Energy Reduction Analysis at New Prague Wastewater Treatment Facility

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Driven to Discover℠

MnTAP

Company Overview

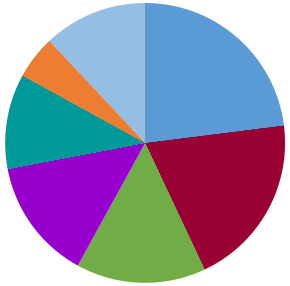
- Remove contaminants from wastewater
- 7,700 residents
- Regulated by Minnesota Pollution Control Agency
- Upgraded in 2010

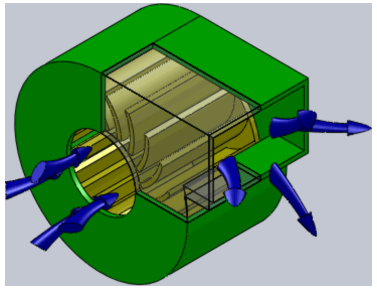
NEW PRAGUE
A Tradition of Progress

Incentives to Change

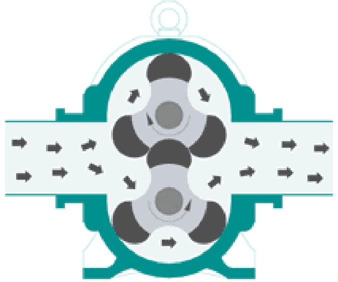
- **Operating budget covered by water and sewage fees**
  - Have exceeded budget
  - Excess covered in city taxes
- **Next MPCA permit may include more requirements**
  - Require additional equipment
  - Minimize energy increase with optimizing

Project Overview

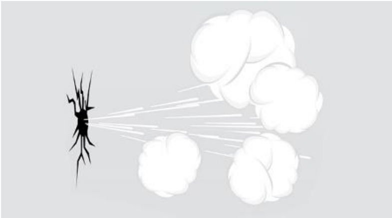




1. **Characterize energy consumption plant-wide**
   - Identify energy-intensive equipment
   - Observe yearly consumption trends
2. **Quantify scrubber/HVAC reductions**
   - Determine suitable # air changes per hour (ACH)
   - Predict savings for reduced exhaust fan speeds

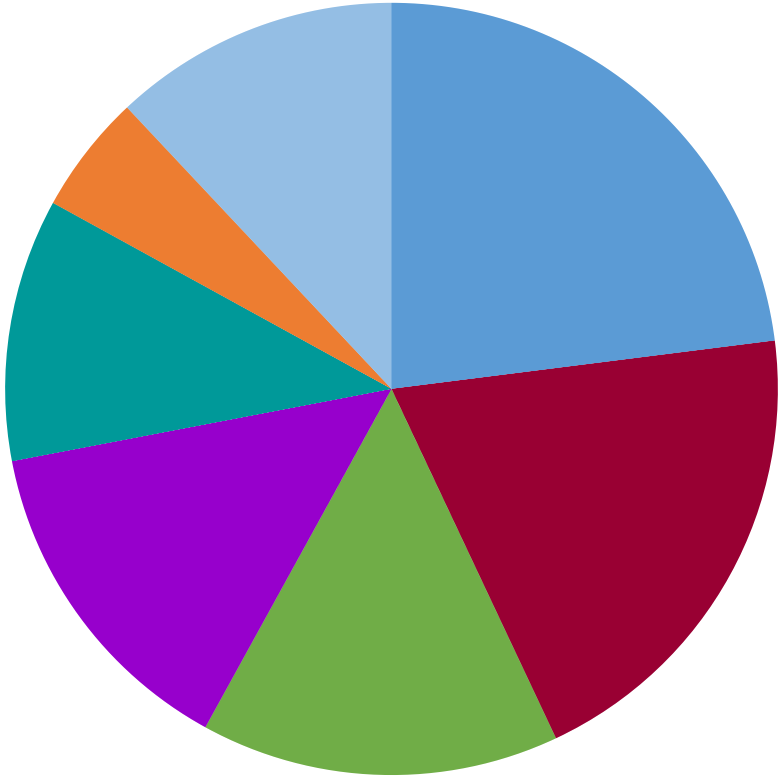


3. **Assess Biological Aerated Filter (BAF) blower reduction**
   - Dissolved oxygen aeration model



4. **Ultrasonic leak study**
   - Find compressed air leaks
5. **Lighting audit**
   - Determine suitable LED replacements and resulting savings

