BUILDING A WORLD OF DIFFERENCE

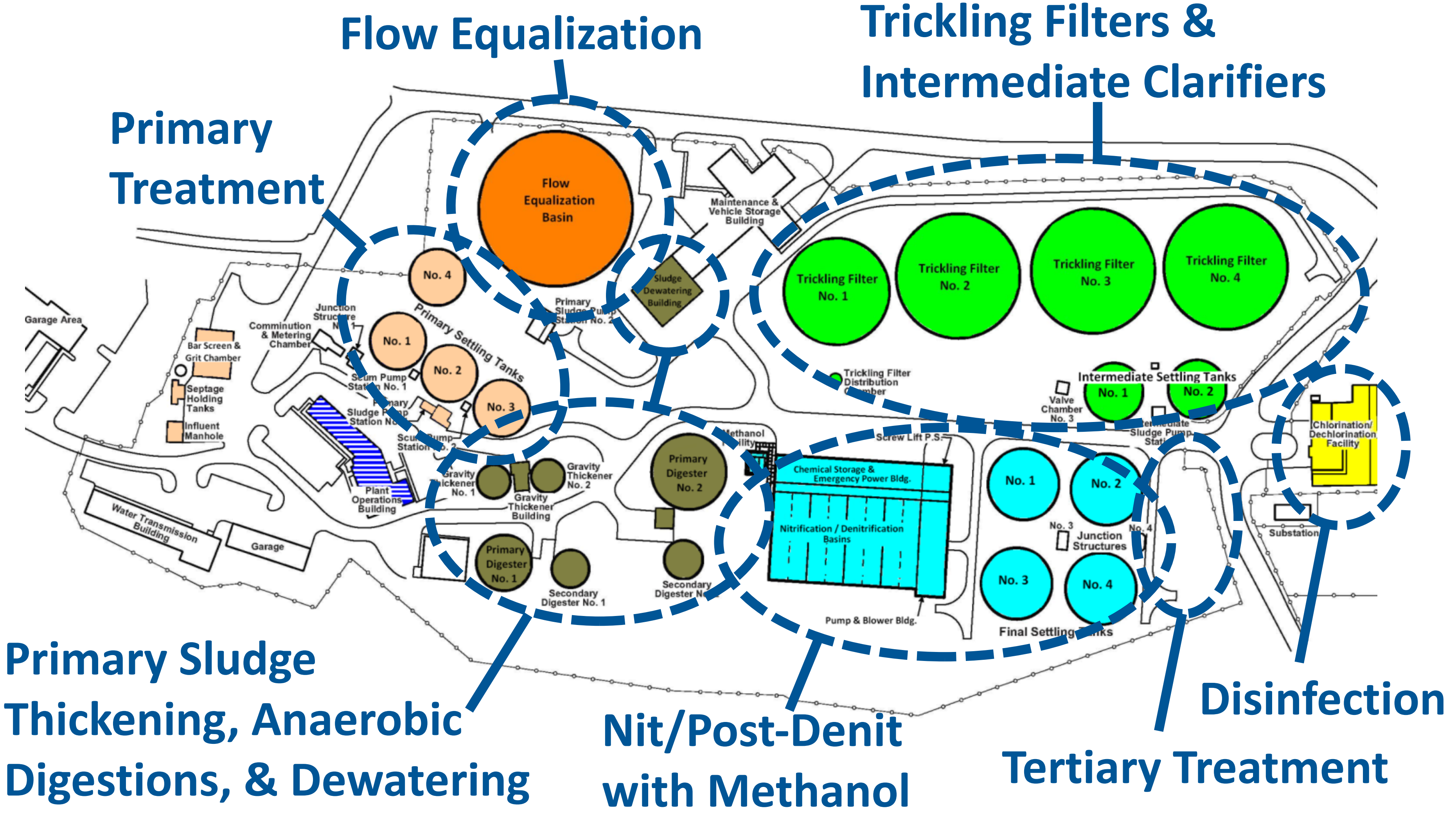
Leveraging Research & Real World Experience to Clarify Phosphorus LOT with Ballasted Sedimentation

Patrick Dunlap
Jim Fitzpatrick
Will Walkup

BLACK & VEATCH

Danbury CT WPCF Background

Danbury WPCF – Current Site



Project Drivers

- Increase Plant Capacity from11.0 mgd to 12.0 mgd
  - (9.0 mgd current average flow)
- Continue to Meet N Load Goals
  - ~4.5 mg/L-N Max Limit at Design Flows
- More Stringent P Limits
  - Local Water Quality Based Limits for Lime-Kiln Brook
  - Currently must Achieve ~0.6 mg/L-P
  - Load Based P Limit eq. to 0.075 mg/L-P at Design Flow
    (Apr-Oct Seasonal Avg. Limit)
  - Monthly & Daily Avg. Limits of 0.14 & 0.31 mg/L-P

