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Operation of Activated Sludge Nitrification

Paul Dombrowski, Woodard & Curran, Inc.
Spencer Snowling, Hydromantis, Inc.

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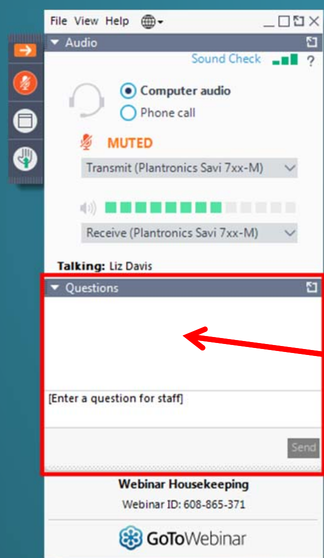
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Paul Dombrowski, PE, BCEE, F.WEF, Grade 6 Operator (MA)

Chief Technologist
Woodard & Curran, Inc.

WOODARD & CURRAN

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Spencer Snowling, Ph.D, P.Eng

V.P., Product Development

Hydromantis Environmental Software Solutions, Inc.

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Environmental Software Solutions, Inc.

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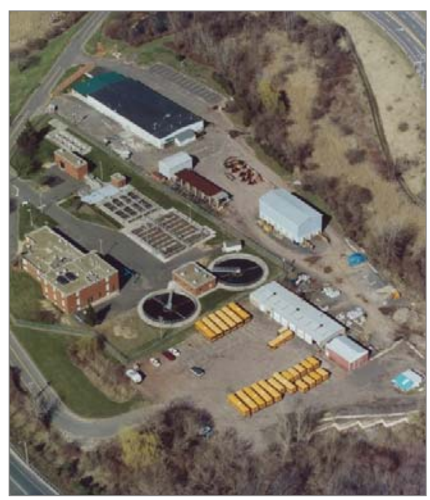
Webinar Agenda

- Introductions
- Activated Sludge Overview
- Simulator Description and Overview
- Nitrification Theory and Examples
- Simulator Examples
- Hydromantis Project
- Questions



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Activated Sludge Overview

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Activated Sludge Operation

- The Activated Sludge Process is a **SYSTEM**
  - Aeration Tank
  - Secondary Clarifier
  - RAS & WAS Pumps
  - Aeration Equipment
- Secondary Treatment (BOD, TSS)
  - Aeration Tanks - Convert soluble, colloidal and remaining suspended BOD into biomass that can be removed by settling
  - Secondary Clarifiers – Flocculate, settle and compact solids to provide effluent low in TSS
  - **KEY – Create a biomass that flocculates well and settles rapidly**

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Key Activated Sludge Relationships

Solids Retention Time (days)

"Average time any particle remains in Reactor Tanks"

$$\textbf{SRT} = \frac{\text{lbs MLSS in Reactor Tanks}}{\text{lbs/d WAS } (X_w) + \text{lbs/d Effluent TSS } (X_e)}$$

What parts of this can an operator control?

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Key Activated Sludge Relationships

Aerobic Solids Retention Time (days)

"Average time any particle remains in Aeration Tanks"

$$\textbf{Aerobic SRT} = \frac{\text{lbs MLSS in Aeration Tank}}{\text{lbs/d WAS } (X_w) + \text{lbs/d Effluent TSS } (X_e)}$$

What parts of this can an operator control?

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Secondary Clarifier Impacts on BNR

Two Key Concepts:

- Effluent TSS contains nutrients
- Secondary clarifiers define allowable reactor MLSS
  - High Aerobic SRT required for nitrification
  - As SRT increases for a given reactor volume, MLSS concentration must increase
  - As a result, allowable MLSS can limit SRT

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Process Simulators

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Simulator Overview

- Model = Series of equations that defines a process or plant
  - Model based on mass balances and biological conversions of organics (COD), nitrogen, phosphorus and solids
- Simulator = Program that uses a process model to experiment with a plant configuration
- OpTool Overlay = Plant-specific layout that provides graphical interface for plant operational testing and training

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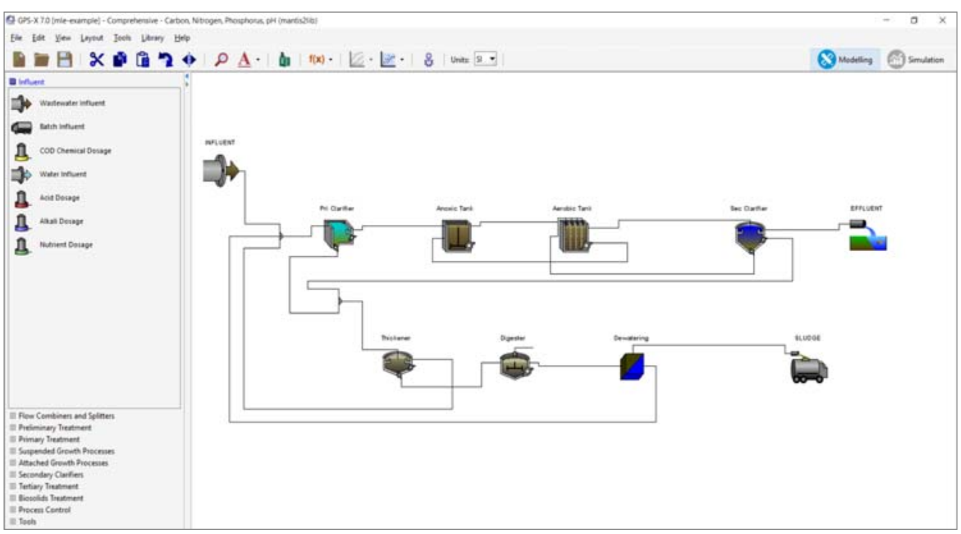
GPS-X Process Simulator



