Optimization Through Design: Implementing Full Scale Carbon Addition to 700 MGD of Wastewater Treatment in NYC

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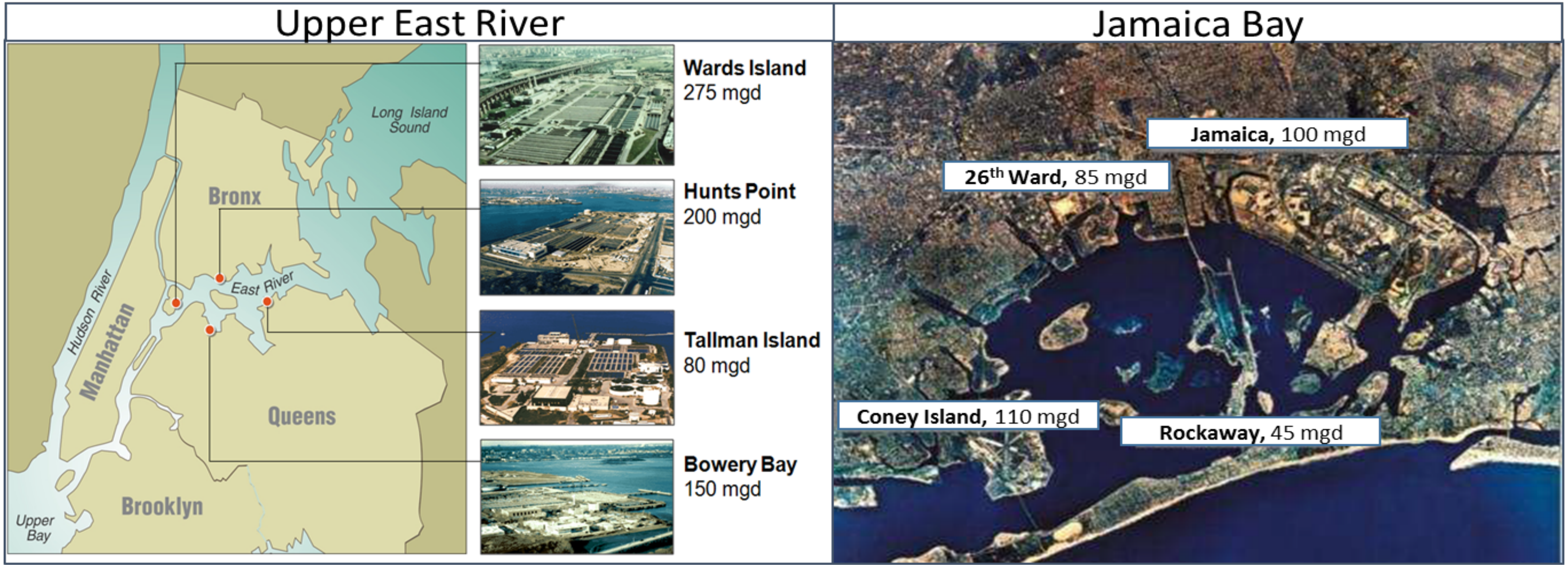
Mission

- Our project's purpose:
  - Reduce Total Nitrogen (TN) in effluent of NYC WWTPs
  - Carbon in primary effluent (PE) insufficient for denitrification
  - Use supplement carbon addition (glycerol) to fuel denitrification
  - Accurately (cost effectively) dose glycerol
- Flexible system design features
- Impressive full scale results
- Additional applications

Presentation Contents:

1. Introduction to NYC BNR
2. Objectives for Carbon addition
3. Challenges
4. Supplemental Carbon (Glycerol) System Overview
5. Glycerol Dosing Control Strategies
6. Full-Scale Testing and Operation
7. Results
8. Next Steps

Introduction: Upper East River and Jamaica Bay WWTPs



- Upper East River aggregate limit permit
- Glycerol Addition: Wards Island, Tallman Island, Bowery Bay

- Jamaica Bay aggregate limit permit
- Glycerol Addition: Jamaica and 26th Ward

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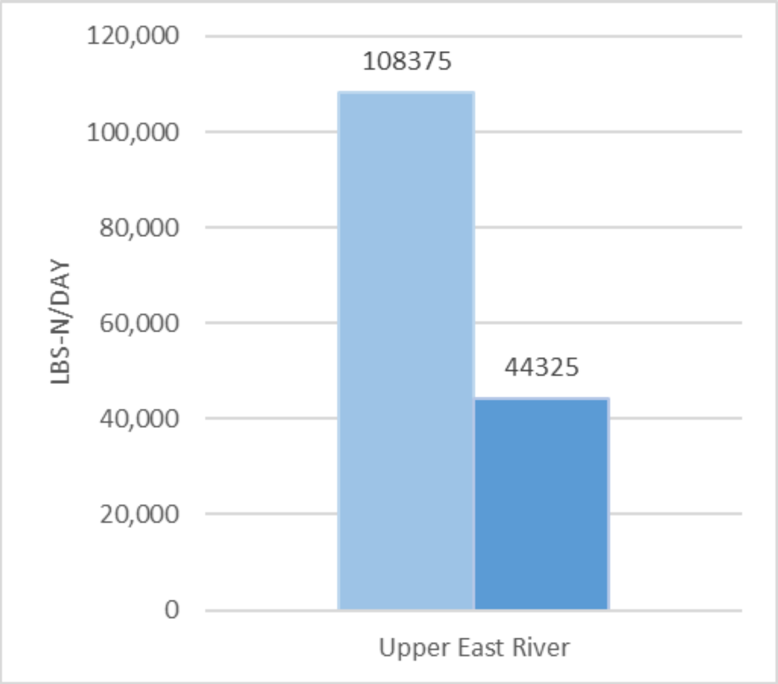
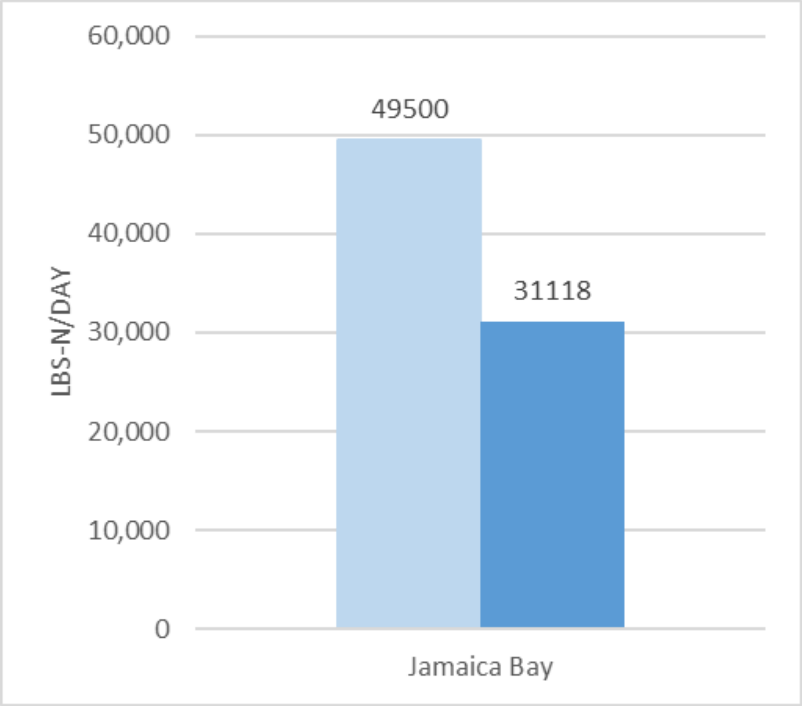
Introduction: Total Nitrogen (TN) Reduction Targets

