HDR

SETTING THE STAGE – NUTRIENT REMOVAL TECHNOLOGIES

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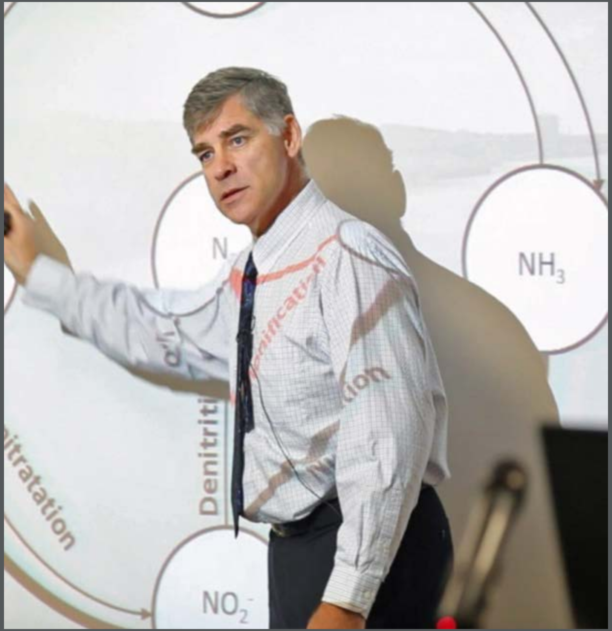
OVERVIEW

Nutrient Removal Technologies

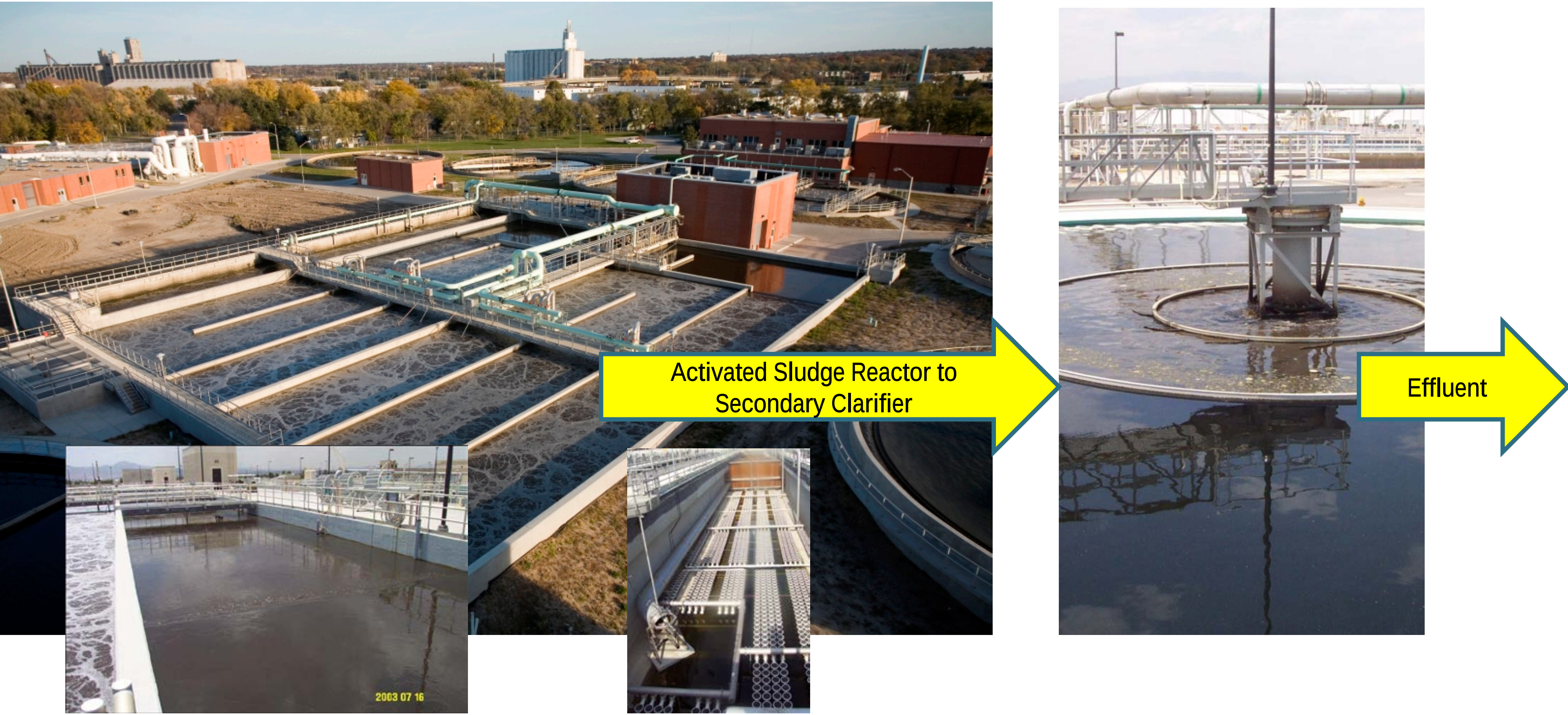
- Advanced Wastewater Treatment
- Key Research Findings
  - WE&RF Nutrient Challenge
- Wastewater Industry Trends
  - Sustainability
  - Net Zero Energy
  - Wastewater as a Resource
  - New Technology
- New Challenges and Competing Demands
  - Nutrient Removal, Toxics, Wet Weather Compliance, etc.
- Adaptive Management
  - Phased Implementation and Compliance Schedules



