June 29, 2017

More Affordable, Reliable and Recoverable Nutrient Removal

Jim Fitzpatrick Senior Process Engineer

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OWEA2017

OWEA 2017 Technical Conference and Exhibition
June 26-29, 2017
Cincinnati, Ohio

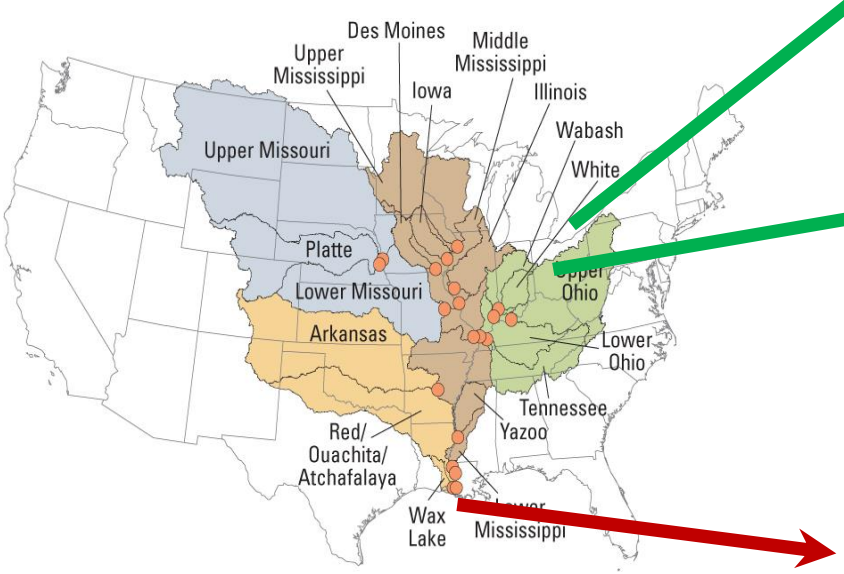
Agenda

- Drivers
- Optimize conventional treatment
- Avoid unintended consequences
- Wet-weather strategies
- Closing thoughts and open discussion

Drivers

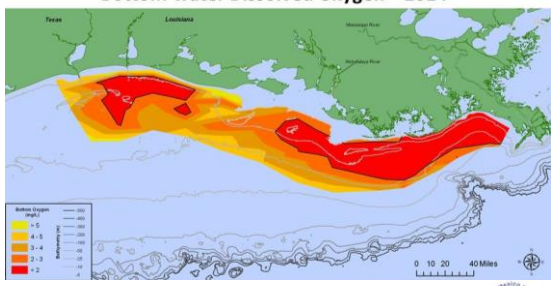
- Aquatic ecology
- Agricultural needs
- Regulatory pressures
- Economics

Near and far.
Large and small.
Point and non-point.



http://water.usgs.gov/nasqan/images/nasqan_ms_web.jpg

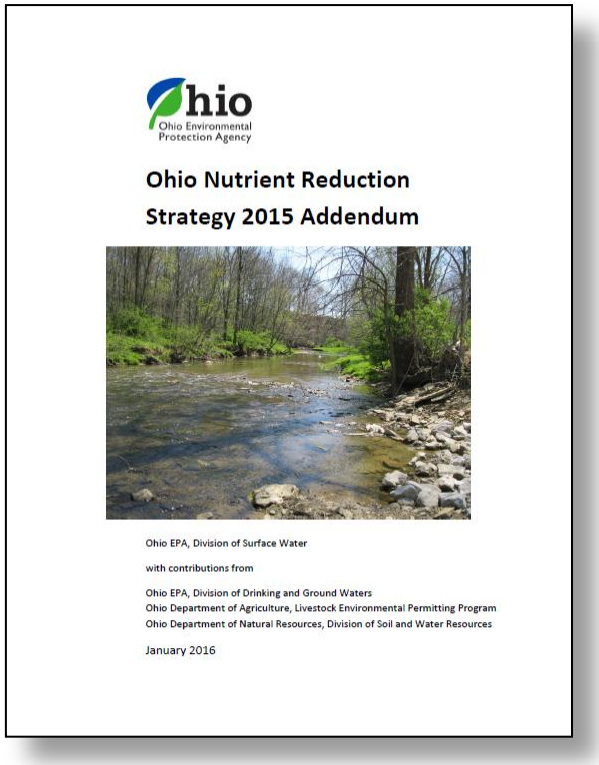
Bottom-water Dissolved Oxygen – 2014



Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU
Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program

Phosphorus → freshwater harmful algal blooms (HAB)
Nitrogen → Estuary and marine eutrophication and hypoxia

Ohio regulatory strategies



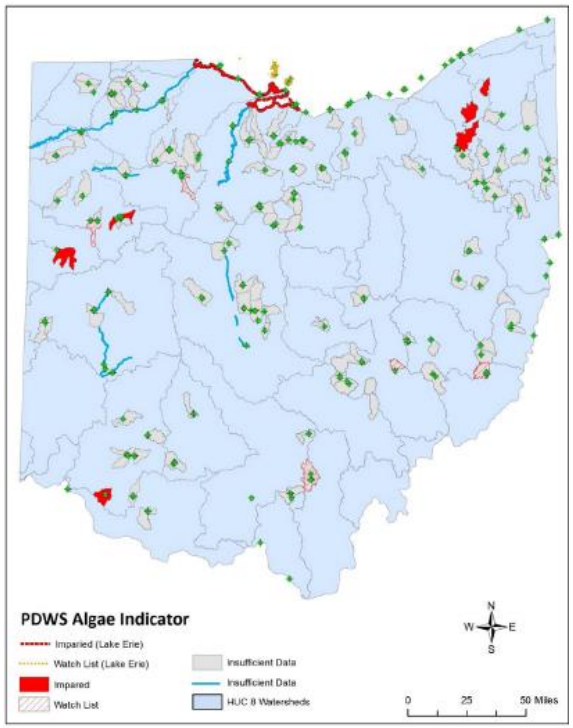
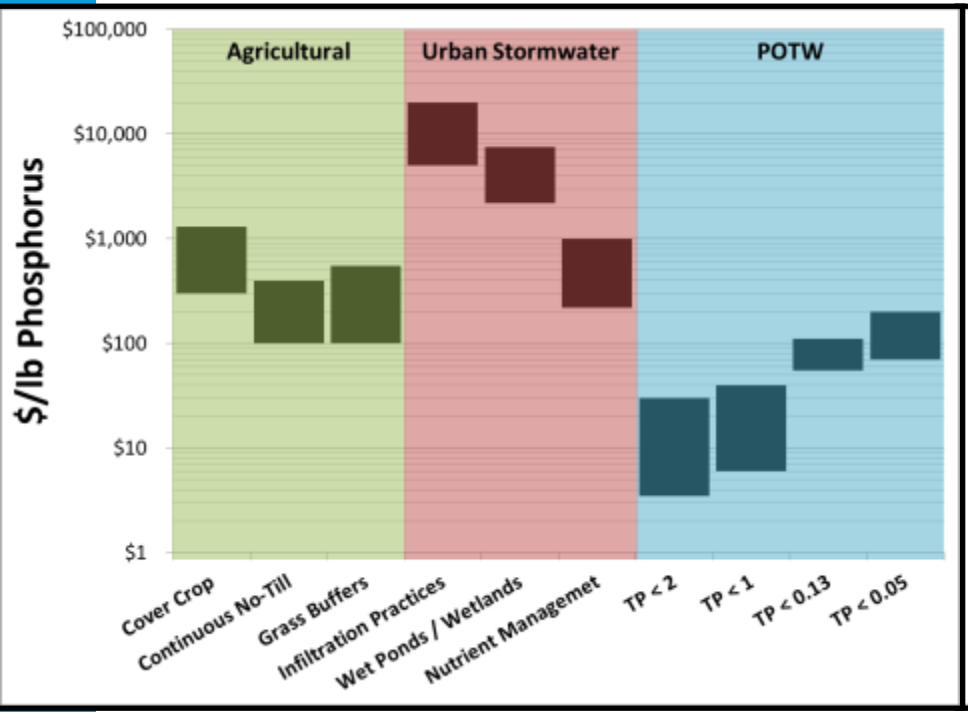


