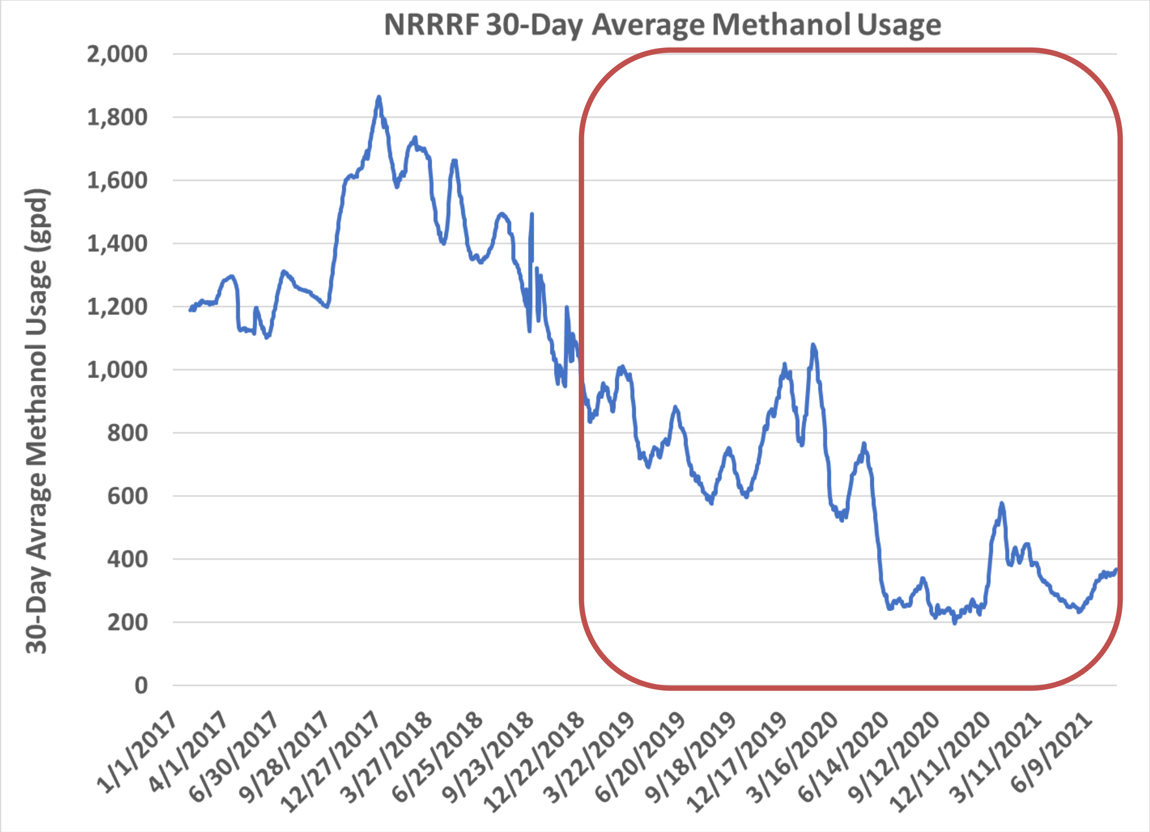
Reduced Blower Demands



(Data through April 2021)