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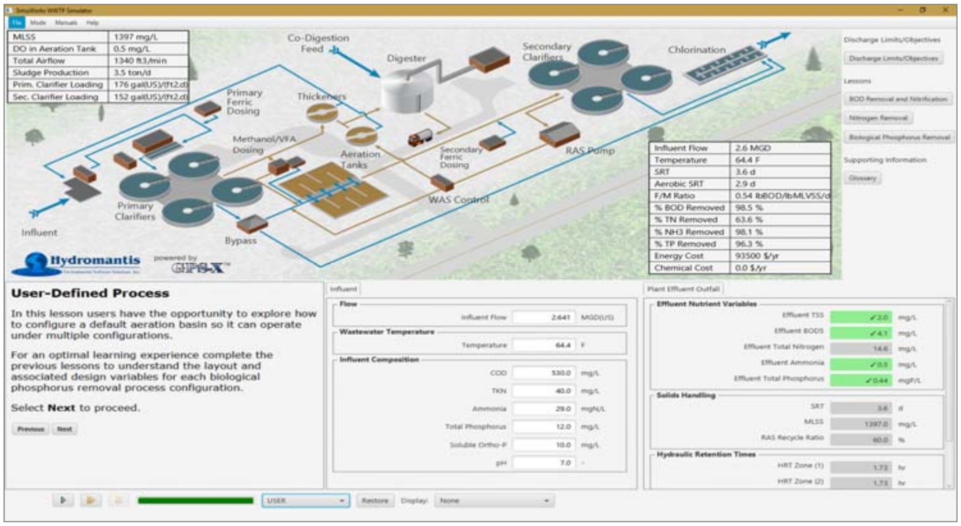
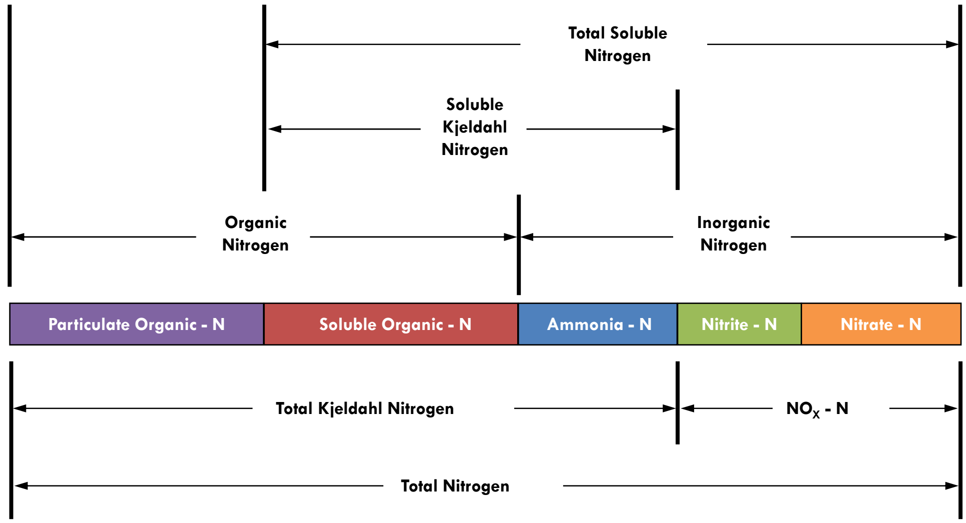
Process Simulator Layout



Nitrogen in the Environment

Forms of Nitrogen



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Why Remove Nitrogen?

- Toxicity: Ammonia
- Oxygen Demand: Ammonia
- Groundwater Contamination: Nitrate
- Eutrophication: Total Nitrogen
  - Long Island Sound
  - Narragansett Bay
  - Chesapeake Bay
  - San Francisco Bay

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Environmental Conditions

- Aerobic
  - Free dissolved oxygen present
- Anoxic
  - No free dissolved oxygen
  - Nitrite and/or nitrate present
- Anaerobic
  - No free dissolved oxygen
  - No nitrite or nitrate

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Biological Nitrogen Removal

- Assimilation
  - Incorporation of nitrogen into cell mass, typically 5% of BOD removed (7-10% of VSS formed)
- Ammonification
  - Conversion of organic nitrogen into ammonia
- Nitrification
  - Oxidation of ammonia to nitrite then nitrate
- Denitrification
  - Reduction of nitrate to nitrogen gas

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Nitrification

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Nitrification Basics

NH_4^+-N + 2 O_2 → NO_3^--N + 2 H^+ + H_2O + Bacteria

Autotrophic Bacteria – Ammonia and Nitrite Oxidizing Bacteria (AOB and NOB)

- Energy from Oxidation of NH_4^+-N
- Carbon from HCO_3^- (BiCarbonate)
- Aerobic Organisms – DO Sensitive (Require 4.6 lb/lb NH_4-N)
- Low Growth Rate – Temperature Sensitive
- Produces Acid – Consumes Alkalinity (7.2 lb/lb NH_4-N)
- pH Sensitive – Acclimation
- Sensitive to Toxics

NITRIFICATION DOES NOT RESULT IN A NET REMOVAL OF NITROGEN FROM WASTEWATER!

NITRIFICATION MUST PRECEDE DENITRIFICATION!

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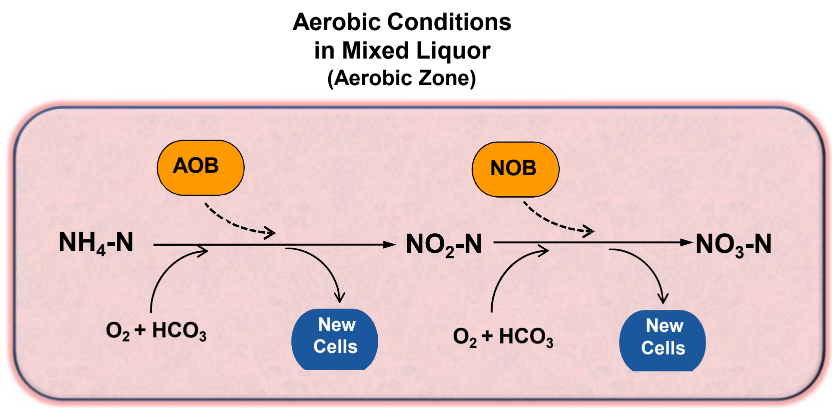
Nitrification Basics

Basic Process Description :