Characterize Energy Consumption

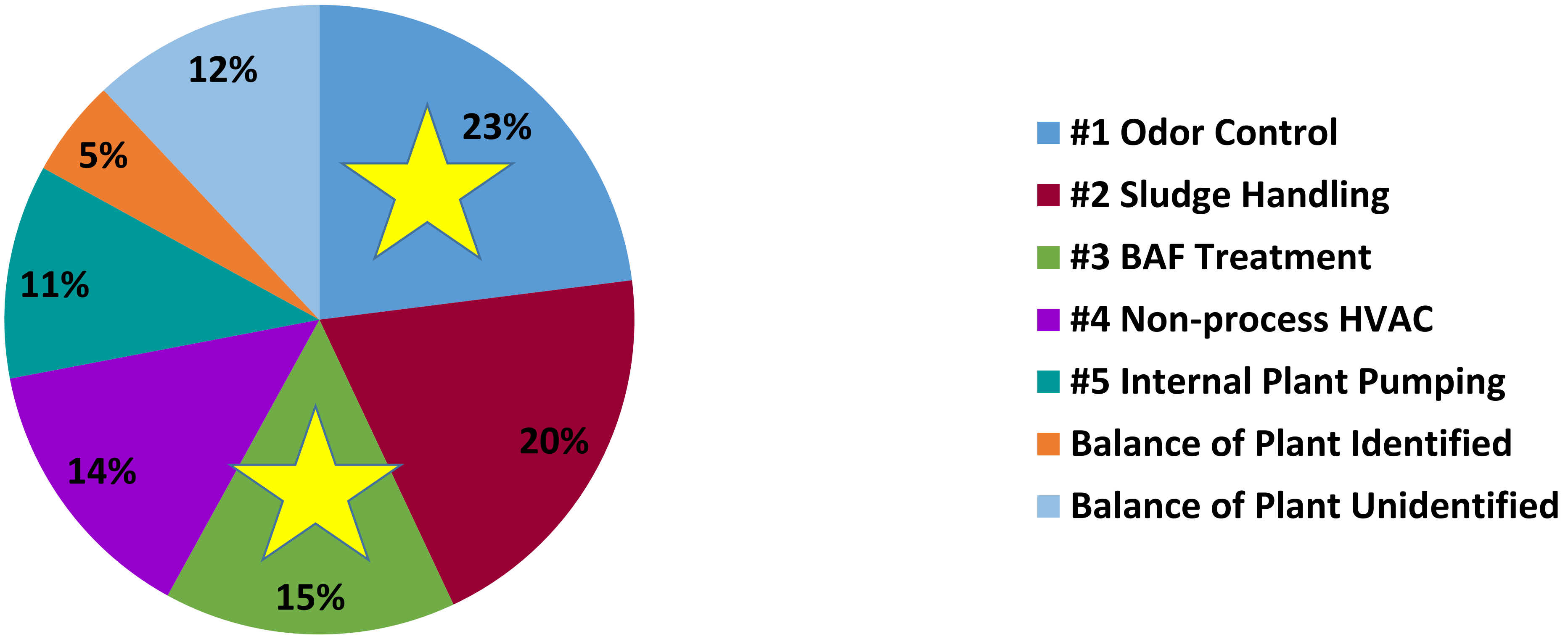


EPA Energy Assessment Tool

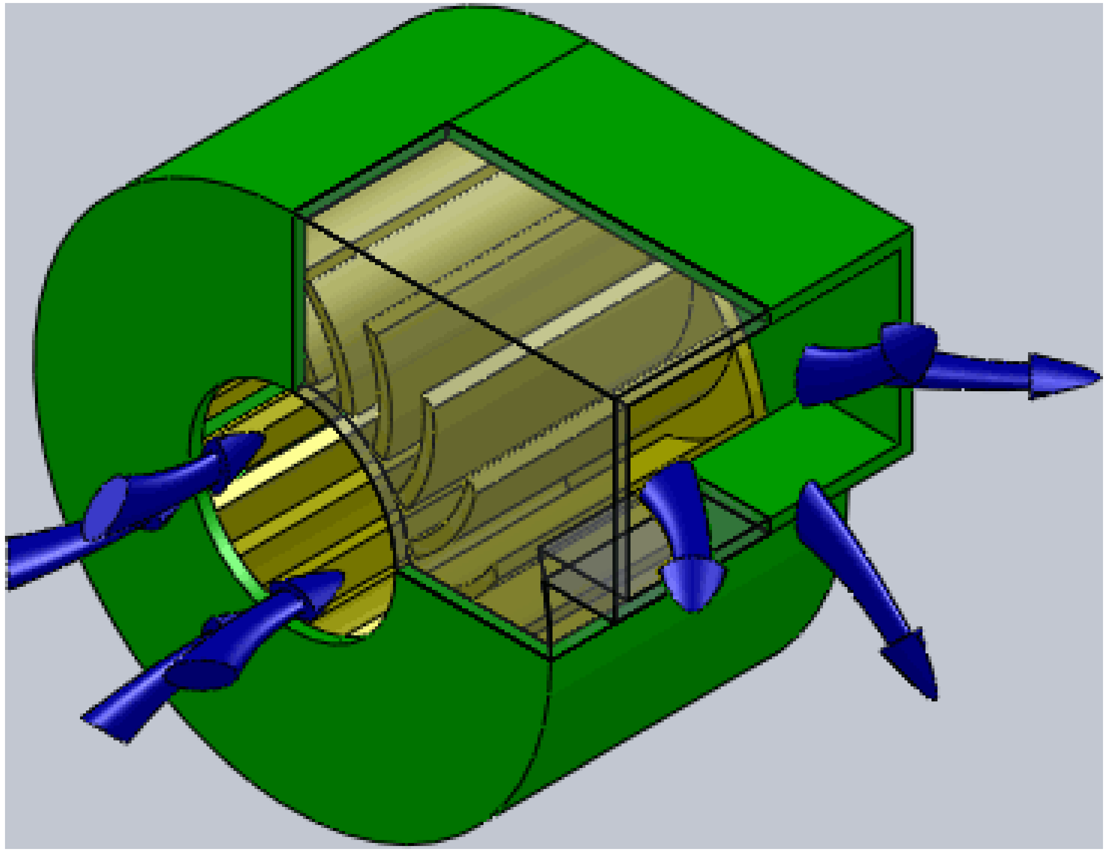
- **Track energy usage for small wastewater facilities**
  - Excel spreadsheet
- **Method:**
  - Collect utility bills from 2014-2017
  - Collect motor specification data
- **Focus on electricity reduction**

Utility	Site Utility Use	Site Utility Costs	% of Costs
Electricity	2,183,200 kWh	$166,663	76%
Natural Gas	79,167 CCF	$48,180	22%
Water & Sewer	870,000 GAL	$4,100	2%

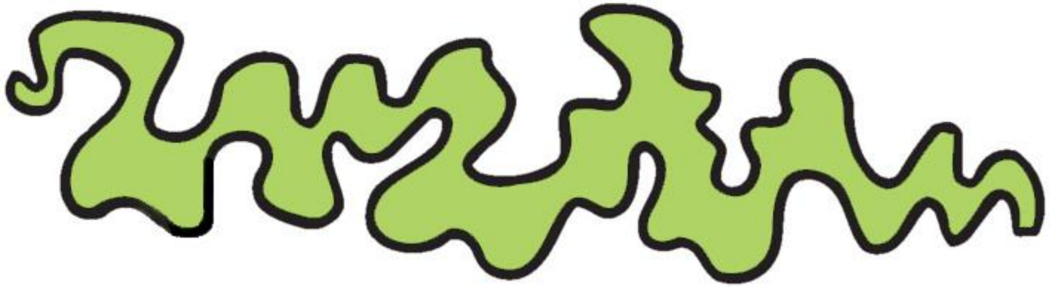
Top Electrical Energy Use Systems



Quantify scrubber/HVAC reductions



Odor Scrubbers



Room	Air changes per hour
BAF	7.2
Pretreatment	4.8
Biosolids	4.0

Option 1.1: 7.2 to 4.9 ACH

Energy reduced (per year)	Implementation Cost	Cost Savings (per year)	Payback Period	Status
106,000 kWh 150 therms	$0	$8,100	Immediate	Implemented