Since July 2018 reduced to one blower for typical operations

Reduced Methanol Usage

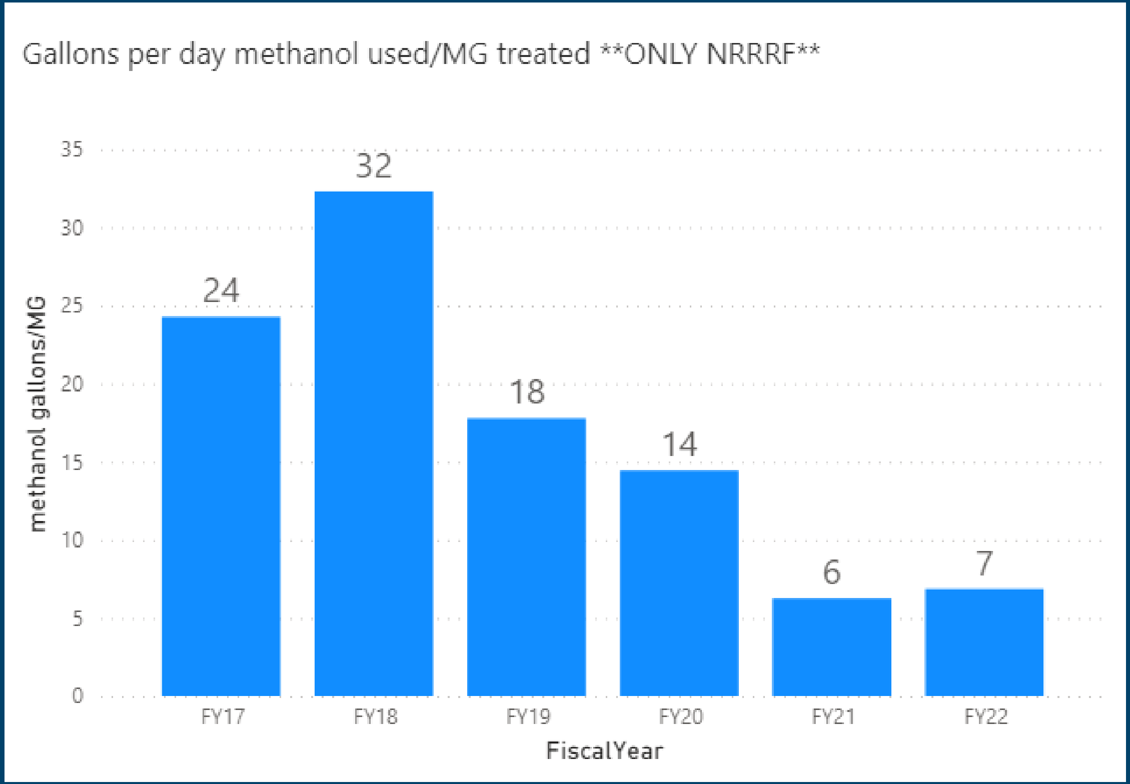


Avg usage reduced from 1,300 gpd (2017) to 560 gpd (2019 – 2021 avg)