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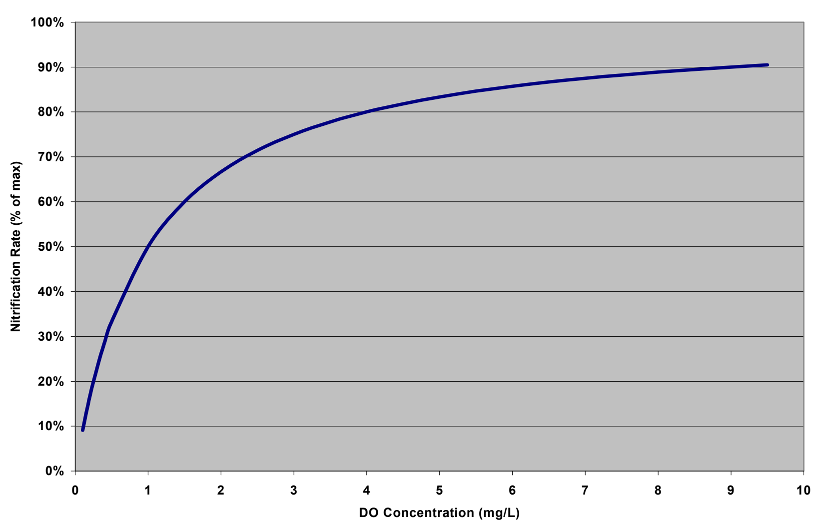
DO Impact on Nitrification



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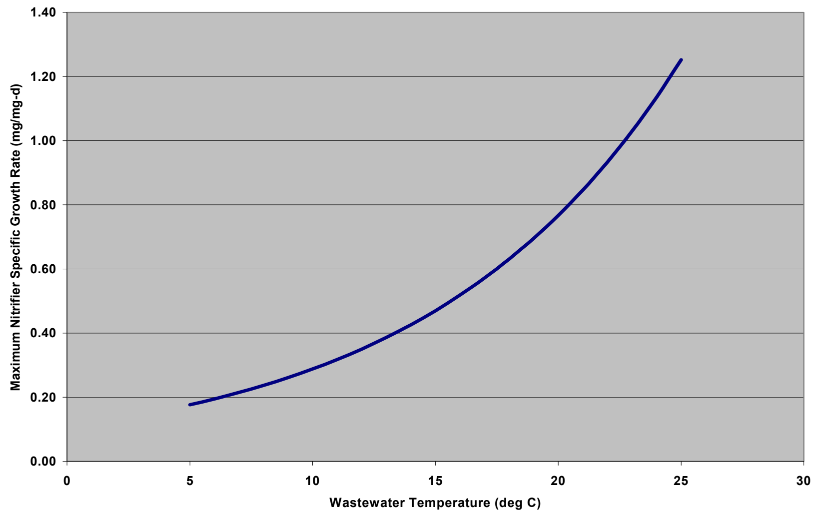
Temperature Impacts on Nitrification



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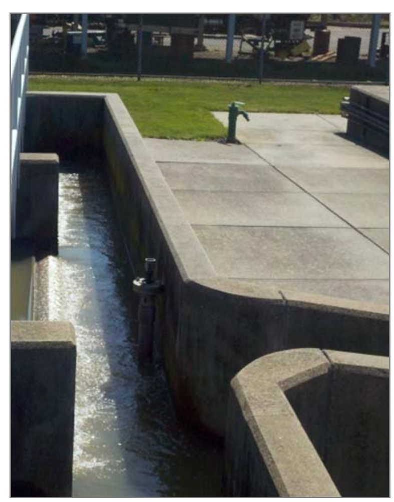
Activated Sludge Nitrification

- System Microbiology
  - Can occur concurrent or following BOD removal
  - Heterotrophs grow faster than Nitrifiers, so must reduce overall system growth rate
  - Depends on Aerobic SRT
- Single Sludge Nitrification
  - Continuous Flow Systems
  - Sequencing Batch Reactors (SBR)
  - Membrane Bioreactors (MBR)
- Separate Sludge Nitrification



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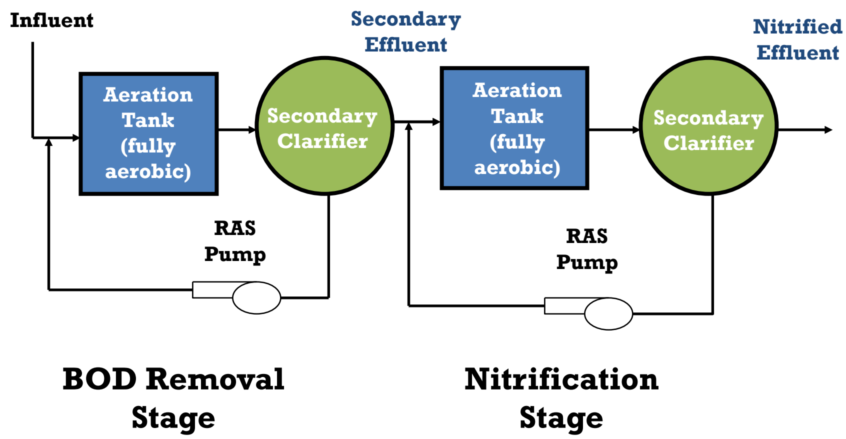
Separate Sludge Nitrification



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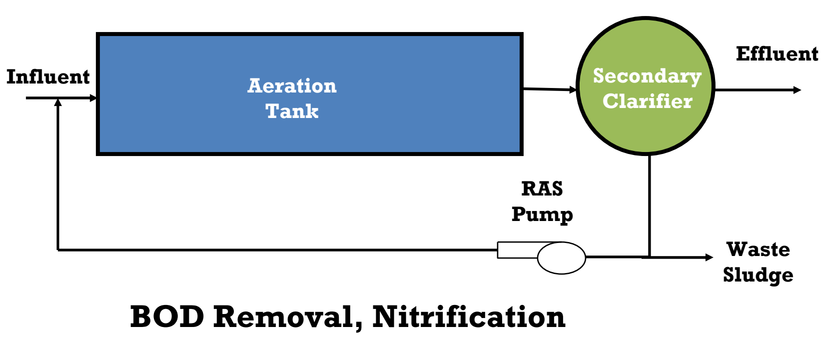
Single Sludge Nitrification



