Extractive Nutrient Recovery as a Green Option for Managing Phosphorus in Sidestreams and Biosolids

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Agenda

- Sidestream treatment overview
- Phosphorus Removal/Recovery Options
- Case Study 1 - Nansemond Treatment Plant
- Case Study 2 – FWHWRC
- Case Studies 3 and 4 – Miami Dade Treatment Plants
- Summary

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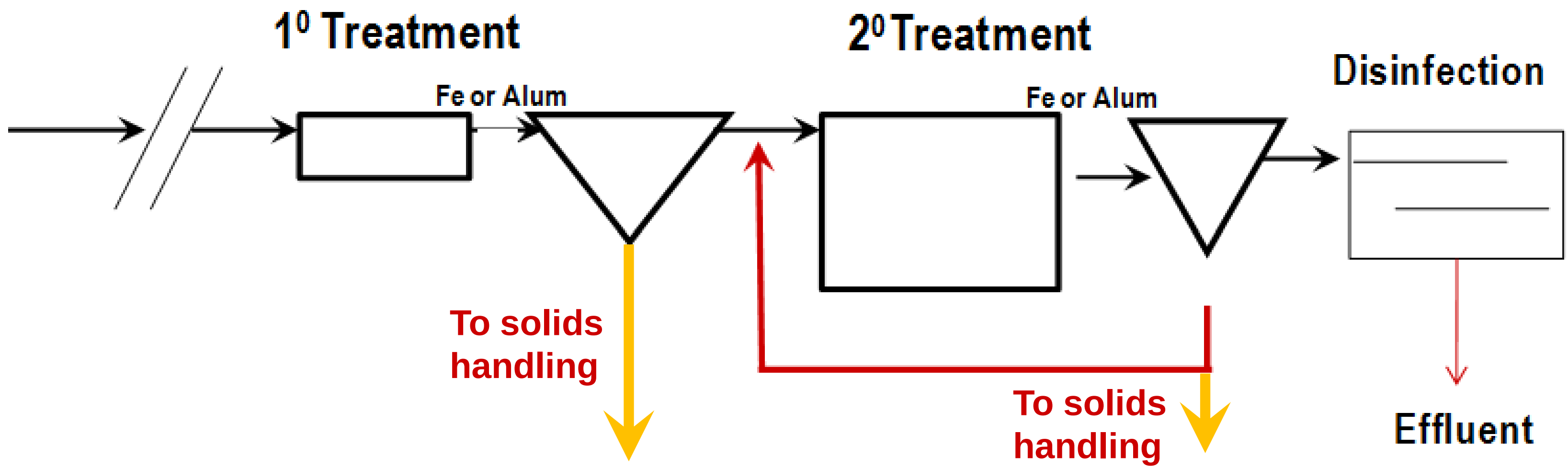
Biological treatment is a cost effective, robust option for carbon and nutrient removal

- Biological nutrient removal uses microorganisms



- Solids generated must be processed before disposal
- Anaerobic digestion is a common solids treatment option

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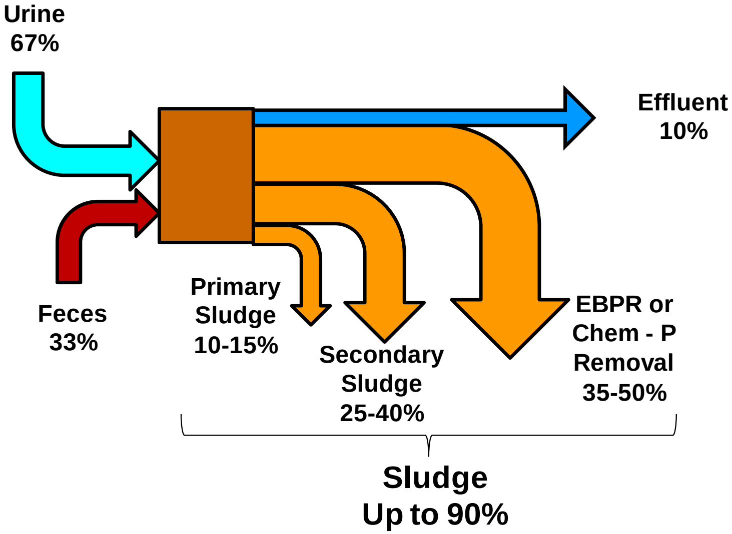
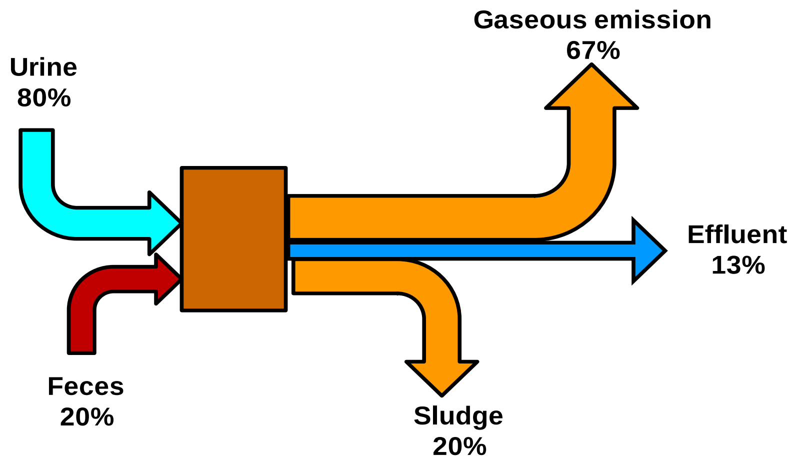
Water resource reclamation facilities accumulate nutrients within the solids process

Adapted from Cornel et al., 2009



Up to 90% of the influent P can be present in the solids stream

Adapted from Phillips et al., 2011



Up to 20% of the influent N can be present in the solids stream

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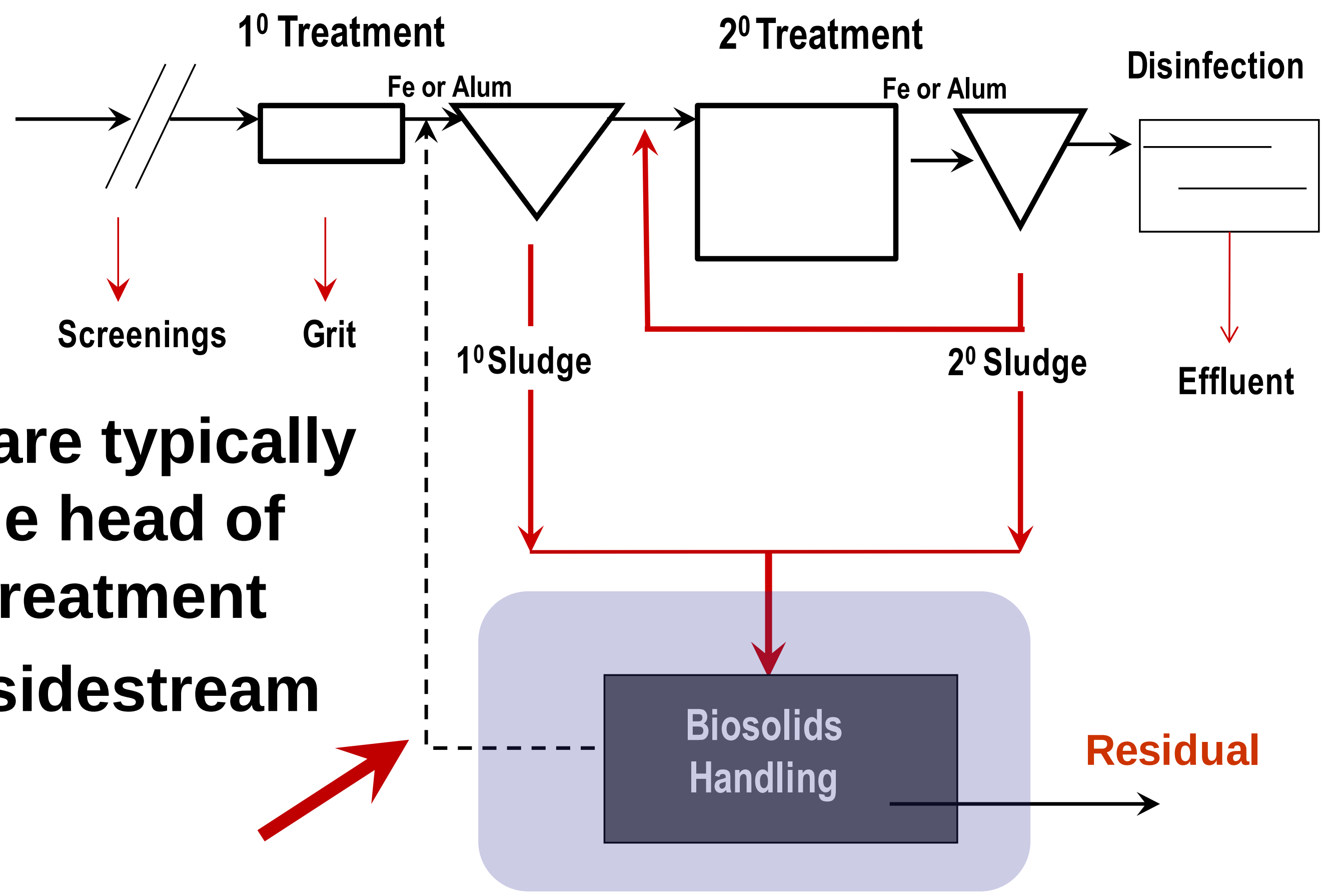
Solids stabilization generates nutrient rich liquid stream



