Improving Energy Efficiency and Effluent Quality and Reducing Operating Costs by Controlling Nitrification and Denitrification Through Operational Modifications

Presented by:

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Co-Authors

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  – Robert Sobeck, P.E.
- Rothberg, Tamburini & Winsor, Inc.
  – Ronald G. Schuyler

Purpose

- Good Effluent Quality
  - Improve effluent quality while saving money
- Minimize Construction Costs
  - No additional construction required
- Save Money
  - Power savings
  - Chemical savings
  - Increased energy efficiency

Outline

- Introduction
- Good Effluent Quality
- Review Issues Facing RVRSA
  - Stringent permit limits
  - Increasing flow and BOD loading
- Solution: Operational Process Control
  - Resolve issues facing plant
- Cost and Energy Savings
- Other Benefits

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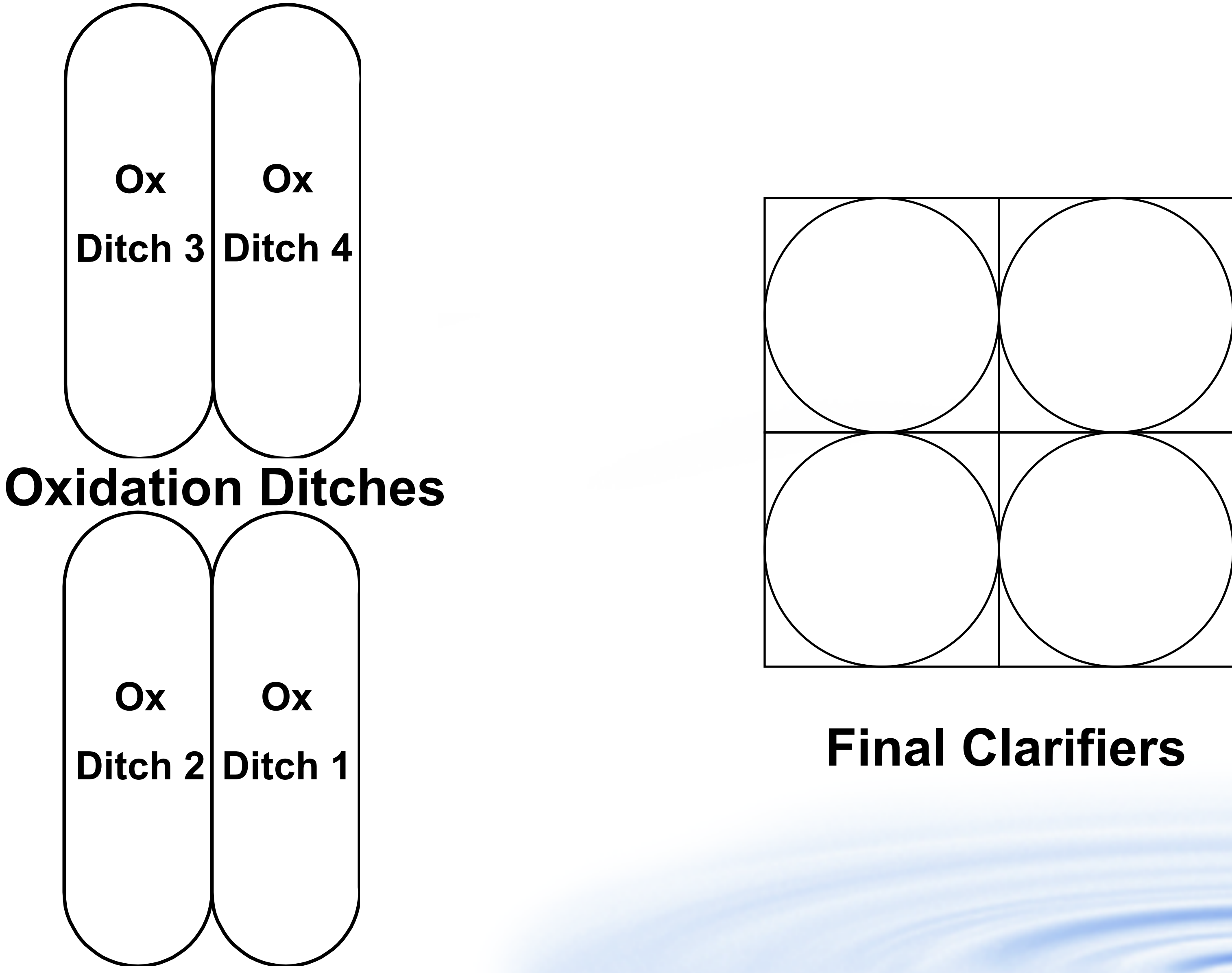
Introduction: General

