I Want My MLE

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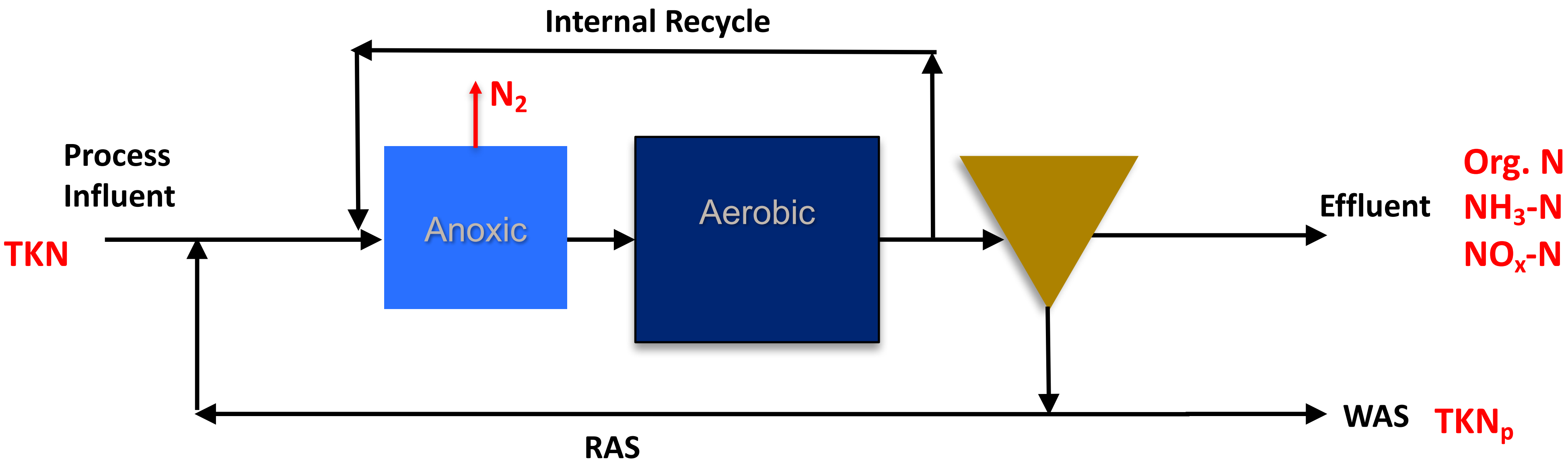
NEWEA – 2017 Annual Conference & Exhibit

Agenda

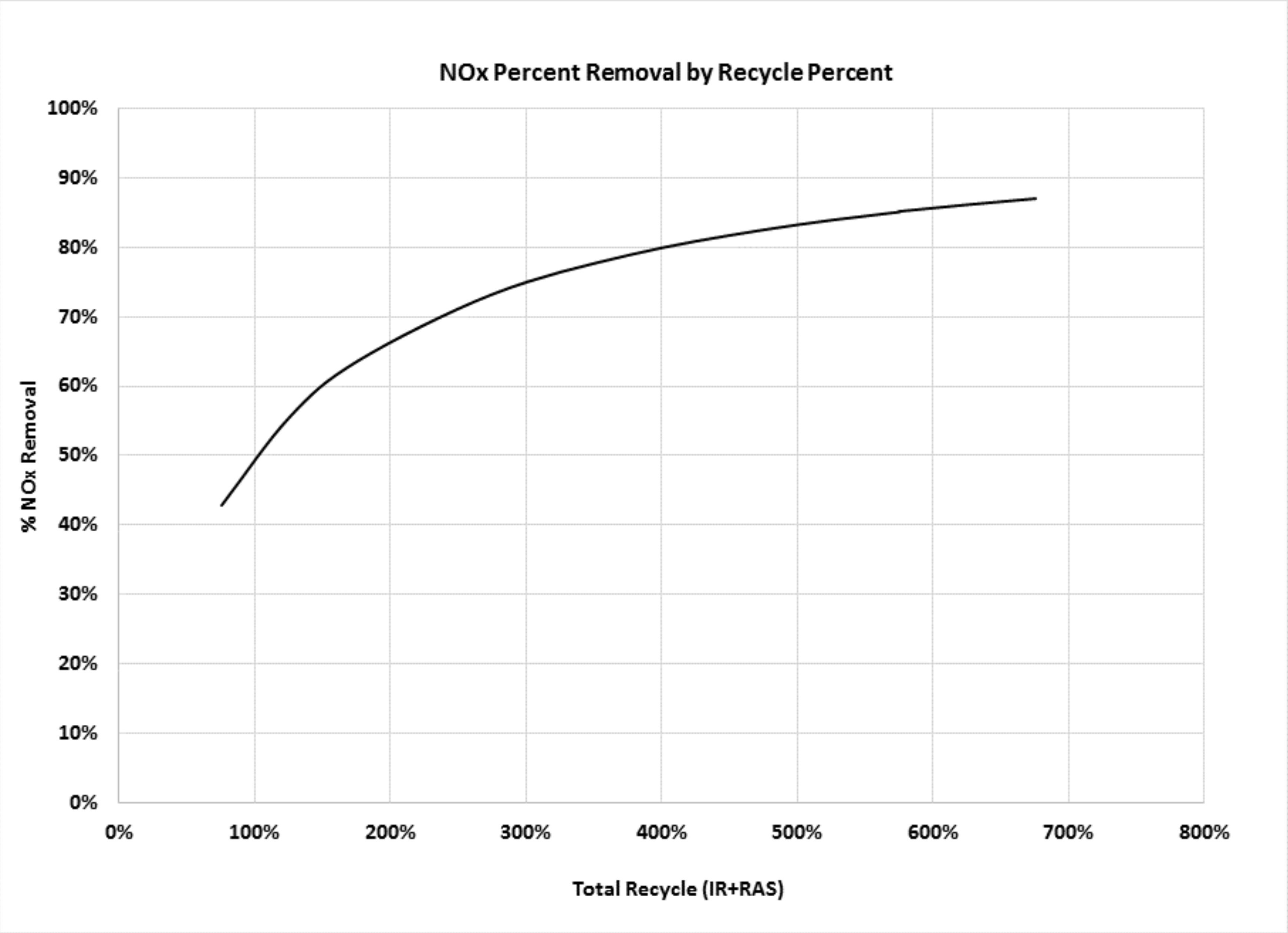
- MLE Process Review (brief)
- TN removal capabilities/limitations
- Optimization of MLE TN removal performance
  - Internal recycle rate
  - Anoxic zone size, relation to IR rate
  - TKN/BOD ratio, relation to anoxic zone size
  - Impacts of supplemental carbon addition
- Control/monitoring to optimize efficiency
- Case study in optimizing treatment – piloting at Brockton AWRF

MLE Process


Internal Recycle
N2
Process Influent
TKN
Anoxic
Aerobic
Effluent
Org. N
NH3-N
NOx-N
WAS
TKNp
RAS

MLE Nitrogen Removal Performance

- Typical effluent TN range: 7 – 10 mg/L
  - NH_3-N: <1 mg/L
  - Organic N: ~ 1 mg/L
  - NO_x-N 5 – 8 mg/L
- Some plants do better
- Some plants don't do as well
- Why?