- Sidestreams are typically returned to the head of the plant for treatment
- Examples of sidestream
  - BFP filtrate
  - GBT filtrate
  - Filter backwash
  - Centrate
  - Digester supernatant

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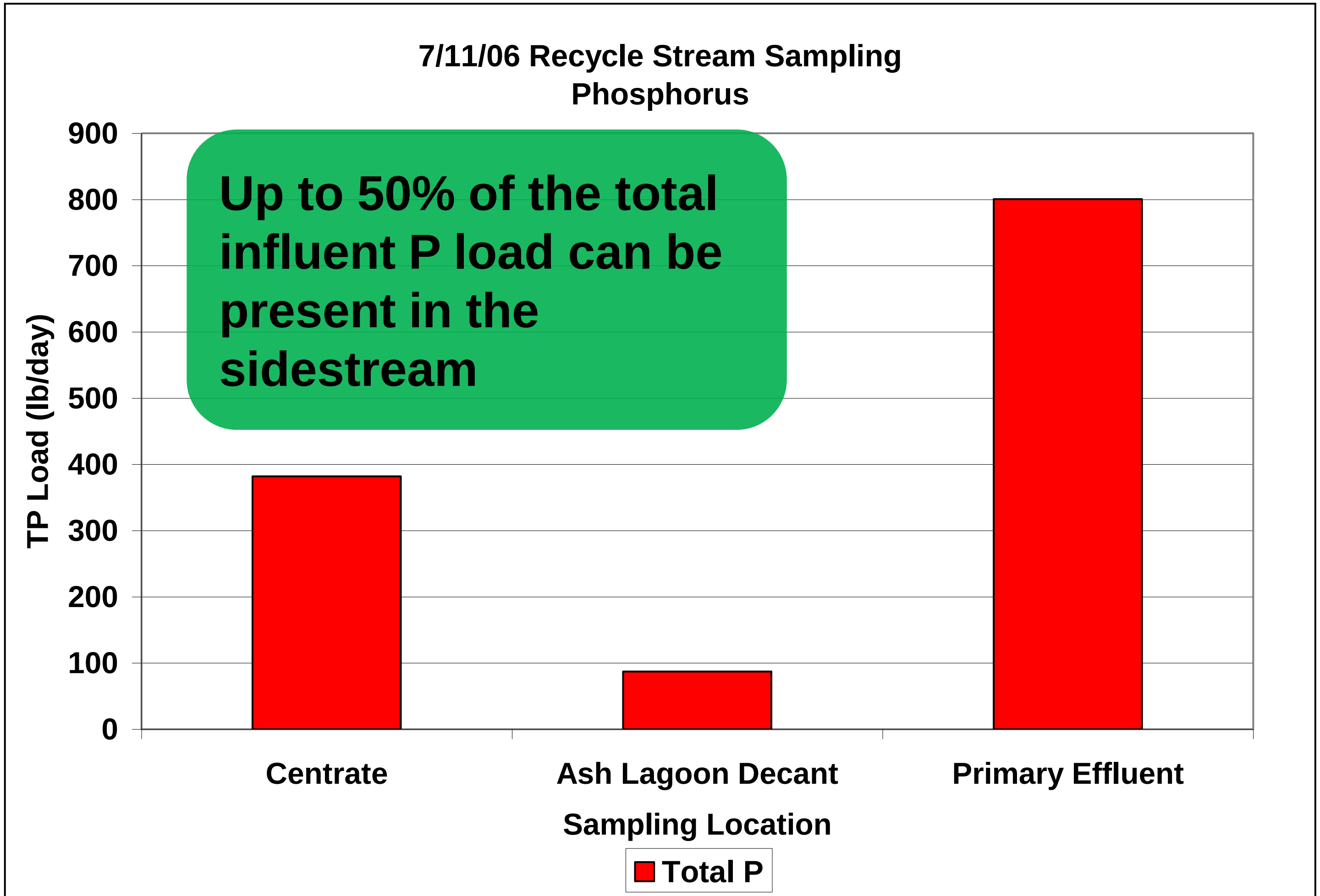
High nutrient recycle loads can upset the mainstream process



Up to 50% of the total influent P load can be present in the sidestream

South Durham, NC Centrate	**21%**	**25%**

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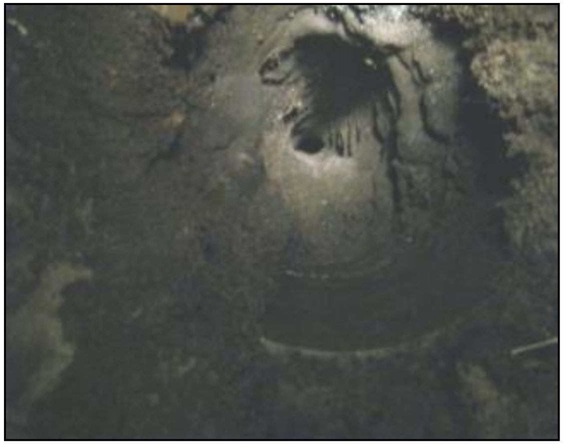
Struvite can be a significant maintenance concern with anaerobic digestion

- Struvite = Mg + NH_4 + PO_4
  - NH_4 & PO_4 released in digestion
  - Typically Mg limited
  - Mg addition (i.e. $Mg(OH)_2$) can promote struvite formation



NYC Newtown Creek WPCP

Miami Dade SDWRF

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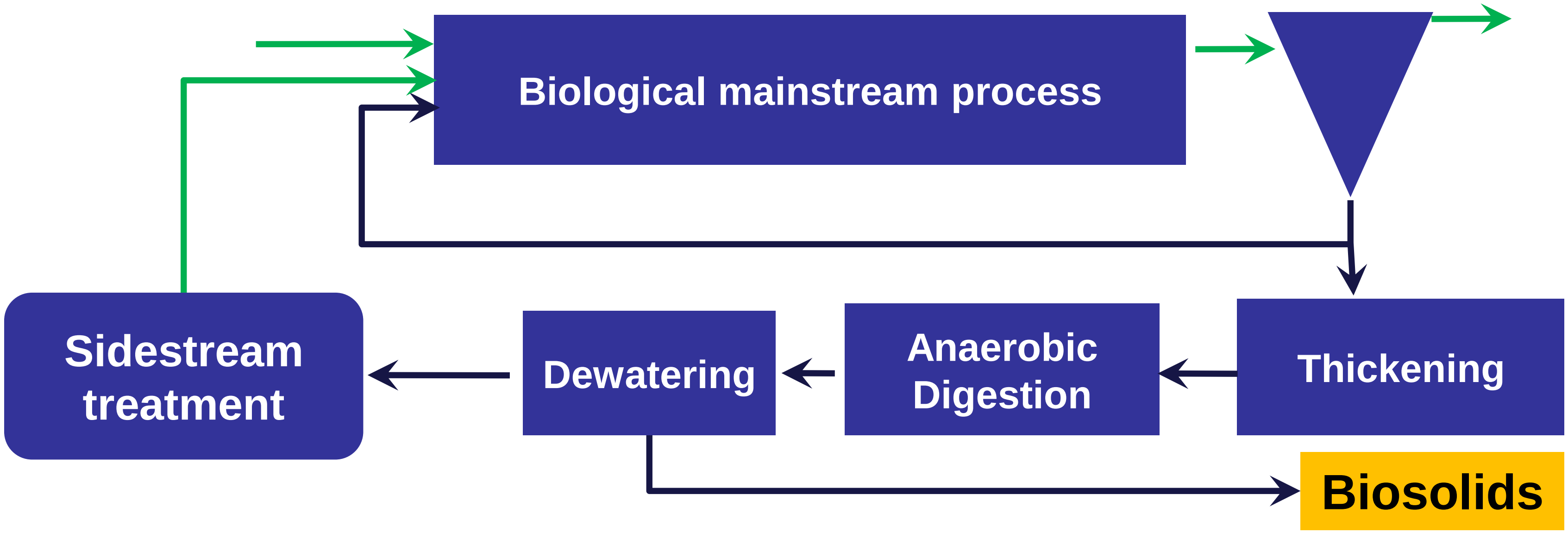
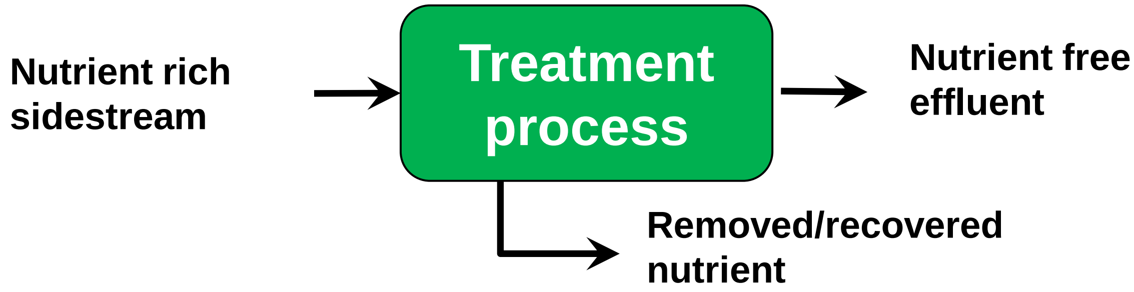
Sidestream treatment is the manipulation of the return liquid stream for a treatment purpose