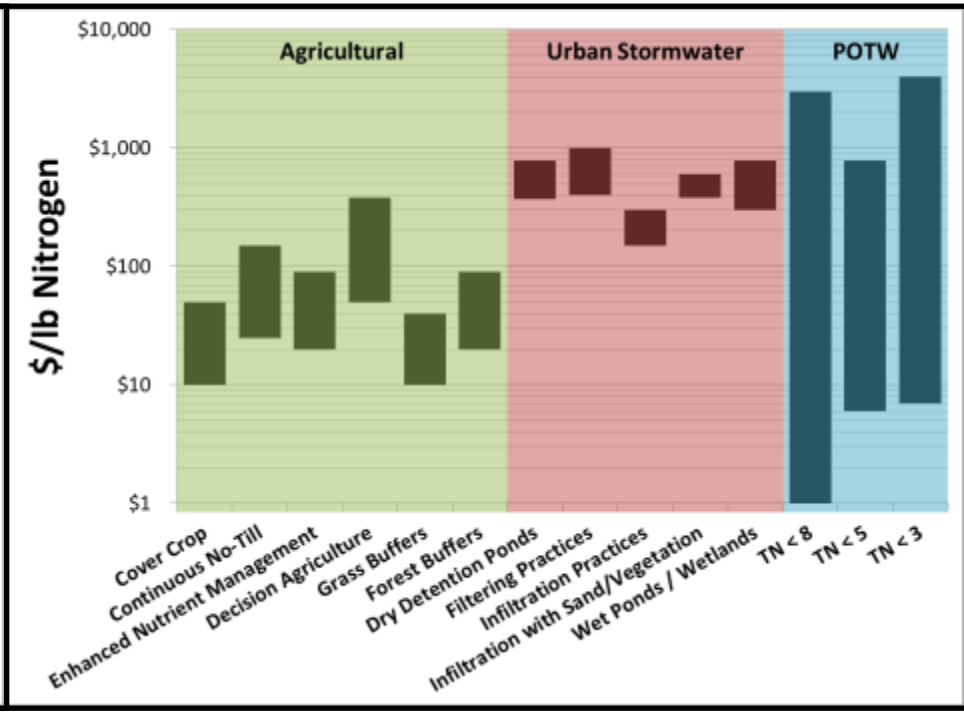
Figure 2. Assessment units with algae indicator results.

Similar to Others in Great Lakes and Upper Ohio River Watersheds

- **Increased monitoring, research, and planning**
- **Integrated and adaptive watershed management**
  1. Agricultural → Best management practices (BMPs)
  2. Urban Stormwater → Overflow control, green infrastructure
  3. POTWs → Tiered technology-based limits (BNR, ENR, LOT, etc.)

Historical costs of different practices





Source: WEF (2015) *The Nutrient Roadmap*, Figures 5.12 and 5.13

Low hanging fruit:

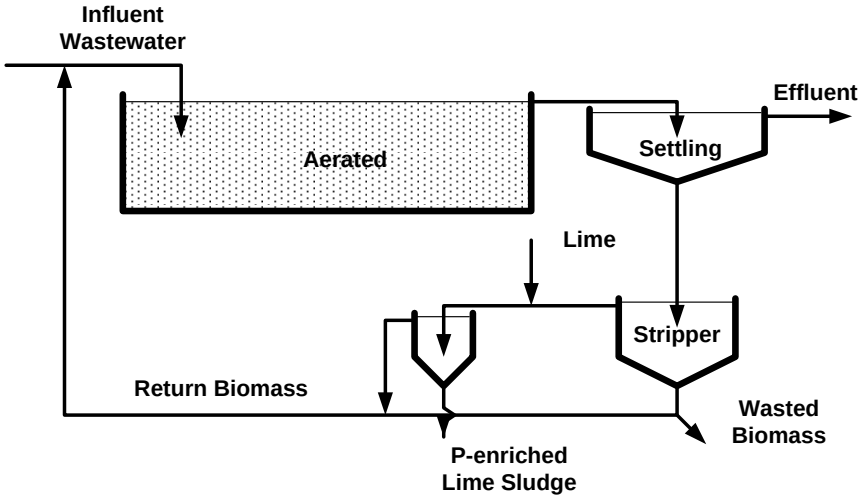
- Phosphorus removal → POTW
- Nitrogen removal → Agriculture (sometimes POTW)

Not a substitute for project-specific alternatives evaluations and opinions of probable costs

Optimize conventional treatment

- Phosphorus removal
- Fermentation and VFA
- Side-stream EBPR (S2EBPR)

Early phosphorus removal



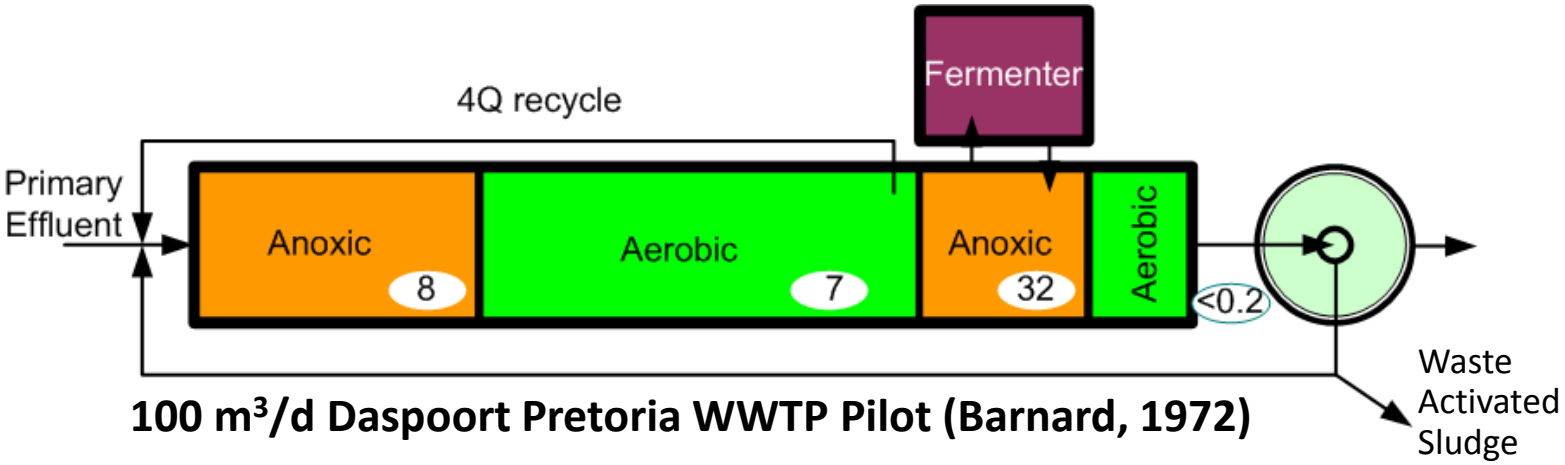
Phostrip Process (1962)

- **High-rate activated sludge**
  - No nitrification
  - All influent to aeration basin
- **RAS stripper tank**
  - 30-40 hr SRT
  - P release from deep anaerobic conditions
- **Supernatant treated with lime**
  - P removed as calcium hydroxy-apatite, $Ca_{10}(PO_4)_6(OH)_2$
  - Fuhs & Chen find phosphate accumulating organism (PAO)

In hindsight…side-stream RAS anaerobic zone and P crystallization, mainstream P uptake

Mixed liquor fermentation (MLF)