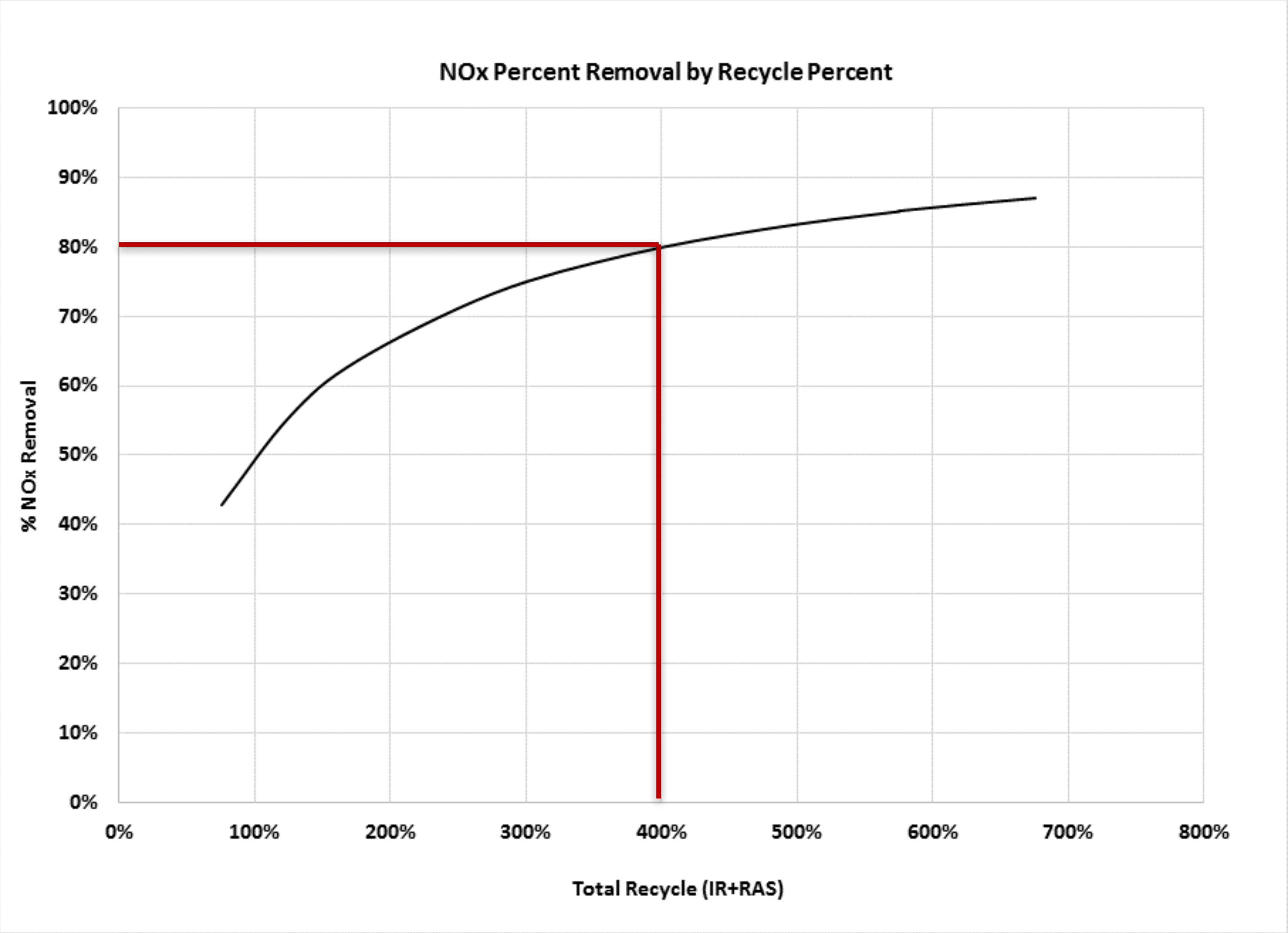

NOx Percent Removal by Recycle Percent
% NOx Removal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
100%
200%
300%
400%
500%
600%
700%
800%
Total Recycle (IR+RAS)

Internal Recycle and NO_x Removal

- Relationship:

  $$\% \text{ rem.} = 100 \times \frac{\% \text{ recycle}}{(\% \text{ recycle} + 100\%)}$$

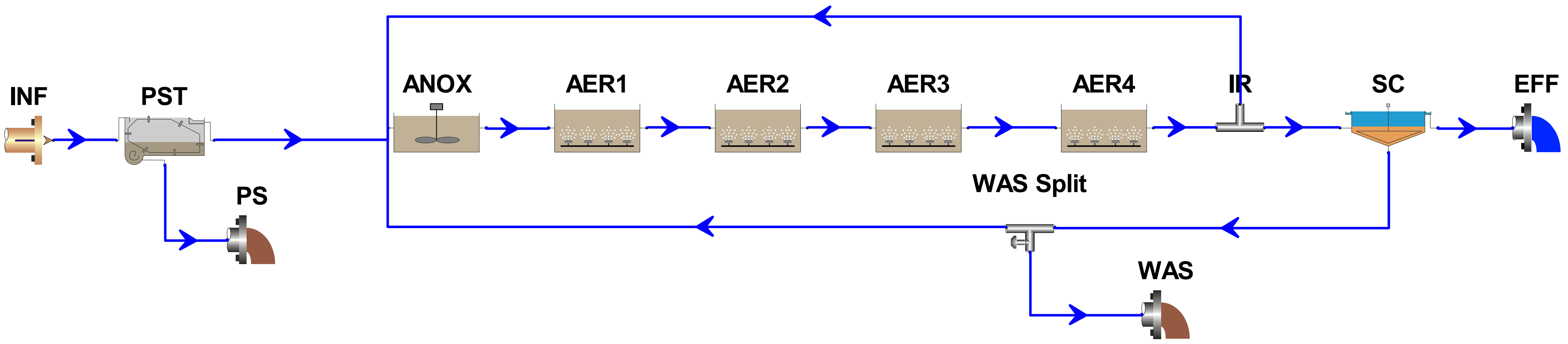
- Indicates *maximum theoretical* denitrification capacity
- Influent TKN concentration dictates possible effluent NO_x concentration



Constraint on Achieving Maximum Theoretical Denitrification: **Anoxic Zone Size**

