PHOSPHORUS REMOVAL IMPROVEMENTS: Carbon addition, operational modifications, and filtrate management

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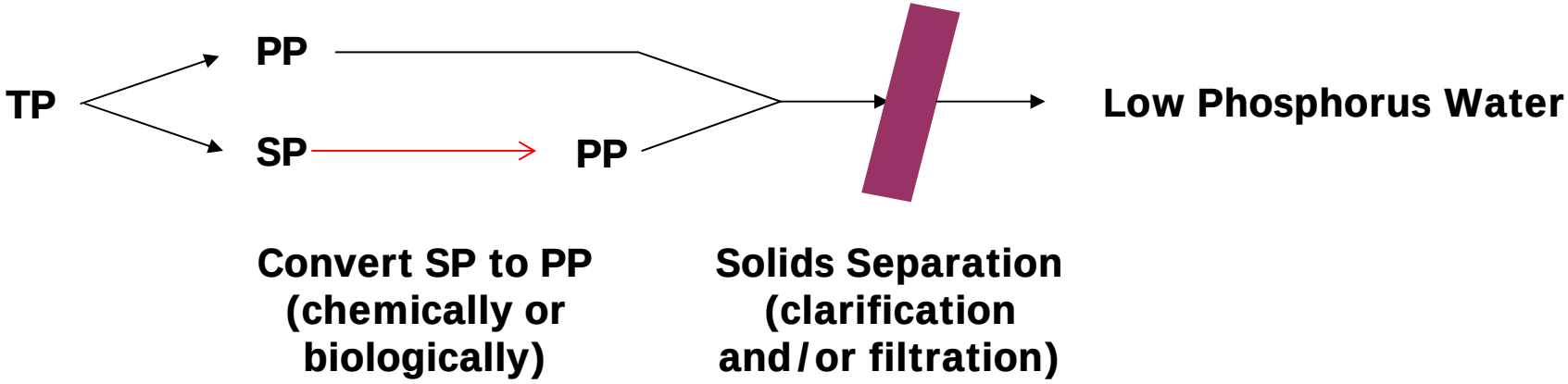
Phosphorus Removal (in one slide!)

- **Soluble and particulate phosphorus**
  - Soluble (SP): biological and/or chemical transformation to particulate phosphorus
  - Particulate (PP): physical removal
- **More stringent phosphorus limitations**
  - Increased conversion of soluble phosphorus to particulate
  - Increased particulate removal

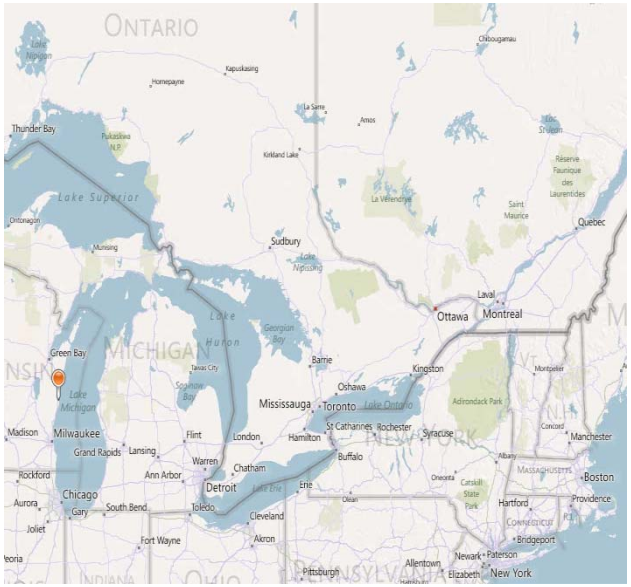


When considering low level P…

- **Conversion of soluble P to particulate P**
  - Optimize biological processes
  - Increase chemical addition efficiency
  - Holistic plant approach
- **Removal of particulate P**
  - Improved clarification (down to ~0.5 mg/L)
  - Filtration/Advanced Filtration (0.3? 0.1? 0.05?)

Sheboygan WWTP

- **Sheboygan, Wisconsin, USA**
  - Located on Lake Michigan
  - ~100,000 person metropolitan area
- **Sheboygan Regional Wastewater Treatment Plant (WWTP)**
  - Unique facility due to codigestion program



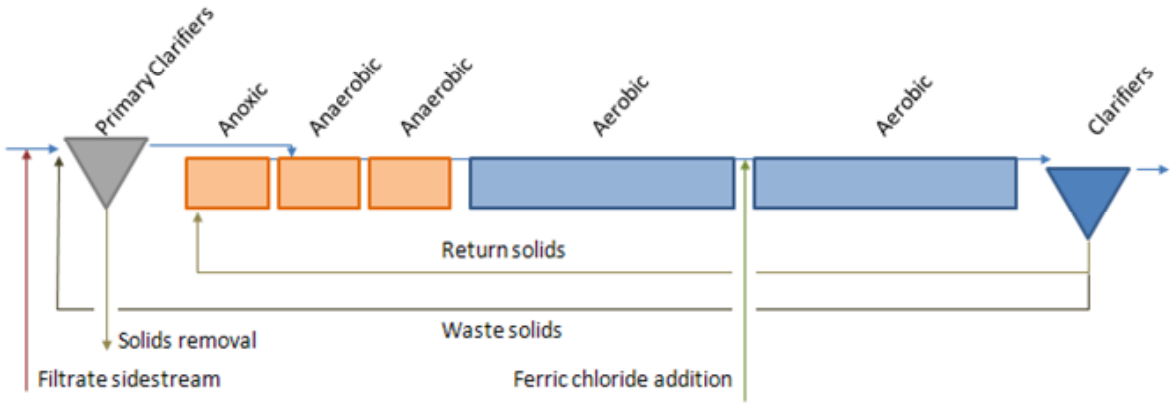
Sheboygan WWTP

- **Upcoming Nutrient Regulations**
  - Current monthly discharge limit: **1 mg/L**
  - Great Lakes discharger
  - Anticipated monthly discharge limit: **0.6 mg/L**
- **Nutrient Removal Evaluation**
  - Testing of ferric chloride in early 2011
  - Addition of external carbon source (QLF)

Optimization Approach

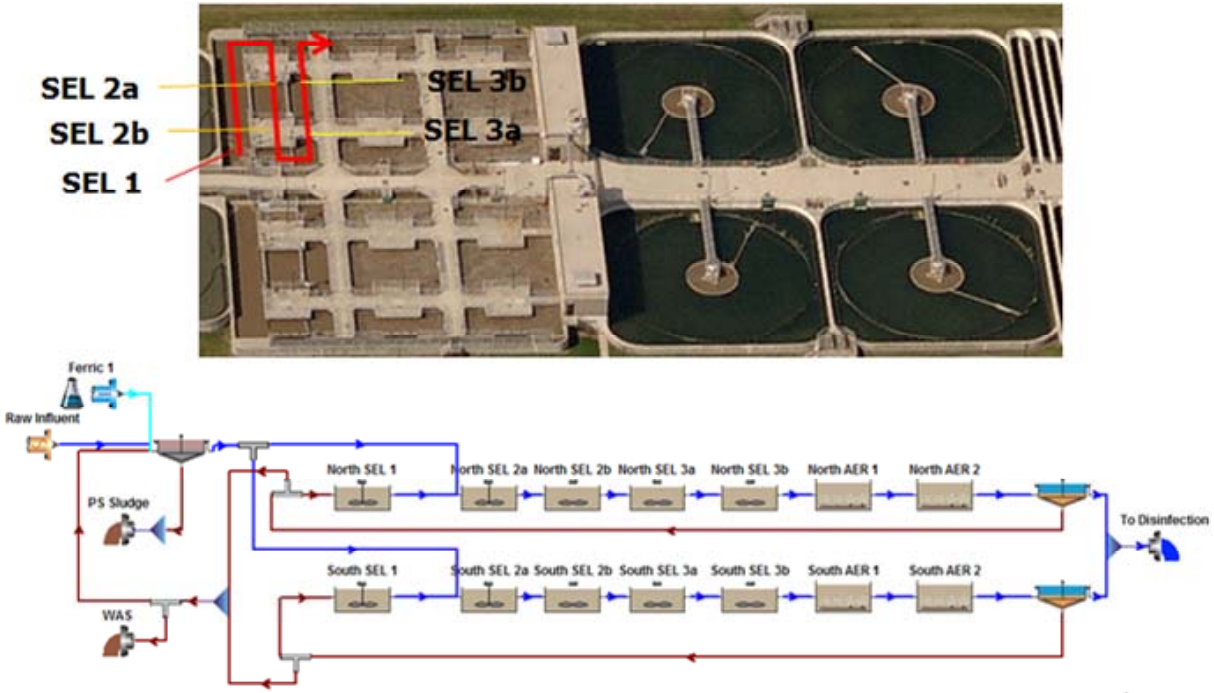
- Develop process model
- Identify potential limitations to bio-p
- Evaluate potential solutions