- Typically focused on nutrient removal or recovery
- Usually economical when sidestreams contribute:
  - ≥15% of the influent TN
  - ≥20% P load
- Can often reuse existing infrastructure to reduce costs



What options are available for sidestream nutrient treatment?



N Removal and recovery

Nitrification/Denitrification

Nitritation/Denitritation

Deammonification

Gas stripping and/or ion exchange

P removal and recovery

Coagulant aided precipitation

Struvite crystallization

P removal from sidestreams relies on chemical precipitation

Coagulant aided precipitation

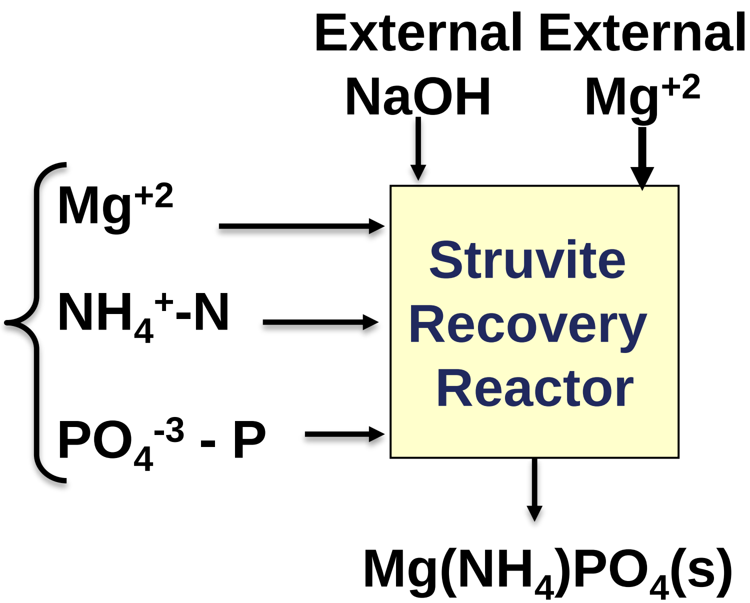
- Uses Alum or Ferric
- Non-proprietary
- Traditionally used for controlling sidestream P at this plant
- High O&M requirement

Struvite recovery

- Forms struvite which can be used as a slow release fertilizer
- Proprietary
  - Ostara
  - MFH
  - Procorp/DHV
  - Paques
  - Veolia

Struvite recovery exploits pH dependent chemical precipitation phenomena

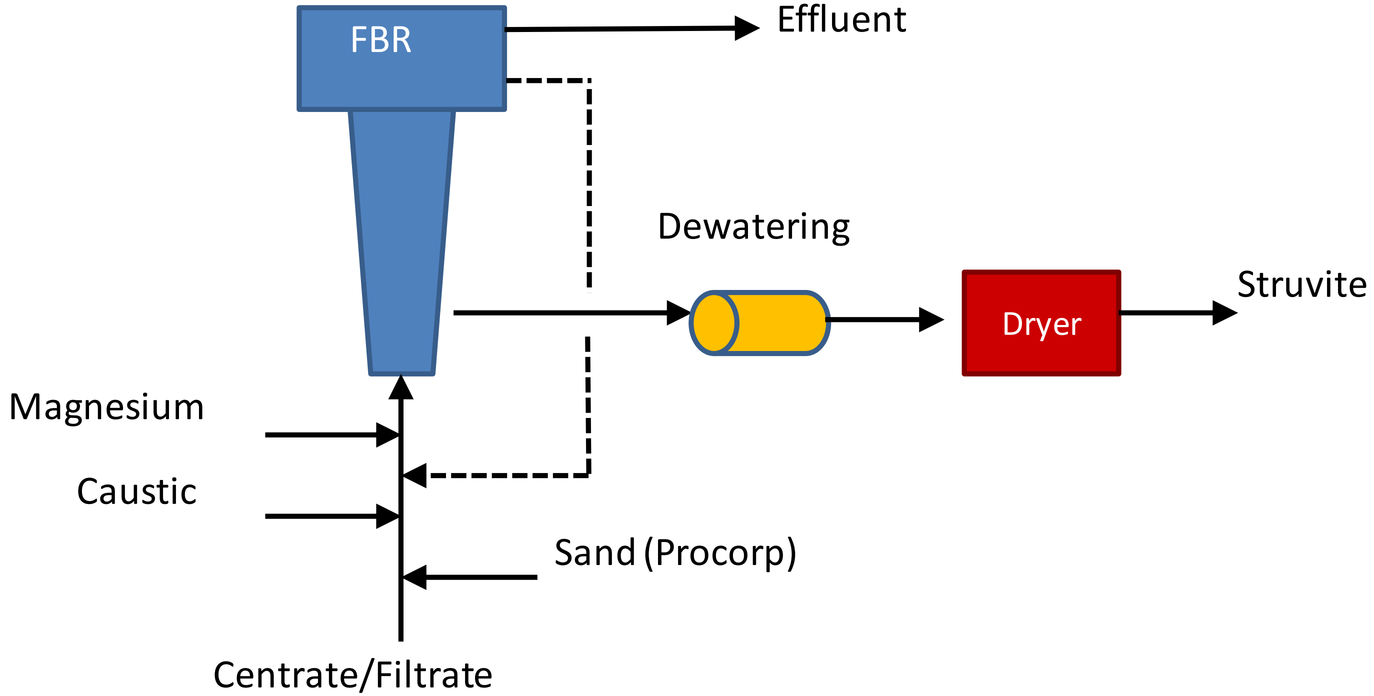
- **Struvite precipitation**
  - N:P ratio in struvite = 0.45 lbs N required per lb P removed
  - N:P ratio in filtrate ~ 2.4-2.6, ammonia in excess



$Mg(NH_4)PO_4(s)$ = struvite

Intentional struvite recovery exploits pH dependent chemical precipitation phenomena