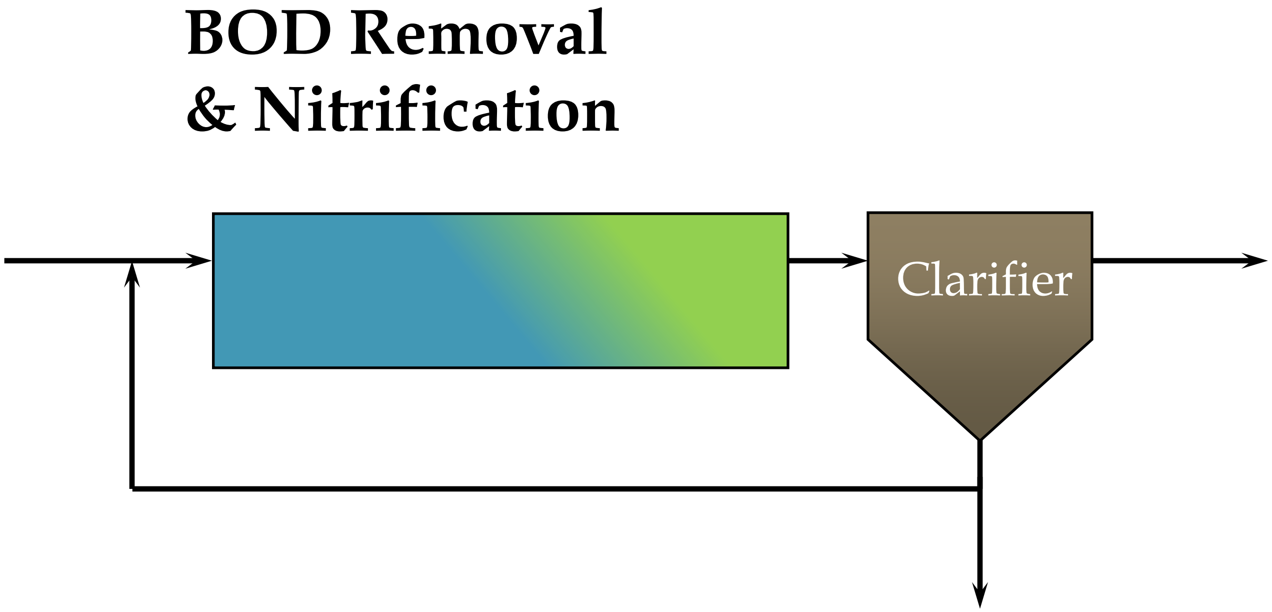

ADVANCED WASTEWATER TREATMENT TECHNOLOGY

Nutrient Removal

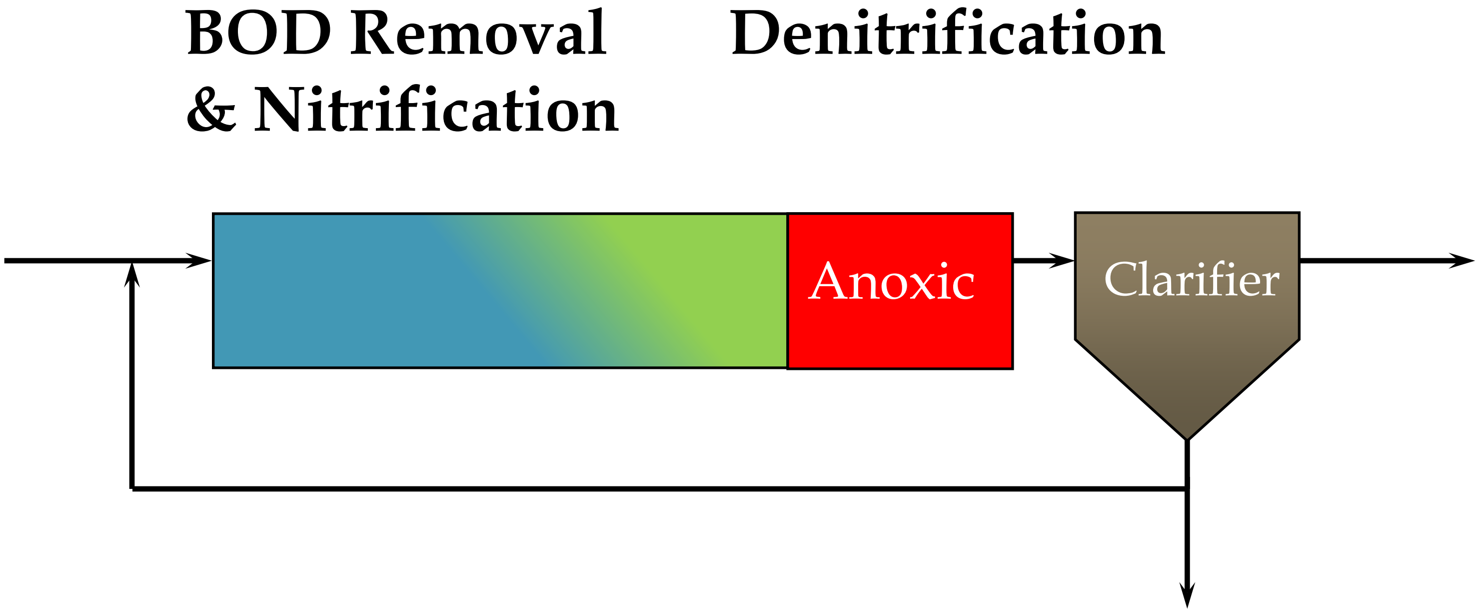
BIOLOGICAL NUTRIENT REMOVAL PROCESSES



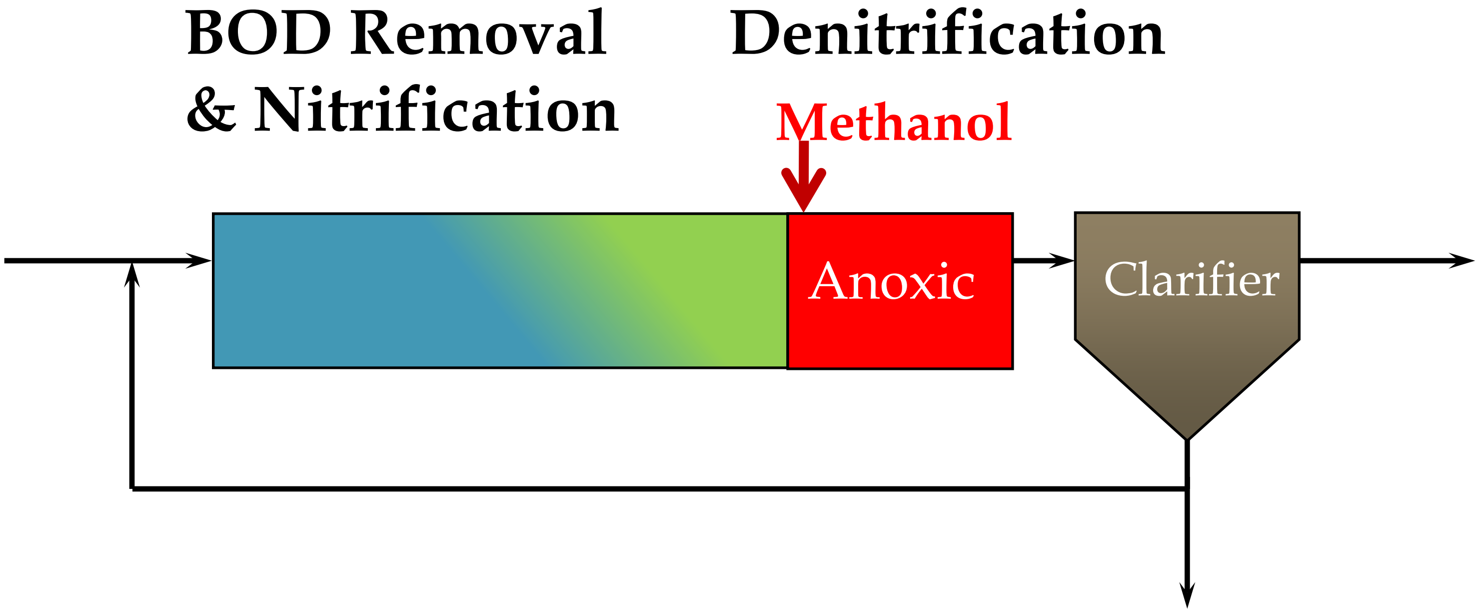
COMBINED BOD & NITRIFICATION



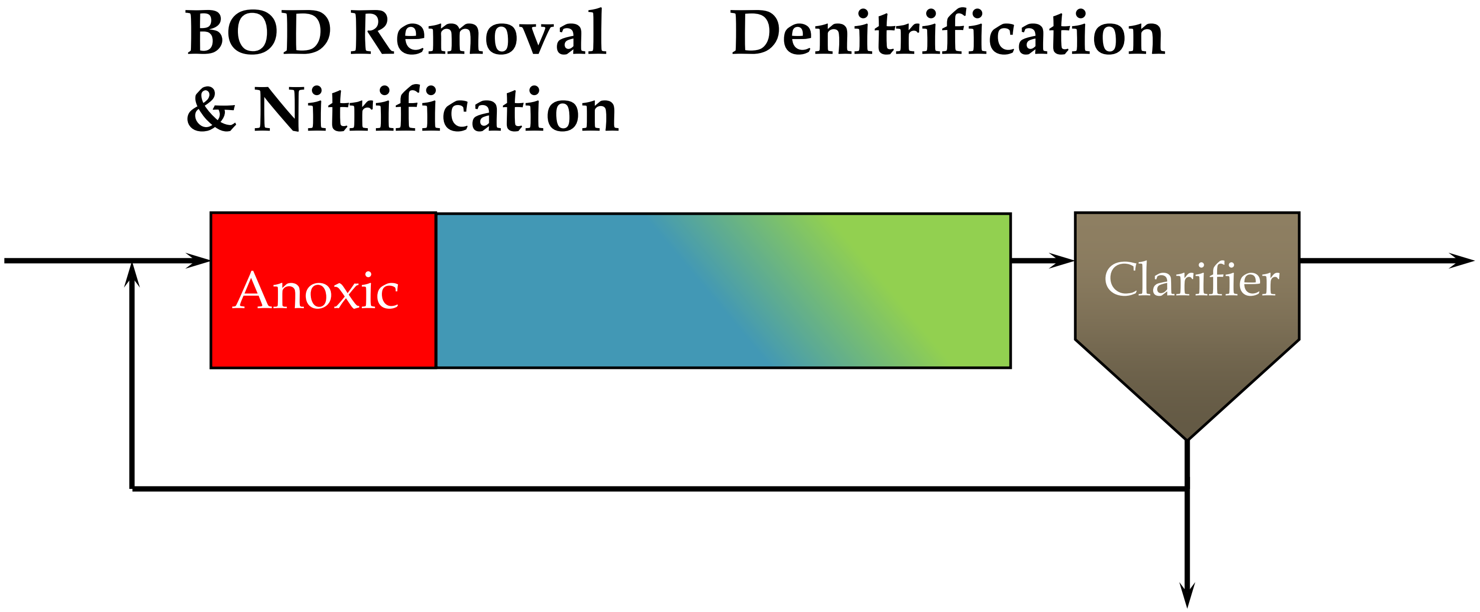
COMBINED BOD & NITRIFICATION & DENITRIFICATION



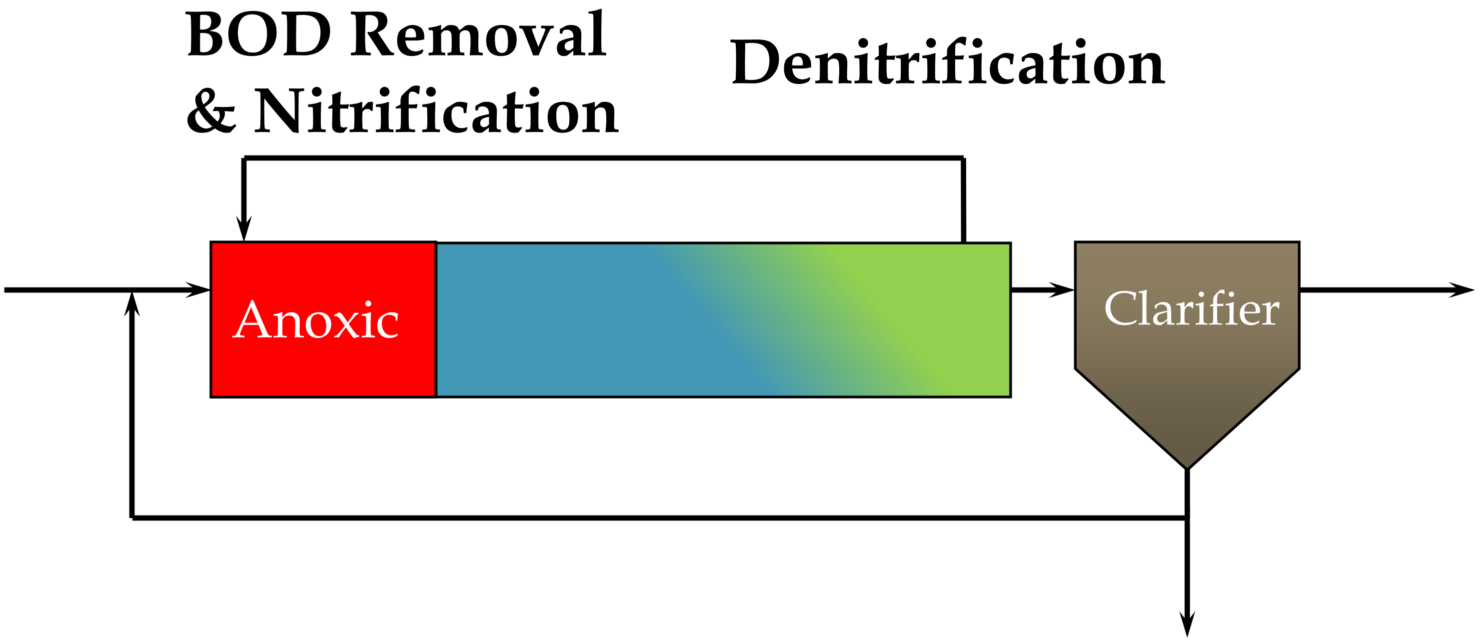
COMBINED BOD & NITRIFICATION & DENITRIFICATION WITH METHANOL



COMBINED BOD & NITRIFICATION & DENITRIFICATION (LUDZACK ETTINGER)

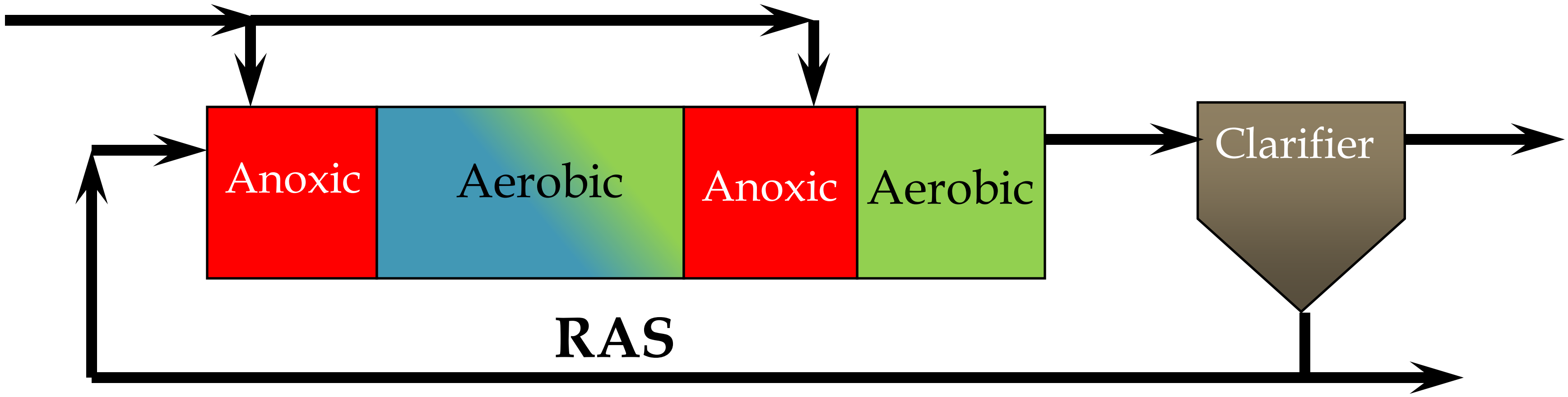


COMBINED BOD & NITRIFICATION & DENITRI-FICATION (MODIFIED LUDZACK ETTINGER - MLE)

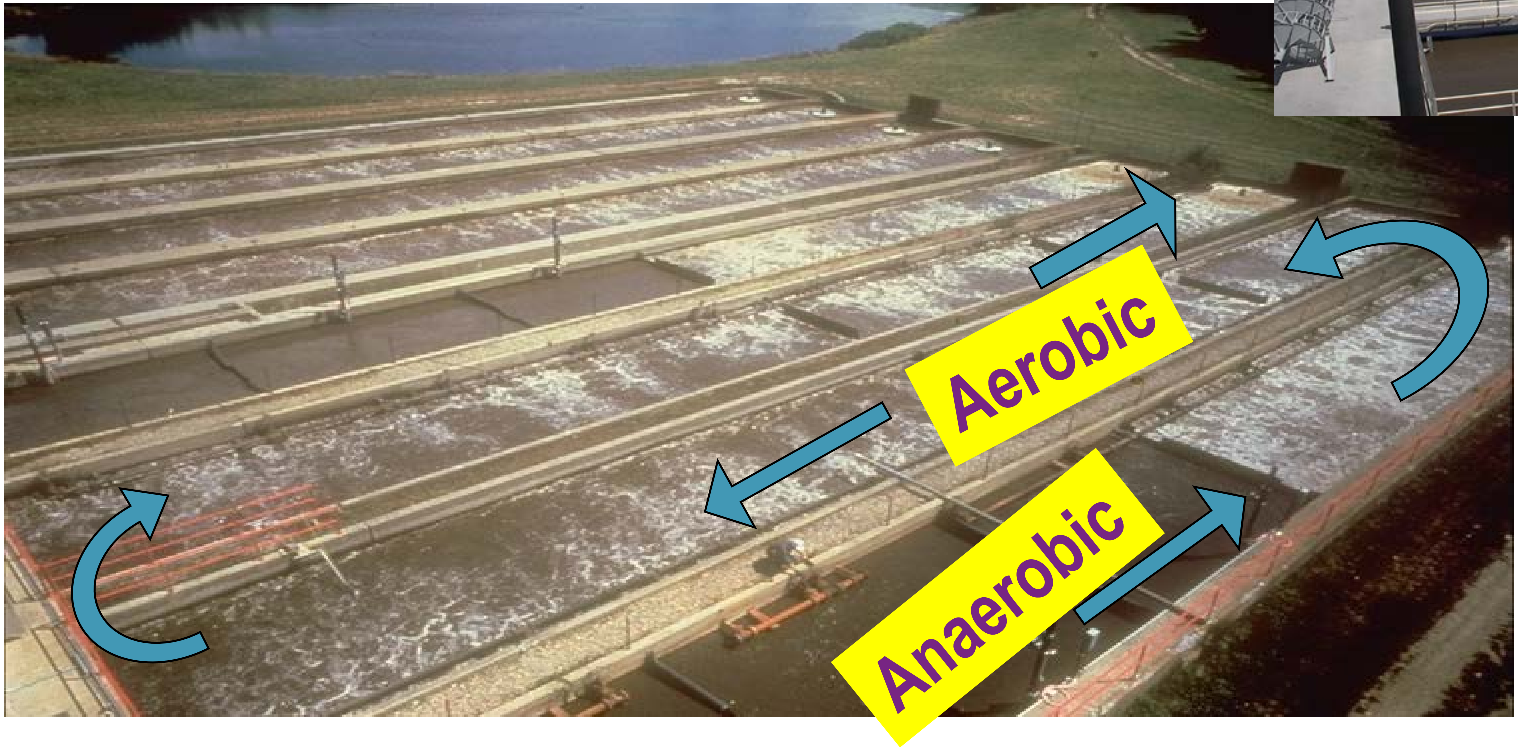


MLE PROCESS

STEP FEED SYSTEM



BIOLOGICAL PHOSPHORUS REMOVAL



TYPICAL EFFLUENT FILTRATION TECHNOLOGIES FOR CHEMICAL PHOSPHORUS REMOVAL

Dual Media Filters
City of Las Vegas

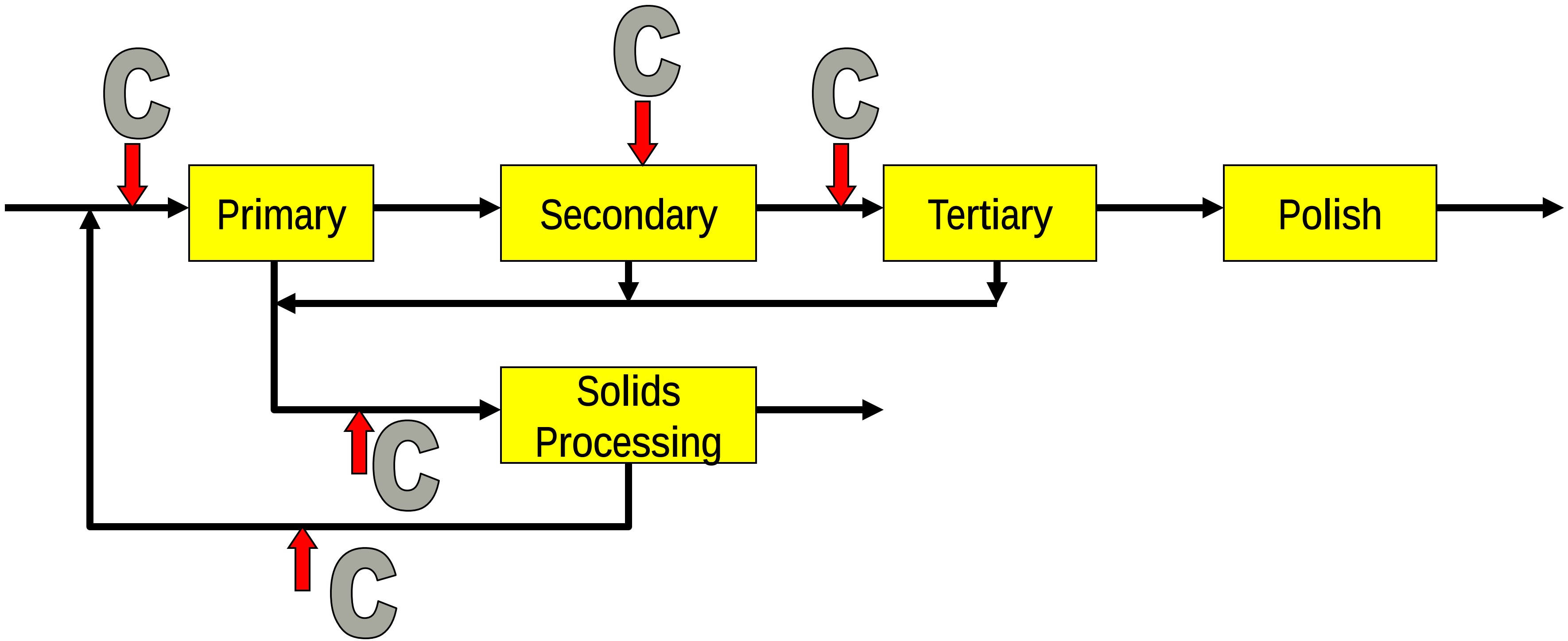
Deep mono-media Filters (West Basin)

Submerged Membranes (West Basin)

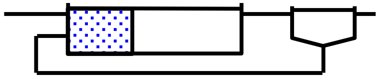
Continuous backwash filter – Ione, CA

Cloth Media Disk at Sonoma Plants

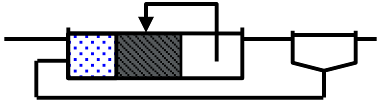
CHEMICAL PHOSPHORUS REMOVAL



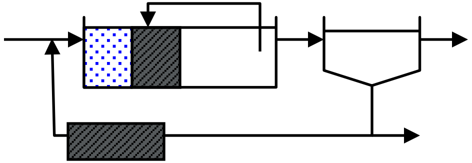
BIOLOGICAL PHOSPHORUS REMOVAL ZONED DESIGN



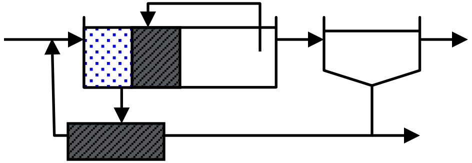
Phoredox (**AO**)



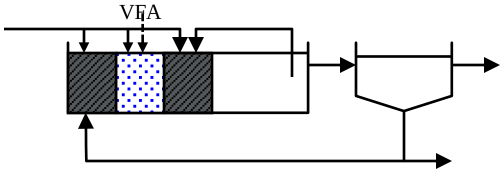
3-stage Phoredox (A2O)



Johannesburg



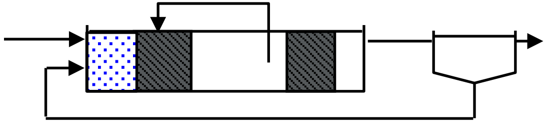
Modified Johannesburg



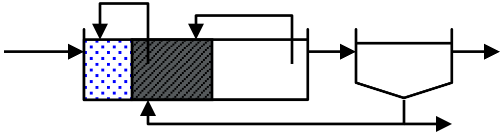
West Bank

Effluent
TP < 1
OP < 0.5

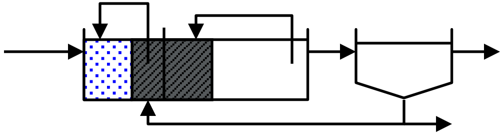
BIOLOGICAL PHOSPHORUS REMOVAL ZONED DESIGN



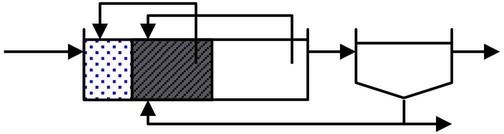
Modified (5-stage) Bardenpho



UCT



Modified UCT

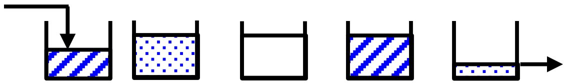


VIP (Virginia Initiative Process)

