No- & Low-Cost Plant Upgrades for WWTPs

November 9th, 2023

SEDAC
SMART ENERGY DESIGN ASSISTANCE CENTER

Providing effective energy strategies for buildings and communities

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

ILLINOIS SUSTAINABLE TECHNOLOGY CENTER
PRAIRIE RESEARCH INSTITUTE

Who We Are

We assist buildings and communities in achieving energy efficiency, saving money, and becoming more sustainable.

We are an applied research program at University of Illinois.

Our goal: Reduce the energy footprint of Illinois and beyond.

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About the IEPA PWI Energy Efficiency Program

The Illinois EPA Public Water Infrastructure Energy Assessment Program helps municipalities reduce the cost of water and wastewater treatment.

- **No-cost** energy assessments and technical assistance
- Comprehensive report listing:
  - Potential savings
  - Estimated economics
  - Funding sources
- Operator continuing education

Apply at: www.smartenergy.Illinois.edu/water

Funding provided in whole or in part by the Illinois EPA Office of Energy. This program is in partnership with the U.S. Dept. of Energy Sustainable Wastewater Infrastructure of the Future (SWIFT) Accelerator for energy efficiency in wastewater treatment.

Why Complete an Energy Assessment?

Older Existing System or No Previous Assessments?

Identify missed opportunities

Plan for capital improvements

Uncover what is possible

3rd party support for WWTP personnel's ideas

New or Recently Upgraded?

Always more to improve

Plan for future opportunities outside the scope of recent projects

New technologies and processes always in development

Identify opportunities for repairs or upgrades and associated funding!

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Apply for an Energy Assessment!

Step 1: Initial Application – Pre-Qualification

- Apply at www.sedac.org/water
- Be located in Illinois and be a publicly-owned plant
- Allow SEDAC/ISTC to visit site – Remote visit is an option!
- Be willing to share facility information
- Share final assessment report with Illinois EPA

Step 2: Data Collection

- Facility information –discharge reports, process flow, etc.
- 2 years of utility bills and DMRs
- We're here to assist!

Step 3: Site Visit Scheduled

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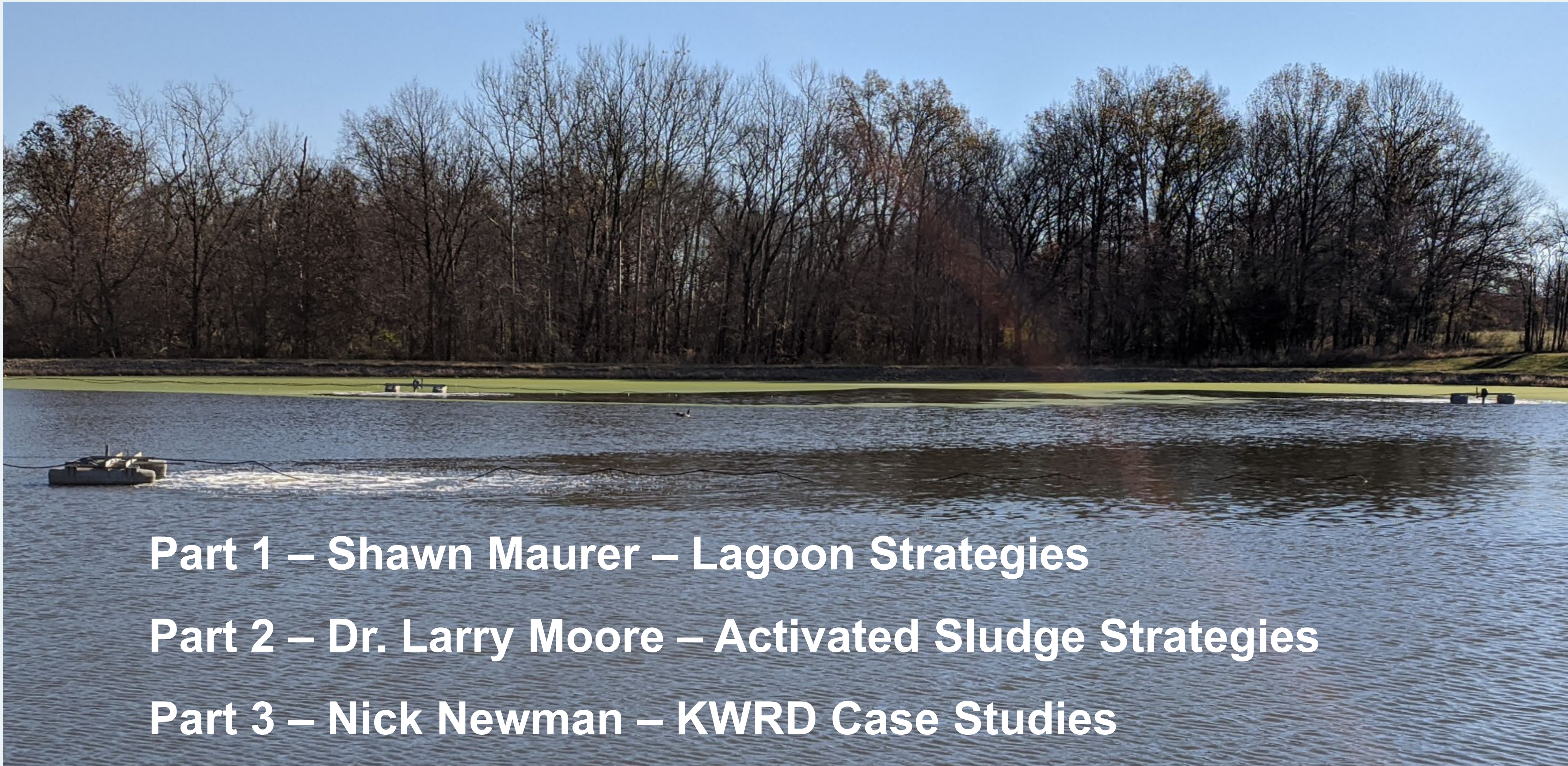
Webinar Outline



