How Oversized Mixers Hurt Activated Sludge Performance

Sticking to rules of thumb can be detrimental to your process and bottom line

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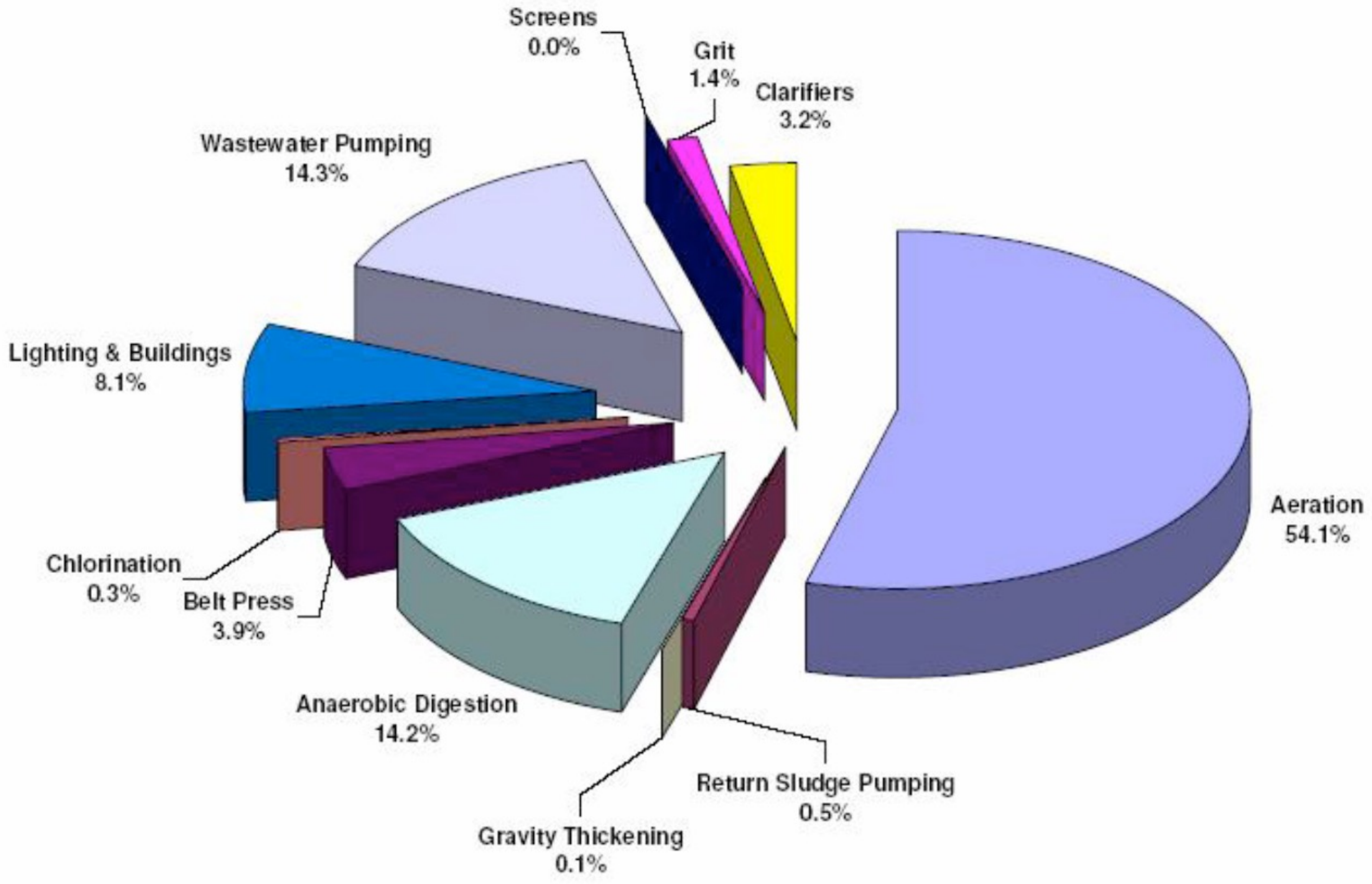
Overview

- The importance of mixing
- Conventional approach
- Consequences of overmixing
- Fundamentals/chemical engineering approach
- Case studies
- Recommendations
- Future research

Importance of Mixing

- Suspended growth systems use suspensions of biomass to:
  - Consume dissolved pollutants
  - Capture particulates
- Mixing is required to:
  - Keep the biomass suspended
  - Allow flocculation of particulates and biomass
  - Ensure available basin volume is used
  - Prevent short-circuiting
  - Blend different streams



Electricity Requirements for Activated Sludge Wastewater

Derived from data from the Water Environment Energy Conservation Task Force *Energy Conservation in Wastewater Treatment*

Recommended mixing criteria commonly cited in literature

Application	Units	Values	Reference
Fine bubble aeration	$scfm/ft^2$	0.12	WEF MOP 8, 2010
Coarse bubble w/ spiral roll	$scfm/1{,}000\ ft^3$	20 – 30	WEF MOP 8, 2010
Channel aeration	scfm/linear ft	2 – 5	WEF MOP 8, 2010
Mixer power level in unaerated zone	hp/mil gal	30 – 40	WEF MOP 8, 2010
Velocity gradient, G - optimum flocculation - minimum tested	s^{-1}	20 – 75 40 15 10	WEF MOP 8, 2010 Parker et al., 1971 Wahlberg et al., 1994 Parker et al., 1971

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Recommended mixing criteria commonly cited in literature

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Fine bubble aeration →	scfm/ft^2	0.12	WEF MOP 8, 2010
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Recommended mixing criteria - Same Units

Application	Assumptions	$scfm/ft^2$	hp/mil gal
Fine bubble aeration		0.12	30
Coarse bubble w/ spiral roll	20 scfm/kcf - SWD = 13 ft - SWD = 20 ft	0.26 0.40	66 100
Channel aeration	2 scfm/ft - Width = 5 ft - Width = 15 ft	0.40 0.13	100 33
Mixer power level in unaerated zone		0.12 0.16	30 40
Velocity gradient, G - optimum flocculation - minimum tested	20/s 40/s 15/s 10/s	0.008 0.032 0.0045 0.002	2 8 1.2 0.5

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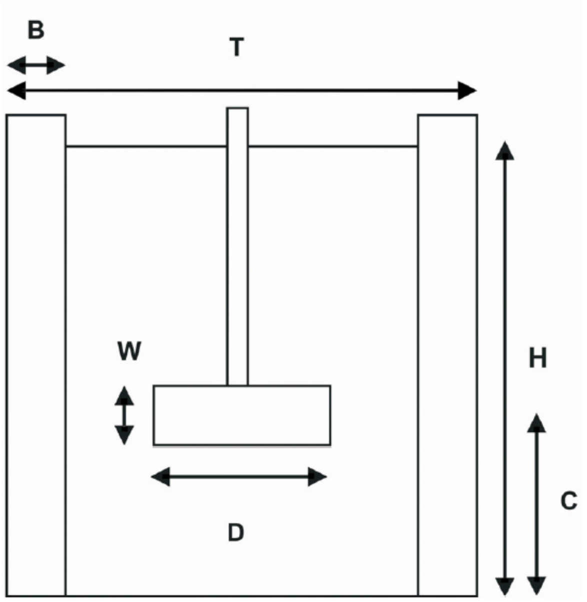
Disadvantages of Over-Mixing

1. Capital spend / O&M Costs / GHG emissions
2. Entrainment of air in anoxic or anaerobic zones and/or excessive DO in aerobic zones => reduced BNR performance
   a. May affect effluent quality
   b. May affect operating cost if dosing a substrate
3. Mixed liquor floc structure damage, lower sludge settleability
   a. May in turn affect system capacity

Optimizing Mixing Energy

- Two questions must be answered
- Criterion: When is a tank mixed enough?
- Design: How can performance from one system be transferred to another?
- Chemical Engineering Industry has also considered these questions

Transferring Performance between Systems



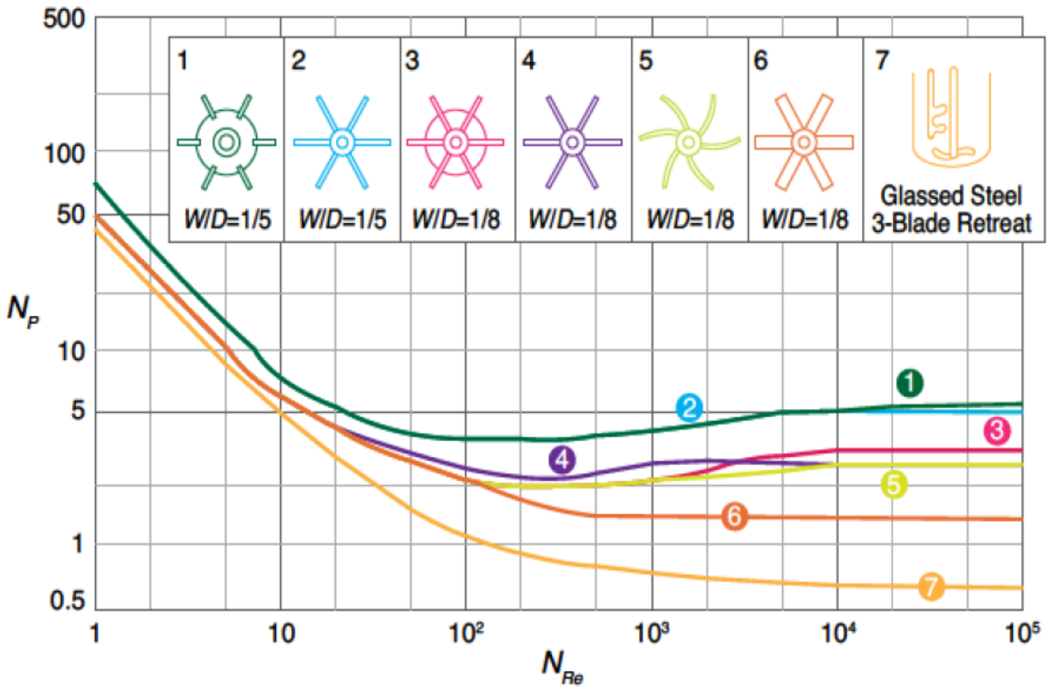
Reynolds: $Re = ND^2/\upsilon$

Flow Number: $N_Q = Q/(ND^3)$

Thrust Number: $Th = F/(\rho N^2 D^4)$

Power Number: $N_P = P/(\rho N^3 D^5)$

N = Rotational speed, Hz
D = Impeller diameter, m
υ = Kinematic viscosity, m^2/s
Q = Flow produced by impeller, m^3/s
ρ = Liquid density, kg/m^3
P = Power required to rotate impeller, W



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When is a Tank Mixed *Enough*?