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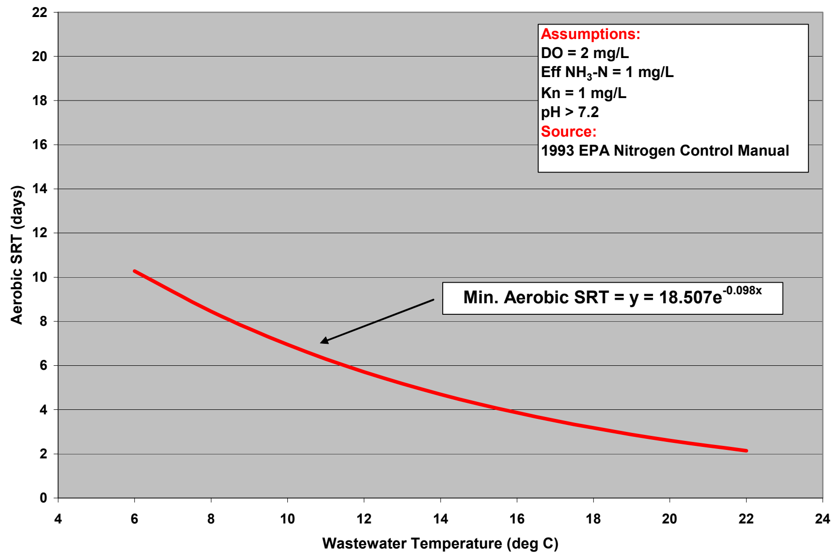
Min. Aerobic SRT for Nitrification



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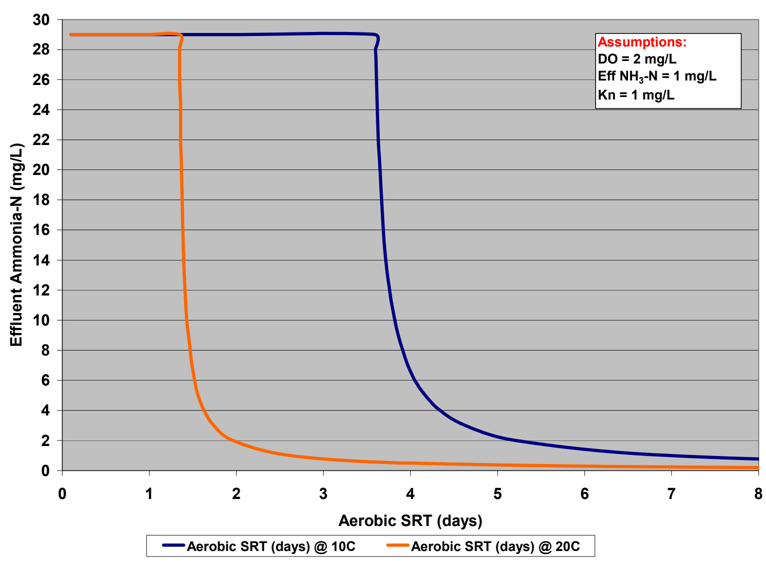
Steady State Nitrification – Temp.



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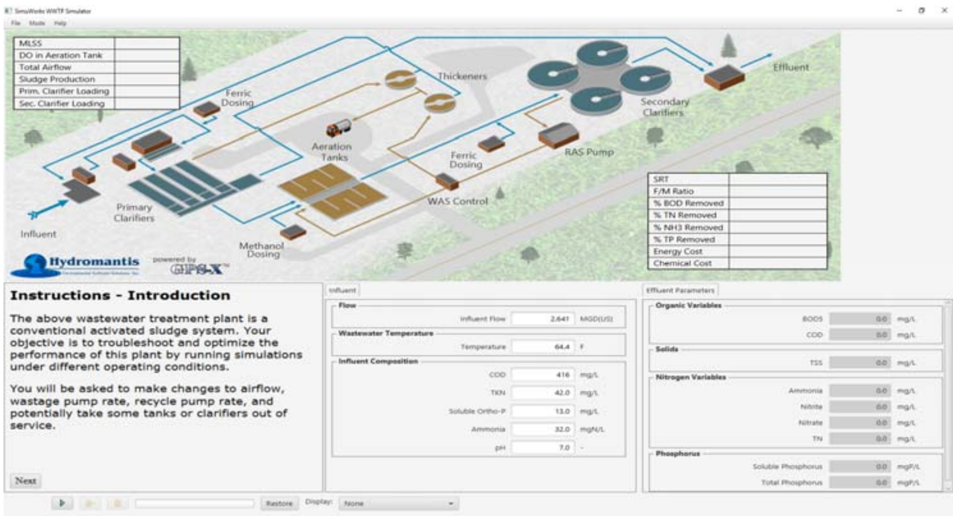
Process Simulator – ASRT Example



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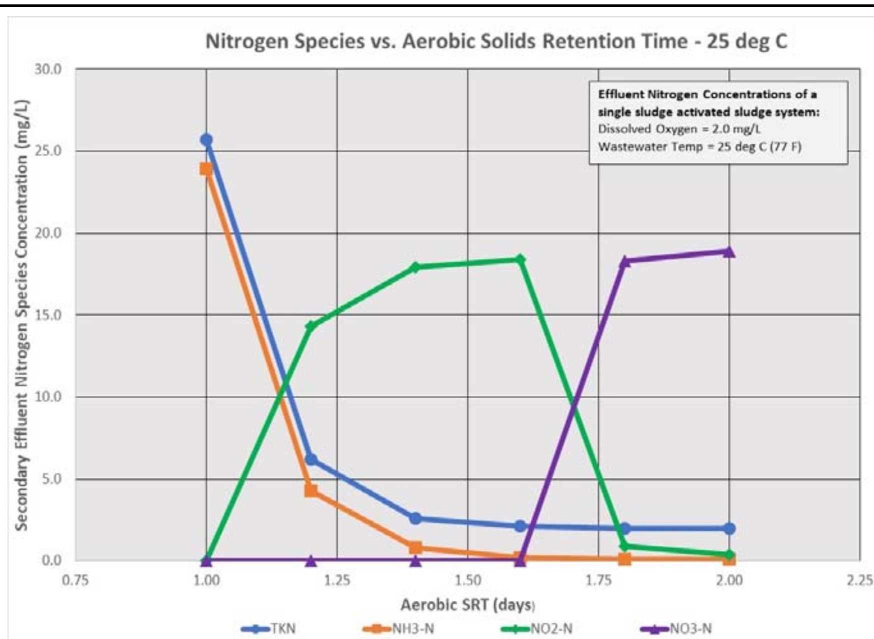