Upper East River



- 59% reduction

Jamaica Bay



- Performance based limits
- Recalculated after major construction completions

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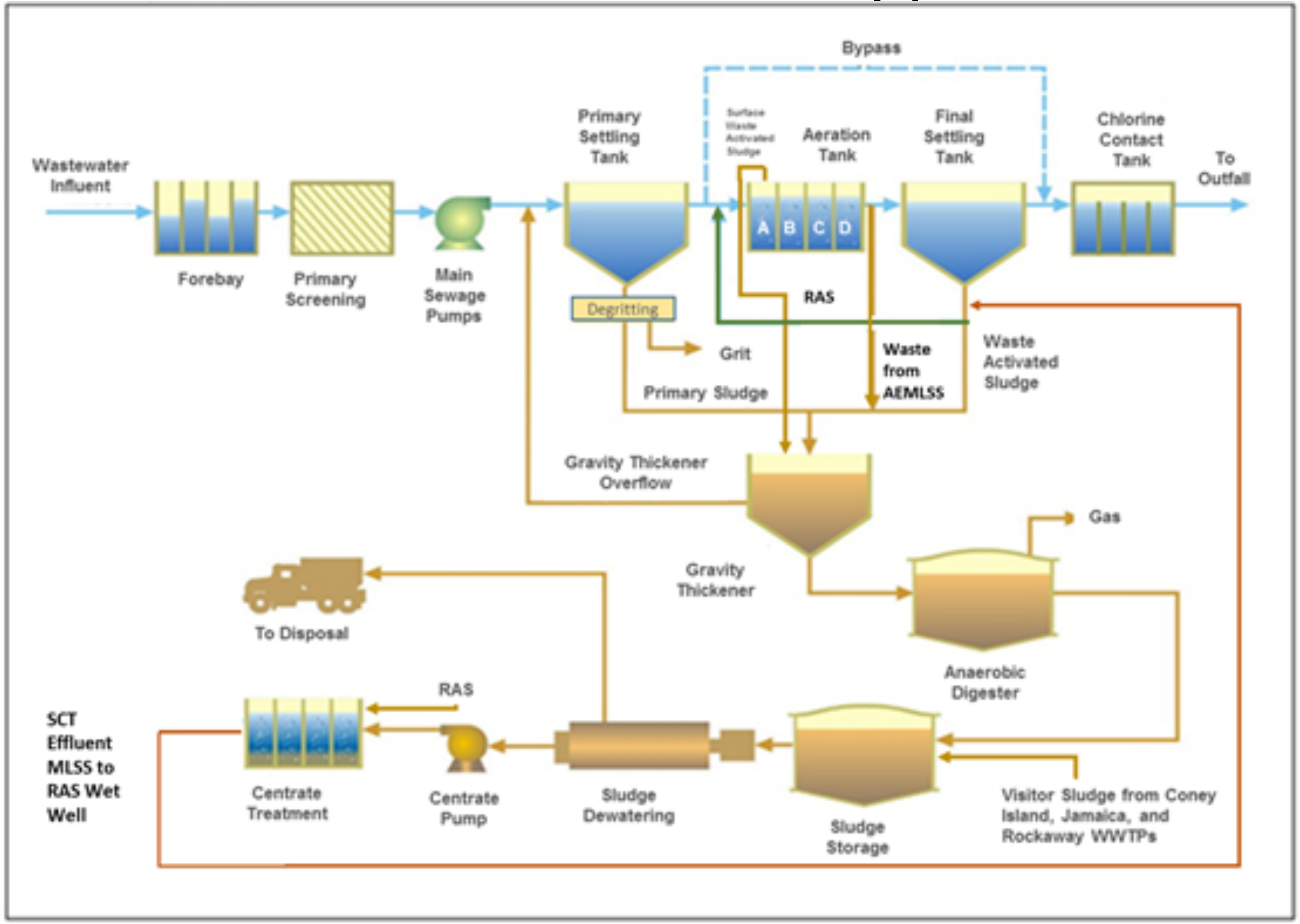
Introduction: BNR in NYC – Typical Plant



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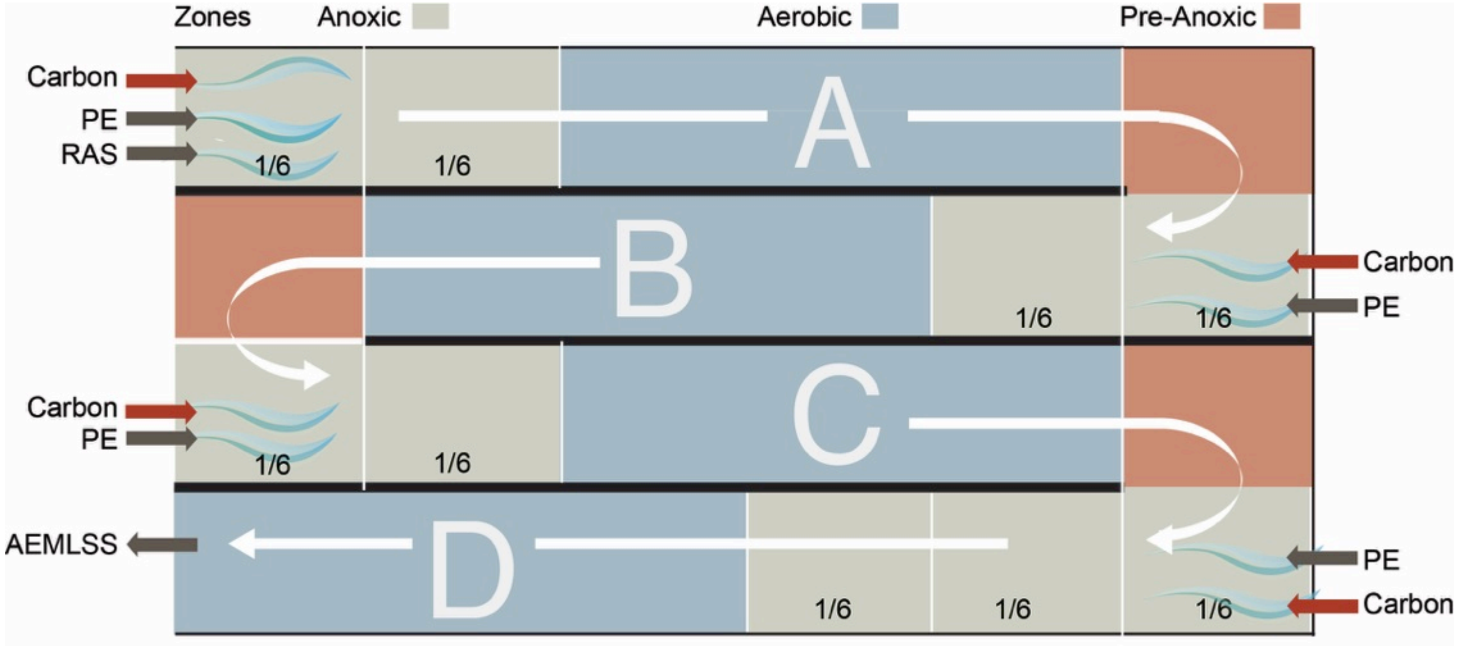
Introduction: Approach to BNR in NYC

- Step Feed BNR
- Phase I BNR Upgrades:
  - Aeration Tanks (e.g., baffling)
  - Aeration Systems
  - RAS/WAS System
  - Froth Control (Surface Foaming)
  - Chemicals
    - ✓ Alkalinity
    - ✓ Polymer
    - ✓ Sodium hypochlorite
  - Separate Centrate Treatment
    - ✓ Dedicated Aeration Tank for high strength waste
- Phase II BNR: Supplemental Carbon Addition