Sheboygan WWTP



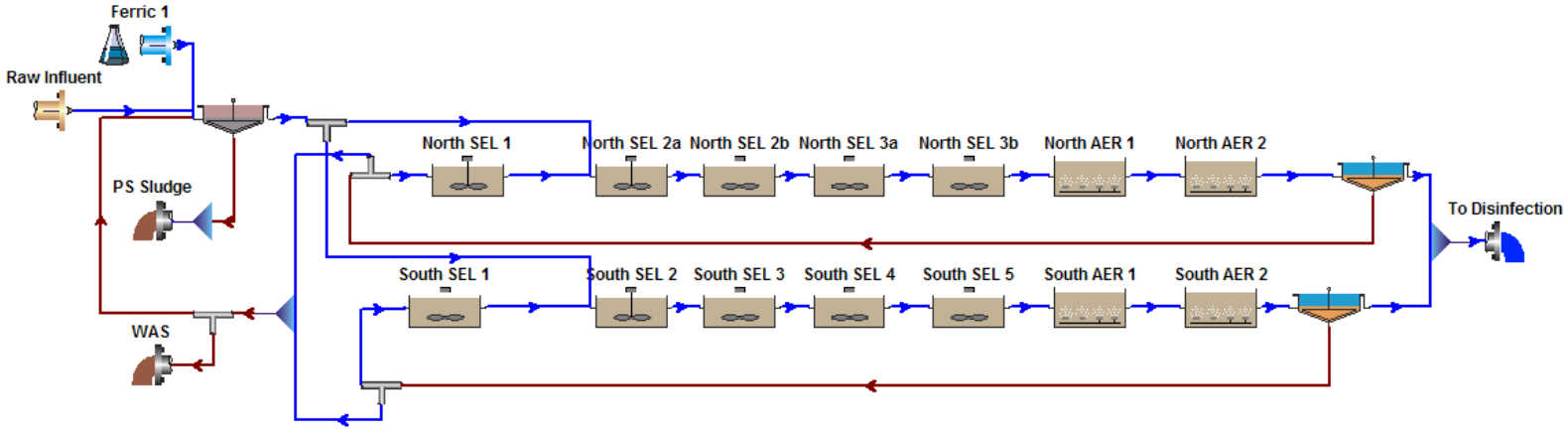
Process Modeling

- Developed in Biowin
- Influent characterization (6 sampling events)



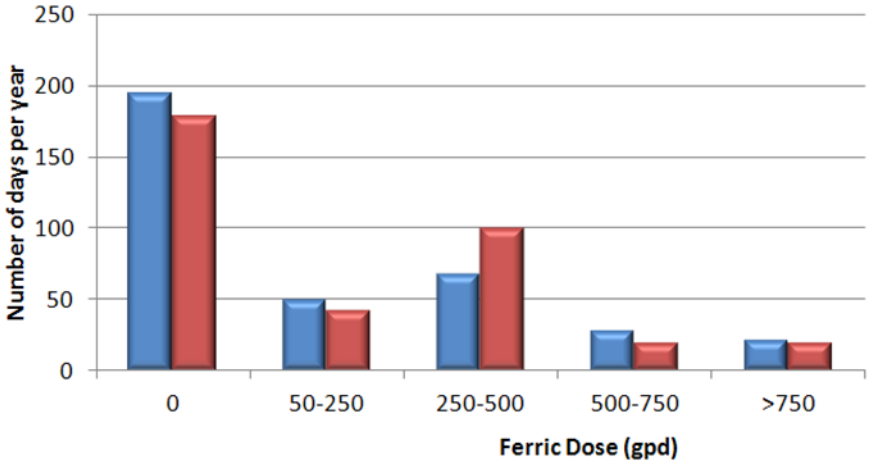
Process Modeling

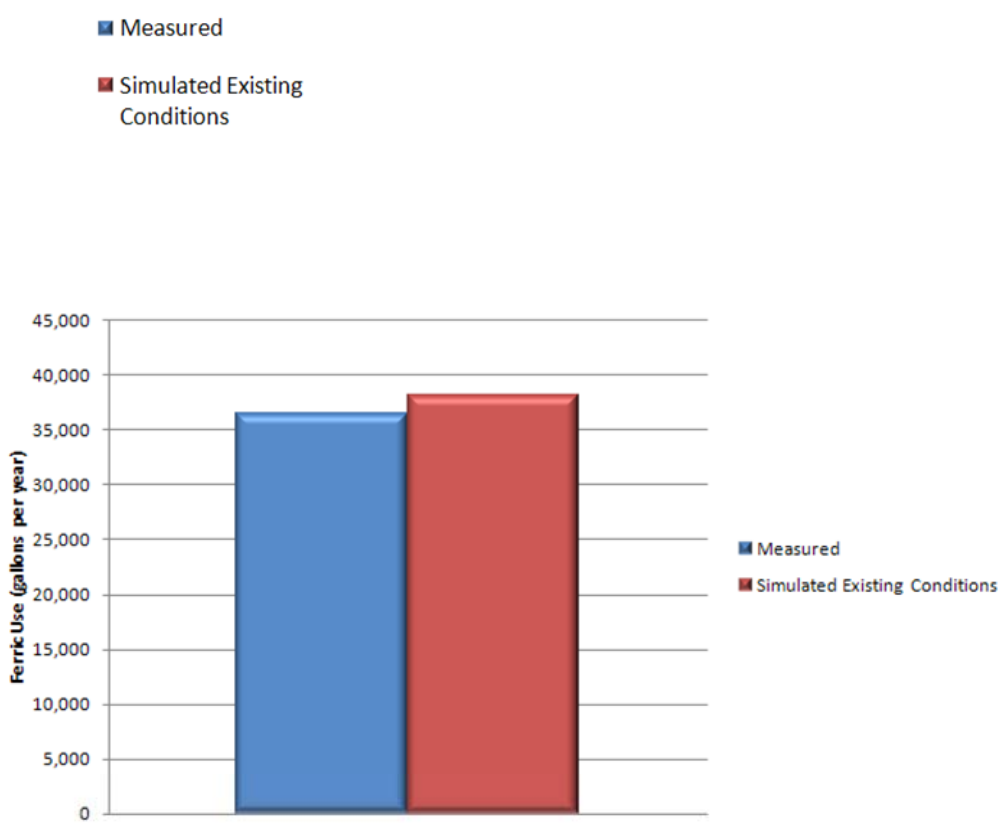
- **Sensitivity to effective influent ammonia concentration**
  - Sheboygan samples influent ammonia weekly
    - Effluent permit is 23 mg/L (Lake Michigan discharge)
  - High strength sidestream is not treated or equalized



