Advanced Aeration Control Systems
at Water Resource Recovery Facilities (WRRFs)

An event from the **Municipal Resource Recovery & Design Committee (MRRDC)**

Alex Doody
CDM Smith
Part 1: Purpose of Aeration Control & Overview of Key Components

John Manning
Freese & Nichols, Inc.
Part 3: Case Study #1: DO-based Aeration Control at SAWS Leon Creek WRC

David Wankmuller
Hazen and Sawyer
Part 2: Aeration Control Strategies

Eric Redmond
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Part 4: Case Study #2: Ammonia-based Aeration Control

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Water Environment Association of Texas

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Nick Landes

Freese & Nichols, Inc.

Moderator

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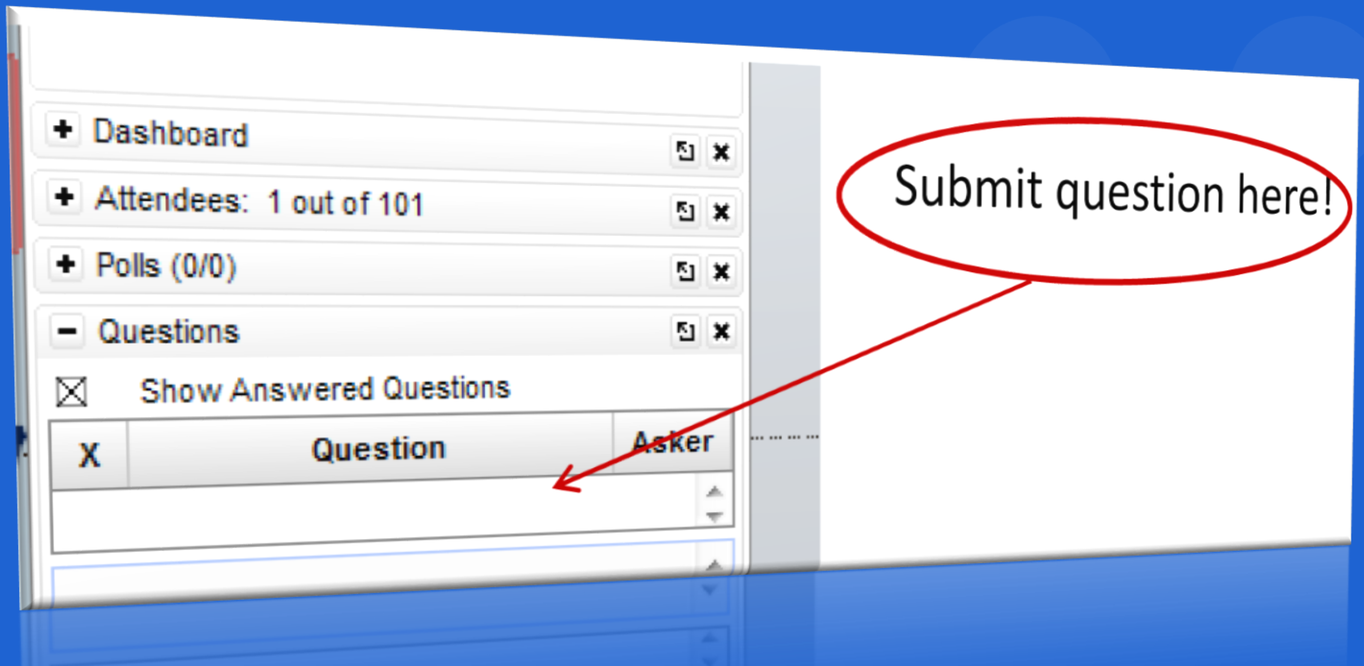

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Part 1:
Purpose of Aeration Control & Overview of Key Components

Alex Doody, P.E.

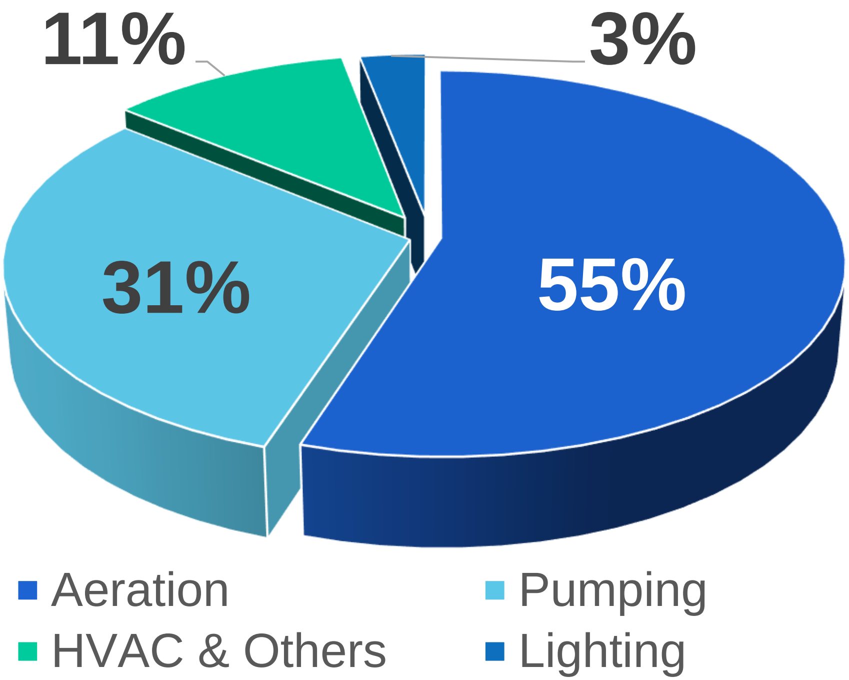
CDM Smith

Why Do We Care About Aeration?

#1: Aeration is the beating heart of the activated sludge process

#2: Aeration is the largest consumer of electric power within a WRRF (50-60%)

- High operating cost
- Environmental impact of energy production

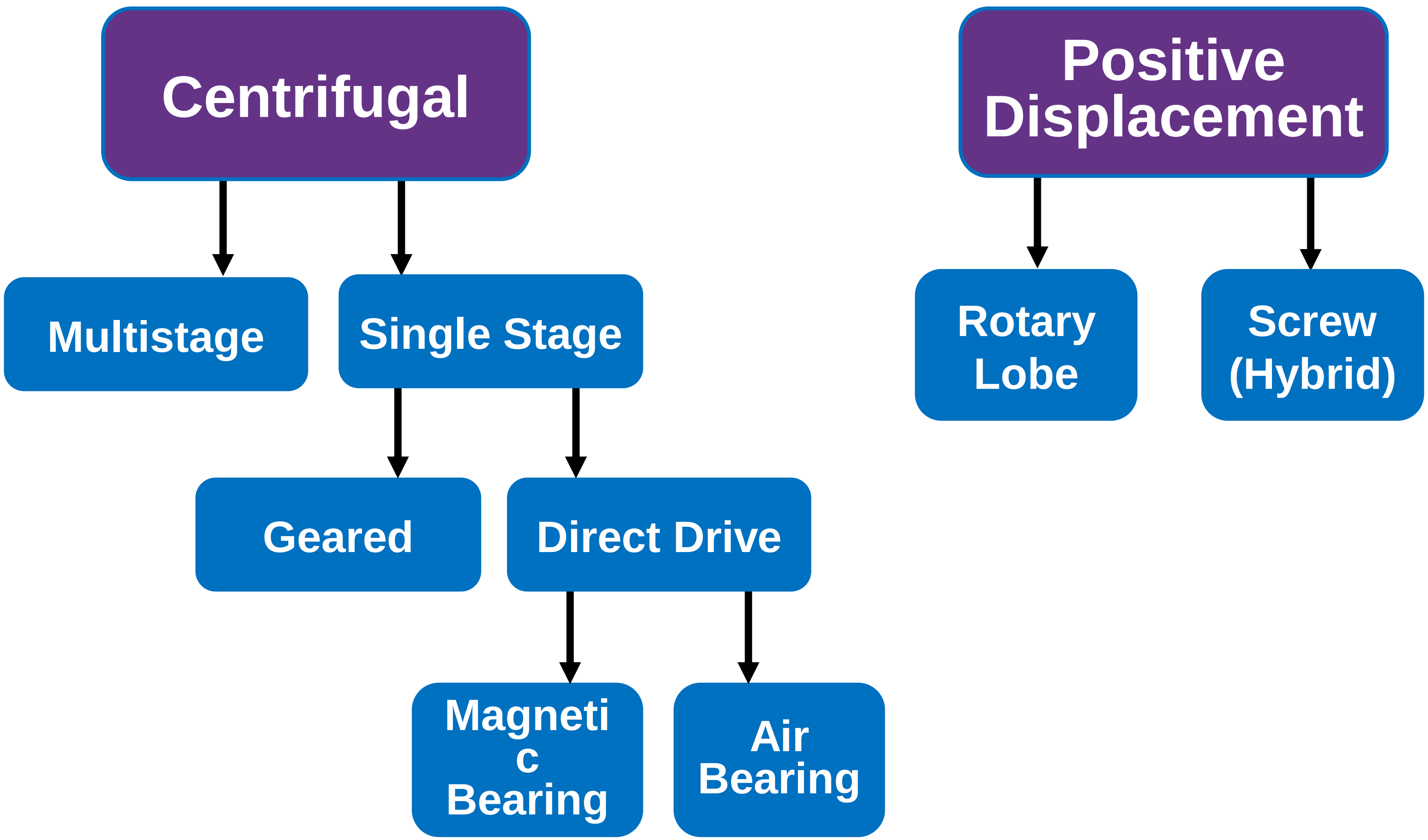


Basic Aeration System Components

+

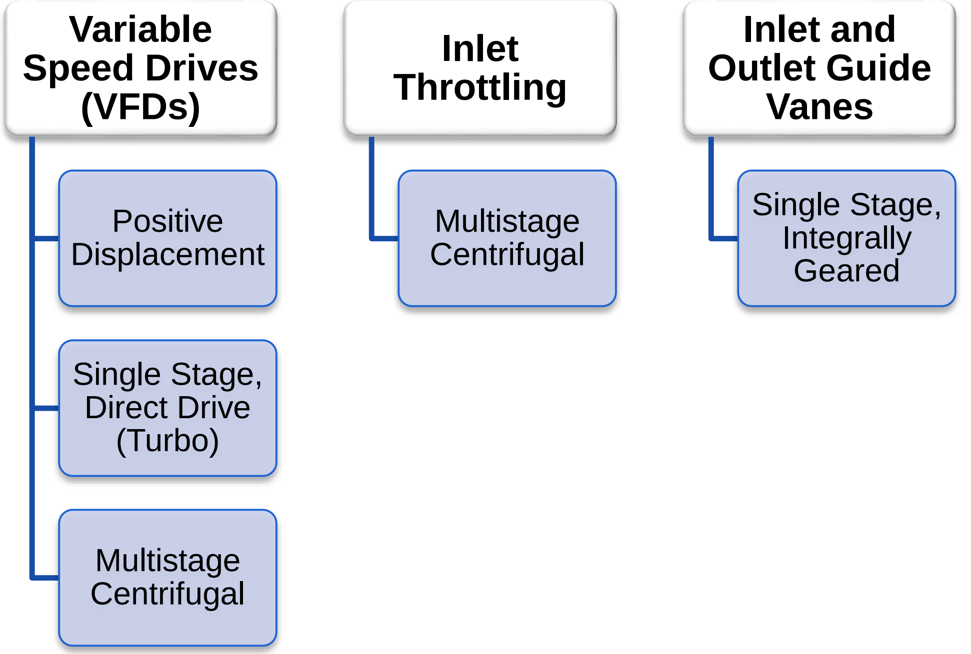
or

Blower Types



Blower Operations

- Constant speed: simple, but wastes energy and excess DO can lead to sludge bulking
- Ways to vary output depending on blower type:



Process Sensors

Dissolved Oxygen

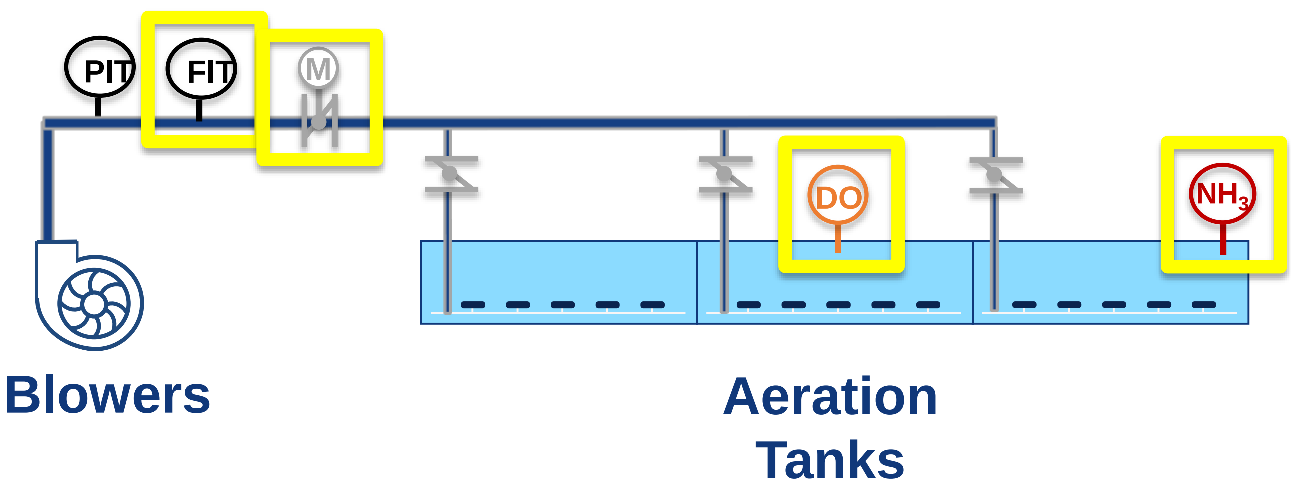
Ammonia

Oxygen Uptake Rate

Water Environm

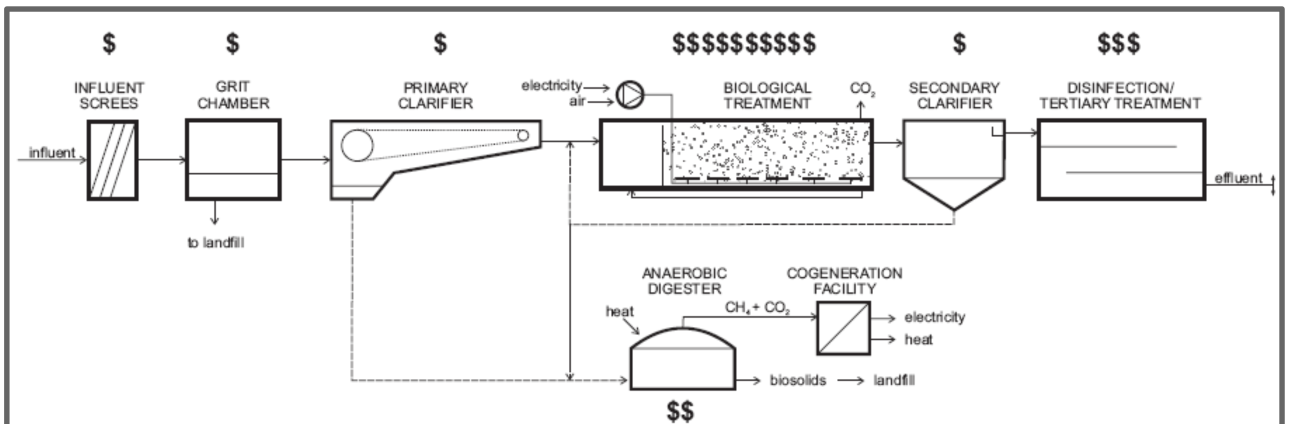
Advanced Aeration Control

Use of <u>process sensors</u>, <u>automated control valves</u>, and <u>flow meters</u> to match process oxygen demands to air supply



Why Advanced Aeration Control?

- When permit limits dictate accurate control for optimal BNR operation
- When energy and other cost savings of advanced control can justify cost of control equipment



Source: Stenstrom and Rosso (2010) www.seas.ucla.edu/stenstro/Aeration.pdf

Modulating Control Valves

- Can be installed in multiple locations:
  - On header to each treatment train
  - On each diffuser dropleg
- Many types and styles available, including:

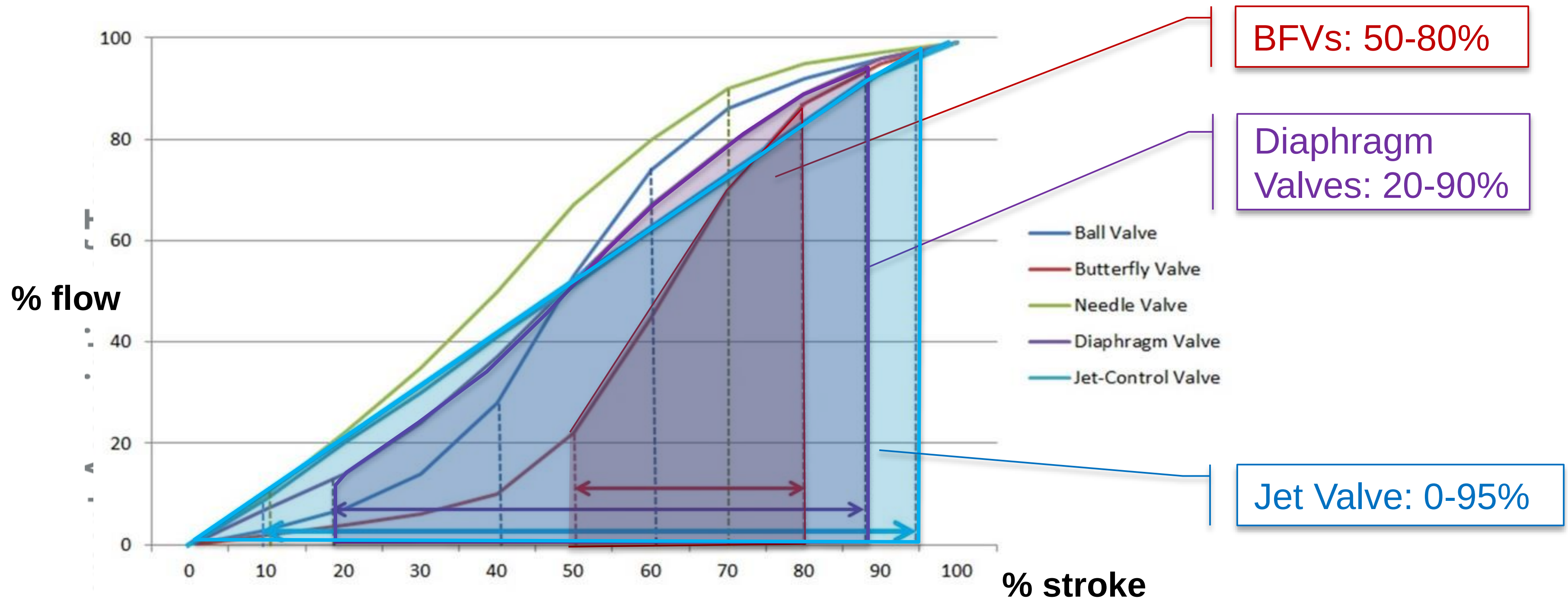

Butterfly Valves


Diaphragm Valves


Jet Valves

- Actuator type also important

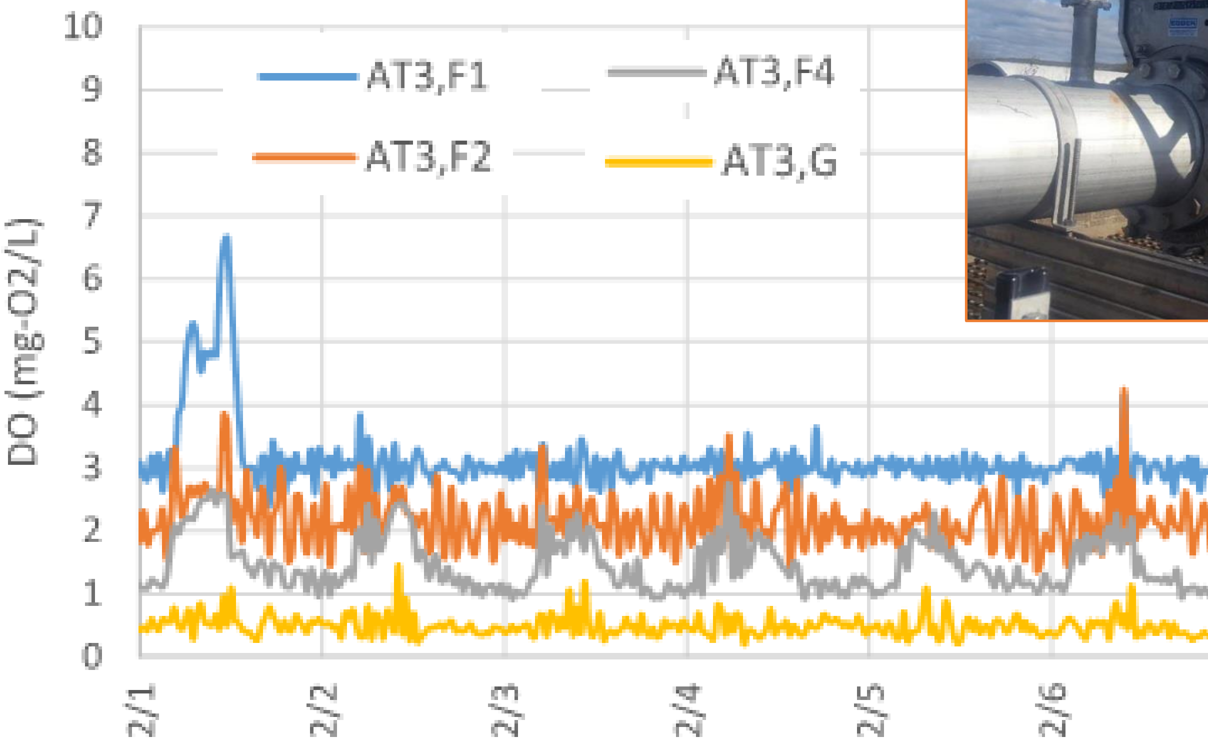
Stable Control Range



Source: The Binder Group

Water

Recently Commissioned Diaphragm Valves at a 36 mgd WRRF



Air Supply Monitoring

Air flow meters:

- Can be provided on blower discharge header or on individual diffuser droplegs

Pressure transmitters:

- Typically installed on blower discharge header
- Rising pressure over time indicates when diffusers need to be cleaned

Ammonia Instrument Types

Type	Ion Selective Electrode Probes	Wet Chemistry Analyzers
Range	Nominally 0 – 1,000 mg/L N Typ calibrated around 1 – 20 mg/L N	Nominally 0.02 – 1,000 mg/L N Typ calibrated around 0.05 – 20 mg/L N
Accuracy	± 5% of mV signal + 0.2 mg/L	± 3% + 0.05 mg/L

Source: Upper Blackstone Clean Water

Source: Hach Company

Ammonia Instruments for ABAC: Lessons Learned

	Ion Selective Electrode Probes	Wet Chemistry Analyzers
Low Ammonia	Often struggle in low ammonia environments (< 1 mg/L NH_4-N)	Better choice for locations with < 1 mg/L NH_4-N
Location	Most common in first half of tank (anaerobic/anoxic or head of aerobic) Mixed success for primary effluent (due to grease)	Most common at end of aerobic zone, secondary effluent, final effluent Mixed success in upstream locations (small tubing turns black)
Accuracy Checks	Require frequent accuracy checks and re-calibration	Accuracy checks recommended to identify when maintenance required on tubing or flow cells
O&M	Replacement cartridge heads can be costly if required multiple times/year	Reagent cost can be reduced by increasing time interval (balanced with process control needs)

Why not just “Keep it Simple ___”?