1. Chemical Engineering – “Just Suspended”:
   No particles on floor for more than 1 second
2. No “clear” water layer on top of water surface
3. Maximum variation of MLSS concentration in depth profile
4. Ratio of standard deviation to mean solids concentration
   Coefficient of variation (CoV) = STDEV/AVE
   - CoV < 25 % (chemical industry)
   - CoV < 10 % (wastewater industry)
5. Point where additional mixing does not significantly affect overall process performance – determined by field testing or by using combined CFD-process models

Other Approaches

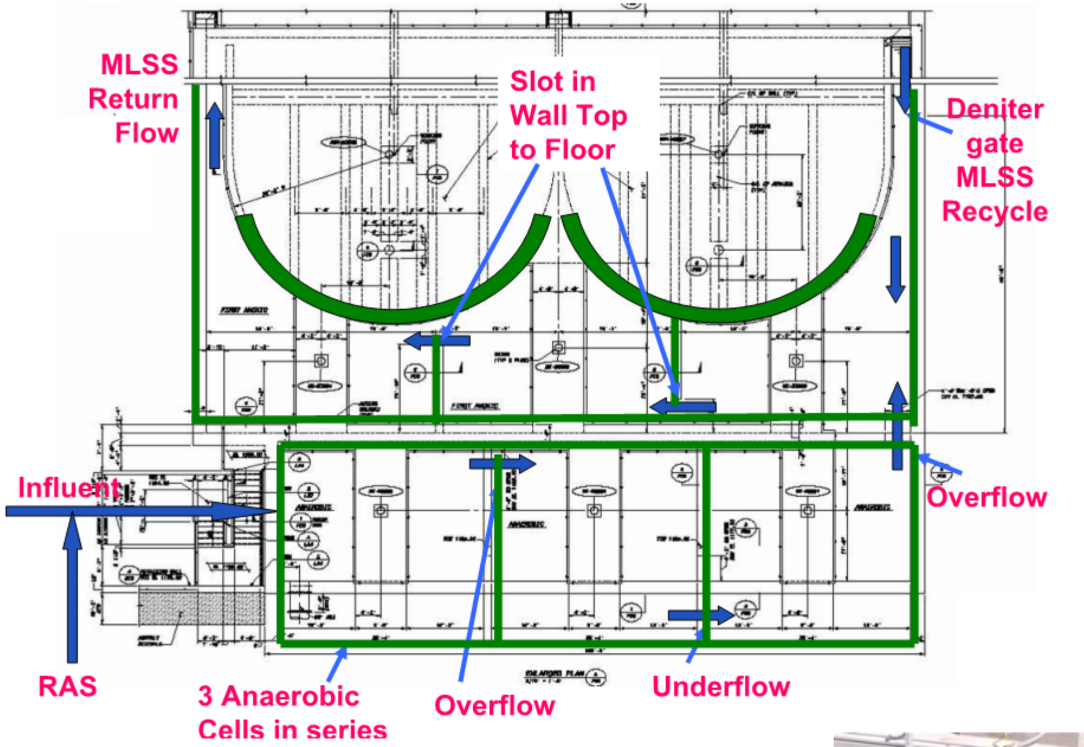
- Mixer Thrust
  - $F_{req} = ½\rho u^2 A_b k$
  - k = Σ(loss factors from friction, bends, aerators, other obstacles)
  - u = assumed minimum flow velocity to keep solids in suspension (0.3 m/s or 1 ft/s)
  - ISO Standard, 21630:2007 for measuring the thrust
  - Most efficient mixer can provide the required thrust at lowest power
- Mixer Flow
  - Techniques exist to measure mixer flow
  - Minimum velocity can be used to calculate required flow
  - Most efficient mixer can generate the most flow at a given power use

Case Studies

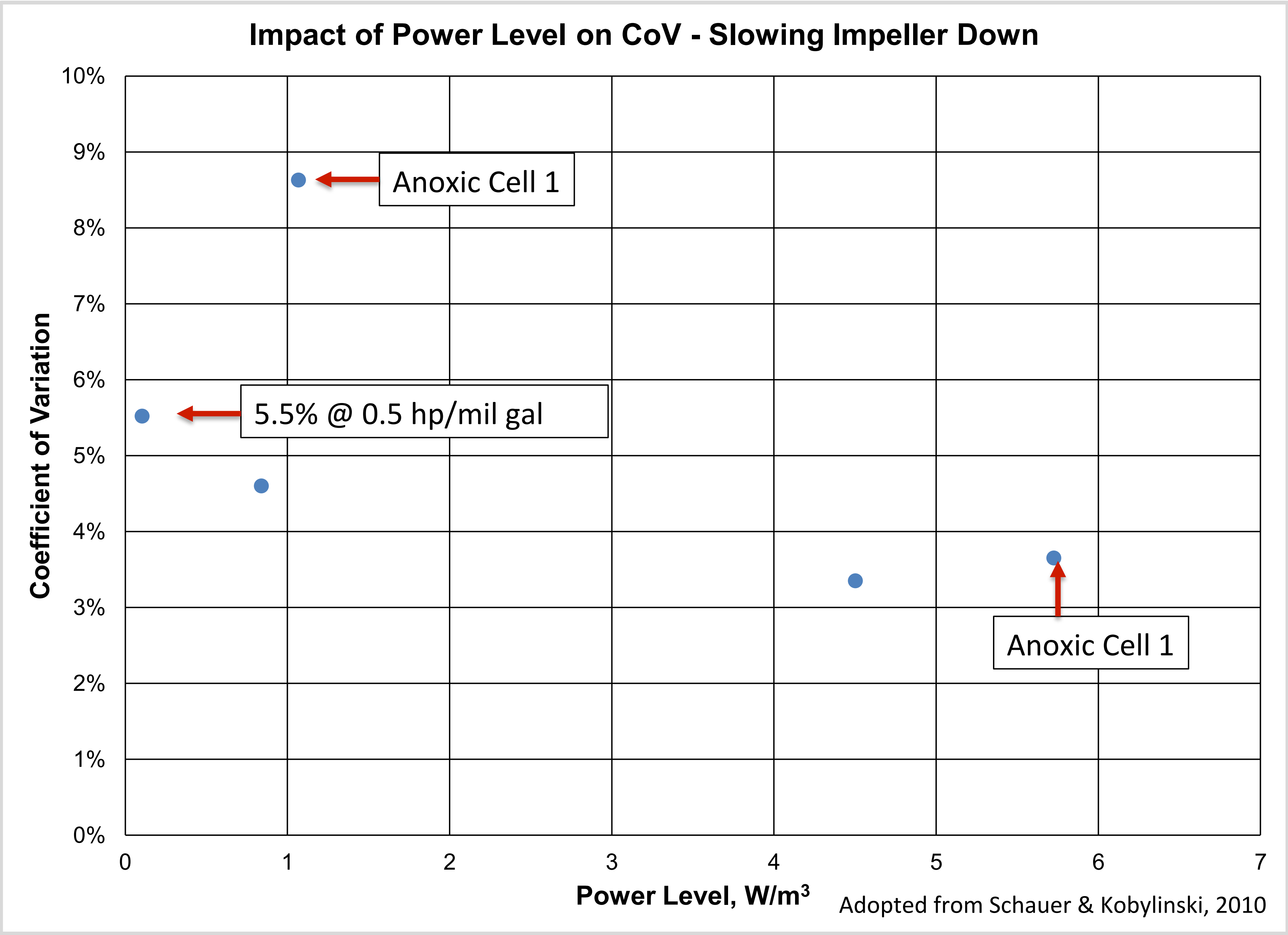
- Five different cases where mixer power levels were optimized in some way
- Consider impact of different power levels on degree of mixing
- Other findings