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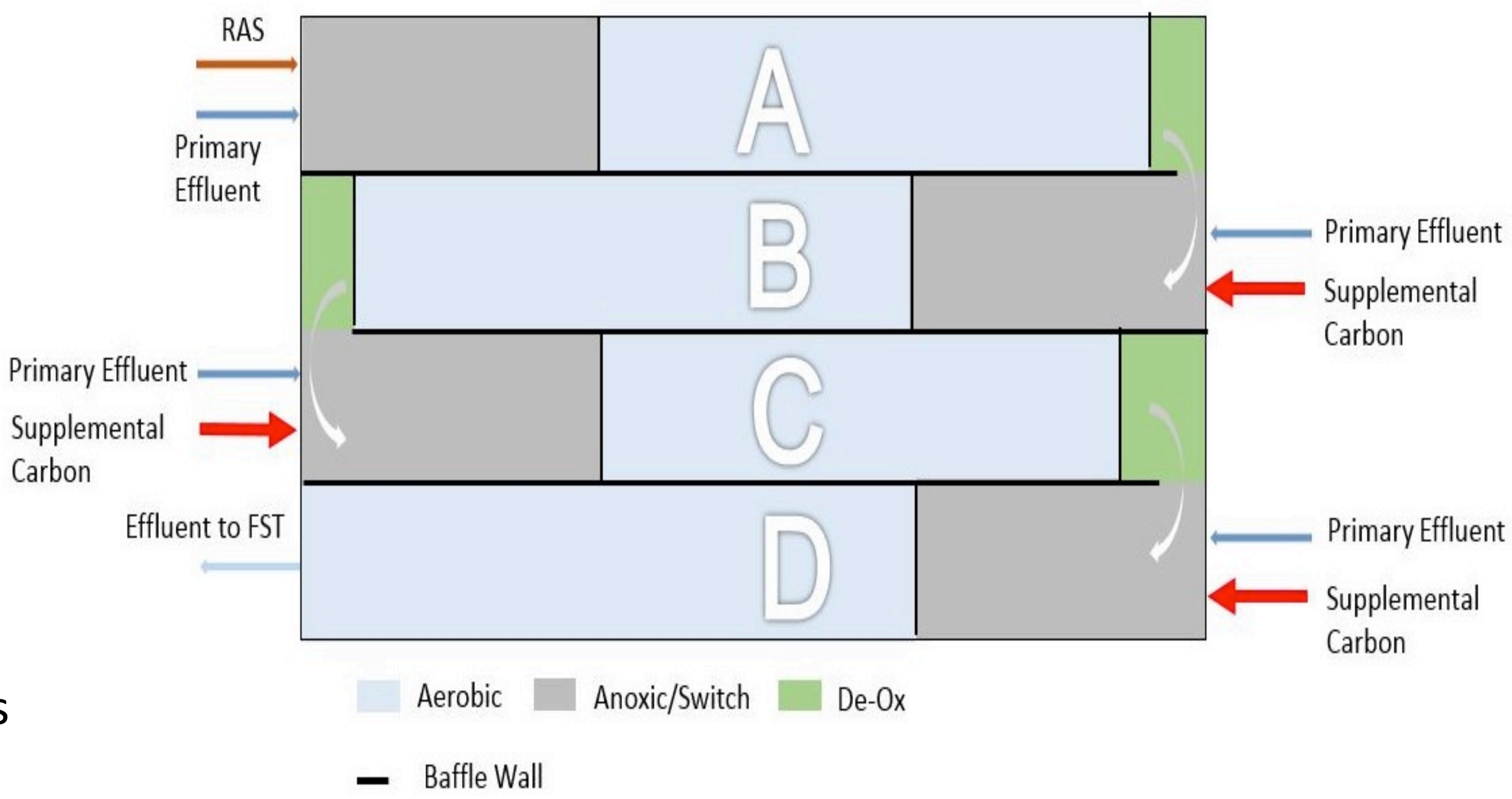
Objectives for Carbon Addition

- TN discharge requirements
- Safety
- Accurately dose (avoid overdosing glycerol)
- Minimizing operational costs
- Simple/flexible to operate
- Consistent between plants
- Operational contingency plans

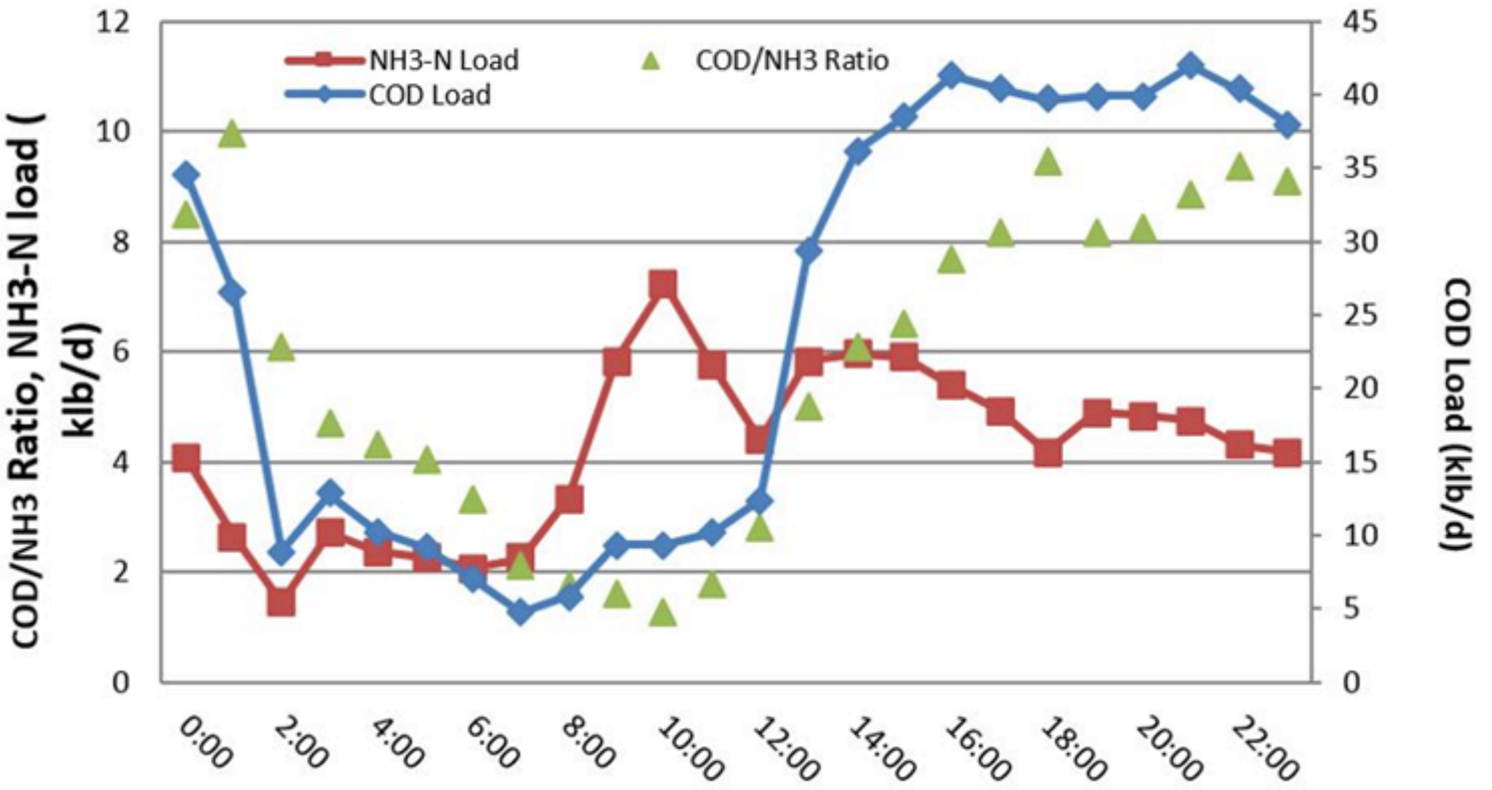
Challenges: Complexity of Step Feed

- Nitrification-Denitrification cycling
- Step feed of PE:
  - Introduces C + N at beginning of each pass
  - sequentially shortening hydraulic retention times (td)
  - pass specific solids inventory (MLSS)