- **Fluidized bed reactor or CSTR used for struvite recovery**



N:P ratio in filtrate ~ 2.4-2.6, ammonia in excess

N:P ratio in struvite = 0.45 lbs N required per lb P removed

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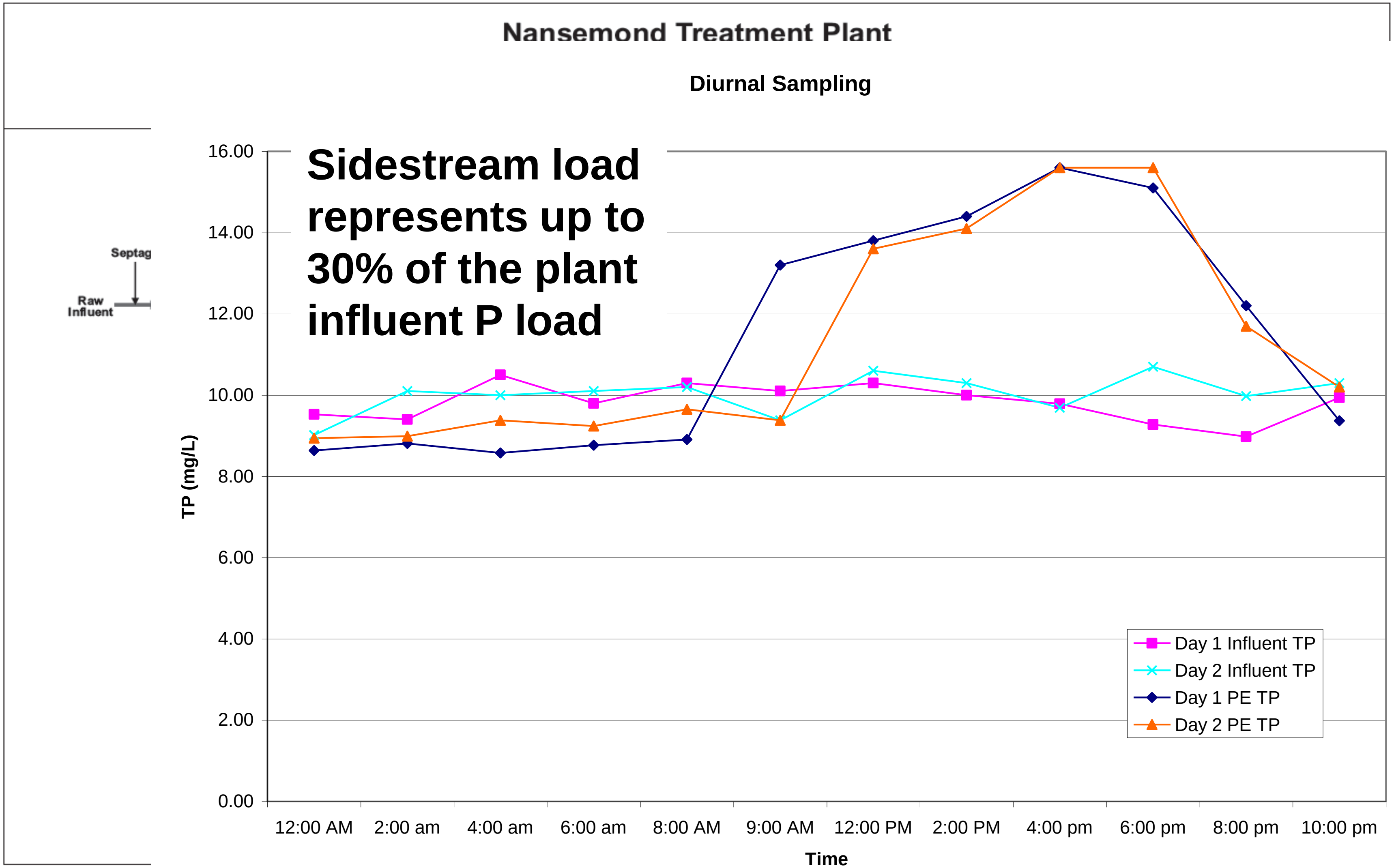
There are several commercial options for struvite recovery

Name of Technology	Ostara Pearl®	Multiform Harvest struvite technology	Phospaq	Crystalactor®	NuReSys
Name of product recovered	Crystal Green ®	struvite fertilizer	struvite fertilizer	Struvite, Calcium-phosphate, Magnesium-phosphate	BioStru®
% efficiency of recovery from sidestream	80-90% P 10-40% NH_3-N	80-90% P 10-40% NH_3-N	80% P 10-40% NH_3-N	85-95% P 10-40% NH_3-N	>80% P 5-20% N
Product marketing/resale	Ostara	Multiform Harvest	N/A	Third party facilitated by Procorp	N/A
# of full-scale installations in design/operation	8	2	2	4	7

Nansemond Treatment Plant is a 30 MGD facility that employs a 5-stage BNR for N and P removal

- **Nansemond – HRSD, Virginia**
  - **30 MGD BNR – 5 Stage**
  - **8 mg TN/L**
  - **1 mg TP/L**

Nansemond Treatment Plant is a 30 MGD facility that employs a 5-stage BNR for N and P removal



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Two options were considered for sidestream P Treatment at NTP

Ferric addition

- Forms ferric phosphate and ferric hydroxide
- Non-proprietary
- Traditionally used for controlling sidestream P at this plant
- High O&M requirement

Struvite recovery

- Ostara Pearl
- Treatment fee option
  - OSTARA provides facility and HRSD pays fee for use
- Capital purchase option
  - NTP purchases equipment and receives annual payments from OSTARA

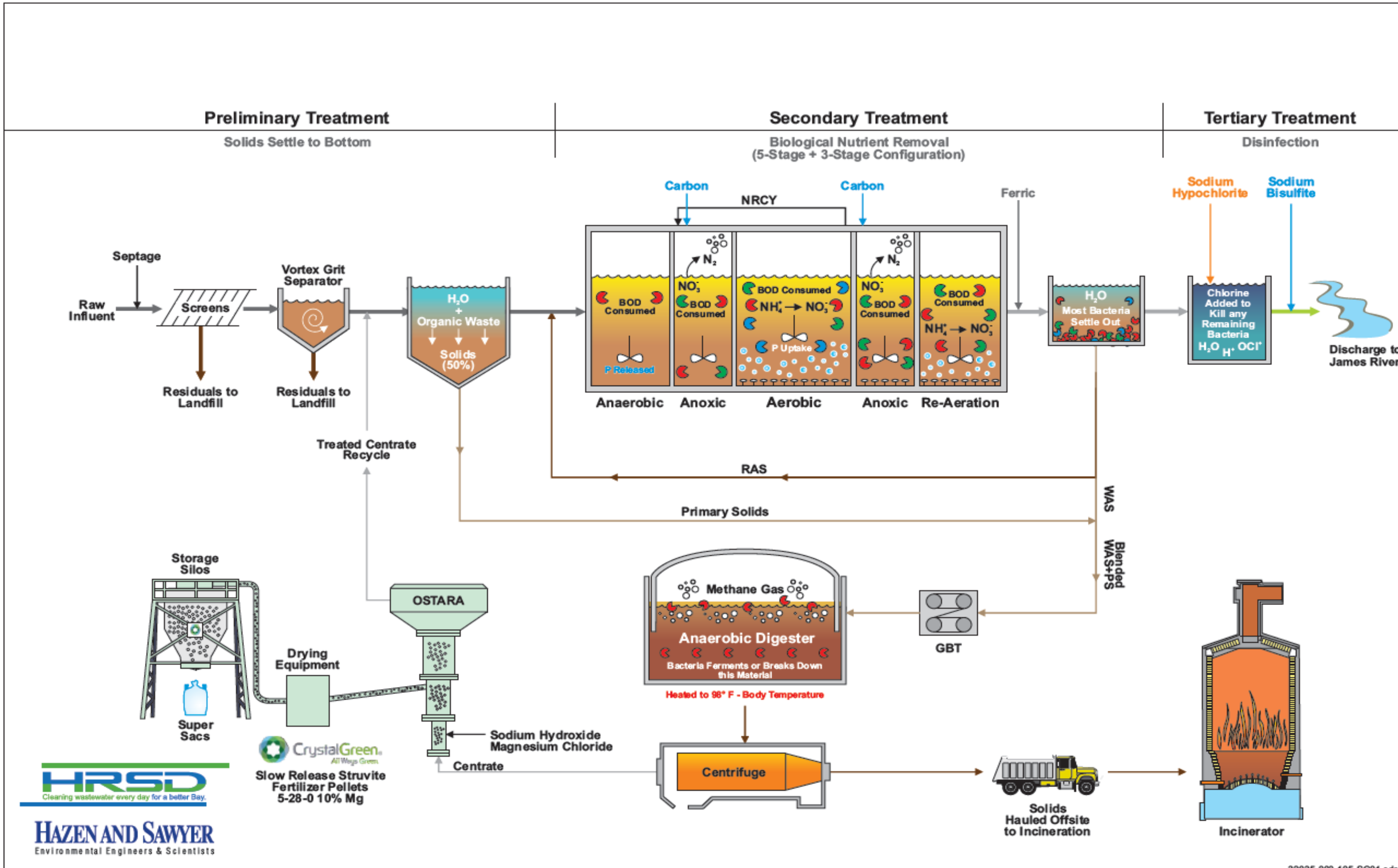
Net present worth analyses indicated that the capital purchase option was the most cost-effective solution

Item	Treatment Fee Option	Capital Purchase Option
Ferric Chloride Chemical Cost	$ (290,000)	$ (290,000)
Sludge Savings	$ (155,000)	$ (155,000)
Methanol Savings	$ (29,000)	$ (29,000)
Oxygen Savings	$ (19,000)	$ (19,000)
Ostara Paybacks	$ (87,850)	$ (135,850)
Total Annual Savings	**$ (580,850)**	**$ (628,850)**
Caustic Cost Allowance	$ 25,000	$ 25,000
Ostara Annual Fee	$ 444,000	$ -
Total Annual Operating Cost	**$ 469,000**	**$ 25,000**
Total Capital Cost	**$ 1,080,000**	**$ 4,143,000**
Present Worth Operating Costs	**$ (1,505,750)**	**$ (8,129,160)**
Net Present Worth[5]	**$ (425,750)**	**$ (3,986,050)**