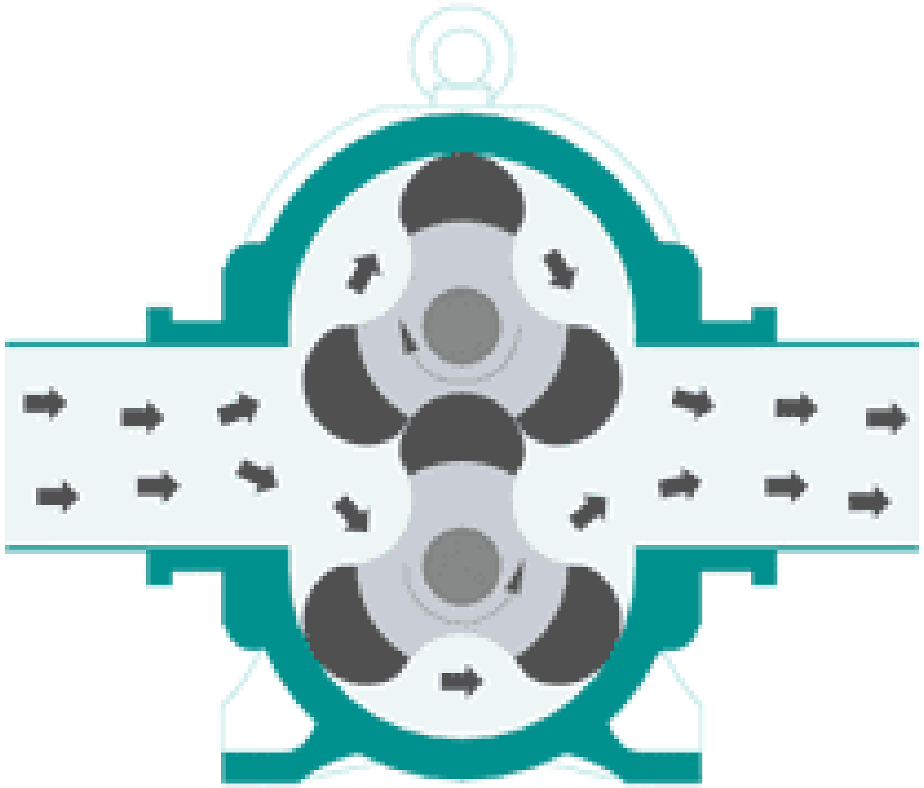
Option 1.2: Sw biosolids and F fan

- **BAF and biosolids o bbers ar different models**
  - Undetermined volumetric
- **Undetermined labor costs**
  - Likely a week
- **Requires further inve n by Evoqua engineers**

Biosolids scrubber fan

BAF scrubber fan

Assess BAF Blower Reduction



Biological Aerated Filter (BAF)

- **Secondary treatment**
  - Removes total suspended solids (TSS), ammonia, and carbonaceous biological oxygen demand
- **Microbes require oxygen**
  - 0.5-2 mg/L dissolved oxygen (DO)

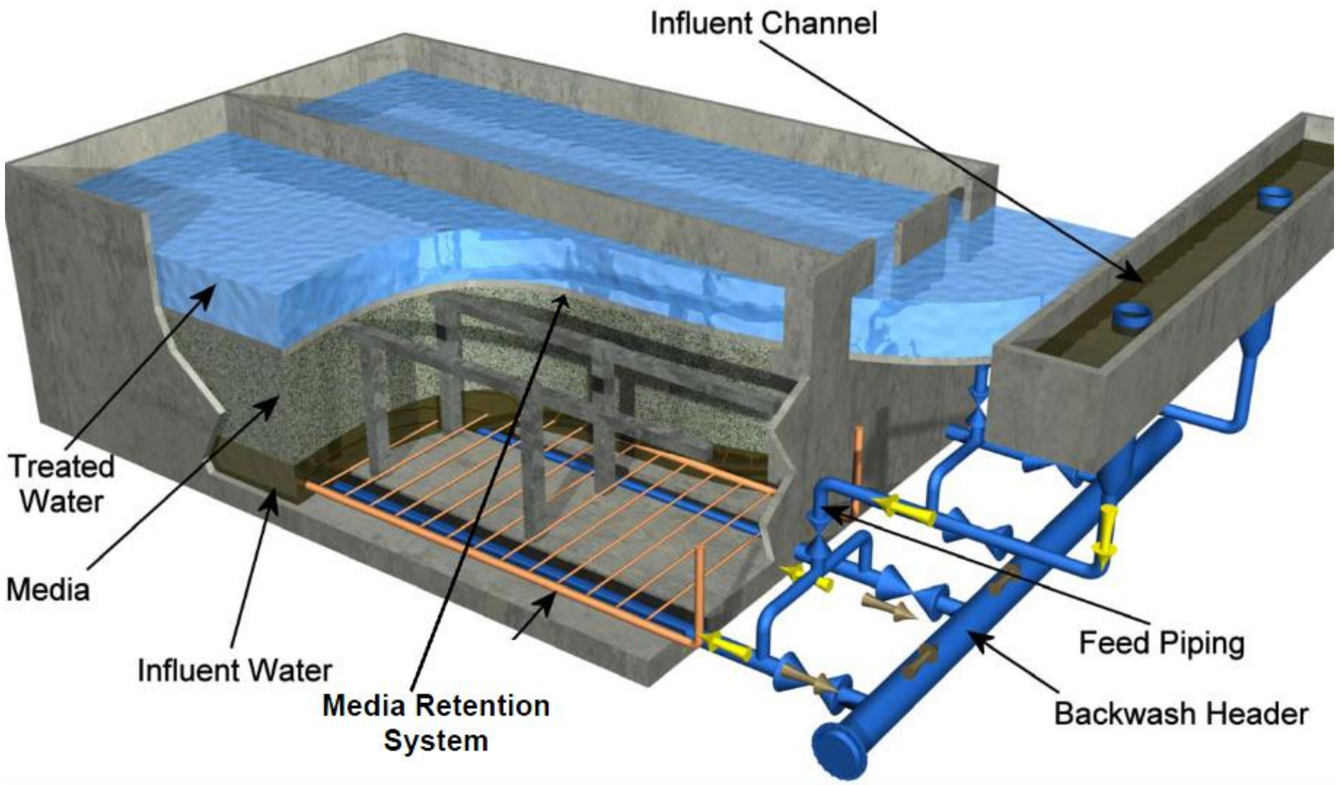
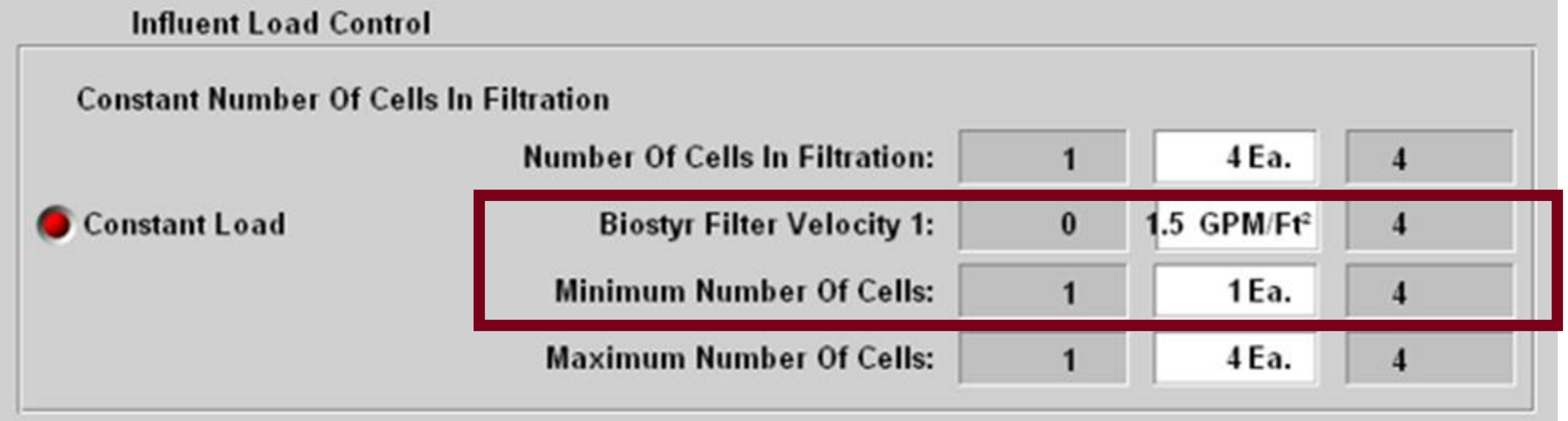