- Rockaway Valley Regional Sewerage Authority
- Configuration
  - Extended air, oxidation ditches
- Aeration: Rotating brush – no VFDs
- Discharge: Passaic River
- Contacts
  - Executive Director: Edward Ho, P.E.
  - Operations Supervisor: Robert Sobeck, P.E.

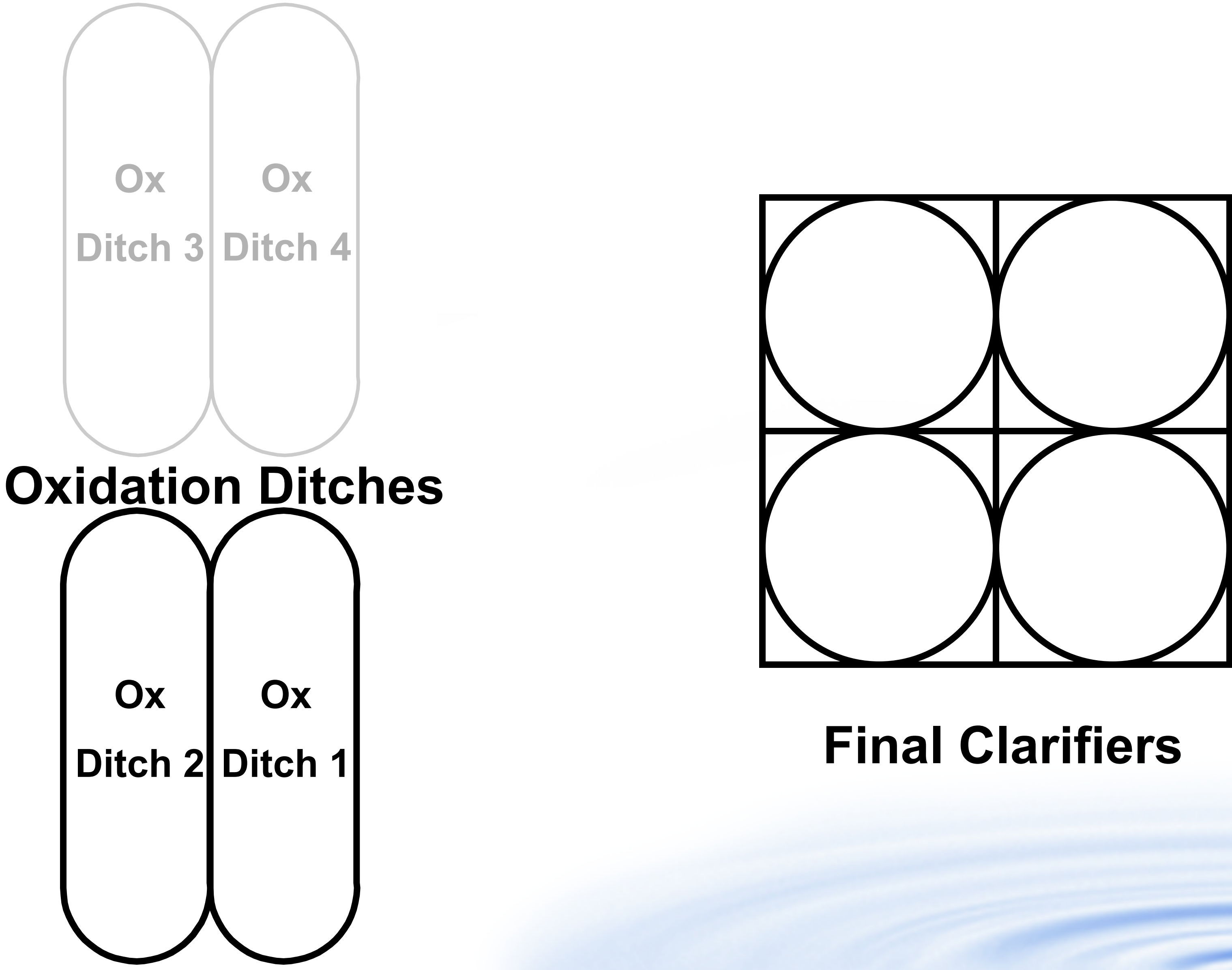
Introduction: Plant Schematic



Introduction: Initial Design Criteria

- Original Rated Capacity: 12.0 MGD
- Design Loadings
  - HRT: 22 hrs
  - Organic Loading: 15.1 lbs cBOD/1000ft^3/d
  - Clarifiers: 382 gal/ft^2/d
- Original Operating Parameters
  - MCRT: 10+ days
  - MLSS: <2,000 mg/L