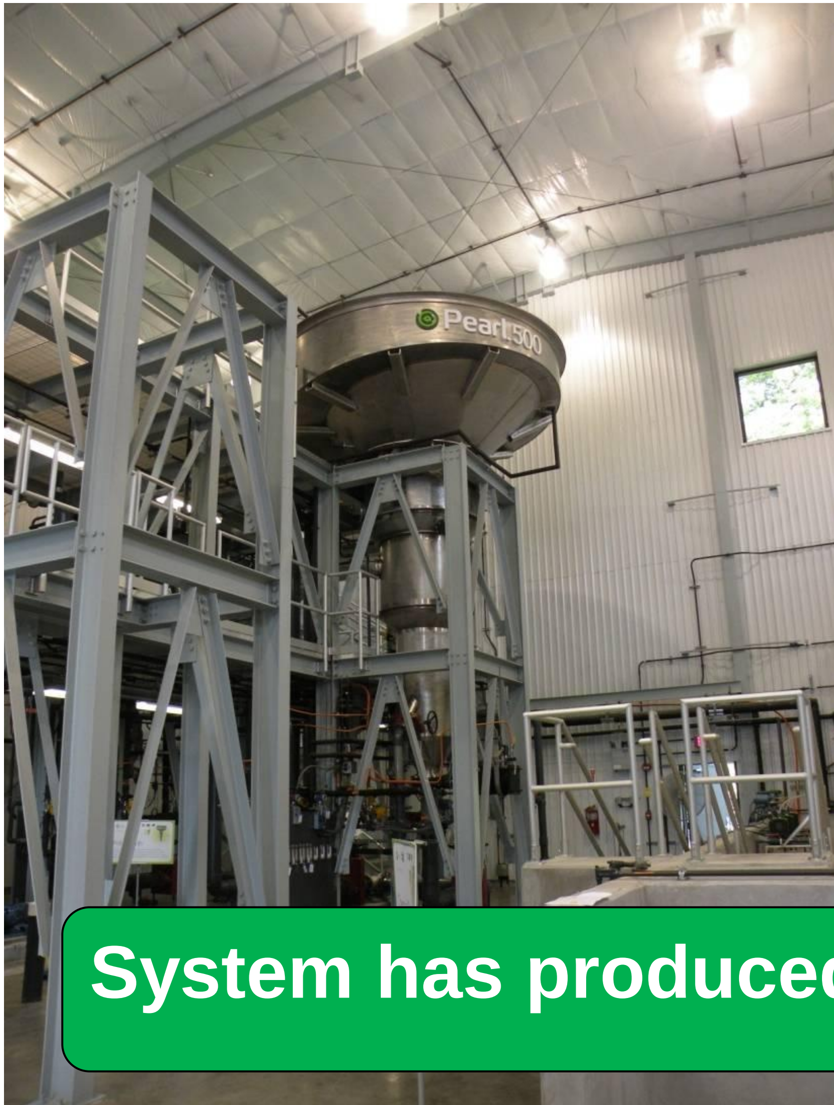
Nutrient recovery option was more cost effective than Ferric addition option

Present worth cost of line 10 over 20 years at 5% cost of financing

NTP constructed and has operated the nutrient recovery facility for ~ 2 years

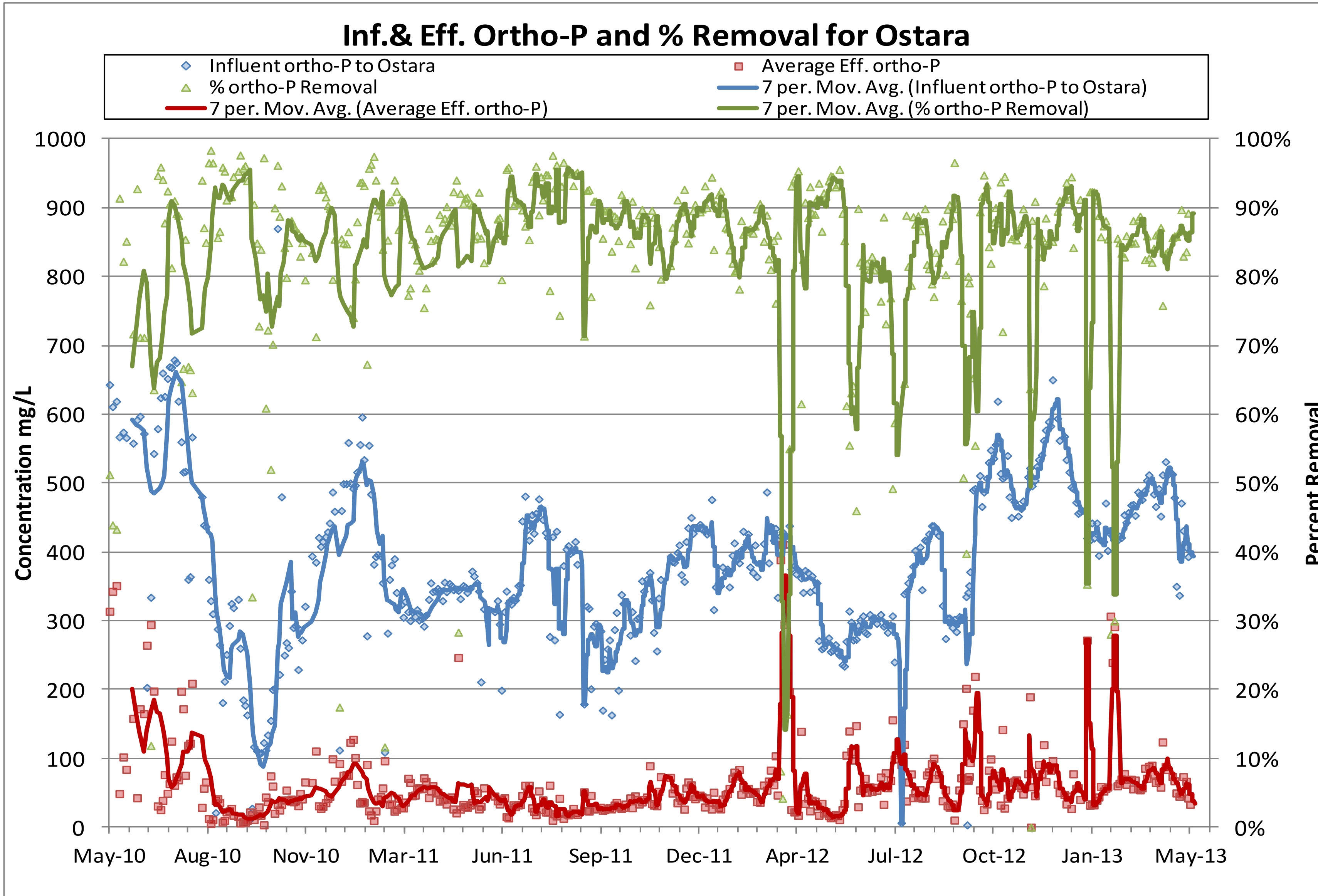


Full scale struvite recovery facility at NTP



System has produced ~ 1100 lb struvite/day

The struvite recovery facility has reduced ortho-P concentrations by approximately 85%