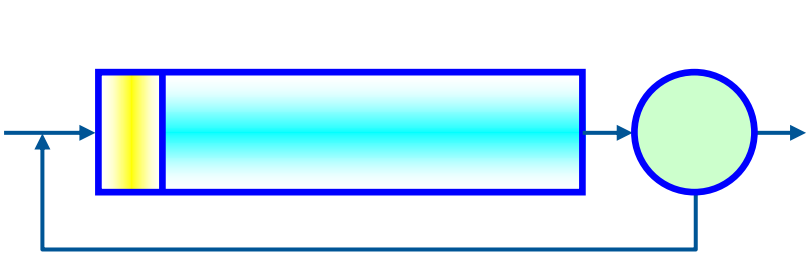
- Fermenter basin not deemed important at the time
- Excellent phosphorus removal resulted that could not be replicated in laboratory
- Barnard suggested biomass (with PAO) should pass through anaerobic phase with low ORP to trigger EBPR
- Suggested Phoredox process by adding anaerobic zone



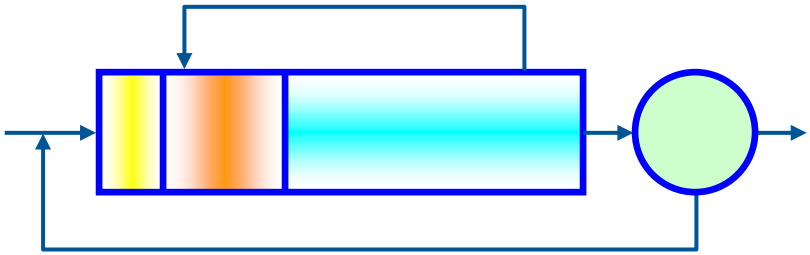
100 m³/d Daspoort Pretoria WWTP Pilot (Barnard, 1972)

Original EBPR pilot had side-stream anaerobic mixed liquor fermenter zone

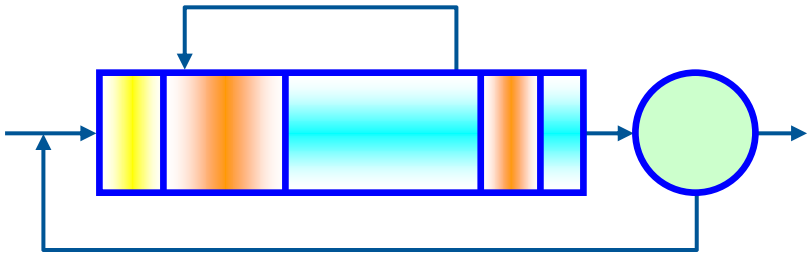
Phoredox process flow sheets



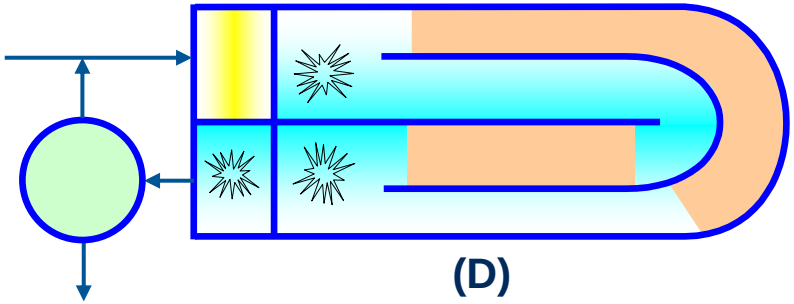
(A)



(B)

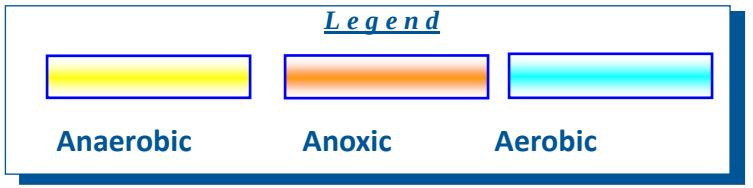


(C)



(D)

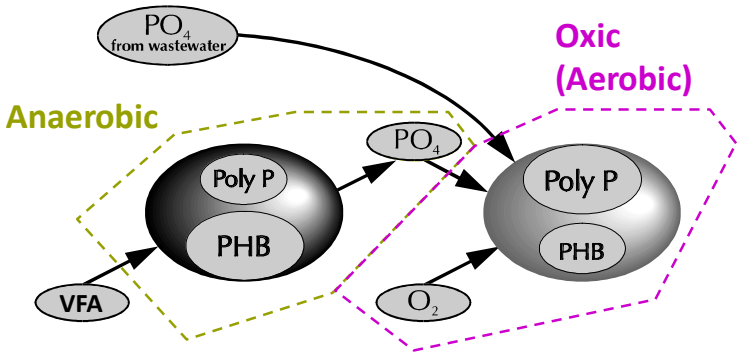
Reduced Nitrates to Anaerobic zone



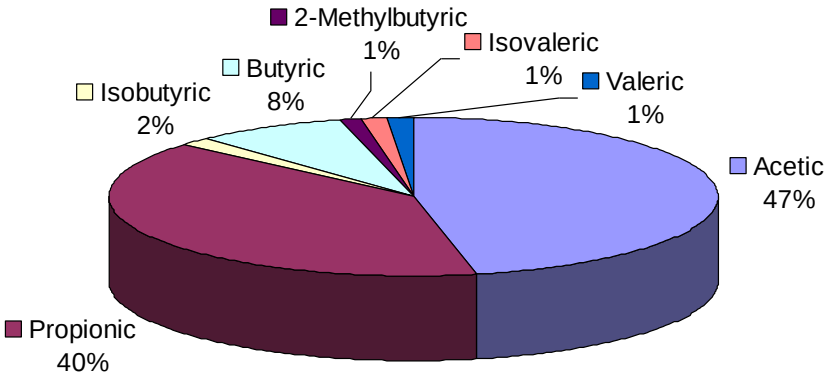
Researchers found *Accumulibacter* predominant PAO

Conventional thinking for EBPR

- Volatile fatty acids (VFAs) drive EBPR mechanism of PAO
- Anaerobic zone required
- Mixture of VFAs required for PAO to outcompete glycogen accumulating organisms (GAO)



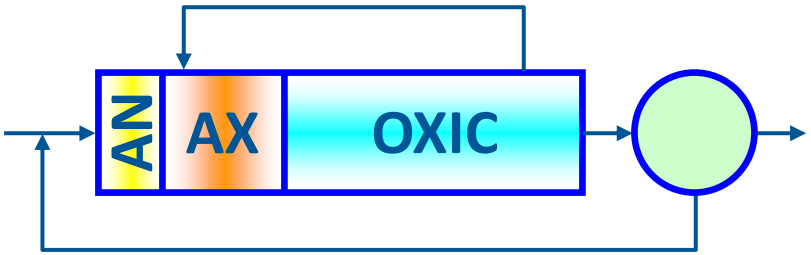
PAO Luxury Uptake Mechanism (Fuhs & Chen, 1975)



Fermentate Analysis Wakarusa WRF (Lawrence, KS 2007)

First Primary Sludge Fermenter (Kelowna, BC 1979)

New reality for EBPR



Traditional EBPR

- Mainstream anaerobic zone
- *Accumulibacter* needs VFA to trigger luxury uptake of phosphorus in oxic zone.

Side-stream EBPR (S2EBPR)

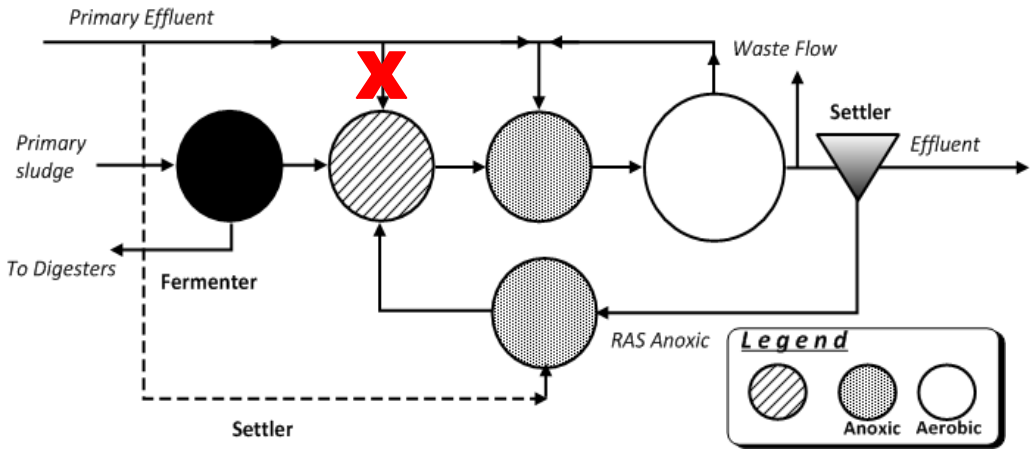
- Side-stream anaerobic fermenter
- *Tetrasphaera* produces VFA and uptakes P in anoxic/oxic and denitrifies in anoxic zone.
- Works together with *Accumulibacter*
- Deep anaerobic conditions fatal for GAOs

Good news for weak influents and wet weather!