Challenges: C:N Variability

- Diurnal variations in influent C:N ratio
- Seasonal operational variations (Nitrification)
- Side stream centrate treatment
- Bottom Line: Carbon demand is variable



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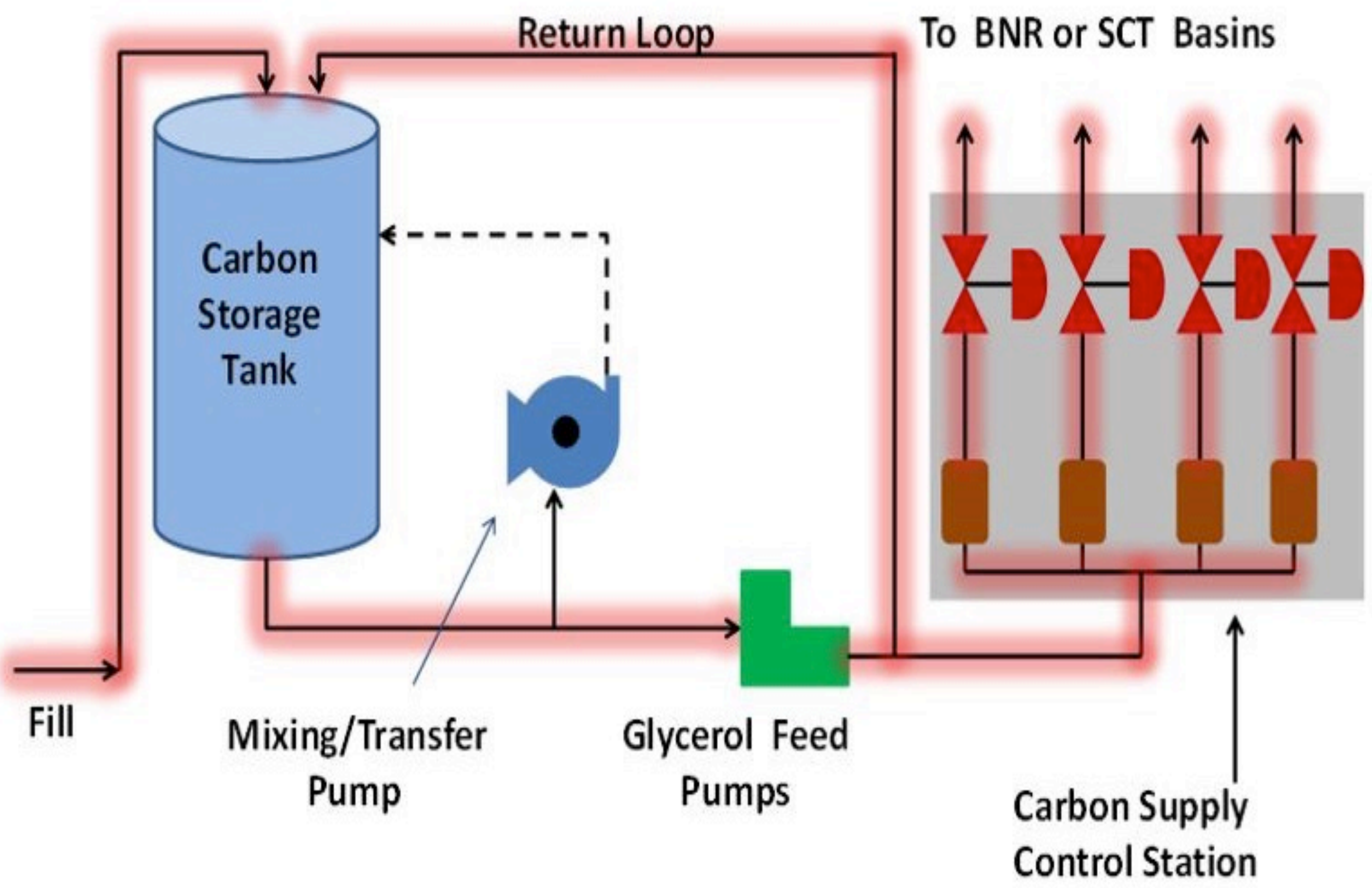
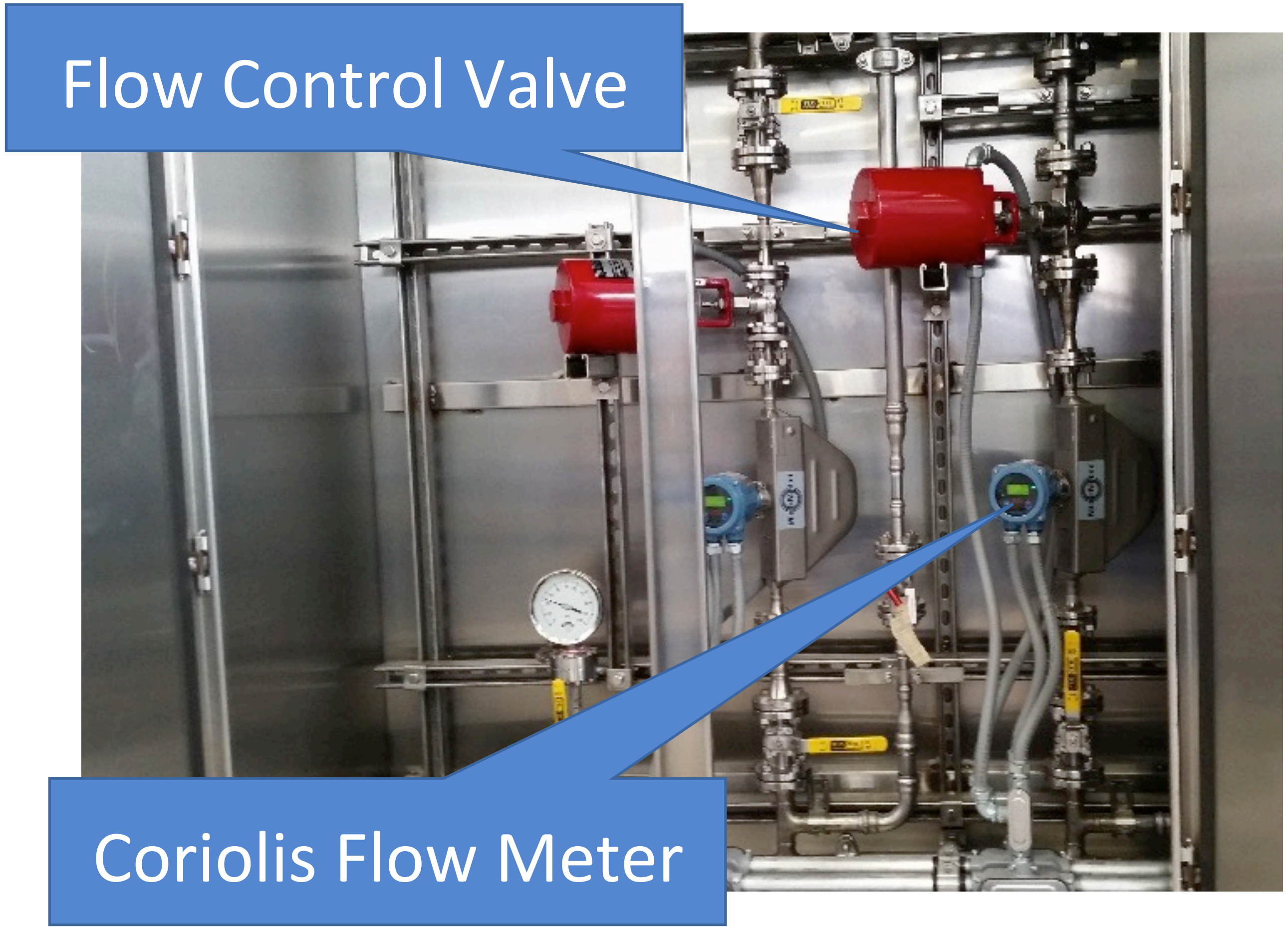
Supplemental Carbon (Glycerol) System Overview:

Supplemental Carbon = Glycerol:

- 70% strength (neat)
- 1,000,000 mg COD/L
- $2/gallon +/- (assumed for budget purposes)
- Non-hazardous (EPA: GRAS)



Glycerol System Overview



- Tandem Flow Control Valve & Flow Meter (in series)
- Flow meter: Measures dosed flow
- Controller:
    - Compares set point to actual dose
    - PID tuning parameters generate valve position correction
- Control valve modulates to maintain set point

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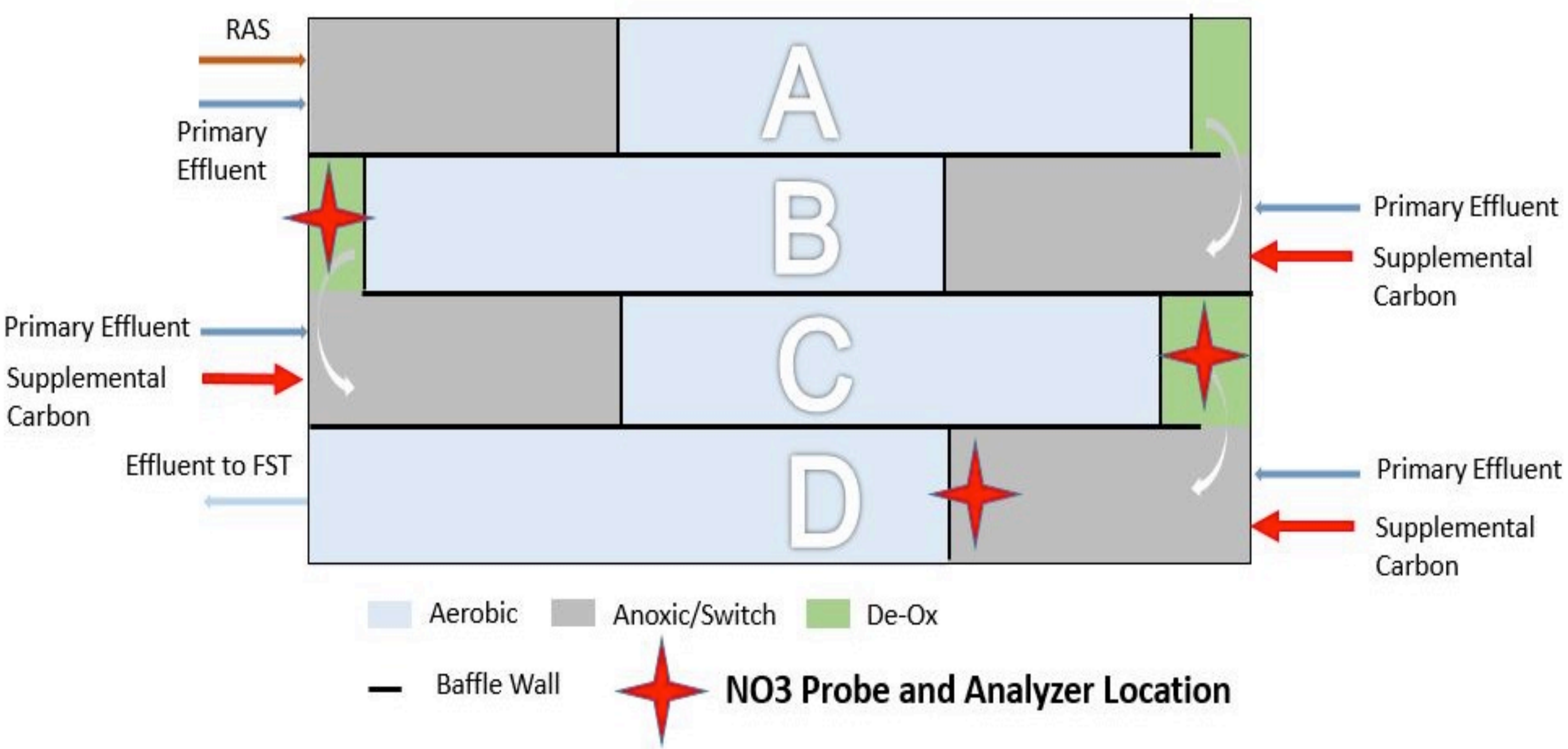
Glycerol System Overview: Instrumentation

- Nitrate probes located
  - End of Pass B (feed forward)
  - End of Pass C (feed forward)
  - End of anoxic zone in Pass D (feed back)



Control Strategies: Glycerol Dosing Strategies

Strategy	Set point established	Flow
Manual	Operator sets valve position	Constant
Semi-Auto	Operator Enters Glycerol Flow Rates	Constant
Historical	Diurnal Lookup Tables (Operator adjustable)	Variable
Flow Paced	PLC factors plant flow x ratio factor	Variable
Nitrate Analyzer Control	Cascade Control: PLC process calculation based on: plant flow, nitrate signals and process parameters	Variable

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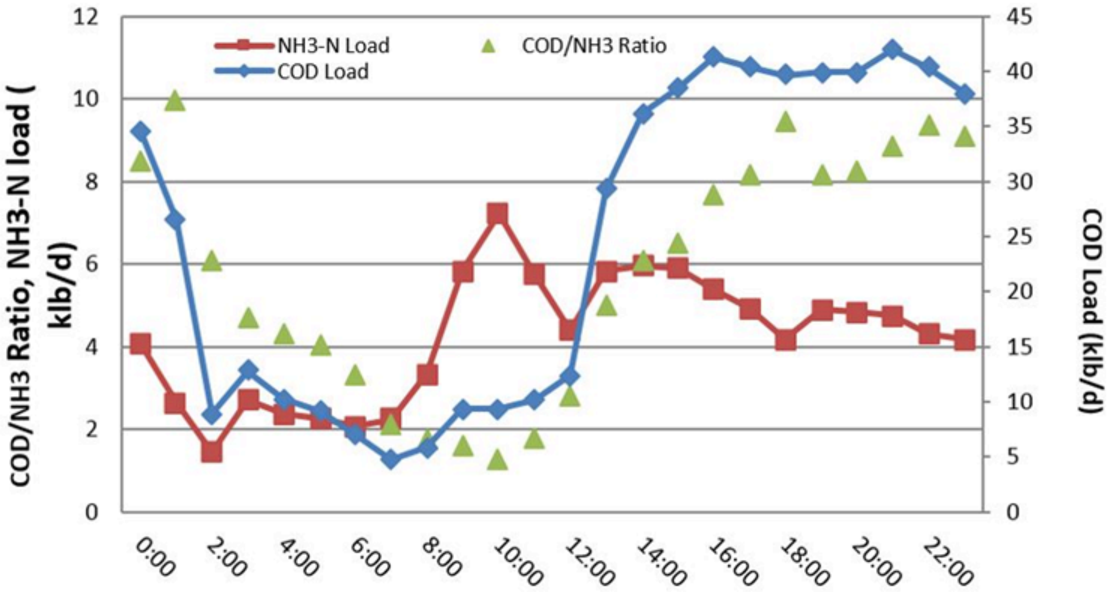
Control Strategies: Manual & Semi-Auto