Meeting Low Level P Limits Planning/Project History

2011

Facility Plan

2 Stage Tertiary Treatment for P Limits (Sedimentation & Deep Bed Filtration)

2014

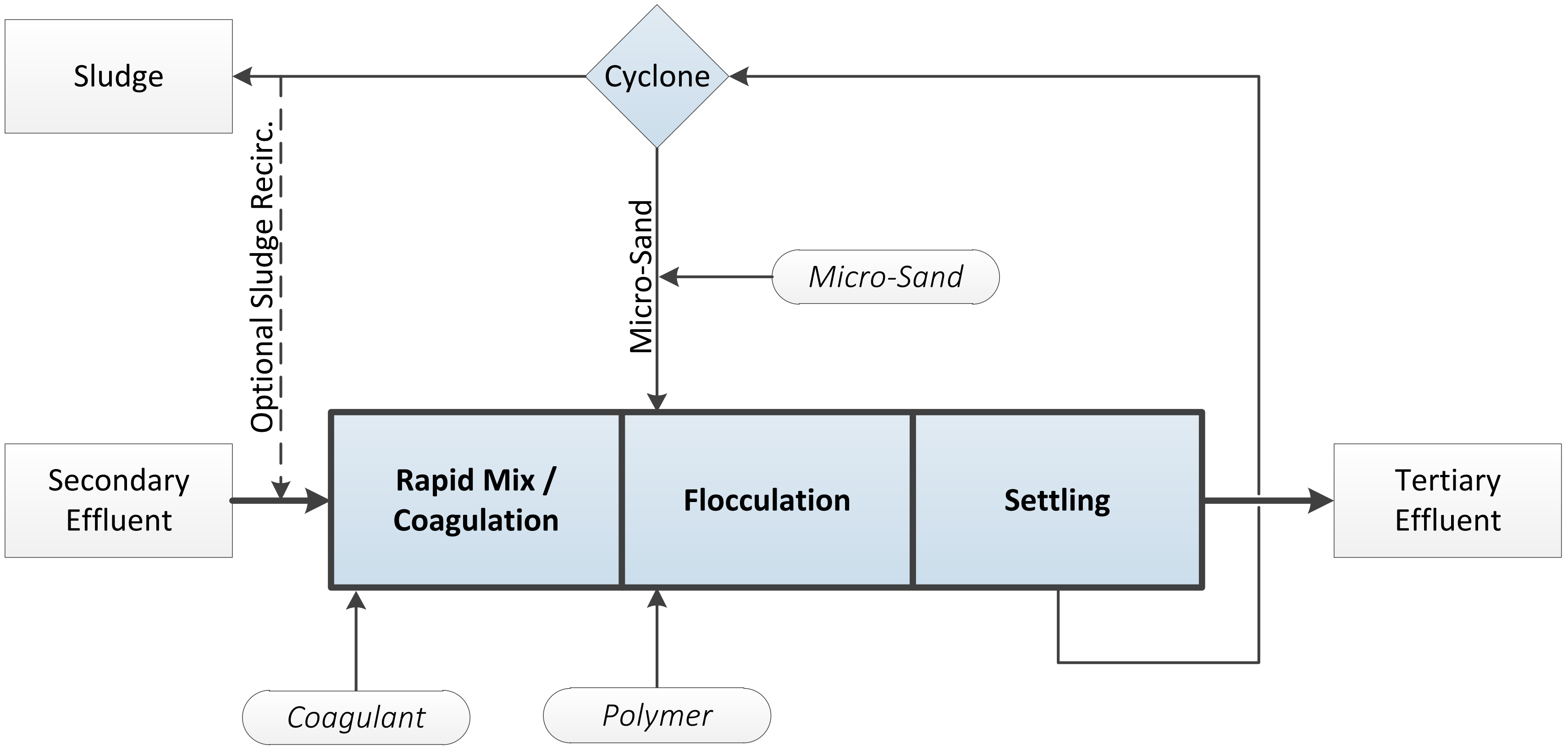
VE Study

Consider Ballasted Sedimentation Process

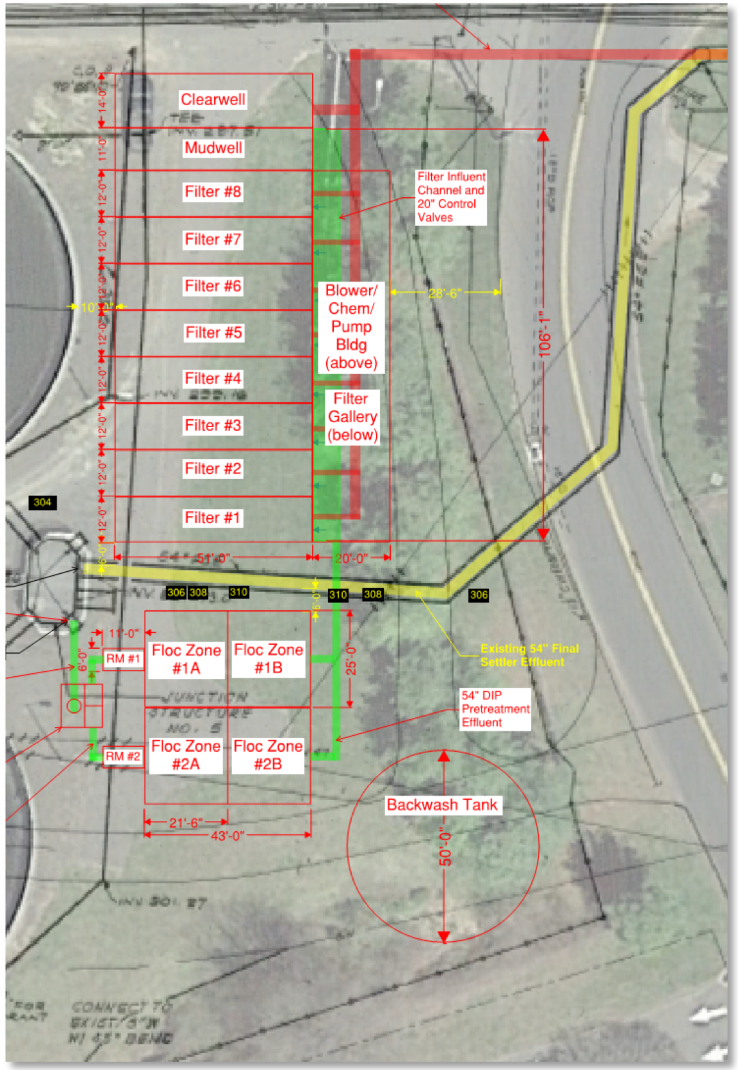
2017

Facilities Plan Refresh & Preliminary Design

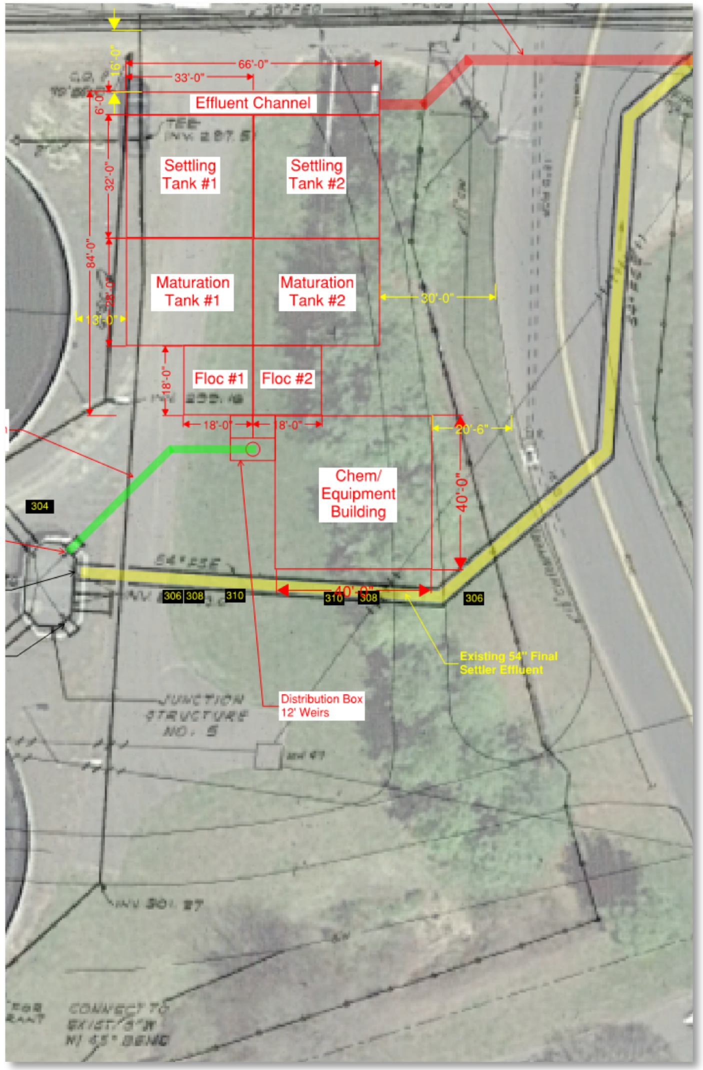
High Rate Ballasted Sedimentation Process