- More efficient use of influent carbon for TP and TN removal
- Less need for chemicals (ferric, alum, methanol, etc.)
- Side-stream is less impacted by wet weather flows

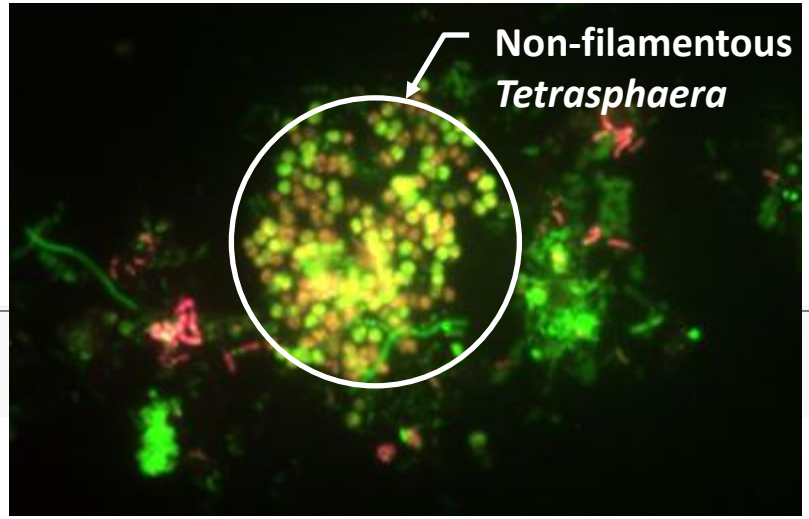
Regional District of Central Okanagan

Westside Regional WWTP, aka "West Bank WWTP" (West Kelowna, BC)



TN < 6 mg/L
BOD < 5 mg/L
TSS < 2 mg/L
TP < 0.15 mg/L

Westside Regional WWTP



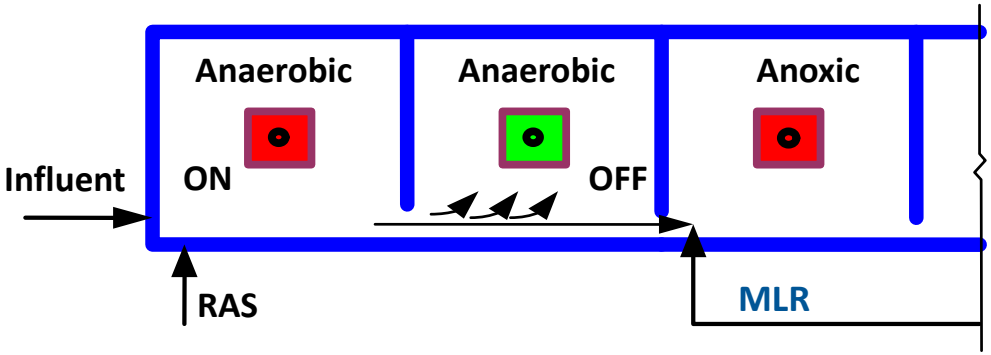
Tetrasphaera **ferment and denitrify. Non-filamentous variety also PAO.**

P uptake in Anoxic and Aerobic Zones

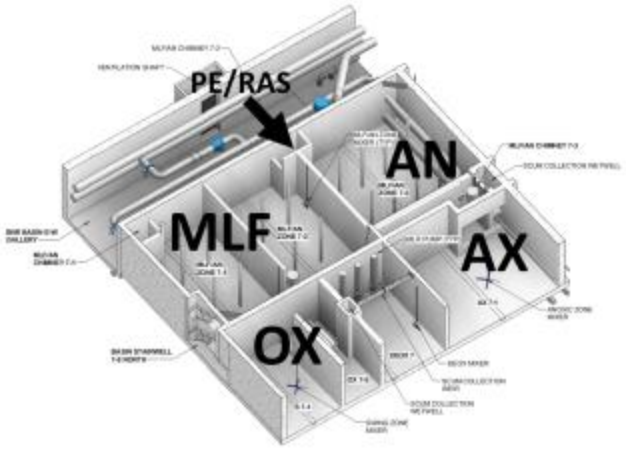
Other S2EBPR examples

RAS or Mixed Liquor Fermenters

- Sacramento, CA
- Olathe, KS
- West Kelowna, BC
- Pinery AWWTP, CO
- Henderson, NV
- Blue Lake & Seneca WWTP, MN
- Joppatowne, MD
- South Cary, NC
- St. Cloud, MN



In-line Fermenter (Pinery, Henderson, St. Cloud, etc.)

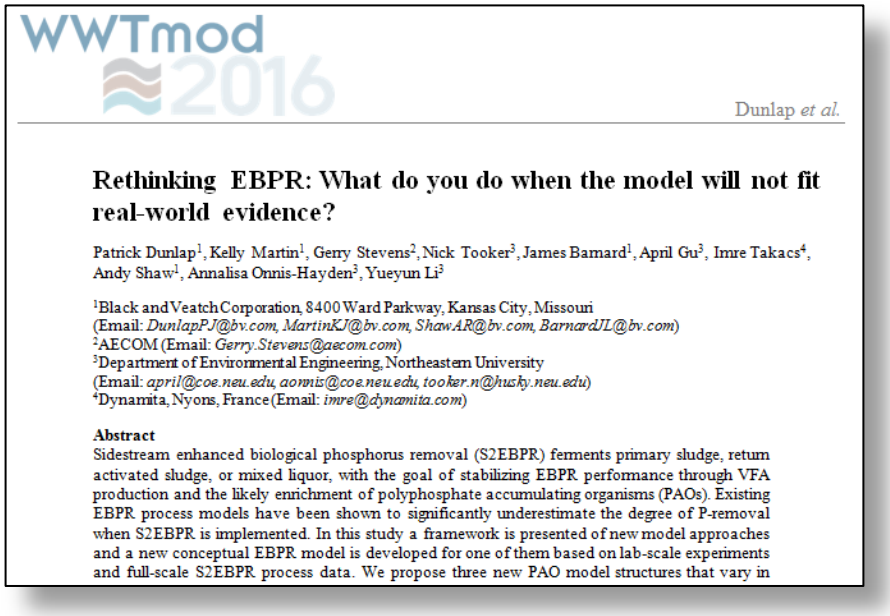


S2EBPR for 181-mgd BNR EchoWater Project (Sacramento, California)

Off-line Fermenter with 5-stage Bardenpho 5.3-mgd Cedar Creek WWTP (Olathe, Kansas)

Worldwide: 75+ S2EBPR facilities in 10+ configurations

S2EBPR model development



WWTmod 2016

Dunlap *et al.*

Rethinking EBPR: What do you do when the model will not fit real-world evidence?

