Nutrient Removal Optimization at NRRRF Using In-Situ Monitoring and Automation

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Raleigh Water

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Acknowledgements

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- Katya Bilyk

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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

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

Introduction / Background

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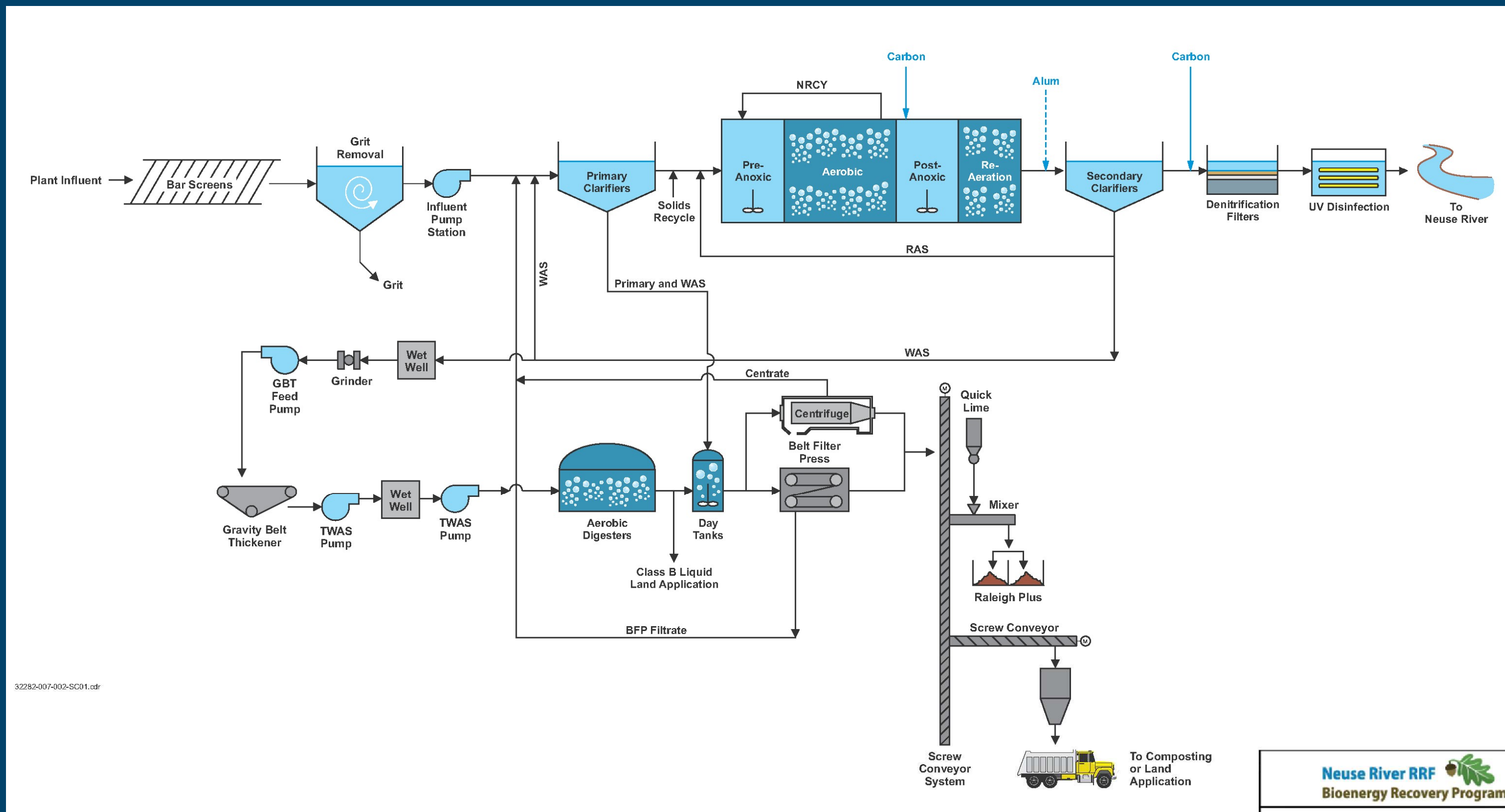
Neuse River Resource Recovery Facility

- 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

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

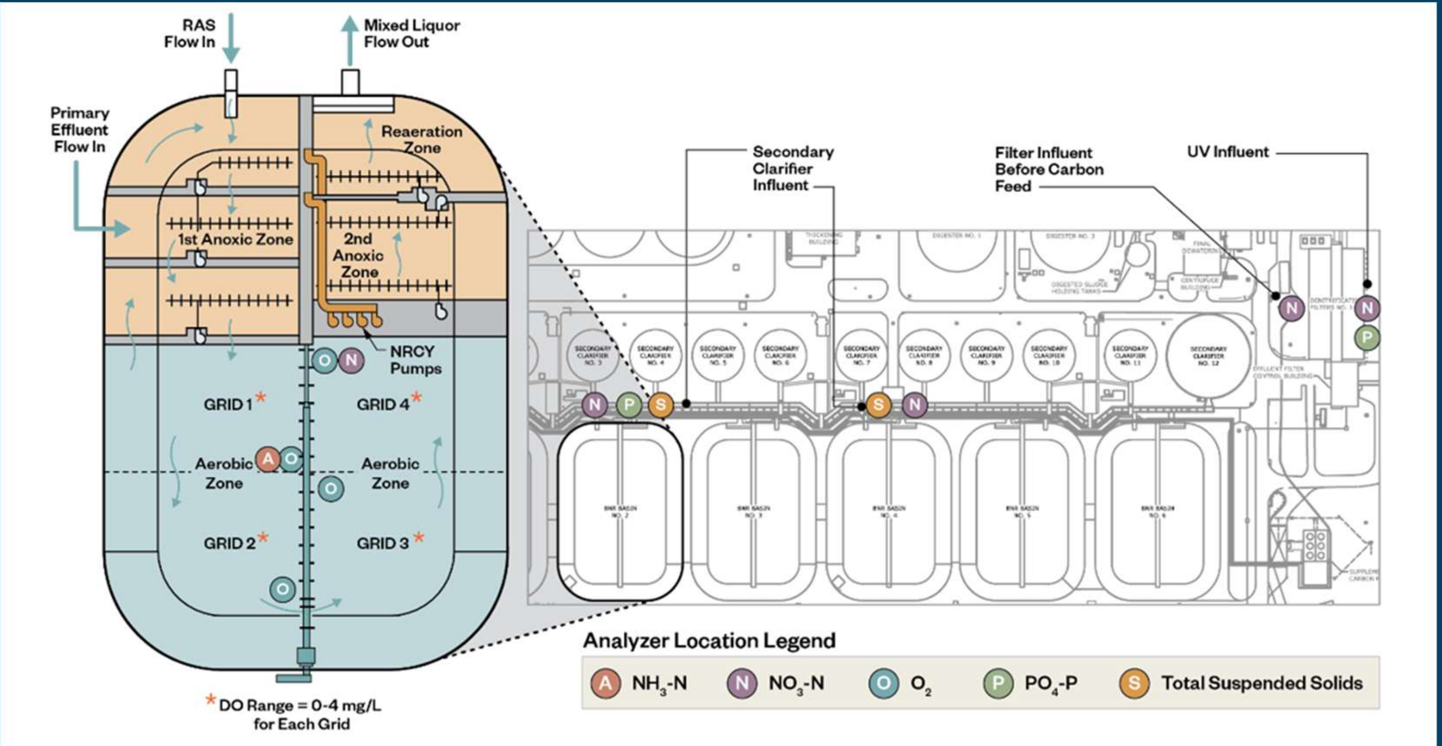
Nov 2018 (Carbon)