- If anoxic zone size is large enough, the maximum theoretical denitrification rate can be achieved
- If anoxic zone size is not sufficient, then:
  - Less nitrate removal
  - Excess internal recycle rate
- Biowin used to develop graphical representation
  - Multiple steady-state simulations
  - Aerobic SRT selected to assure complete nitrification
  - DO setpoint of 2 mg/L in aerobic zones – no simultaneous nitrification/denitrification (SND) in aerobic zones

Biowin Model – Generic WWTF



Criterion	Value	Criterion	Value
Influent - Flow - BOD - TSS - TKN	 5 mgd 220 mg/L 230 mg/L 45 mg/L	Bioreactor volumes - Anox - Aer 1 – Aer 4	 20 – 40% of aerobic volume 0.50 MG each
Primary removals	TSS: 65 percent (specified) BOD: 35 percent TKN: 12 percent	Aerobic SRT	10 days
MLSS	~ 2,000 mg/L	Aerobic zone D.O.	2.0 mg/L

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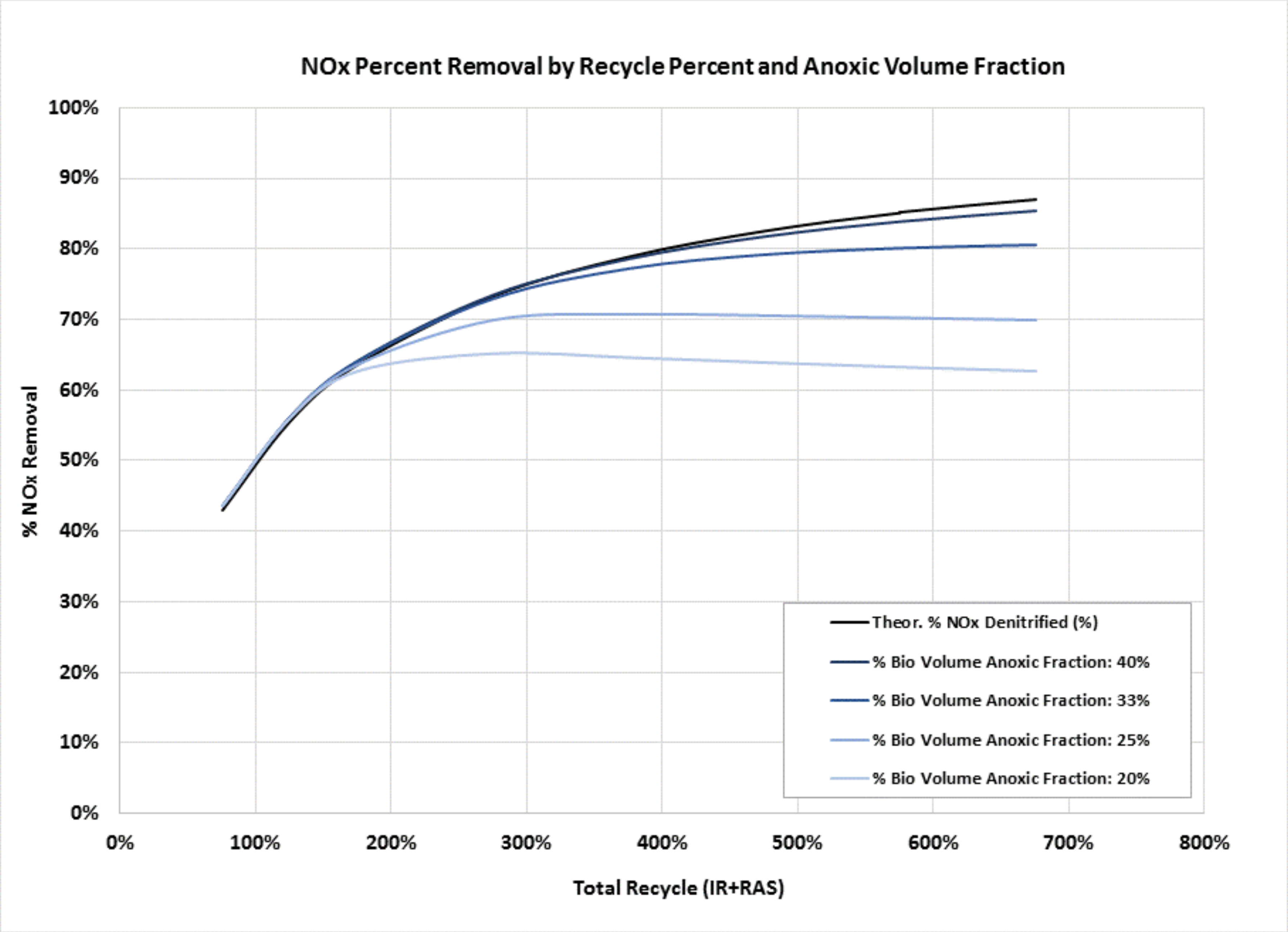
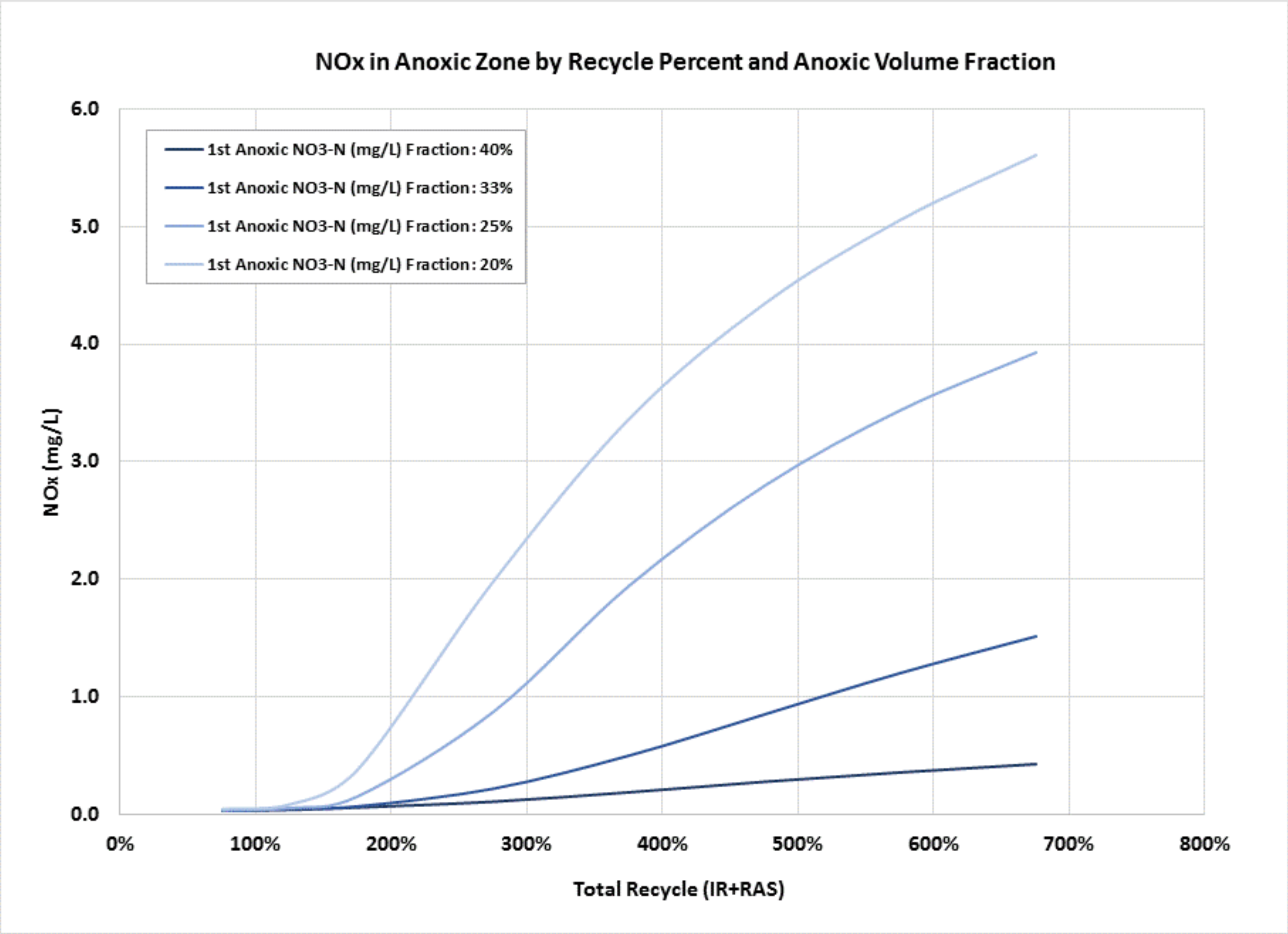