Part 1 – Shawn Maurer – Lagoon Strategies

Part 2 – Dr. Larry Moore – Activated Sludge Strategies

Part 3 – Nick Newman – KWRD Case Studies

Lagoon No- and Low-Cost Improvements

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Natural Oxygen Production & Use

- ✓ **Algae**:
  - ✓ In daytime, algae produce DO – can lessen aeration demand.
  - ✓ At night, algae consume DO and release CO2. Die-off also consumes DO.
- ✓ Aeration can be scheduled to take advantage of algal DO.
- ✓ **Air Contact/Wave Action:**
  - ✓ Surface area of lagoon and wind have a small impact on lagoon DO.
  - ✓ Generally too small to control for.

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Surface Aerators

Horizontal Jet

1.5 to 2.1 kg O_2/kW-hour

(2.5 to 3.5 lbs O_2/hp-hour)

EPA Aerated, Partially Mixed Lagoons Tech Sheet
https://www3.epa.gov/npdes/pubs/apartlag.pdf

By the numbers, we'd expect to run **7-20 HP** 24 hours for a plant with ~300 # BOD/day

Horizontal Aspirator

Vertical Splash

Images courtesy Triplepoint™

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Sub-Surface Aerators

Fine Bubble

Coarse Bubble

3.7 to 4 kg O_2/kW-hour

(6 to 6.5 lbs O_2/hp-hour)

EPA Aerated, Partially Mixed Lagoons Tech Sheet
https://www3.epa.gov/npdes/pubs/apartlag.pdf

At standard conditions, we'd expect to run only **~5-8 HP** 24 hours for a plant with ~300 # BOD/day

Images courtesy of Water Online and Cole-Parmer

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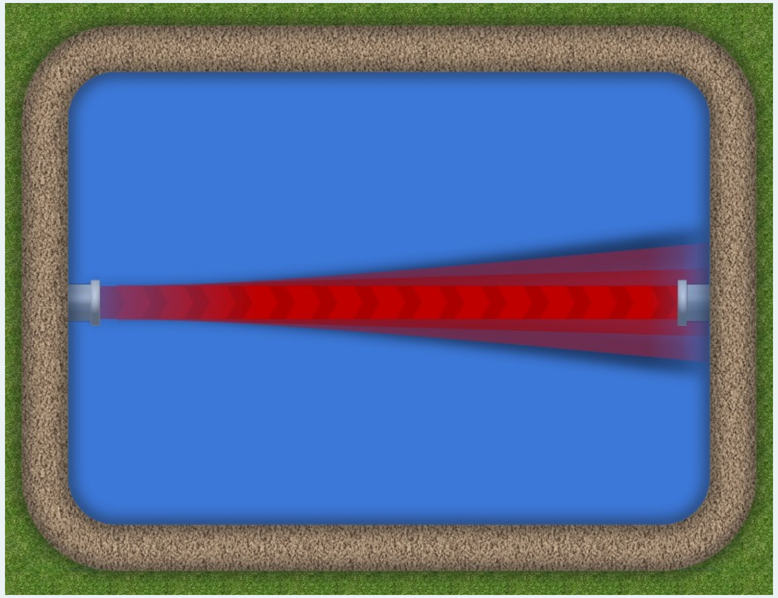
Aerator Locations

- Dependent on lagoon influent and effluent pipes, wind direction, sludge accumulation, and aerator locations.
- Surface aerators can be used to disrupt short circuit flows, increasing retention time and improving treatment.
- Possible, but more difficult to do with subsurface aerators.