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_3-N Probe

Real Time Process Control Programs

- **DO / Ammonia-Based Aeration Control**
  - Better match air demands to biological demand
  - Reduce blower demand and supplemental carbon demands
- **Load Based Equalization**
  - Operate EQ basin based on target ammonia loads (vs flow)
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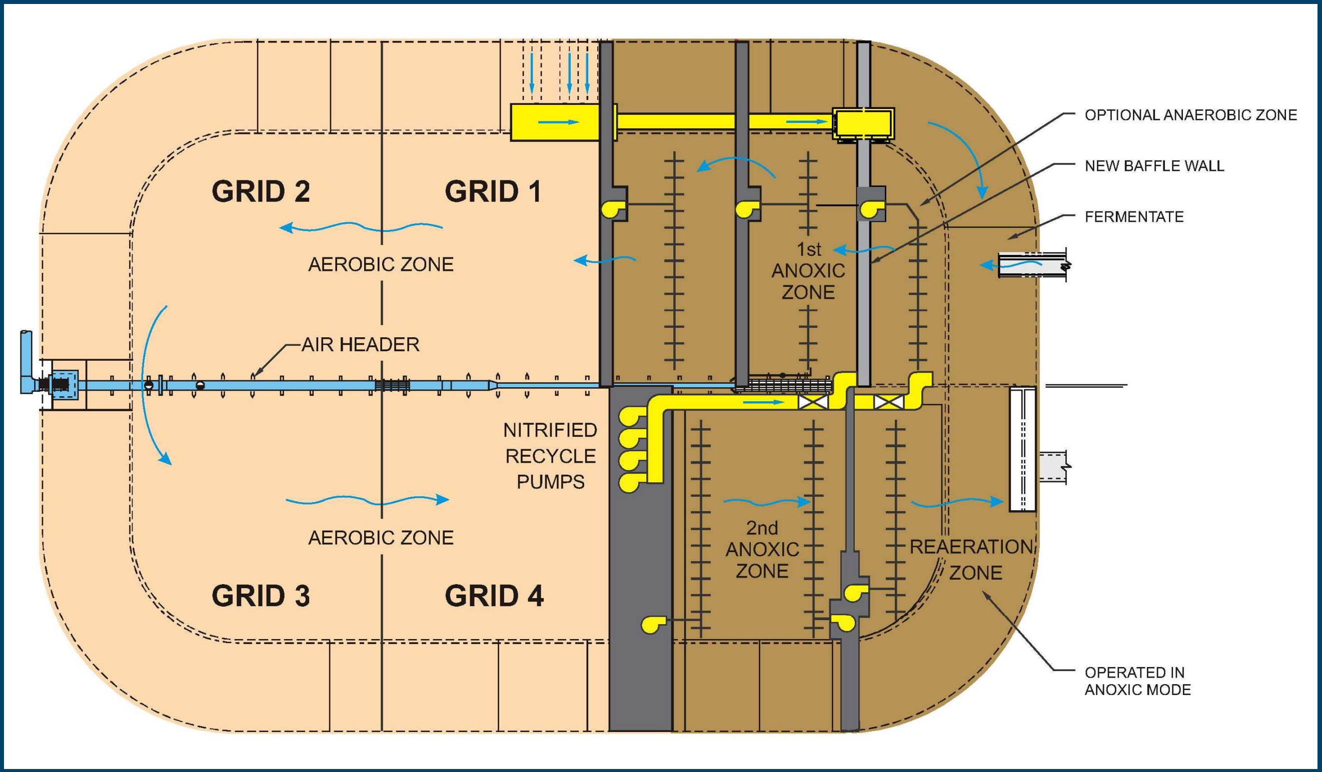
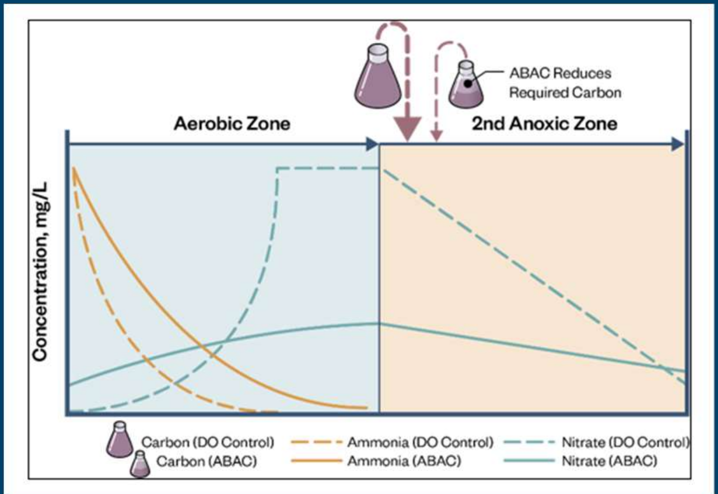
Each Aeration Grid Has Own DO Control Zone



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)