NOx Percent Removal by Recycle Percent and Anoxic Volume Fraction
% NOx Removal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
100%
200%
300%
400%
500%
600%
700%
800%
Total Recycle (IR+RAS)
Theor. % NOx Denitrified (%)
% Bio Volume Anoxic Fraction: 40%
% Bio Volume Anoxic Fraction: 33%
% Bio Volume Anoxic Fraction: 25%
% Bio Volume Anoxic Fraction: 20%

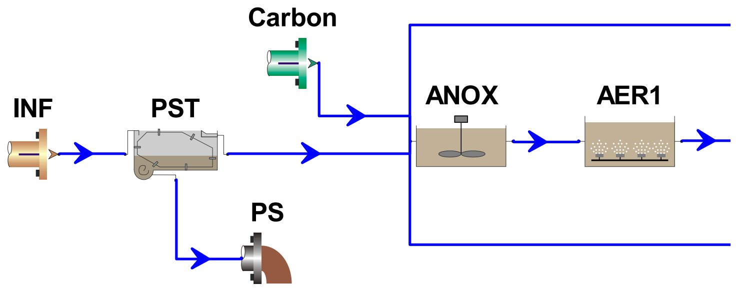

NOx in Anoxic Zone by Recycle Percent and Anoxic Volume Fraction
1st Anoxic NO3-N (mg/L) Fraction: 40%
1st Anoxic NO3-N (mg/L) Fraction: 33%
1st Anoxic NO3-N (mg/L) Fraction: 25%
1st Anoxic NO3-N (mg/L) Fraction: 20%
NOx (mg/L)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0%
100%
200%
300%
400%
500%
600%
700%
800%
Total Recycle (IR+RAS)

Constraint on Achieving Maximum Theoretical Denitrification: **TKN:BOD Ratio**

- TKN:BOD ratio in anoxic zone has major impact on denitrification capacity of the zone
- Example empirical relationship (Stensel, et. al 1982):

$$SDNR_{20} = 0.03(F/M)\left(\frac{F_b}{0.30}\right) + 0.029$$

- SDNR (specific denitrification rate) also varies by:
  - Temperature
  - F_b (active biomass fraction of MLVSS)
    - Site-specific kinetic and stoichiometric conditions