Model Calibration

- **Detailed discussion for another day…**

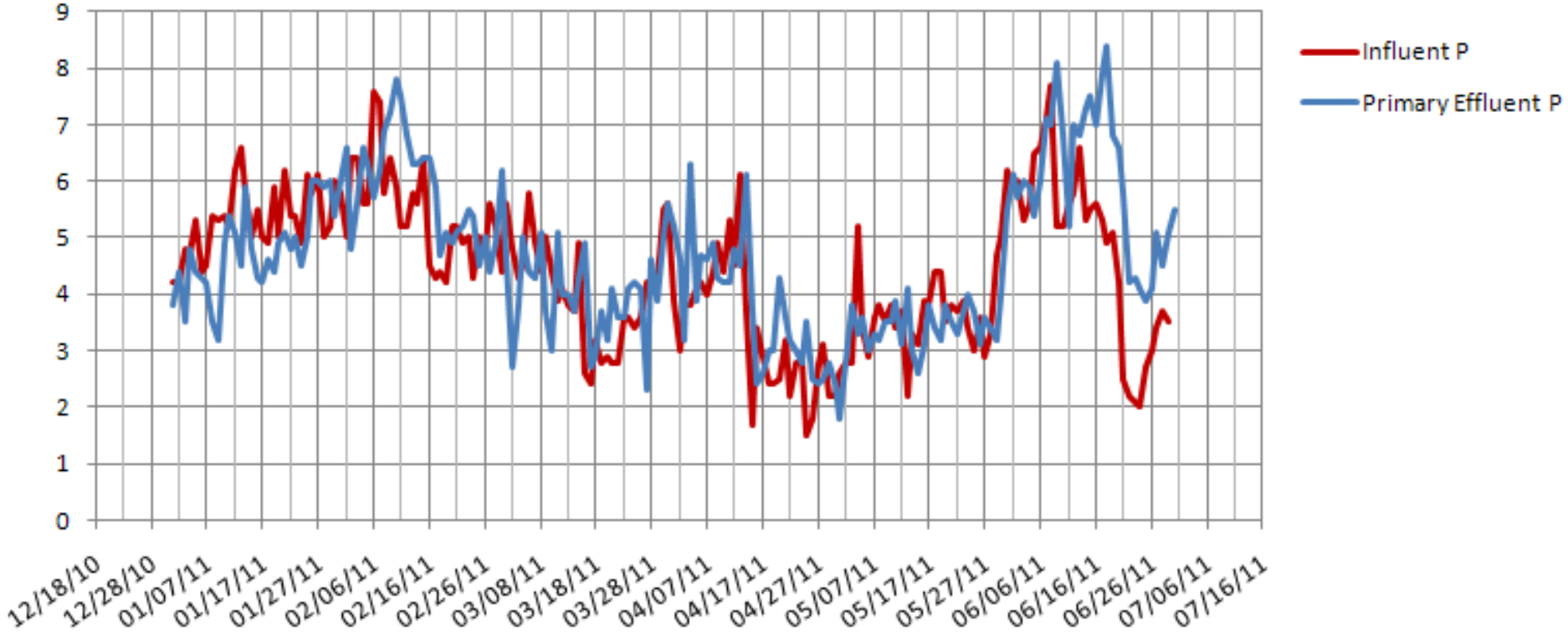




Potential Limitations to Bio-P

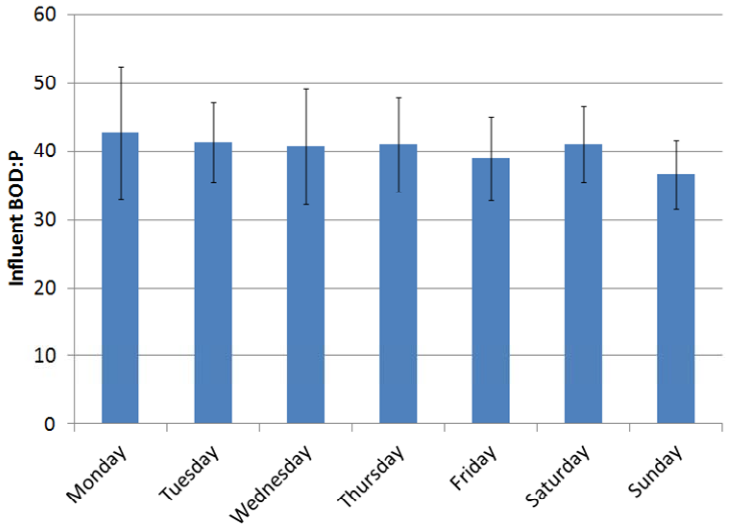
- Influent BOD:P
- Influent TKN?
- Anaerobic contact time

Primary Effluent Phosphorus

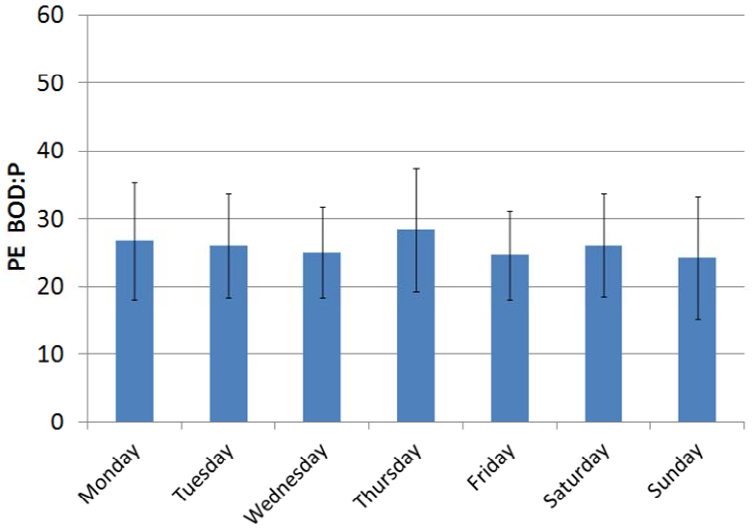


Challenge 1: Primary Effluent Phosphorus Concentration

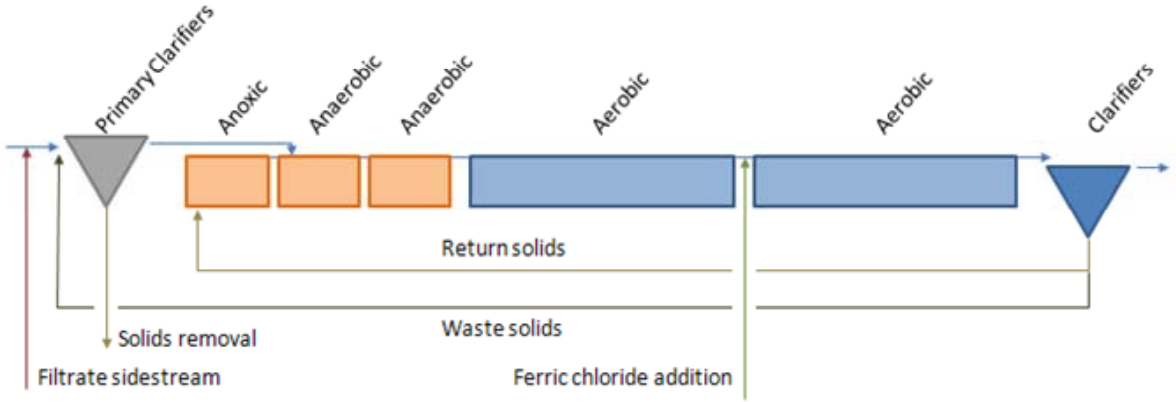
BOD:P



Raw Influent



Primary Effluent



Challenge 1: Primary Effluent Phosphorus Concentration

Nitrogen and Phosphorus Removal

- **Indirect impact**
  - TKN is oxidized to nitrate
  - Nitrate in RAS competes for VFAs/carbon
  - Reduces anaerobic contact time *and* VFA concentration
- **Sources**
  - Raw influent
  - Anaerobically digested sludge filtrate flow

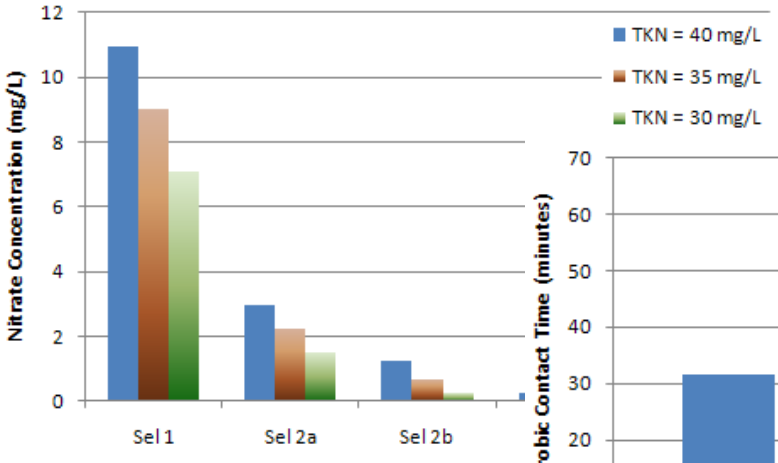
Nitrogen and Phosphorus Removal

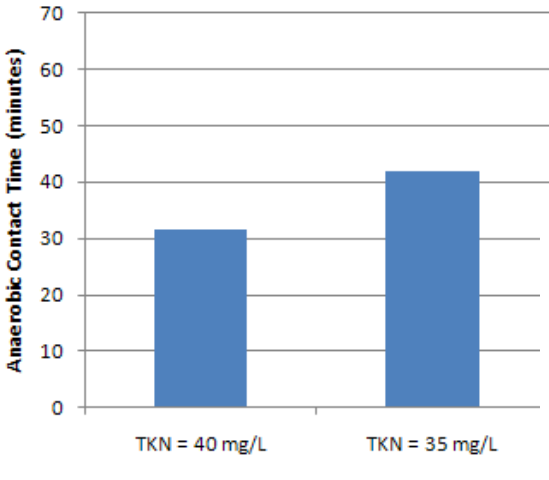
- **Primary Effluent Data**
  - Not strictly regulated for effluent ammonia
  - Inconsistent measurement of PE TKN