1. If energy or other cost savings can justify cost of control equipment
2. When permit limits dictate accurate control for optimal performance (important for BNR systems especially)
3. Process performance trending, which provides data useful for trouble-shooting when problems arise

Well-Designed Aeration Controls Will:

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1. Achieve process set point (DO typically) quickly and maintain set point under variable loading conditions

2. Maintain set points with as few equipment starts/stops as possible (blowers, valve actuators)

3. Optimize energy use by minimizing air flow needed for process needs and by reducing pressure loss

Part 2:
Aeration Control System Strategies

Water Environment Association of Texas

Dave Wankmuller, P.E.

Hazen and Sawyer

Outline

- DO – Based Aeration Control
  - DO control with mechanical aeration
  - DO Control with diffused aeration and blowers
    - Tapered diffuser layout
    - Control with:
      - Blower modulation ONLY
      - Airflow based control
      - Pressure based control
    - Most Open Valve automated control types
- Ammonia-Based Aeration Control (ABAC)
  - Why might consider (energy/BNR process control)
  - Types of ABAC

Mechanical Aeration

- Many different types:
  - Vertical/Horizontal
    - Platform mounted – Submerged/Surface
    - Floating Aerators – Aspirating/Non Aspirating

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waterworld

PP Aquatech

Mechanical Aeration Control Techniques

- **Variable water level**
  - Effluent weir or slide gate adjusted to raise or lower surface level
  - As submergence decreases, the OTR (and power draw) decreases*
- **Variable speed**
  - As speed of aerator is reduced, the OTR decreases*
  - Typically Implemented with VFDs
  - Must maintain mixing
- **Variable operating time**
  - Cycle units on and off based on DO setpoints

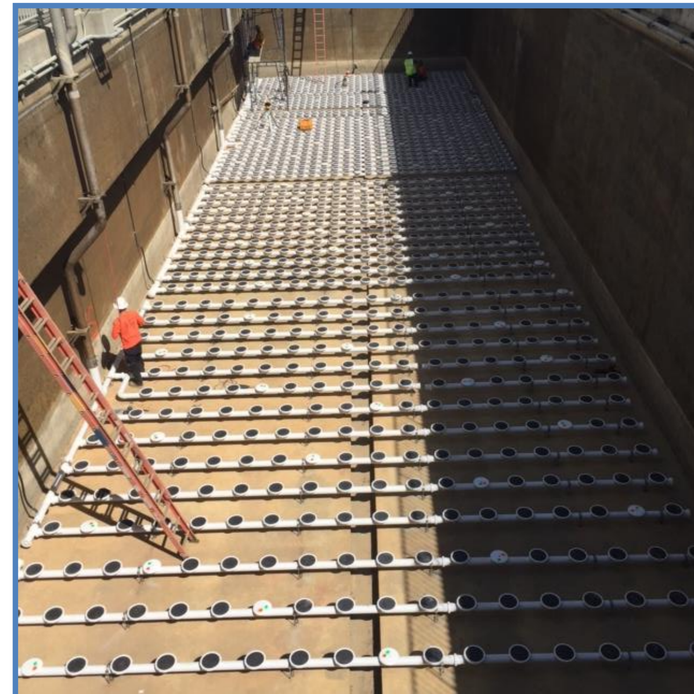
*Note: relationship between varying water level/speed may not be linear to OTR

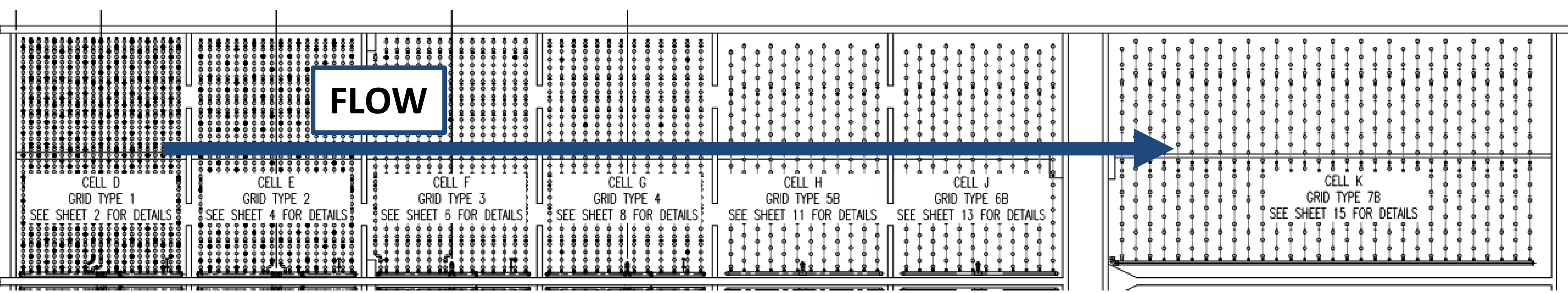
Blowers & Diffused Aeration

- Tapered diffuser layout
- Control with:
  - Blower modulation ONLY
  - Airflow Based Control
  - Pressure Based Control
- Most Open Valve automated control types

Tapered Aeration

- Reducing the number of diffusers per ft^2 SA traveling down tank
- Diffusers are typically tapered based on the anticipated OUR through the basin
- Highest oxygen demand at the head of the basin
  - Need more air and/or higher density of diffusers in that zone





Tapered Aeration

- As you travel down the basin
- Oxygen Demand decreases

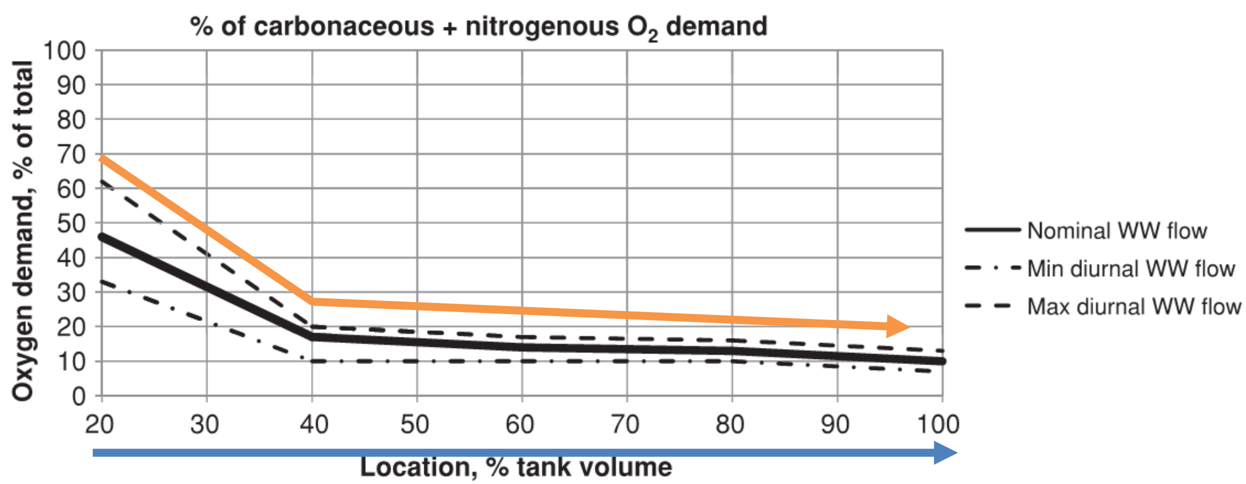


FIGURE 4.17 *Variation of oxygen demand along tank length*

Image: Jenkins

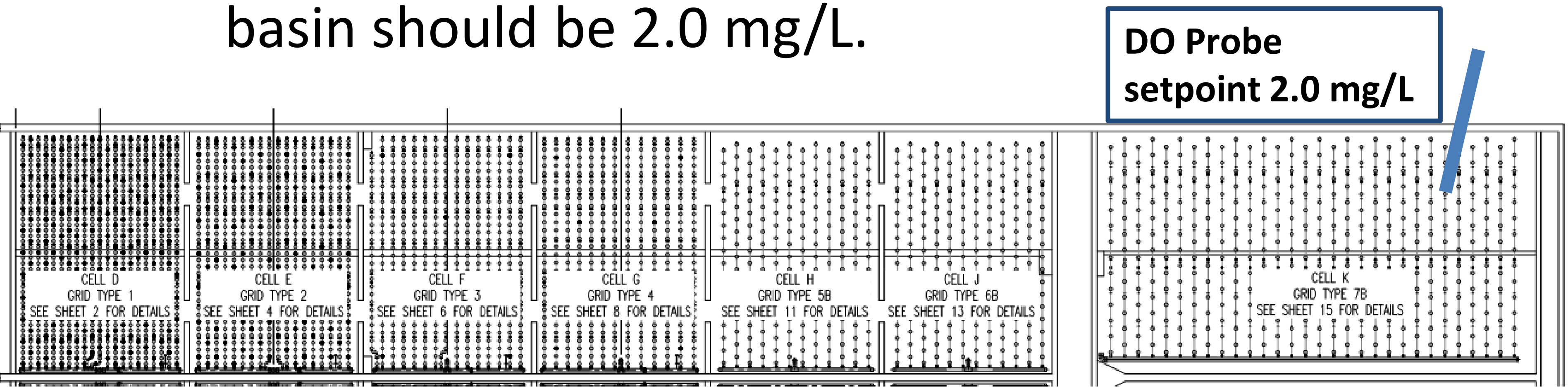
- Up to 50% of the aeration demand can be in the first 20% of the basin

<u>OUR Calculations:</u>

- OUR Can be estimated with modeling software
- Site specific OUR can be determined with offgas testing