Short Circuiting Reduces Treatment Time and Quality

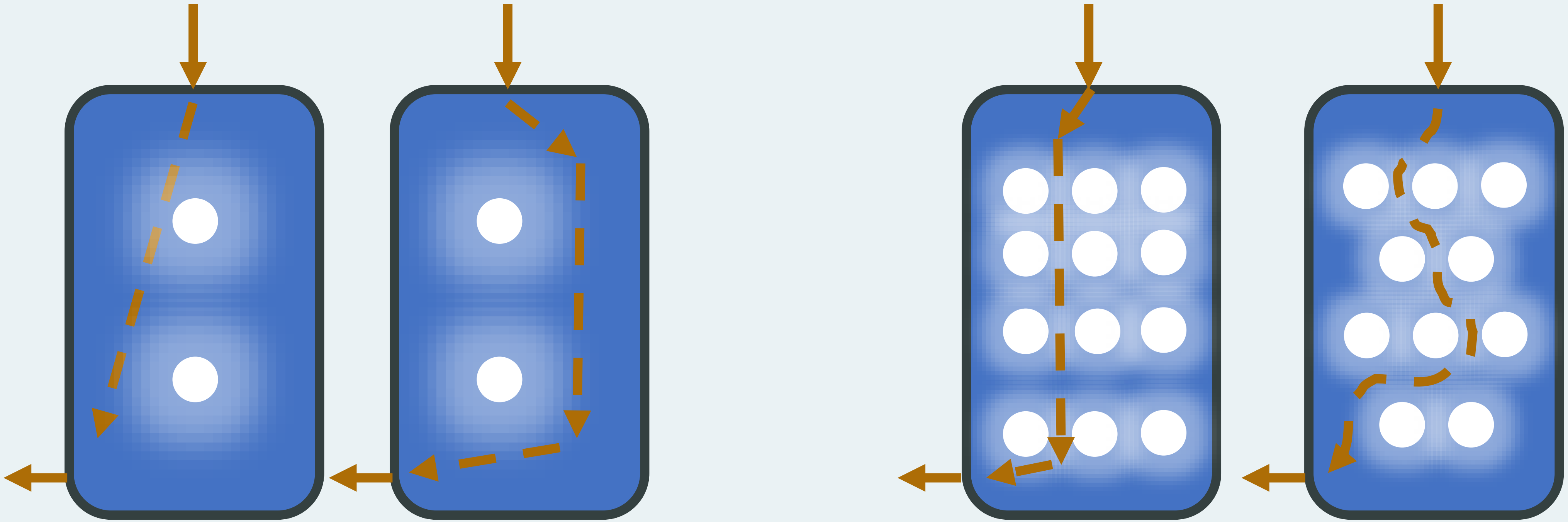
Image Sources:
Short circuit: www.lagoons.com/blog/industrial-wastewater/causes-of-lagoon-short-circuit/
Good Detention Time: https://www.wwdmag.com/operations-maintenance/what-process-short-circuiting-water how-combat-it

Good Flow Ensures Full Detention Time and Treatment

Effective Mixing

Short-circuiting can be corrected by adjusting mixer/aerator placement

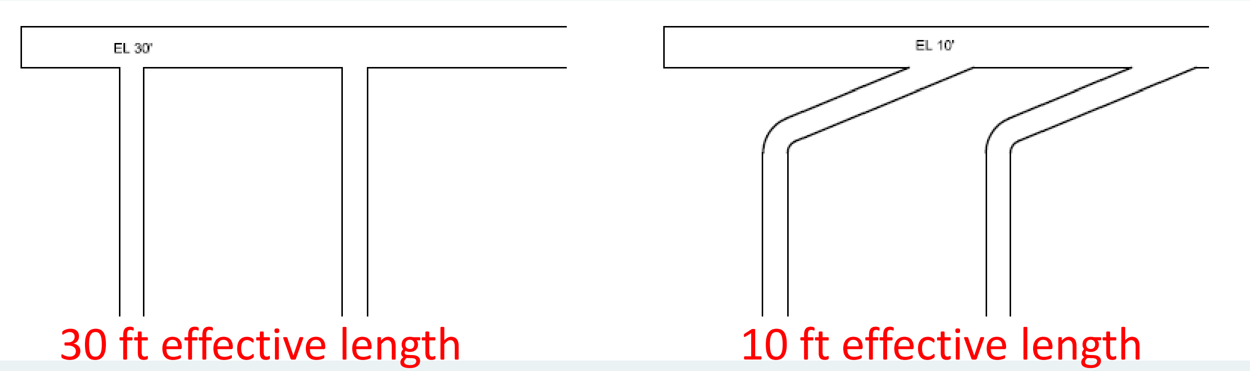
Examples:

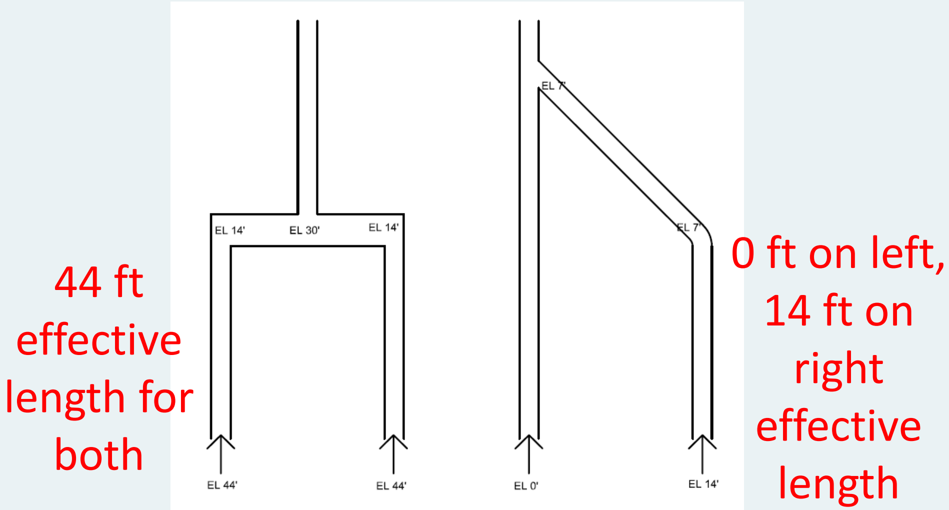


Early Design Decisions

Design aeration piping with low-friction elements

- 45-degree elbows instead of 90’s
- Y’s instead of T’s
- Slight increase in pipe diameter
  - Balance added material cost with long-term energy savings





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Time Clocks

Time clocks are an affordable and simple way to control aeration energy input where blowers are easily turned on and off.