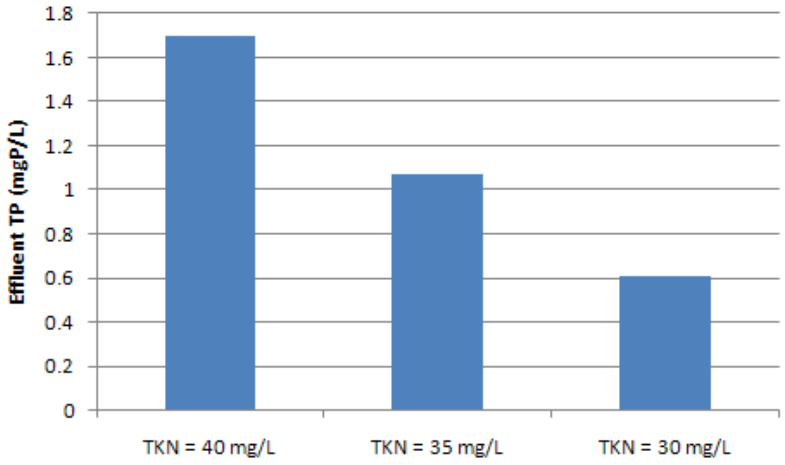
Primary Effluent Data – January to June 2011

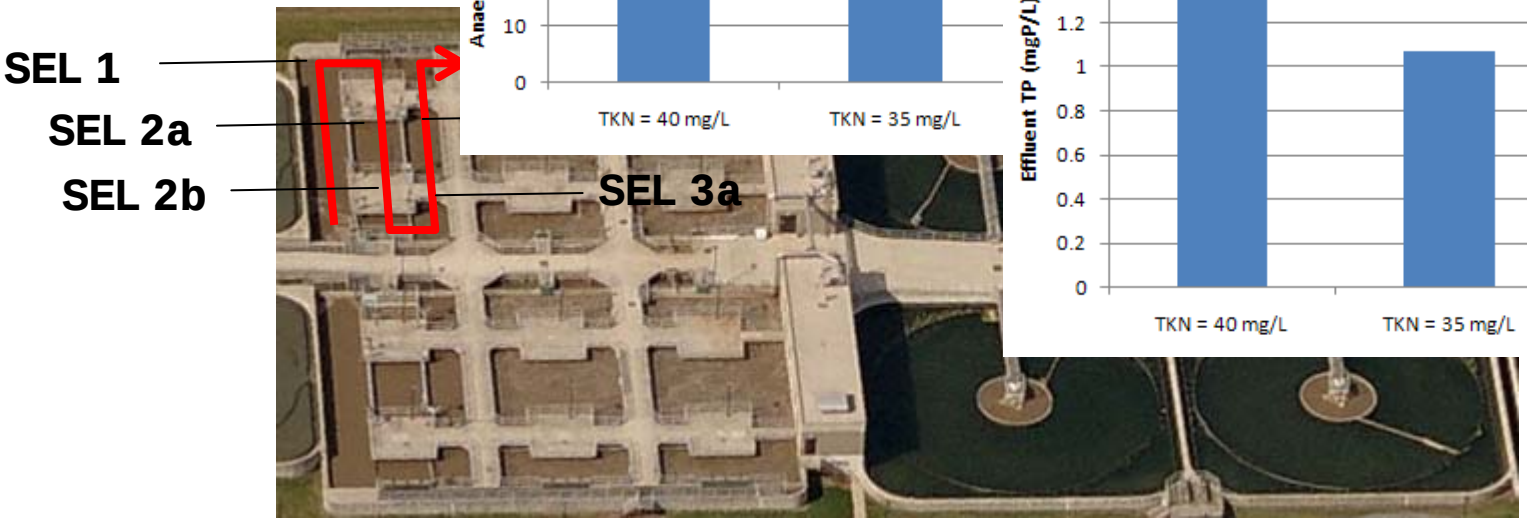
	PE BOD (mg/L)	PE TKN (mg/L)	PE TP (mg/L)
Average	131.7	30.3	4.6
Standard Deviation	42.11	13.43	1.36
n	180	**12**	180