Case Study #1: Reducing Impeller Speed

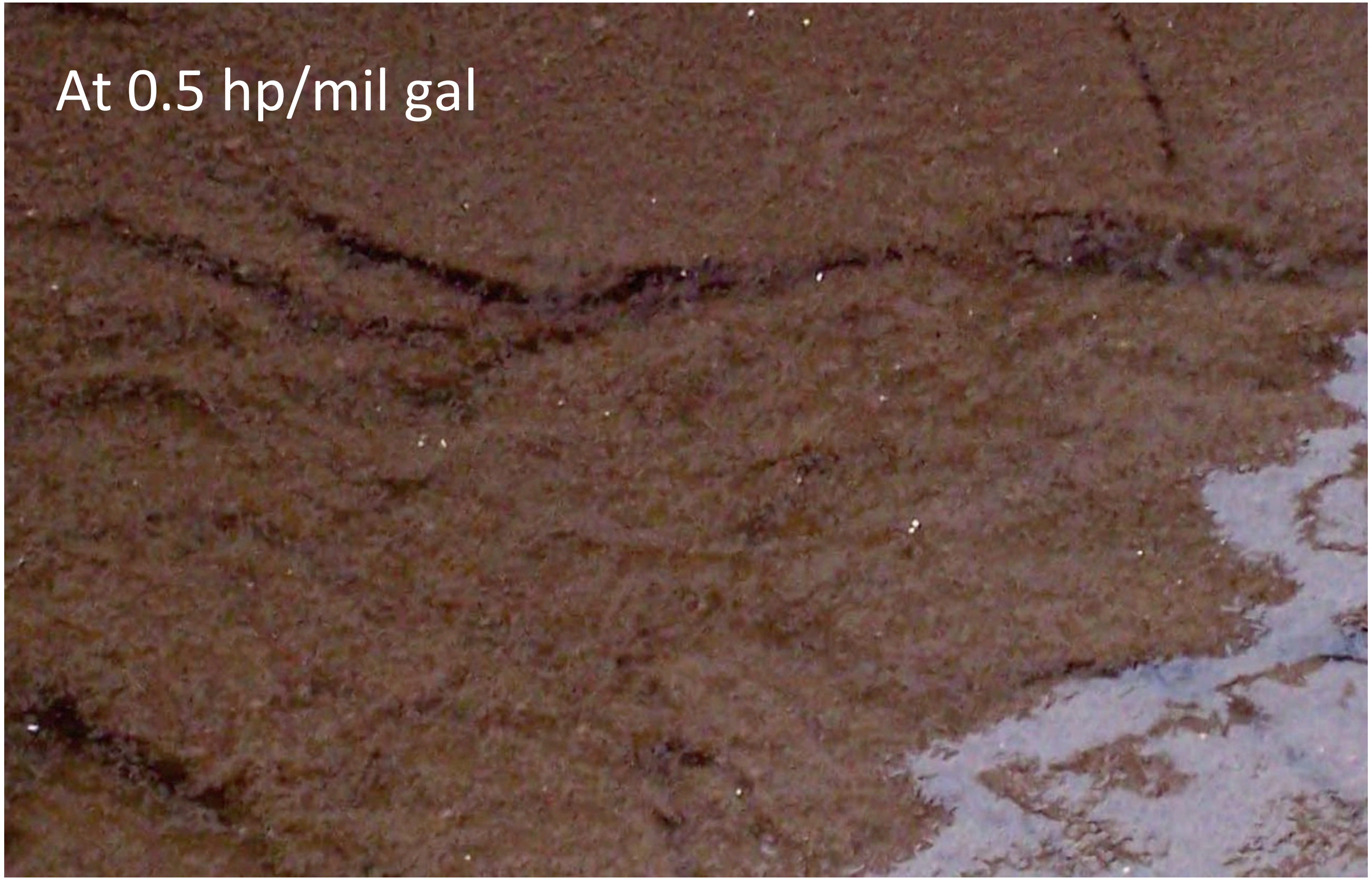
- 5-stage Bardenpho process
- Axial flow down-pumping impellers
- 5 HP
- Design 38 rpm



Schauer & Kobylinski, 2010


Impact of Power Level on CoV - Slowing Impeller Down
Coefficient of Variation
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
1
2
3
4
5
6
7
Power Level, W/m³
Anoxic Cell 1
5.5% @ 0.5 hp/mil gal
Anoxic Cell 1
Adopted from Schauer & Kobylinski, 2010

Impact of Mixing Energy on Flocculation



Schauer & Kobylinski, 2010

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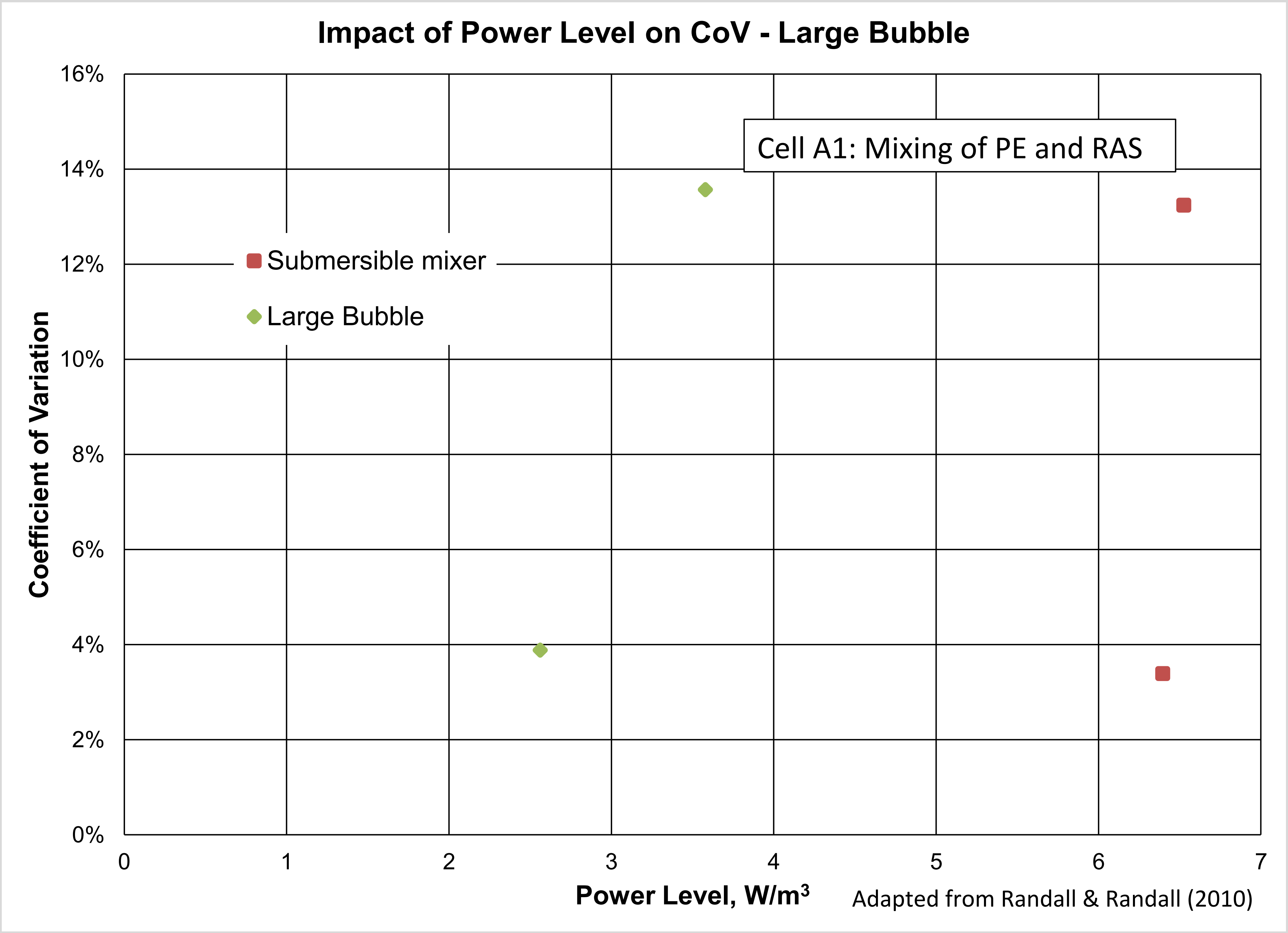
Case Study #2: Large Bubble Mixing

- F. Wayne Hill Water Resources Center in Gwinnett County, Georgia (60 mgd Design)
- 2009 Large bubble diffusers installed in 2 anaerobic zones
- Comparison with submersible mixers in other basins

Randall & Randall (2010)



Exhibit

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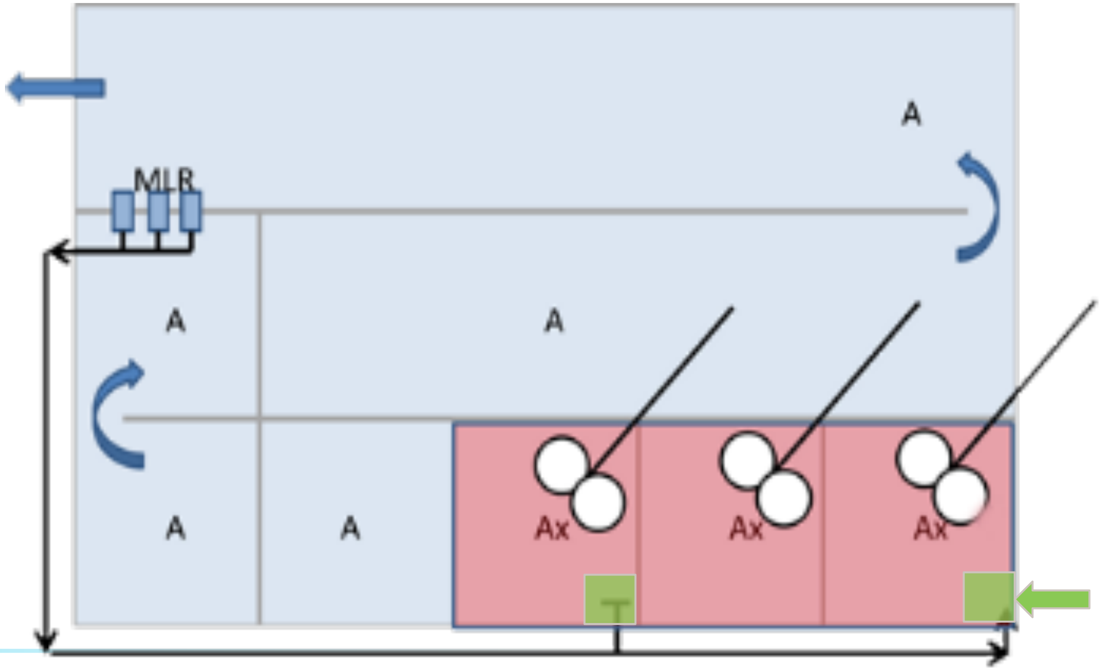
Case Study #3: Mixing Without Mixers?