Real Time Process Control Programs

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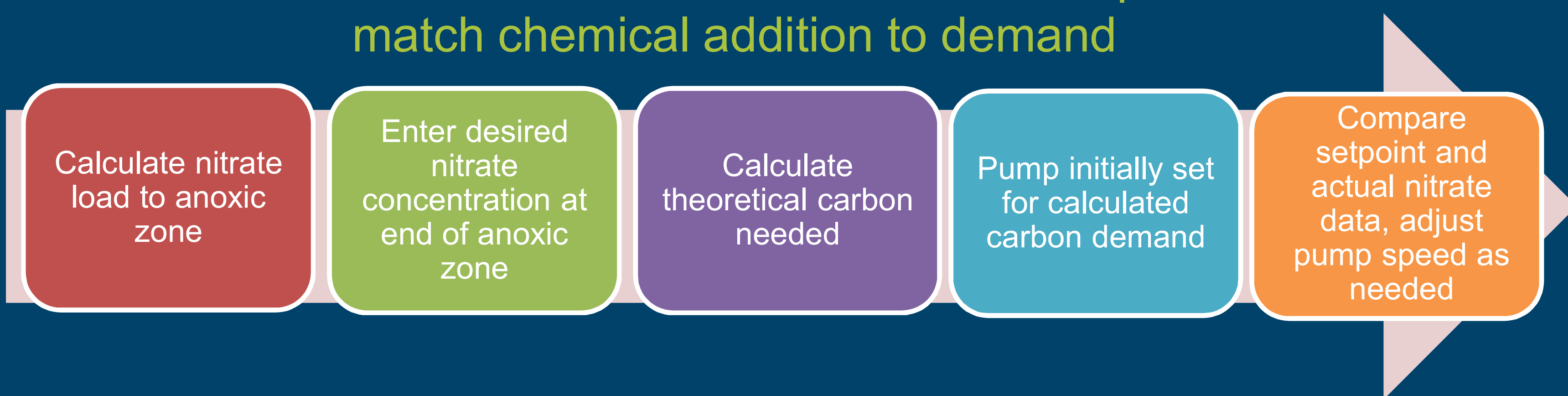
Supplemental Carbon Feed Program

- 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



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Real Time Process Control Programs

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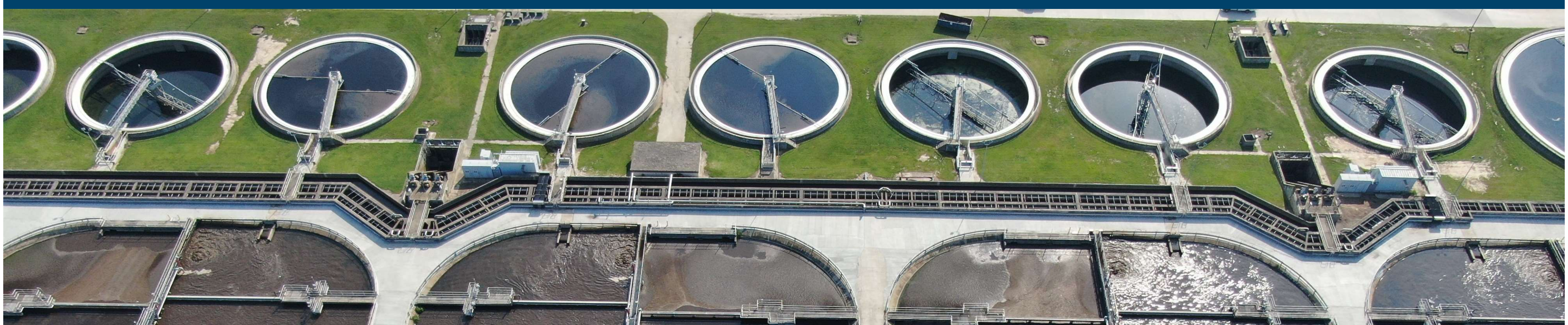
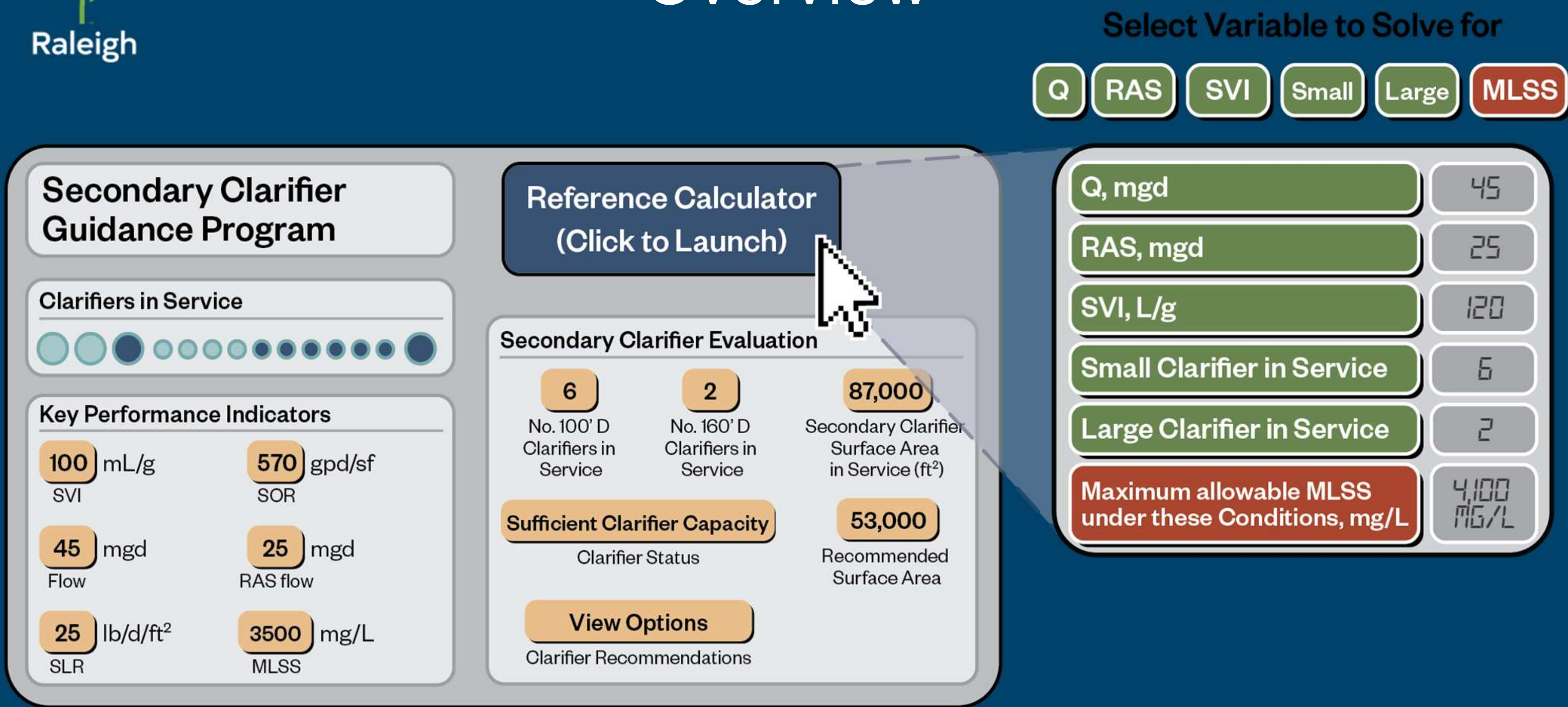
Secondary Clarifier Guidance Program