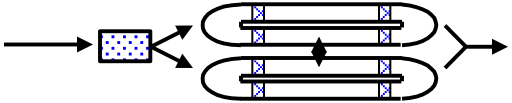
Effluent
TP < 1
OP < 0.5

BIOLOGICAL PHOSPHORUS REMOVAL MIXED DESIGN

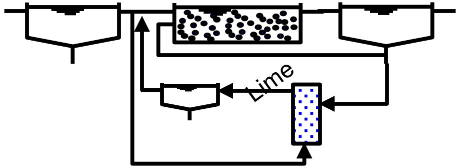
Effluent
TP < 1
OP < 0.5



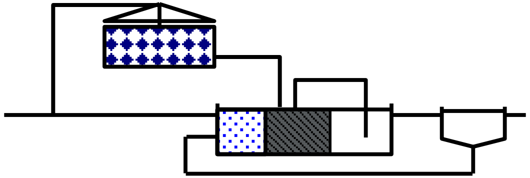
SBR



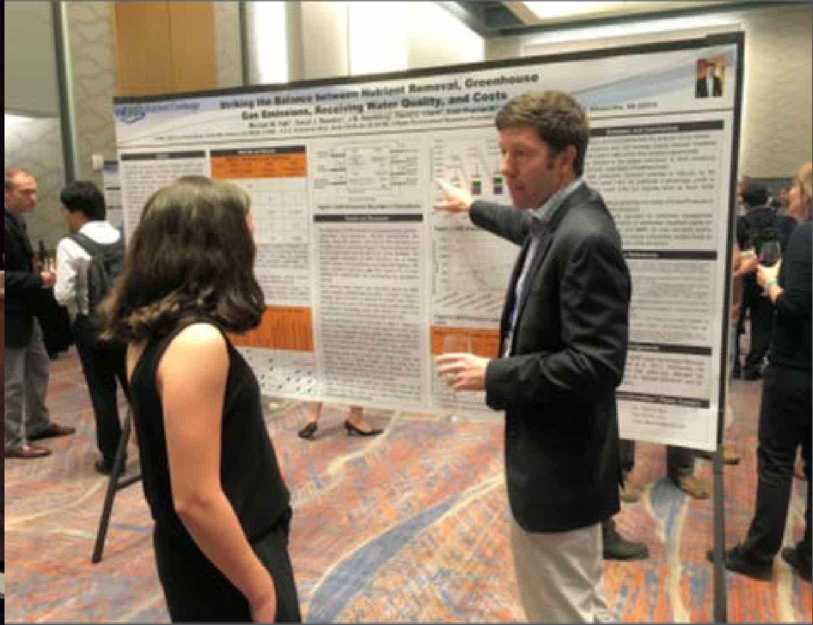
Biodenipho



PhoStrip



Trickling Filter with EBPR



WATER ENVIRONMENT & REUSE FOUNDATION (WE&RF) NUTRIENT CHALLENGE

Key Findings from 5+ Year International Research Program

WATER ENVIRONMENT & REUSE FOUNDATION (WE&RF) NUTRIENT CHALLENGE

www.werf.org/nutrients

Go to **KNOWLEDGE AREAS: Nutrients**
>50 completed and ongoing projects

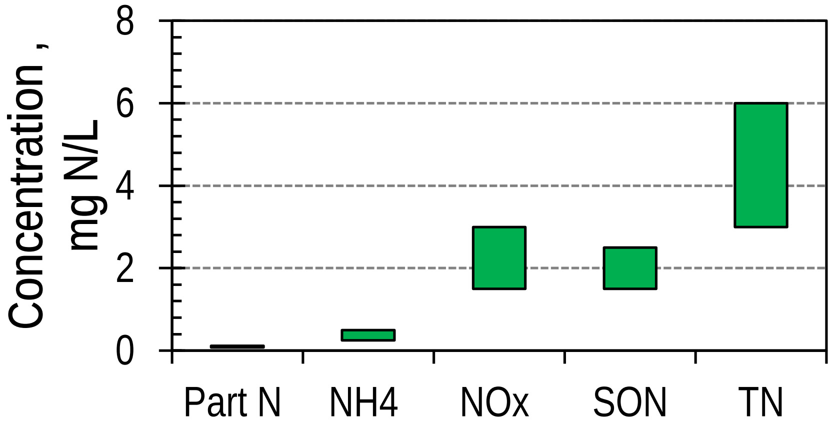
- Objectives
- Provide science-based solutions and recommendations that:
  - (1) support utility decisions to use sustainable wastewater nutrient removal technologies to meet various receiving water body requirements and other wastewater treatment goals (e.g., climate change, sustainability, cost-effectiveness, reliability), and
  - (2) inform regulatory decision making that is moving toward increasingly higher levels of nitrogen and phosphorus removal.

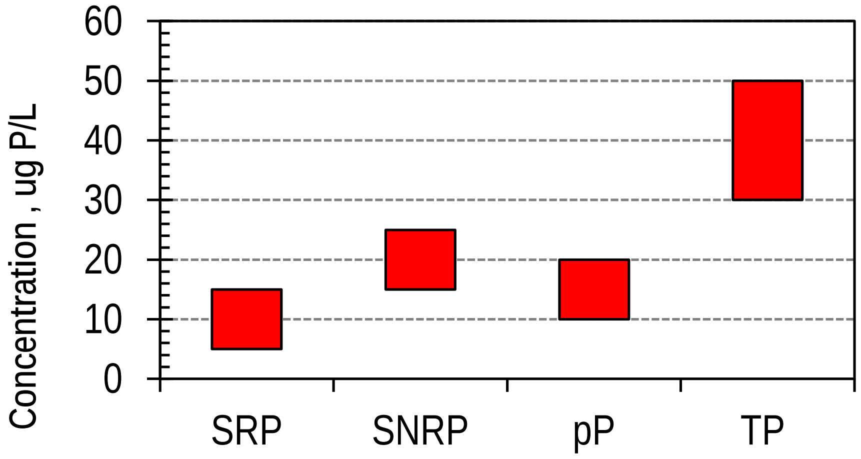
INDIVIDUAL NUTRIENTS SPECIES ARE KEY TO CONTROLLING THE TOTAL

Total N				
Soluble N				Particulate N
Ammonia (NH4+NH3)	NO3	NO2	Sol Org.	Particle Organic N

Total P					
Soluble P			Particulate P		
Reactive P sRP	Sol NonReactive P sNRP		pRP	Particulate NonReactive P pNRP	
Reactive P sRP	Acid Hydrolyzable sAHP	Organic sOP	pRP	Acid Hydrolyzable pAHP	Organic pOP

NUTRIENT SPECIES BASED ON WRRF PERFORMANCE





- Soluble Organic Species are difficult to remove with current technology
- Inorganic and particulate species are well removed

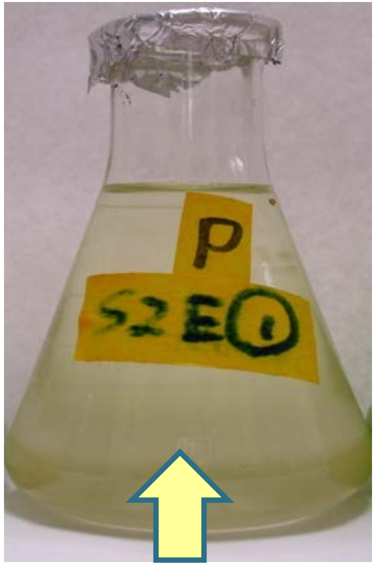
WATER ENVIRONMENT & REUSE FOUNDATION (WE&RF) NUTRIENT RESEARCH PROGRAM

ADVANCED TREATMENT AND EFFLUENT NUTRIENT SPECIATION AND BIOAVAILABILITY

Reduced Concentration

Secondary Effluent BAP

Altered Speciation



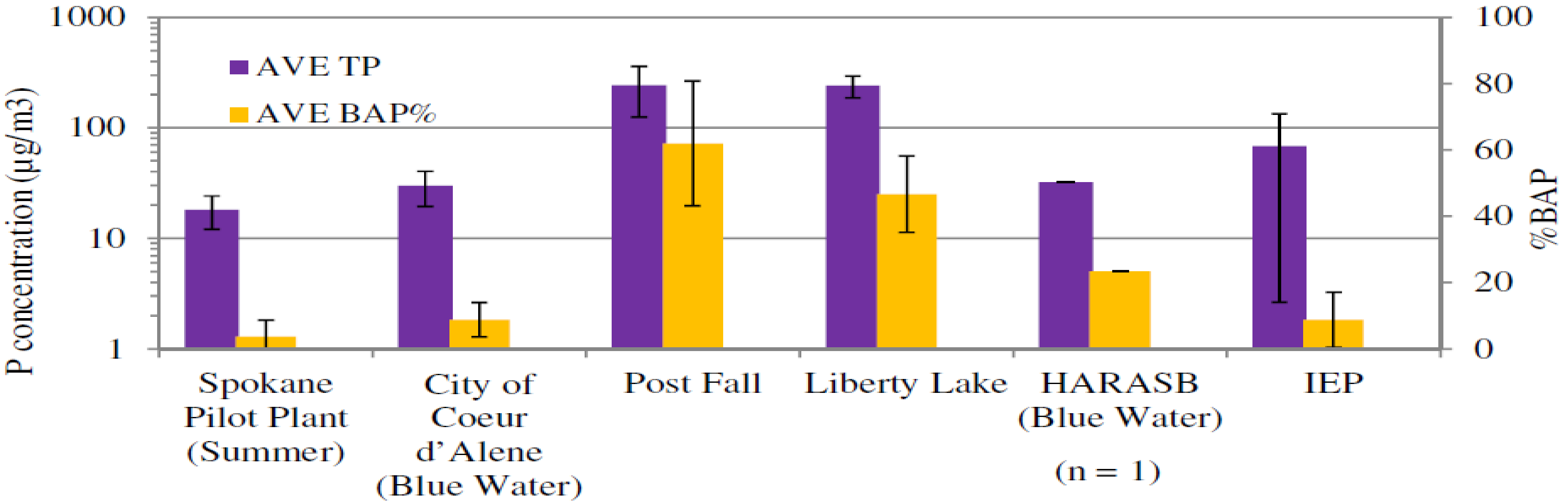
Alum/settled Effluent BAP

Reduced Bioavailability

Alum/Filtered Effluent BAP

Michael T. Brett & Bo Li Phosphorus Bioavailability Studies, University of Washington

EFFLUENT TP AND BIOAVAILABILITY (%BAP)

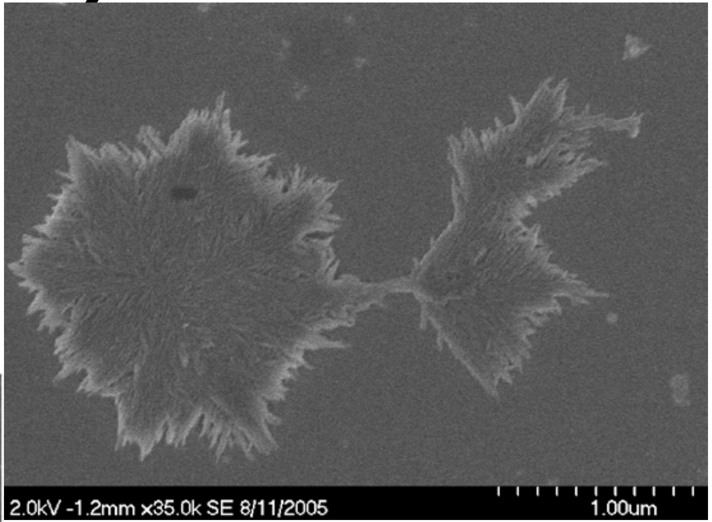


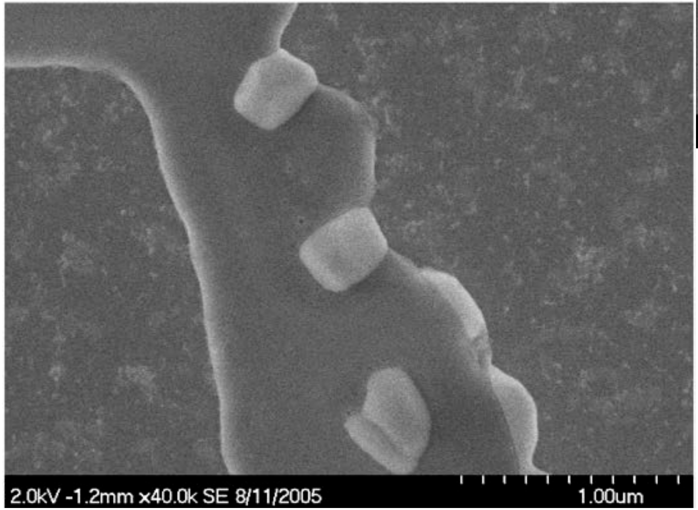
Li & Brett (2011) Spokane Regional Wastewater Bio-Availability Study (Final Report) Feb 2011. Univ Washington.