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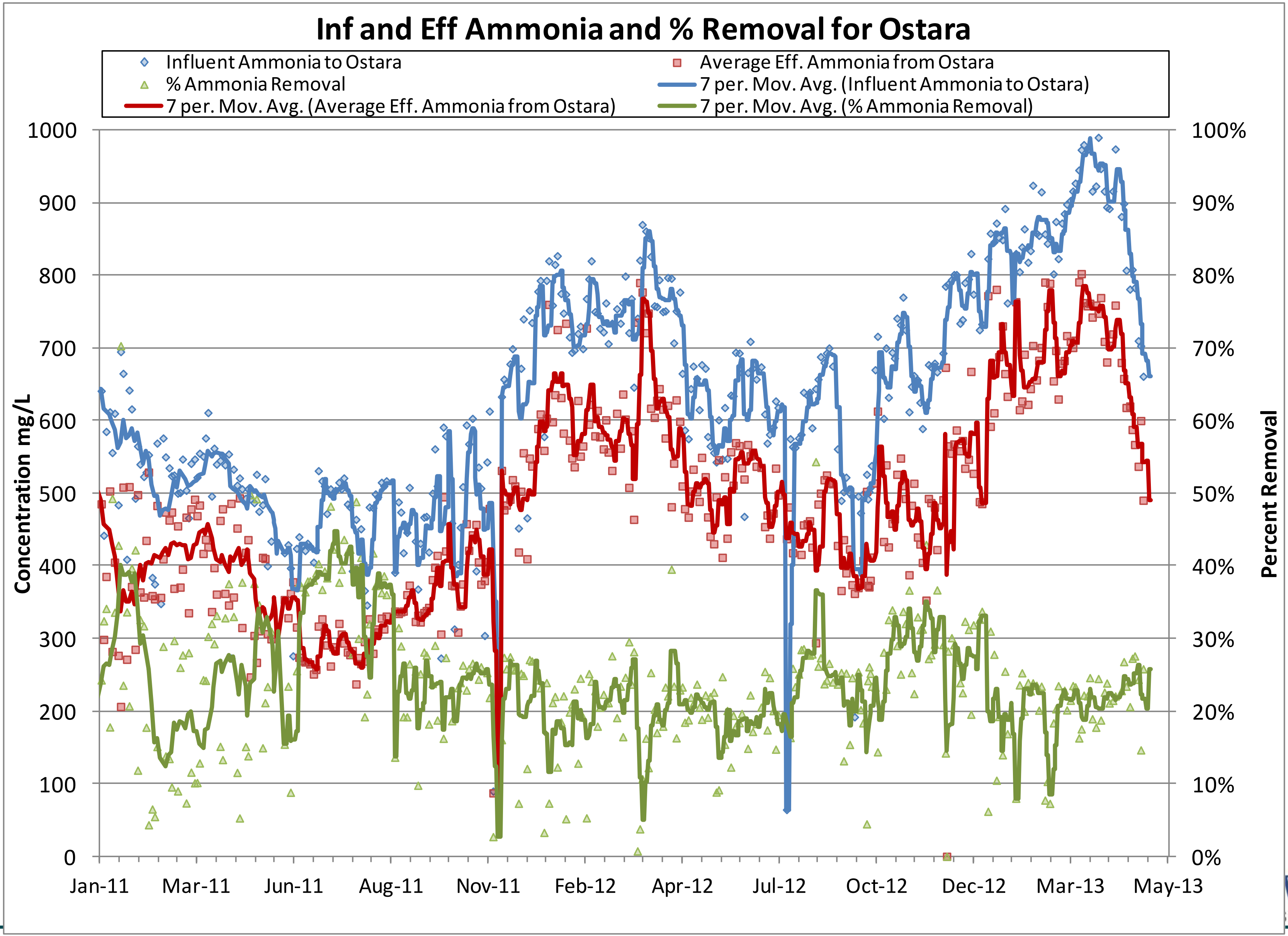
Ammonia removal has averaged 25%



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F. Wayne Hill Water Reclamation Center

Gwinnett County, GA

60 MGD advanced WWTP

0.08 mg/L TP effluent limit

Bio-P and chemical trim for P-removal

In 2009, F. Wayne Hill Changed from Bioxide to $Mg(OH)_2$ in Collection System for Odor Control

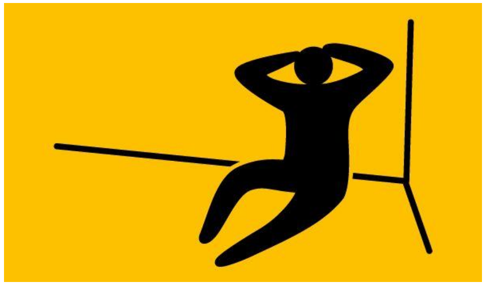
- Pros: Eliminated need for ALK addition at plant
- Cons: Struvite formation in centrate lines, centrifuges, digester complex
- Sludge from 22 mgd Yellow River Bio-P plant coming, which would substantially increase P load in sidestreams and SFP

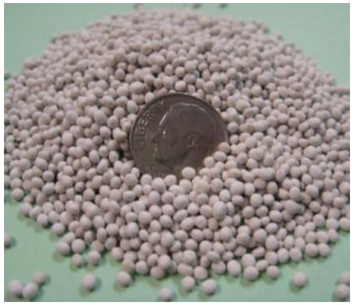
Limiting effluent P and struvite formation are key drivers for this plant

- **Phosphorus outlets:**
  - Effluent (Limit TP = 0.08 mg/L)
  - Sludge cake (precipitated complex, biomass, struvite)
  - Struvite solids from nuisance formation

- **Study goal: determine best solution for struvite issue (Mg continues) or P recycle issue (Mg stops)**
  - Nutrient Recovery
  - Metal salts