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Variable Frequency Drives (VFDs)

Have VFDs already?

- Are they reducing aeration/pumping energy use?
- Check for manual vs automatic operation!

Automation for Lagoons?

Locating DO sensors can be tricky:

- Effluent of each cell can indicate cell's overall performance
- Generally, need combination of tests to understand lagoon aeration needs, though
  - Ammonia
  - DO
  - TSS

Can help to automate aeration choices

Also have seen flow-paced aeration control for lagoons

Images courtesy https://sensorex.com/dissolved-oxygen/

Questions?

sedac-info@illinois.edu
800-214-7954

www.smartenergy.Illinois.edu/water

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No- and Low-Cost Options for Improving Activated Sludge:

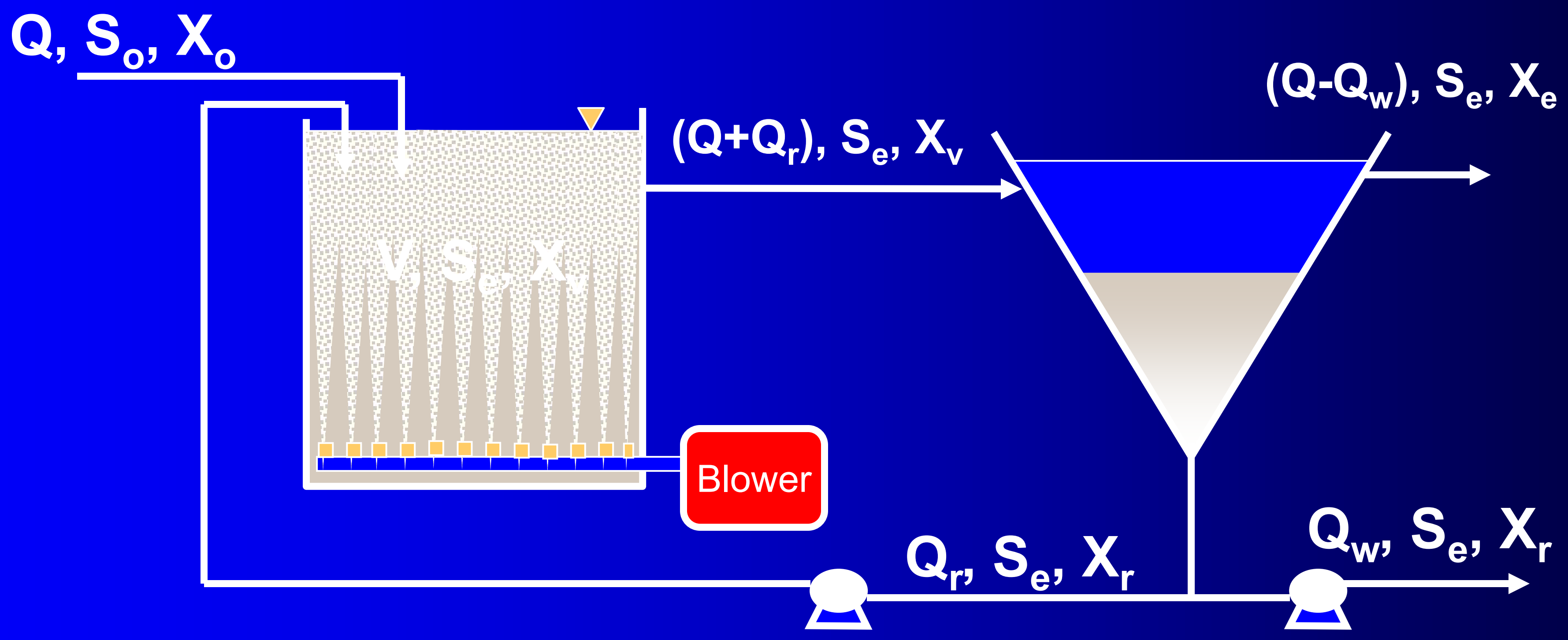
Save Energy; Save Money; Reduce Nutrient Discharge

Larry W. Moore, Ph.D., P.E., WEF Fellow

Outline

I. Automatic DO Control
II. Facilitating Denitrification in Oxidation Ditches
III. Facilitating Denitrification in Sequencing Batch Reactors (SBRs)