- City of Boulder WWTF
- 3 anoxic zones, 5-hp floating mixers in each
- 2 ABs IS in summer; 3 ABs IS in winter
- RAS & MLE combined in chimney in Zone 1



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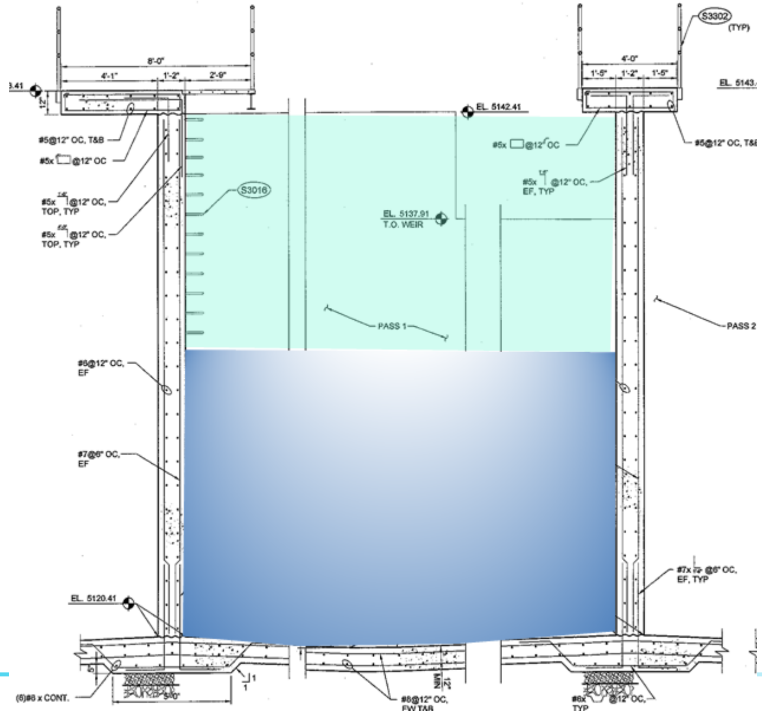
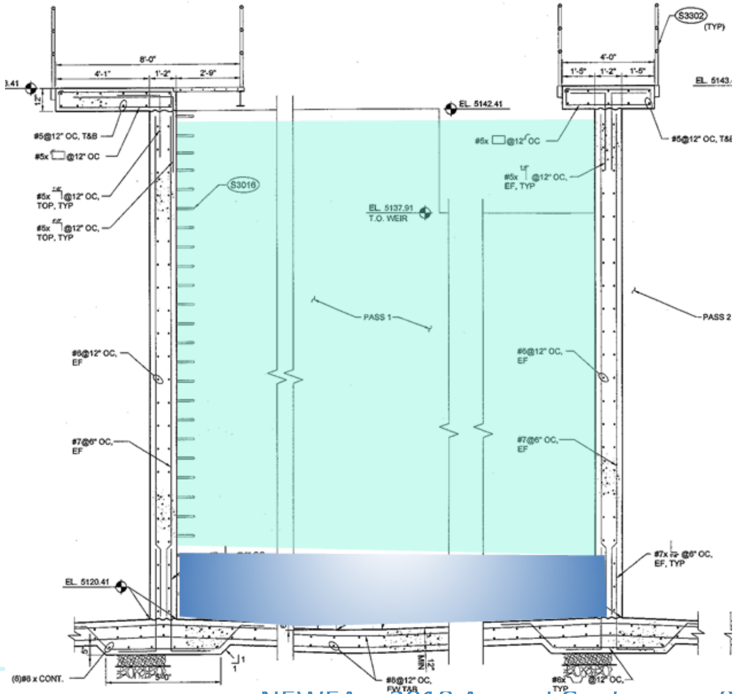
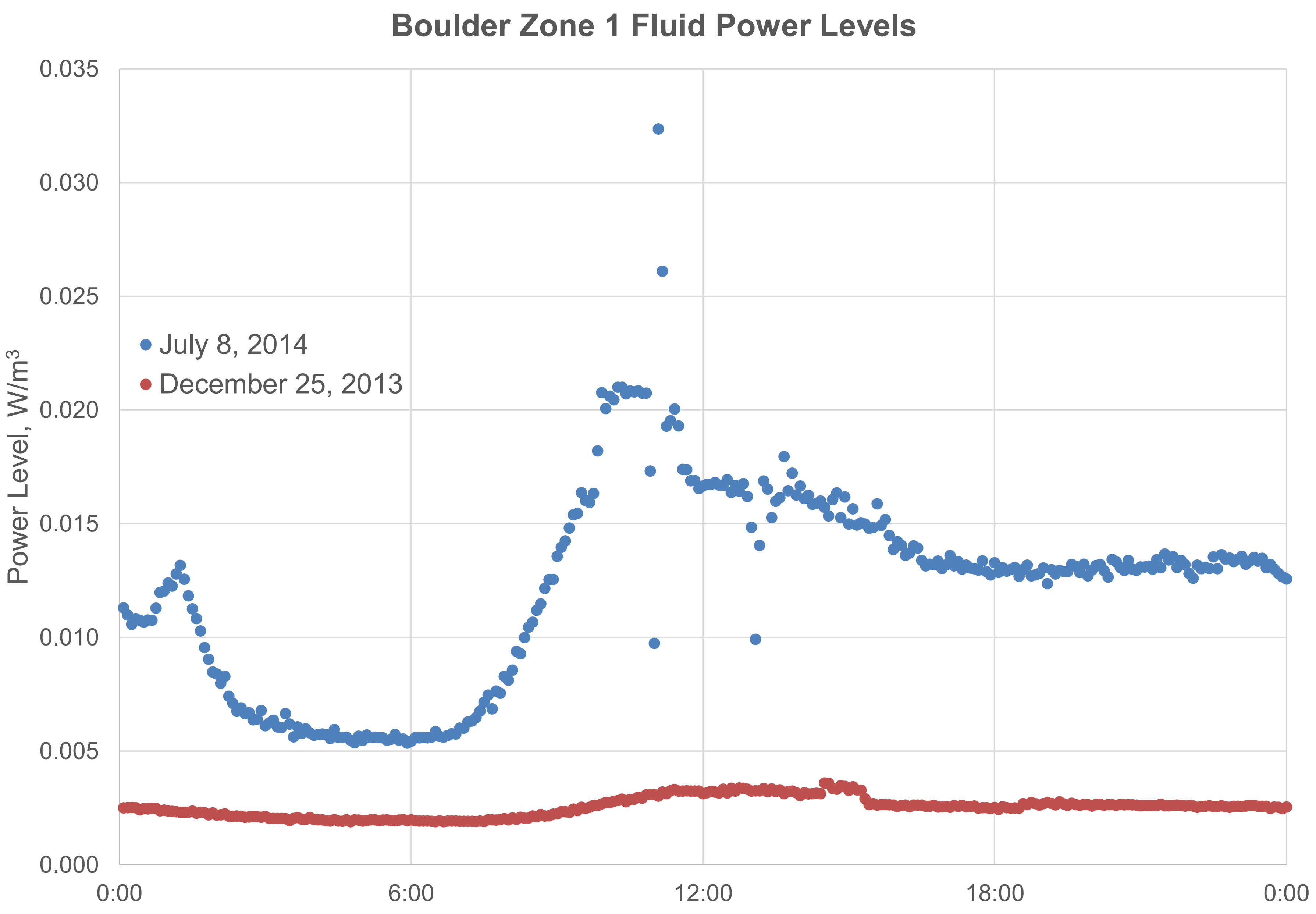
Two Different Flow Events – Mixers Off

	Christmas Day 2013	July 8, 2014
Flow Conditions	Low (3 AB IS)	Normal (2 AB IS)
Mixers off	1 Zone	Zone 1-3
Solids blanket depth	9 - 12'	0 to 3.5’