Site constraints favor ballasted sedimentation

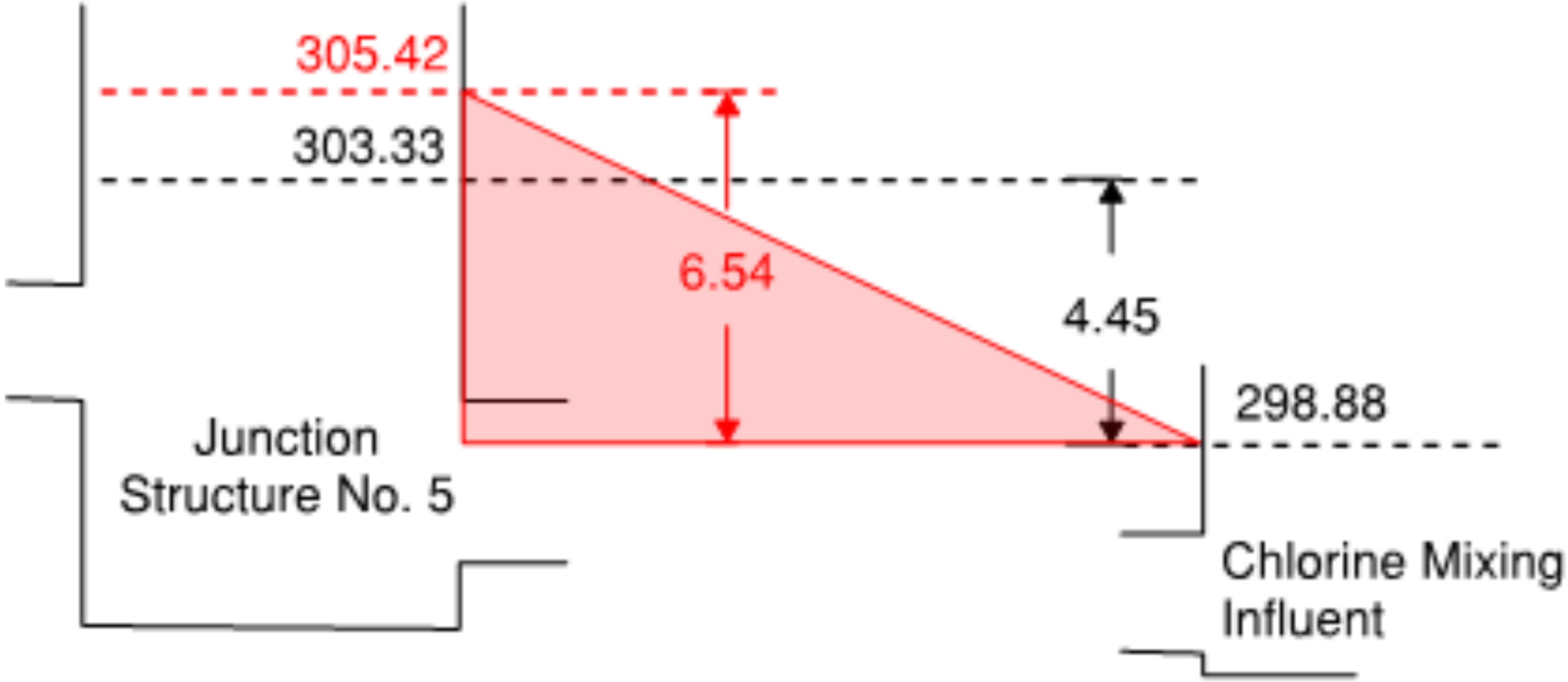


Deep Bed Filters



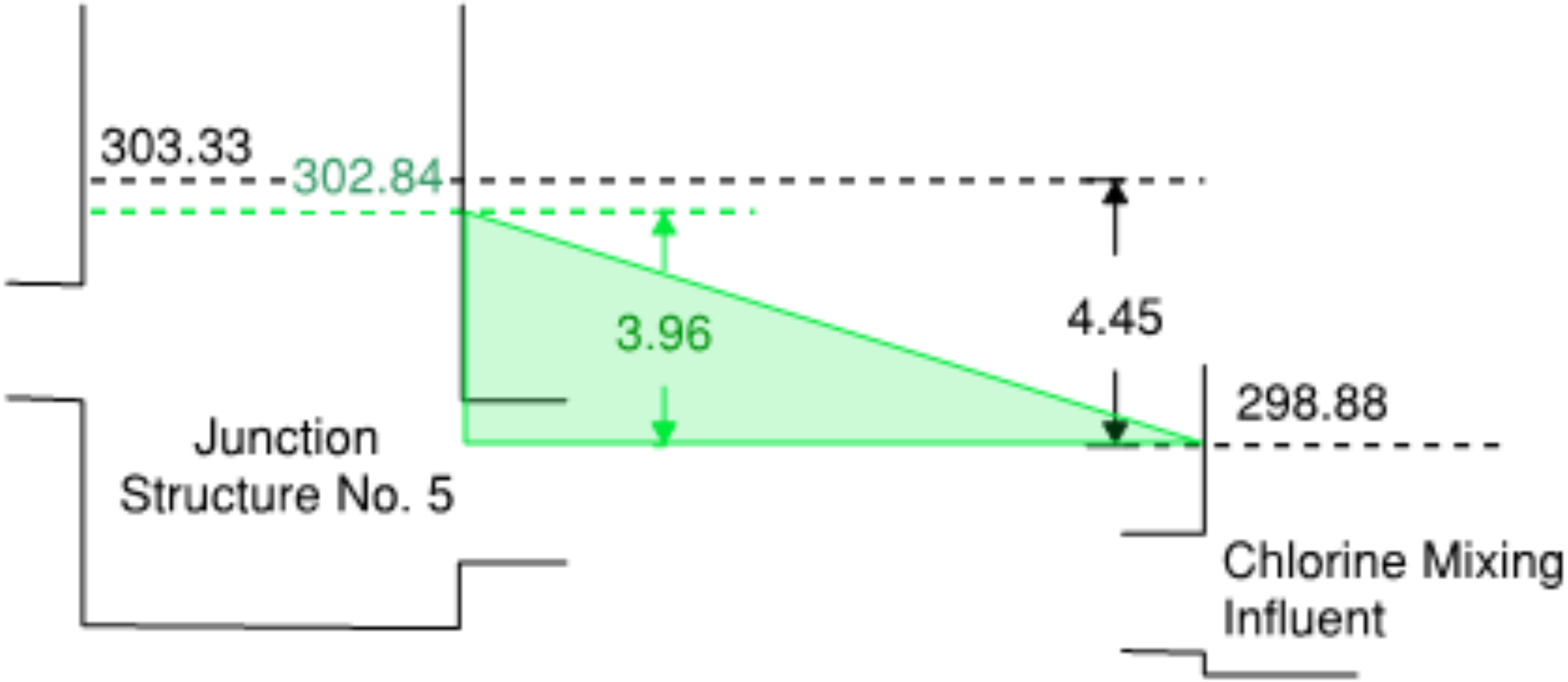
Ballasted Sedimentation

Deep Bed Filters Hydraulic Profile



- 6.54 feet of head required
- Intermediate pumping needed

Proposed Hydraulic Profile



- 3.96 feet of head required
- Fits within hydraulic window available

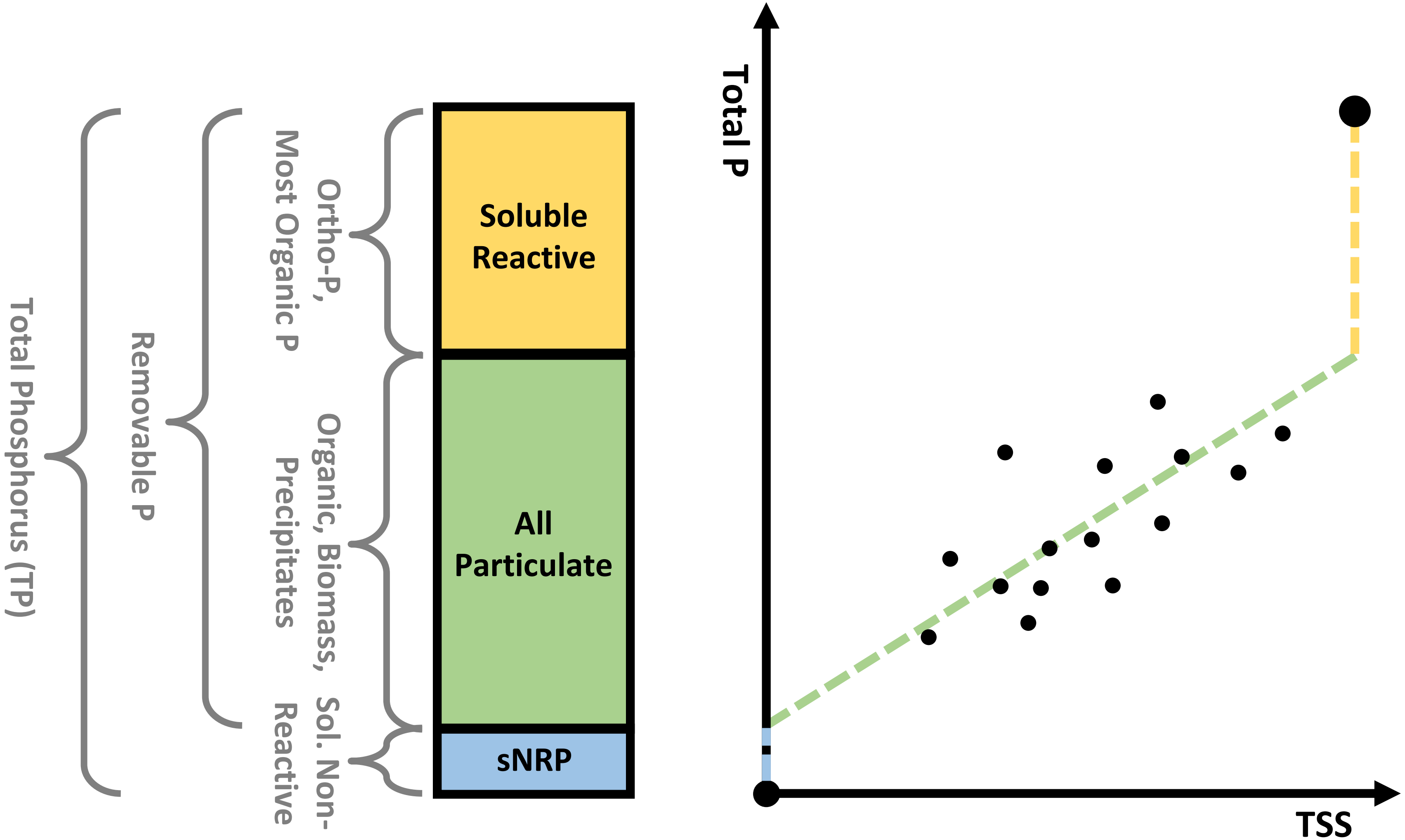
Ballasted Sedimentation Summary

Advantages	Disadvantages
Smaller footprint	Less common / newer technology
Lower head loss	Higher dependency on coagulation and flocculation sub-processes
Less hydraulic impact of peak flows/loads	Lower TSS Removal
Lower capital cost	