Five options were considered for sidestream P removal from F. Wayne Hill AWRF



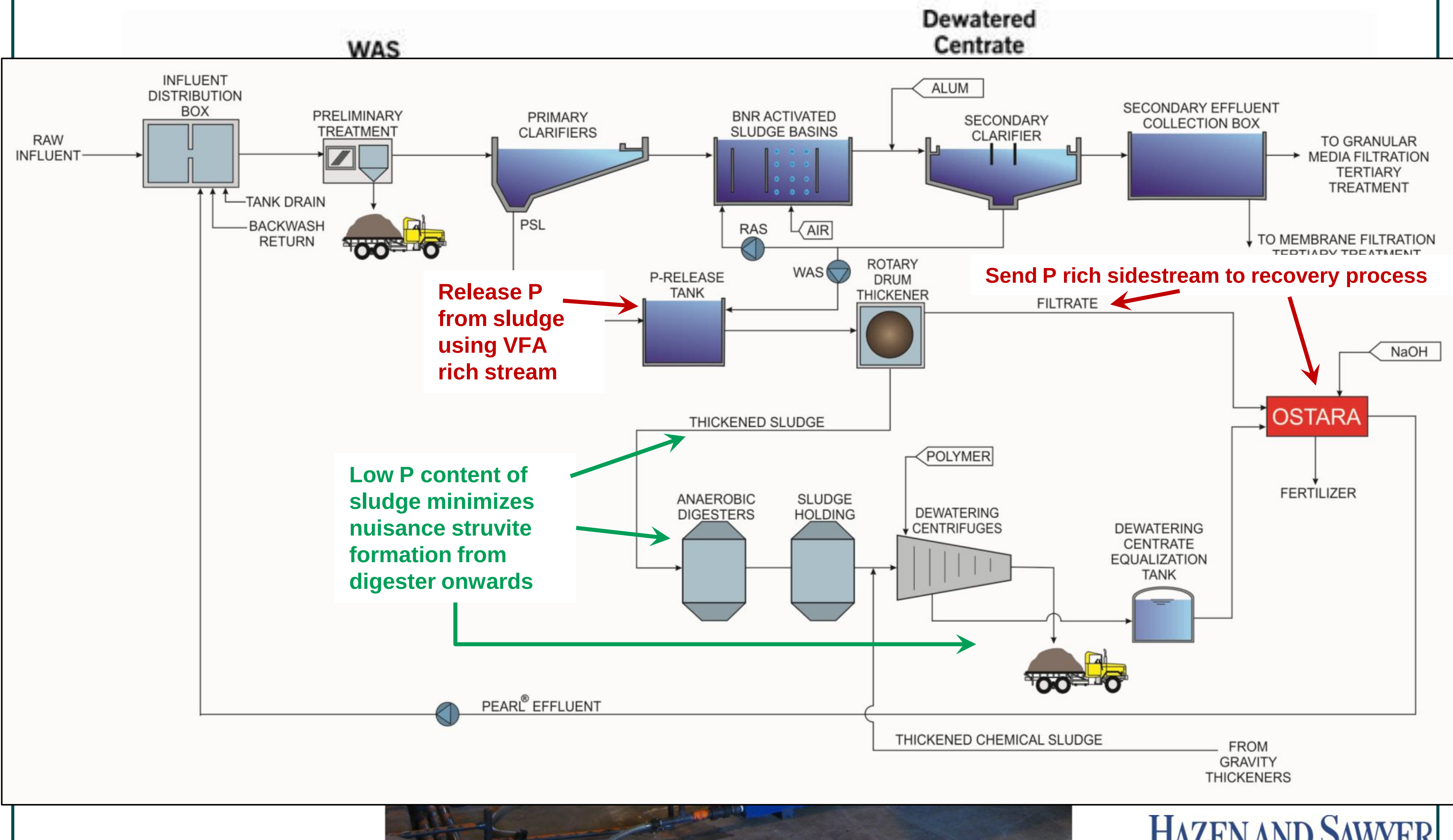


Do Nothing

Ferric addition with and without $Mg(OH)_2$ addition

Struvite recovery with and without WASStrip™

WASSTRIP™ concept minimizes nuisance struvite production



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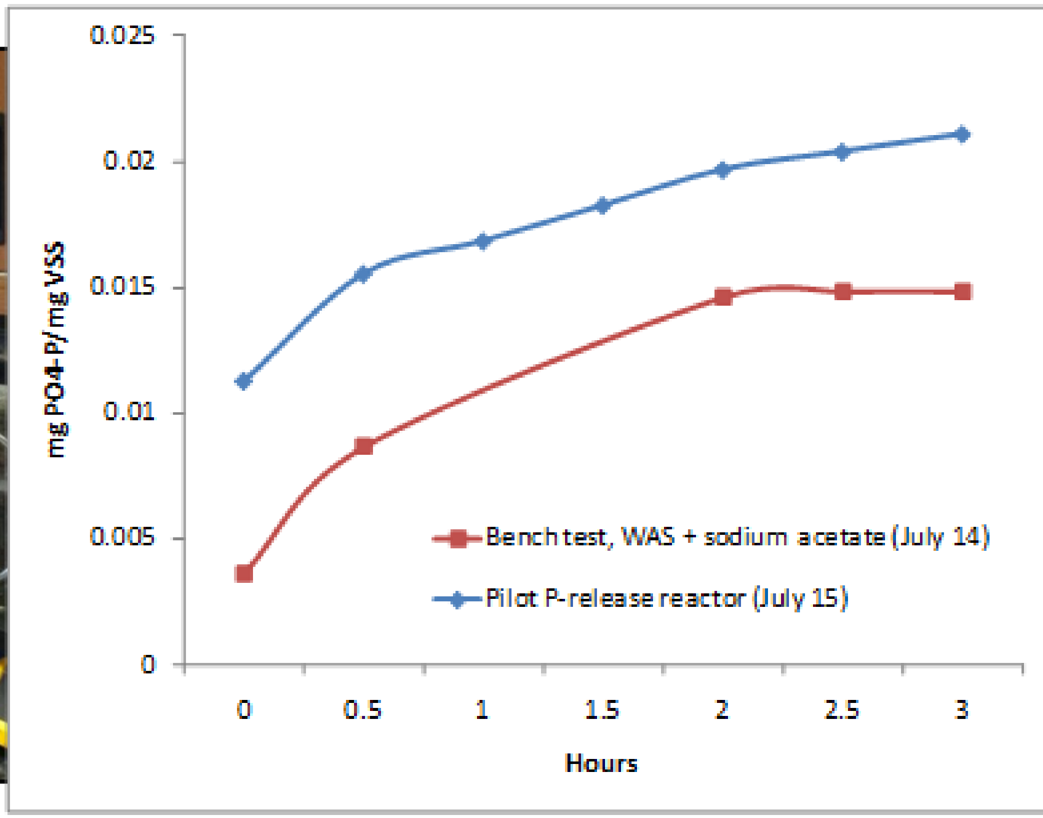
Bench scale testing of the WASSTRIP™ process was performed

- Determine levels and rates of PO_4 release from WAS
- Optimize parameters to maximize PO_4 release in pilot studies
  - Anaerobic retention time and WAS:PS blend ratio



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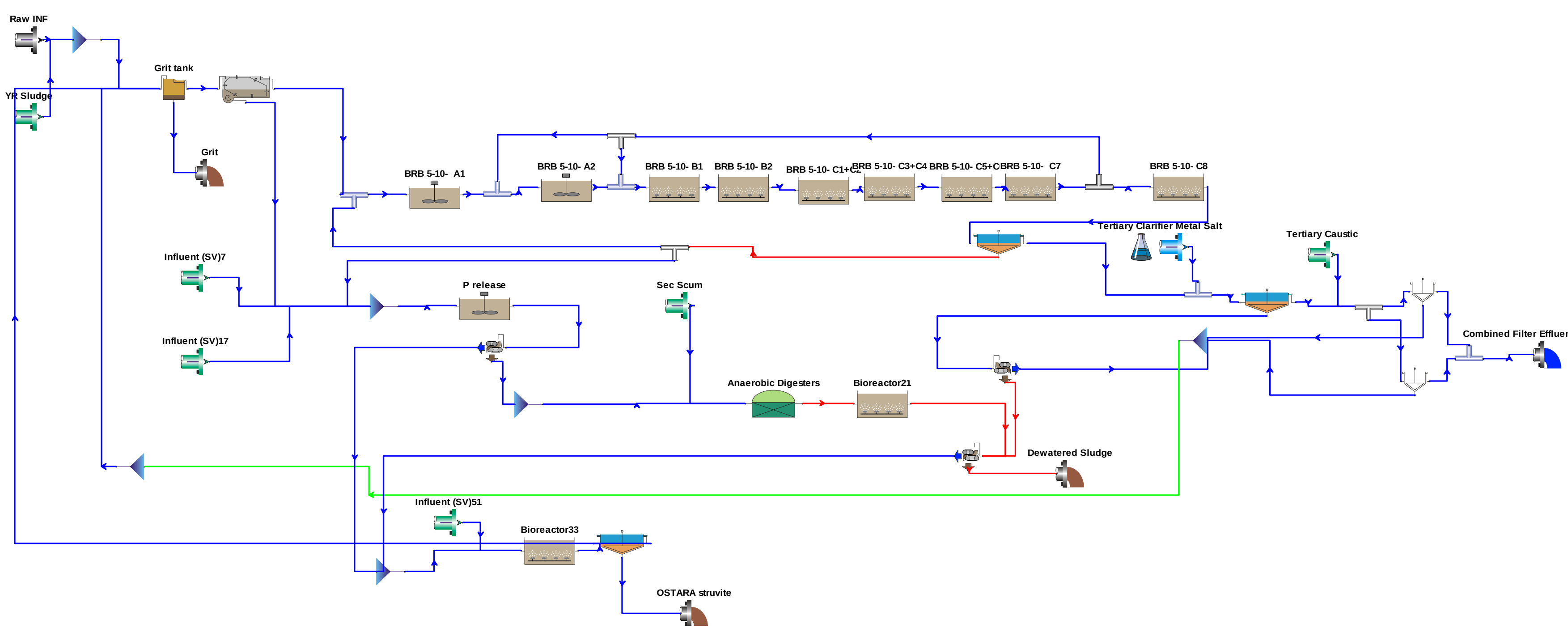
Using the pilot data, Biowin™ process modeling was used to simulate each alternative

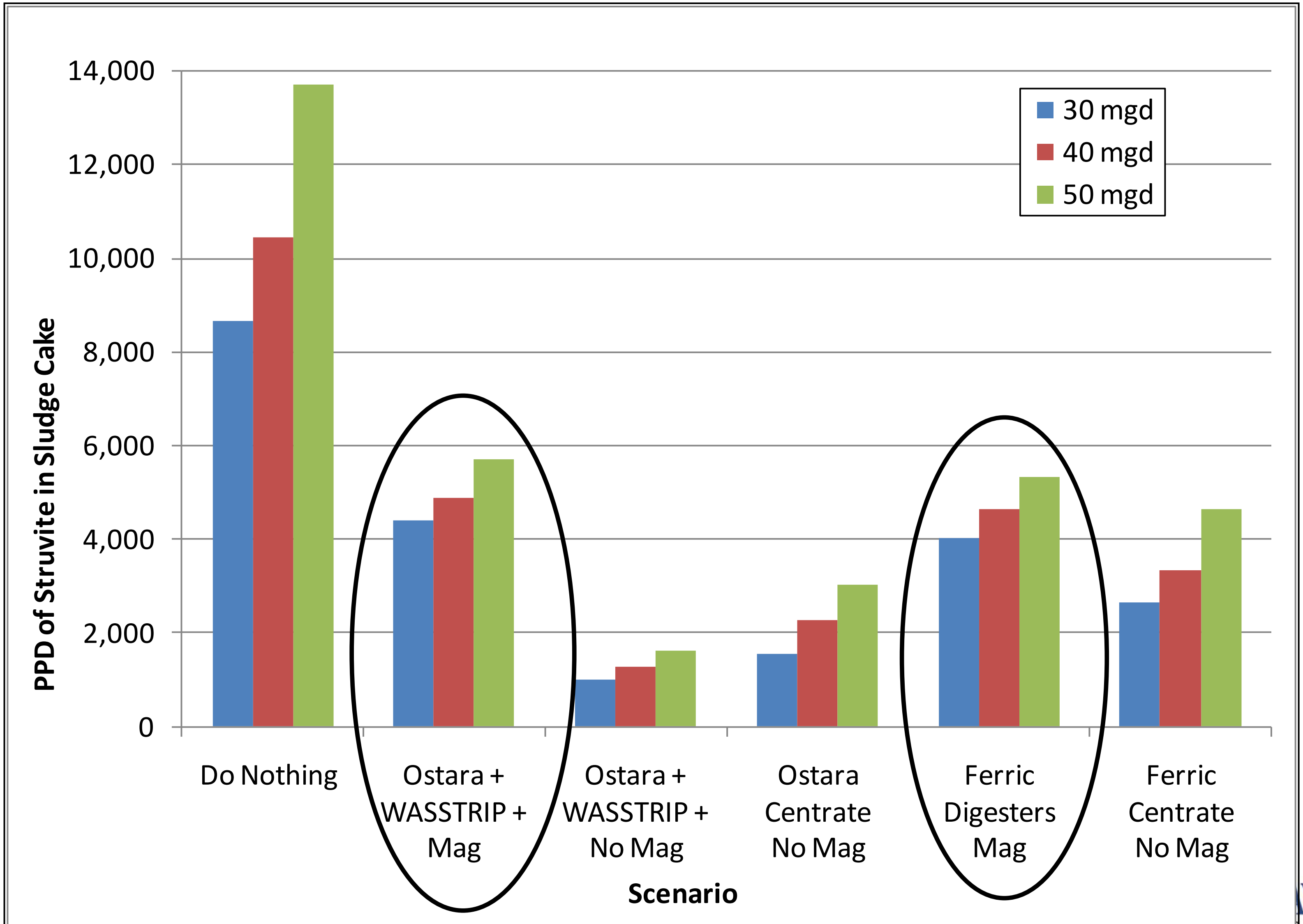
1. **Use calibrated whole plant model to simulate alternatives at each flow scenario**