- 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

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



Secondary Clarifier Program Concept Overview



Outcomes & Benefits

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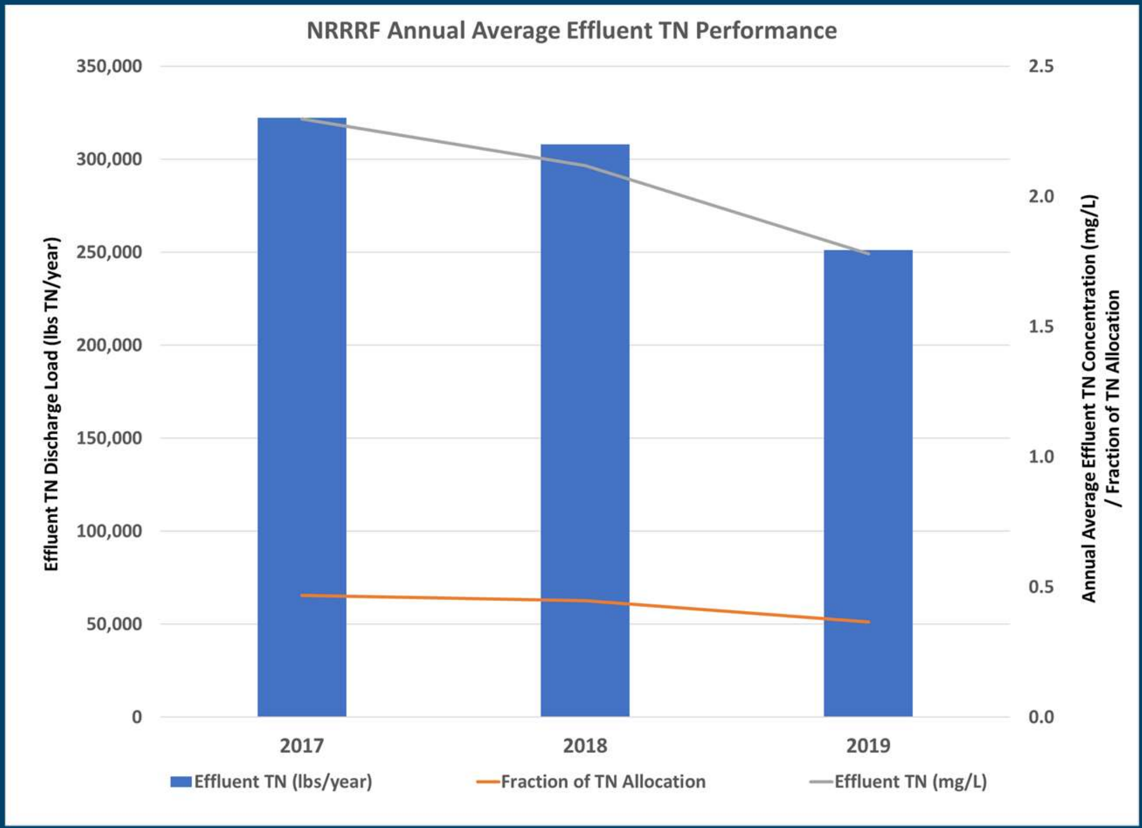
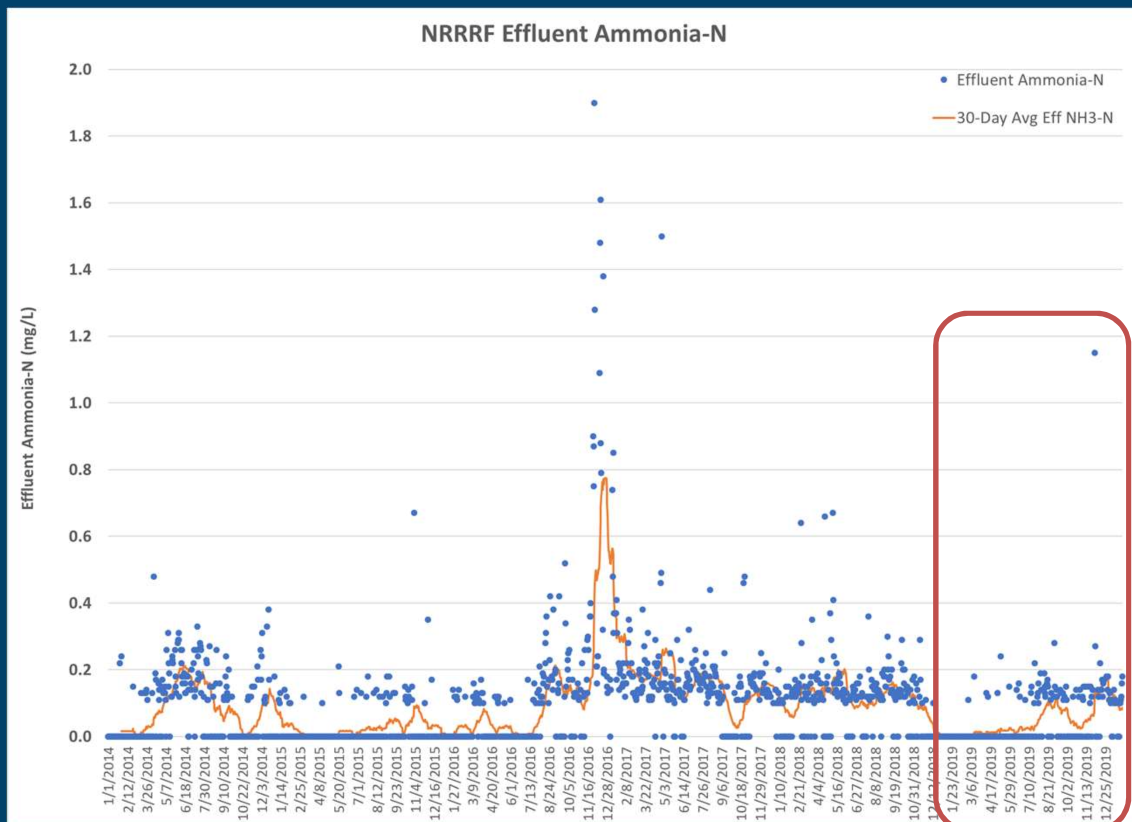
Reduced Effluent TN