Introduction: Current Operation



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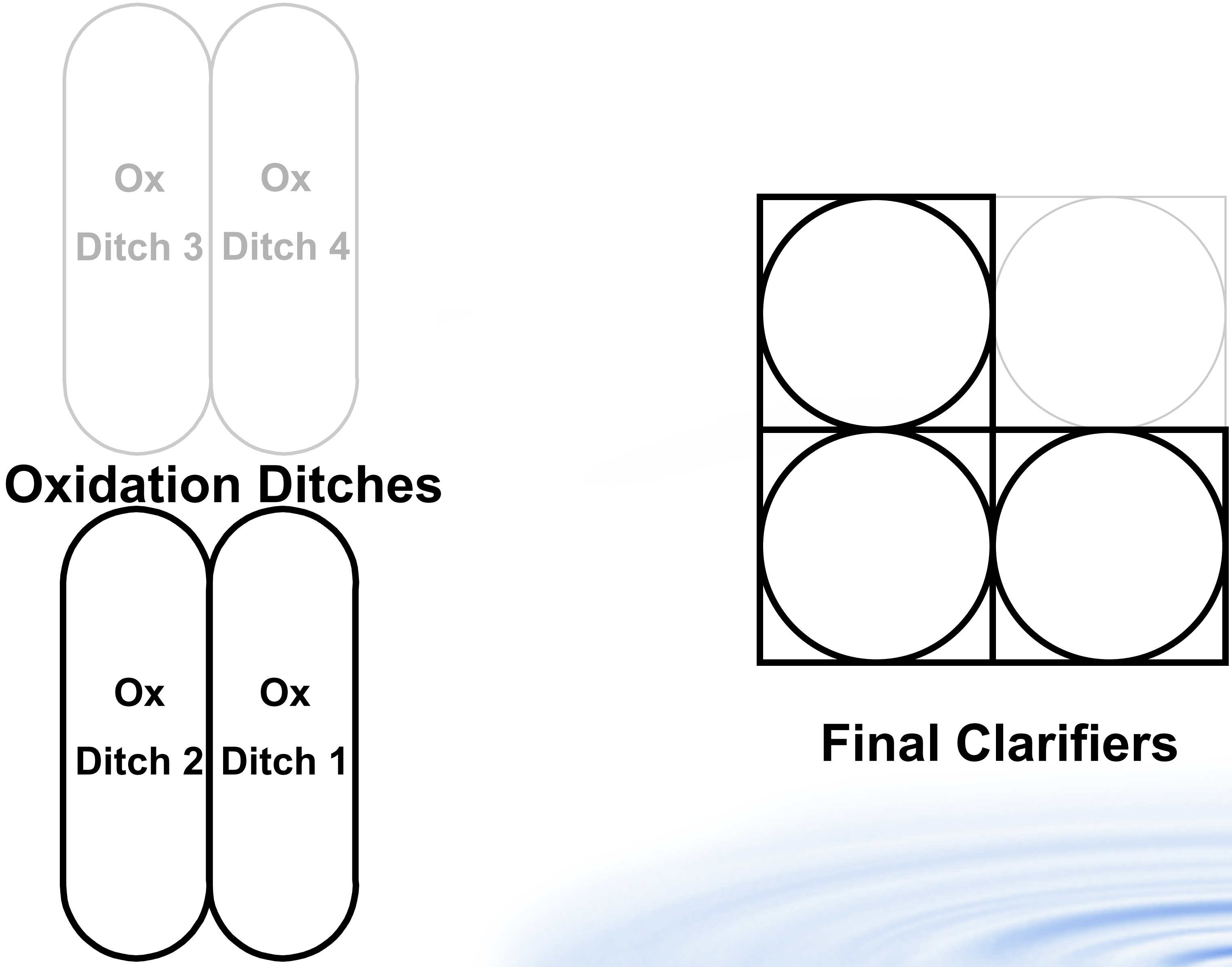