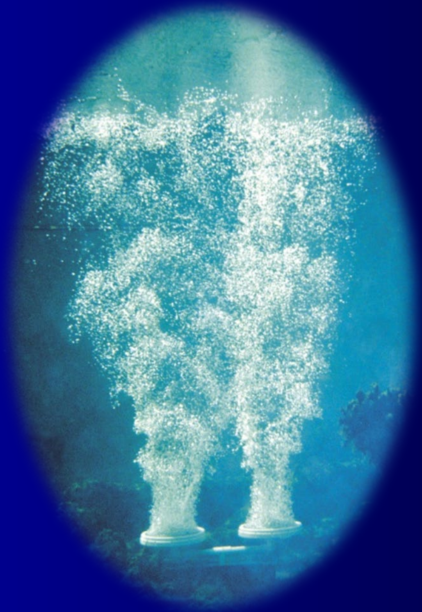
Activated Sludge Basic Schematic



I. Enhance the Activated Sludge Process by Automatically Controlling the Aeration System

Aeration Devices

Overall, aeration devices used for the activated sludge system represent the most significant consumers of energy within a WWTP.



Automated DO Control

- A WWTP may save considerable energy by quickly adjusting to variable conditions within the basin
- Oxygen required for biotreatment is proportional to organic and ammonia loading in the influent wastewater.
- Oxygen demand for aeration dips in the middle of the night and peaks in the morning and evening.

Automated DO Control

- Tight DO control can save a WWTP between **10% and 30% of total energy costs.**
- Energy savings will be site specific and are highly dependent on the control system in place prior to the upgrade to automated process control.
- The payback period for installing automated DO control is typically a few years.

How Automatic DO Control Works

- These systems use real-time dissolved oxygen (DO) concentration readings from DO probes located within the aeration basins as inputs to a process controller.
- The process controller provides control output to the aeration system that responds by:
  - adjusting surface aerator or blower speed
  - turning surface aerators off and on
  - adjusting variable vane diffusers on blowers
  - adjusting the position of drop-leg control valves to deliver the proper air amount

Automated DO Control Systems

- They typically use some form of a feedback control loop, whereby aeration system output is manipulated in response to changes in the DO level in the aeration basin.
- Control strategies can be very simple, such as on on-off or setpoint control, or complex based on proprietary algorithms.

II. Enhance Oxidation Ditch Processes by Facilitating Denitrification

Organisms and Their Means of Respiration

- Aerobic - use elemental oxygen
- Anoxic - use nitrate (NO_3) or nitrite (NO_2)
- Anaerobic - use other terminal electron acceptors (SO_4 , CO_2) or none at all
- Facultative - two or more means of respiration
- Fermentative - no terminal electron acceptor

Denitrification

- Heterotrophic
- Anoxic (facultative)

Factors Affecting Denitrification

- **Substrate degradability**
- pH
- **Dissolved oxygen**
- Temperature

Benefits of Denitrification

- Denitrification significantly reduces Total N loading on the receiving stream
- Denitrification generates 3.57 lb alkalinity per lb nitrate-N converted to N gas
- Denitrification saves 2.86 lb oxygen per lb nitrate-N converted to N gas
- Denitrification can reduce total oxygen requirements 10% to 15%