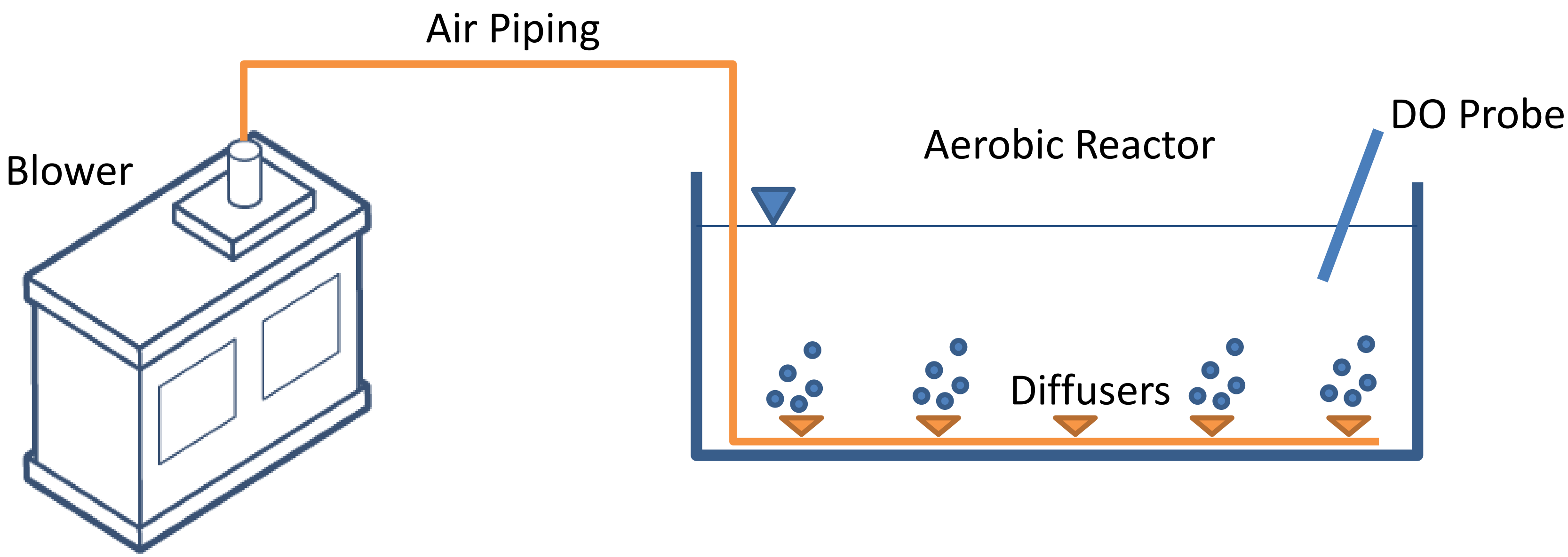
Tapered Aeration

- Tapering diffusers is necessary to achieve even DO distribution throughout the tank
- Theoretically if DO probe is located at the end of the tank
  - Under design load conditions do in the entire basin should be 2.0 mg/L.



Blower Modulation Only

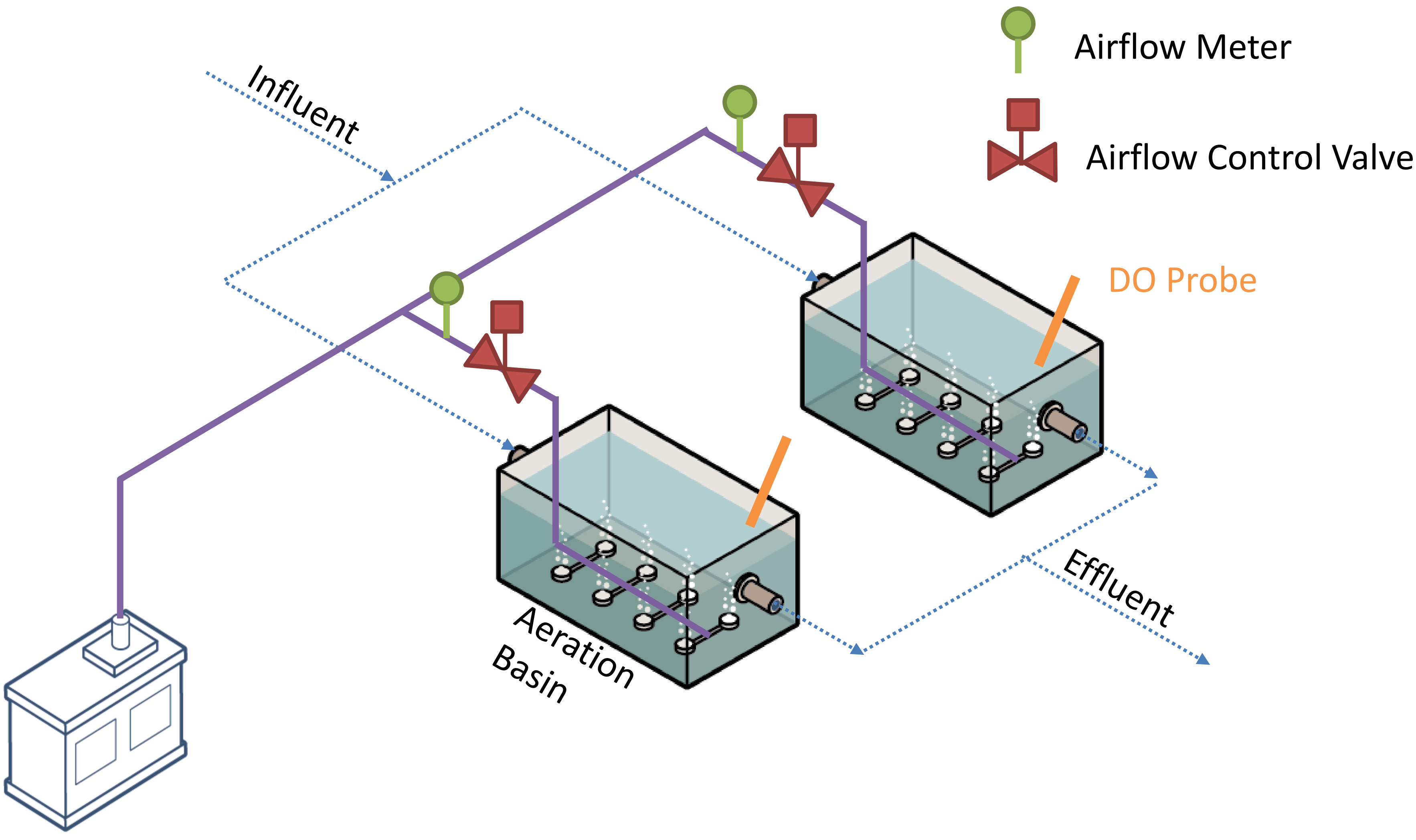
- Modulate airflow from the blower using:
  - VFD
    - PD, Turbo, Multi-stage
  - Inlet Throttling
    - Multistage
  - Guide Vanes
    - Single-stage IG
- Increase Airflow to Increase DO, and vice versa
  - Or if blower is at full capacity, increase # of blowers online



Airflow Based Control

- PID feedback loop
  - Airflow is the process variable
  - Valve position is the manipulated variable
- Program looks at three variables
  - DO error – how far is the program from the DO setpoint
  - Airflow Setpoint (Calculated Value)
  - Actual Airflow (Read at the airflow meter)

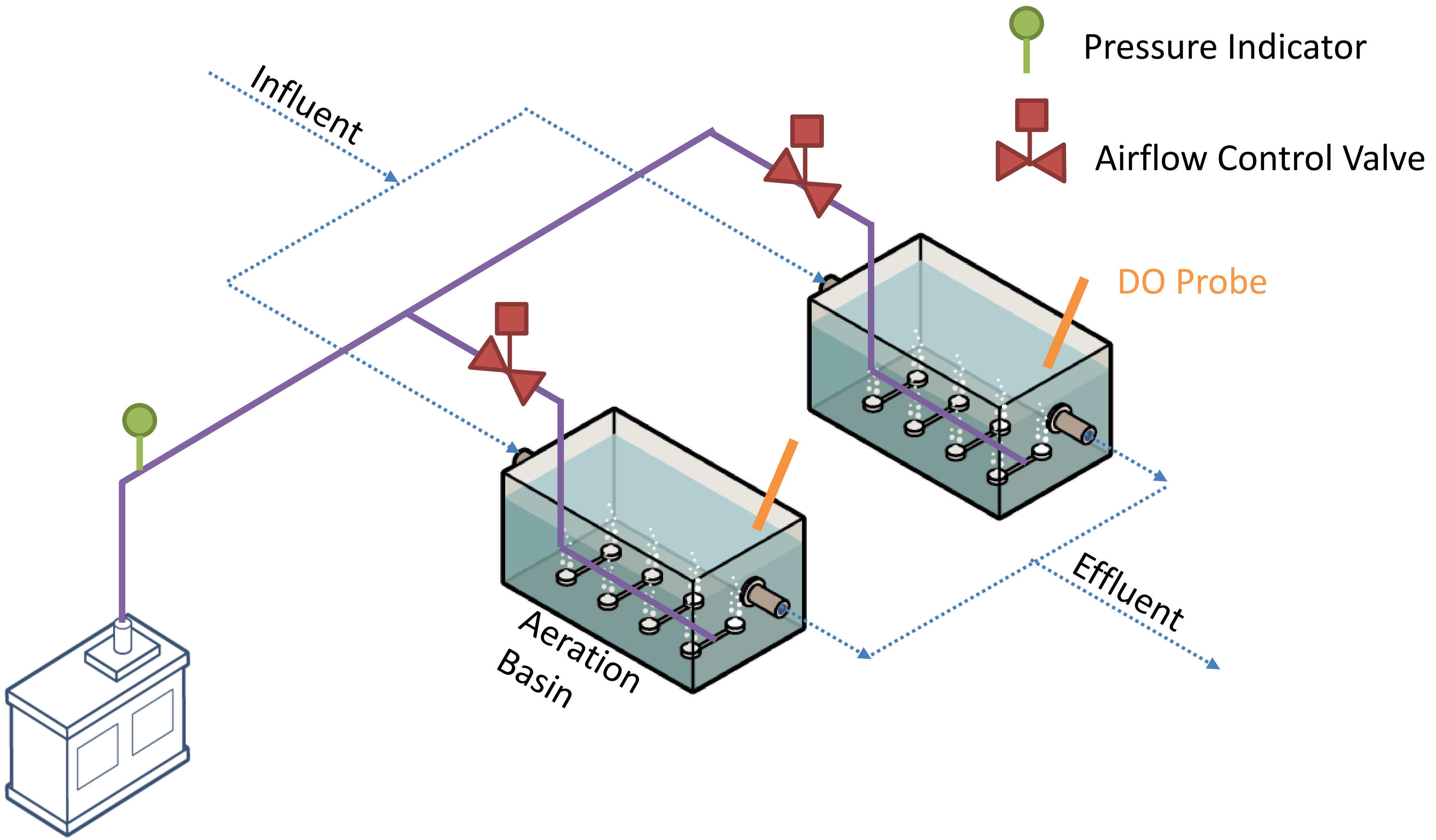
Simplified Airflow Control Aeration Diagram



Pressure Based Control

- Maintain a specific header pressure
  - Cascade Loop
    - Loop 1 – DO controlled based on modulating control valves
    - Loop 2 – Maintains pressure in main header by increasing/decreasing blower speed/inlet valve position
- Implemented since the 1960s
  - Most controllers were single loop PIDs
- If tuned incorrectly, valves and blower speed can oscillate around setpoint (hunting)