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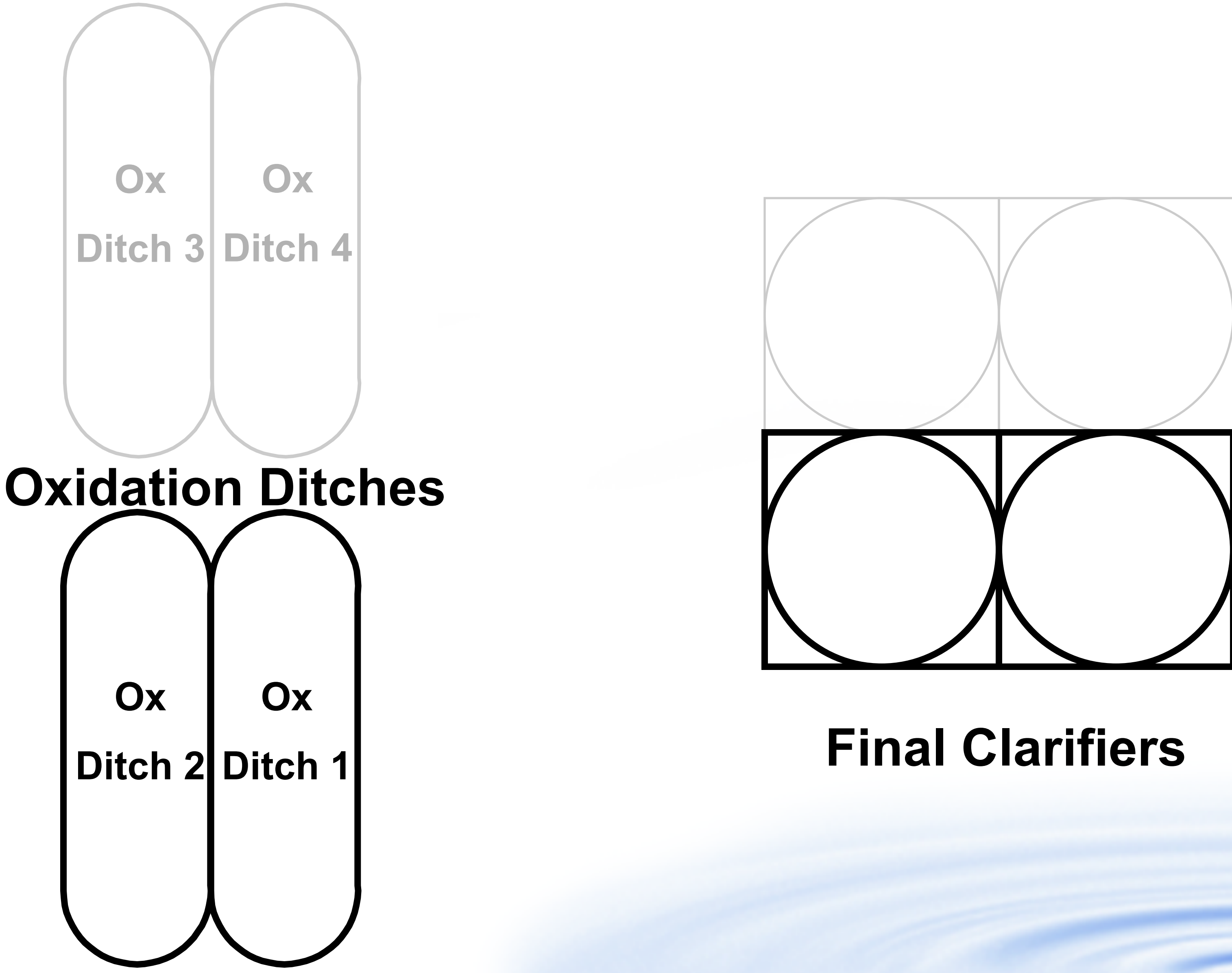
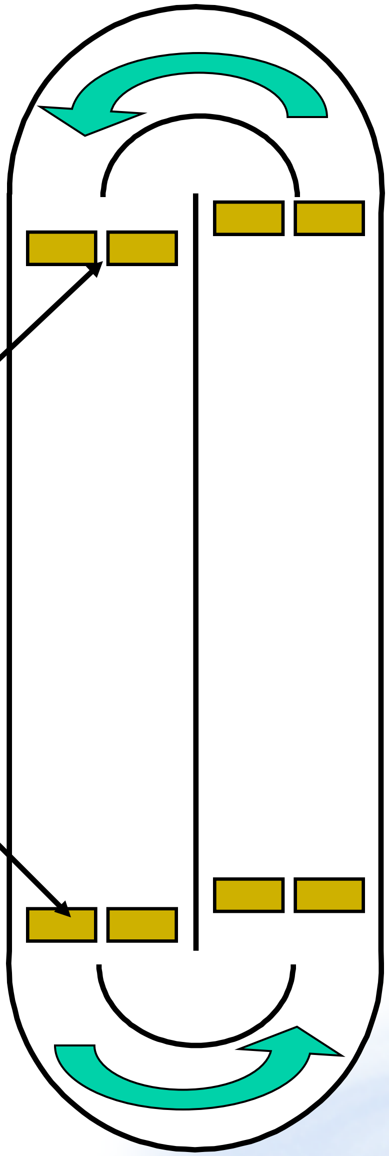
Introduction: Current Operation