Nitrogen and Phosphorus Removal



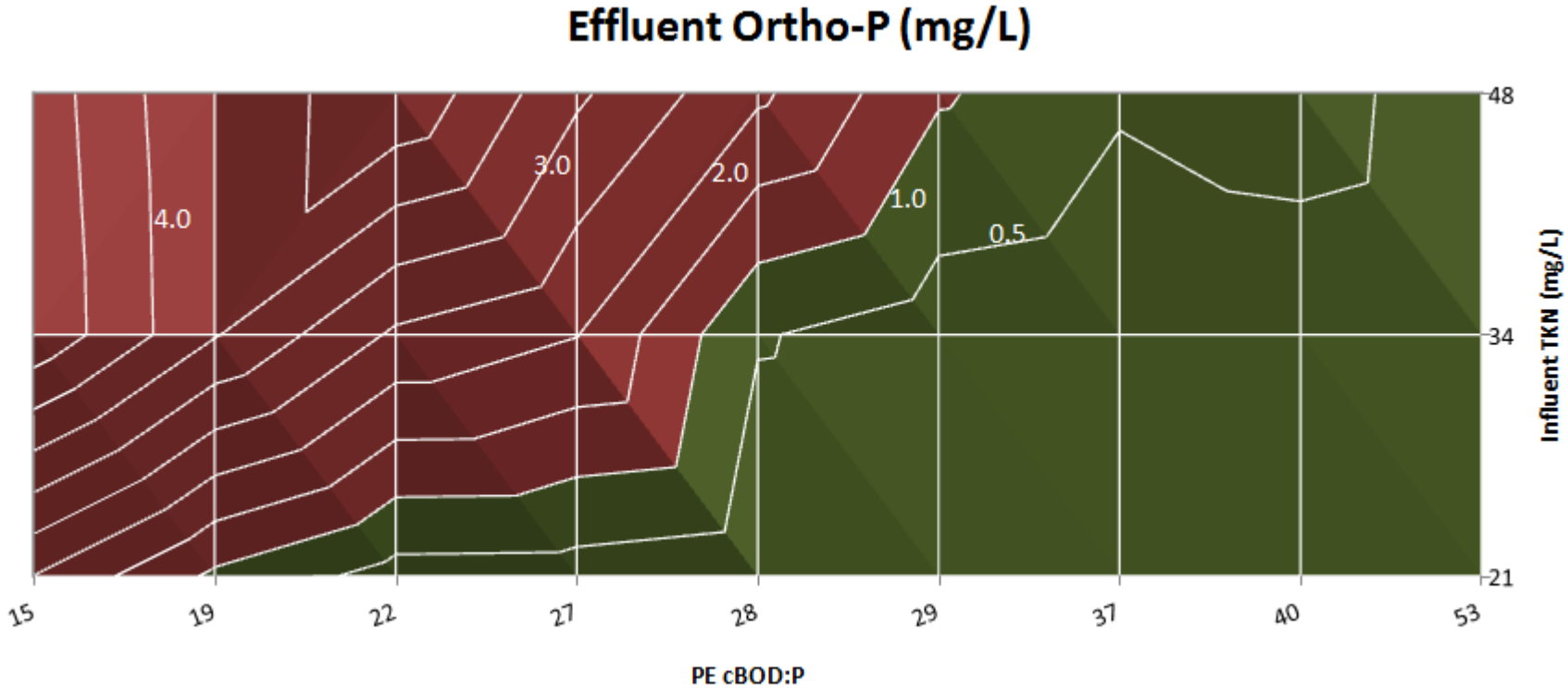


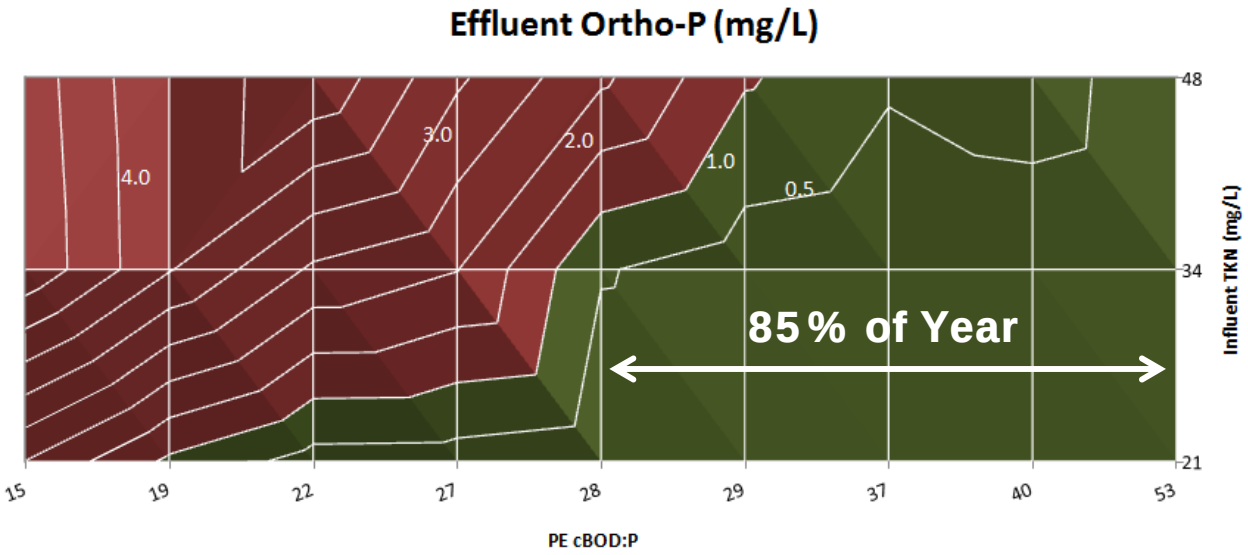


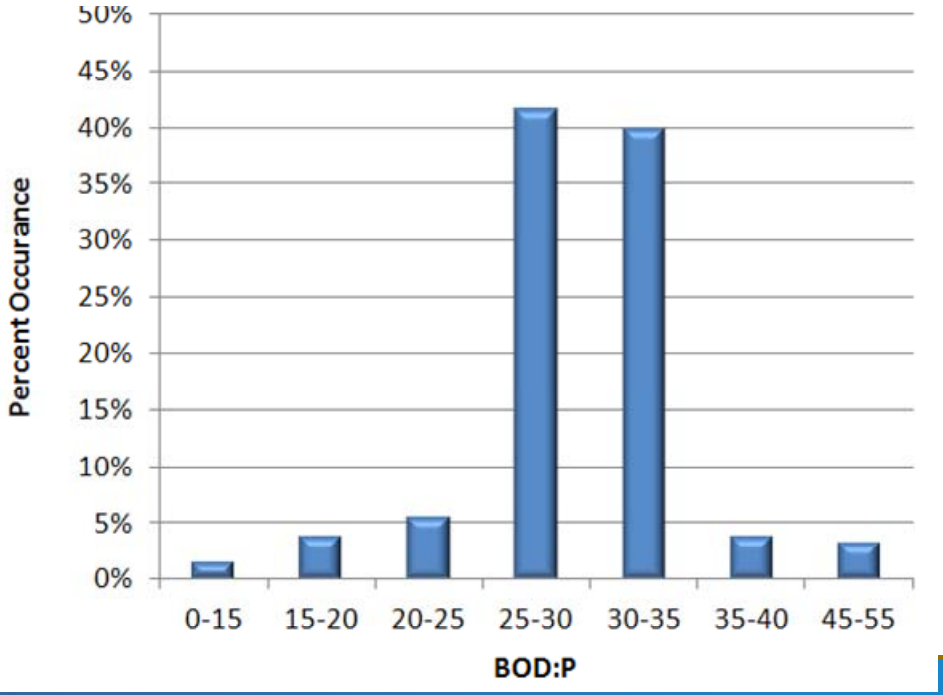


Nitrogen and Phosphorus

- Simulate multiple conditions
- Develop effluent P topo map

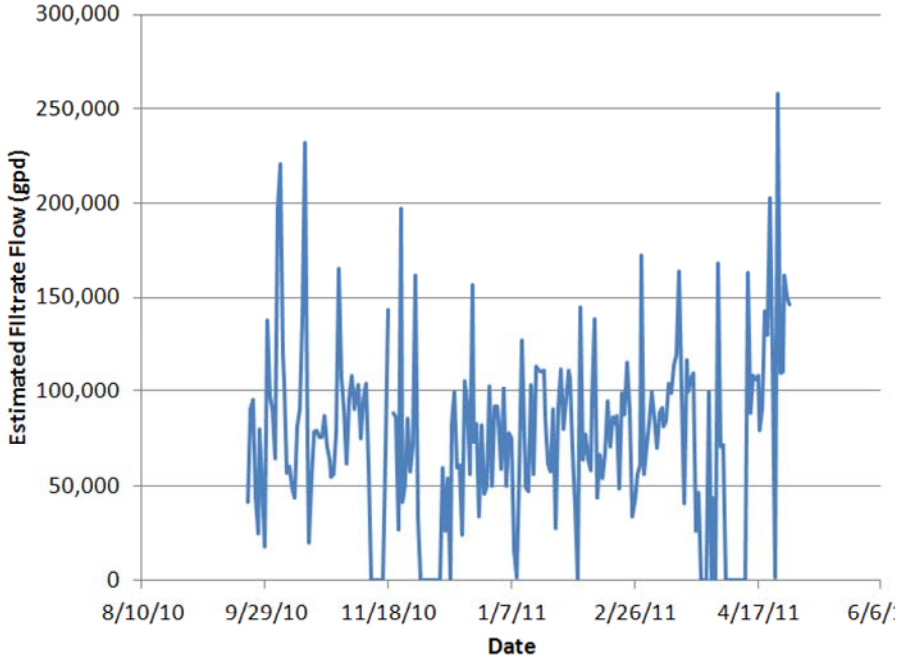


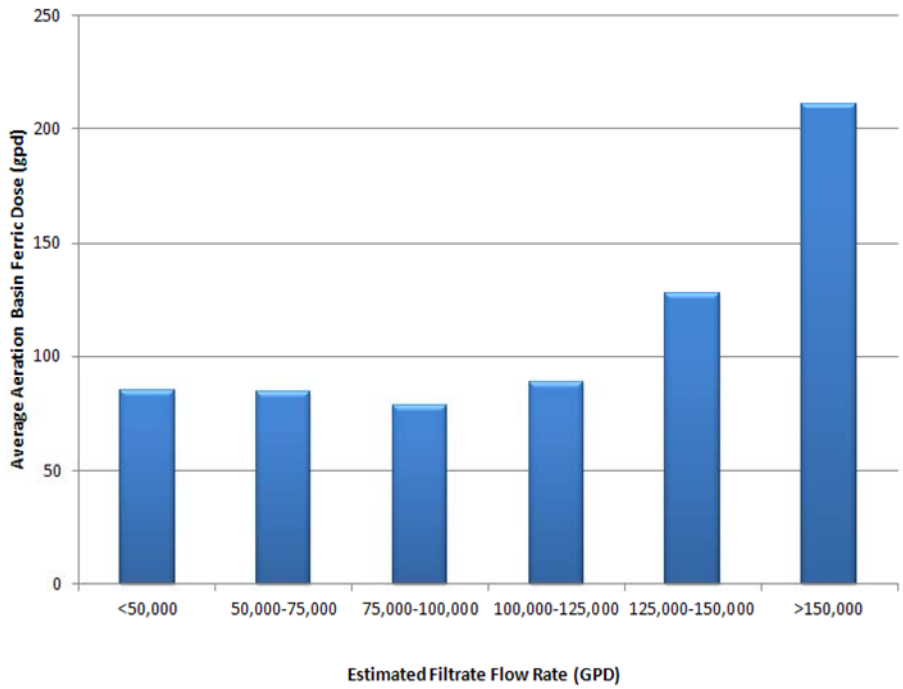

Effluent Ortho-P (mg/L)
4.0
3.0
2.0
1.0
0.5
85% of Year
48
34
21
Influent TKN (mg/L)
15
19
22
27
28
29
37
40
53
PE cBOD:P


50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percent Occurance
0-15
15-20
20-25
25-30
30-35
35-40
45-55
BOD:P

Where is the nitrogen coming from?