Pros	Cons
Simple	Overdoses part of the day
Constant Flow	Overdose = Overspend



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Control Strategies: Historical Data Mode

Pros	Cons
Follows diurnal hourly lookup table	Not based on real time signal(s)
Operator adjustable	Does not account for centrate variable loading
Not reliant on plant flow signal	Does not account for process upsets
Not reliant on probes	

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Control Strategies: Automatic “Flow Paced”

Pros	Cons
Dosing is proportional to plant flow signal	Does not account for actual C & N
	Does not account for centrate variable loading
	Does not account for process upsets
	Does not account for diurnal C:N
	Must shut off during rain events (else over dose)

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Control Strategies: Nitrate Analyzer Control

Pros	Cons
Accounts for Plant Flow	Probes maintenance (biweekly cleaning/calibration)
Accounts for Process Parameters (Operator Adjustable)	Relies on having plant flow signal
Accounts for Kinetics and Stoichiometry	Process parameters need to be updated with operational changes (e.g., seasonally)
Process calculations determine each glycerol dose set point	
Kinetic limitations prevent over dose	

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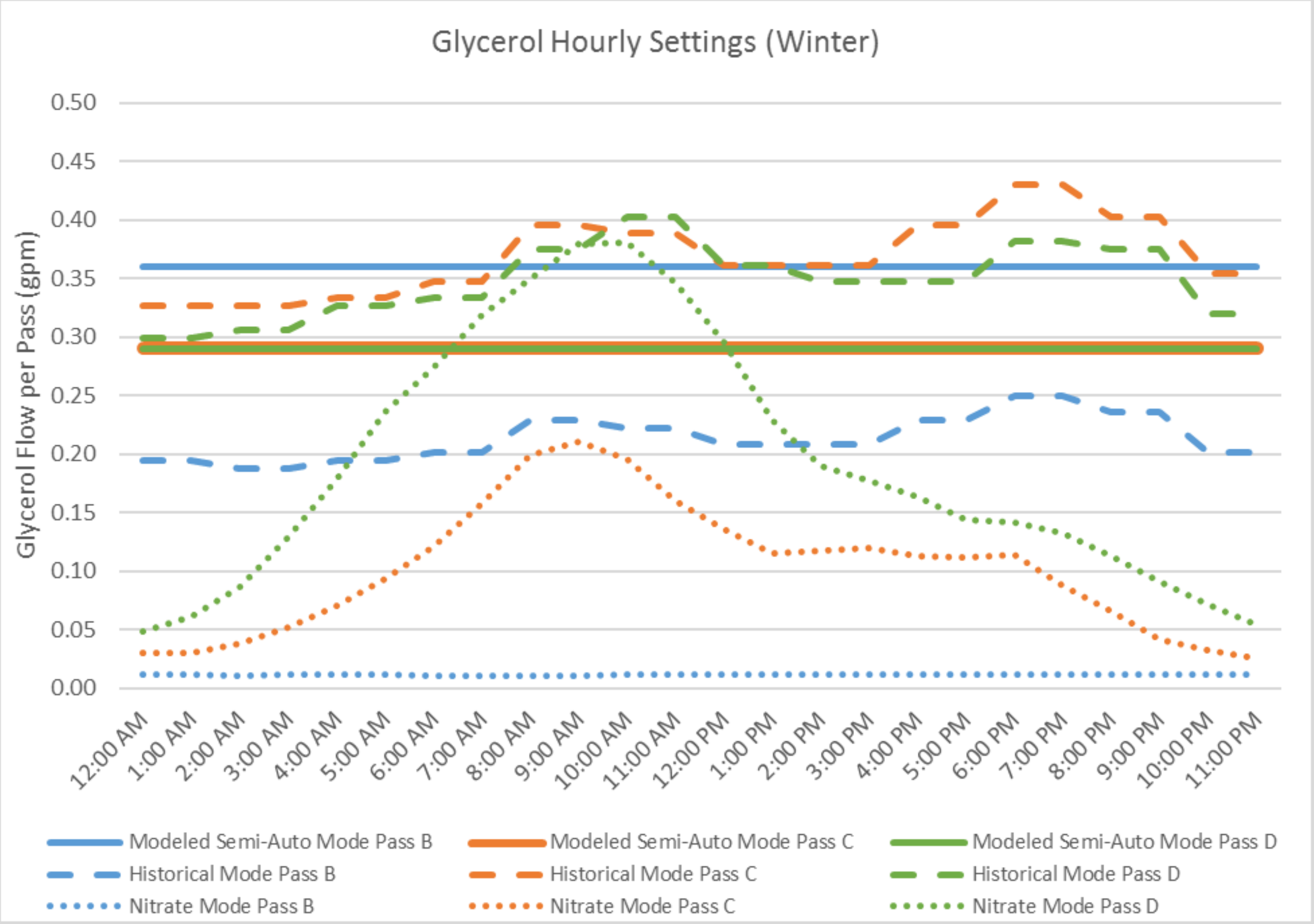
Control Strategy Comparison (at 26th Ward)

- Semi-auto mode 2,710 gpd (modeled)
- Historical mode 2,680 gpd (modeled)
- Nitrate mode 880 gpd (actual)



Control Strategies: Contingency, Contingency, Contingency

- What if probes fail?
  - Historical
  - Flow pace
- What if plant flow signal lost?
  - Semi-Auto
  - Historical
- What if PLC fails?
  - Semi-Auto (Local control loop)
- What if local control loop fails?
  - Manually position valves
- Various control strategies → operational flexibility