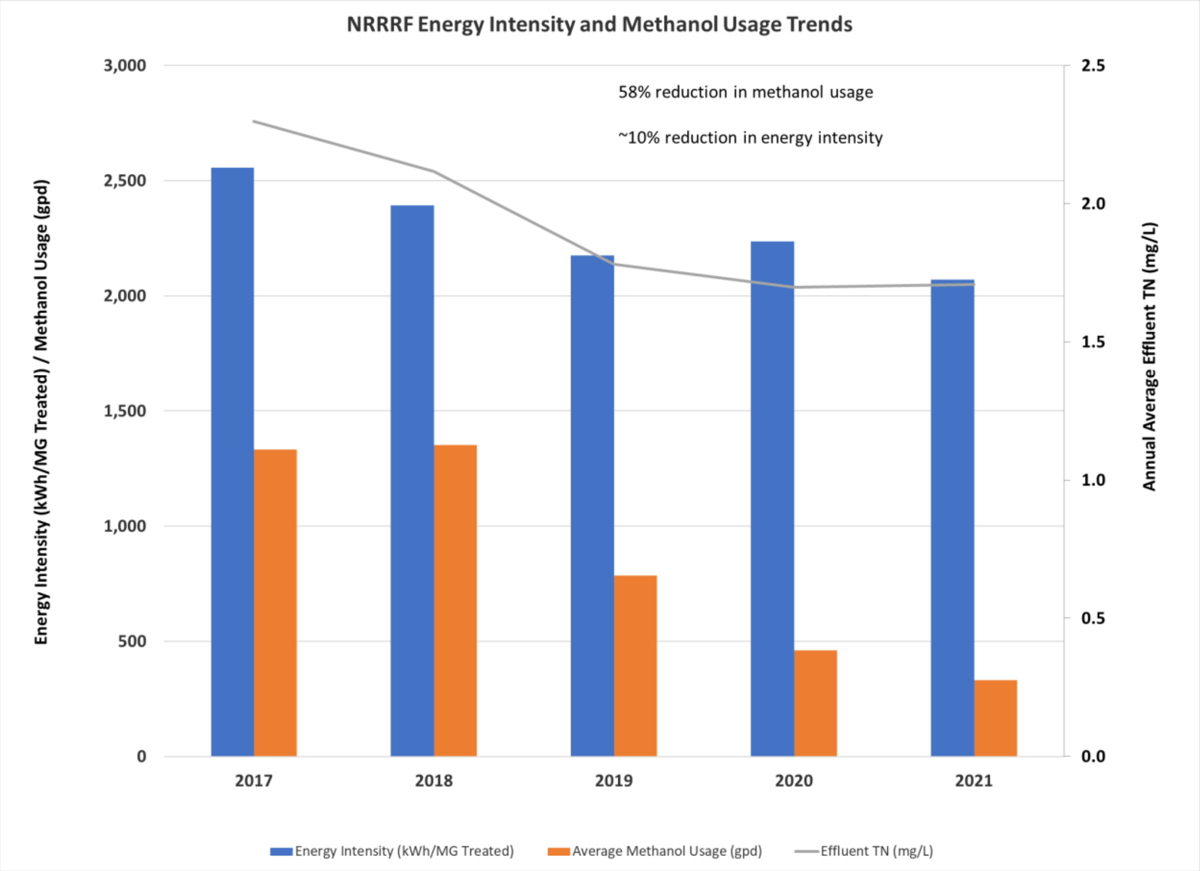
58% methanol usage reduction

>$300,000 in chemical savings / year at $1.10/gal

Gallons Methanol / MG Treated



Energy Intensity and Methanol Usage Trends



Conclusions

- Automated 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
  - Utilizes secondary clarifier guidance program
- Evaluation of low-ammonia chemical analyzer for better ABAC controls

Acknowledgements

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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

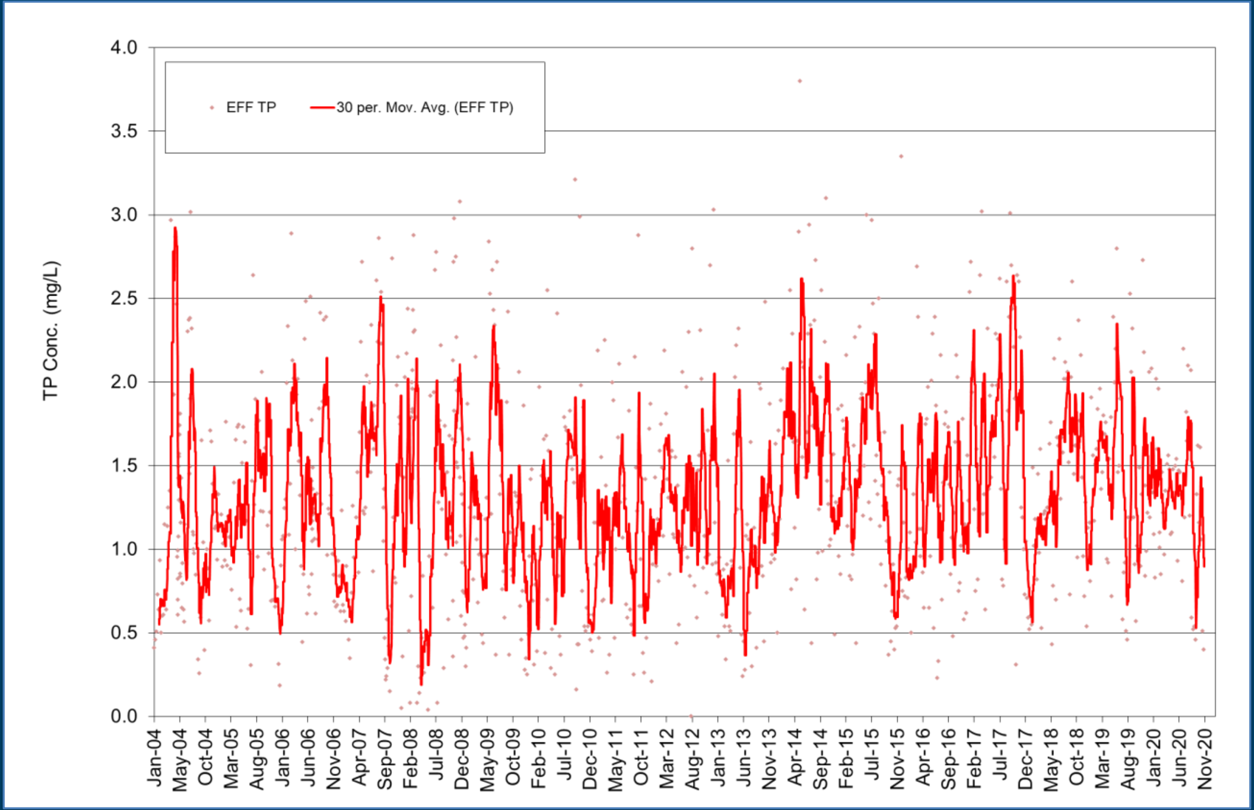
Load Based EQ - Key Take Aways / Lesson Learned

- Changes historical diurnal EQ pattern
- More frequent cleaning
- Establish setpoint based on current average ammonia loads

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.

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