Fig. 2 BAF schematic by Veolia/Kruger

Option 2.1: Adjust controls settings

- **Reduces blower operating hours**
- **New Prague's optimal set point at 1.5 gallons per minute per sqft**



New Prague SCADA set point screen shot

Option 2.1: Adjust controls settings

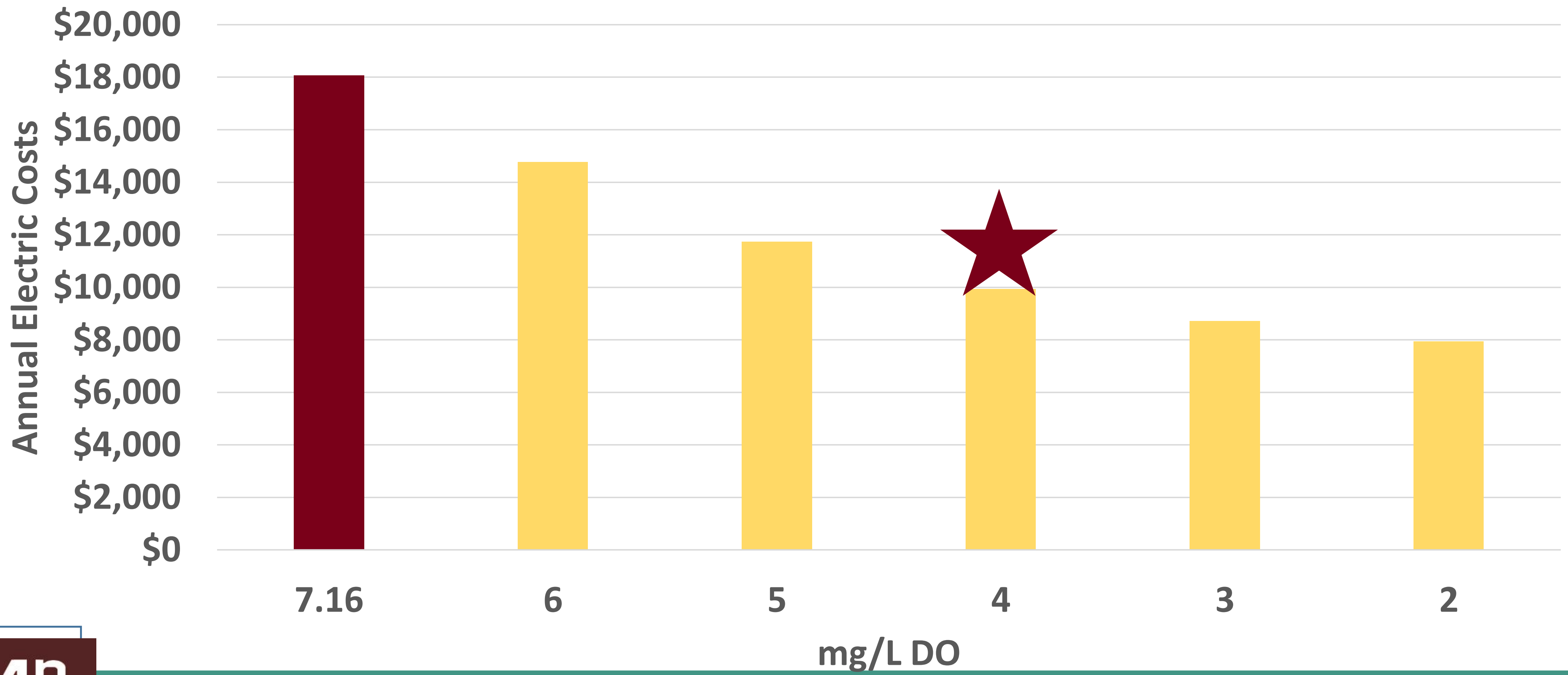
Energy reduced (per year)	Implementation Cost	Cost Savings (per year)	Payback Period	Status
148,000 kWh	$0	$11,200	Immediate	Implemented

Option 2.2: Install VFDs to BAF Blowers

- **Reduces power consumption during operation**
- **Price to be determined**
  - Likely 4-5 years
  - Rebates available
- **Eliminate inrush**
  - Reduces electric costs
  - Increase blower lifespan

Allen Bradley PowerFlex 753, the proposed VFD for installation

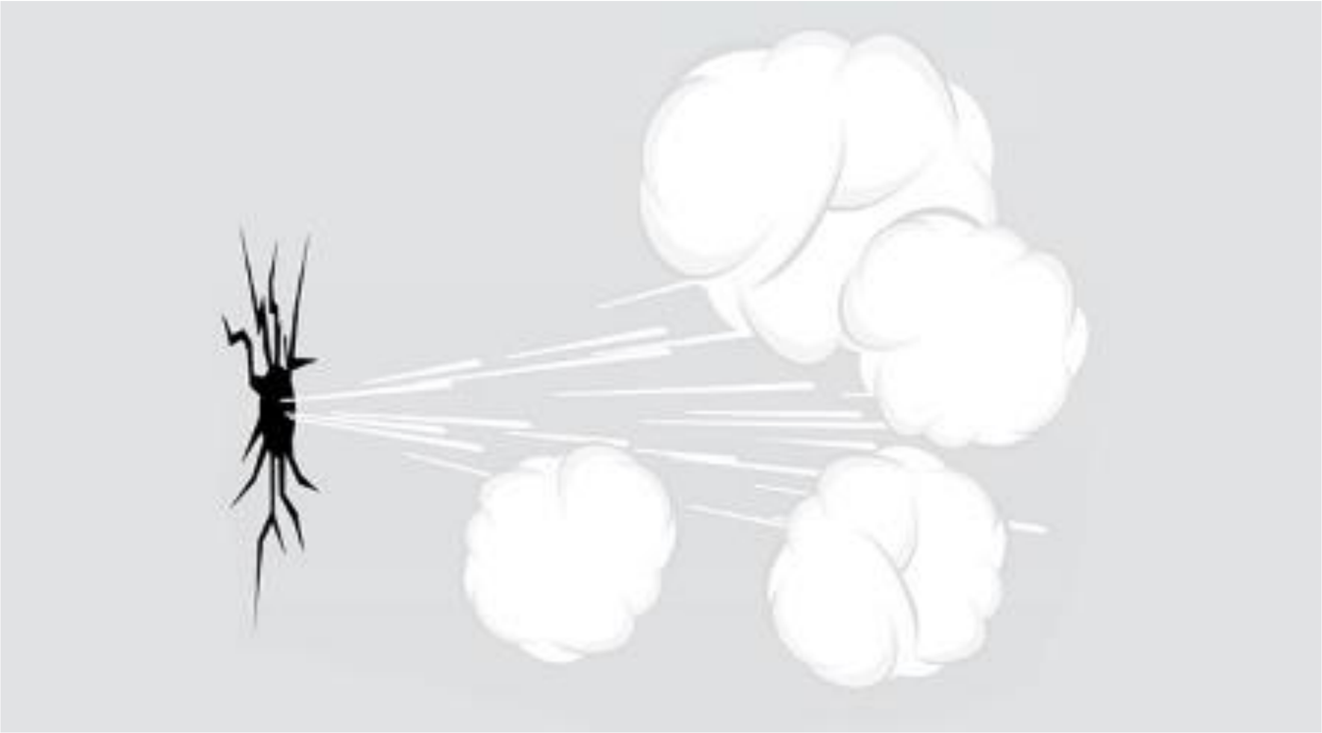
Option 2.2: Install VFDs to BAF Blowers and target 4.0 mg/L DO