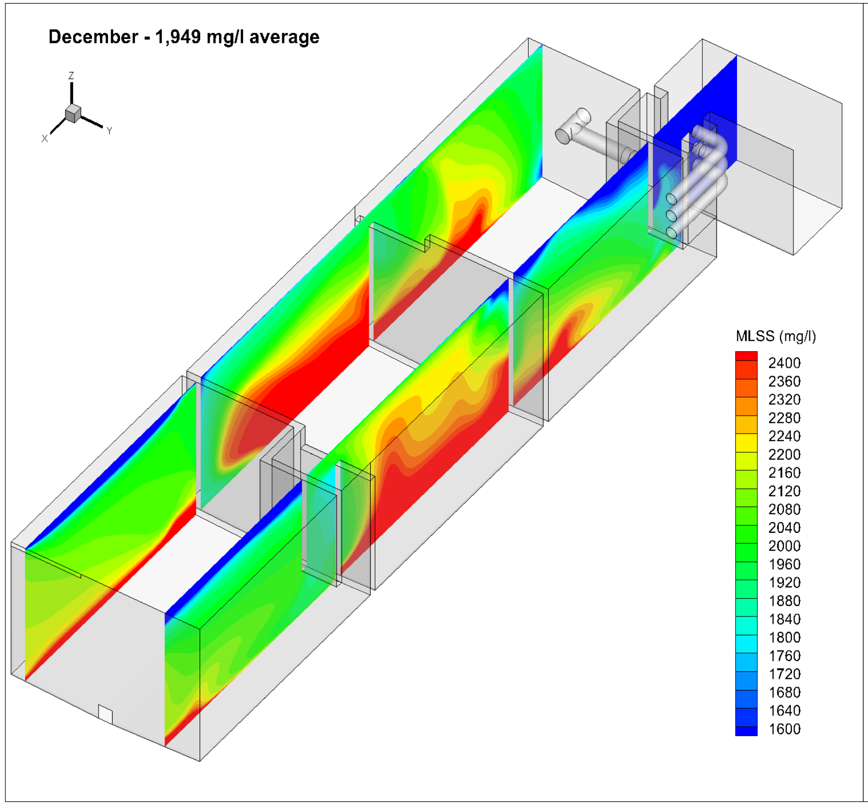


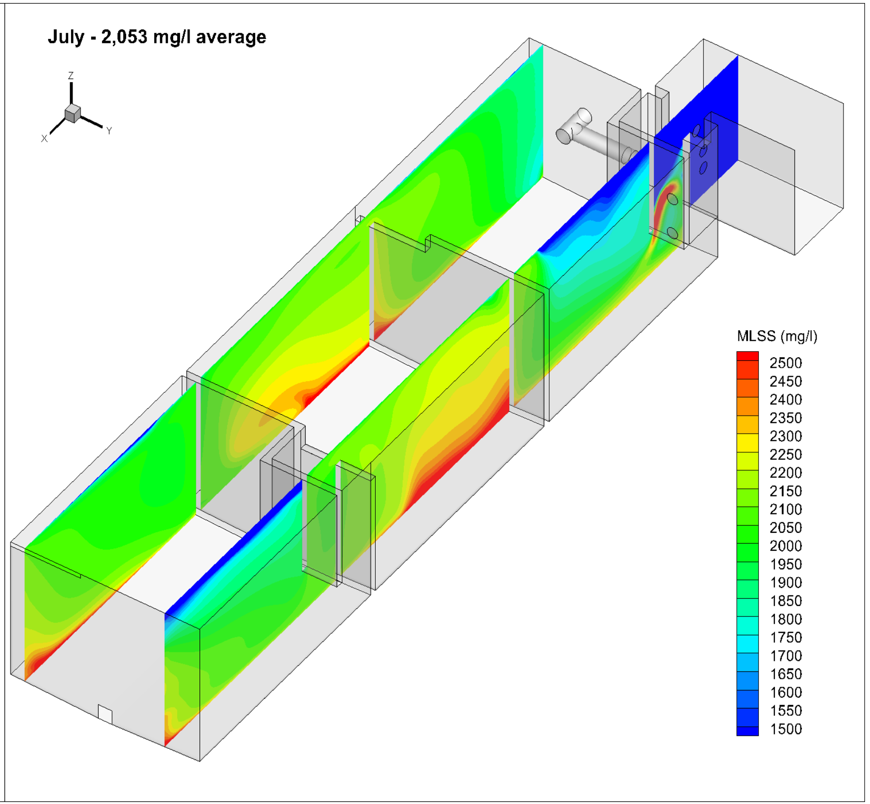



Boulder Zone 1 Fluid Power Levels
Power Level, W/m3
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0:00
6:00
12:00
18:00
0:00
July 8, 2014
December 25, 2013

CFD Modeling of Both Events

Christmas Day 2013 | **July 8, 2014**



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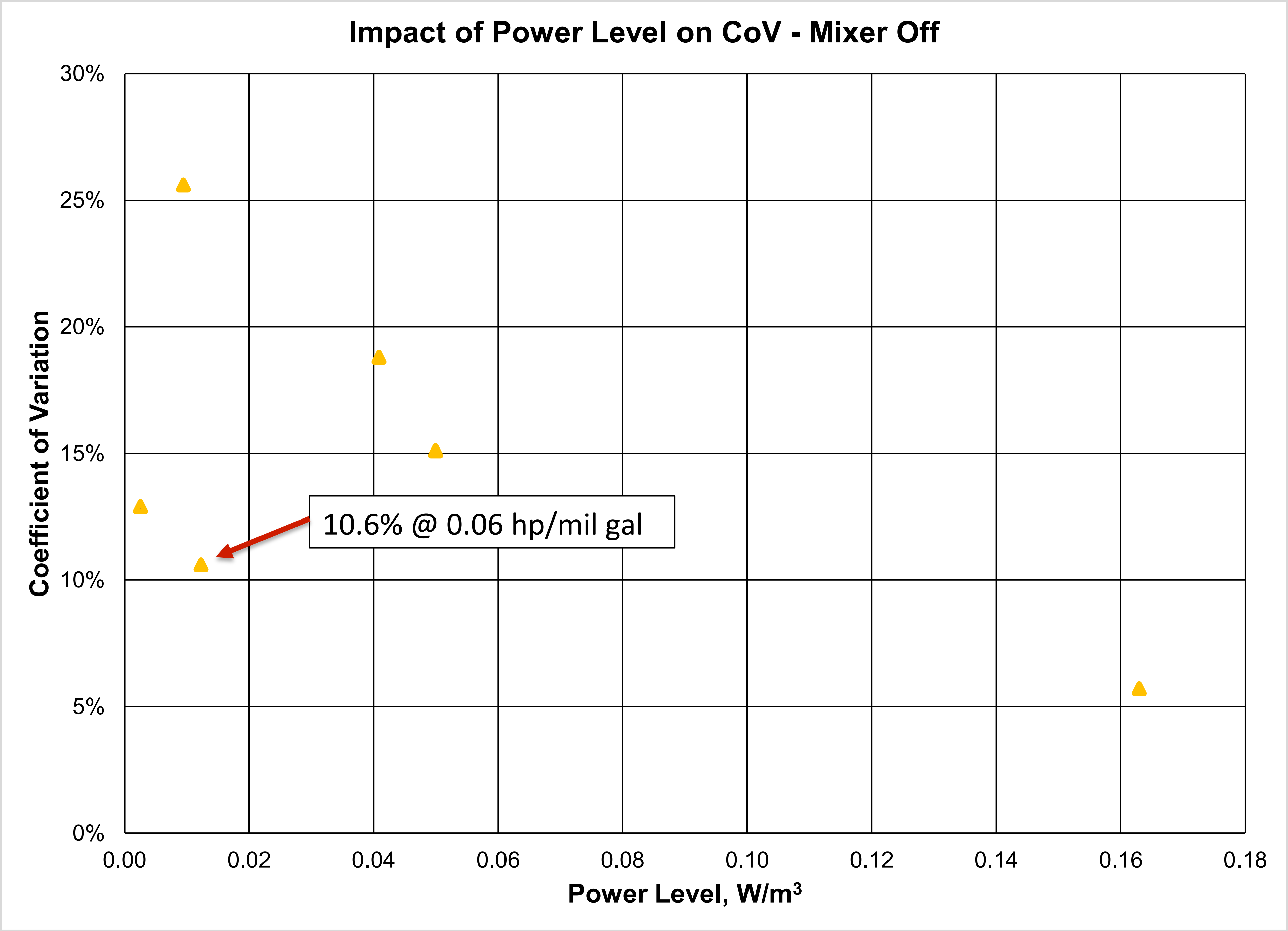

Impact of Power Level on CoV - Mixer Off
Coefficient of Variation
30%
25%
20%
15%
10%
5%
0%
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
Power Level, W/m3
10.6% @ 0.06 hp/mil gal

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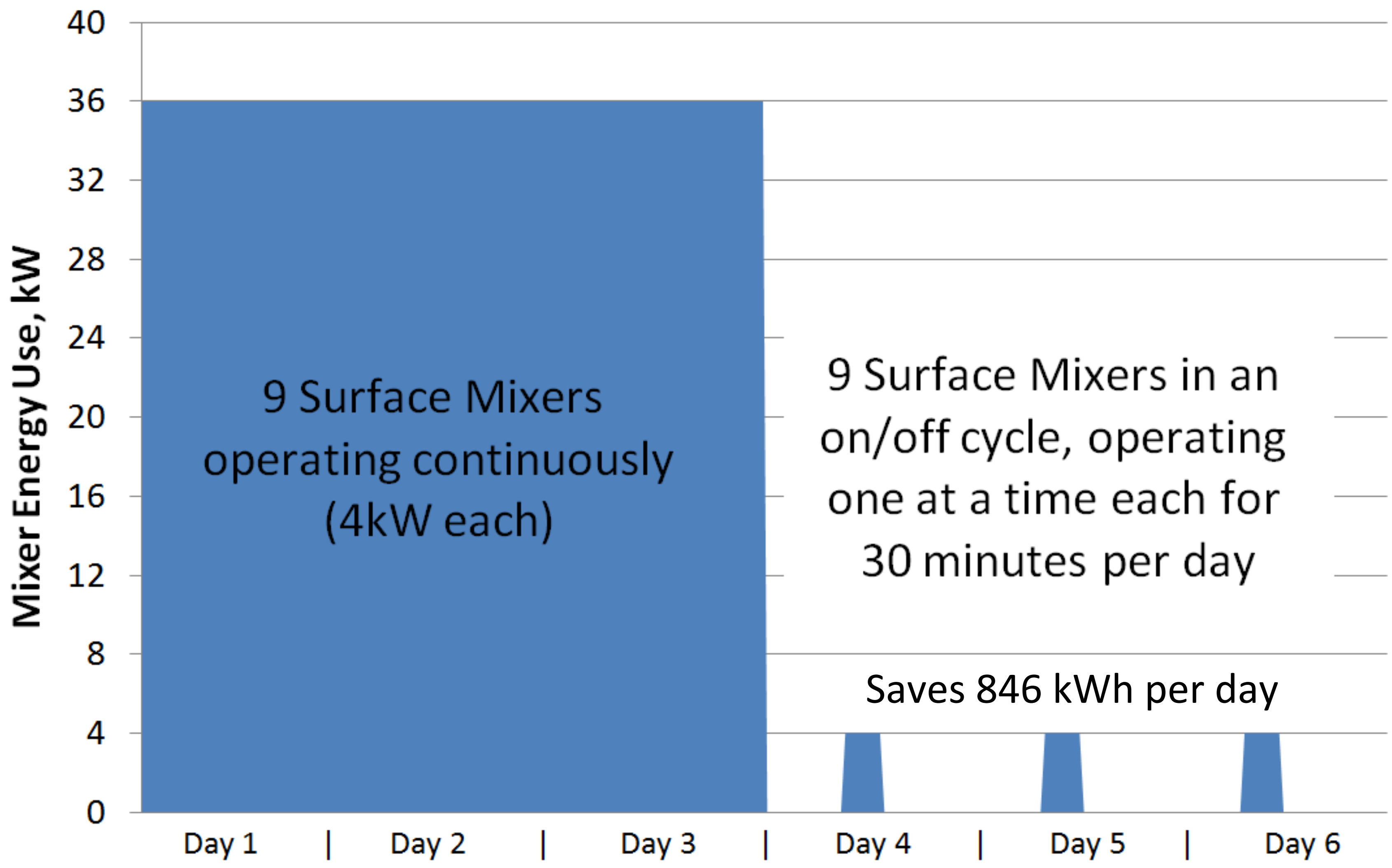
Mixing Without Mixers - Update