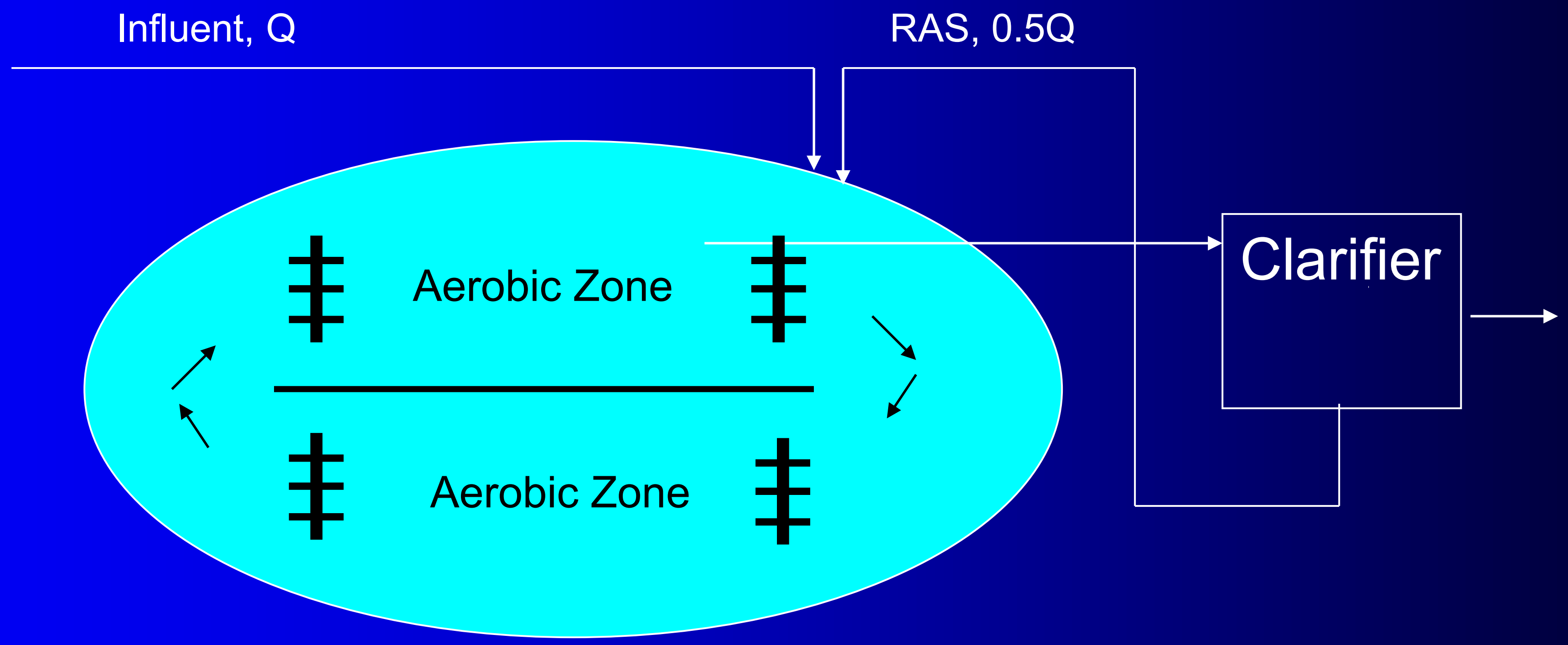
Impact of DO on Denitrification Rates

DO Conc, mg/L	Relative Denitrification Rate
0.0	100%
0.1	40%
0.2	20%
0.3	10%

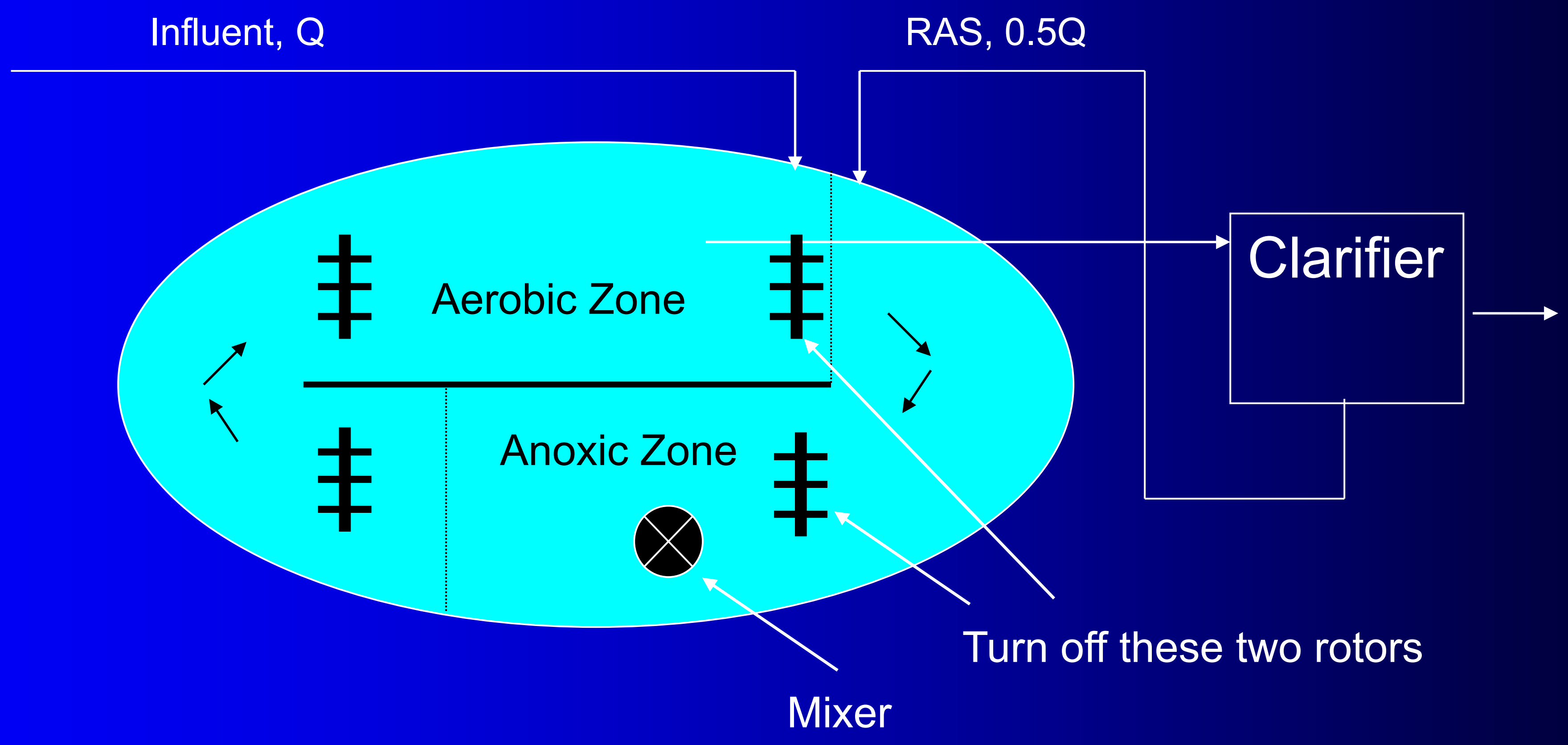
WWTP Changes to Achieve Denitrification in Extended Aeration Systems