2004 – 2018 Avg:
2.4 mg/L

2019 Avg:
1.8 mg/L

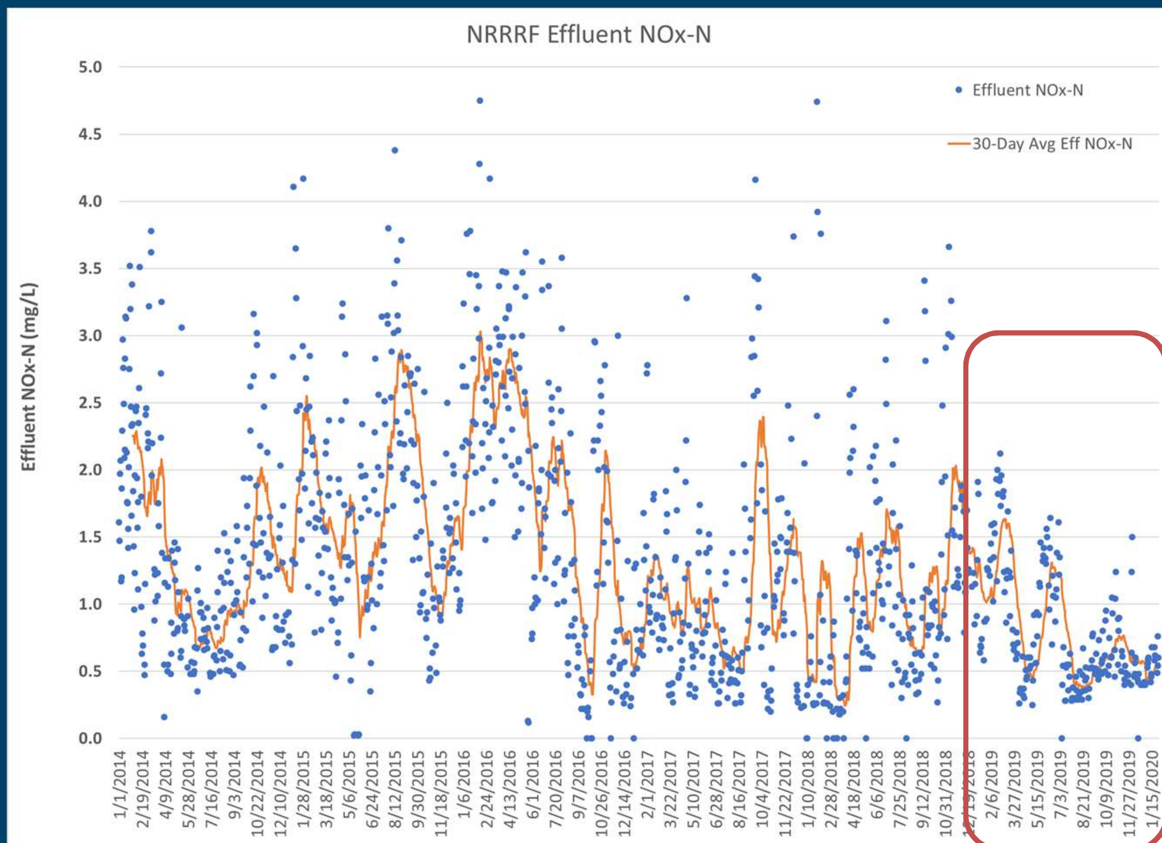
Improved Process Stability



2004 – 2017 Avg:
0.1 mg/L

2019 Avg:
0.05 mg/L

Improved Process Stability



2004 – 2017 Avg:
1.5 mg/L

2019 Avg:
0.8 mg/L

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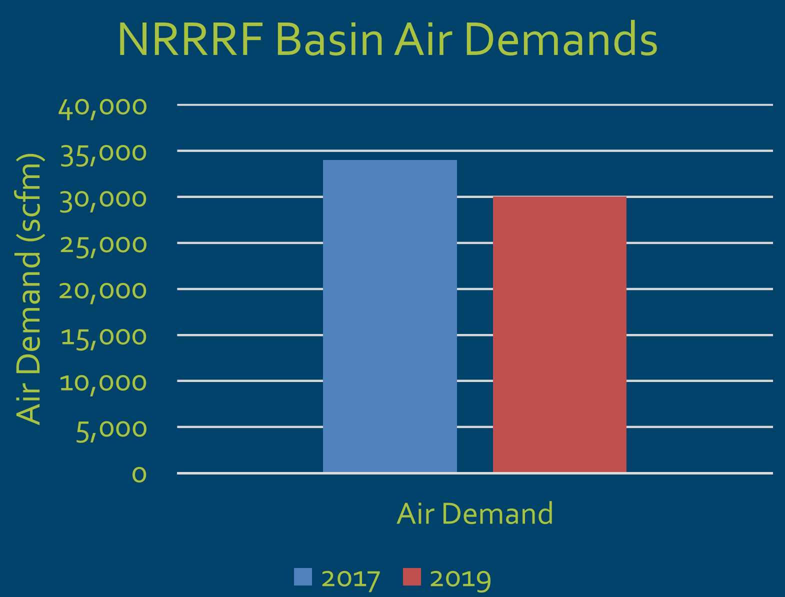
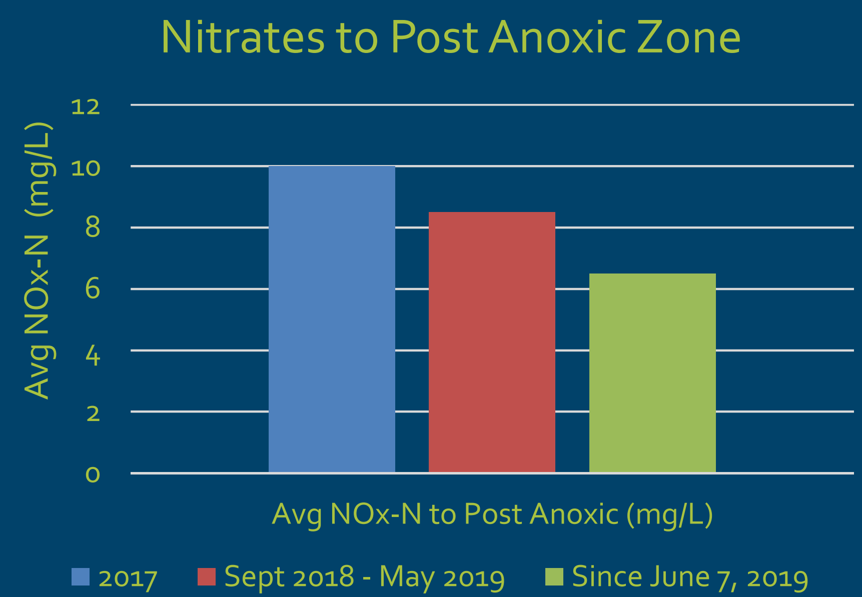
Variable	Avg.	Max.	Peaking Factor
NH_3 Load into Basins	12,990	13,360	1.0
NH_3 Load to Primary Effluent Distribution Box	12,982	15,360	1.2