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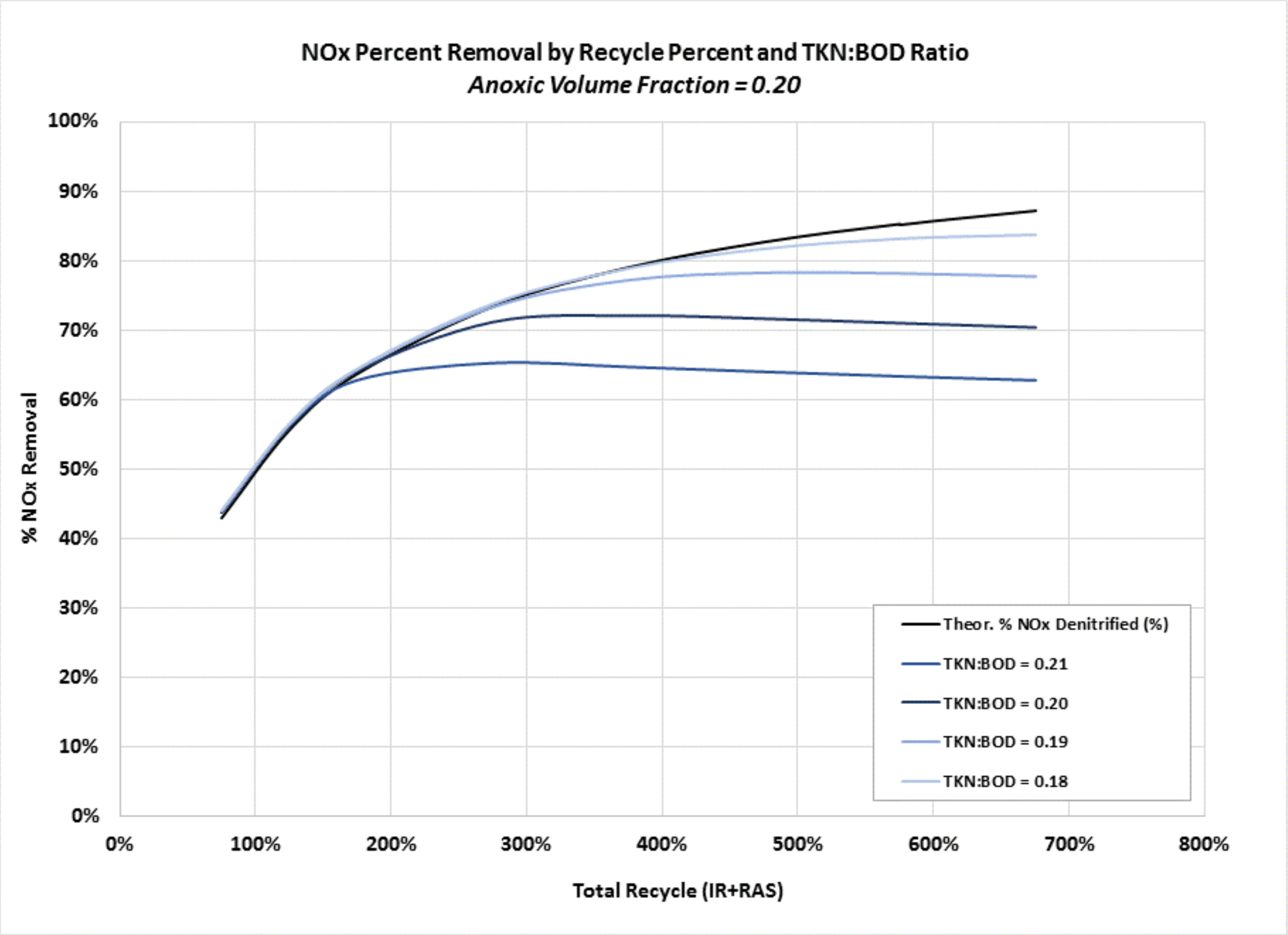
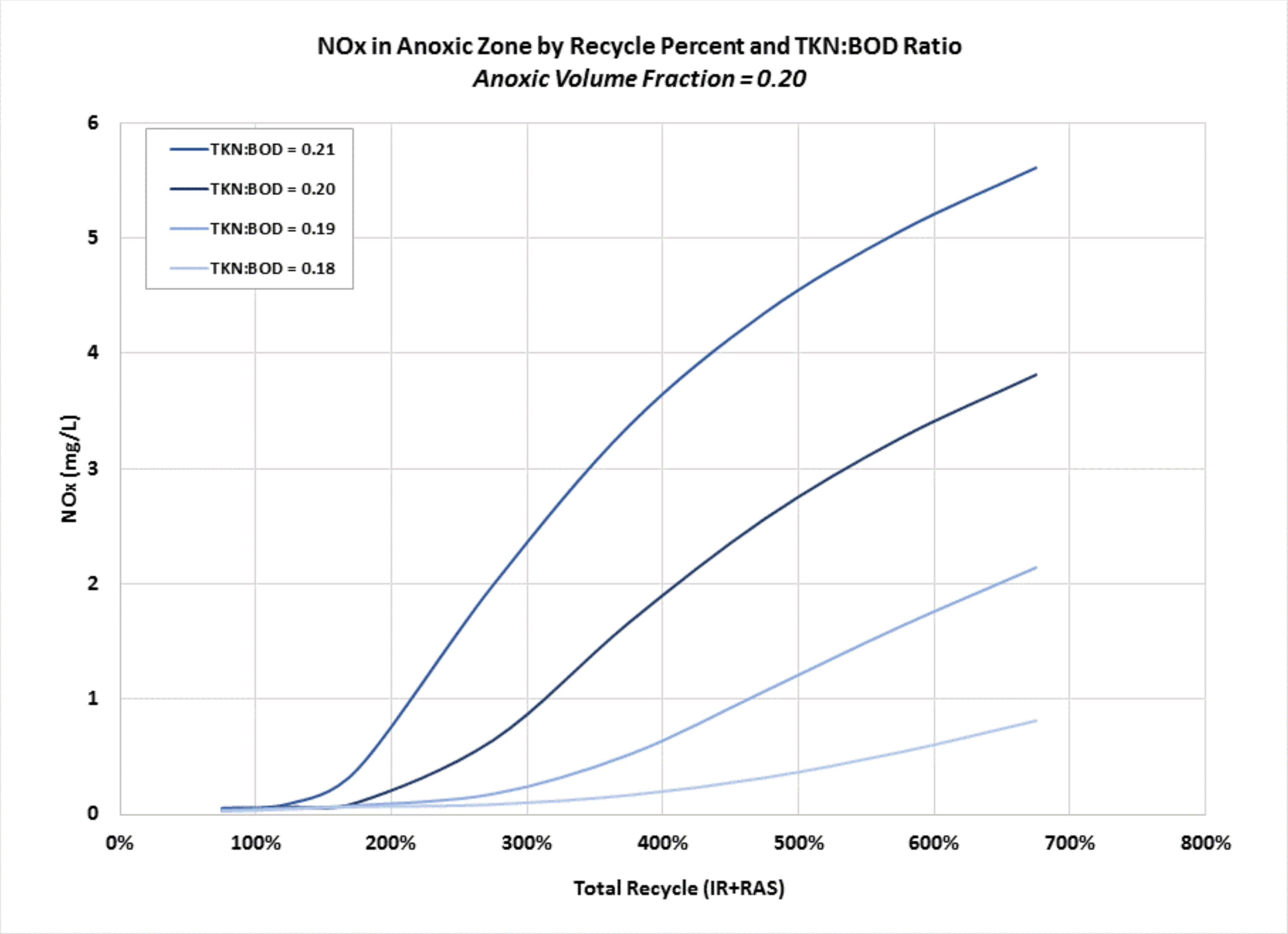
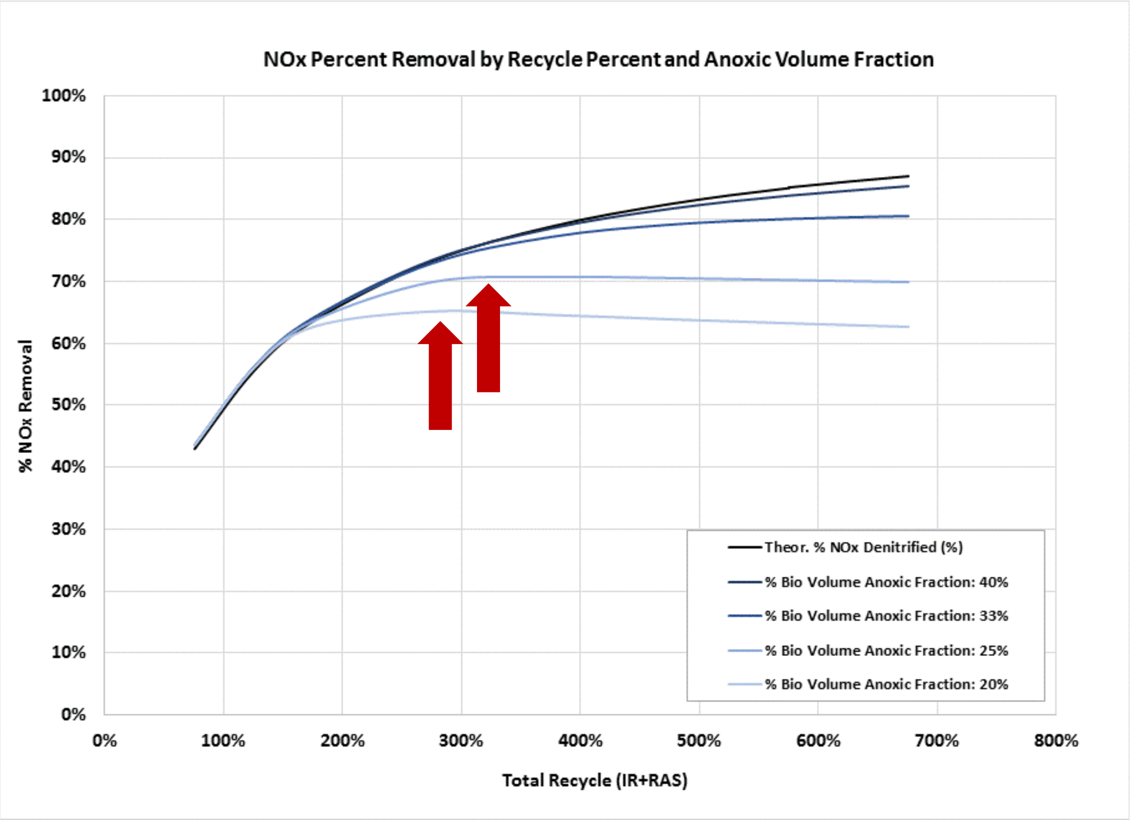