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Case Study #4: Minimum Air for Mixing

- Same Facility: City of Boulder WWTF
- High DO concentrations in downstream part of the ABs were interfering with denitrification
- Noticed that airflow was frequently controlled by minimum setpoints
- Comparing the minimum setpoints to commonly used mixing criteria (0.12 scfm/sf & 0.5 scfm/diffuser) suggested that these could be reduced in two of the three aeration grids
- Reduced by 37.5 and 28.6%, in ACZ1 &2, respectively

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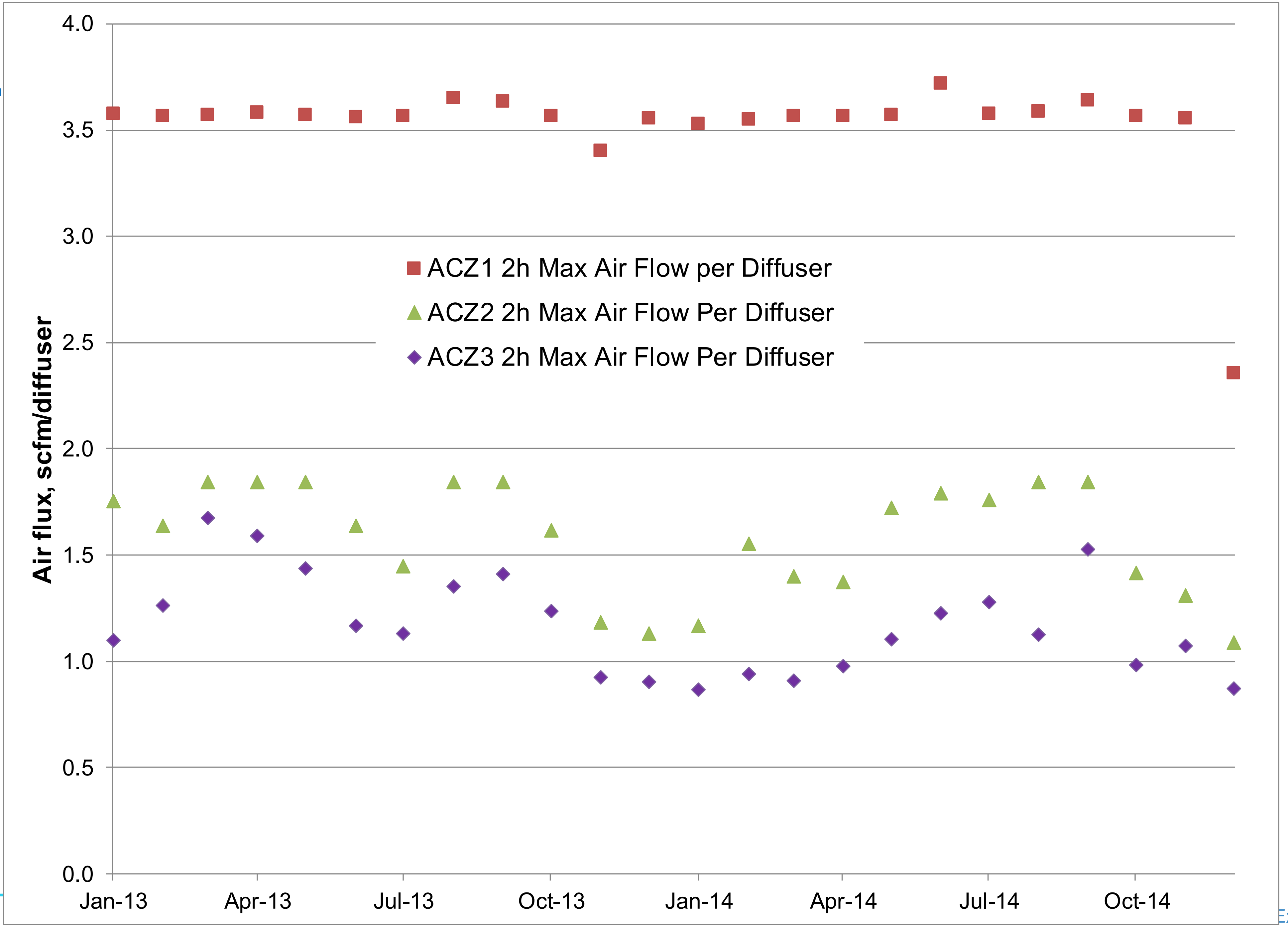
Reduction in Minimum Airflow Setpoint

Percent of time aeration is controlled by minimum mixing air setpoints on average

Period	Before lowering min. air		After lowering min. air	
Grid	**Summer**	**Winter**	**Summer**	**Winter**
ACZ 1	2%	21%	0%	0%
ACZ 2	36%	61%	14%	21%
ACZ 3	42%	83%	61%	64%

Pote



Exhibit

Fine Bubble Aeration: How much is *enough*?

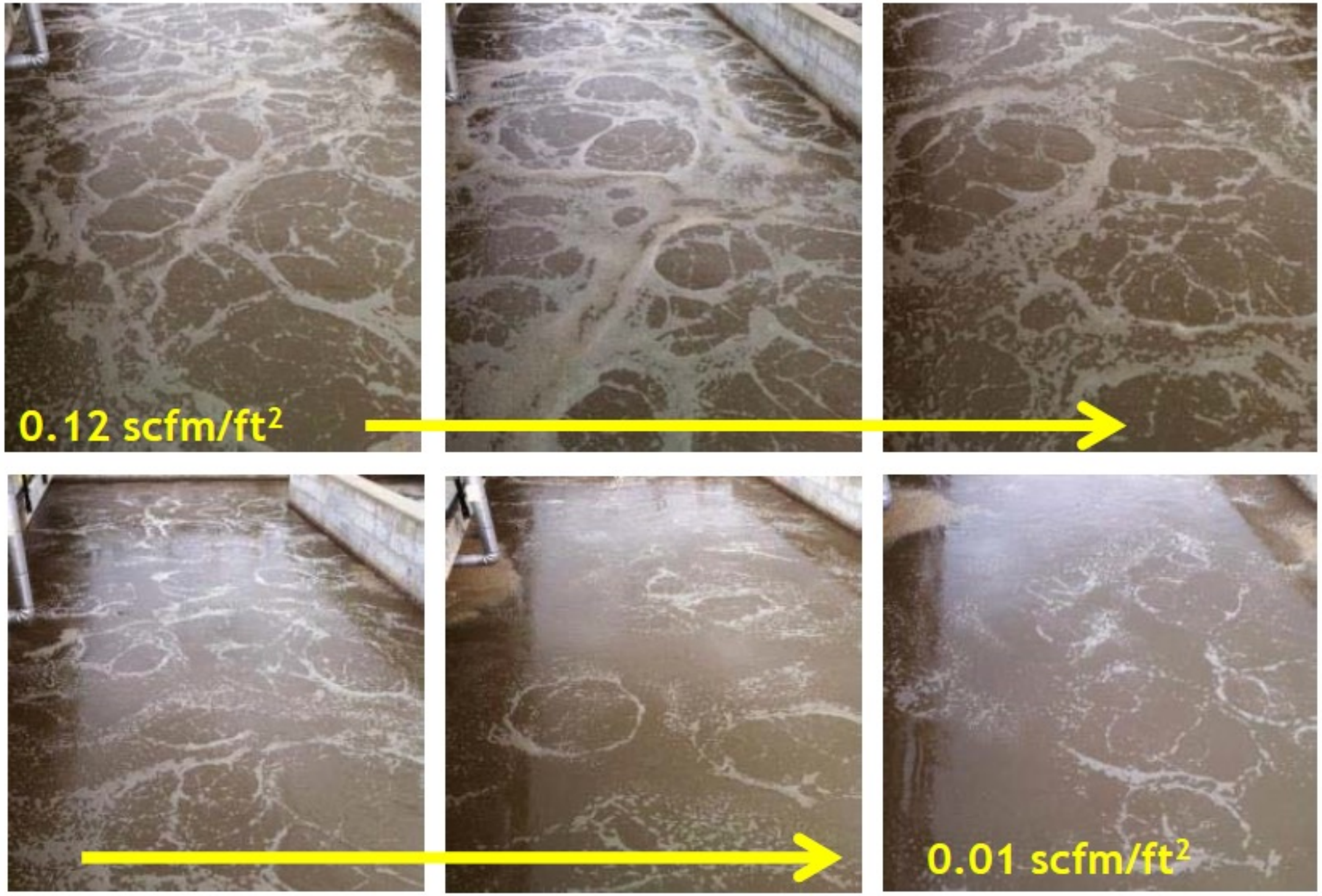
- Further reduction in mixing air: < 0.12 scfm/sf
- First test: reduce airflow stepwise from 0.12 to 0.04 scfm/sf, keep for 10 minutes, sample three depths at two locations, done twice
- Results showed no correlation between air flux and CoV
  - Lowest CoV: 0.12, 0.07, 0.07 and 0.05 scfm/sf
- Second test: run first grid @0.06 scfm/sf 4 PM -> 7 AM
- No distinguishable blanket or MLSS gradient
- Results suggest that 0.06 scfm/sf is sufficient to keep mixed liquor in suspension