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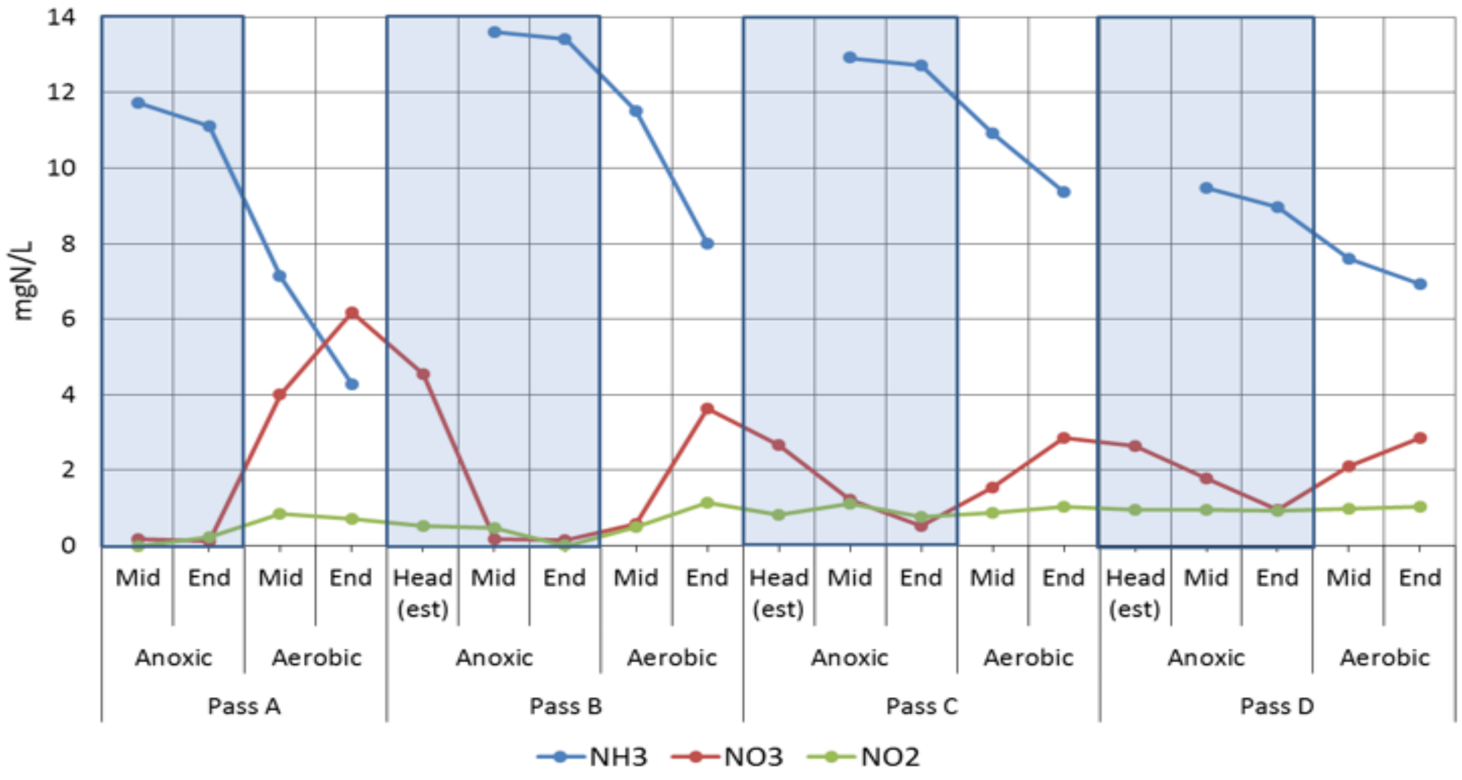
Full Scale Testing and Operation: Optimization Sampling

- 6 month sampling program profiling aeration tanks
  - Ammonia
  - Nitrate
  - Nitrite
- Optimize semi-auto dosing strategies with sampling results
- Batch testing studied glycerol kinetics



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Full Scale Testing and Operation at 26th Ward

- Side by side performance comparison:
  - AT 1 – Nitrate mode
  - AT 2 – Semi-Auto mode (optimized)

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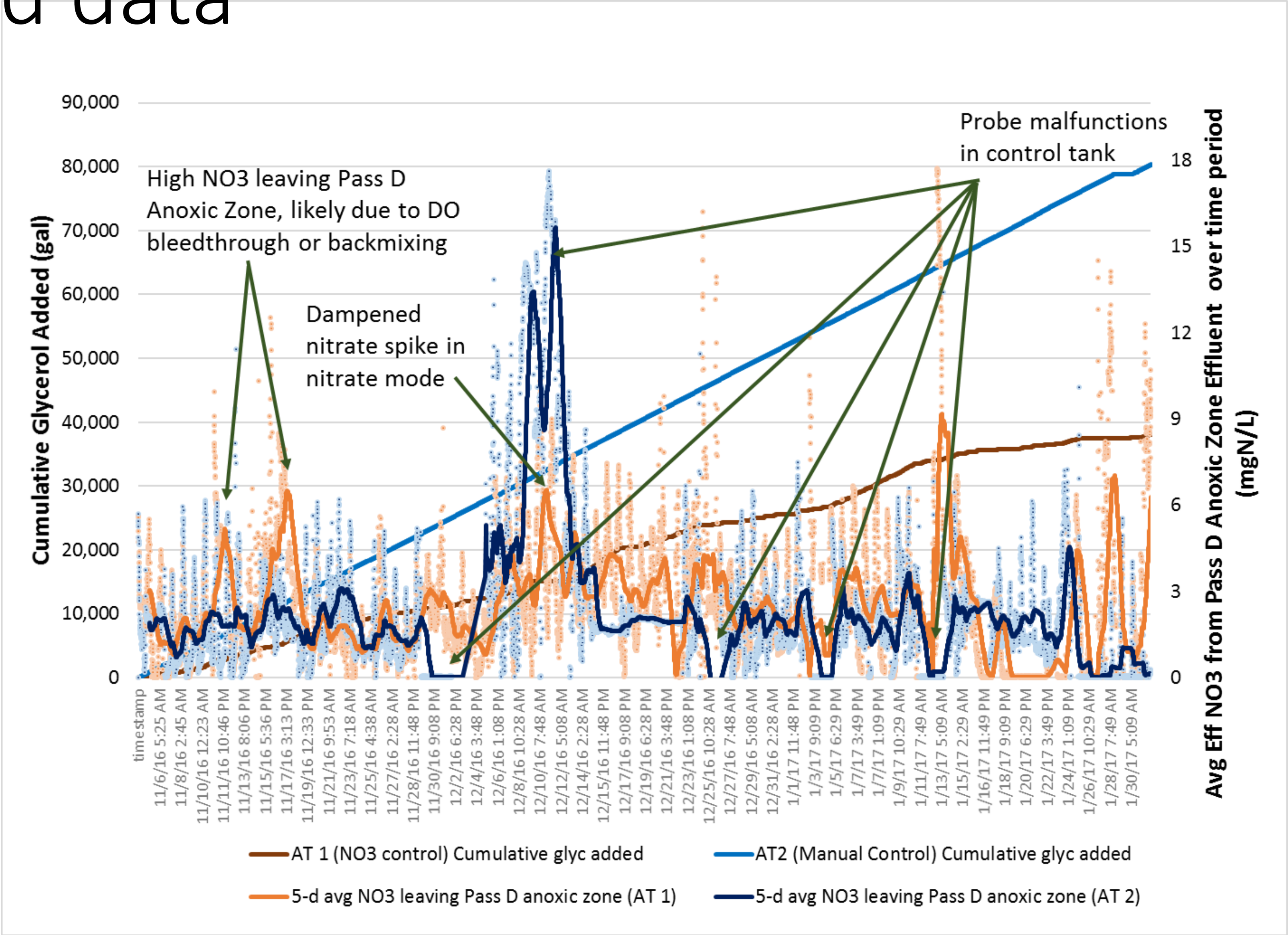
Testing Setup and data

- Similar Operation conditions:
    - Flow per tank
    - DO
    - Flow splits
    - Solids
- Nitrate in effluent is comparable (2 to 3.5 mg-N/L)