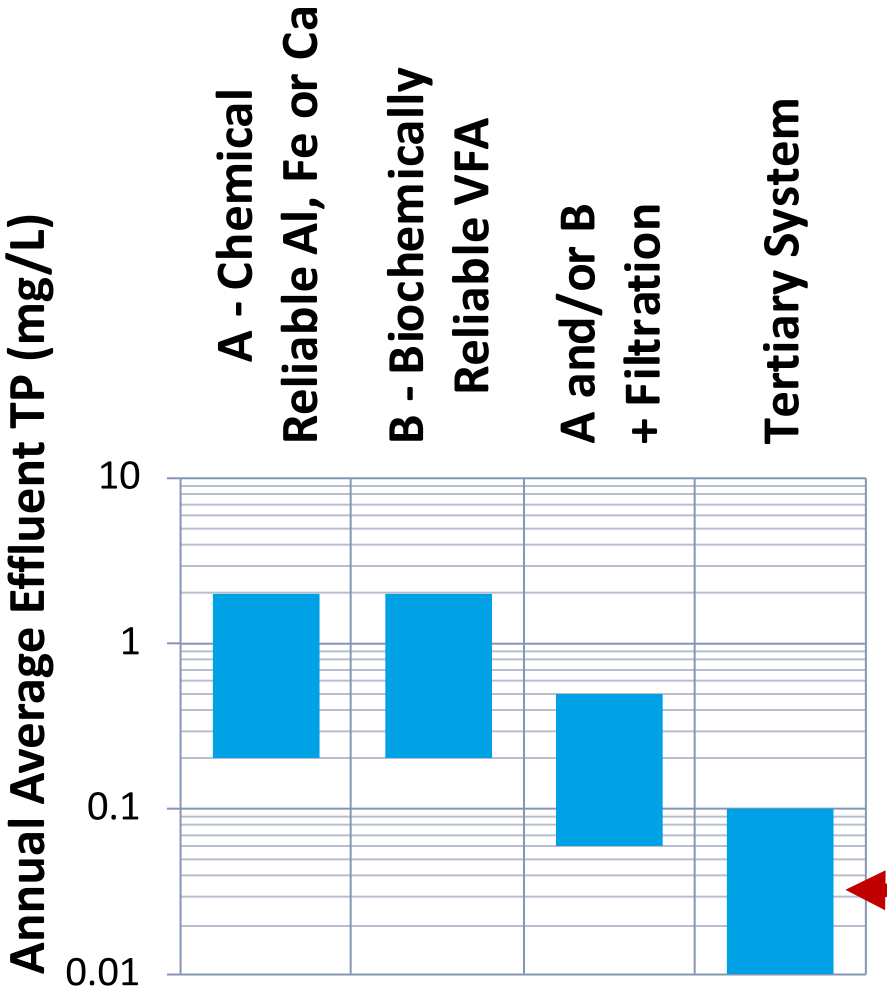
Recommendation to further evaluate ballasted sedimentation while leaving accommodations for 2nd Tertiary Stage Filters