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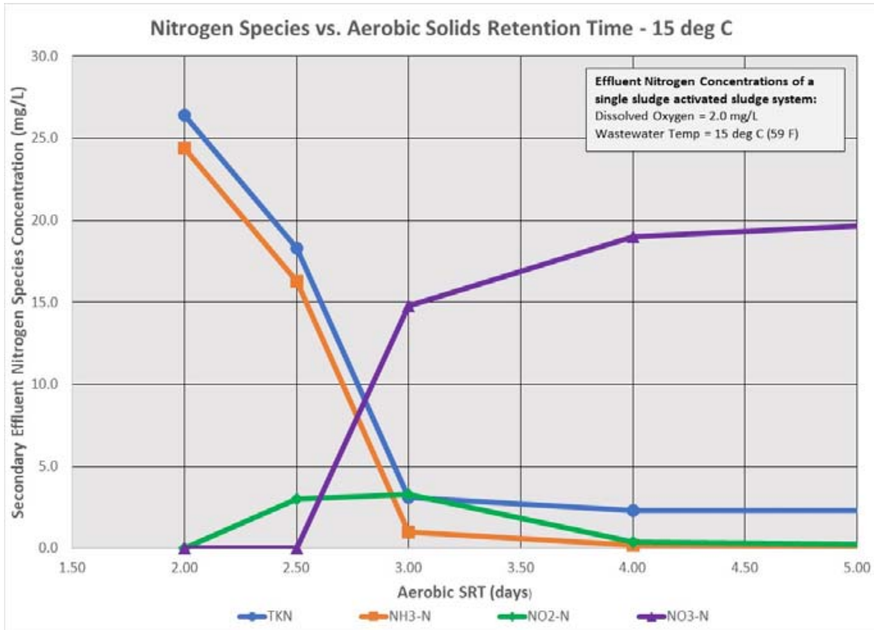

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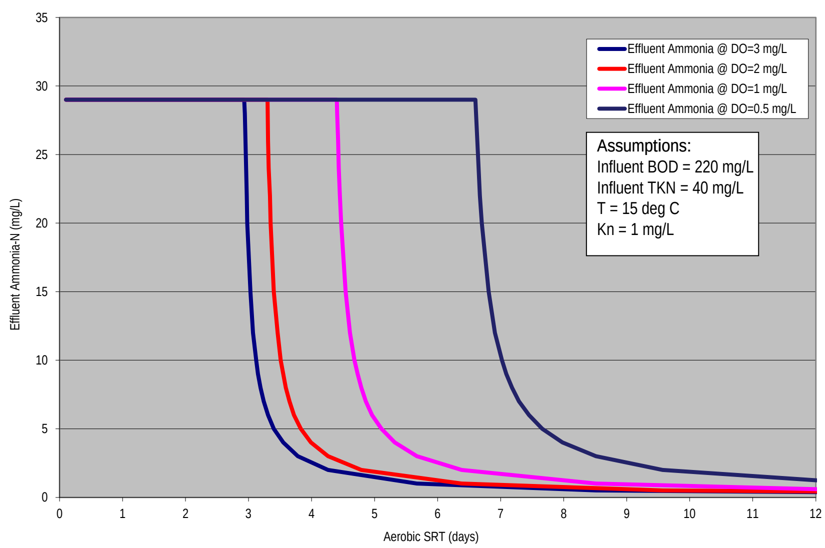
Steady State Nitrification – D.O.