Introduction: Oxidation Ditches



Rotating Brush Aerators

4 Aerators per ditch

- 100 hp per aerator

Good Effluent Quality: What is it?

- What is good effluent?
  - Meets permit limits?
  - Exceeds permit limits
  - Also: **Economical**
- What is necessary to make good effluent?
  - Capable plant
  - Proper process control

Good Effluent Quality: Permit Limits

- Permit Effluent Limits (monthly average)
  - cBOD: 8 mg/L
  - TSS: 30 mg/L
  - NH_3-N: May-Oct 1.8 mg/L
    Nov-Apr 6.0 mg/L
  - TMDLs recently established for Total Phosphorus
    - Possible future TP limit ~0.8 mg/L
- Currently No Total Nitrogen Limit

Issues Facing RVRSA

- Stringent permit limits
- Increasing influent flow
- Increasing BOD loading
- High nitrate in Passaic river
- Denitrification occurring in clarifiers

Issues Facing RVRSA: Increasing Flow and BOD Loading

- Increasing influent flow
  - Flows from ~9 MGD in 1990's
  - Current daily average flow 11 MGD
- Increasing BOD loading
  - Tighter sanitary sewers
  - Water conservation products

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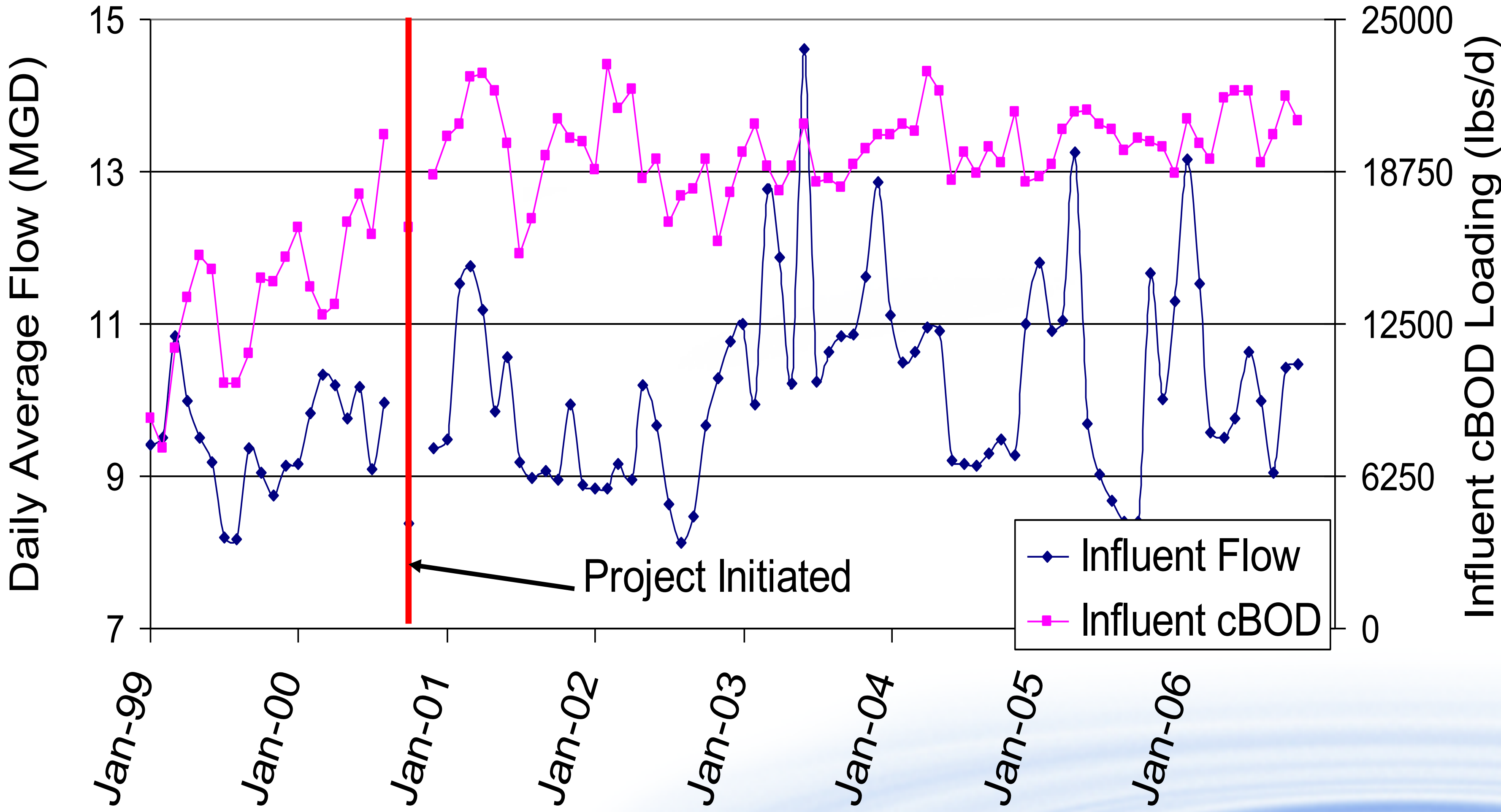