Reduced Peak Loads to Aeration Basin

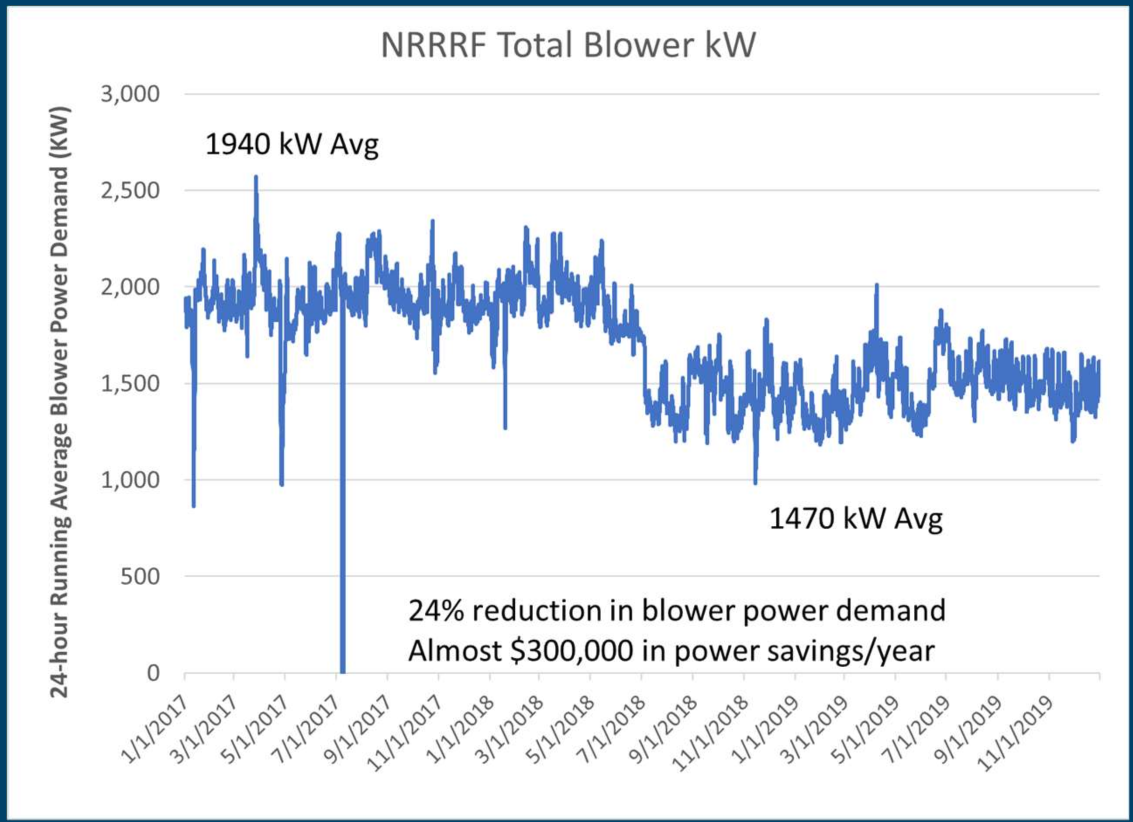
Reduced Air Demands / More SND





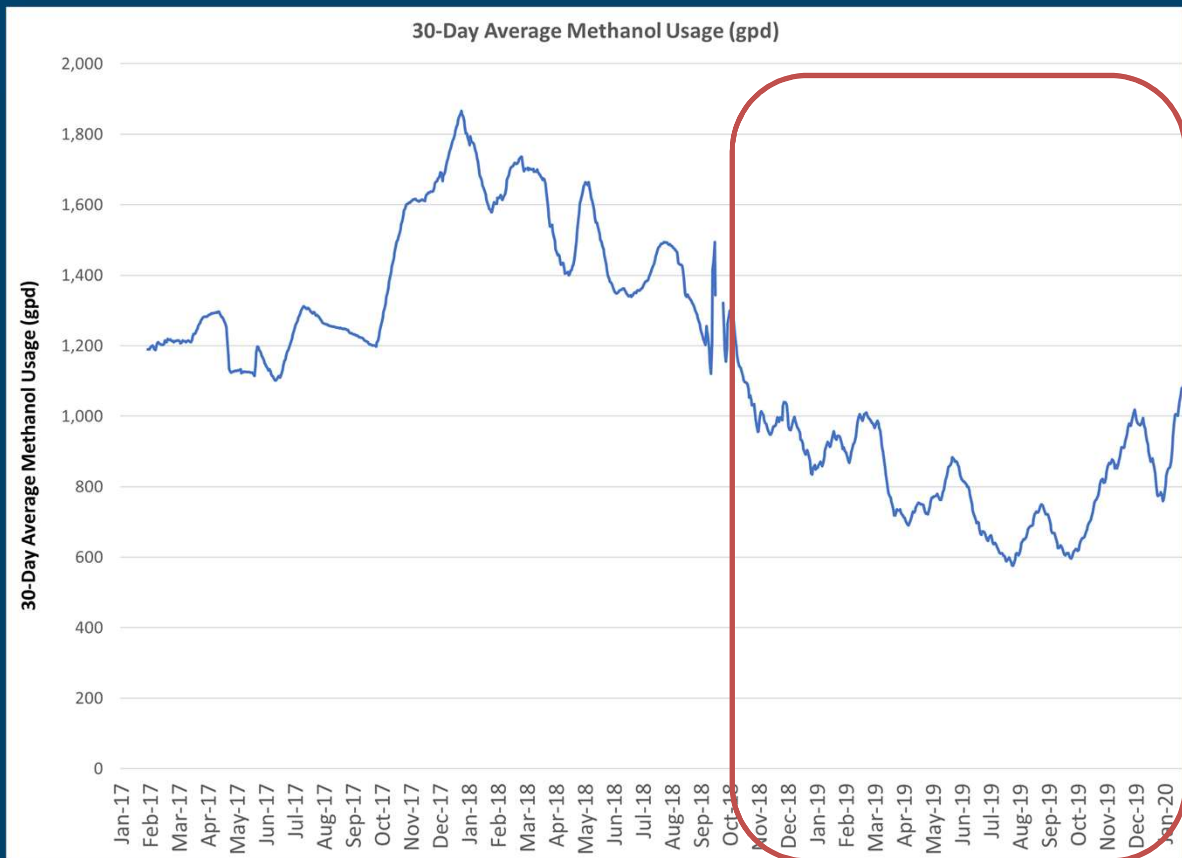
Avg SVI: 82 mL/g

Reduced Blower Demands



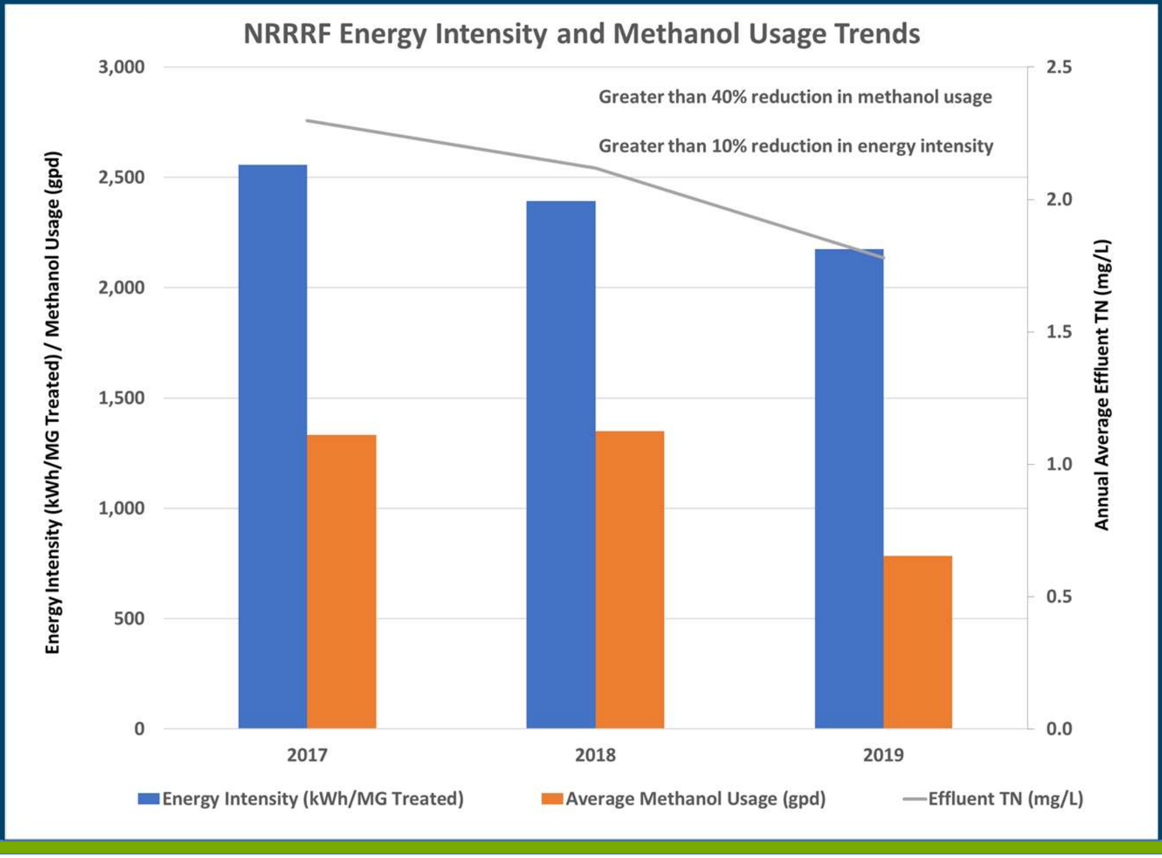
Since July 2018 reduced to one blower for typical operations

Reduced Methanol Usage