FERRIC PHOSPHATE (FEPO4) PRECIPITANT

SCOTT SMITH, WILFRID LAURIER UNIVERSITY

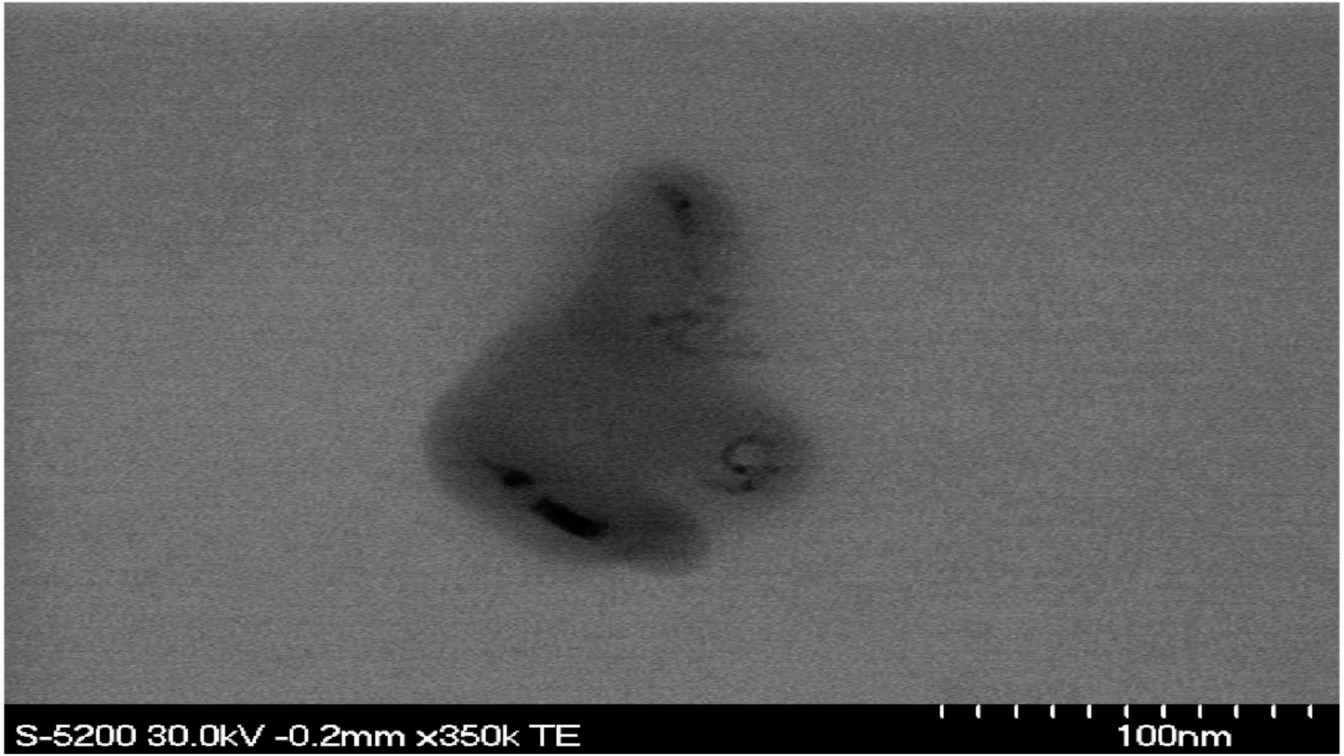
pH 7-->





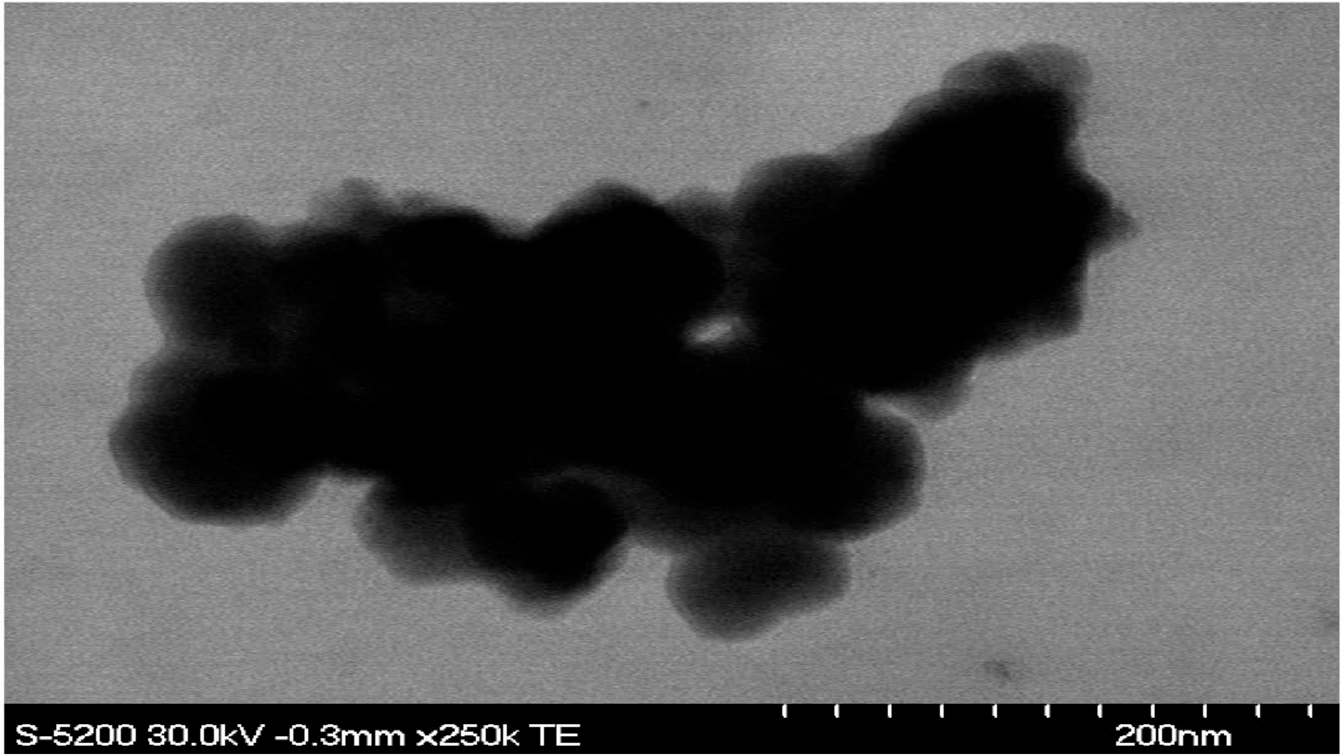
← pH 3

FRESH HFO



Scott Smith, Wilfrid Laurier University

YOUNG HFO



Scott Smith, Wilfrid Laurier University

AGED HFO

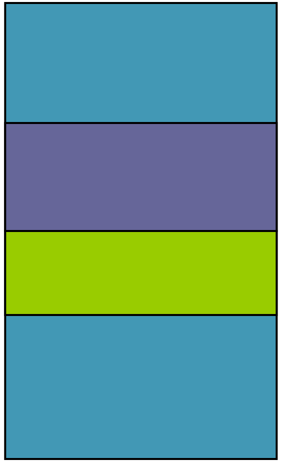
Scott Smith, Wilfrid Laurier University

$FePO_4$ precipitant

After 4 days.
Hard !!

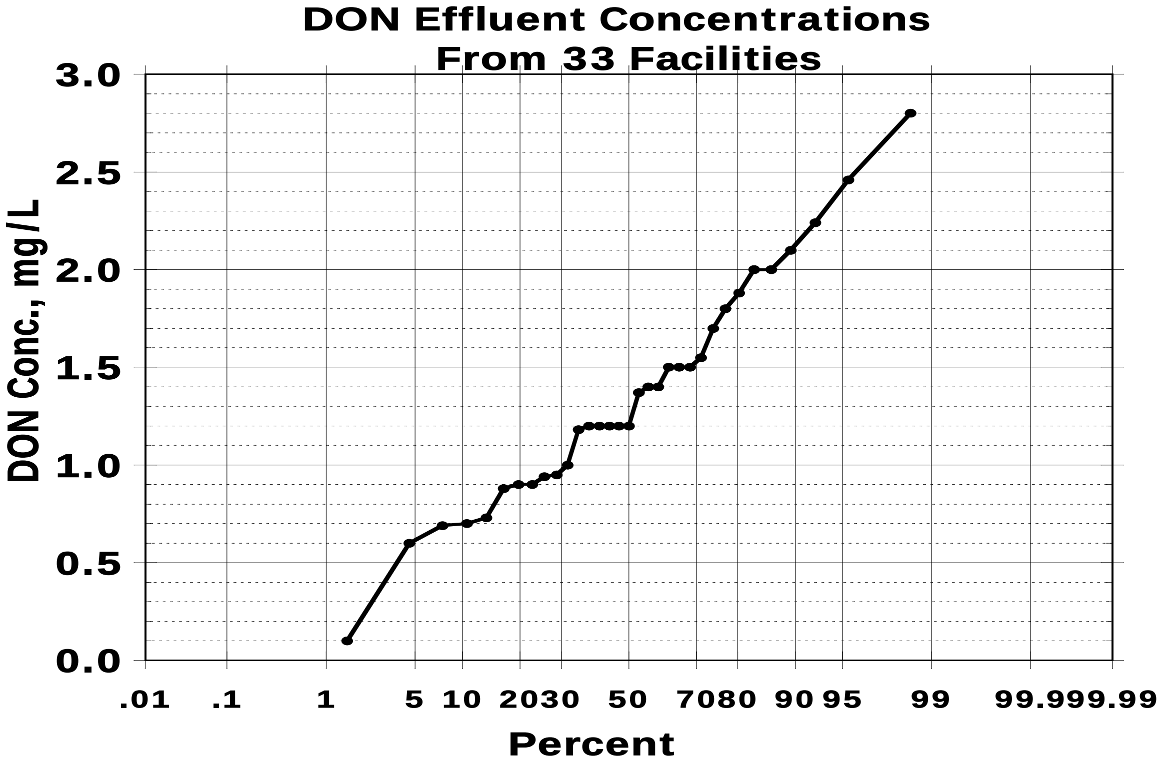
Scott Smith, Wilfrid Laurier University

EFFLUENT NITROGEN SPECIES FOLLOWING ADVANCED NUTRIENT REMOVAL TREATMENT



	Effluent
Nitrite+nitrate	~0.5 – 3 mg/L
Ammonia	~0.1-0.5 mg/L
Particulate organic nitrogen	~0.01-1.0 mg/L
Dissolved organic nitrogen	~0.5-2 mg/L

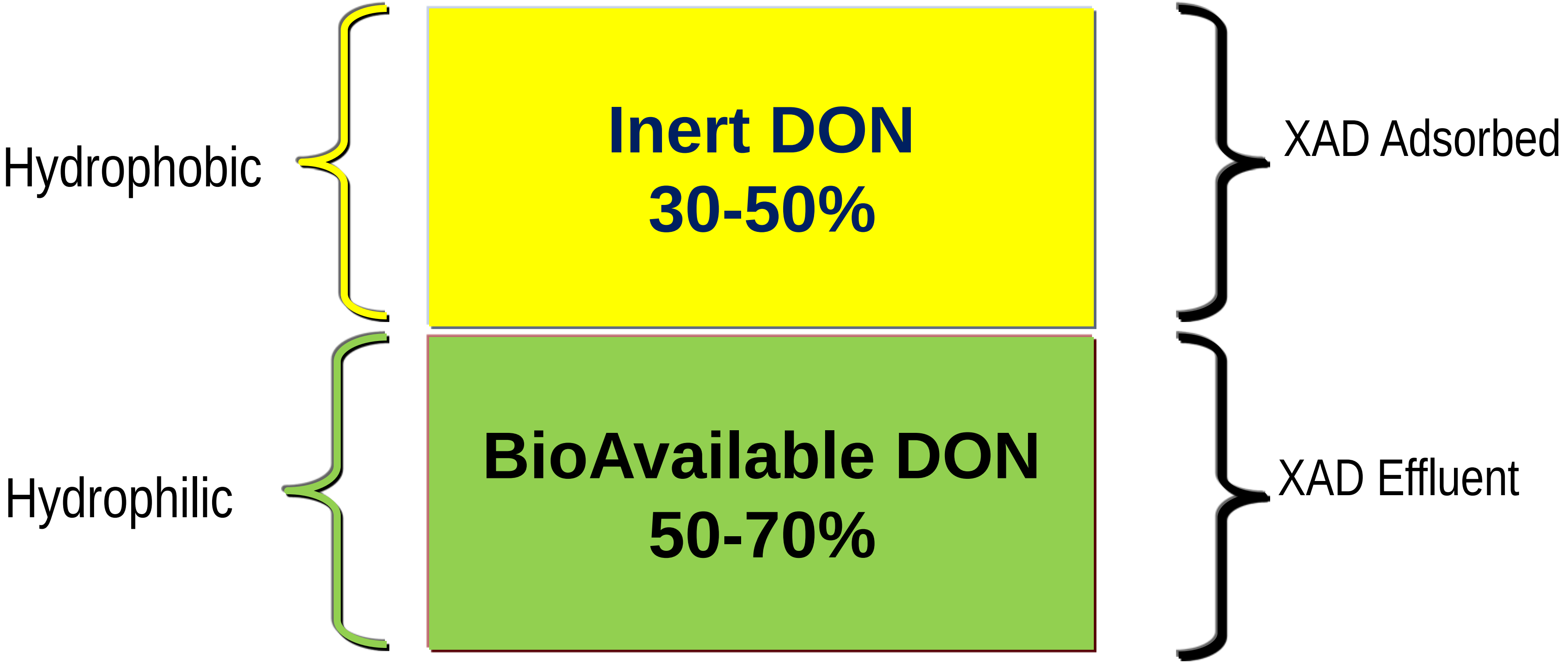
EFFLUENT DISSOLVED ORGANIC NITROGEN (DON) VARIES FOR DIFFERENT WWTPS



D. Stensel, University of Washington

WERF
Water Environment Research Foundation
Collaboration. Innovation. Results.

CONCEPTUAL MODEL FOR DISSOLVED ORGANIC NITROGEN (DON) FRACTIONS

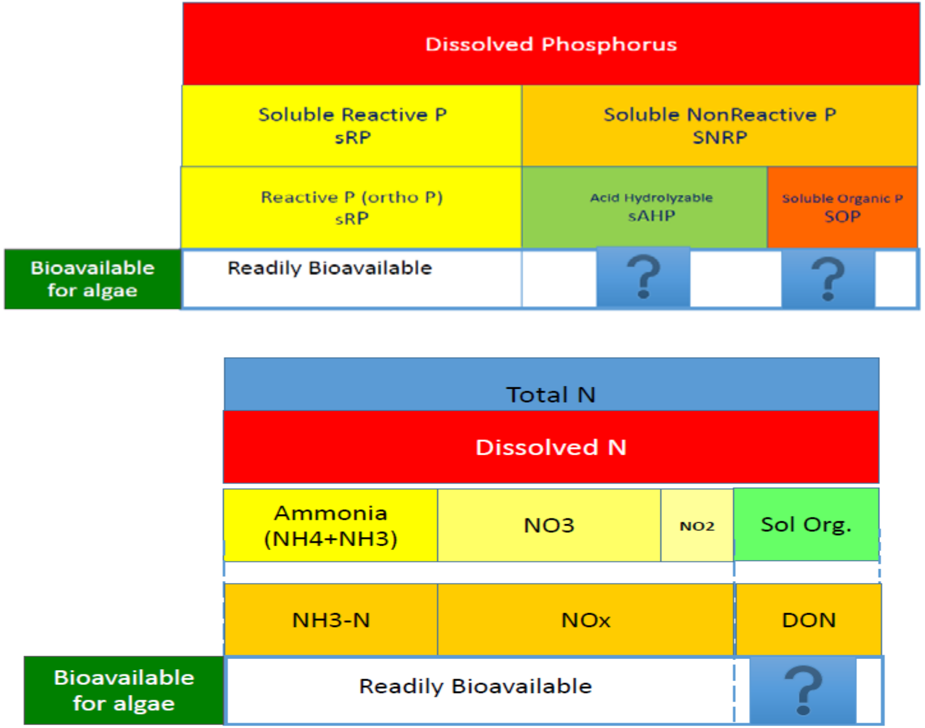


David Sedlak, Univ. California, Berkeley

WATER ENVIRONMENT & REUSE FOUNDATION (WE&RF) NUTRIENT RESEARCH PROGRAM

UNDERSTANDING SPECIATION AND ITS IMPACT ON FACILITY DESIGN AND RECEIVING WATERS

- A fundamental understanding of nutrient species is necessary to interpret, improve, and eventually incorporate appropriate technologies in the design of facilities requiring removal to very low levels and understand the impacts on receiving waters



WASTEWATER AND WATER QUALITY MODELING TERMINOLOGY FOR NITROGEN SPECIES

<table>
<tr><td></td><td colspan="7">Total N (TN)</td></tr>
<tr><td></td><td colspan="5">Total Soluble N (TSN)</td><td colspan="2">Total Particulate N (TpN)</td></tr>
<tr><td></td><td>Ammonia (NH_3) + Ammonium (NH_4)</td><td>Nitrate (NO_3)</td><td>Nitrite (NO_2)</td><td colspan="2">Soluble Organic N (SON)</td><td colspan="2">Particulate Organic N (pON)</td></tr>
<tr><td>Modeling Terminology</td><td>Ammonia + Ammonium</td><td>Nitrate</td><td>Nitrite</td><td>Dissolved Organic Nitrogen Labile</td><td>Dissolved Organic Nitrogen Refractory</td><td>Particulate Organic Nitrogen Labile</td><td>Particulate Organic Nitrogen Refractory</td></tr>
<tr><td></td><td>Total Ammonical N (TAN)</td><td colspan="2">Total Oxidized N (NO_x)</td><td colspan="4"></td></tr>
<tr><td></td><td colspan="3">Total Inorganic N (TIN)</td><td colspan="4">Total Organic N (TON)</td></tr>
</table>

WASTEWATER AND WQ MODELING TERMINOLOGY FOR PHOSPHORUS SPECIES

<table>
<tr><td></td><td colspan="6">Total Phosphorus (TP)</td></tr>
<tr><td></td><td colspan="3">Total Soluble P (TSP)</td><td colspan="3">Total Particulate P (TpP)</td></tr>
<tr><td></td><td>Soluble Reactive P (SRP)</td><td colspan="2">Soluble Non-reactive P (SNRP)</td><td>Particulate Reactive P (pRP)</td><td colspan="2">Particulate Non-reactive P (pNRP)</td></tr>
<tr><td>Modeling Terminology</td><td>Phosphate</td><td colspan="2">Dissolved Organic Phosphorus Labile and Refractory</td><td>Particulate Organic Phosphate Labile</td><td colspan="2">Particulate Organic Phosphate Refractory</td></tr>
<tr><td></td><td>Soluble Reactive P (SRP)</td><td>Soluble Acid Hydrolyzable P (SAHP)</td><td>Soluble Organic P (SOP)</td><td>Particulate Reactive P (pRP)</td><td>Particulate Acid Hydrolyzable P (pAHP)</td><td>Particulate Organic P (pOP)</td></tr>
</table>

TECHNOLOGY PERFORMANCE

“How Low Can We Go?”
(Considering performance, reliability and uncertainty in design)

EFFLUENT QUALITY FOR WASTEWATER TREATMENT TECHNOLOGIES[1]

Parameter	Typical Municipal Raw Wastewater, mg/l	Secondary Effluent (No Nutrient Removal), mg/l	Typical Advanced Treatment Nutrient Removal (BNR), mg/l	Enhanced Nutrient Removal (ENR), mg/l	Limits of Treatment Technology, mg/l	*Typical In-Stream Nutrient Criteria, mg/l*
Total Phosphorus	4 to 8	4 to 6	1	0.25 to 0.50	0.05 to 0.07	*0.020 to 0.050*
Total Nitrogen	25 to 35	20 to 30	10	4 to 6	3 to 4	*0.3 to 0.600*

Las Vegas, NV

(TP 0.170 mg/l)

Clean Water Services, OR

(TP 0.100 mg/l)

Lacy, Olympia, Tumwater Thurston Co (LOTT), WA

(TIN 2 mg/l)

Coeur d'Alene, ID

(TP 0.050 mg/l)