LOW LEVEL P-REMOVAL

Forms of P in Tertiary/Secondary Effluent



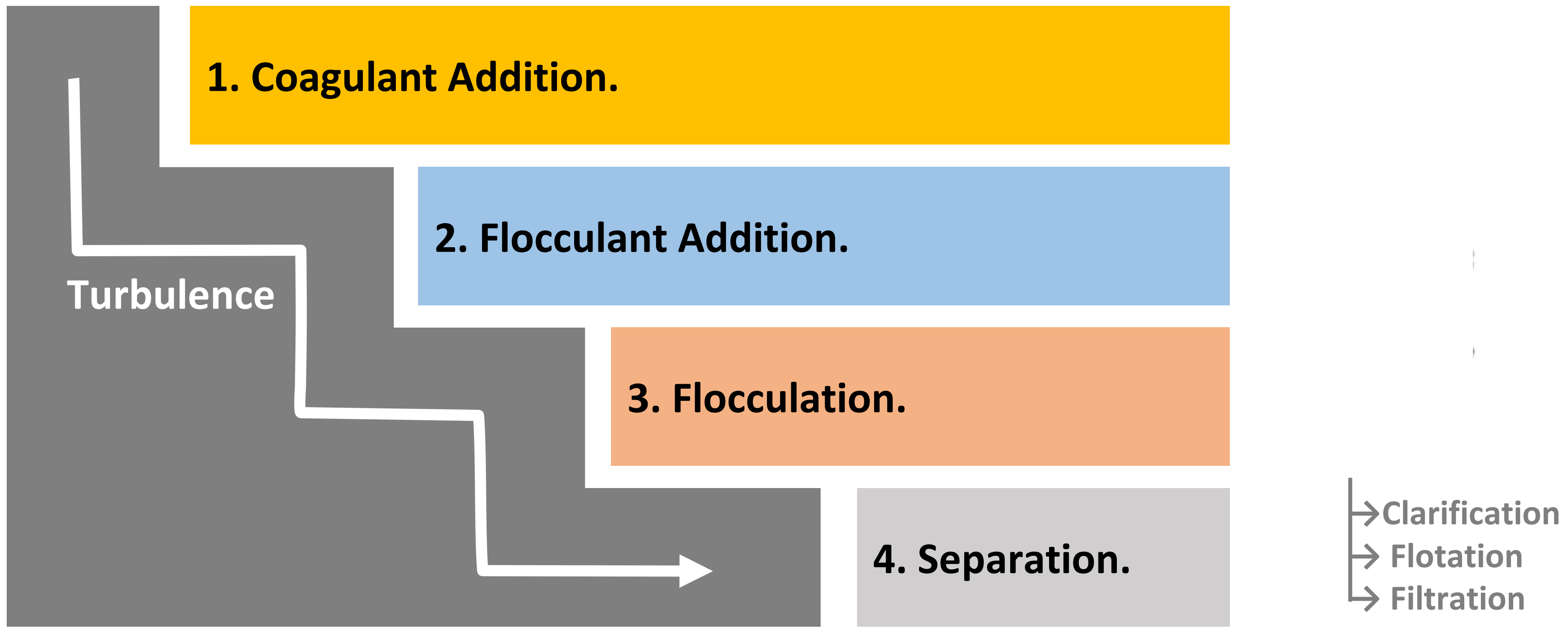
P Removal Treatment Options



Several alternatives

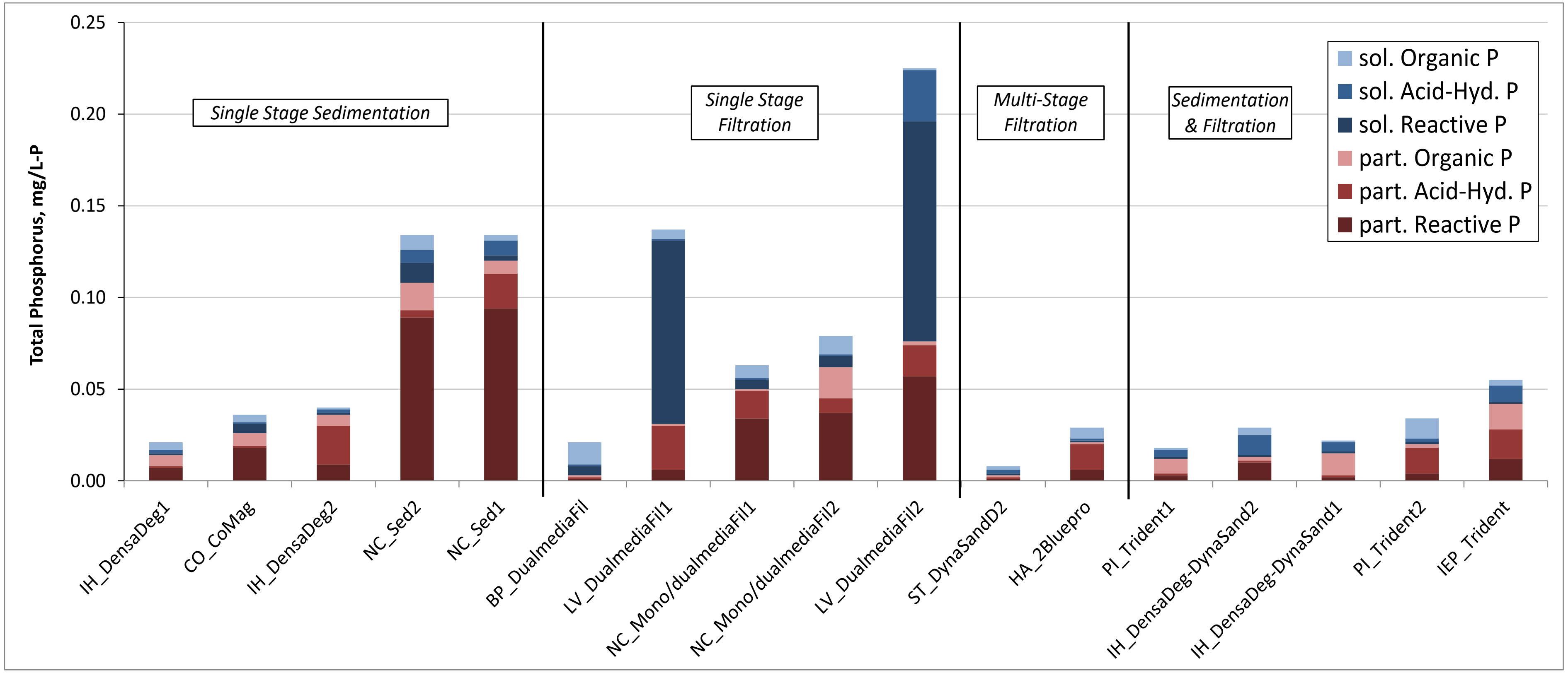
- Chemically enhanced clarification / filtration / DAF
- ~~Media adsorption / IX~~
- ~~Algal-based activated sludge~~