- Avg usage reduced from 1,300 gpd (2017) to < 800 gpd (2019)
- >40% methanol usage reduction
- ~ $200,000 in chemical savings / year at $1.15/gal

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

Thank you!

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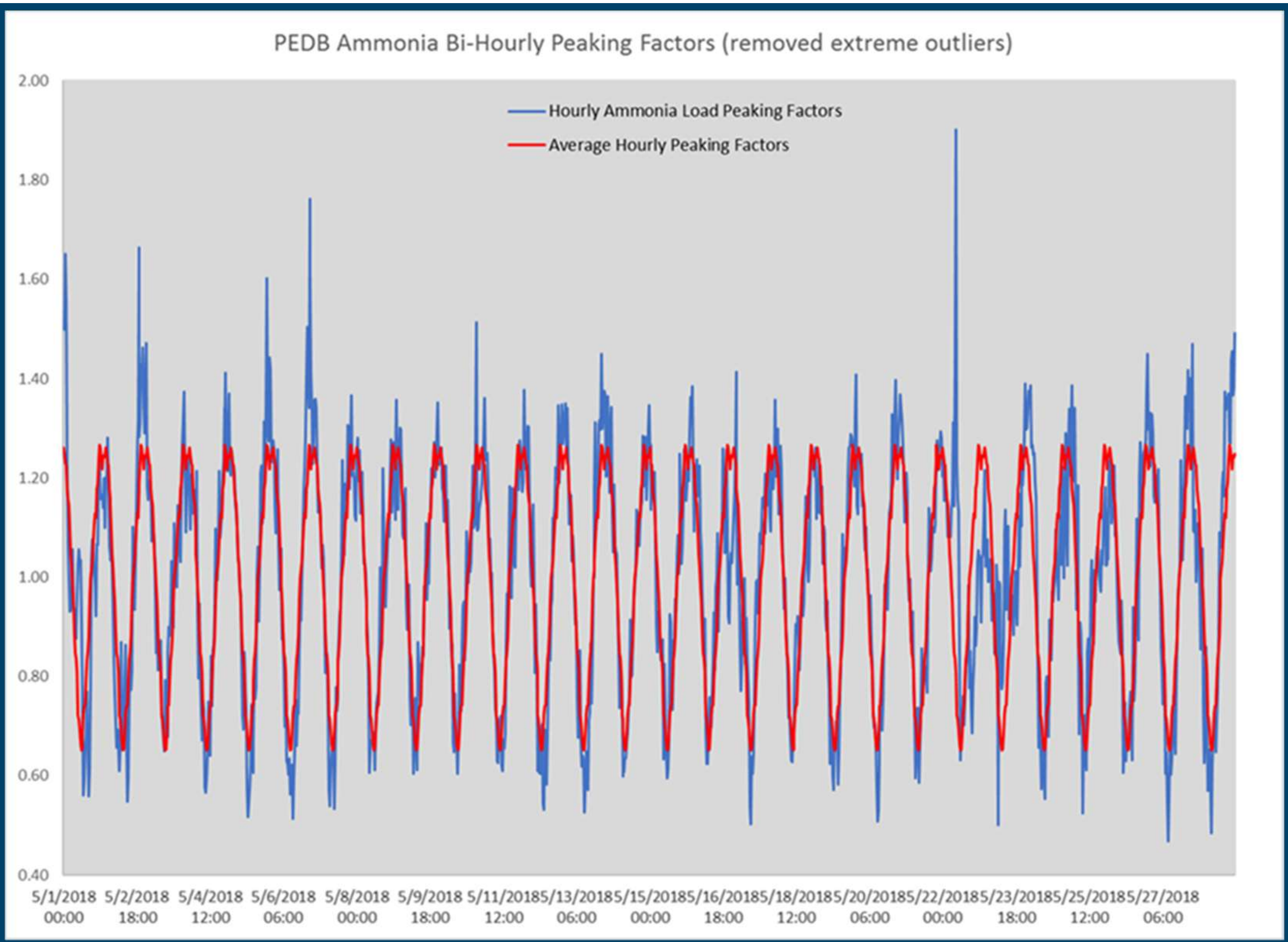
ABAC Key Take Aways / Lessons Learned