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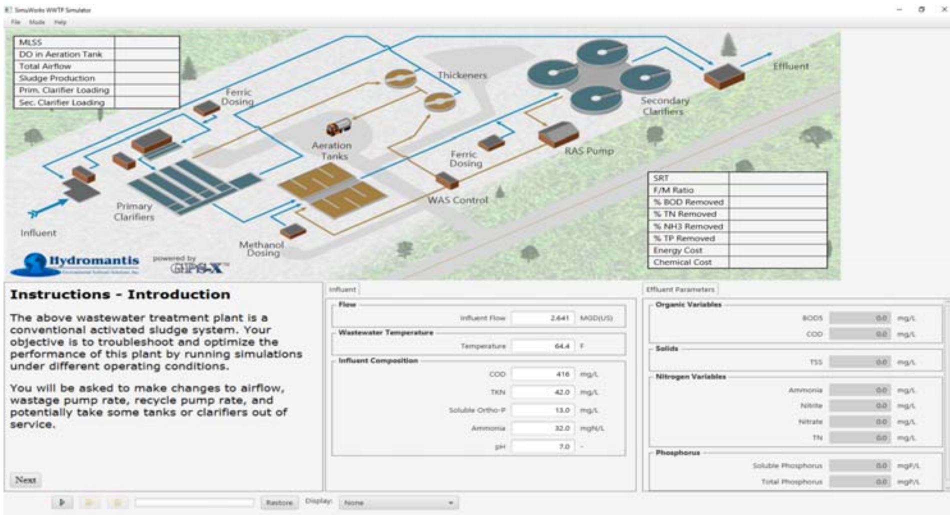
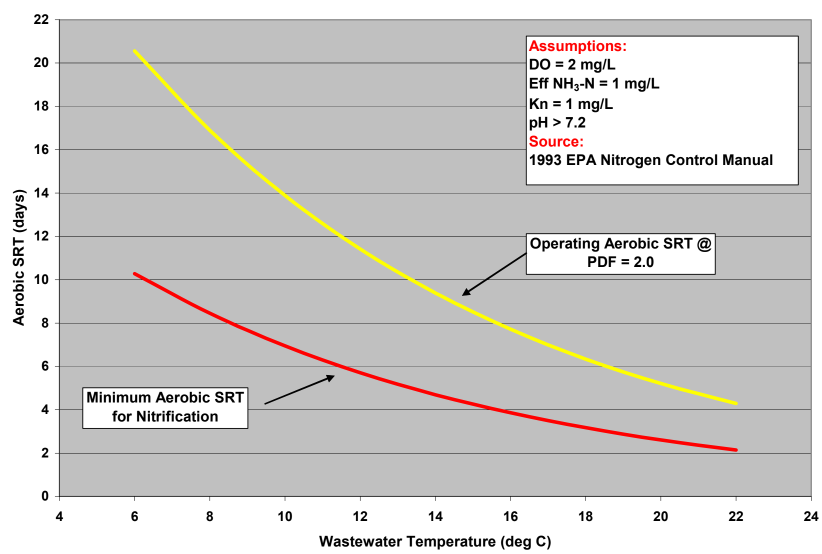
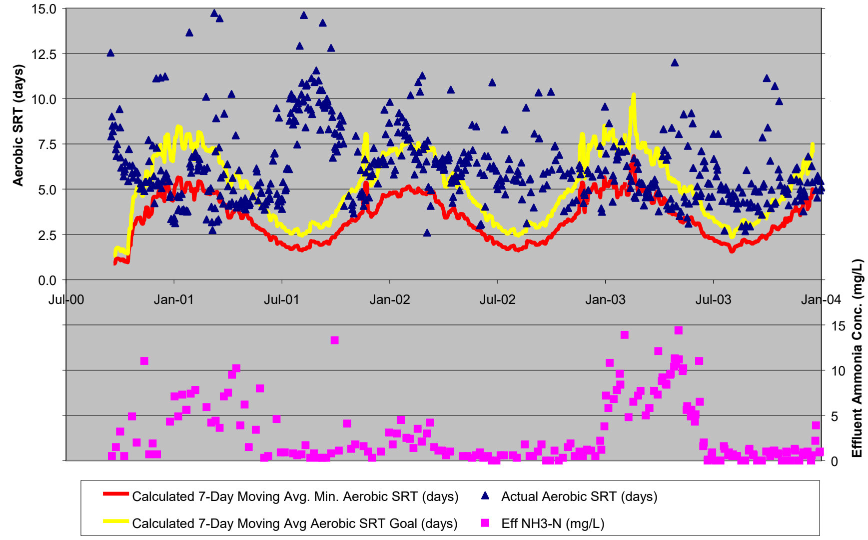
Process Simulator – DO Example



Aerobic SRT for Nitrification



Nitrification Performance – 4 Years



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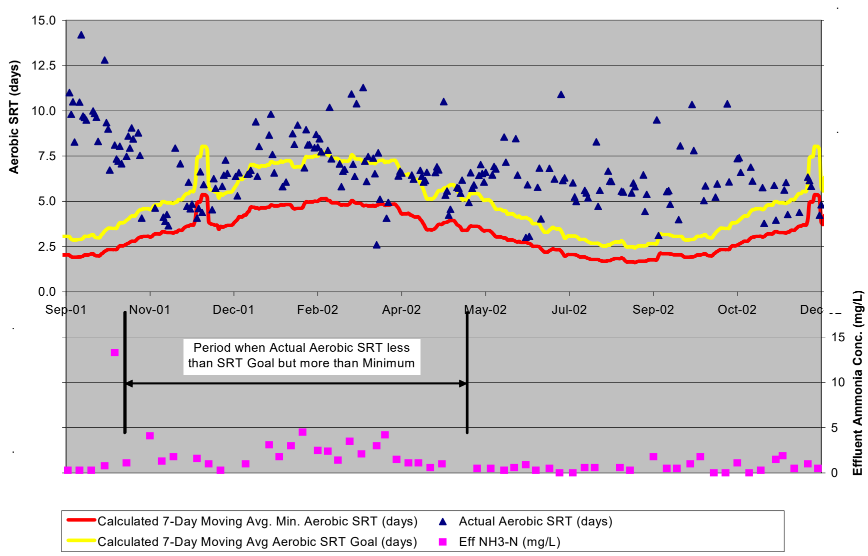
Nitrification Performance – 2002



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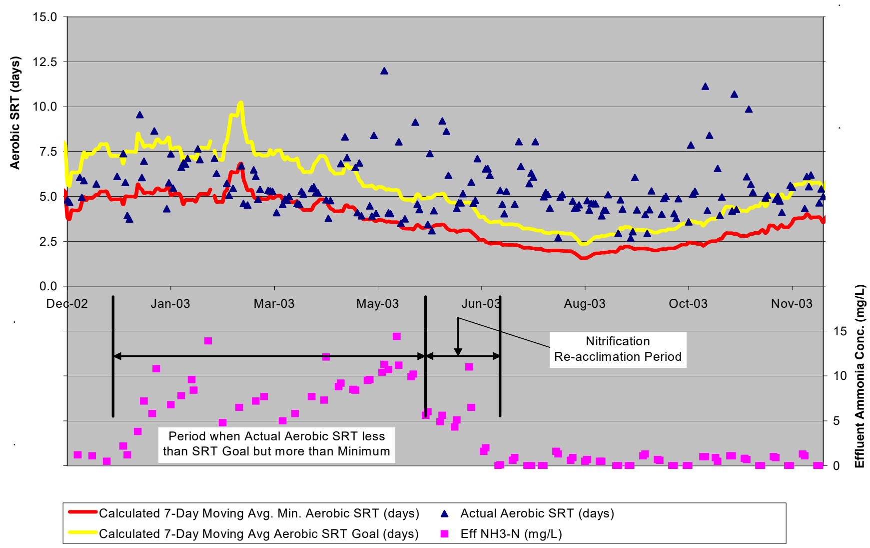
Nitrification Performance – 2003



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Nitrite "Lock"

- Nitrite-N is an intermediate product of nitrification
- Causes:
  - Low aerobic SRT
  - Low pH
  - NOB toxicity
- Impacts:
  - Chlorine demand (5 mg Cl per mg NO2-N)
  - Disinfection performance problems
  - Effluent toxicity
- Solutions