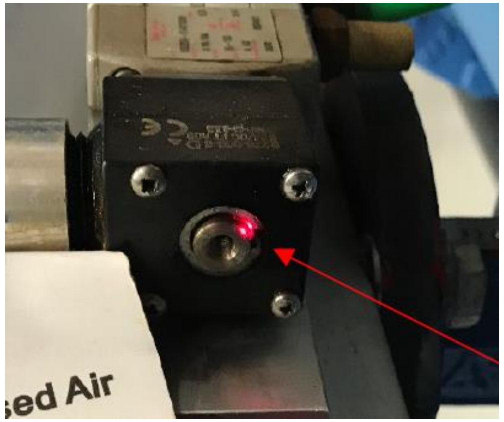
Option 2.2: Install VFDs to BAF Blowers and target 4.0 mg/L DO

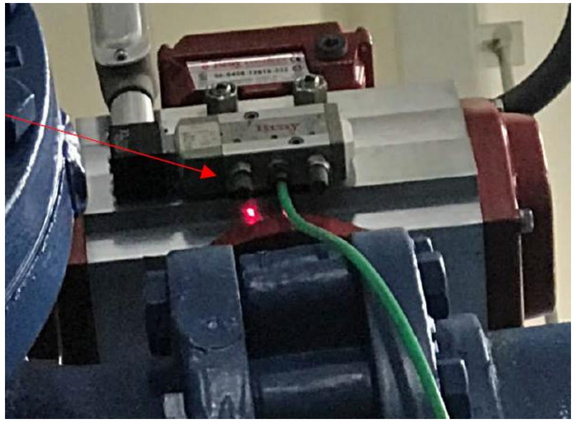
Energy reduced (per year)	Implementation Cost	Cost Savings (per year)	Payback Period	Status
107,000 kWh	TBD	$8,100	4-5 years	Recommended