2. **“Do Nothing” scenario is modeled for comparison of struvite formation**

3. **The modeling results were used to assess effectiveness of the nutrient control strategy and also to estimate costs for the BCE.**



P recovery provides equivalent struvite reduction compared with the ferric addition option



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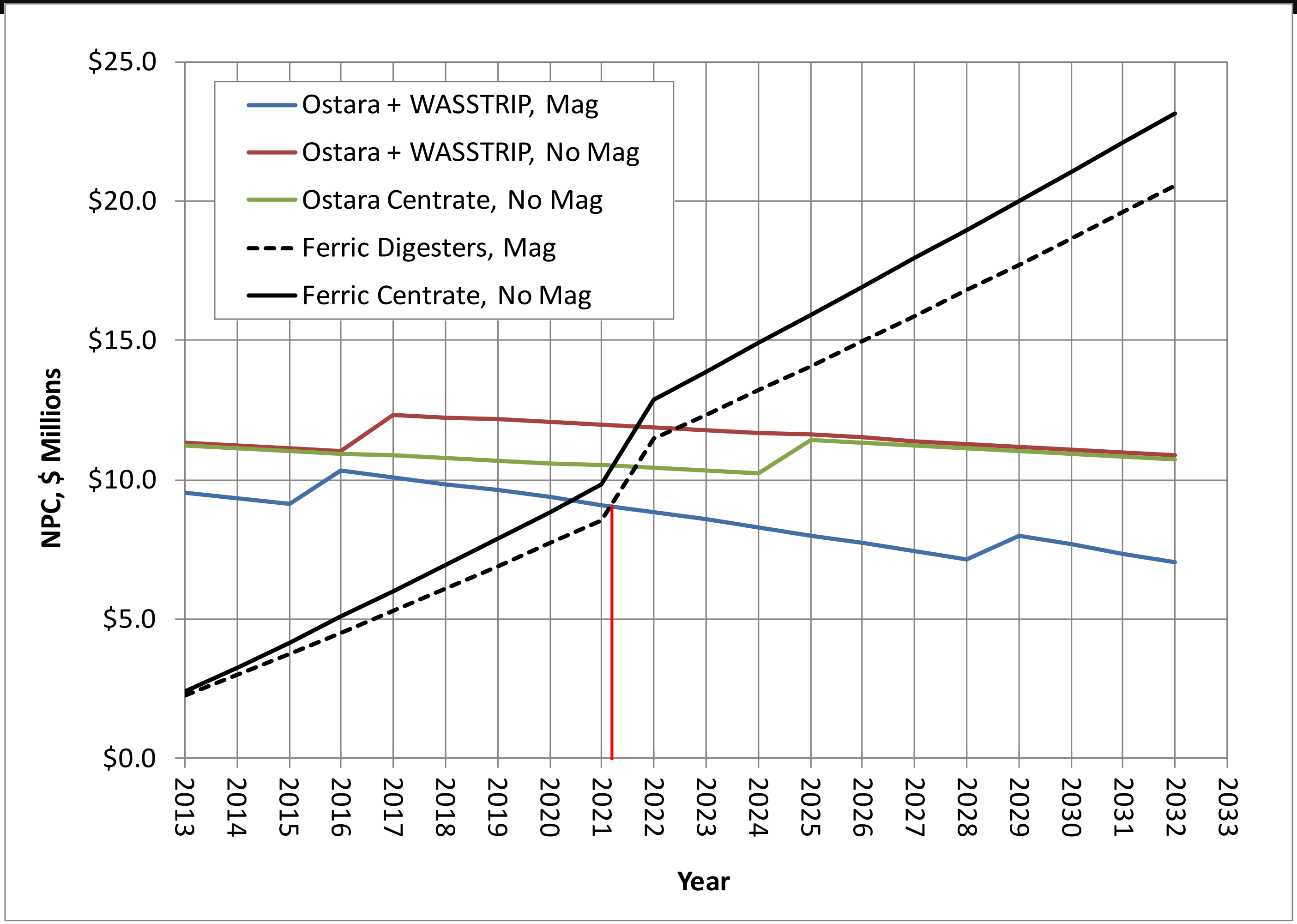
Struvite recovery + WASSTRIP has lowest net present cost and 8-Year Payback



- **FWHWRC is pursuing nutrient recovery option**

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Miami-Dade resource recovery

- Pure oxygen facilities
- Meets secondary treatment standards
- Disposal through deep injection wells

CDWWTP – 143 mgd AADF

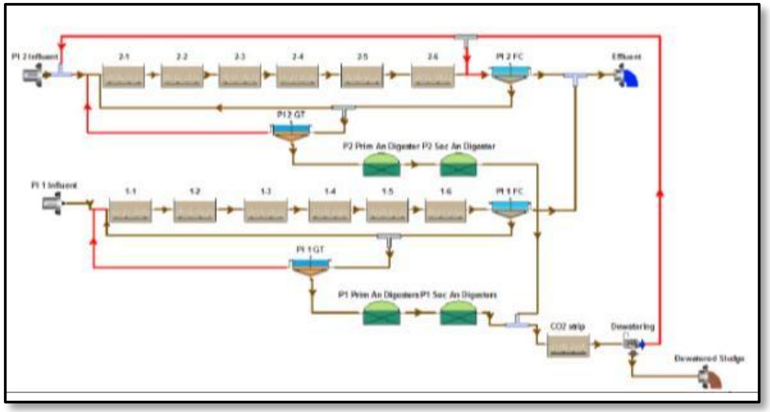
SDWWTP – 112.5 mgd AADF

- Significant nuisance struvite formation issue

Miami Dade resource recovery - evaluations

In-situ Coupon Testing to Determine Degree of Struvite Formation and Confirm Theoretical Ferric Dose

Bench Scale Testing to Determine Optimal Ferric Dose



Modeled Struvite Potential and Reduction for Each Alternative & Performed Cost Evaluation

Ostara Pilot Test

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Nutrient Recovery was the most cost effective option at both plants

	CDWWTP		SDWWTP		
	Ferric Addition	OSTARA	Existing**	Ferric Addition	OSTARA
Capital ($M)	1.0	4.9	–	0.9	4.9
Annual O&M ($M)	0.5	negligible	0.4	0.4	(0.07)
20 Year Present Worth ($M)*	10.7	negligible	8.4	8.3	(1.4)
20 Yr Net Present Worth ($M)*	11.7	4.9	8.4	9.2	3.5

Notes: * 6% interest and escalation
** Could be significantly higher

- Long term recommendation is to implement nutrient recovery at both facilities

Summary

1. Reduce energy and chemical consumption in the mainstream process
2. Provide factor of safety for mainstream nutrient removal process
3. Minimize nuisance struvite formation and reduce O&M costs

To mainstream

Sidestream treatment

Dewatering

Anaerobic Digestion

Thickening

Biosolids

1. Manipulate the nutrient content of the biosolids
2. Provide plant with alternative revenue stream

Summary

- **Compare struvite crystallization with precipitation with coagulant (i.e., alum or ferric)**
- **Payback site-specific and dependent on the P load**
- **Tool for Evaluating Resource RecoverY (TERRY) developed through WERF grant to help facilities perform high level evaluation for implementing P recovery**

Title:	Tool for Evaluating Resource Recovery Beta Version 1
Contents:	Module for estimating capital and O&M costs associated with implementing sidestream P control using struvite recovery Module for performing cost benefit analyses of alternatives
Quick reference instructions:	Click on Start Tab Enter facility specific data into relevant sections in the each worksheet. The user will be guided to enter data in subsequent worksheets using the color code provided in the key below. The user can navigate between worksheets using hyperlinks embedded in each worksheet.

Data Entry Instructions	
(green)	means entered by user
(blue)	means titles or calculated values

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