- **Sidestream ammonia?**
  - Filtrate also has increased phosphorus concentration…





Challenge 2: Sidestream Impact on Ferric Dosing

What can we do?

Challenge 1: Primary Effluent Phosphorus Concentration

Challenge 2: Sidestream Impact on Ferric Dosing

- **Add more ferric chloride**
- **Add additional carbon**
- **Process modifications for increased RAS denitrification / decreased PE TP**
- **Manage filtrate sidestreams**

How do we evaluate our options?

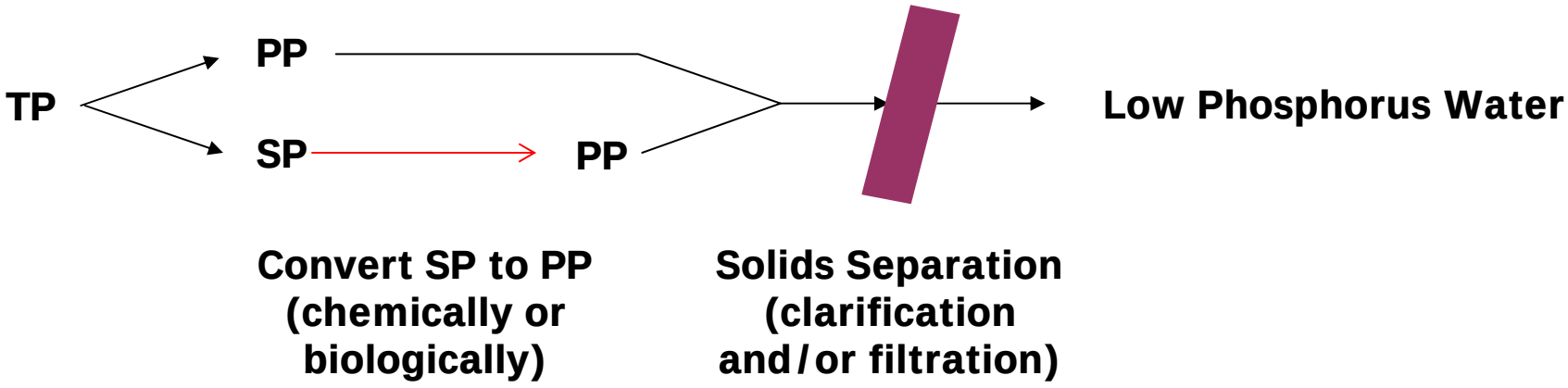
- **Pilot testing**
- **Process modeling**
  - Review potential of each alternative
  - Examine using dynamic modeling
  - Develop life cycle costs that account for variability

Option 1: More Ferric

- **Online analysis with Chemscan**
- **OrthoP bandwidth**
  - Greater than 0.4 mg/L = turn on pump
  - Less than 0.3 mg/L = turn off pump
- **Uses more chemical, but very efficiently**
- **Control is a key to low level P**

Option 2: Carbon Addition

- **Biological conversion of SP to PP**
  - Dependent on available carbon
  - Add more carbon = get more release and uptake

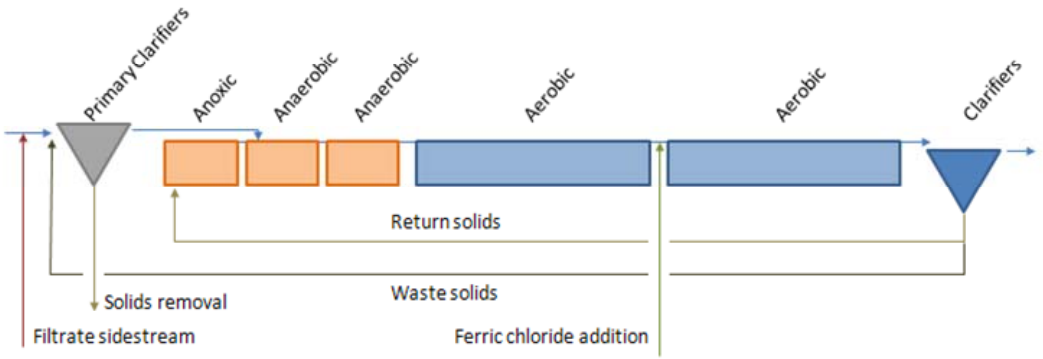


Option 2: Carbon Addition

- **Quality Liquid Feeds (QLF)**
  - EnhanceBio$^{P+N©}$
  - Adding readily biodegradable COD (rbCOD)
  - Conversion of volatile fatty acids (VFAs)
  - Two purposes:
    - Provide enough carbon for both denitrification and PAOs
    - Provide more carbon for PAOs

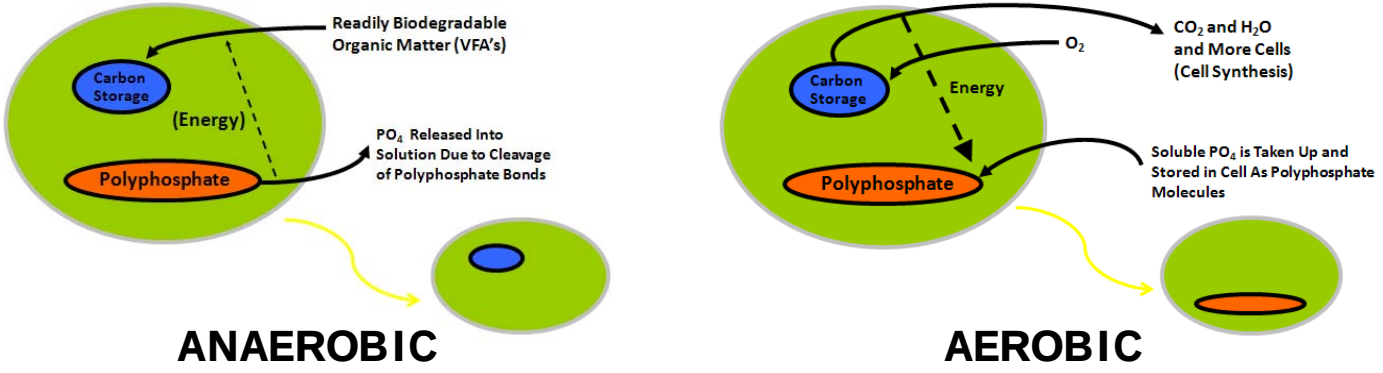
Option 2: Carbon Addition

- **Nitrate in RAS**
- **Nitrate needs to be removed without using up VFAs**
  - Nitrate removal may be limited in endongenous zone
  - EnhanceBio$^{P+N©}$ would reduce nitrate and increase food for PAOs



Option 2: Carbon Addition

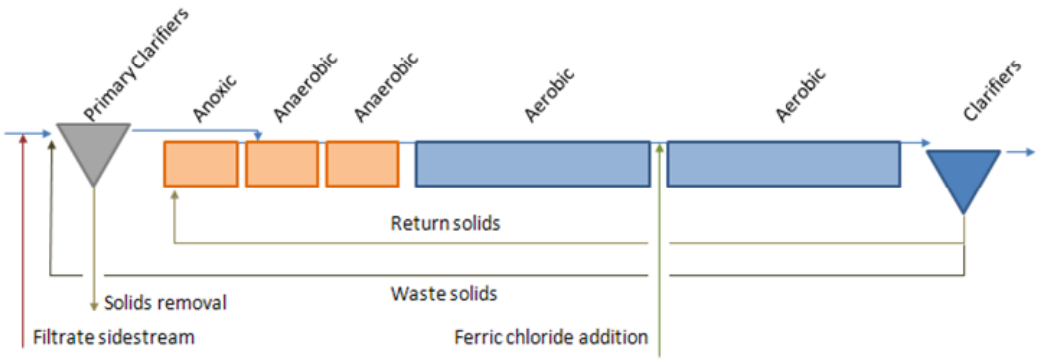
- PAOs need carbon to release P
- More carbon = more “good” release
- More “good” release = more uptake