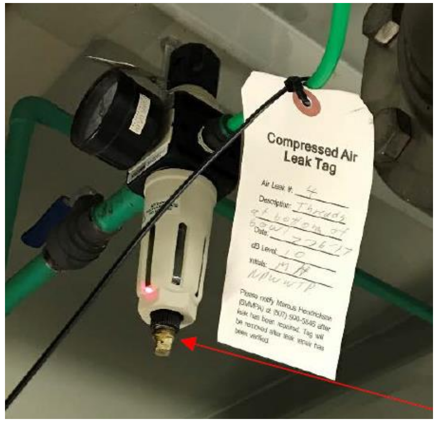
Ultrasonic Leak Study

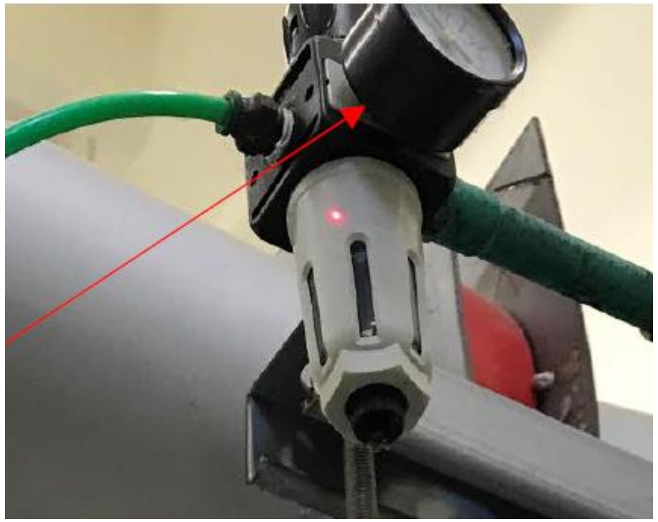


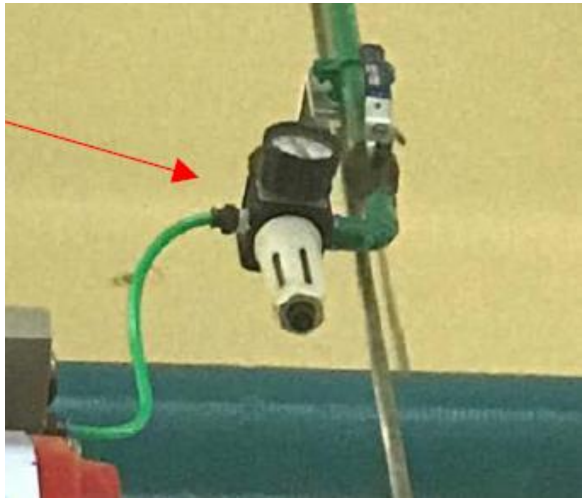
8 Leaks Found











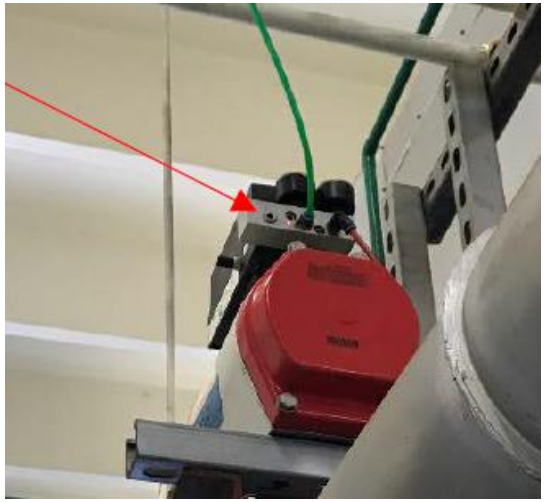
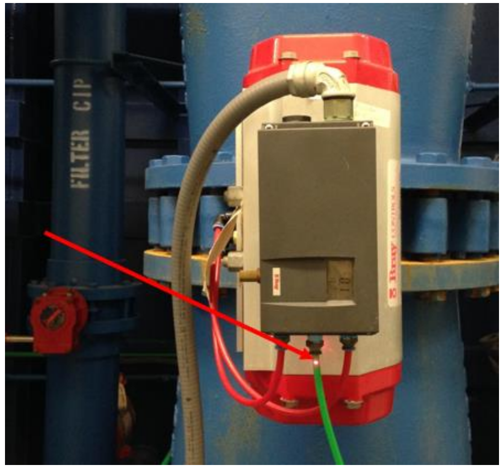
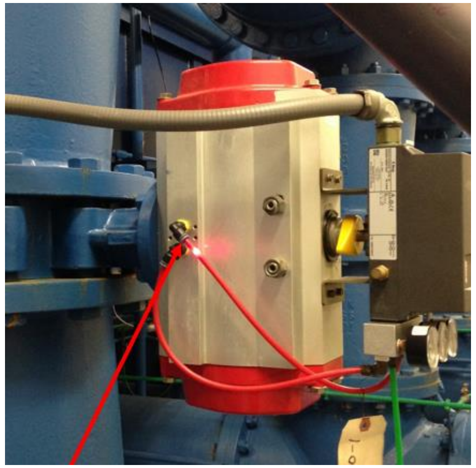
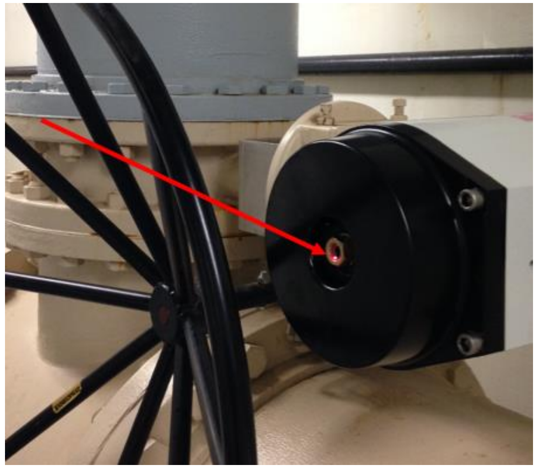


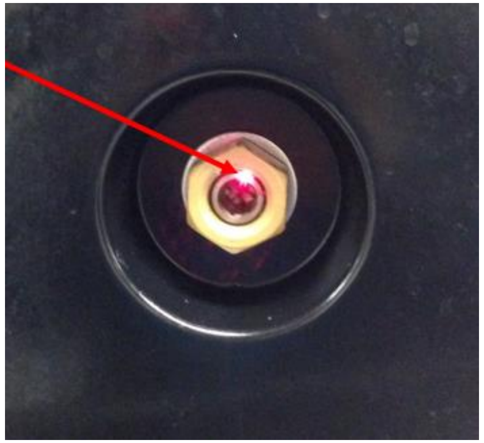
Photo credit: Marcus Hendrickson

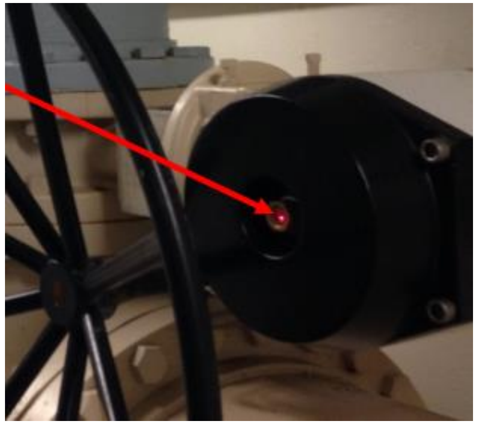
6 Additional Leaks Found

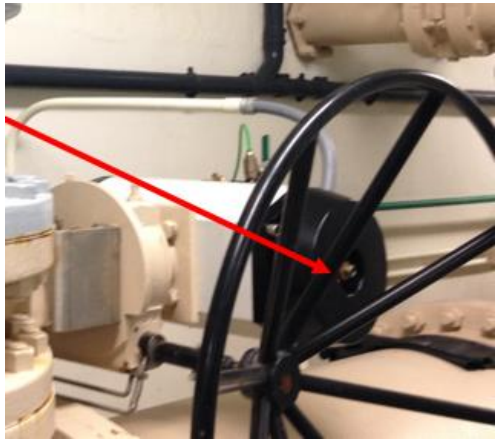












Option 3.1: Seal compressor leaks

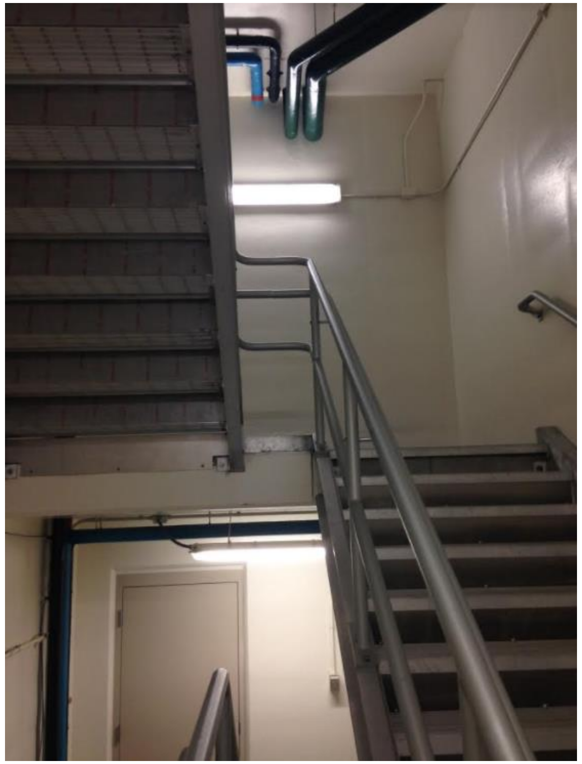
Energy reduced (per year)	Implementation Cost	Cost Savings (per year)	Payback Period	Status
13,820+ kWh	$220	$1,050+	2.6 months	In progress

Lighting Audit

LED Technology Constantly Improving

- **New Prague WWTF lighting**
  - 112 lights are on 24/7
  - 4 ft 32 watt fluorescent lights
- **LED refits**
  - Longer lifespan (50,000 hours)
  - Lower power consumption (18 watt)
  - Compatible with ballasts

Main hall lighting



Stairwell lighting

Option 4.1: Upgrade lights to LED

Energy reduced (per year)	Implementation Cost	Cost Savings (per year)	Payback Period	Status
28,600 kWh	TBD	$2,100	2-3 years	Recommended

LED exterior fixture in progress of installation

Potential Savings Summary

Recommendations	Annual Reduction	Implementation Cost	Annual Savings	Payback Period	Status
Reduce ACH to 4.9	106,000 kWh 150 therms	$0	$8,100	-	Implemented
Change controls and reduce DO to 4.0 mg/L using VFD	254,740 kWh	TBD	$19,300	4-5 years	Recommended
Seal leaks	13,820+ kWh	$220	$1,050+	2.6 months	In Progress
Upgrade to LED	28,600 kWh	TBD	$2,100	2-3 years	Recommended
Totals	**403,000 kWh 150 therms**	**TBD**	**$30,550**	**TBD**	-

Future recommendations

- **Reduce scrubber and make-up air unit to 4.0**
  - Reduces 125,000 kWh and $9,500
- **Study VFD installation on main lift station pump effects**
  - Eliminate inrush throughout facility
  - Prolong motor life
- **Sludge aeration blower**
  - Possible upgrades and installations

Personal Benefits

- Immersion in wastewater
- Put ChemE skills to the test
  - Need more MechE and EE background
- Communicating with vendors
- Deeper appreciation for operation & maintenance
- Learn about considerations in engineering & design
- “I don’t know”

Special thanks to the following

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Thank you for listening!