Patrick Dunlap[1], Kelly Martin[1], Gerry Stevens[2], Nick Tooker[3], James Barnard[1], April Gu[3], Imre Takacs[4], Andy Shaw[1], Annalisa Onnis-Hayden[3], Yueyun Li[3]

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Abstract
Sidestream enhanced biological phosphorus removal (S2EBPR) ferments primary sludge, return activated sludge, or mixed liquor, with the goal of stabilizing EBPR performance through VFA production and the likely enrichment of polyphosphate accumulating organisms (PAOs). Existing EBPR process models have been shown to significantly underestimate the degree of P-removal when S2EBPR is implemented. In this study a framework is presented of new model approaches and a new conceptual EBPR model is developed for one of them based on lab-scale experiments and full-scale S2EBPR process data. We propose three new PAO model structures that vary in

- **B&V team with Northeast University and Dynamita to develop S2EBPR model for future ASM update.**
- **In the meantime, we have design criteria from real-world operations, and "work-arounds" with current ASM-based software (BioWin, GPS-X, etc.).**

- **Why did profession miss this until now?**
  - *Tetrasphaera* need ORP $\lesssim$ -250 mV; most anaerobic zones struggle to get -150 mV
  - Impossible to achieve with NO_3 or DO present
  - Turbulence, air entrainment, or coarse bubble air mixing prevent low ORP
  - Weak and fresh influent dilutes VFA
  - Mixing energy too high (>0.08 hp/kcf)

Other reasons for BNR

- **Increased process stability and clarifier capacity**
  - Biological selector helps prevent sludge bulking, decrease sludge volume index (SVI).
- **Side benefits from denitrification**
  - Recover some alkalinity. Better nitrification and effluent buffering.
  - Offset some O_2 demand. Potentially lower aeration costs.
  - More stable sludge blanket in secondary clarifier.
- **Potential nutrient recovery**

It's not just about effluent quality

Avoid unintended consequences

- Solutions to biosolids impacts
- Struvite
- Brushite

Making BNR work with anaerobic digestion

Causes

- PAOs in WAS anaerobically release $(PO_4)^{3-}$, Mg^{2+} and K^{+}.
- NH_4^{+} released later during digestion.

Consequences

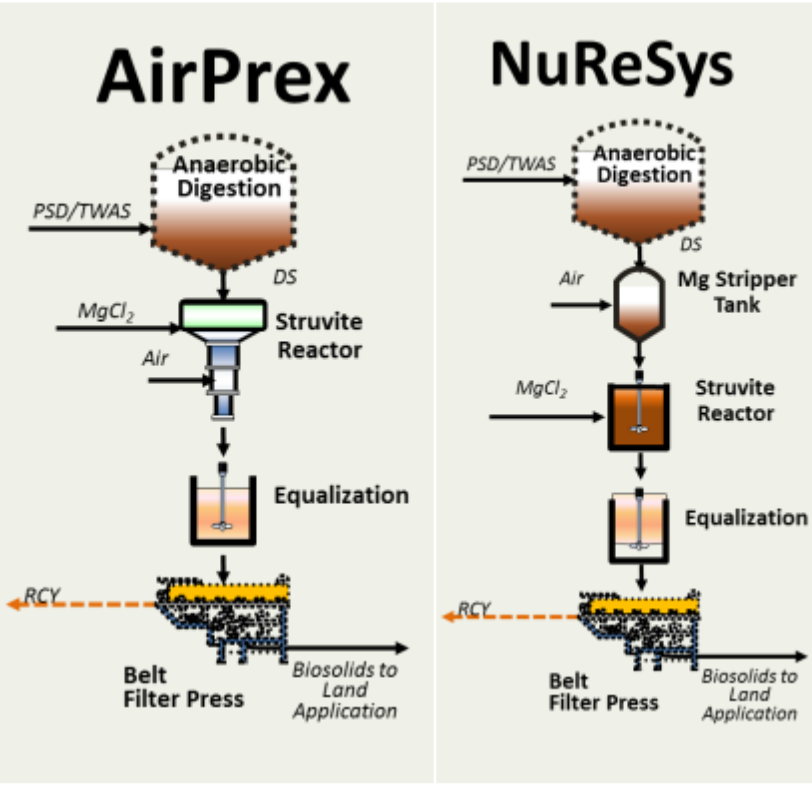
- Nutrient recycle
- Struvite scaling
- Vivianite scaling if Fe^{2+} present
- Decreased biosolids dewaterability

From Shimp, G.F.; Barnard, J.L.; Bott, C.B. It's always something. Water Environment & Technology, June 2014, 26(6), 42-47.

Important for reaching energy, carbon footprint and nutrient goals…sustainably.