Simplified Pressure Based Aeration Diagram

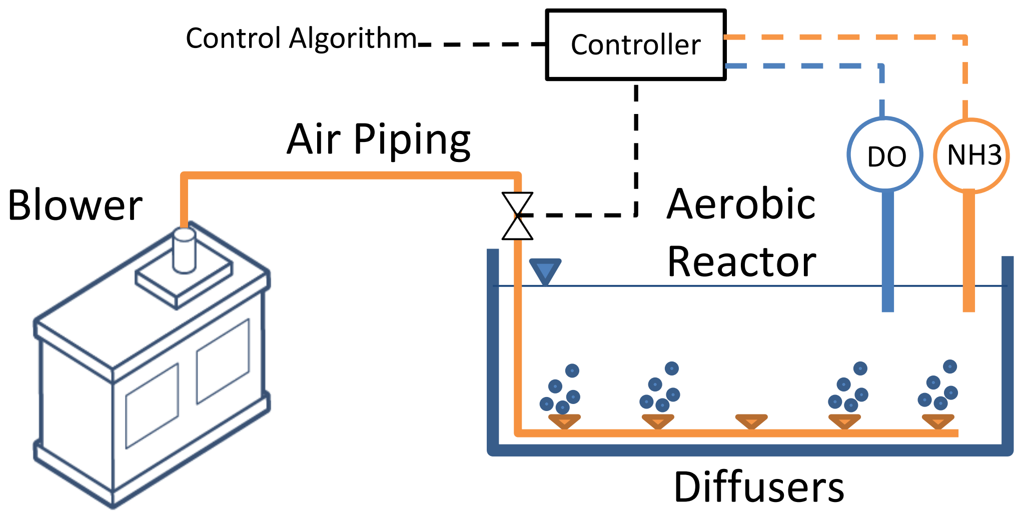


Most Open Valve Control

- Modification to previous control loops to reduce discharge pressure (and therefore energy)
- One of the aeration control valves shall be at the "maximum" position at all times – This is the "most open valve"
- Flow Based Control
  - Once a valve achieves "most open valve" position – it is locked in that position
    - Other valves modulate based on DO requirements
    - Eventually a second valve will achieve "most open valve" position and the first valve will be allowed to close
- Pressure Based Control
  - Program re-adjusts the pressure setpoint based on valve position
  - If one valve is at maximum, but not achieving DO setpoint, increase pressure setpoint (0.05 – 0.1 psig)

Ammonia Based Aeration Control (ABAC)

- Concept – use an ammonia setpoint in the aerobic zone to determine the optimal DO setpoint, typically for nitrification



Simplified Control Algorithm:

- Operator selects effluent ammonia set-point
- When effluent ammonia is greater than set-point, controller increases DO
- When effluent ammonia is below set-point, controller decreases DO

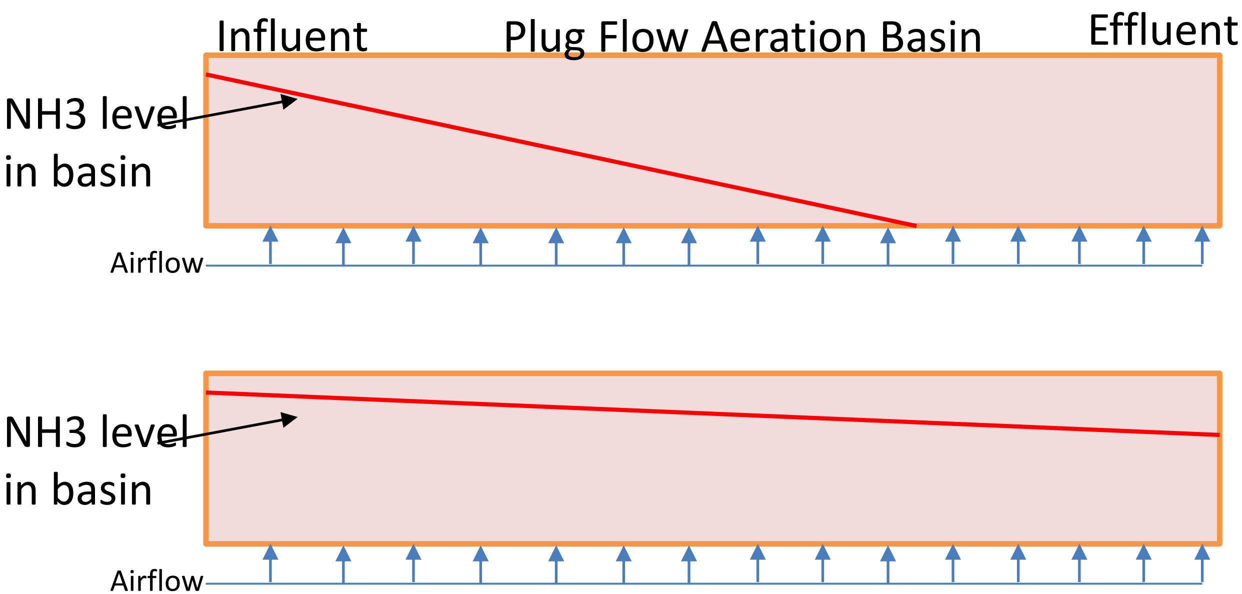
Types of ABAC

- Directly control airflow based on ammonia concentration
- Cascade control
  - Control DO conc. based on desired ammonia conc. → airflow adjusts to maintain DO concentration
- Feedforward
  - Ammonia probe at the head of the aerobic zone, program calculates airflow necessary for nitrification
- Feedback
  - Ammonia probe at the end of the aerobic zone, program decreases DO if below setpoint and increases DO if above setpoint
- Feedforward and feedback
  - Ammonia probe at beginning and end of zone, calculates air necessary for nitrification, corrects based on the ammonia probe reading at the end of the zone.

Why ABAC?

- Ensure nitrification by the end of the aerobic tank
  - Help meet NH3 permit limit
  - Sometimes a basin needs a DO above a typical setpoint of 2.0 mg/L to achieve full nitrification
- Optimize nitrogen removal efficiency
  - Supplying the amount of air necessary for nitrification (no more, no less)
  - For facilities that denitrify and have a second anoxic zone - reduces carbon usage due to less DO entering anoxic zones
- Minimizes airflow and energy use
  - Only supplying the air you need = less energy usage
- Maximize simultaneous nitrification and denitrification (SND) at low DO concentrations
  - For low TN facilities – SND encourages nitrification and denitrification to occur in the same zone

The Objective of ABAC is to Use the Entire Aerobic Volume to Remove NH3

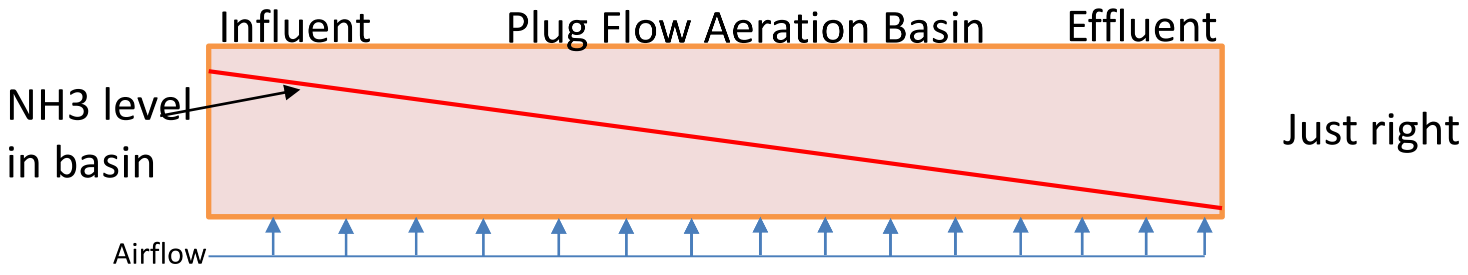


Too much air
- Energy consumption
- Carbon oxidation

Not enough air
- High effluent ammonia

ABAC

- Operator selects effluent ammonia set-point
- When effluent ammonia is greater than set-point, controller increases DO
- When effluent ammonia is below set-point, controller decreases DO



Part 3:

Case Study #1: DO-based Aeration Control at SAWS Leon Creek WRC

Water Environment Association of Texas

John Manning, P.E.

Freese & Nichols, Inc.

Case Study

- SAWS Leon Creek Plant
  - Take an alternative interactive approach for the design of an automated Dissolved Oxygen control system at the aeration basins
    - SAWS operators
    - Maintenance staff

Topics

- Design Coordination
- Construction Coordination
- Training
- Testing

SAWS Leon Creek WRC

- Conventional activated sludge plant
  - Peak capacity of 92MGD
  - Average daily flow rating of 46MGD

Leon Creek WRC Site Plan and Scope of Work

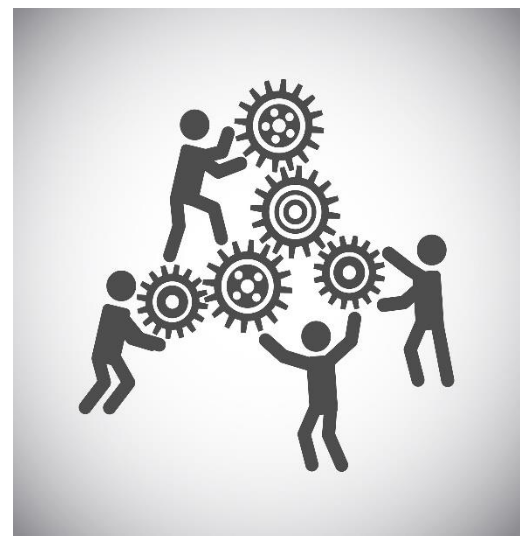
15 AERATION BASINS

SAWS Leon Creek WRC
Project Goal

- Ease operations with the automation of 15 aeration basins
  - Modify manual air flow control valves to motorized modulating flow control
  - Add air flow meters to each basin
  - Add D.O. analyzers to each basin

Modified Design Steps

- SAWS requested workshops in the Engineering scope
  - Workshops Included
    - Aeration basin maintenance and controls considerations with plant staff early in design
    - Controls review
      - Design
      - Construction
    - Milestone reviews
      - Design
    - Training
      - Construction



SAWS Operations Requests

- Simplified system
  - Automatic mode
  - Manual mode
  - Service mode
- Simplified graphics
  - Show status of each mode on same screen
- Make process troubleshooting manageable and flexible

Construction Interaction

- Review HMI screen development
  - DCS
  - Aeration Basin Control Manufacturer
- Testing
  - 100 hour run test
  - 30 day acceptance tests
- Training
  - Manufacturer provided with support from Engineers
  - Operator put their hands on the systems while the instructor and engineering is there

Results

- Keeping operations involved from design through construction can positively affect end results
- Transitioning to the automated system was easier since hands on training was available
- An operator thanked SAWS Project Manager for providing a simple system
- Maintaining engineer staff involvement throughout the projects life was beneficial to operations
- Metric ---- Two Thumbs up!!