NOx Percent Removal by Recycle Percent and TKN:BOD Ratio
Anoxic Volume Fraction = 0.20
% NOx Removal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
100%
200%
300%
400%
500%
600%
700%
800%
Total Recycle (IR+RAS)
Theor. % NOx Denitrified (%)
TKN:BOD = 0.21
TKN:BOD = 0.20
TKN:BOD = 0.19
TKN:BOD = 0.18


NOx in Anoxic Zone by Recycle Percent and TKN:BOD Ratio
Anoxic Volume Fraction = 0.20
TKN:BOD = 0.21
TKN:BOD = 0.20
TKN:BOD = 0.19
TKN:BOD = 0.18
NOx (mg/L)
0
1
2
3
4
5
6
0%
100%
200%
300%
400%
500%
600%
700%
800%
Total Recycle (IR+RAS)

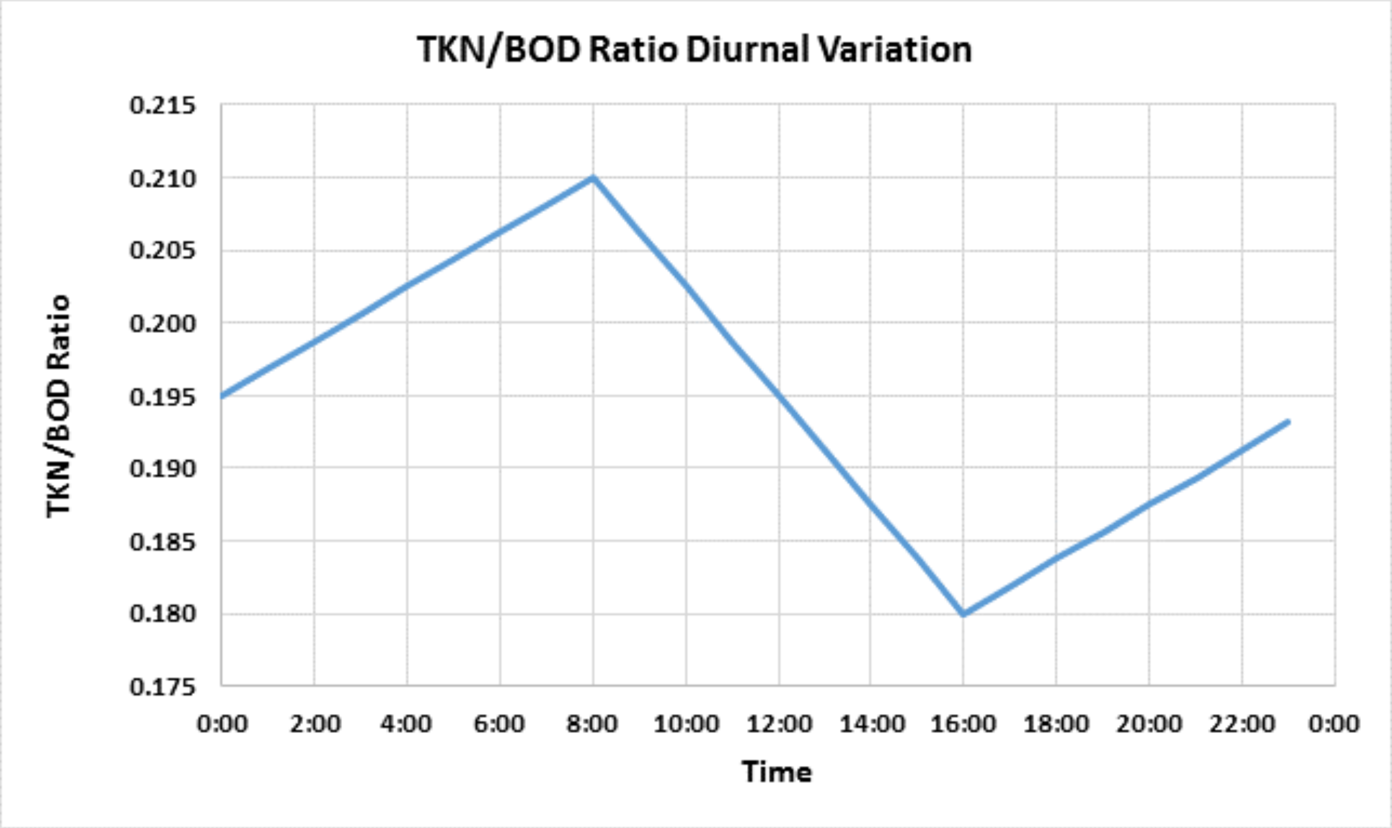
Control/Monitoring to Optimize Efficiency – DO Poisoning

- DO in the internal recycle flow reduces denitrification capacity of the anoxic zone
- 1 lb of DO = 0.35 lbs NO_3-N
- Need sufficient DO to achieve full nitrification in the aerobic zone – but how much is really needed?
  - 2 mg/L?
  - 1.5 mg/L?
  - 1 mg/L?
- Is it possible to reduce aerobic volume and maintain nitrification?