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Alkalinity Check

- Should maintain at least 50-75 mg/L Alkalinity in Effluent
- Effluent Alkalinity = $Alk_{inf} - Alk_{nit} + Alk_{denit}$
- Alkalinity also consumed through Chemical P Removal
- Chemicals typically used to add Alkalinity:
  - Sodium Hydroxide (NaOH) – aka Caustic Soda
  - Sodium Carbonate (Na2CO3) – aka Soda Ash
  - Sodium Bicarbonate (NaHCO3) – aka Baking Soda
  - Magnesium Hydroxide (Mg(OH)2) – aka Milk of Magnesia
  - Potassium Hydroxide (KOH) – aka Caustic Potash or Lye
  - Quicklime (CaO)

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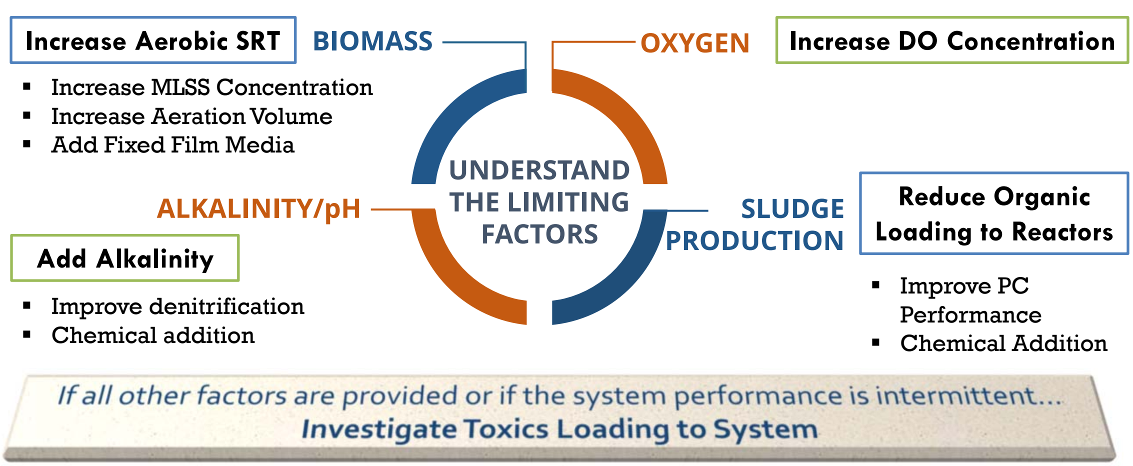
Evaluating and Improving Nitrification



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Nitrification Case Study

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Nitrification Case Study

- North Davis Sewer District, Syracuse, Utah
- 80 sq. miles, 200,000 pp.
- 34 MGD capacity
- Biological Nitrogen Removal
- Chemical Phosphorus Removal

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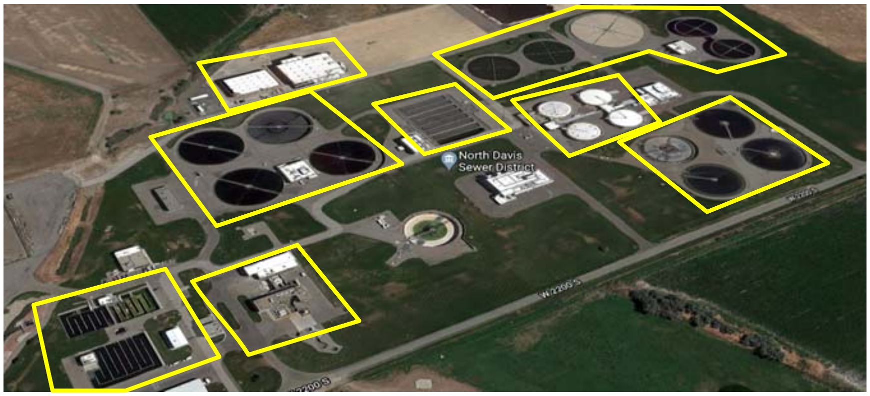
North Davis Sewer District (NDSD)



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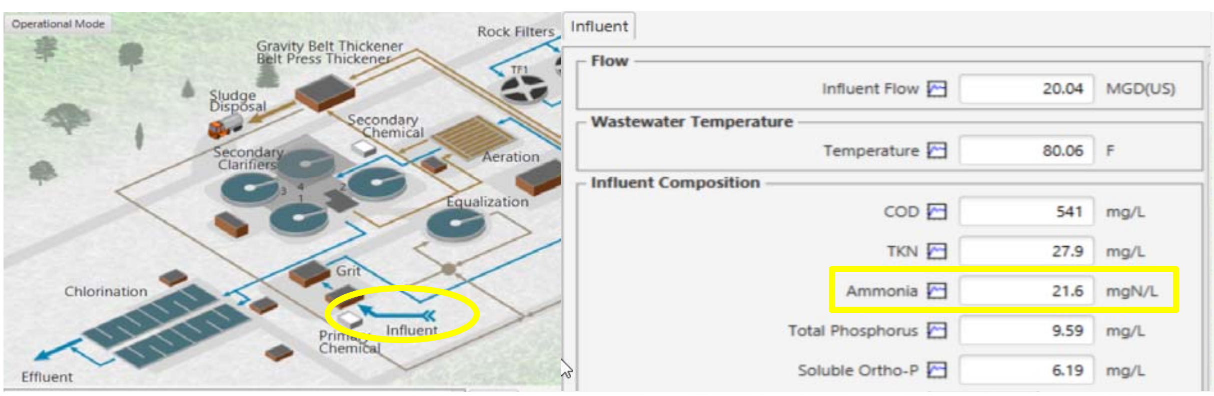
North Davis Sewer District (NDSD)



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North Davis Sewer District (NDSD)

- Nitrification Study:
  - Start from conditions resulting in high effluent ammonia
  - What changes are required to get effluent ammonia to < 2.0 mgN/L?