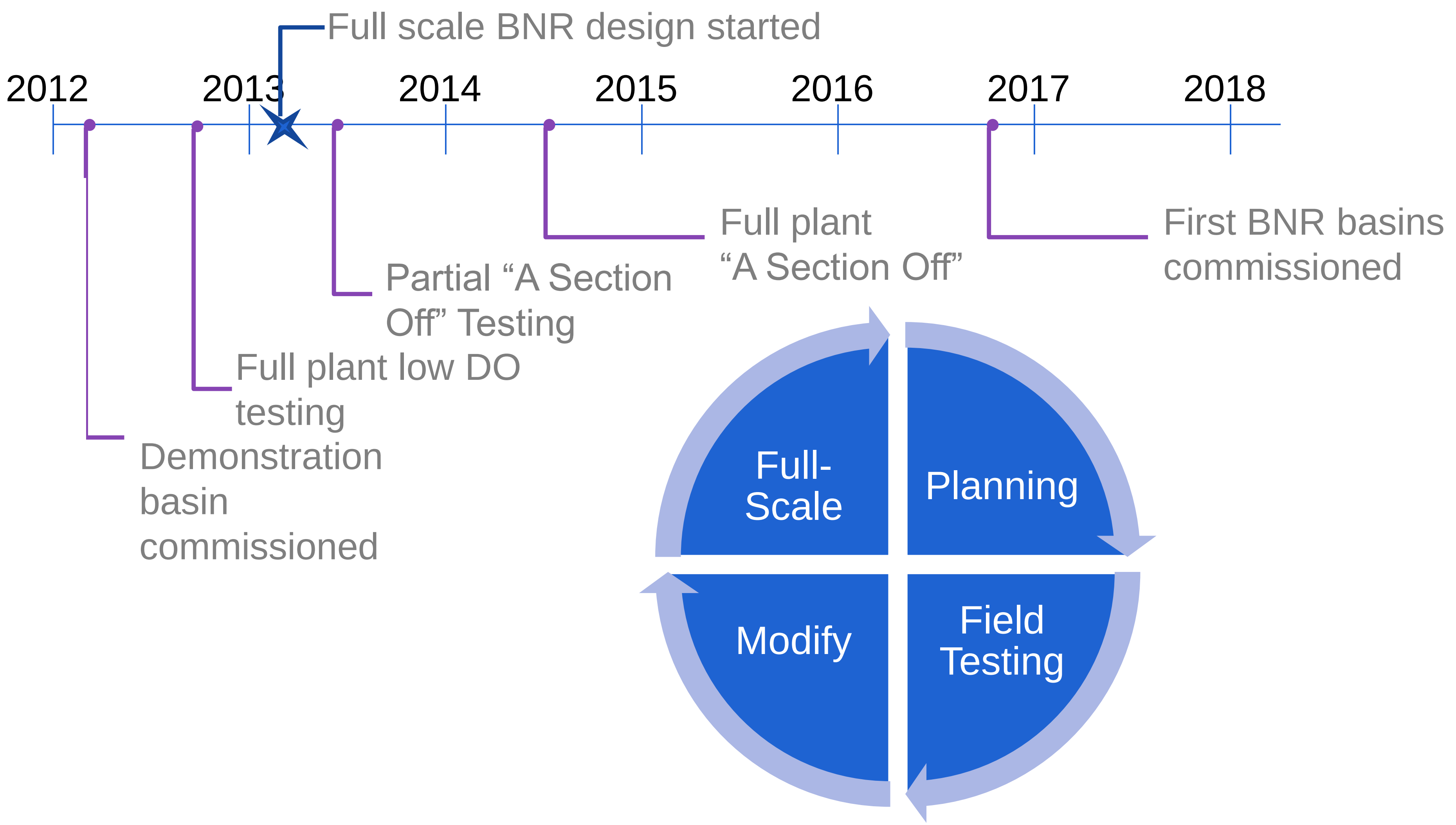
Part 4:

Case Study #2: Ammonia-based Aeration Control

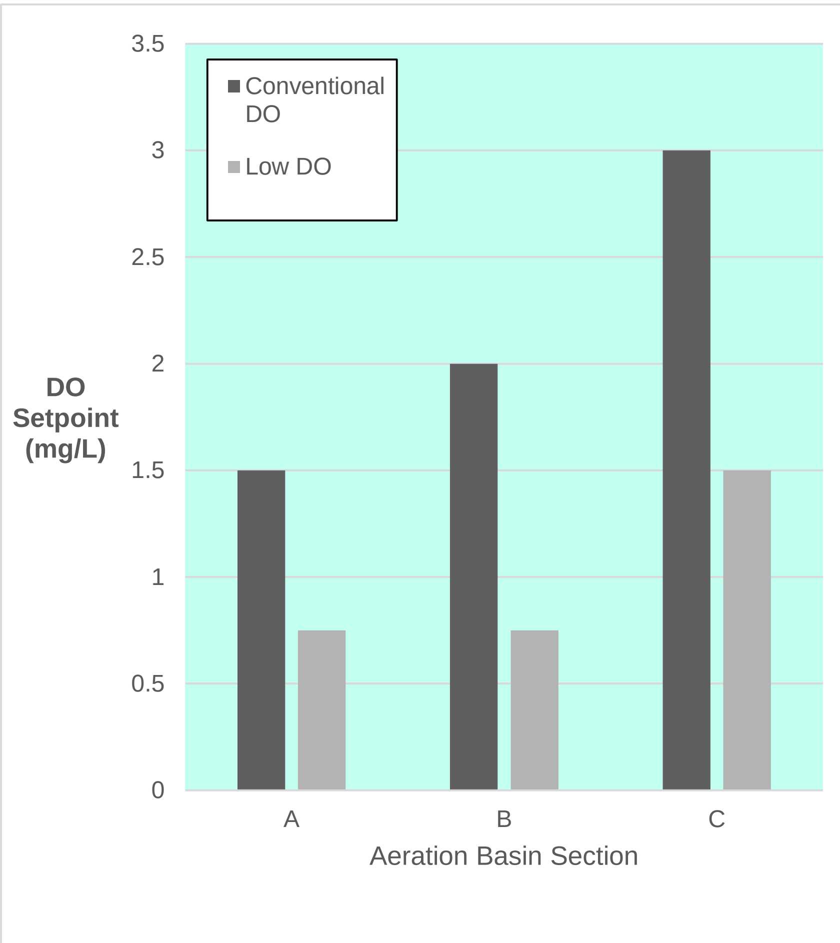
Eric Redmond, P.E.

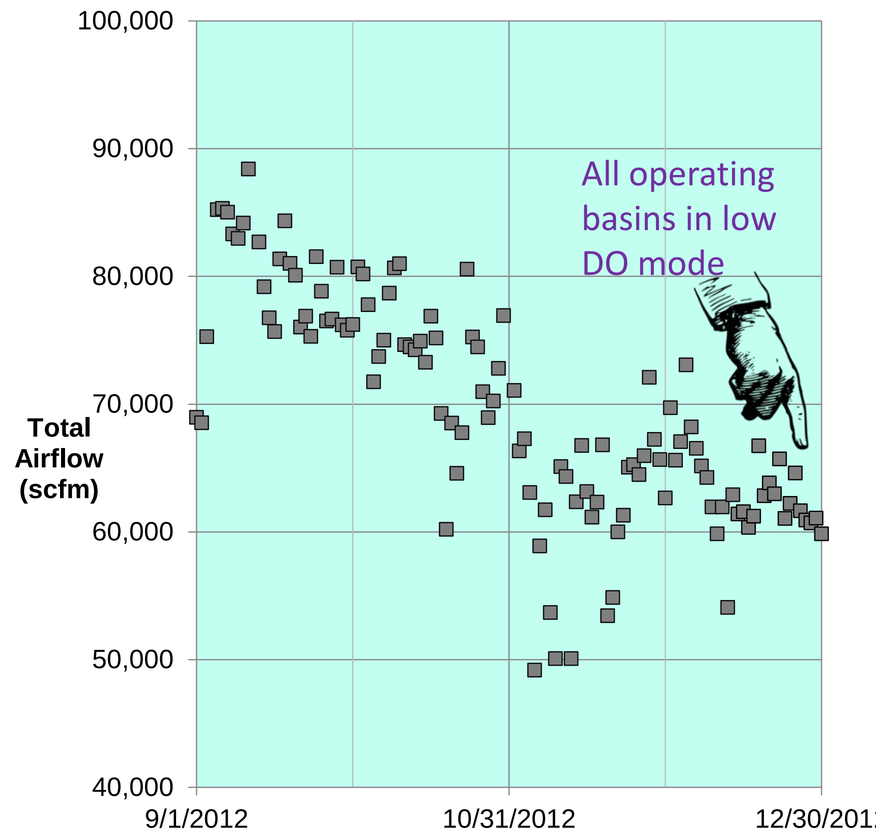
Black & Veatch

Timeline to aeration implementation



Full Scale Testing





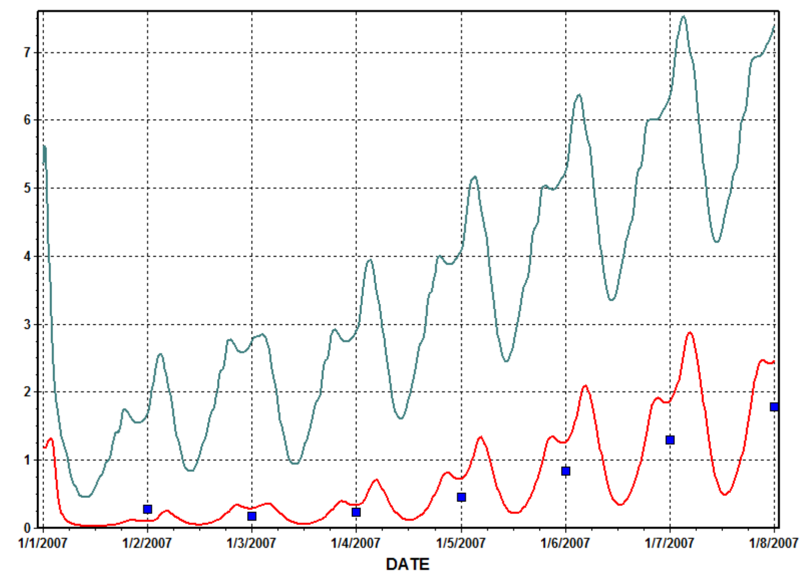
Are there major risks that need to be mitigated during design?

- **Largest risk: sensitivity to ammonium loads**
  - **Low DO setpoint decrease *rate***
  - **Still same mass of bacteria, just slowed down**
  - **Increase DO, increase rate to a *certain point***

Systematic increasing of load during winter conditions simulated under design conditions

Simulated Ammonium Concentration

mg N/L



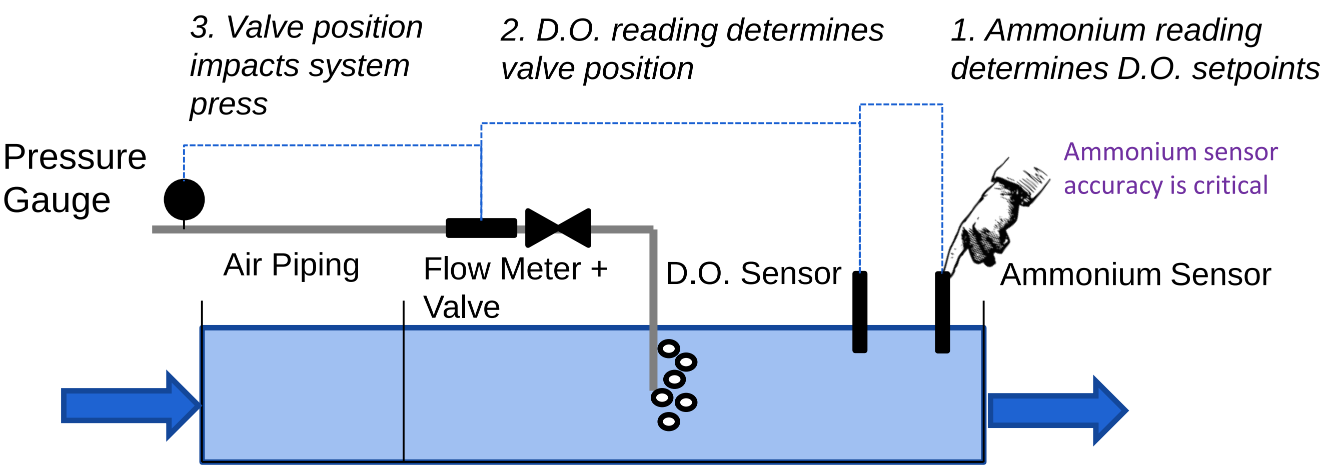
Dots = 24 hr composite

Project Objective

- **Objective:** Implement ammonium based airflow control (ABAC)
- **Goals:**
  a. Reduce aeration energy
  b. Improve process controls and monitoring
  c. Meet effluent NH4 requirements
  d. Implement selector zones