Control/Monitoring to Optimize Efficiency – In Real-Time

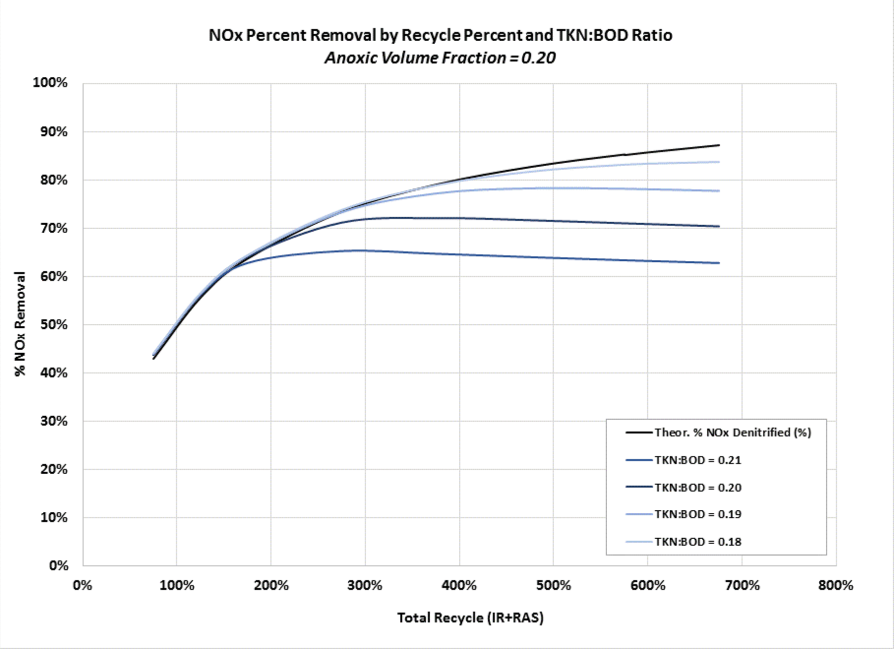
- TKN/BOD varies throughout the day
- Flow-pacing IR rate results in:
  - Periods when IR rate is too high (DO, energy waste)
  - Periods when IR rate is too low (less NO_x removal than should be possible)
- Example:



Control/Monitoring to Optimize Efficiency – In Real-time

TKN/BOD Ratio	IR Rate	% NOx Removal	NOx-N Produced	NOx-N Denitrified
Average = 0.195	Paced at 300%	0.70	978 lbs/day	685 lbs/day
Varies from 0.18 to 0.21	Optimized as function as TKN/BOD	0.78	978 lbs/day	763 lbs/day

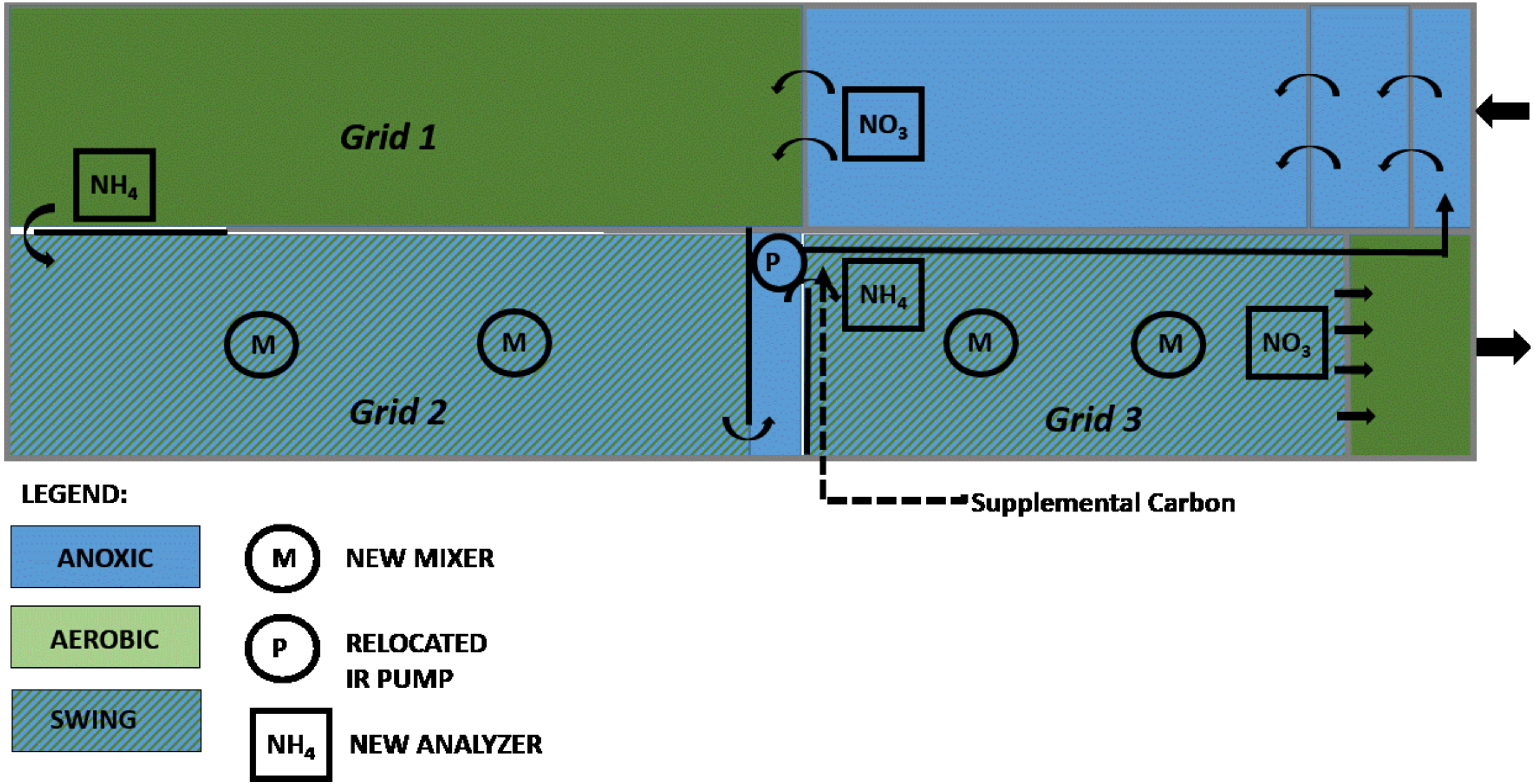
- 763 – 685 = 78 lbs/day more NOx denitrified
- @ 5 mgd = 1.9 mg/L