- ~~Reverse Osmosis~~

The particle formation is key to chemically enhanced treatment



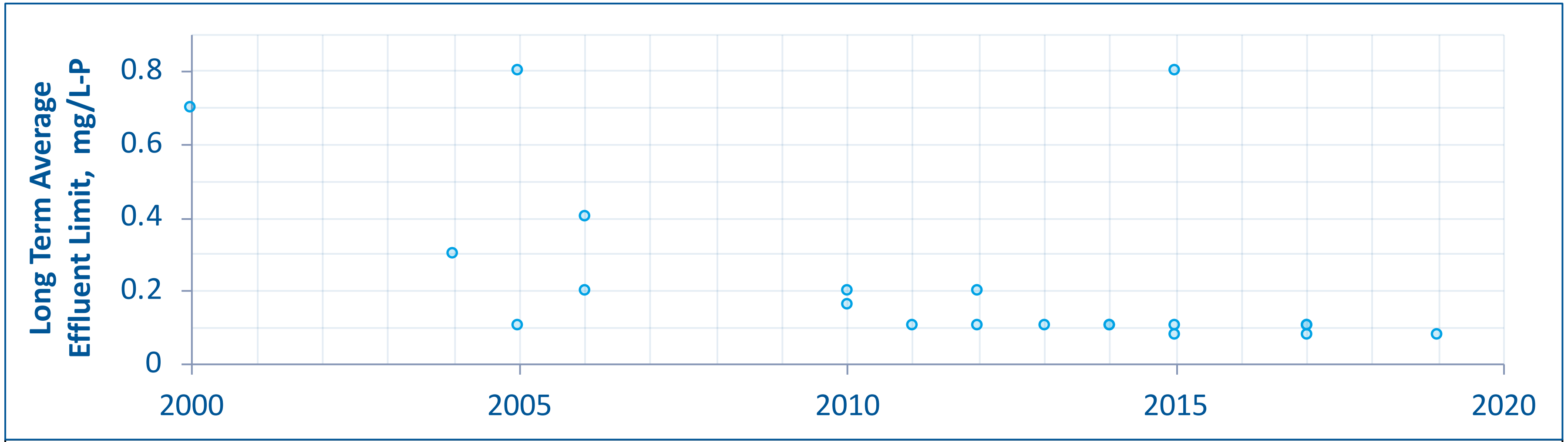
REVIEW OF BALLASTED SEDIMENTATION PERFORMANCE

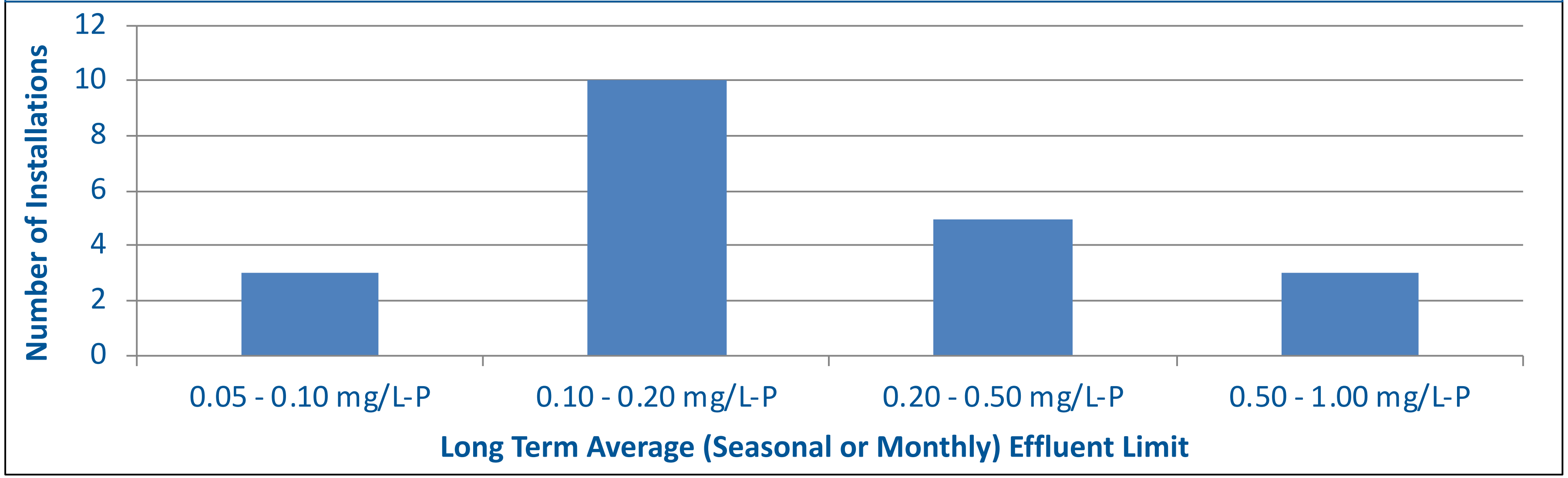
1 & 2 Stage Tertiary P Removal – Full Scale Eff. P Fractionation (from WERF, 2014)