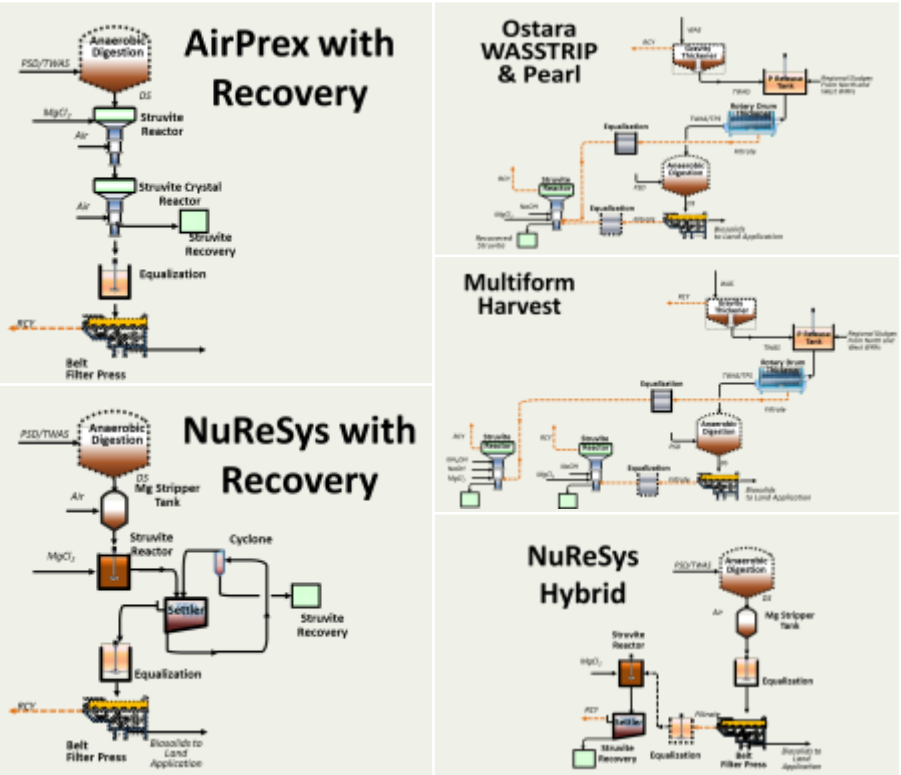
Turn struvite problem into the solution

Struvite Sequestration



- Struvite crystals remain in biosolids
- Optional recovery add-on

Struvite Recovery



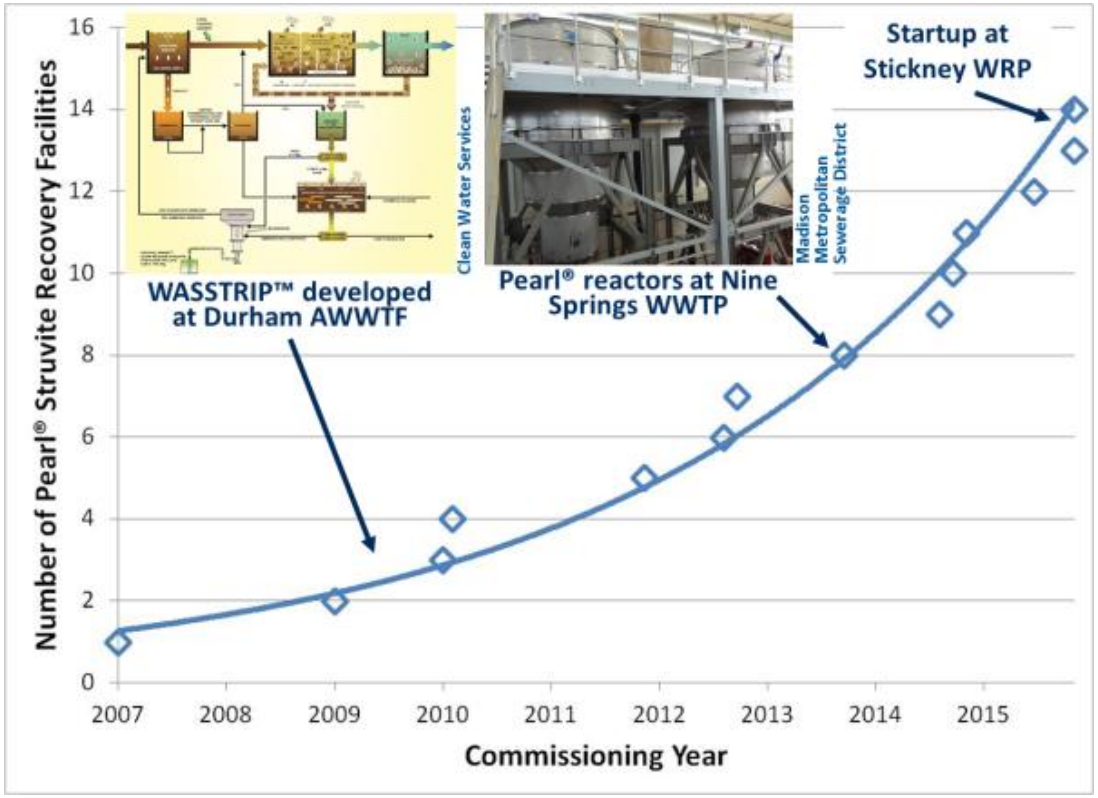
- Struvite crystals separated from biosolids as separate fertilizer product
- Decrease P content of biosolids

Project-specific evaluation and selection

Side-stream crystallization gaining traction

Main Goals

- Minimize nuisance scaling and deposits
- Improve biosolids dewaterability
- Reduce P & N recycle loads
- Decrease P content of biosolids
- Recover fertilizer product



Struvite choices include Ostara Pearl®, MHI Multiform™, CNP AirPrex®, Schwing Bioset/NuReSys®, Paques PHOSPAQ™, KEMA Phred™ and DHV Crystalactor®

Also CNP CalPrex® for brushite recovery from acid-phase digester

World's largest nutrient recovery facility

- **1.4 BGD capacity**
- **TP ≤ 1 mg/L (1 Feb 2018)**
  - Optimize EBPR
  - Reduce TP recycle
- **Predicted struvite recovery**
  - 5,350 lb/day PO_4-P
  - 7,700 ton/yr fertilizer

16-mgd Liverpool WWTP
Medina County, Ohio

Design-build improvements to be completed in 2019

- Includes struvite sequestration + S2EBPR

Basis of Design

Criterion	Pearl + WASSTRIP	AirPrex w/ Harvesting	AirPrex	Degas + Ferric	Ferric
1. WWTP Performance					
Reduce nuisance precipitate formation	High	Medium	Medium	Medium	Low
Improve phosphorus removal capacity	High	Medium	Medium	High	Medium
Improve reliability to meet TP limits	High	Medium	Medium	Medium	Medium
Offers improvements to the dewatering process	High	High	High	Medium	High
2. Environmental / Health / Social / Economic					
Perform nutrient recovery	High	Medium	Low	Low	Low
Reduce chemical sludge quantity produced/disposed	High	High	Medium	Low	Low
3. Financial					
Net Present Value of alternative	High	Medium	Low	Medium	Medium
Capital costs of alternative	High	Medium	Low	Medium	Medium
4. Risk Assessment					
Technological track record	Medium	Low	Low	High	High
Manpower hours and skill required	Medium	Medium	Medium	Low	Low

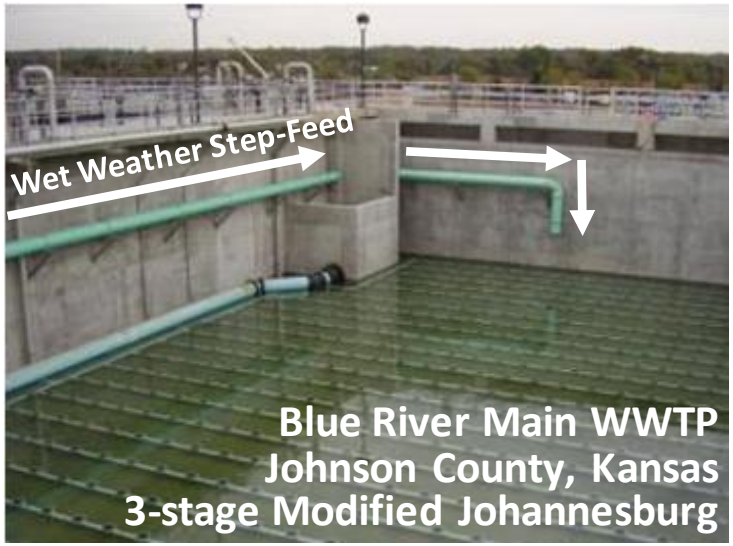
Energy savings performance contract reduces risk to County

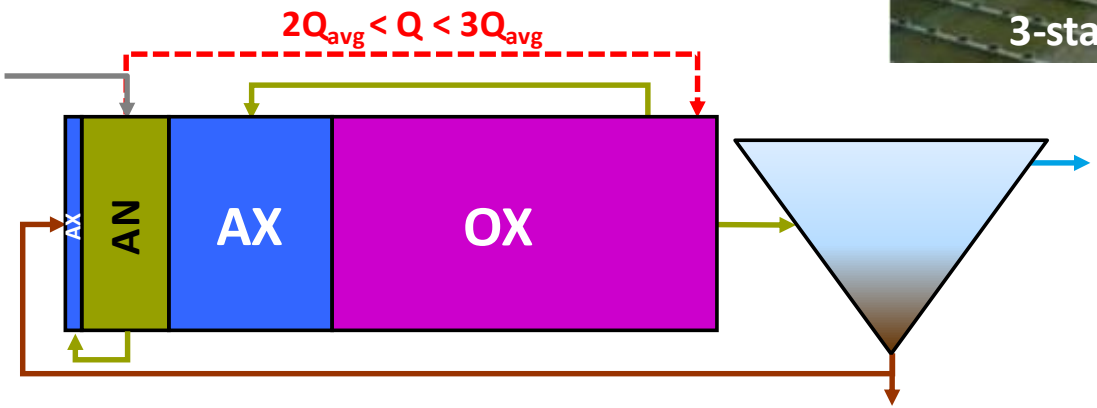
Wet-weather strategies

- Don’t upset your BNR bugs
- BNR can be designed to “weather the storm”

Deep step-feed helps "weather the storm"

- Temporary change to contact stabilization mode for wet-weather flows
- "Biological contact" or "biocontact"
- Good fit for plug-flow or step-feed basins





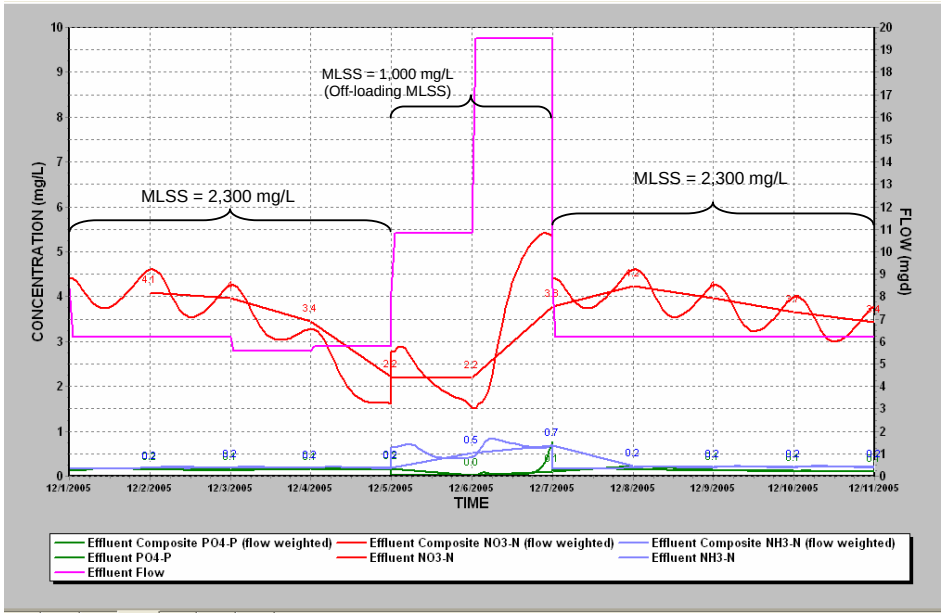
MJHB with Wet-Weather Step-Feed

Maximizing biological treatment of wet-weather flows

Biomass transfer accomplishes same thing

- Transfer some RAS or MLSS to offline storage.
- Return biomass after storm flows pass.
- Good fit for complete-mix baxins, oxidation ditches, etc.