Control Scheme

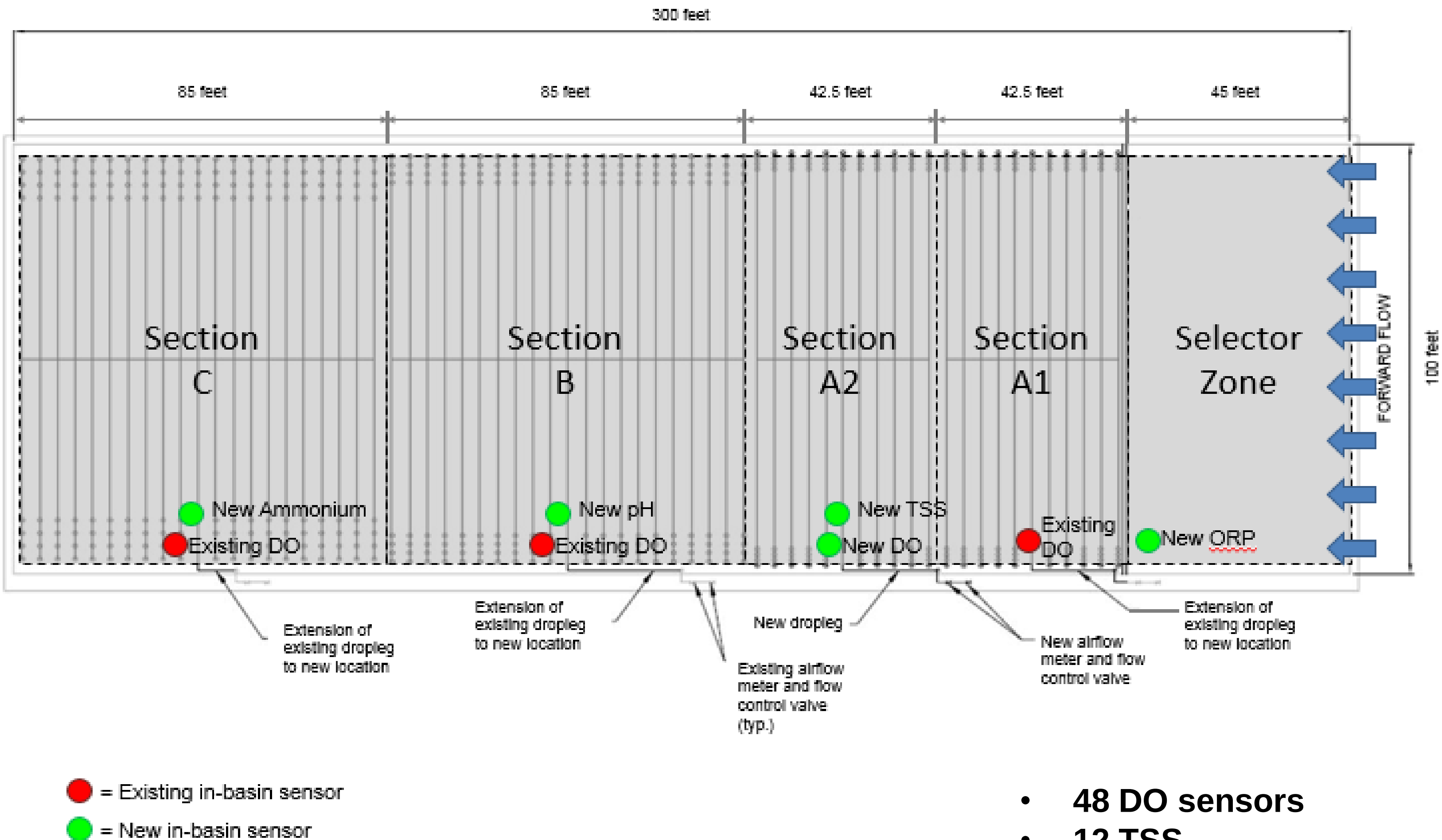
Typical DO Control Scheme
Ammonium Based Aeration Control (ABAC)



Example Setpoints

Zone	Low DO, mg/L	High DO, mg/L
A1	0.3	0.3
A2	0.5	0.5
B	0.9	1.5
C	1.2	1.7
Target NH_4		1.0

Diffusers, Selector Zone, and ABAC



- **48 DO sensors**
- **12 TSS**
- **12 pH**
- **12 Ammonium**
- **12 ORP**

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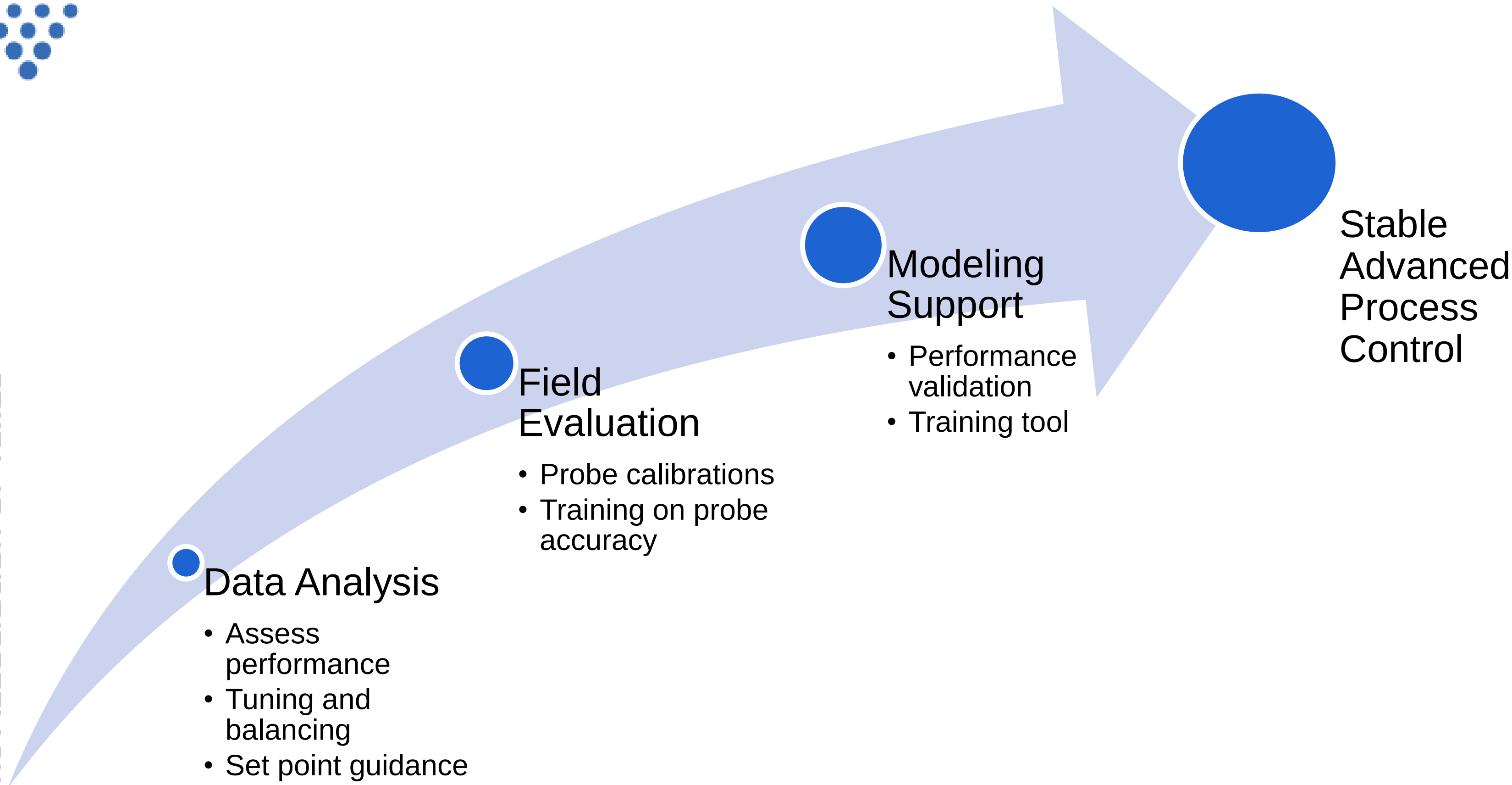
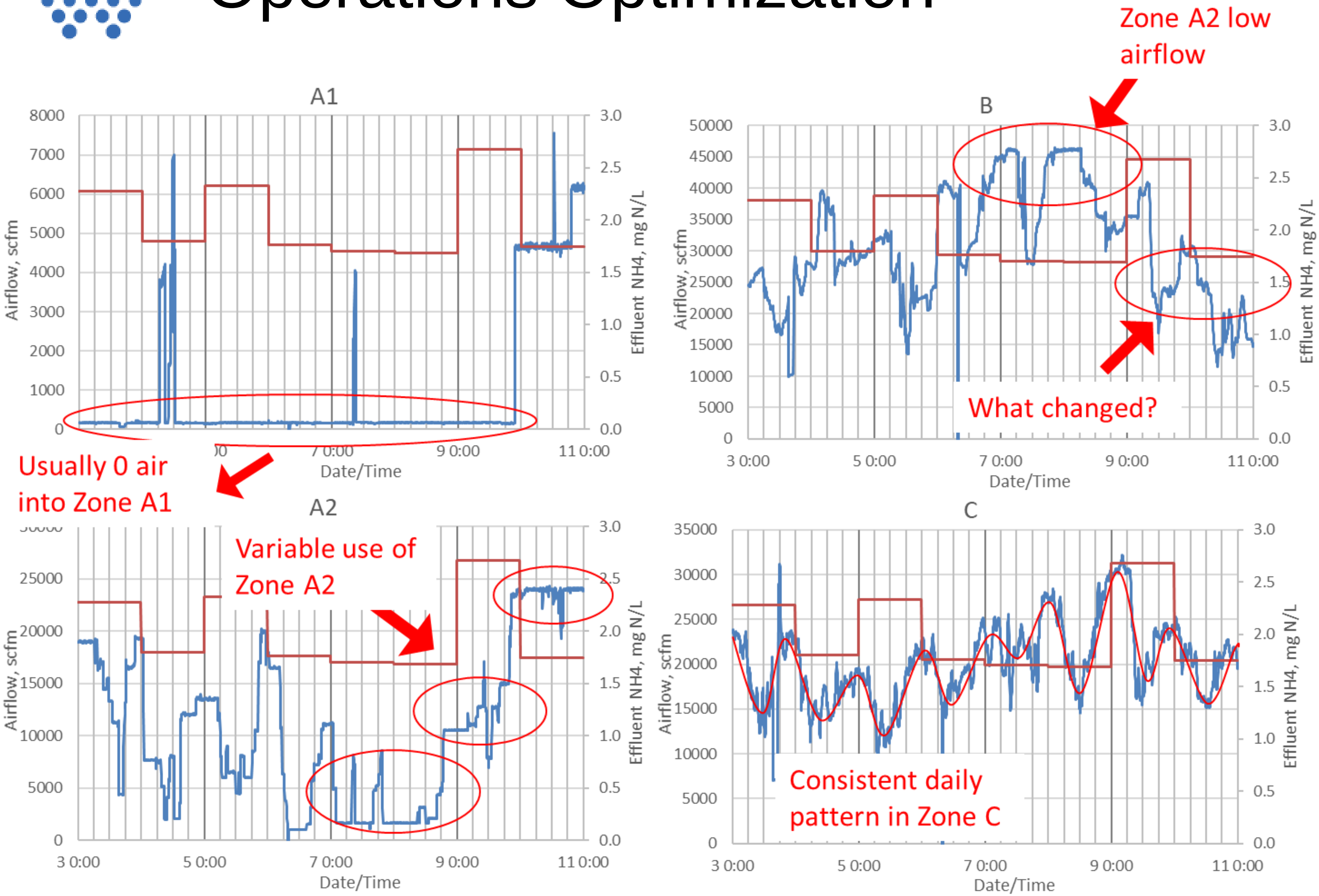
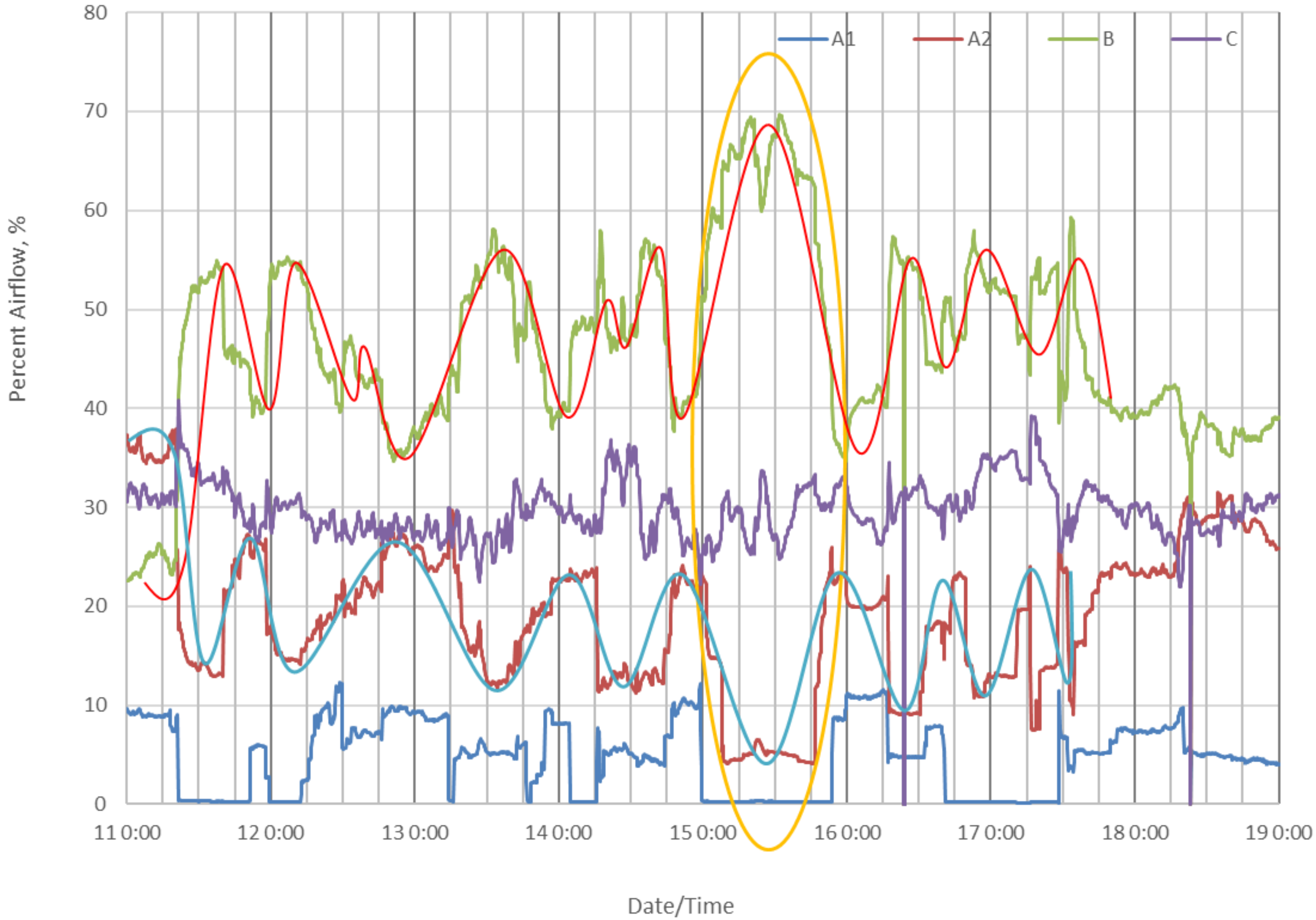