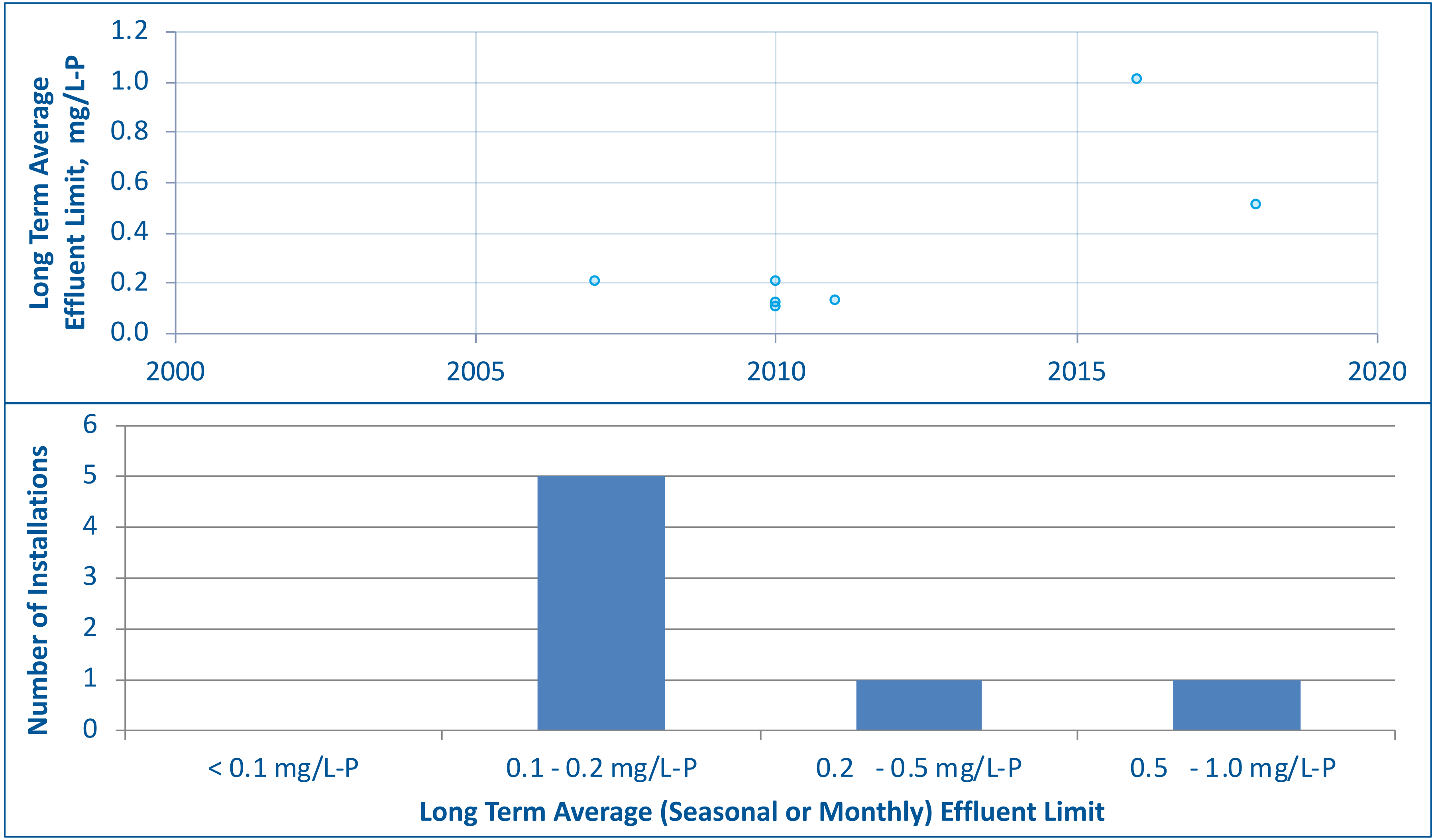
- *Single Stage Sedimentation similar to single stage Filtration*
- *2-Stage Processes to achieve <0.05 mg/L-P*
- *Previous case Studies*