Issues Facing RVRSA: Increasing BOD Loading



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Issues Facing RVRSA: Nitrate Problems

- High NO_3-N in Passaic River
  - River nitrate concentration approaching or exceeding 10 mg/L drinking water limit
  - Possible reasons
    - Nitrification requirement for all treatment plants upstream of RVRSA
    - Drought conditions

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Issues Facing RVRSA: Denitrification

- Denitrification in the clarifiers
  - "Squircles"
  - Poor settling due to filaments
  - Periodic incomplete nitrification
    - some NH_3-N violations
  - Difficulty controlling rising blankets
    - had three or four clarifiers online

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Possible Solutions: What RVRSA Could Have Done

- Use third oxidation ditch for additional cBOD loading
  - Increases aeration hp 50%
- Denitrify with mixed liquor recycle
  - Add anoxic tank
  - Additional pumping costs

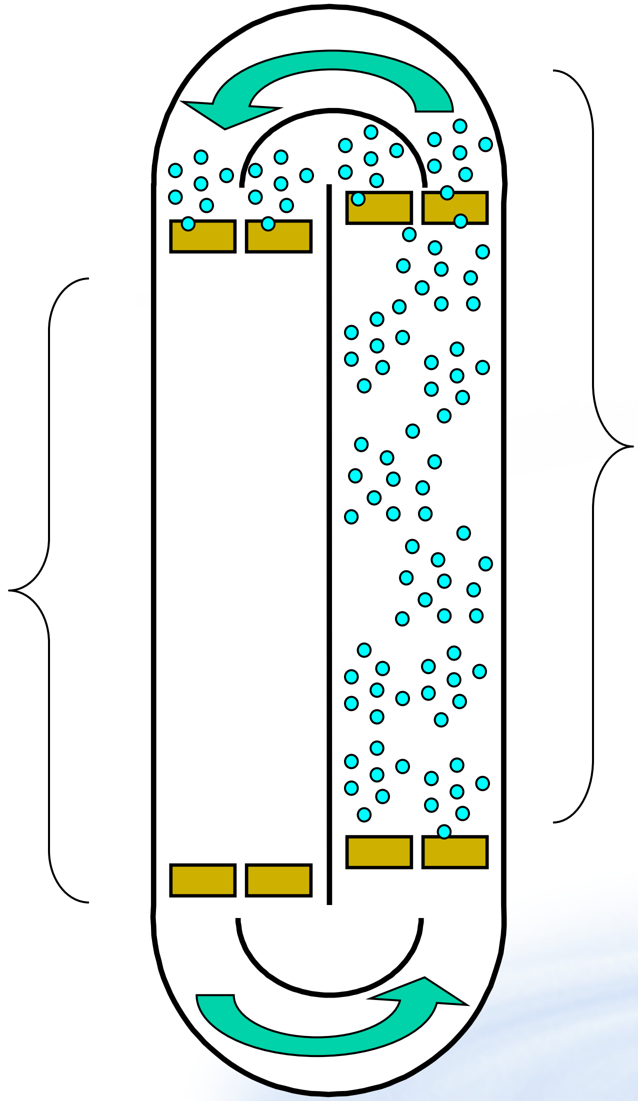
Solution: Tight Operational Process Control