Questions?

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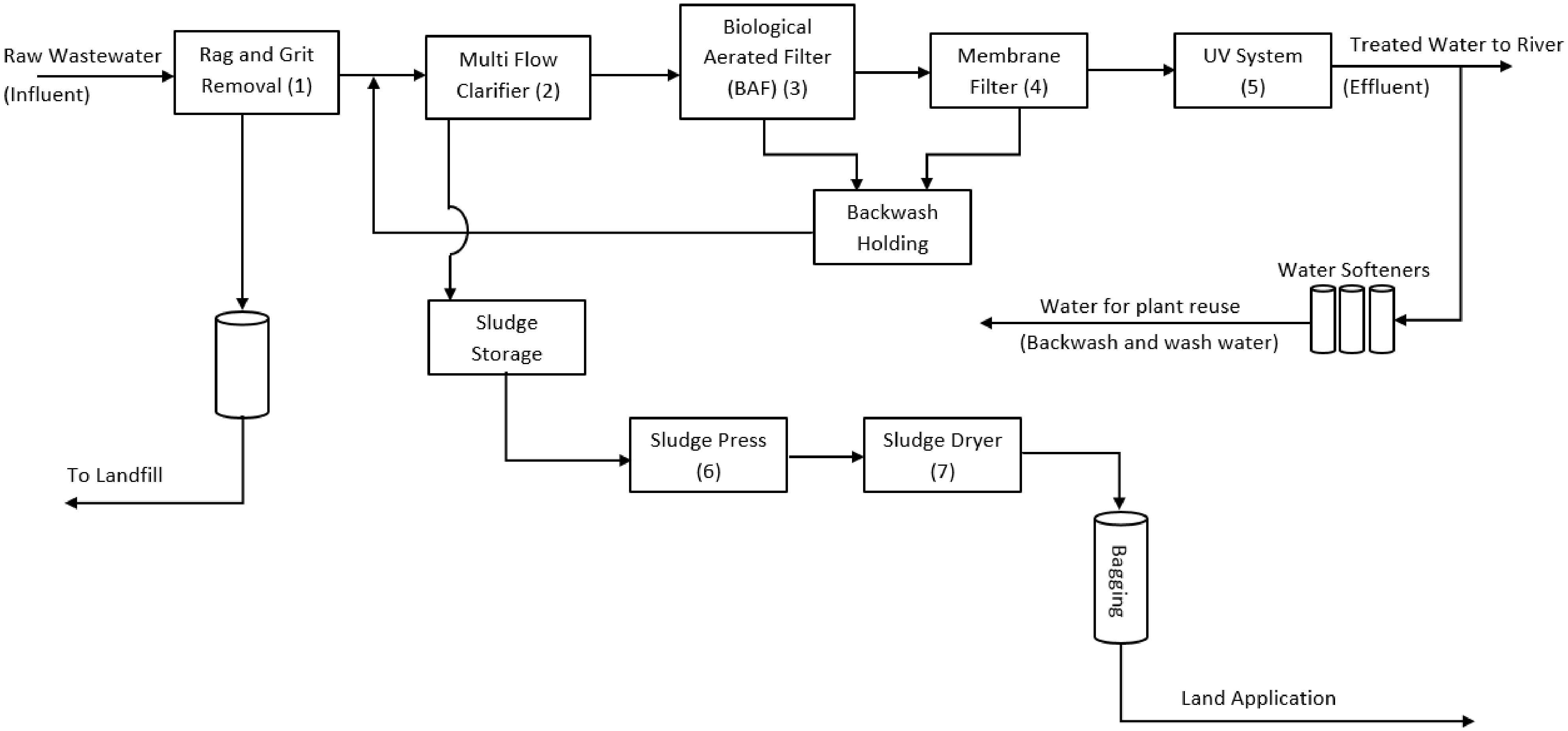
City of New Prague Wastewater Plant Flow Diagram



Air changes per hour

$$ACH = \frac{Q}{V} \times 60\,\frac{min}{hr}$$

Scrubber	Volume served [ft^3]	Scrubber Volumetric Flow Rate [ACFM]	ACH [hr^{-1}]
BAF Upper Gallery	79,250	9,500	7.2
Pretreatment	125,212	10,000	4.8
Biosolids	114,973	7,600	4.0

Fan affinity laws

$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

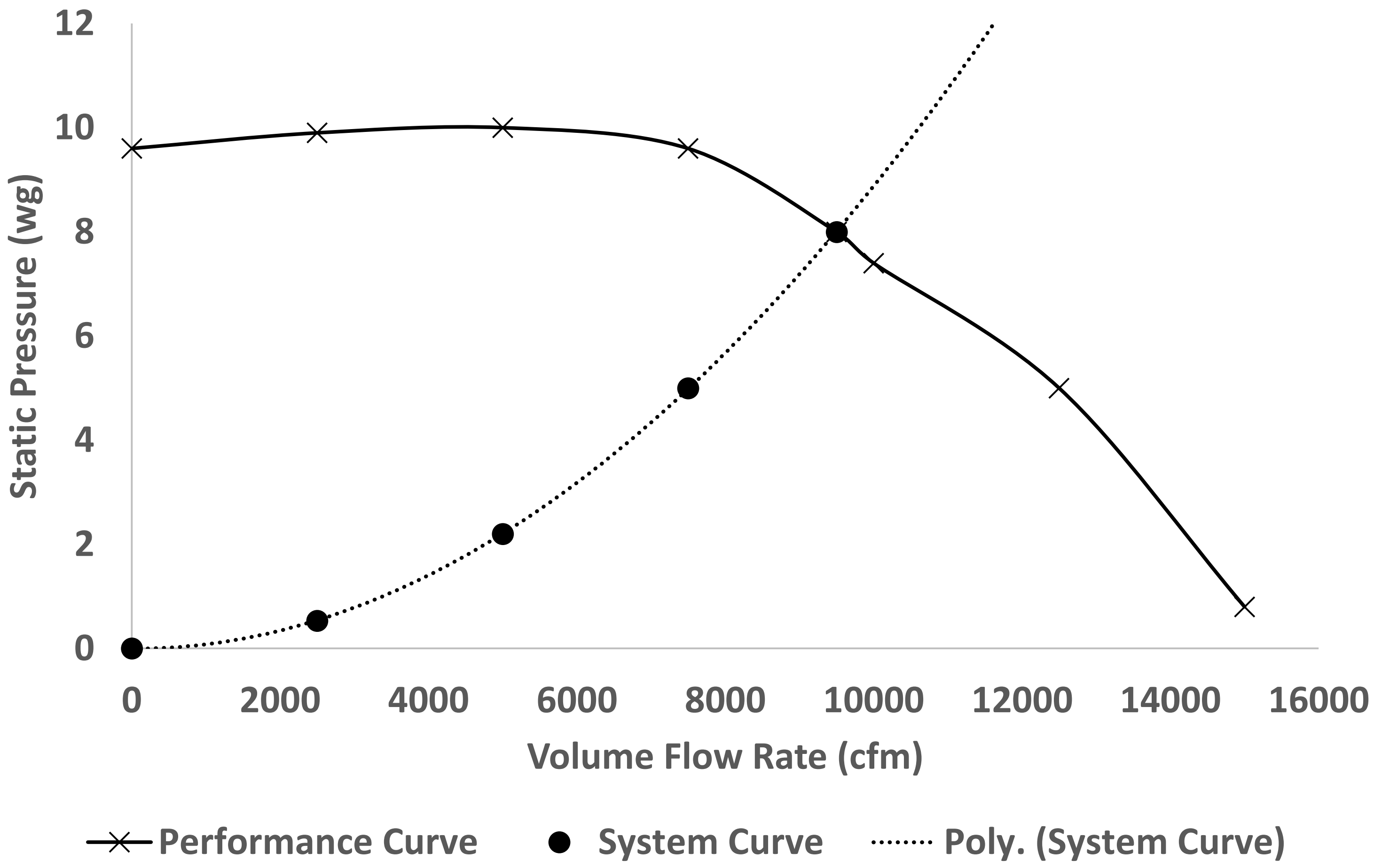
$$\frac{\Delta P_1}{\Delta P_2} = \left(\frac{n_1}{n_2}\right)^2$$