Effluent Parameters

Organic Variables	BOD5	6.5	mg/L
	COD	40.6	mg/L
Solids	TSS	7.2	mg/L
Nitrogen Variables	Ammonia	10.1	mg/L
	Nitrite	0.2	mg/L
	Nitrate	0.3	mg/L
	TN	12.9	mg/L
Phosphorus	Soluble Phosphorus	3.38	mgP/L
	Total Phosphorus	3.86	mgP/L

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North Davis Sewer District (NDSD)

- Nitrification Study:
  - What are the conditions in the activated sludge system (DO and SRT)?

MLSS	1665 mg/L
Average DO in Aeration Tank	0.4 mg/L
Total Airflow	20.0 ft3/s
Sludge Production	11.6 ton/d

SRT	5.37 d
F/M Ratio	1.6 lbBOD/lbMLSS/d
% BOD Removed	97.0 %
% TN Removed	53.6 %
% NH3 Removed	52.8 %
% TP Removed	59.8 %
Energy Cost	252100 $/yr
Chemical Cost	2562000 $/yr

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North Davis Sewer District (NDSD)

- Nitrification Study:
  - How can we increase DO?

MLSS	1702 mg/L
Average DO in Aeration Tank	1.6 mg/L
Total Airflow	40.0 ft3/s
Sludge Production	11.6 ton/d

Increase Airflow

Airflow Control

Total Airflow to Basins 4,5	400	ft3/min
Total Airflow to Basins 1-3,6-8	800	ft3/min

Airflow Control

Total Airflow to Basins 4,5	800	ft3/min
Total Airflow to Basins 1-3,6-8	1600	ft3/min

Effluent Parameters

Organic Variables	BOD5	5.5	mg/L
	COD	39.2	mg/L
Solids	TSS	7.3	mg/L
Nitrogen Variables	Ammonia	8.3	mg/L
	Nitrite	0.7	mg/L
	Nitrate	2.8	mg/L
	TN	14.1	mg/L
Phosphorus	Soluble Phosphorus	3.35	mgP/L
	Total Phosphorus	3.84	mgP/L

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North Davis Sewer District (NDSD)

- Nitrification Study:
  - How can we increase DO?

MLSS	1713 mg/L
Average DO in Aeration Tank	4.9 mg/L
Total Airflow	100 ft3/s
Sludge Production	11.6 ton/d

Increase Airflow

Airflow Control

Total Airflow to Basins 4,5	800	ft3/min
Total Airflow to Basins 1-3,6-8	1600	ft3/min

Airflow Control

Total Airflow to Basins 4,5	2000	ft3/min
Total Airflow to Basins 1-3,6-8	4000	ft3/min

Effluent Parameters

Organic Variables	BOD5	5.4	mg/L
	COD	39.1	mg/L
Solids	TSS	7.3	mg/L
Nitrogen Variables	Ammonia	7.4	mg/L
	Nitrite	0.8	mg/L
	Nitrate	4.3	mg/L
	TN	14.7	mg/L
Phosphorus	Soluble Phosphorus	3.35	mgP/L
	Total Phosphorus	3.83	mgP/L

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North Davis Sewer District (NDSD)

- Nitrification Study:
  - How can we increase SRT?

Decrease WAS

Aeration WSS Pumping

Aeration WSS Flow 0.999 MGD(US)

SRT	5.5 d
F/M Ratio	1.6 lbBOD/lbMLSS/d
% BOD Removed	97.5 %
% TN Removed	47.1 %

Effluent Parameters

Organic Variables	BOD5	5.4	mg/L
	COD	39.1	mg/L
Solids	TSS	7.3	mg/L
Nitrogen Variables	Ammonia	7.4	mg/L
	Nitrite	0.8	mg/L
	Nitrate	4.3	mg/L
	TN	14.7	mg/L
Phosphorus	Soluble Phosphorus	3.35	mgP/L
	Total Phosphorus	3.83	mgP/L

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North Davis Sewer District (NDSD)

- Nitrification Study:
  - How can we increase SRT?

Decrease WAS

Aeration WSS Pumping

Aeration WSS Flow 0.999 MGD(US)

Aeration WSS Pumping

Aeration WSS Flow 0.4 MGD(US)

SRT	10.4 d
F/M Ratio	0.6 lbBOD/lbMLSS/d
% BOD Removed	98.0 %
% TN Removed	47.8 %

Effluent Parameters

Organic Variables	BOD5	4.4	mg/L
	COD	39.0	mg/L
Solids	TSS	8.7	mg/L
Nitrogen Variables	Ammonia	1.9	mg/L
	Nitrite	0.2	mg/L
	Nitrate	10.1	mg/L
	TN	14.5	mg/L
Phosphorus	Soluble Phosphorus	3.38	mgP/L
	Total Phosphorus	3.9	mgP/L

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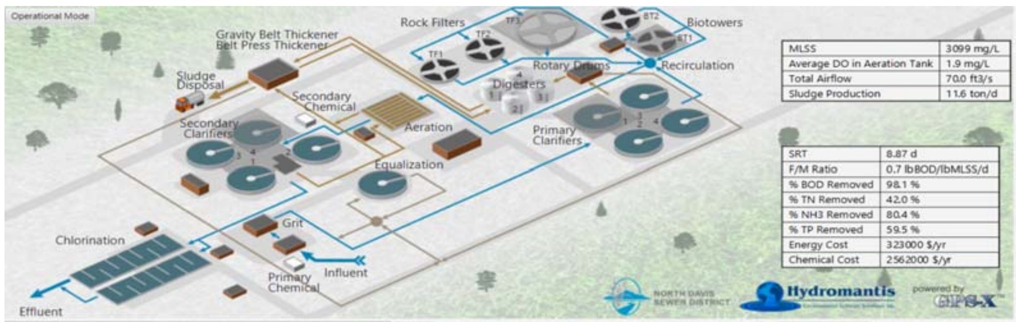
North Davis Sewer District (NDSD)

- Nitrification Study:
  - ↑ DO, ↑ SRT = ↓ Ammonia



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Questions?

Paul Dombrowski
pdombrowski@woodardcurran.com
(860) 253-2665

Spencer Snowling
Snowling@hydromantis.com
(905) 522-0012

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