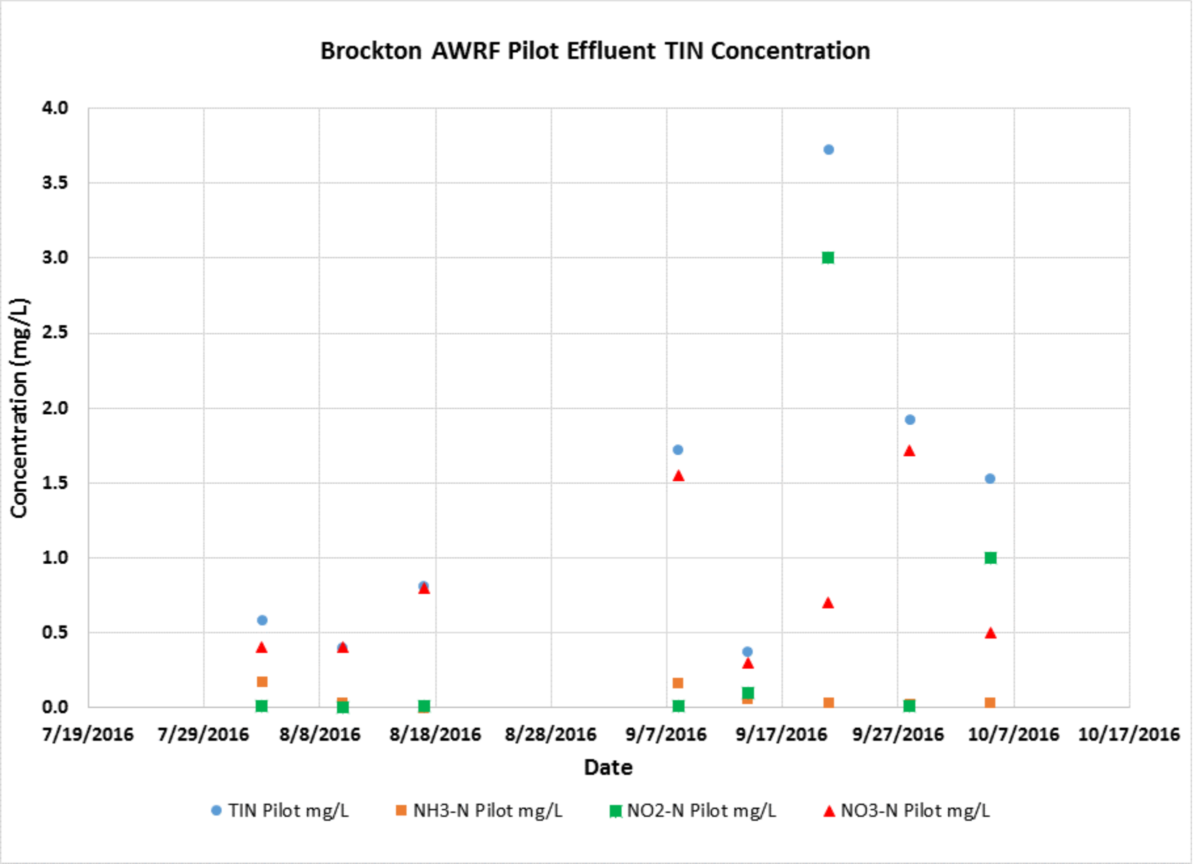
Case Study in Optimizing Treatment: Brockton AWRF Pilot

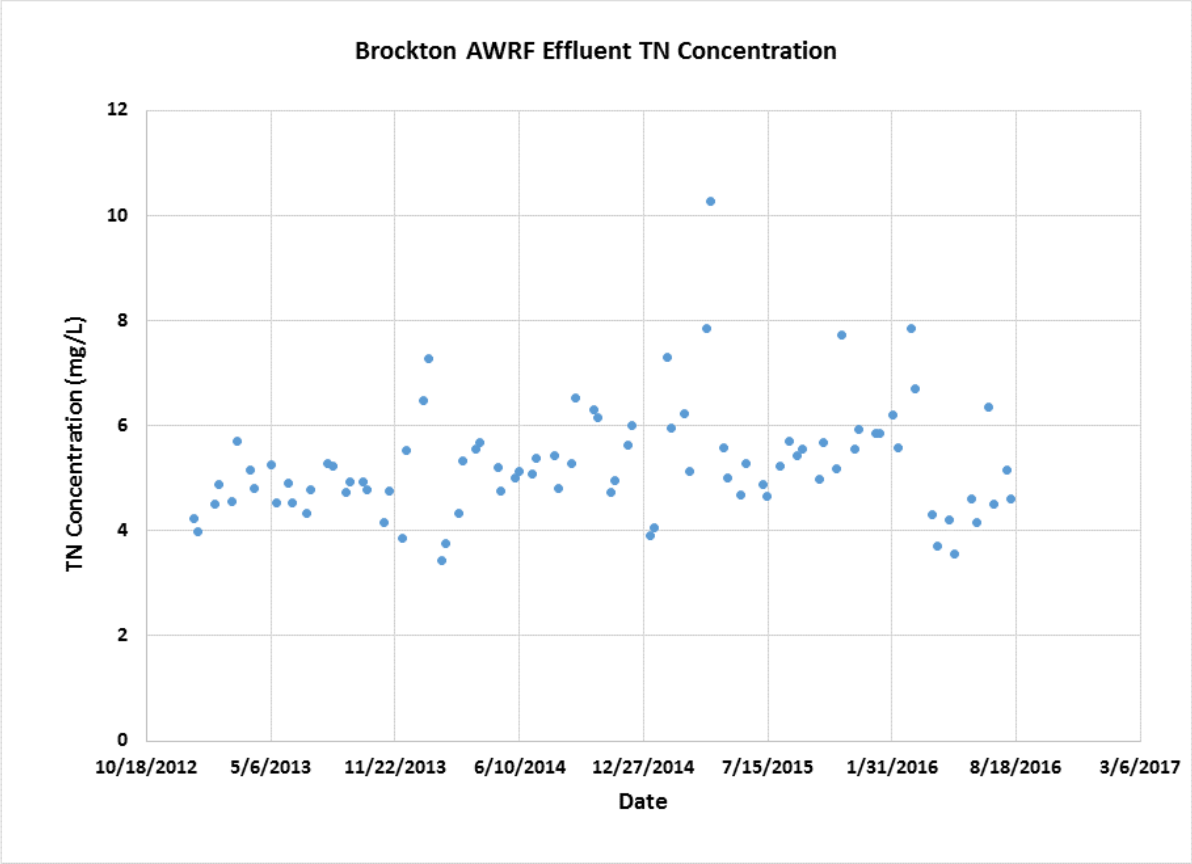
- Major upgrade completed ~ 2008
  - Biological process upgrade to MLE process
  - Year-round NPDES ammonia limits
  - No TN limit
  - Bioreactor volume available allowed for anoxic volume
  - Anticipated average MLE effluent TN concentration: 5.5 mg/L
- New target treatment goal of 3 mg/L TN
- Desktop analysis indicated this was possible with optimized process
- Piloting initiated in 2016 to verify. Pilot utilizes:
  - Process analyzers to monitor and optimize nitrification and denitrification
  - Swing zones (represent a seasonal change from MLE)
  - Supplemental carbon

Brockton AWRF Pilot Basin Arrangement



Brockton AWRF Pilot Basin Early Results





Summary

- MLE performance is reliable, predictable and limited
- Internal recycle rate “rule” represents the best-case denitrification efficiency
- IR rate may either under-utilize or exceed anoxic zone denitrification capacity
- TKN/BOD ratio is fundamental to optimal IR rate
- Supplemental carbon improves performance of MLE, IF the influent has low TKN/BOD ratio and/or the anoxic zone is small
- Real-time data from process analyzers is vital to optimizing the process

Water Partnership with CDM Smith

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