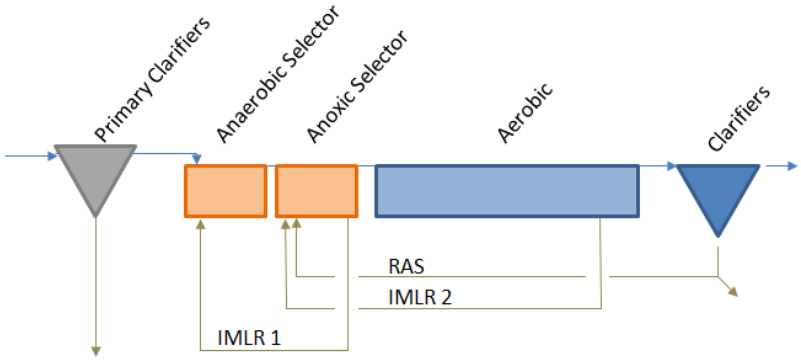
Option 3: Process Modification

- **Modified University of Capetown (MUCT)**
  - Process modification to increase RAS denitrification
  - Improves anaerobic release
- **Do not co-thicken WAS and PS**
  - Reduce P in primary clarifiers

Johannesburg (existing)

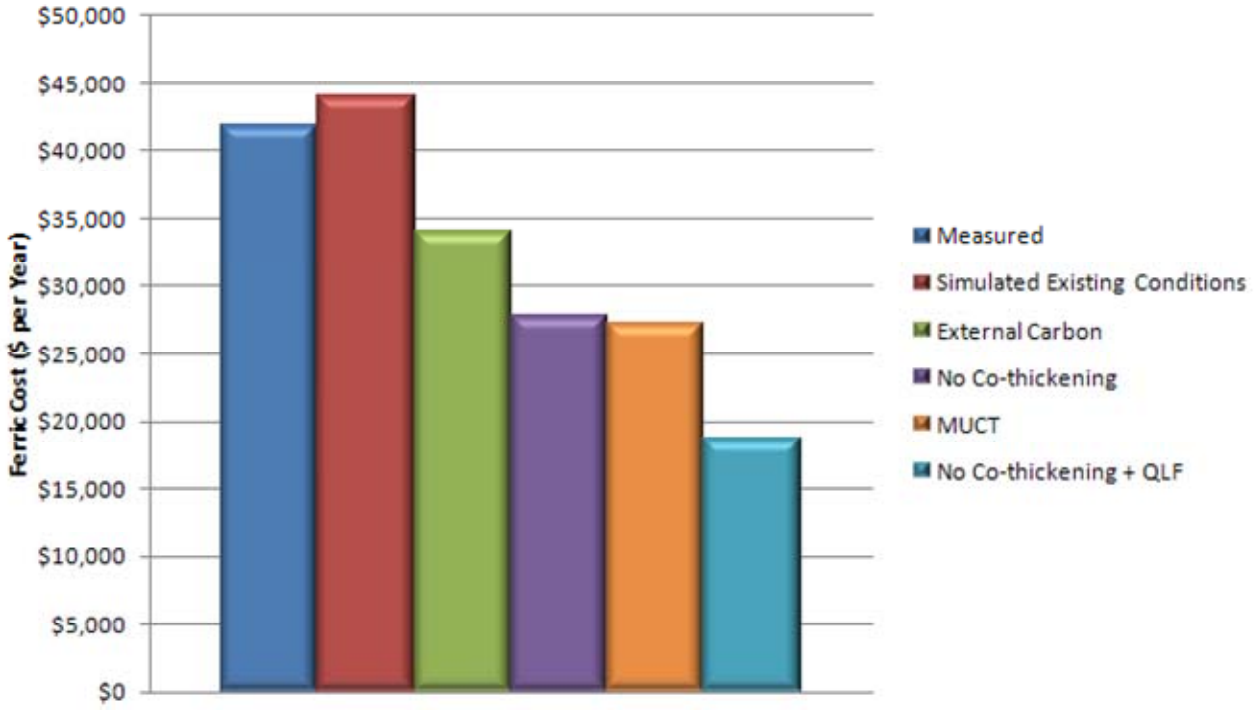


MUCT (Modification)



Evaluation

- **Simulate different strategies over same conditions**



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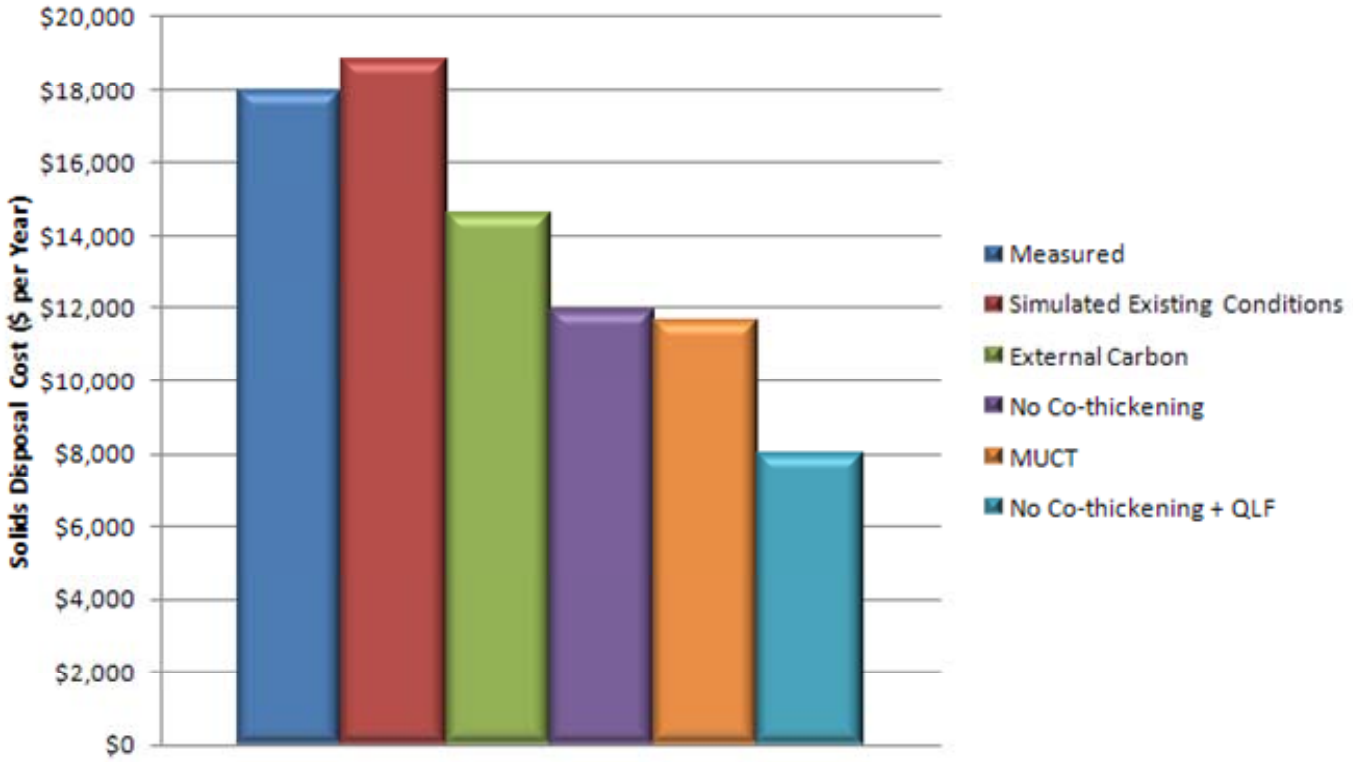