$$\frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

Calculating motor frequency

1. **Calculate new Q**
   - $Q = \frac{ACH}{V \times 60 \frac{min}{hr}}$
2. **Determine new static pressure using performance curve**
   - $SP_{4.9\ ACH} = 8.93 \times 10^{-8}\ Q_{4.9\ ACH}^{2} - 4.32 \times 10^{-6}\ Q_{4.9\ ACH} - 0.005 = 2.47$
3. **Use fan affinity law between speed and pressure**
   - $RPM_{4.9\ ACH} = \left[\frac{SP_{4.9\ ACH}}{SP_{7.2\ ACH}} RPM_{7.2\ ACH}^{2}\right]^{\frac{1}{2}}$
4. **Convert speed to frequency**
   - $f = \frac{RPM_{4\ ACH} \times p}{120}$

Scrubber fan performance curve



New Prague Effluent Requirements

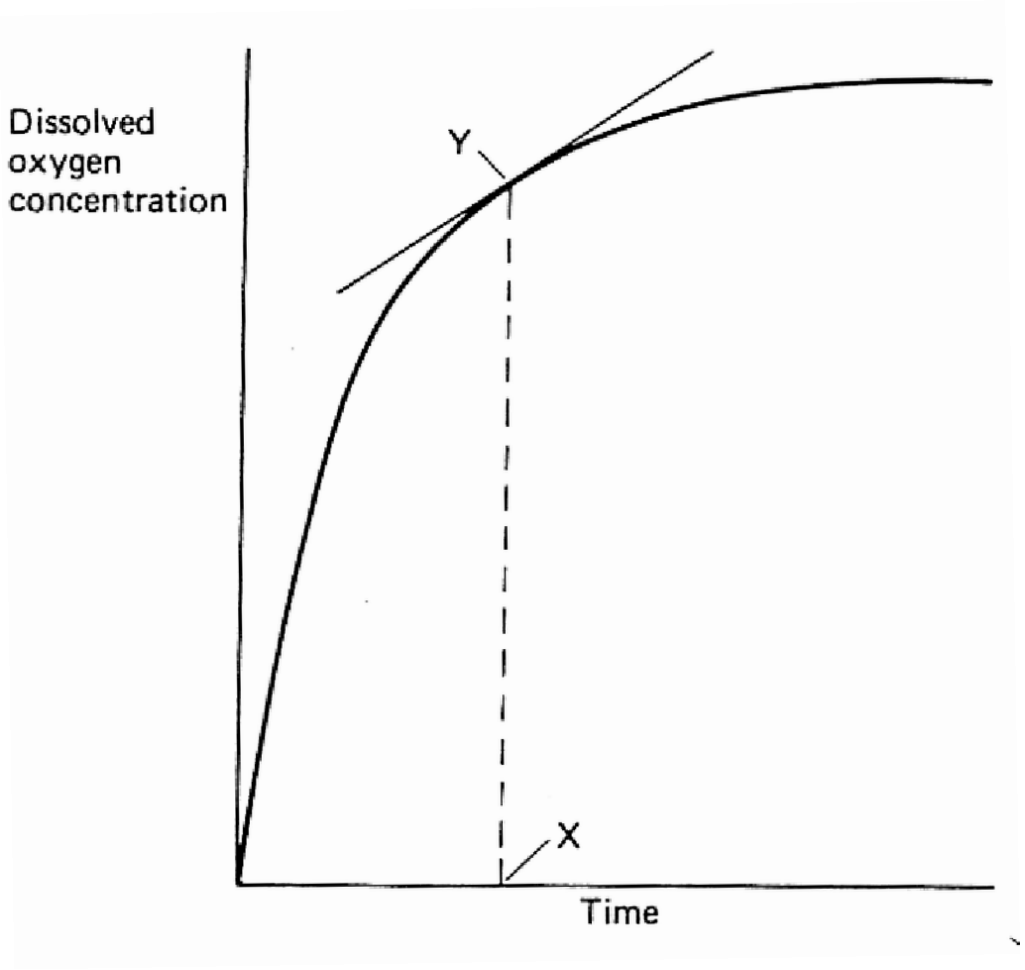
Parameter	Limit (mg/L)	Limit Type	Effective Period
Dissolved Oxygen (DO)	7	Calendar Month Minimum	Jan-Dec
Carbonaceous Biological Oxygen Demand (CBOD), 05 Day	5	Calendar Month Average	Jan-Dec
Nitrogen, Ammonia, Total	7.7	Calendar Month Average	Dec-Mar
Nitrogen, Ammonia, Total	1.3	Calendar Month Average	Apr-May
Nitrogen, Ammonia, Total	1.0	Calendar Month Average	Jun-Sep
Nitrogen, Ammonia, Total	1.9	Calendar Month Average	Oct-Nov
Total Suspended Solids (TSS)	30	Calendar Month Average	Jan-Dec

SCADA Calculations

$$V_f = \frac{Q_{inf} + Q_{BW} - Q_{sludge}}{A_{cell} + N_f}$$

$$N_F = \frac{Q_{in}}{A_{cell} + V_f}$$

Oxygen transfer rate



$$\frac{dC}{dt} = k_L a \cdot (C_{sat} - C)$$

Zhang, Wei & Li, Zheng Jian & Agblevor, Foster. (2005). Microbubble fermentation of recombinant Pichia pastoris for human serum albumin production. Process Biochemistry. 40. 2073-2078. 10.1016/j.procbio.2004.07.022.