Update: Current Operation

- Reduced DO set points for three aeration grids from 2.5, 2.0 and 1.5 mg/L, each -> 2.0, 1.5 and 1.0 mg/L
  - Estimated savings: 1,000 kWh/day
- Plugged 16% of diffusers in ACZ2 and 19% in ACZ3
  - Dramatic reduction in overnight high DOs, due to better turndown capacity
  - Estimated savings: 250 kWh/day
- Effluent TIN dropped from 15 to 8.5 mg/L (other improvements contributed), while saving almost 2,100 kWh/d, or $60,000/year

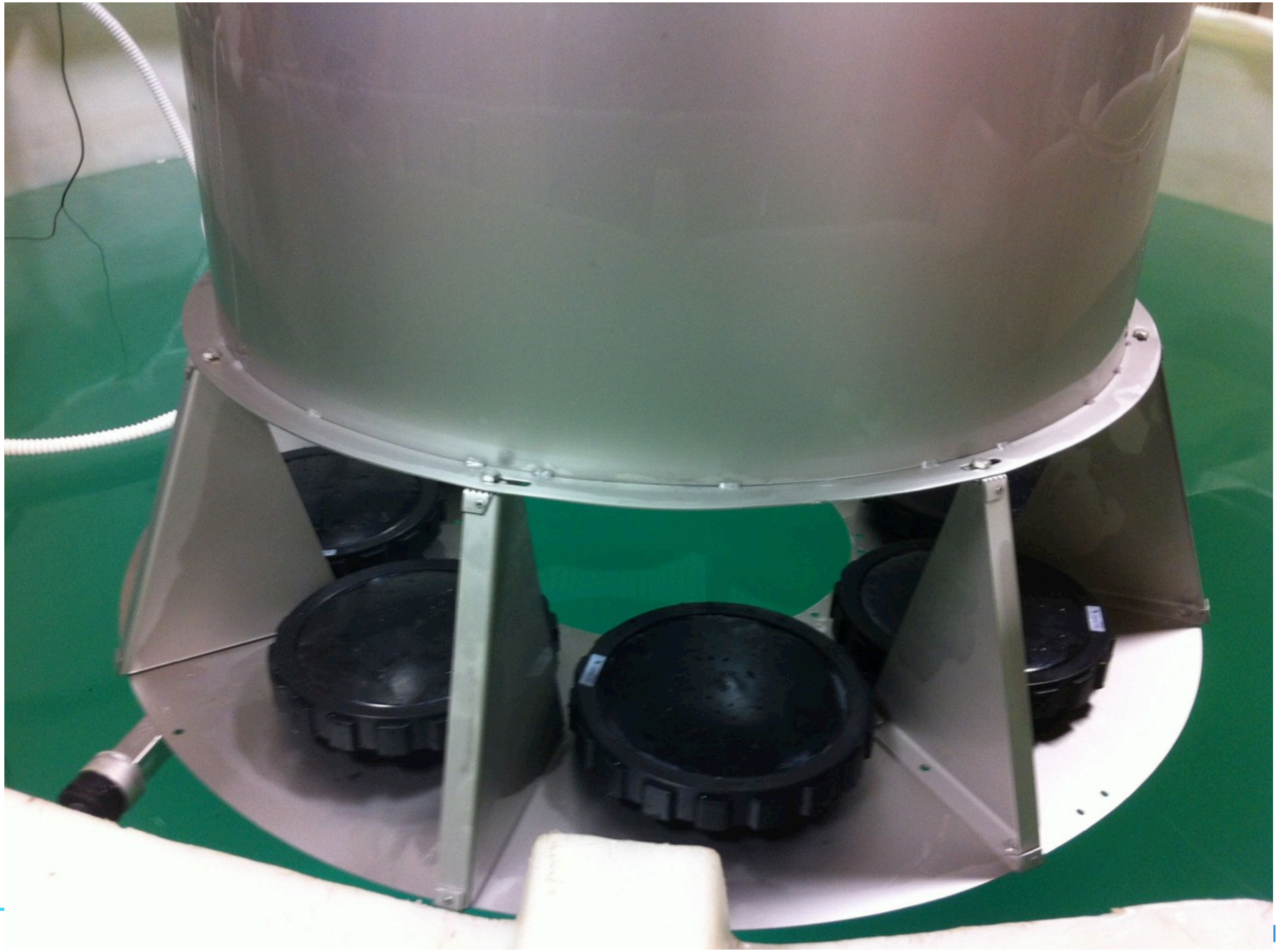
Applications

Constraints: Mixing requirements

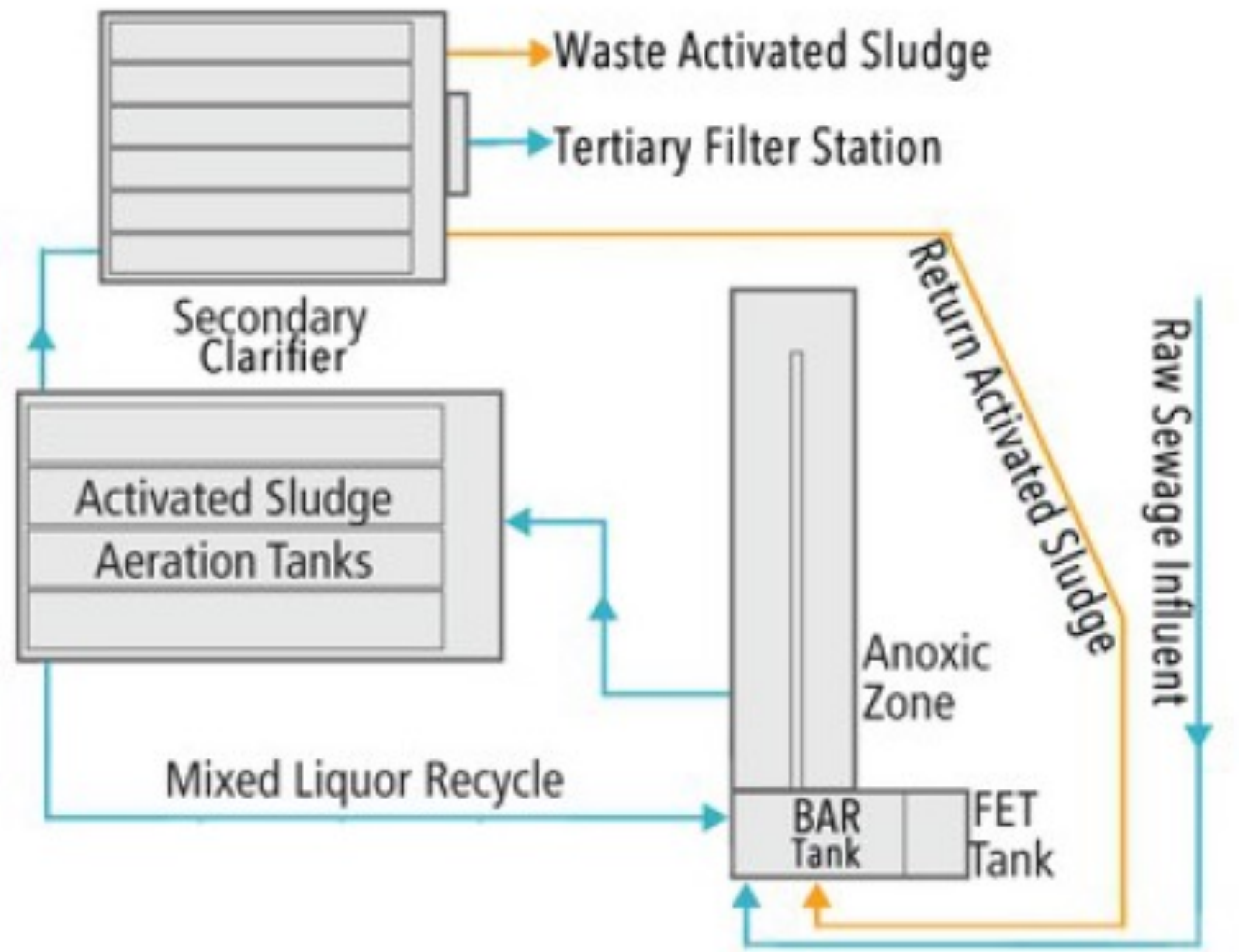


Schauer, 2012

Case Study #5: Fine Bubble Mixers



Ventura Water Reclamation Facility

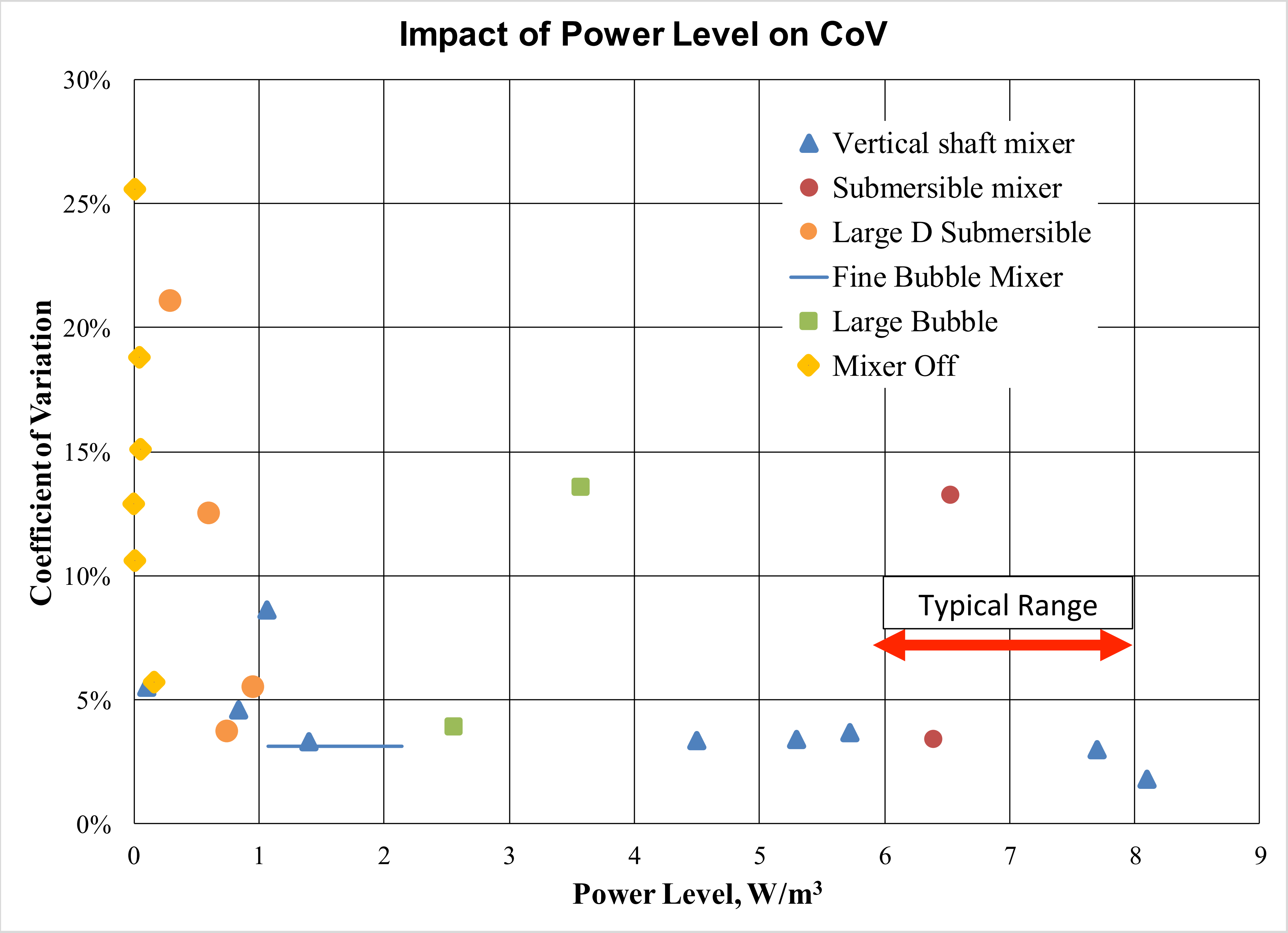


Ventura WRF – Aeration Basin

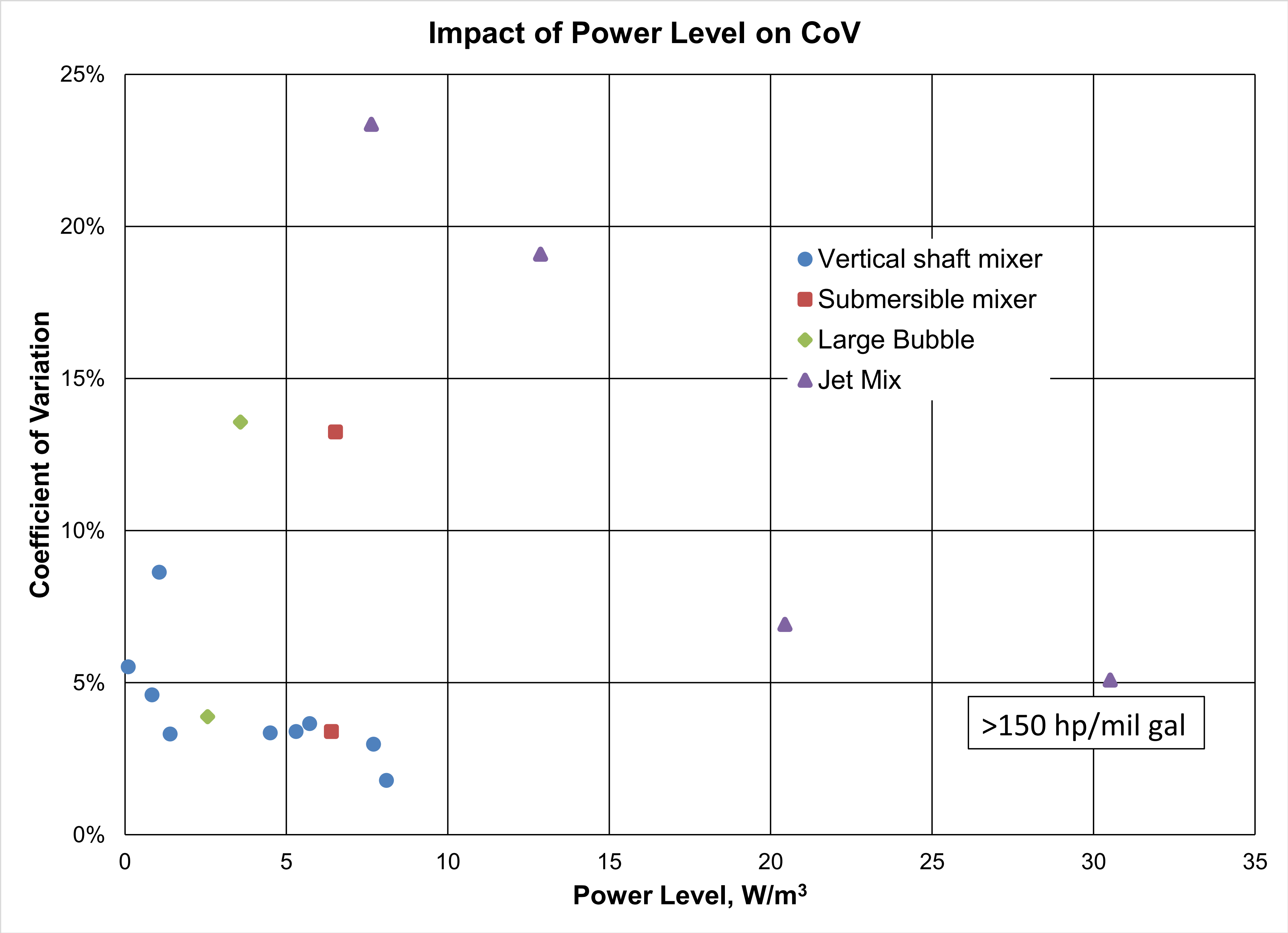
Fine Bubble Mixer at Ventura WRF

- Mixers allowed air to be turned off at d/s end of ABs
  - Effluent NO3-N dropped from 10 to 6mg/L
  - Supplier claims 45% energy savings
- Initially: 1 mixer per basin
  - Weekly aeration revealed some settled solids
  - Added a second mixer
- Testing confirmed effective mixing (CoV of 3.1%)
- Operators claim to have measured no DO
- Operators like ease of installation
- Units can be maintained without taking basins OOS

In Co



Exhibit


Impact of Power Level on CoV
Coefficient of Variation
0%
5%
10%
15%
20%
25%
0
5
10
15
20
25
30
35
Power Level, W/m³
Vertical shaft mixer
Submersible mixer
Large Bubble
Jet Mix
>150 hp/mil gal

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Recommendations