- Process control expert: Bob Sobeck
- Nitrification & denitrification in ditches
  - High DO and low DO zones
  - Turn off some brush aerators
- Take one to two clarifiers offline
- Improved Process Control
  - Better nitrification
  - Increase cBOD loading to ditches
  - More aeration during high NH_3-N loading

Solution:
Denitrification in Oxidation Ditches

Anoxic Zone

Organics + NO_3^- $\rightarrow N_2$



Aerobic Zone

Organics + $O_2 \rightarrow CO_2$

$NH_3 + O_2 \rightarrow NO_3^-$

Solution: Denitrification in Oxidation Ditches

- Nitrification & Denitrification in Ditches
  - High DO and low DO zones
  - Lower overall average DO
- Methods of Control
  - Ditch effluent ammonia and nitrate several times a day
    - reduce aeration during low NH_3 loading
  - DO control
  - ORP could be used, other applications

Solution: Increased Process Control

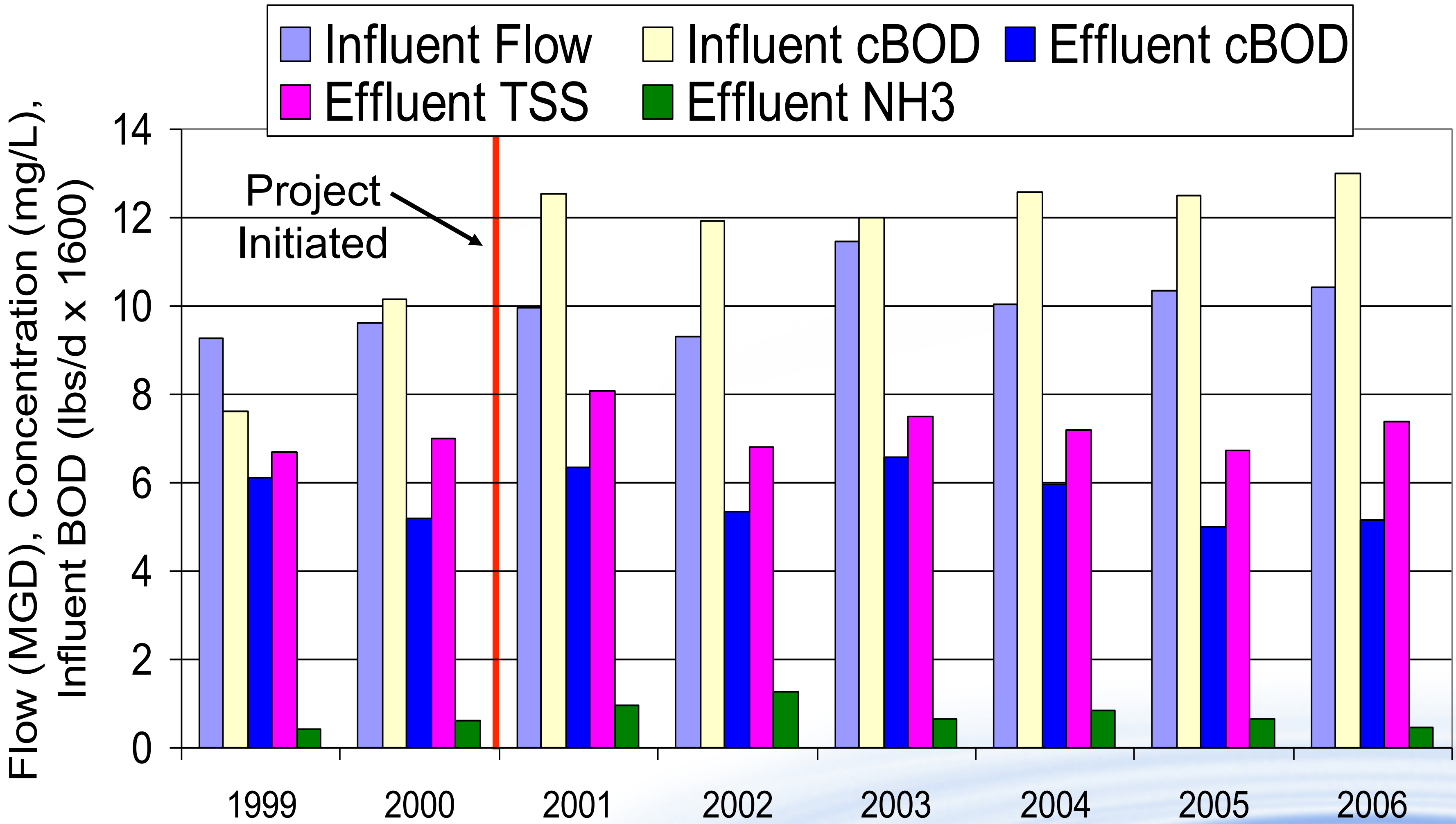
- Process Control
  - Increase MLSS in the aeration basins to meet increased cBOD loading
  - Allow for better nitrifier growth
  - Requires more aeration time during high NH_3-N loading
- Methods of Control
  - Wasting flow, waste concentration
  - Solids inventory