Evaluation

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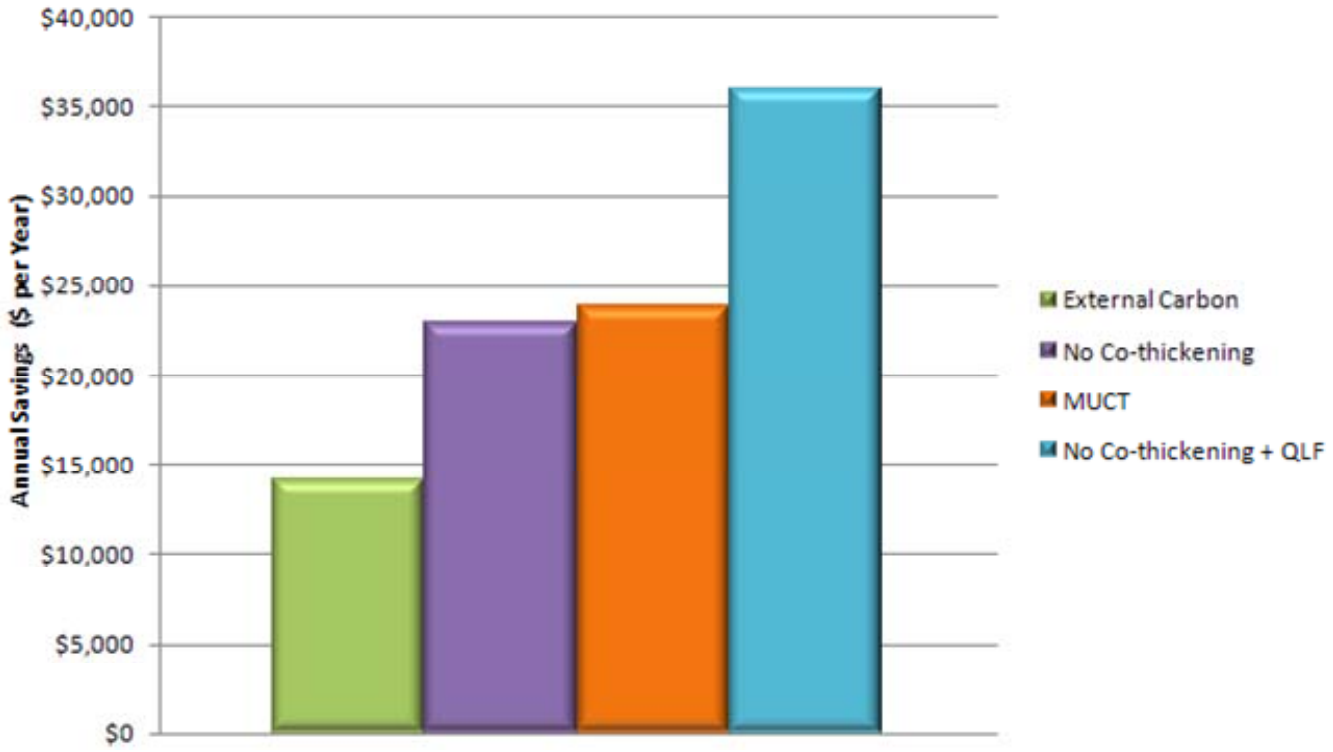
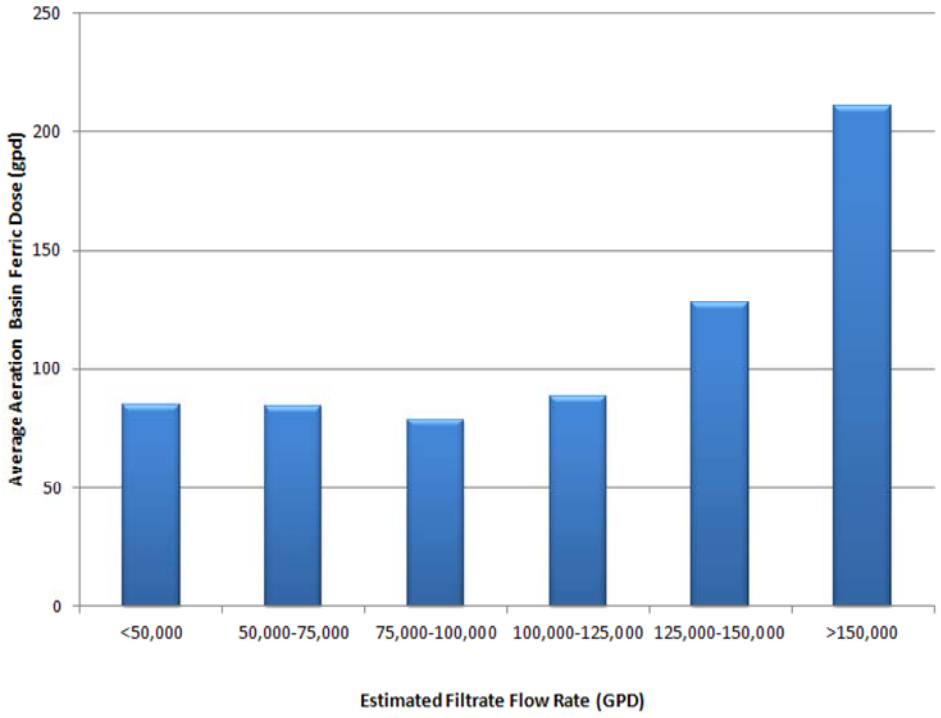


Option 4: Filtrate Management

- **Avoid slugging the GBTs**
  - Operational change
  - Avoid "slug" thickening
  - More consistent
  - Still being implemented
  - More active management
    - Reduced chemical

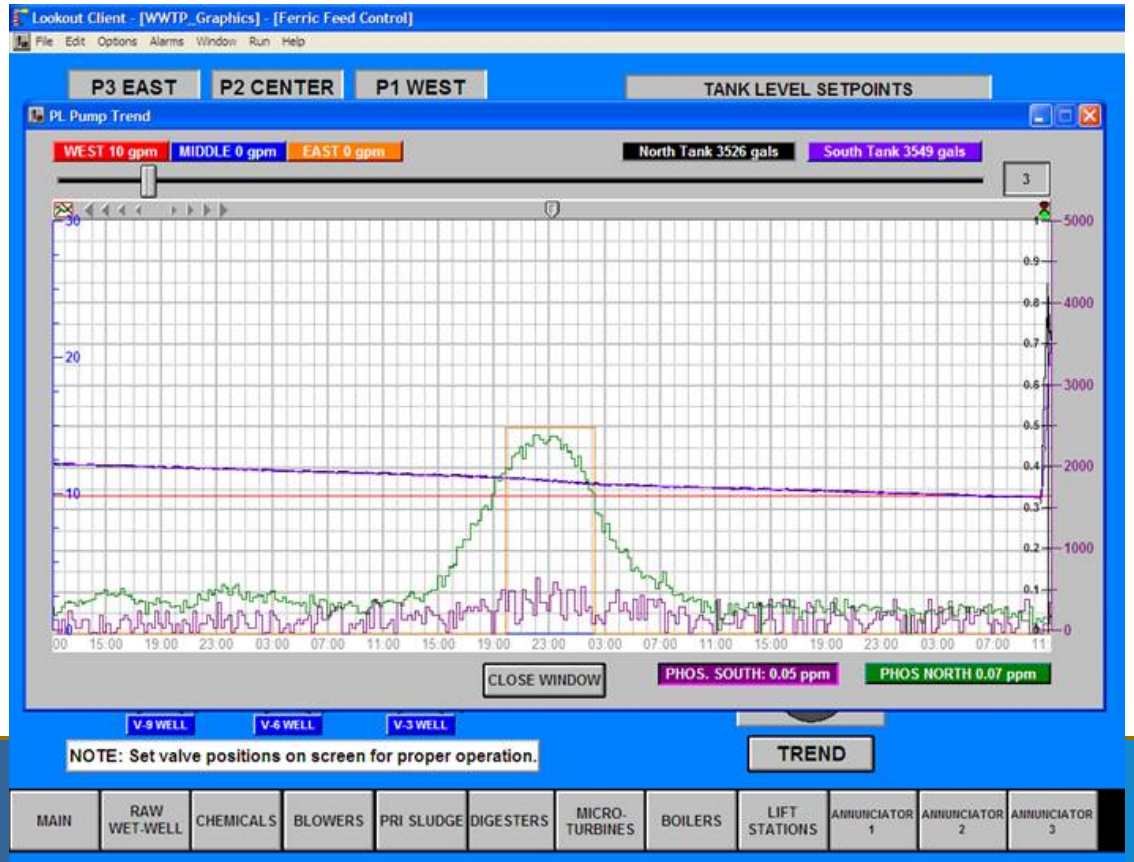


Results?

- **Sheboygan RWWTP is focusing on chemical polishing**
  - Simple control strategy
  - Effective results
- **Solution will be different for every plant**
  - BOD:P
  - Wastewater variability
  - Sidestream loads
  - Chemical mixing

Take Home Message

- **Sheboygan does *really* well, <u>most</u> of the time**
- **Excursions are the main challenge**



Questions?

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