- Install mixers with adjustable power levels
  - Opportunity to minimize mixing (and aeration) energy
  - May be win-win: lower power use AND better effluent quality
  - Allows each system to be field optimized
  - Some mixers supplied with integral VFD
  - Mixing power level can be controlled by time of day
- Apply intermittent mixing
  - Different strategy for minimizing mixing energy
  - Allows operators to manage demand charges
  - Time-based control typically used – potential for other controls

Recommendations, continued

- Avoid prescriptive specifications: ~~35 hp/mil gal~~
  - Creates the wrong incentive
  - Implies specifier has knowledge of mixer technology
  - Ignores site specifics: geometry, sludge settling characteristics, etc.
  - Consider performance-based specifications instead
- Blend upstream of mixed zones
  - Improve reaction kinetics
  - Minimize energy required for ~~blending~~ suspension
  - May contribute to keeping solids in suspension

Future Developments

- How to Size a Mixer for Minimum Power?
  - A universal "hp/mil gal" number is NOT the goal
  - A universal "scfm/sf" for *full floor* fine bubble air MAY work
  - Engage suppliers for their recommendations
  - Specify mixers with downturn capabilities
- More data are needed
  - CoV for TSS can be readily determined
    - Standards for testing must be developed
  - Impact of geometry – mixer radius of influence
    - Use CFD for analysis
  - How flocculation impact kinetics
  - OTR for fine bubble air mixers

Contact us!

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