- Modify oxidation ditch to provide anoxic and aerobic zones
- Modify oxidation ditch operation with on/off aeration cycles to achieve denitrification
- Modify SBR system to include anoxic and aerobic cycles

Oxidation Ditch Before Modification



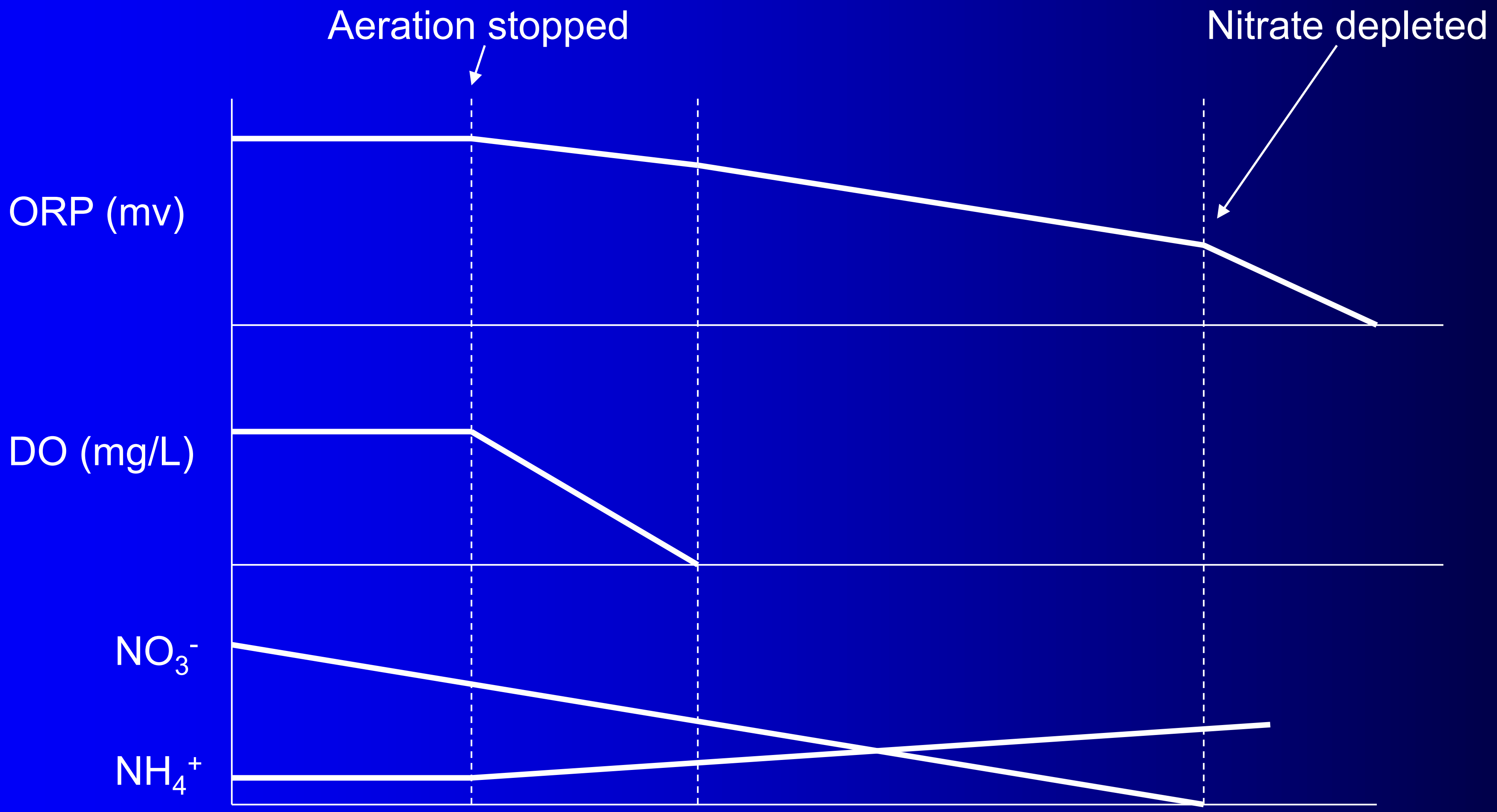
Oxidation Ditch After Modification



Intermittent Aeration for N Removal in Oxidation Ditch

- Cycle time for on/off operation of aerators may vary
- Process control with DO and ORP monitoring
- When aerator is off, must provide mixing
- During off period, oxidation ditch becomes anoxic reactor, and nitrate is consumed as bacteria degrade BOD
- ORP data are used to terminate off cycle and start aeration

Change in ORP and DO in On/Off Operation



Factors Affecting On/Off Operation

- Oxidation ditch HRT
- Influent flow rate
- TKN and BOD concentrations
- Number of on/off cycles per day
- Ditch MLSS concentration

Nitrogen Removal in Oxidation Ditch

Expected Effluent Quality:

BOD_5	5 - 15 mg/L
TSS	10 - 20 mg/L
Ammonia-N	< 1 mg/L
NO_x-N	5 - 10 mg/L
Total N	7 - 14 mg/L