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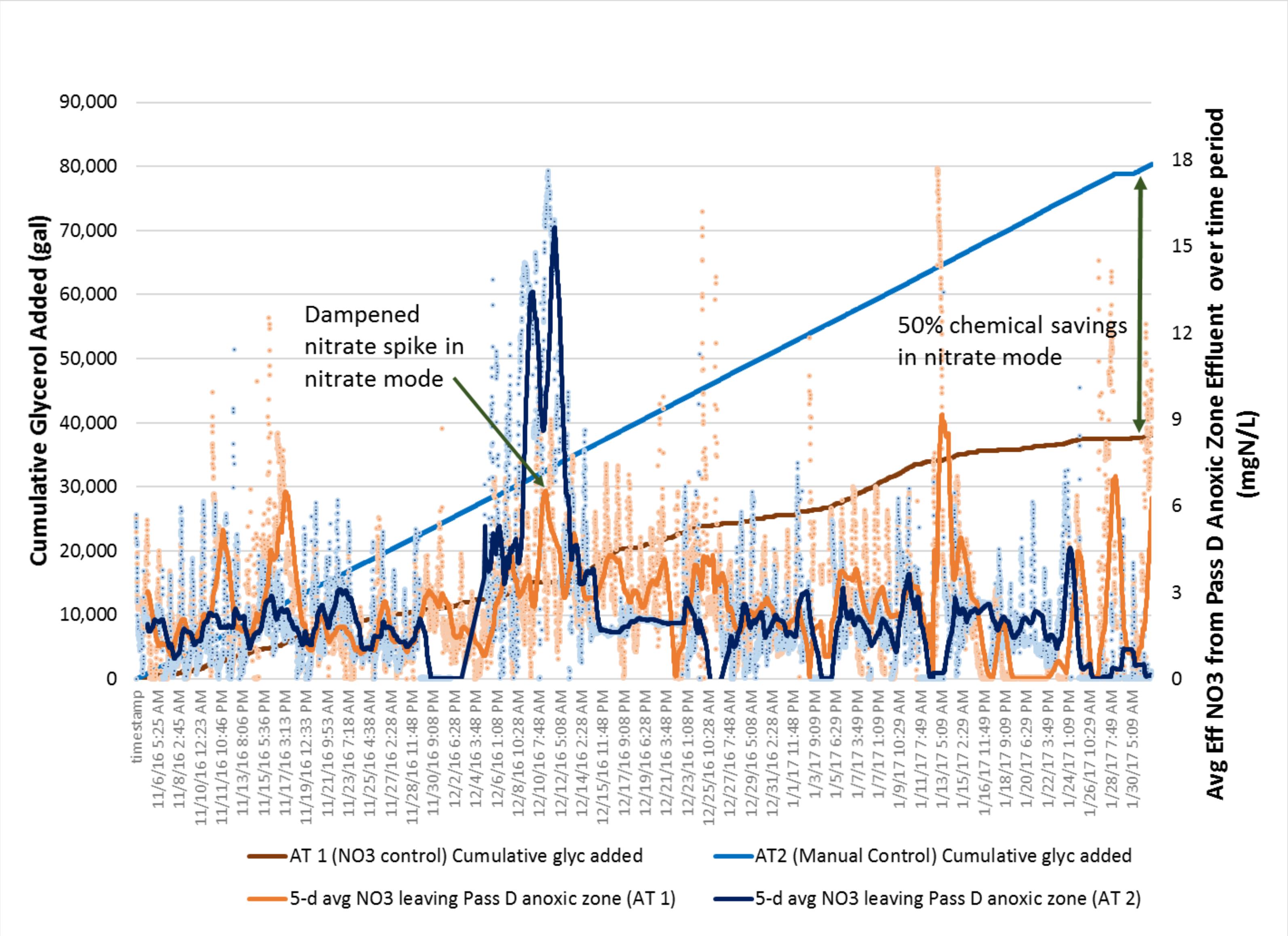
Results

- Nitrate mode uses ½ the glycerol used in semi-auto mode
- Nitrate mode avoids overfeeding in the presence of high NO3 due to kinetic limitations in PLC code



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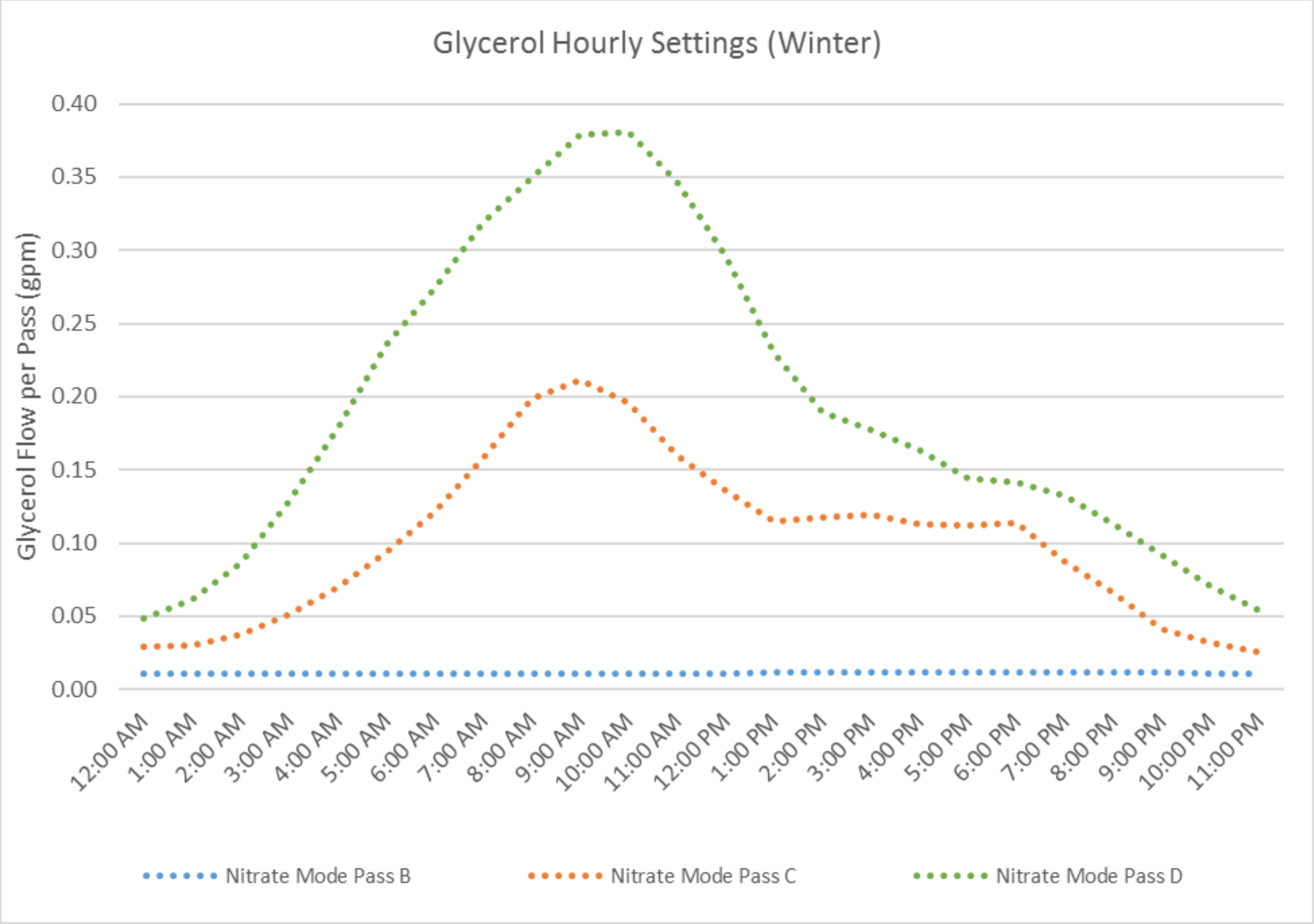
Results

- Glycerol feed peaks with Nitrate control: mid morning
- Reinforced the optimization sampling results



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Estimated Annual Glycerol Usage and Cost by Strategy (Assuming ~$2.00/gal) at 26th Ward

Strategy	Annual Glycerol Usage (gal)	Annual Glycerol Cost ($)
Semi-Auto Constant Dose (Initial)	988,000	$1,976,000
Semi-Auto Constant Dose (Optimized)	673,000	$1,346,000
Nitrate Control	319,000	$639,000
Potential Savings	**354,000+**	**$707,000+**

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Take-aways & Next Steps

- Various control strategies → operational flexibility
- Control strategies + optimization sampling → process efficiency → cost savings
- Advanced control strategy + optimization:
  - Demonstrated effectiveness for carbon addition
  - Also useful for other chemical addition with measurable feedback
- Next Steps for NYC:
  - 26th Ward implementing full plant nitrate control strategy
  - 26th Ward tune historical control strategy based on nitrate control strategy
  - Similar for remaining four plants

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