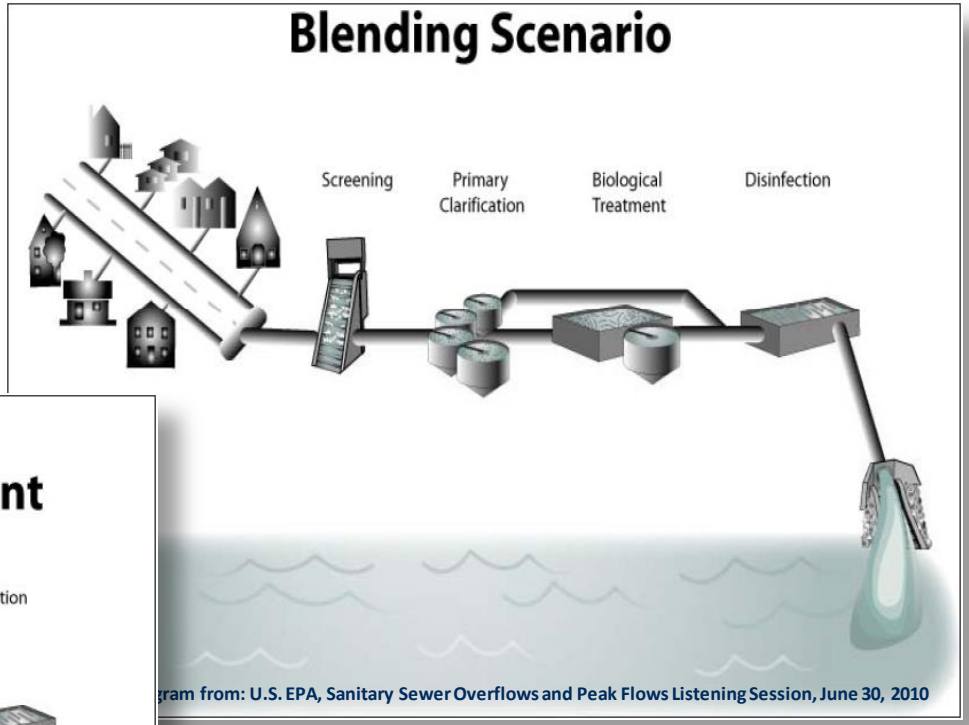
Offline Biomass Storage
Rogers, Arkansas
5-stage Bardenpho with Oxidation Ditch



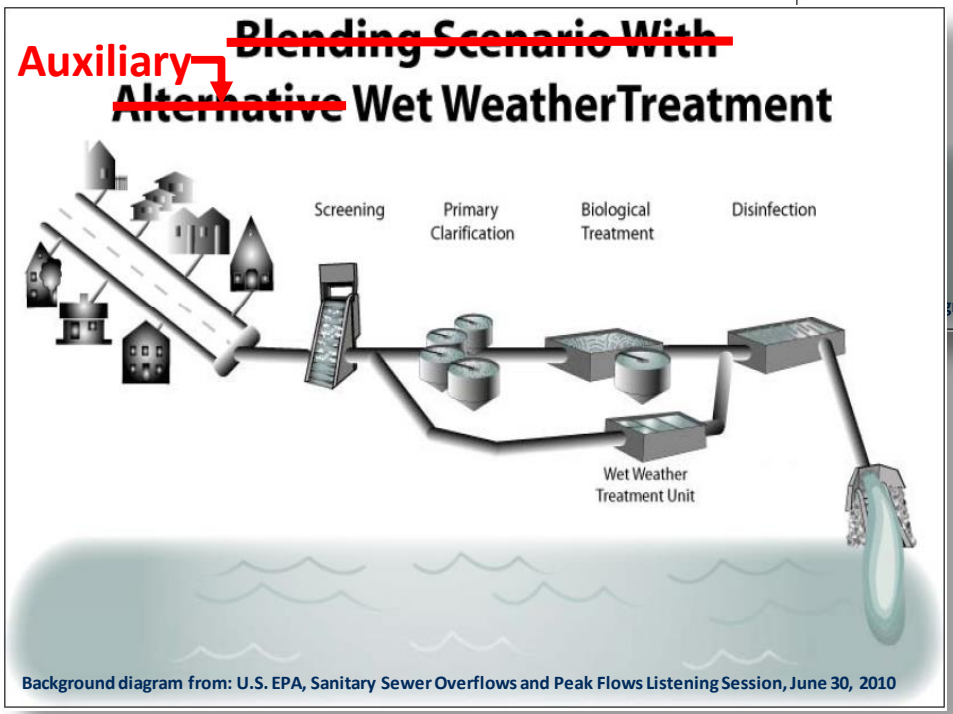
BioWin Process Model
of RAS Transfer Operations

Another way to reduce SLR to clarifiers… temporarily.

Blending or auxiliary treatment for higher peaking factors



gram from: U.S. EPA, Sanitary Sewer Overflows and Peak Flows Listening Session, June 30, 2010

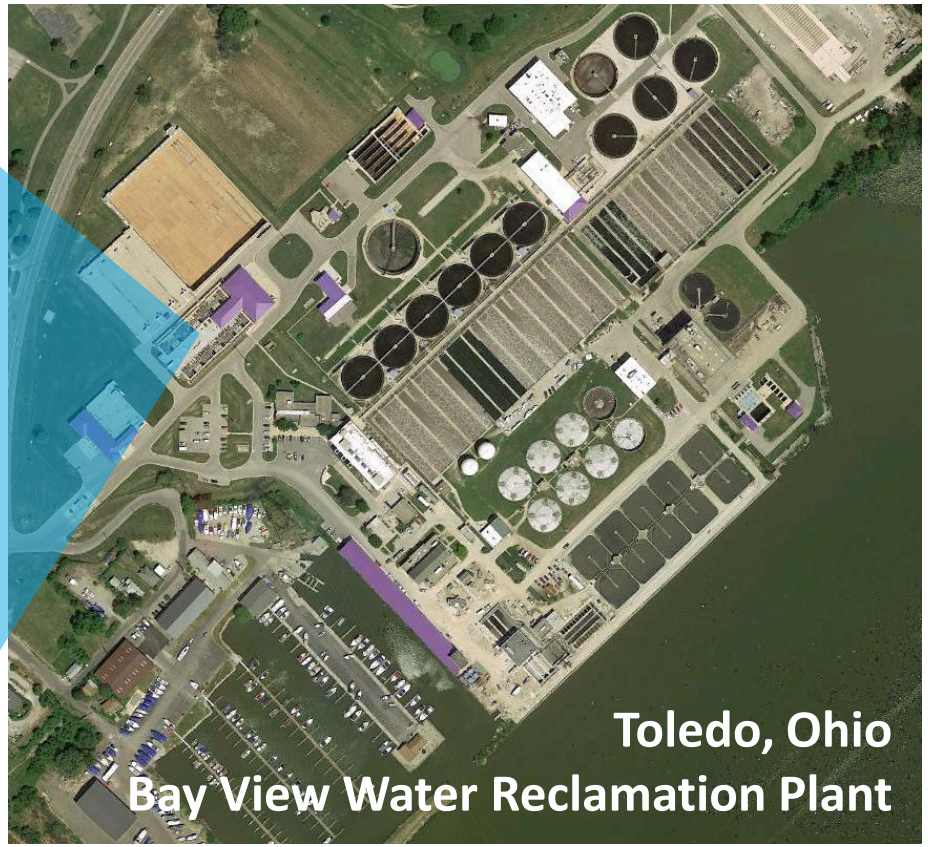


Background diagram from: U.S. EPA, Sanitary Sewer Overflows and Peak Flows Listening Session, June 30, 2010