III. Enhance SBR Processes by Facilitating Denitrification

Nitrogen Removal in SBRs

- Use anoxic and aerobic cycles to effectively remove nitrogen
- Cycles are:
  - Fill (anoxic)
  - React (aerobic/anoxic)
  - Settle
  - Decant

Nitrogen Removal in SBRs

Expected Effluent Quality:

BOD_5	3 - 10 mg/L
TSS	5 - 15 mg/L
Ammonia-N	< 1 mg/L
NO_x-N	3 - 10 mg/L
Total N	5 - 12 mg/L

Kishwaukee Water Reclamation District

No/Low-Cost Energy Projects

Kishwaukee WRD

- <u>**General Background**</u>
  - DeKalb Sanitary District (1928)
  - Serves Community of 45,000
    - DeKalb, Malta
    - NIU, Kishwaukee College
    - Unincorporated DeKalb Co.
  - Rated 8.63 MGD
  - Average Daily Flow = 5 MGD
  - 185 Miles of Public Sewer, 11 Pumping Stations

KISHWAUKEE WATER RECLAMATION DISTRICT

Origins of Energy Improvements

- **KWRD recently completed Ph. 1B Improvements Project**
  - Gave more controls, sensing, and ability to better experiment with process
  - On-site power production
- **Openness to innovation and change from administration**
- **Began engaging in ComEd Strategic Energy Management (SEM) Program in Feb 2022**
  - Volunteer program for O&M energy reductions at WWTPs

On-Site Energy Production

Two 375 kW CHP Units use biogas from treatment process

- Capable of producing roughly 115% of KWRD's power

SEM Platform as Launchpad

Project Overview/Implementation

- Actively driving plant and questioning how things are done
- "Tweak and Peak"; uncomfortable is ok
- Common project types: setpoints, runtimes, and S.O.P.s

66 Total Projects: Potential Savings | 0 kWh/yr Electricity Savings | $ 0 /yr Avoided Cost | 0 Metric Tons CO_2e/yr Avoided Emissions

★	#	Name	Status	Due/Completion Date
☆	1	Quantify amp draw of centrifuge boosters Gem | Non-potable Water	On Hold	
★	2	Lower DO Setpoints Gem | Secondary Treatment	In Progress	
☆	3	Turn off heat in sand filter building Gem | HVAC	Complete	Complete 2022-06-24
☆	4	Reduce runtime of secondary digester mixers Gem | Digestion	In Progress	
★	5	Reduce WAS tank blower 1401/1402 pressure and air flow - P Gem | Aeration System	Complete	Complete 2023-01-11
☆	6	Reduce runtime of primary sludge pumps Gem | Primary Treatment	Complete	Complete 2022-10-31
☆	7	Reduce runtime of digested sludge storage mixing pump Gem | Digestion	Complete	Complete 2022-05-09
☆	8	Reduce run time of phos tank mixers Gem | Secondary Treatment	Complete	Complete 2022-05-27

KISHWAUKEE WATER RECLAMATION DISTRICT

Project Spotlight - Raw Wet Well Level

- **Raw wet well level previously set to 5.5ft**
- **Slowly raised to 8ft over two years (2.5ft increase)**
- **Resulted in reduction from 156.5 to 150.6 amps**
  - Power supply runs at 480 - 3 phase
- **Generally equates to 10% overall power reduction; potential annual savings of 65,700 kWh**
  - = $5,256/year

Before

After

Project Spotlight - Secondary Digester Mixer Runtime Reductions

- **KWRD has four anaerobic digesters**
  - Two secondary digesters, 50hp mixer motors
- **Previously running for cycle of 75 min on/15 off; now 45 on/30 off**
  - Total runtime reduction of 8.5 hours per day
- **Potential annual savings of 232,000 kWh**
  - = $18,560/year

Project Spotlight - UV System Optimization

- **UV disinfection system operational between May and October (6 months)**
- **Implementing setpoint adjustments and more frequent cleaning since May 2023**
- **Estimated annual savings of 141,500 kWh**
  - Average decrease in power consumption of 800 kWh/day
  - = $11,320/year

Projects Overview (cont.)

- Turn off AHU in unoccupied spaces
- Reduce WAS tank blower pressure and airflow (50% to 30% flow; 10hr/day)
- Reduce pressure of NPW booster pumps (90 psi to 75 psi)
- Boiler recirculation pumps speed reduction (275 gpm to 175 gpm)
- Turn off air to WAS storage tank during off-hours
- TWAS pump speed reduction (45 gpm to 30 gpm)

Non-Energy Impacts

Improved Equipment Lifespan

- Reduced runtimes/load extend equipment lifespan

Changes to Labor Hours

- Need to assess and address risk of backsliding
- Has not changed required labor hours quantifiably in long-term (at first perhaps)

District-Wide Enthusiasm and Involvement

- The entire staff has become more aware and involved of how plant functions
- Always looking for new improvements

Final Considerations

Balancing Innovation and Plant Health

- Openness to change at all levels (District-wide engagement)
- Small, incremental changes
- Plant health/operation is paramount

Project Persistence and Thinking Long-term

- Need to assess and address risk of backsliding
- Getting everyone aware and involved

Questions?

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