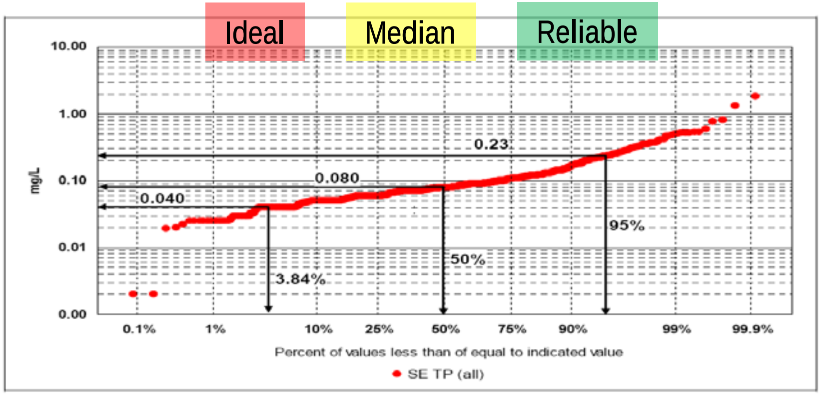
[1]*Ignoring Considerations of Variability and Reliability of Wastewater Treatment Performance*

Water Environment Research Foundation (WERF) "*Nutrient Management: Regulatory Approaches to Protect Water Quality, Volume 1 – Review of Existing Practices*," Project #NUTR1R06i

ADVANCED NUTRIENT REMOVAL PERFORMANCE

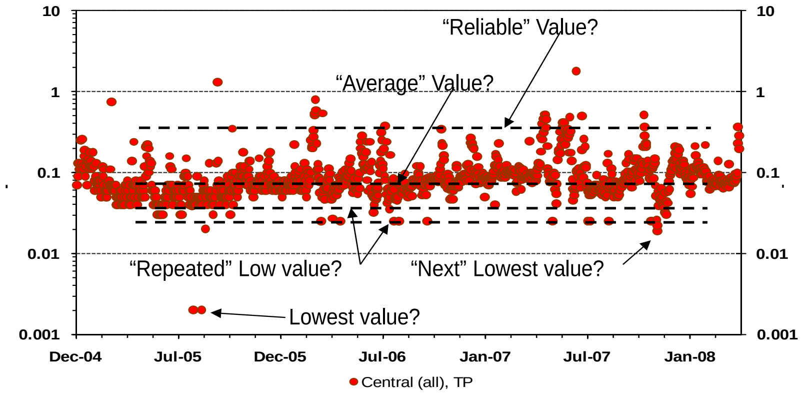
- Effectiveness of Advanced Treatment for Nutrient Removal
  - Variability in Treatment Performance
  - Reliability
  - Effluent Speciation
    - Bioavailability

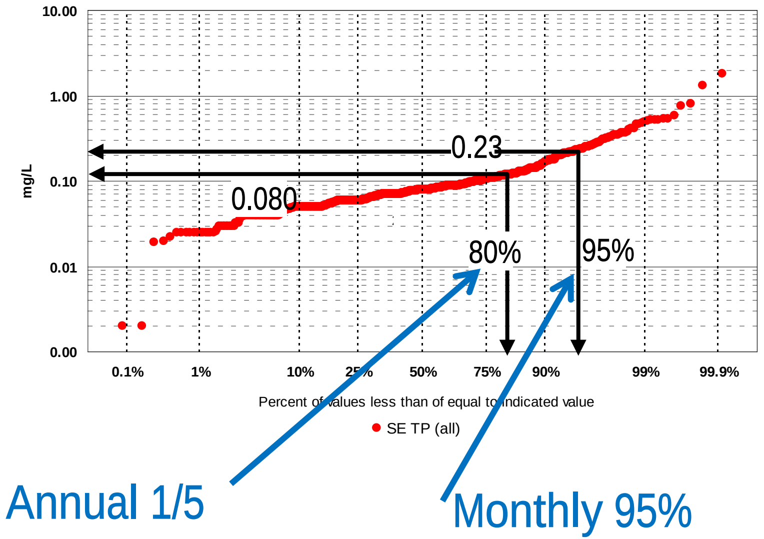
Technology Performance Statistics



Neethling, JB; Stensel, H.D.; Parker, D.S.; Bott, C.B.; Murthy, S.; Pramanik, A.; Clark, D. (2009) What is the Limit of Technology (LOT)? A Rational and Quantitative Approach. *Proceedings of the WEF Nutrient Removal Conference*, Washington DC, Water Environment Federation, Alexandria, Virginia.

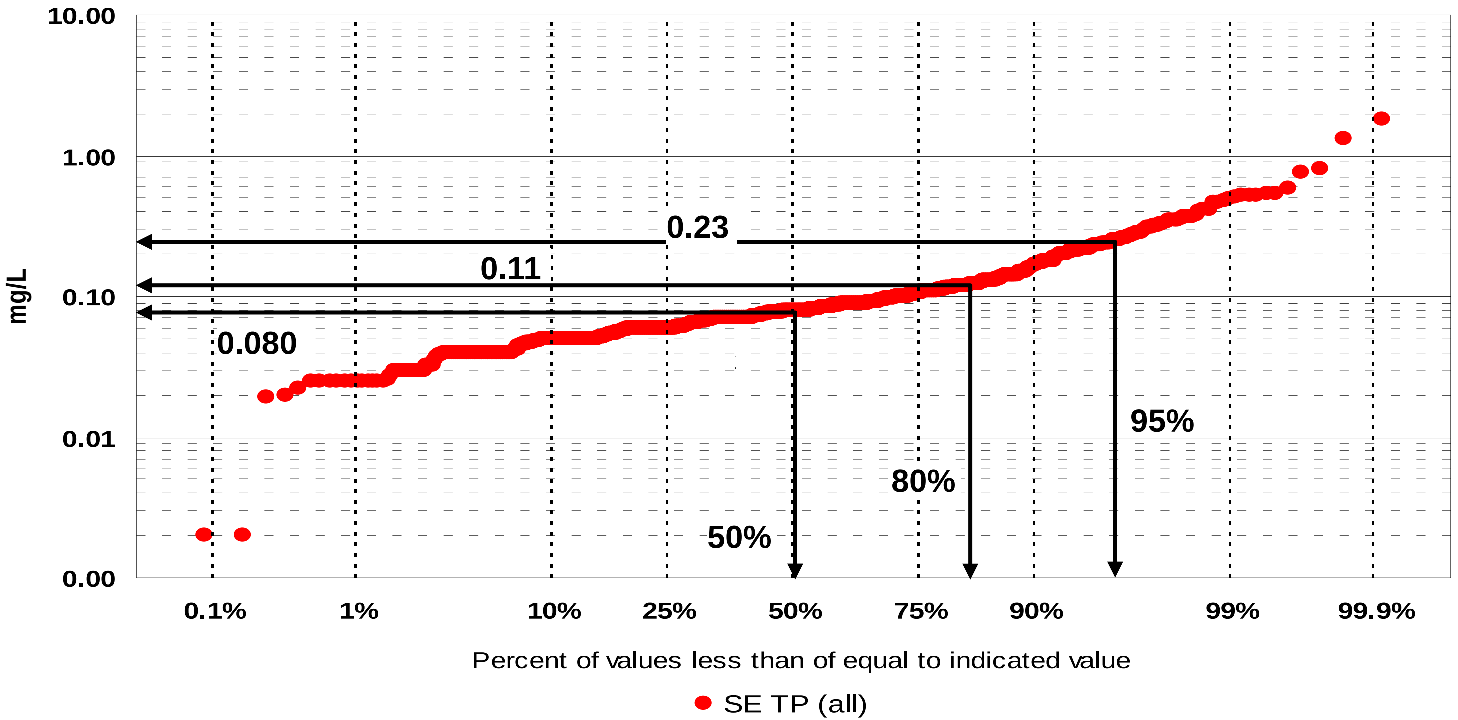
TREATMENT PERFORMANCE VARIABILITY IMPACTS RELIABILITY





Neethling et al. (2009) *WEF Nutrient 2009,* Alexandria, VA.

- Statistical variability is characteristic in even exemplary plants with different configurations
- Long averaging periods warranted given inherent variability while approaching “zero”
- Simple statistics can properly define reliability providing designers a design basis for facilities



TECHNOLOGY PERFORMANCE STATISTICS (TPS)

- Quantifies Effluent N and P Performance and Reliability
  - Statistical Description of Probability of Achieving a Specific Concentration
  - Examples
    - Median Performance Represents Average Treatment: TPS-50%
      - 50% Data is Below and 50% is Above This Concentration
    - TPS-95%: Performance Achieved 95% of Time
      - Exceeded 5% of Time

APPLICATION OF KEY TECHNOLOGY PERFORMANCE STATISTIC VALUES

Limit	Technology Performance Statistics (TPS)	Statistical Probability	Interpretation	Effluent Performance Implication
Best Achievable Performance	TPS-14d	3.84th percentile[1]	The best performance possible with the technology under the optimal or best operating conditions. This represents the LOT (Limit of Technology).	This limit will be exceeded 96% of the time.
Average Technology Achievable Limit	TPS-50%	50th percentile	This represents a measure of the concentration that was achieved on a statistical annual average basis.	As the median performance, the process exceeds this 6 times per year.[2]
Reliable Technology Achievable Limit	TPS-95%	95th percentile	This represents the concentration that can be achieved reliably by the technology.	This limit is exceeded 0.6 times[2] per year – 3 times in a 5 year period.

TECHNOLOGY PERFORMANCE STATISTICS APPLICATION TO DISCHARGE PERMITTING

Benefits

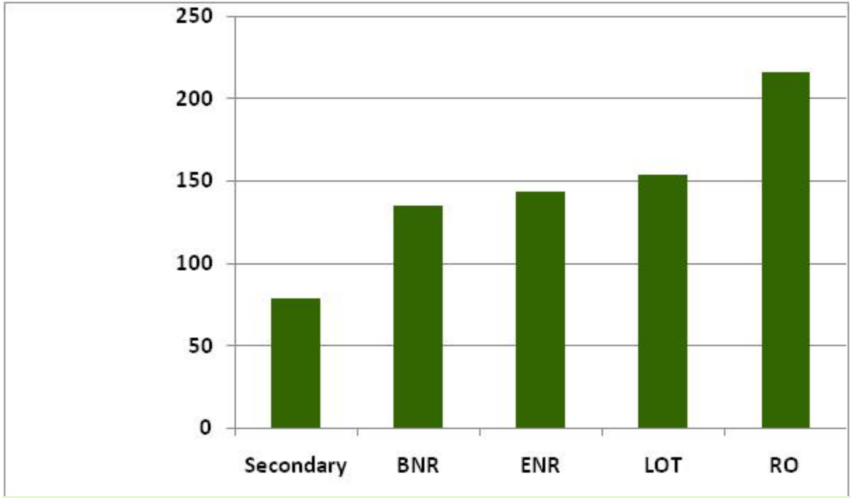
- Accurate Numerical Depiction of Treatment
  - Detailed Treatment Performance Data
  - WERF Nutrient Challenge Key Resource
- Direct Accounting for Effluent Variability
- Statistical Definition of Effluent Performance Requirements
  - Defines Process Design Requirements in Terms of Average and Reliable Performance

Limitations

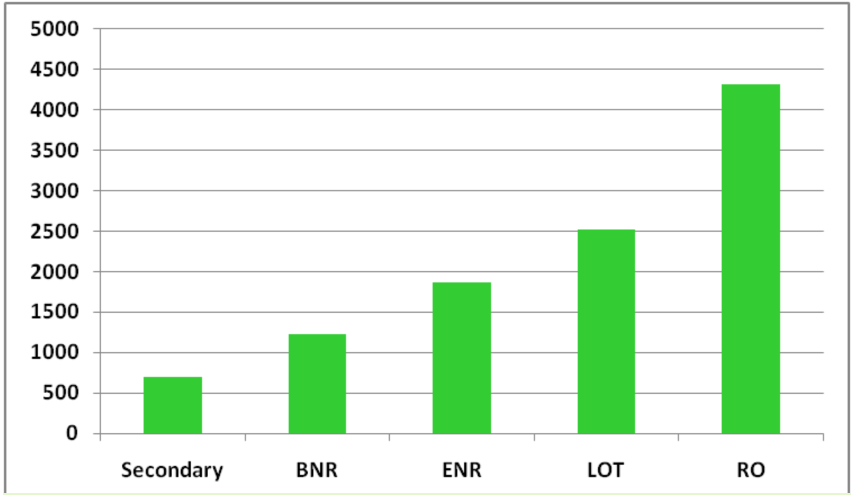
- Requires Linkage to Receiving Water Quality Criteria
  - Allowable Frequency and Duration

SUSTAINABILITY

TREATMENT COSTS ESCALATE SUBSTANTIALLY APPROACHING TECHNOLOGY LIMITS



Estimated Capital Costs for 10 mgd Capacity (Million $)

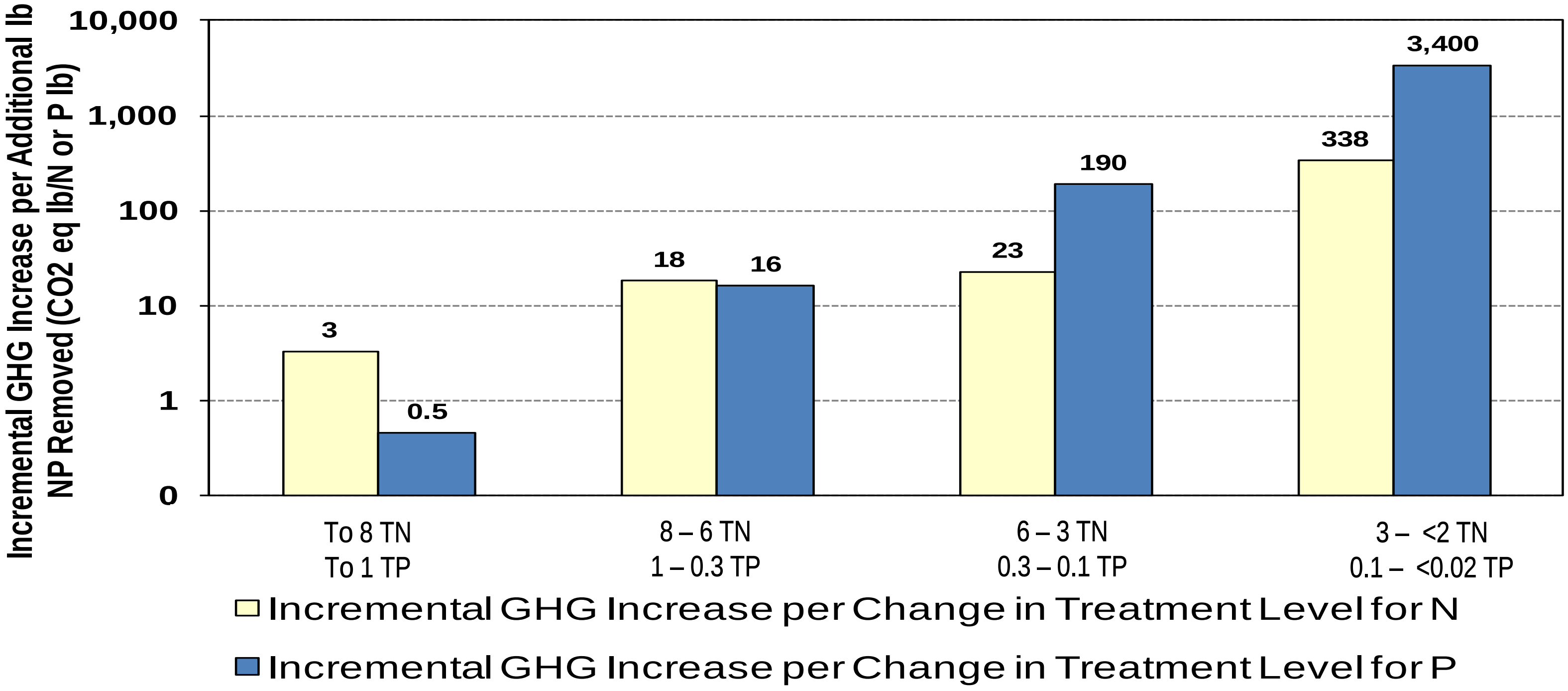


Estimated O&M Costs for 10 mgd Capacity ($1,000/yr/10 MG Treated)