- 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



PEDB Ammonia Bi-Hourly Peaking Factors (removed extreme outliers)
Hourly Ammonia Load Peaking Factors
Average Hourly Peaking Factors
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
5/1/2018 00:00
5/2/2018 18:00
5/4/2018 12:00
5/6/2018 06:00
5/8/2018 00:00
5/9/2018 18:00
5/11/2018 12:00
5/13/2018 06:00
5/15/2018 00:00
5/16/2018 18:00
5/18/2018 12:00
5/20/2018 06:00
5/22/2018 00:00
5/23/2018 18:00
5/25/2018 12:00
5/27/2018 06:00

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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

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

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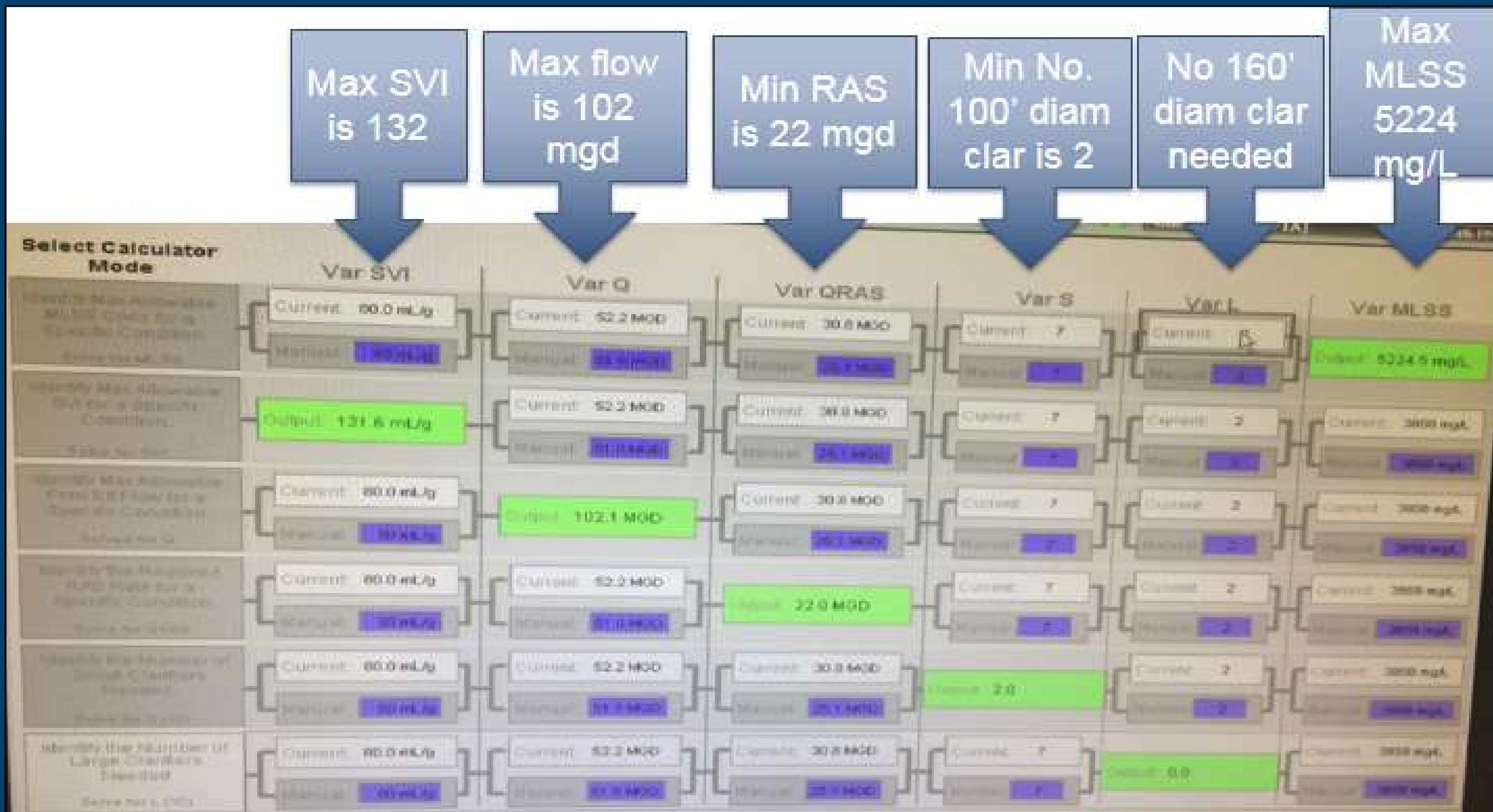

Clarifier Program - Key Take Aways / Lesson Learned

- 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