STARTUP AND OPTIMIZATION

Operations Optimization

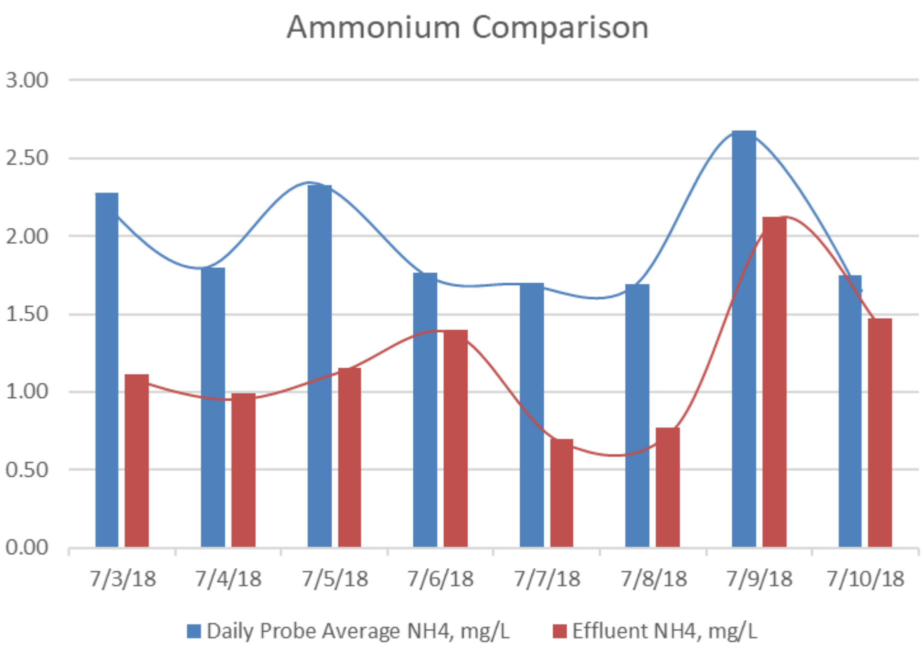


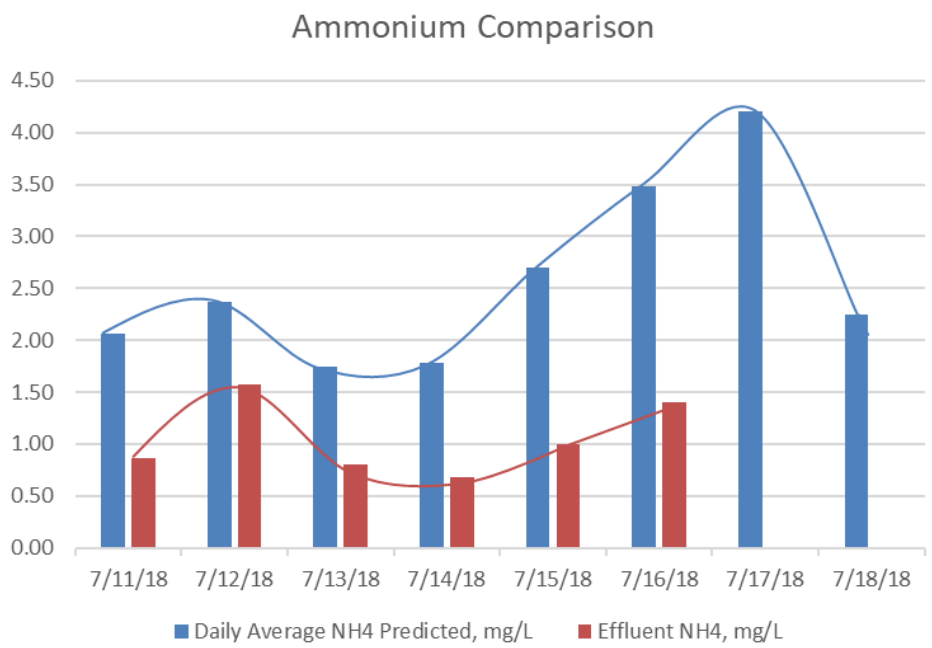
Consistent operation between zones



- Zones A1 and A2 greatly impact downstream Zone B
- All zones should be similar to Zone C with no trend

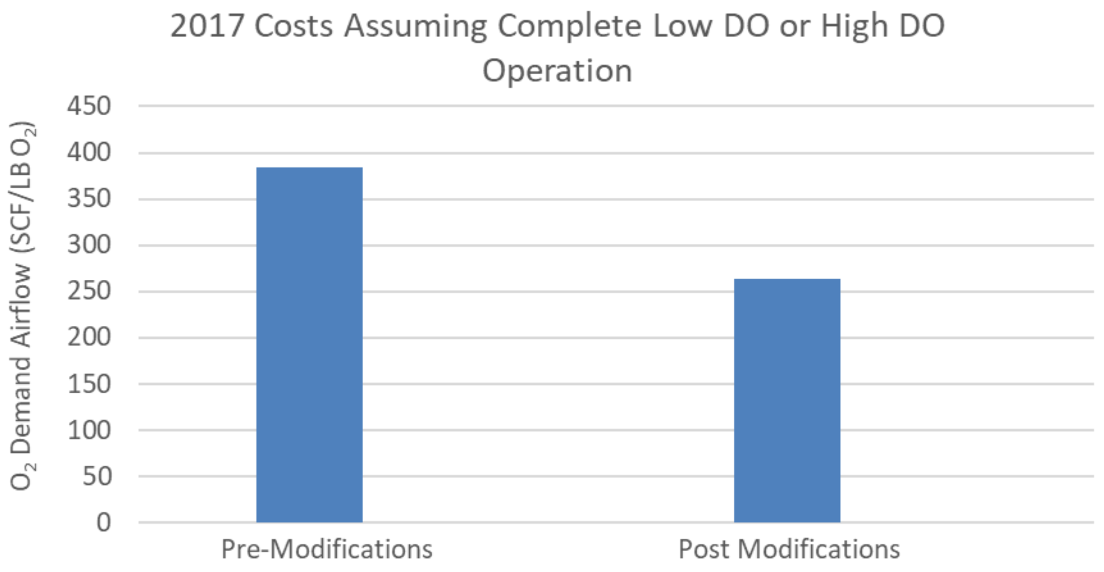
How well are the NH4 probes performing?





- ❖ Probe values closely matching trend of effluent data
- ❖ Effluent lab data typically 1-2 mg N/L lower

Is it worth it?



Predicted annual costs		
Infrastructure	Annual Cost[1] ($/year)	% Annual Savings
Pre-Construction	$1,275,930	31%
Post-Construction	$875,360	
Total Difference	**$400,570**	

[1] Costs were developed assuming 28 scfm/HP and an electricity rate of $0.055 /kWh.

Lessons Learned

- Operations and maintenance training
- Demonstration testing
- Open communication
- Data review and analysis

CEU Questions

*Go to **weat.org/events** to view the webinar, presentation slides, multi-site user sign in sheets, and webinar questions for CEU credit.*

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1. Oxygen demand is the highest at the head of the aeration basin
   - ***a) True***
   - ***b) False***
2. Modulating airflow from a blower can be done using:
   - **a) Variable Frequency Drives (VFDs)**
   - **b) Inlet Throttling**
   - **c) Inlet and Outlet Guide Vanes**
   - **d) All of the Above**
3. Ammonia-based Aeration Control (ABAC) system uses an effluent ammonia set point to determine the optimal Dissolved Oxygen (DO) required for nitrification:
   - ***a) True***
   - ***b) False***

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