Water Environment Research Foundation (WERF) "*Striking the Balance Between Wastewater Treatment Nutrient Removal and Sustainability*" November 2010

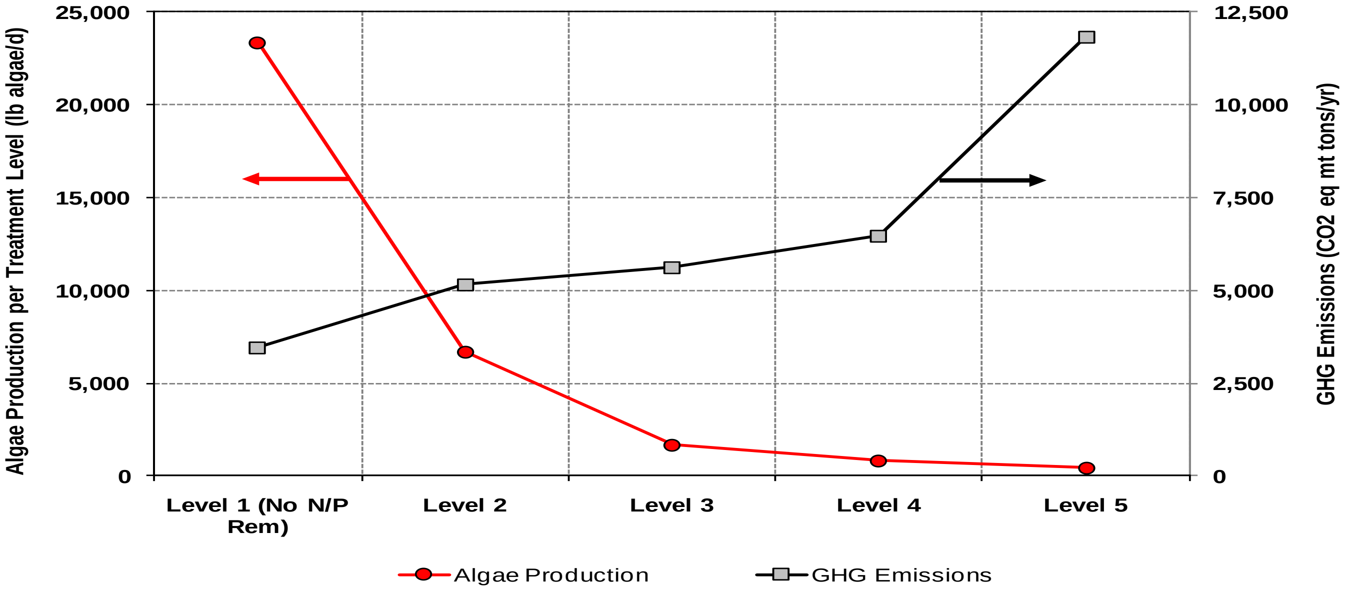
1. *Secondary Treatment (No nutrient removal)*
2. *Biological Nutrient Removal (BNR) TP 1 mg/L TN 8 mg/L*
3. *Enhanced Nutrient Removal (ENR) TP 0.1-0.3 mg/L TN 4-8 mg/L*
4. *Limit of Treatment Technology (LOT) TP <0.1 mg/L TN 3 mg/L*
5. *Reverse Osmosis (RO) TP <0.01 mg/L TN 1 mg/L*

INCREMENTAL GREENHOUSE GAS (GHG) EMISSIONS FOR N AND P REMOVAL



Adapted from Falk et al., 2011. "Striking the Balance Between Nutrient Removal in Wastewater Treatment and Sustainability" WERF Nutrient Removal Challenge project NUTR1R06n.

ALGAL PRODUCTION POTENTIAL V. GREENHOUSE GAS PRODUCTION

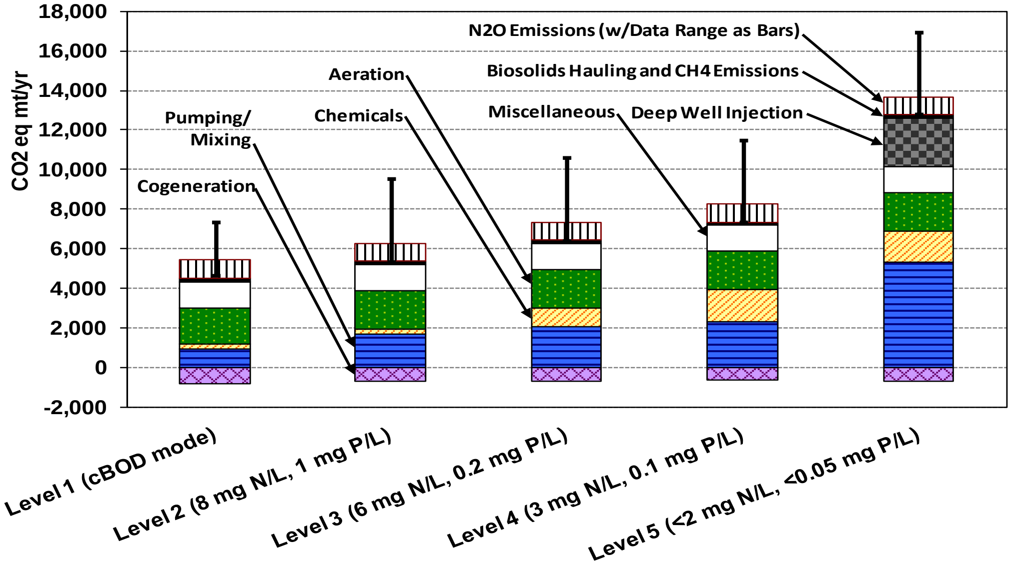


Water Environment Research Foundation (WERF) "*Striking the Balance Between* <u>*Wastewater Treatment Nutrient Removal and Sustainability*" November 2010</u>

1. *Secondary Treatment (No nutrient removal)*
2. *Biological Nutrient Removal (BNR) TP 1 mg/L TN 8 mg/L*
3. *Enhanced Nutrient Removal (ENR) TP 0.1-0.3 mg/L TN 4-8 mg/L*
4. *Limit of Treatment Technology (LOT) TP <0.1 mg/L TN 3 mg/L*
5. *Reverse Osmosis (RO) TP <0.02 mg/L TN 2 mg/L*

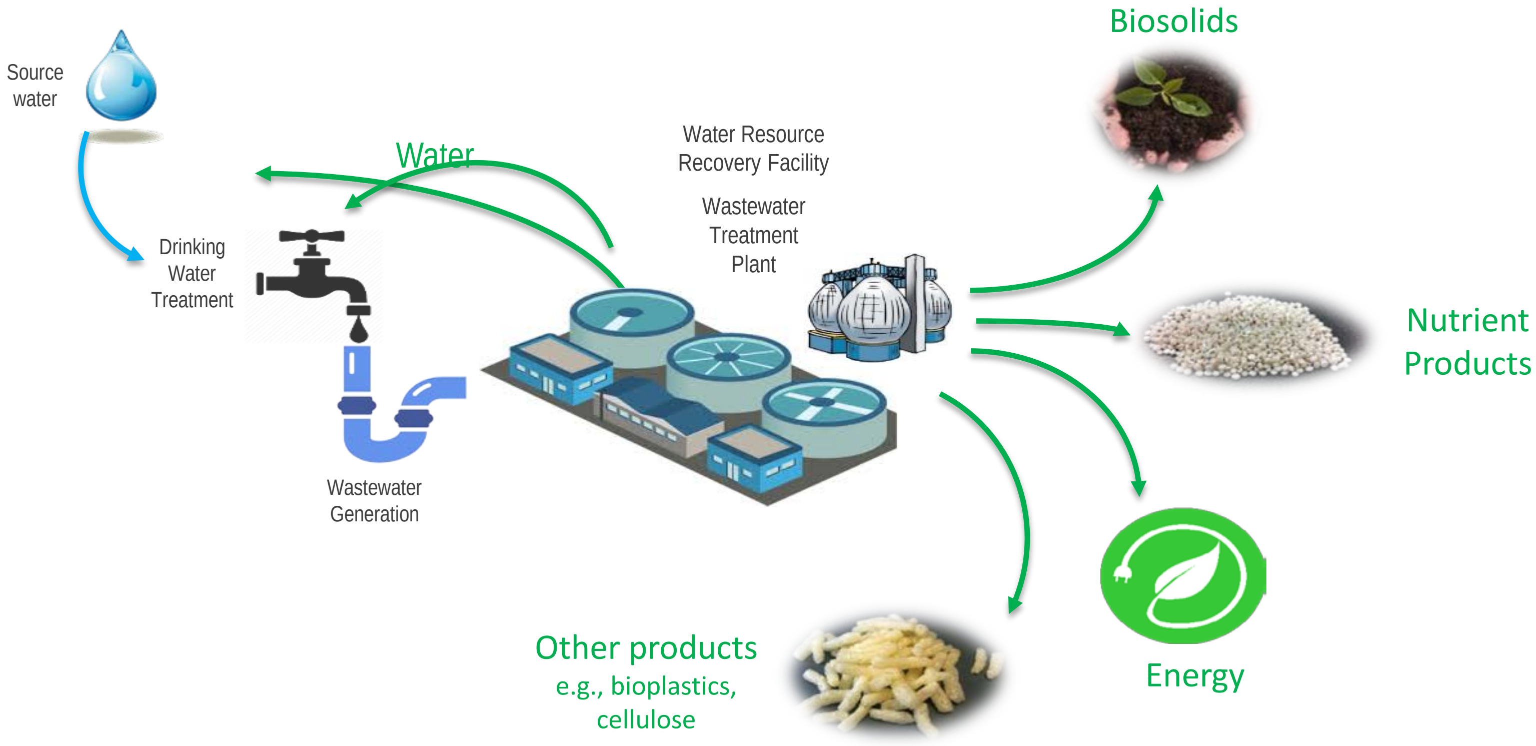
CONSIDERING SUSTAINABILITY IN THE DESIGN OF LOW NUTRIENT FACILITIES

- NUTR1R06n Striking the Balance between Nutrient Removal in Wastewater Treatment and Sustainability (Falk et al, 2011)
- NUTR1R06v Development of Sustainable Approaches for Achieving Low Phosphorus Effluents (deBarbadillo et al, 2015).
- NUTR1R06R14f Sustainability Evaluation of Nutrient and Contaminants of Emerging Concern Removal Technologies using Life Cycle Assessment (Gu et al, 2016)



WASTEWATER AS A RESOURCE

Paradigm Shift in Water Management



Source: WEF/WE&RF Webinar "Creative Solutions for the Recovery of Commodities from Wastewater", May 25, 2016