Solution: Current vs. Design

- Comparison of current operational parameters and design parameters

Parameter	Design	Current
HRT, hrs	22.0	12.9
Organic Loading, lbsBOD/1000ft^3/d	15.1	27.0
Clarifiers, gal/ft^2/d	382	700
MCRT, days	10+	10
MLSS, mg/L	<2,000	2,400

Solution:
Maintaining Excellent Effluent Quality



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Cost and Energy Savings: Direct Savings

- On/Off Aeration Power Savings
  - 800 hp available (in the two online ditches)
  - Estimated 560 hp used on average
    - More at higher NH3 loading
    - Less at lower NH3 loading

$$240\,hp \times \frac{24\,hr}{day} \times \frac{0.746\,kW}{hp} \times \frac{\$0.08}{kW \cdot hr} = \$344 / d$$

  - Savings: $125,000 / yr

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Cost and Energy Savings: Direct Savings

- Keeping 3rd Ditch Offline
  - 200 hp necessary

$$200\,hp \times \frac{24\,hr}{day} \times \frac{0.746\,kW}{hp} \times \frac{\$0.08}{kW \cdot hr} = \$286/d$$

  - Savings: $105,000 / yr
- Total Energy Savings: $230,000 / yr

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Cost and Energy Savings: Indirect Savings

- Increased oxygen transfer efficiency

$$AOTE = SOTE \cdot \alpha \cdot \frac{\left(\beta \cdot C_{SW} - C_L\right)}{9.17\ mg/L} \cdot \theta^{(T-20)}$$

  - At 1000' and 20°C: β = 0.95 and C_{SW} = 8.9
  - At DO = 2.0 mg/L, $\frac{(0.95 \times 8.9 - 2.0)}{9.17} = 0.70$
  - At DO = 1.0 mg/L, $\frac{(0.95 \times 8.9 - 1.0)}{9.17} = 0.81$
  - Increase in efficiency of 16%

Other Benefits

- Reduces chlorine usage
  - Chlorine gas used as disinfectant
  - Less nitrite remaining in effluent to consume chlorine residual
  - Decreased 11%
- Significantly less nitrate to river
  - Not a permit requirement
- Re-rated WWTP
  - Increased the permitted capacity of WWTP from 12.0 MGD to 15.9 MGD

Other Benefits: Phosphorus Removal

- Presently TP to 1.5 mg/L
- Future Enhanced Biological Nutrient Removal
  - Add anaerobic tank ahead of oxidation ditches
  - TP reliably under 1.0 mg/L w/o chemical
- Future Coagulation and Filtration
  - Add aluminum or iron salt
  - Cloth filters (or sand filters) for TP as low as 0.2 mg/L

Questions

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