Auxiliary treatment example

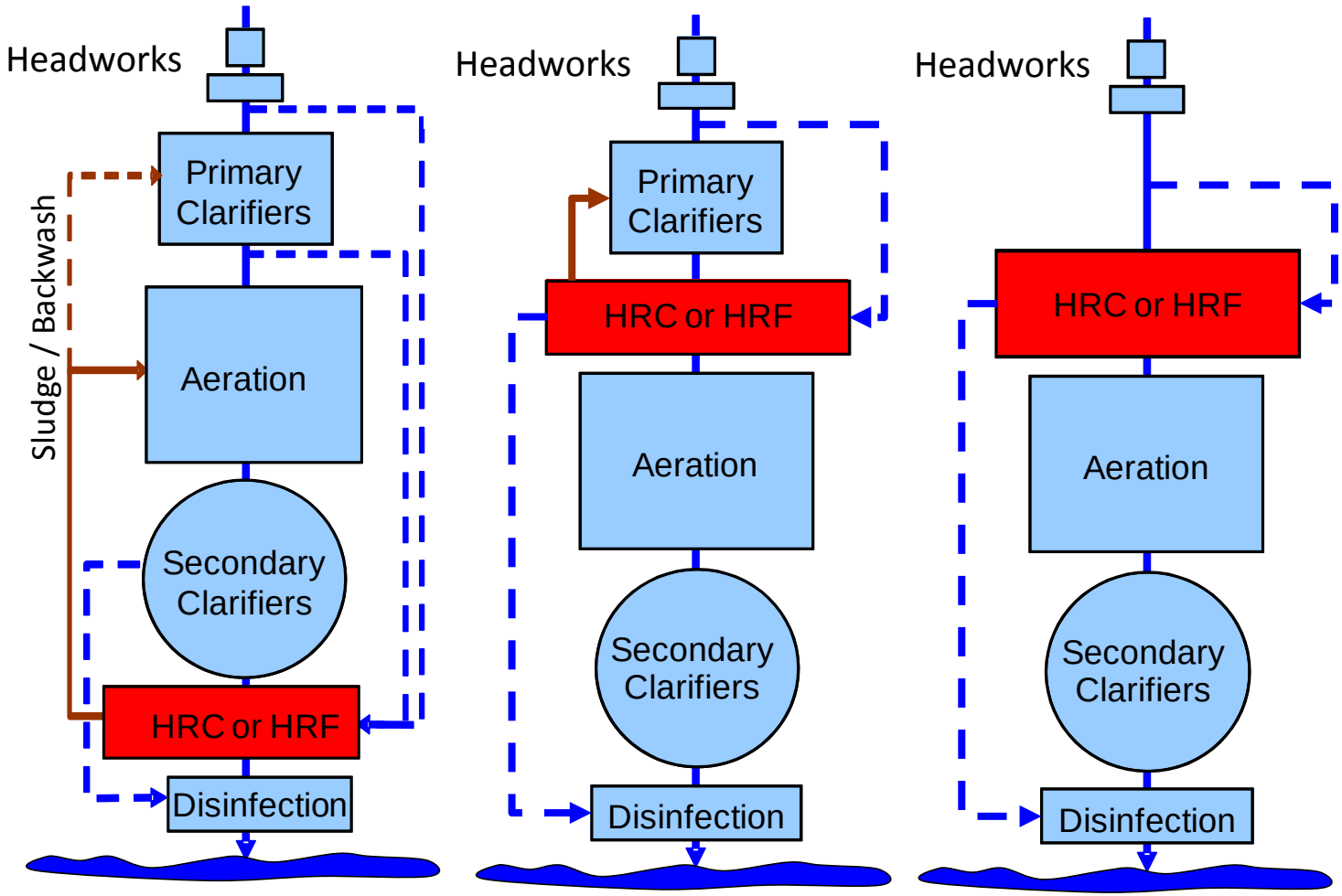

232-mgd DensaDeg HRC Facility

Parameter	Average Effluent (mg/L, 2007-2009)
TSS	21
$CBOD_5$	22
TP	0.3


Toledo, Ohio
Bay View Water Reclamation Plant

- **Activated sludge trains**
  - 70-mgd annual average
  - 195-mgd peak
- **Parallel HRC trains**
- **Total 400-mgd peak capacity**

Consider dual-use for both dry and wet weather benefits



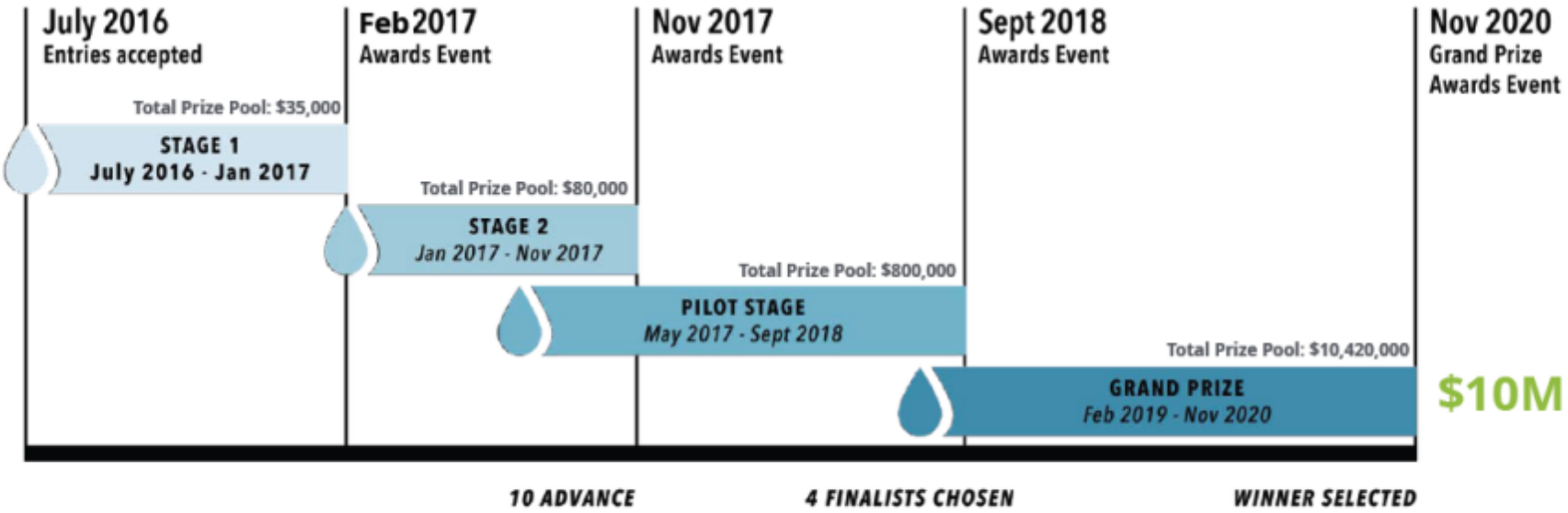
Examples include Fox Metro, IL; Rushville, IN; Johnson County, KS; Little Rock, AR

Closing thoughts and open discussion

Seeking radically cheaper technology for <0.01 mg-P/L

EVERGLADES FOUNDATION

Prize Structure



Stay tuned!

- http://www.barleyprize.com/
- #barleyprize
- B&V on judging panel

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