STRUVITE - MAP

Magnesium Ammonium Phosphate

STRUVITE CONTROL APPROACH

Allow or promote struvite
Formation

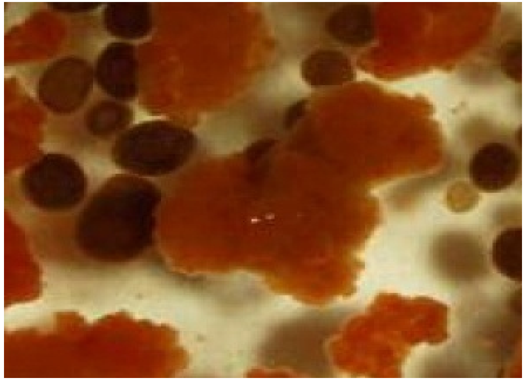
Minimize or prevent struvite
Deposits

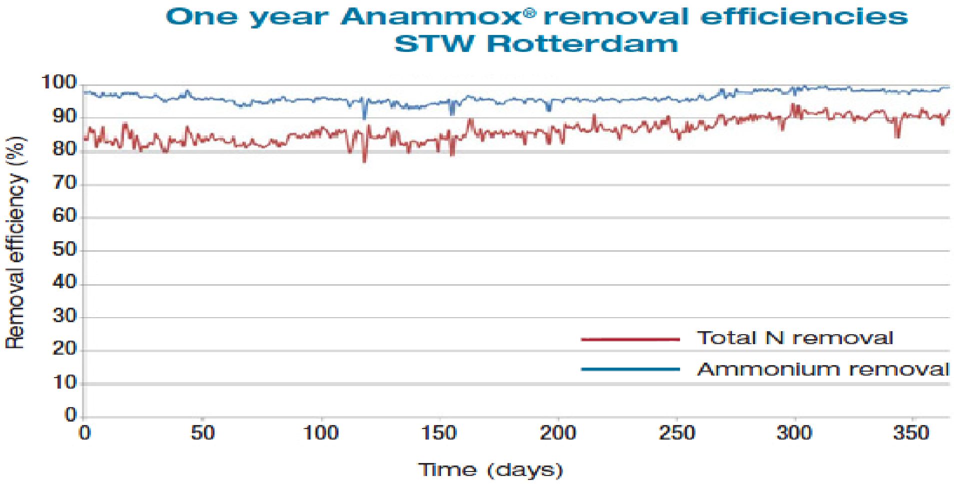
CREATING VALUE FROM WASTE

From **Problems**

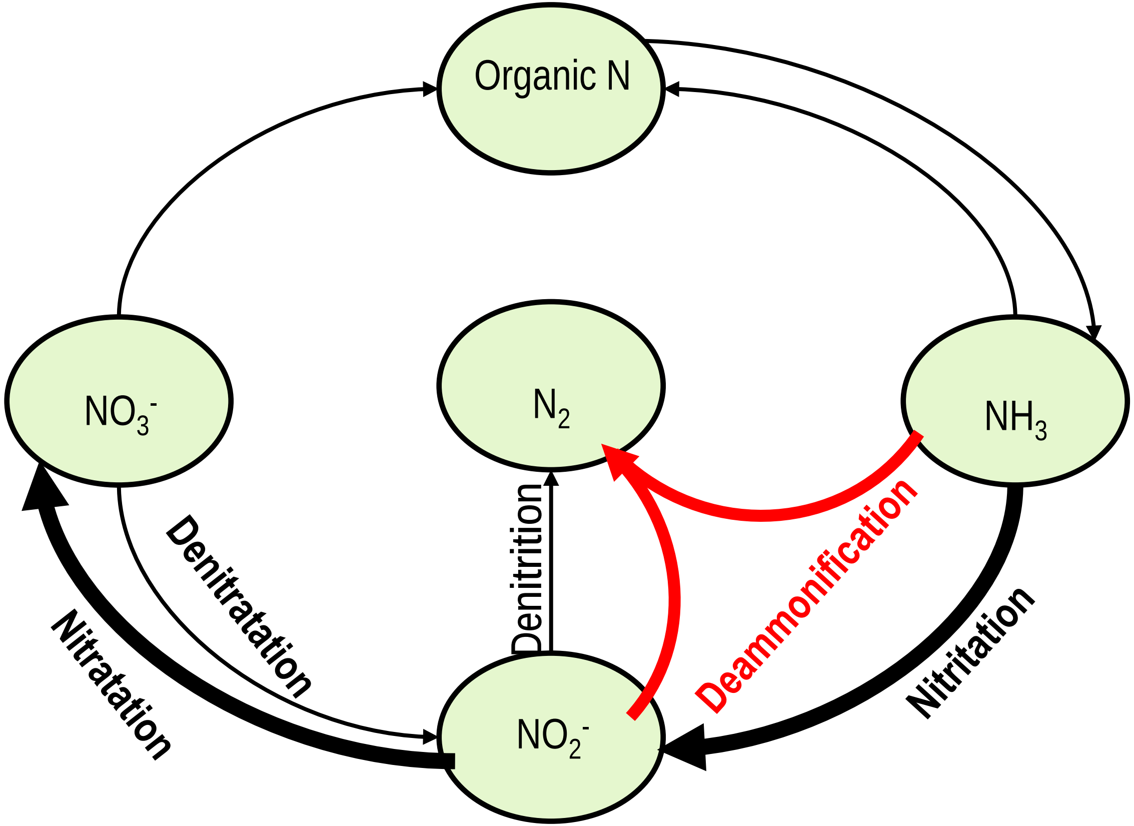
To **Solutions**

SIDESTREAM TREATMENT OF SOLIDS DEWATERING RETURNS TO LIQUID STREAM TREATMENT - ANAMMOX DEAMMONIFICATION

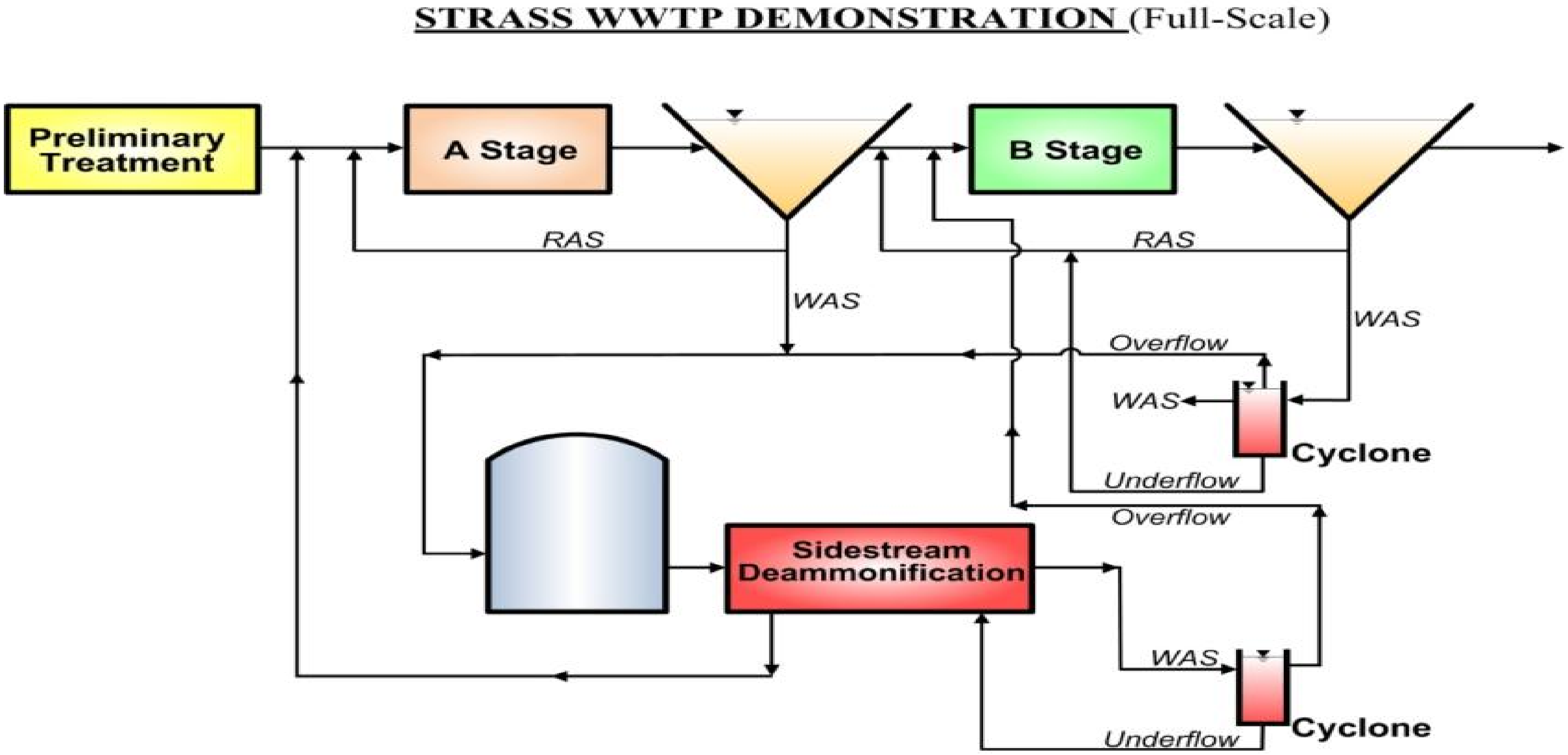




NITROGEN TRANSFORMATIONS – ANAMMOX/DEAMMONIFICATION



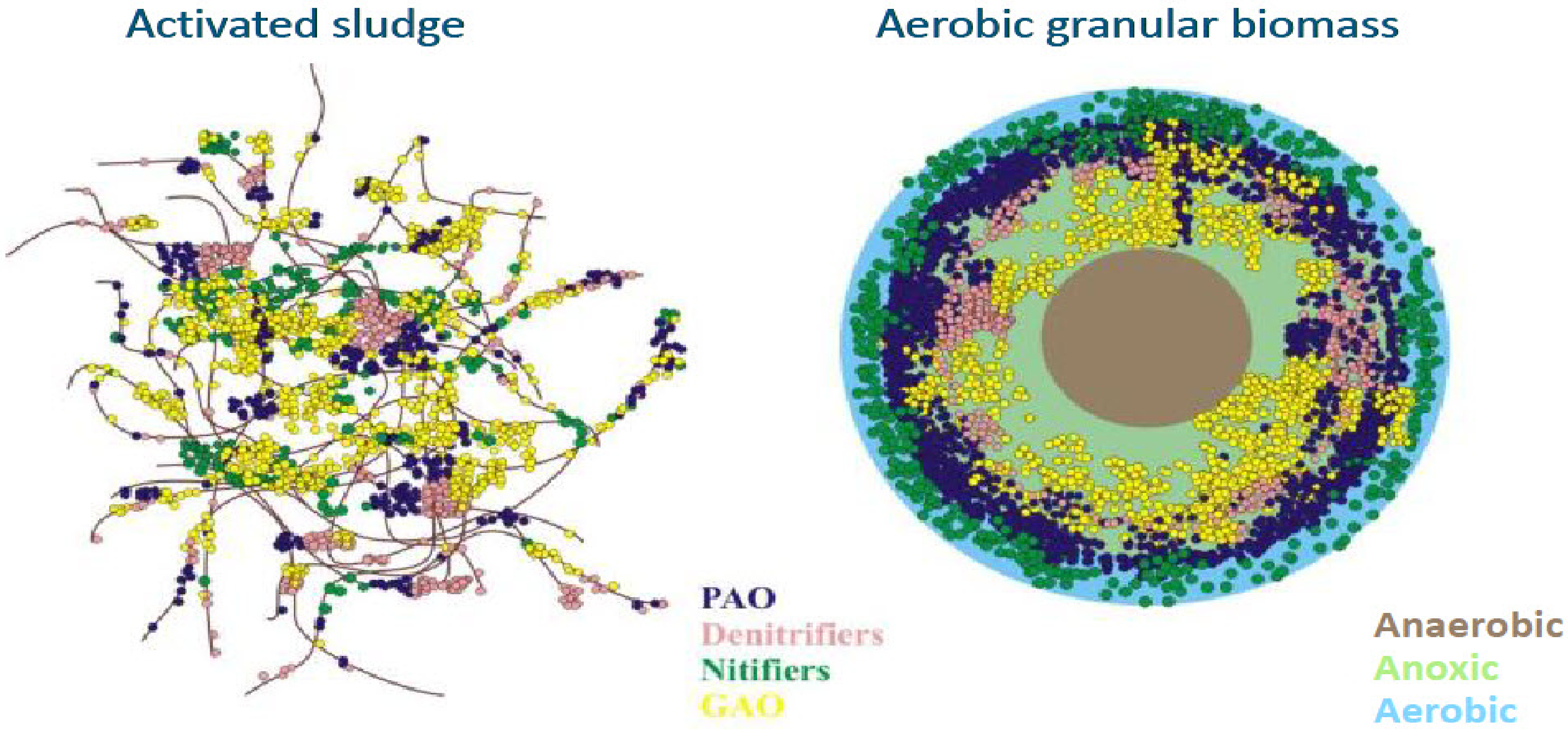
MAINSTREAM ANAMMOX



Wett et al 2010

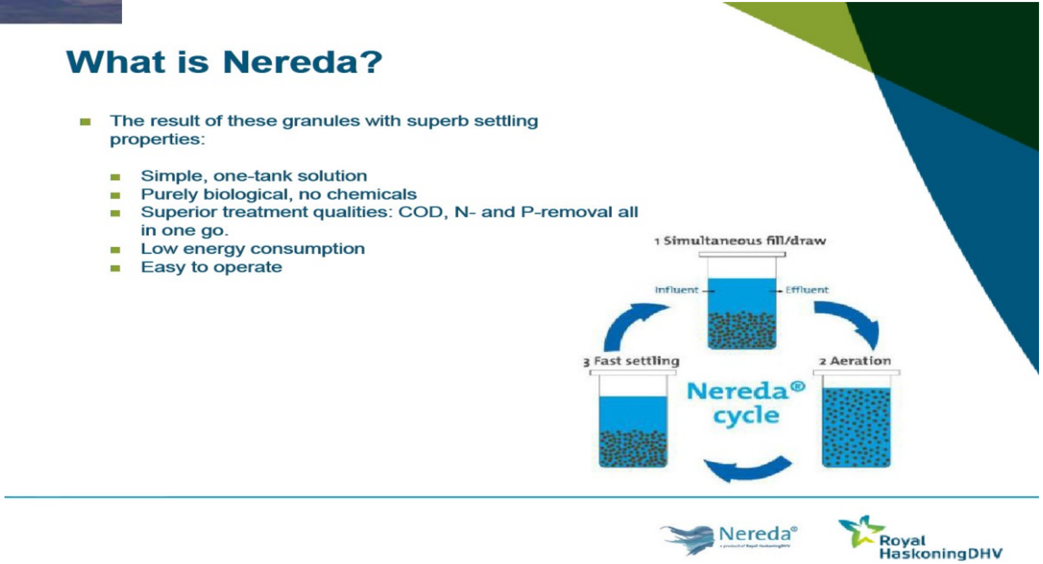
GRANULAR ACTIVATED SLUDGE (G_RAS)

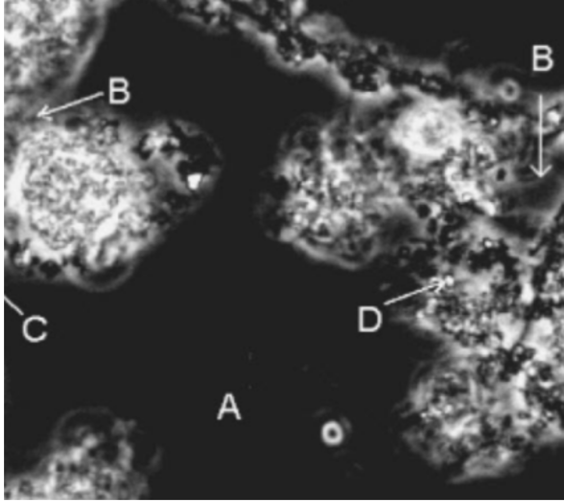
GRANULAR ACTIVATED SLUDGE (G$_{R}$AS)

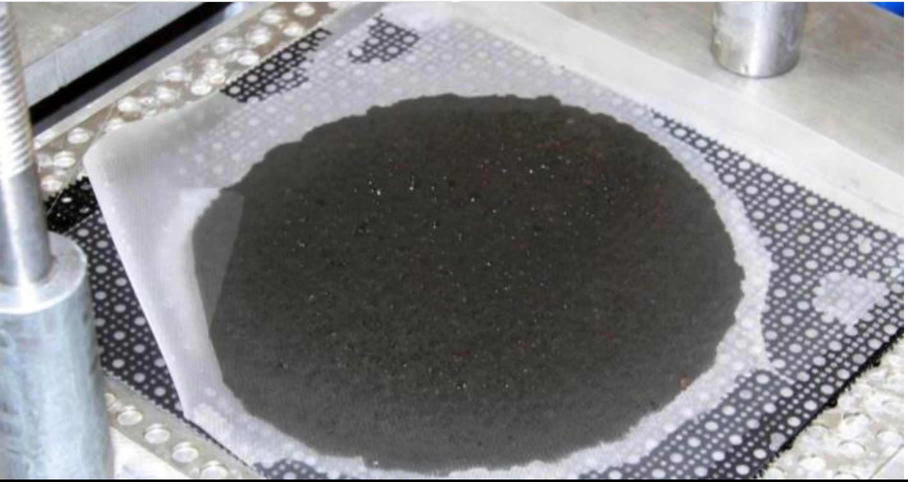


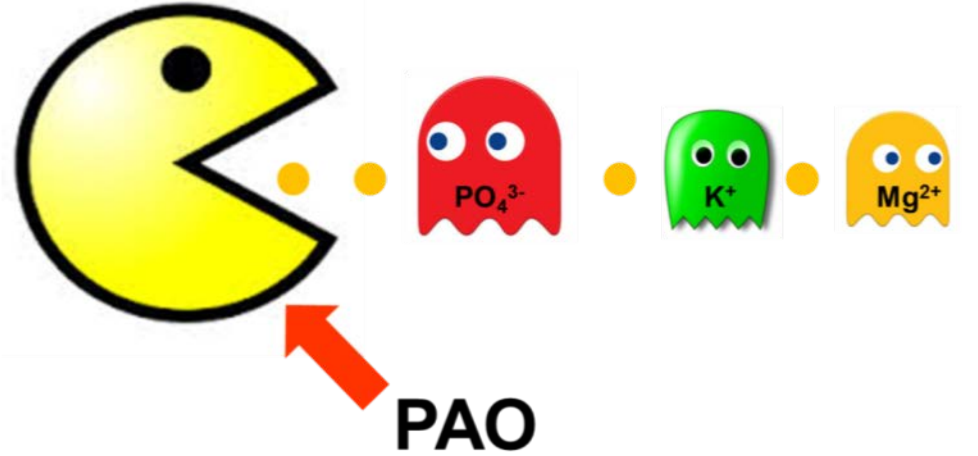
Courtesy Delft University of Technology

GRANULAR ACTIVATED SLUDGE (G_RAS)









DEWATERING IMPACTS FROM PHOSPHORUS REMOVAL

BIOSOLIDS DEWATERING OPTIMIZATION

Seminar for Factors Impacting Dewatering

Thursday, May 12th, 10am-3pm (Optional Plant Tour, 8-9:30am)
Brightwater Education and Community Center, North Room

Would you like to take "trial and error" out of dewatering?

You are invited to learn about the wide range of factors that impact dewaterability and dewatering performance, as well as operations costs. Important factors outside the dewatering building are often overlooked, such as upstream treatment processes and industrial contributors. Seasonal changes, service area changes, resource recovery measures (such as co-digestion and phosphorus recovery) can affect a plant's overall performance. For dewatering equipment procurement, understanding these factors and interrelationships can help minimize the risk that post-startup performance results in lengthy disputes between vendors and owners.

Seminar Speakers

Our featured speaker, Dr. Julia Kopp developed a thermo-gravimetric sludge analysis method that predicts the maximum cake TS for specific equipment with great accuracy. The same method can be used to confirm and quantify changes in dewaterability.

Julia Kopp, PhD, internationally-known expert in sludge treatment and dewatering, and owner of Kopp Sludge Consulting. For over 20 years Dr. Kopp has been advising utilities as well as equipment and technology vendors in digestion and dewatering matters.

Mario Benisch is a senior wastewater process engineer with HDR in Portland, Oregon and brings two decades of experience planning, modeling, designing, and optimizing wastewater treatment facilities.

Jeff Zahller is a chemical and process engineer with HDR in Bellevue, Washington. He has 15 years of experience in applied research, process design, facility analysis, and startup/commissioning of wastewater treatment plants.

Pat Roe is a wastewater treatment program manager in HDR's Bellevue, Washington Office. Pat has been extensively involved in wastewater solids management and handling projects for over 36 years.

Part 1 of the seminar will focus on various factors impacting dewatering and dewaterability, including:

- Liquid treatment process
- Polymer and coagulants
- Operation, monitoring, and control
- Testing, procurement, and design

Part 2 of the seminar will transition into factors that impact digestion, dewatering, and disposal:

- Sludge pretreatment (THP, CHP, Airprex, etc)
- Co-digestion of food waste or other external sources
- Case studies

CEU Credits Requested   Lunch will be provided!
Please contact sasha.woods@hdrinc.com **by May 6** to register

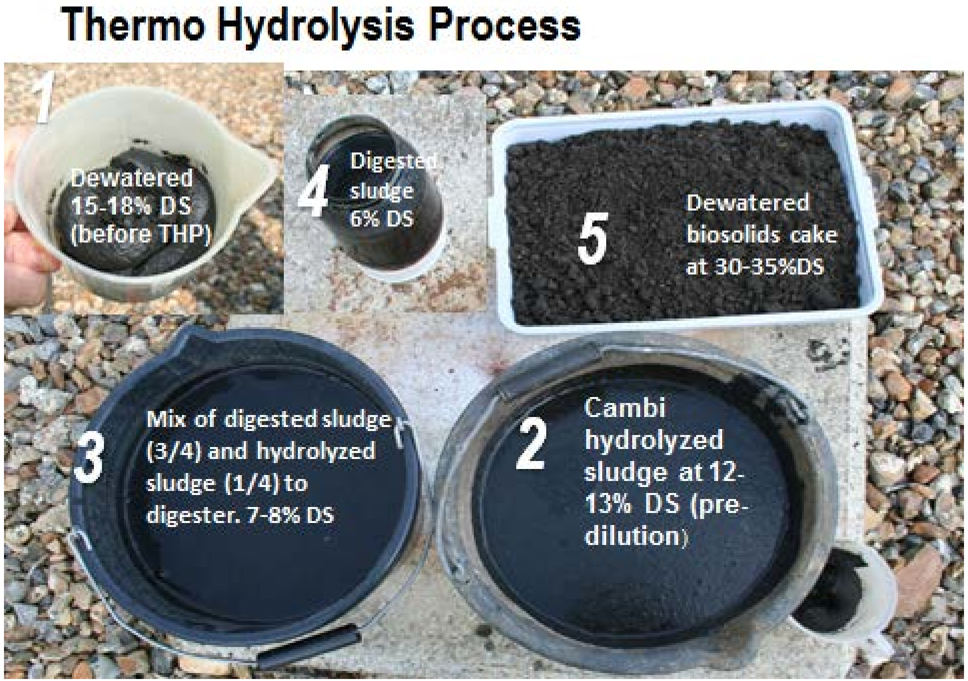
Kopp Sludge Consulting   HDR

THERMAL HYDROLYSIS – ENHANCED SOLIDS DESTRUCTION, CAKE SOLIDS, AND BIOGAS PRODUCTION

THERMO HYDROLYSIS PROCESS (THP) FOR SOLIDS TREATMENT

- High Pressure
- High Temperature (steam)
- 30 – 45 minutes
- For raw or digested sludge

Thermo Hydrolysis Process



NEW CHALLENGES

Nutrient Removal, Wet Weather Compliance, etc

NEW CHALLENGES AND COMPETING DEMANDS

- Nutrients
  - Nitrogen and Phosphorus
- Wet Weather Compliance
  - Increasing Storm Frequency and Intensity
- Toxics
  - Revised Federal Ammonia Criteria
  - Human Health Water Quality Criteria
    - Recent Rulemaking in Oregon, Idaho, and Washington
    - ~100 Compounds
      - » PCBs, Mercury, Arsenic, Benzo-a-Pyrene, Bisthphlate, etc
- Resiliency
  - Drought, Sea Level Rise, Seismic, Storms, Flooding, etc
- Asset Management

CLIMATE CHANGE

Impacts in Rainfall Intensities

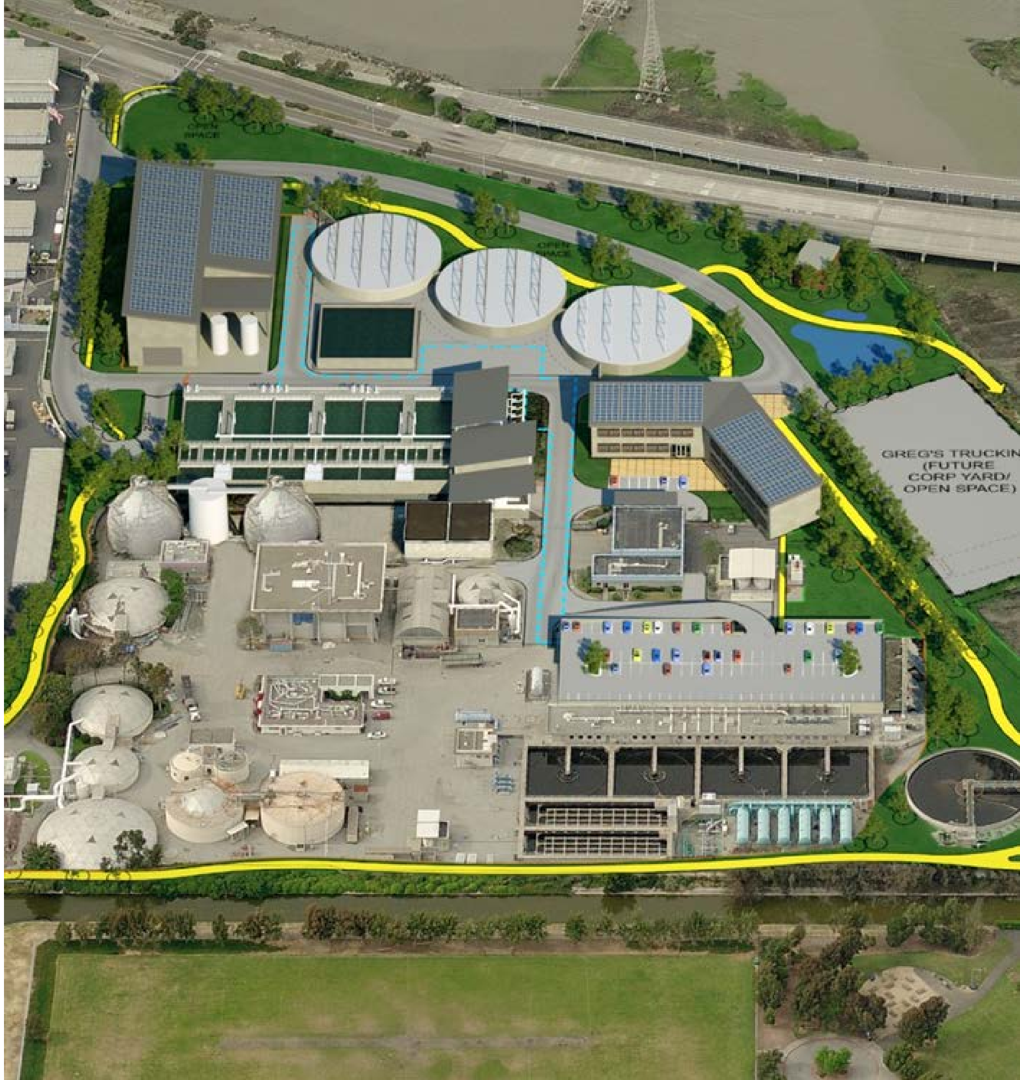
- Distribution of Changes in Fitted 1- and 24-h Annual Maxima from 1956–1980 to 1981–2005 at Seattle–Tacoma, Spokane, and Portland Airports (Rosenberg, E.A. et al. (2010))

Return Period (Years)		1-hour Storm			24-hour Storm		
		SeaTac	Spokane	Portland	SeaTac	Spokane	Portland
2	% Change	4.80%	6.50%	3.50%	22.90%	4.90%	−2.9%
	1981-2005 Value (in)	1.8	1.7	1.8	1.3	1.7	2.2
5	% Change	4.30%	1.50%	3.60%	29.40%	6.20%	4.30%
	1981-2005 Value (in)	4.3	4.7	4.3	2.1	3.8	4.2
10	% Change	5.80%	−4.1%	4.20%	32.10%	8.20%	9.80%
	1981-2005 Value (in)	8	11.9	8.2	3.1	6.5	6.6
25	% Change	9.10%	−12.6%	5.40%	34.30%	11.50%	17.70%
	1981-2005 Value (in)	17.3	47.9	19	5.7	12.8	11.5
50	% Change	12.60%	−19.3%	6.70%	35.20%	14.50%	24.20%
	1981-2005 Value (in)	30.3	155	35.6	9.3	20.5	17.1

SAN MATEO, CALIFORNIA

CITY OF SAN MATEO, CALIFORNIA

- Nutrient Removal and Wet Weather Flow Management Upgrade and Expansion Project
- New BNR Membrane Bioreactor (BNR/MBR)
  - Replacing Existing Secondary Processes
  - Bardenpho-type Configuration
    - Anaerobic, Anoxic, Aerobic, Deoxygenation (DeOx), Post-anoxic
- Dual Use Clarifiers (DUC)
  - Primary Clarifiers in Normal Operating Mode
  - Chemically Enhanced Primary Treatment (CEPT) (1 Clarifier) and Secondary Clarifiers (2 Clarifiers) for BioCET for Wet Weather Mode
- Biological and Chemically Enhanced Treatment (BioCET)



JOHNSON COUNTY KANSAS TOMAHAWK

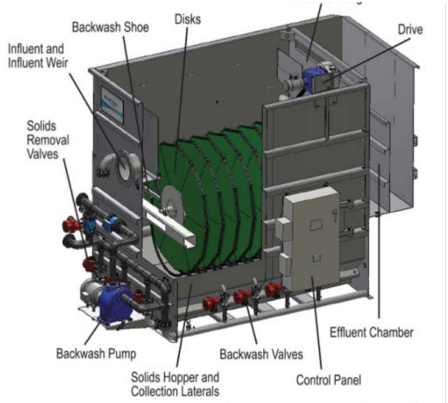
JOHNSON COUNTY KANSAS WASTEWATER

TOMAHAWK CREEK WASTEWATER TREATMENT FACILITY

- Discharge to Blue River (MO) via Indian Creek & Missouri River Basin
- Complex Permitting and Compliance History
  - Peak Wet Weather Compliance Consent Decree
  - Nitrogen and Phosphorus for Indian Creek
- Wet Weather Treatment Options
  - High Rate Clarification vs. Compressible Media Filtration
  - VE Led to Selectio of Pile Cloth Media Filter
- Capacity
  - Tertiary Polishing Up To 3x Average Flow 57 mgd
  - Peak Wet Weather Enhanced High Rate Treatment 115 mgd
  - Total Peak Flow 172 mgd

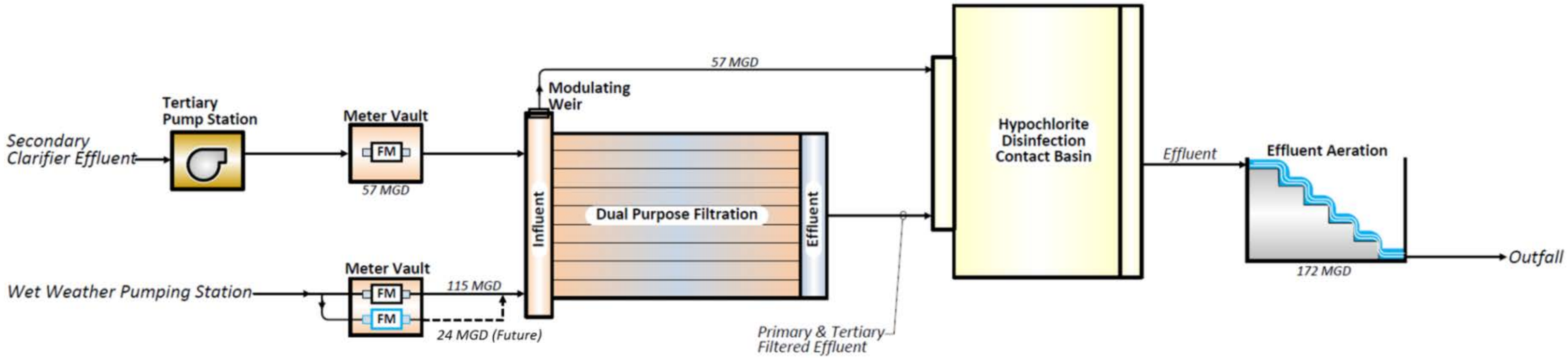
<u>Dual Purpose Tertiary Process</u>

- Dry Weather Effluent Polishing
- Peak Wet Weather Flow Filtration



Images courtesy Aqua-Aerobic Systems

DUAL-PURPOSE TERTIARY PROCESS FOR TOMAHAWK CREEK WWTF



Parameter	Effluent Limit (*Goal)	Averaging Period
TSS	30 mg/L 45 mg/L	Monthly Weekly
BOD_5	15 – 20 mg/L 25 – 30 mg/L	Monthly Weekly
NH_3-N	0.6 – 2.3 mg/L 7.0 – 11.8 mg/L	Monthly Daily
TN	*10 mg/L	Annual
TP	*0.5 mg/L	Annual

Tertiary polishing up to 3Q = 57 mgd

+ Peak WW EHRT up to 115 mgd

Peak WWTF capacity = 172 mgd

ADAPTIVE MANAGEMENT

PHASED IMPLEMENTATION AND COMPLIANCE SCHEDULES

SINGLE VS. MULTIPHASE IMPLEMENTATION

SINGLE VS. MULTIPHASE IMPLEMENTATION

Single Phase

- Implement Entire Program to Meet Final Effluent Limits
- Most Conservative Design
  - Add Costs for Over-design
- Challenging to Address
  - Site Specific Issues
  - Unique Wastewater Characteristics
  - Potential Shortcomings

Multiphase

- Technology Development
  - Pilot Studies, Full Scale Studies, Stress Testing, Operating Experience
- Early Nutrient Reduction Opportunities
  - Optimization Studies
  - Sidestream Treatment
- Adaptive Management
  - Feedback for Refinements
    - Design Criteria, Process Train, Equipment, Controls, Chemicals, etc.
  - Receiving Water Quality Monitoring
- Requires Extended Compliance Schedule

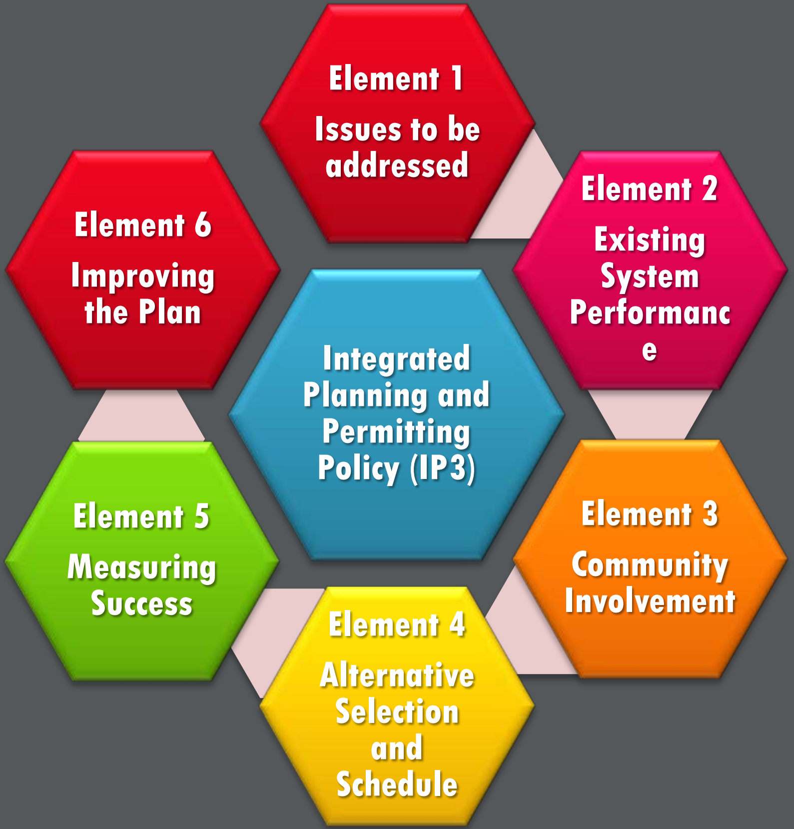
INTEGRATED PLANNING

- 2012 EPA Framework
  - Green Infrastructure
  - Community Involvement
- Allows Spending Prioritization Focused on Local Community Goals
- Provides Opportunity for Schedule Flexibility
  - CIP Smoothing
  - Overall Extended Compliance Period
- Does Not Relieve Any Ultimate Regulatory Obligations
- Could be Coupled with Stormwater
  - and Perhaps Other Water Related Needs
- Priorities of New Federal Administration
  - “Cooperative Federalism”

EPA FRAMEWORK

Integrated Municipal Stormwater And Wastewater Planning Approach Framework

"The integrated planning approach does not remove obligations to comply with the CWA, nor does it lower existing regulatory or permitting standards, but rather recognizes the flexibilities in the CWA for the appropriate sequencing and scheduling of work."



SETTING THE STAGE – NUTRIENT REMOVAL TECHNOLOGIES

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December 5, 2017