ACTIFLO Installations for Low Level P

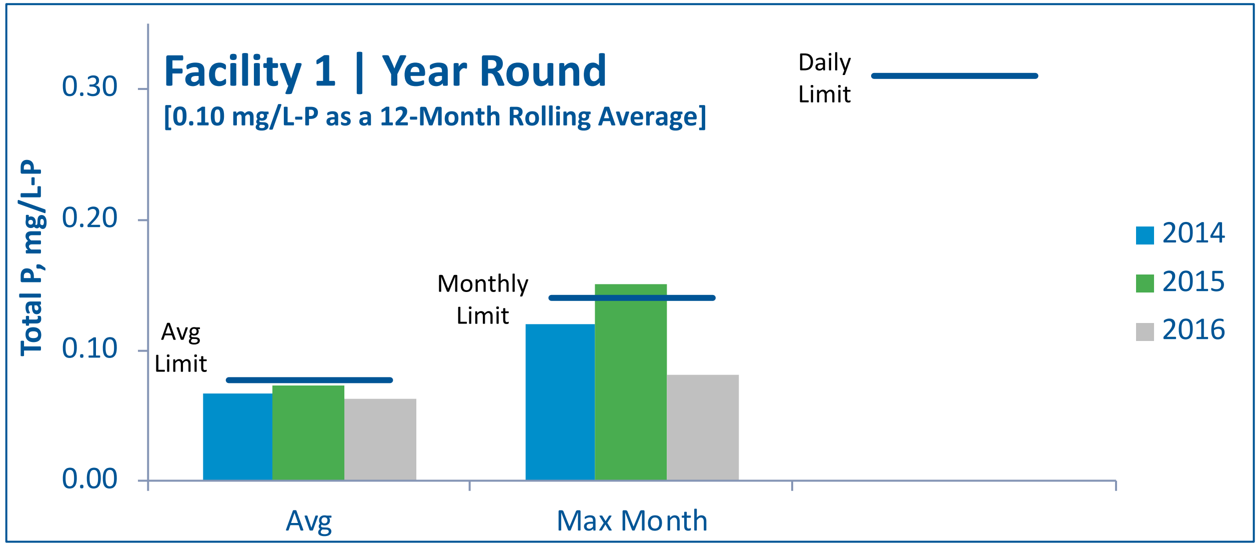




CoMag Installations for Low Level P

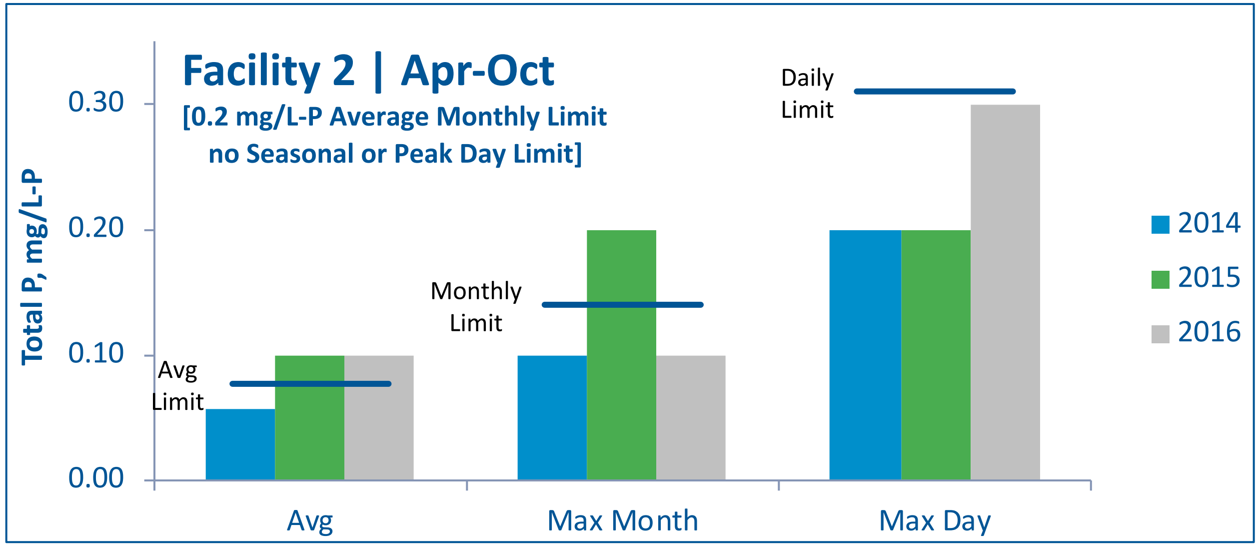


Review of publically available DMRs

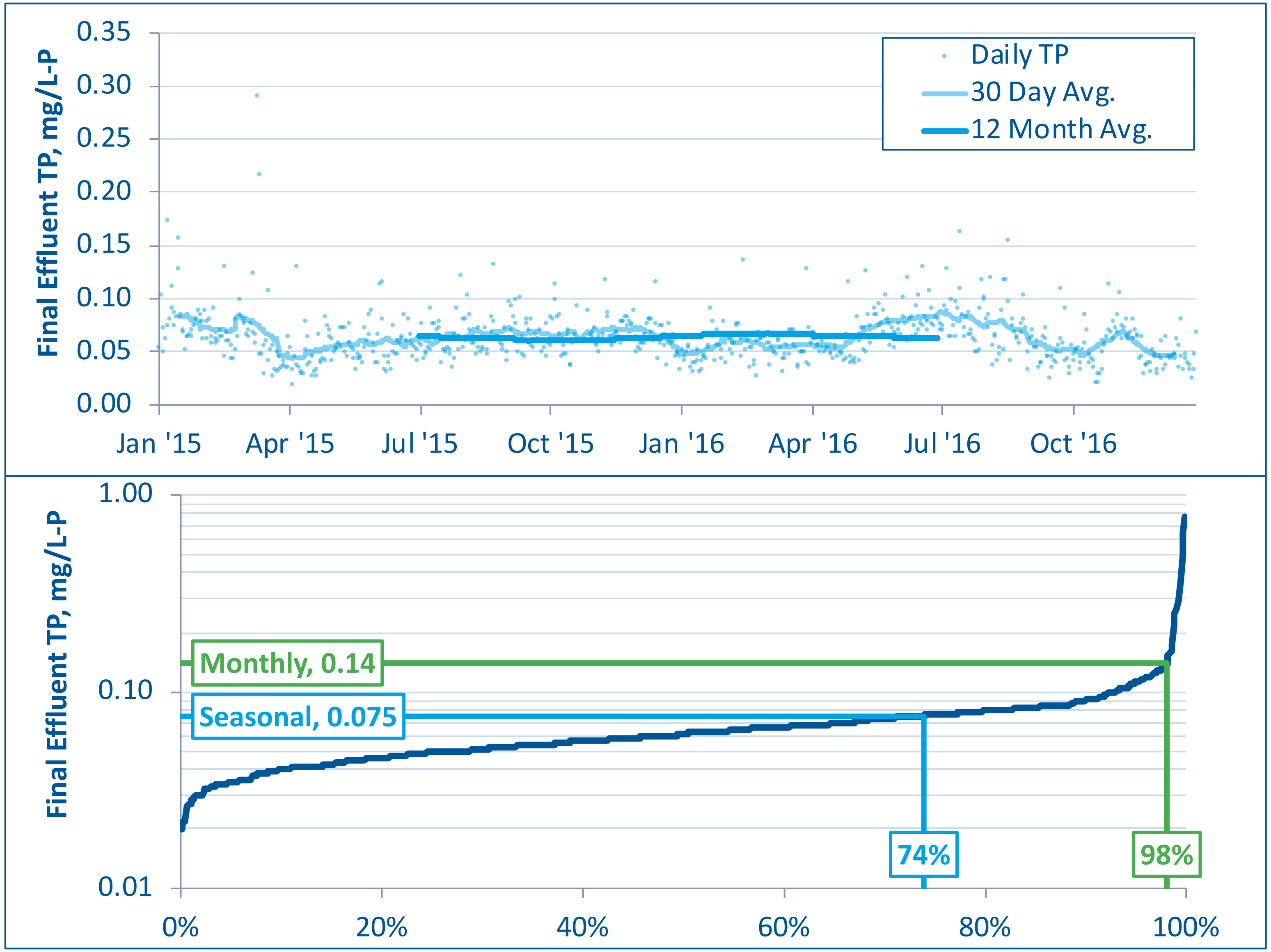


Facilities nearly meet Danbury limits despite higher limits...

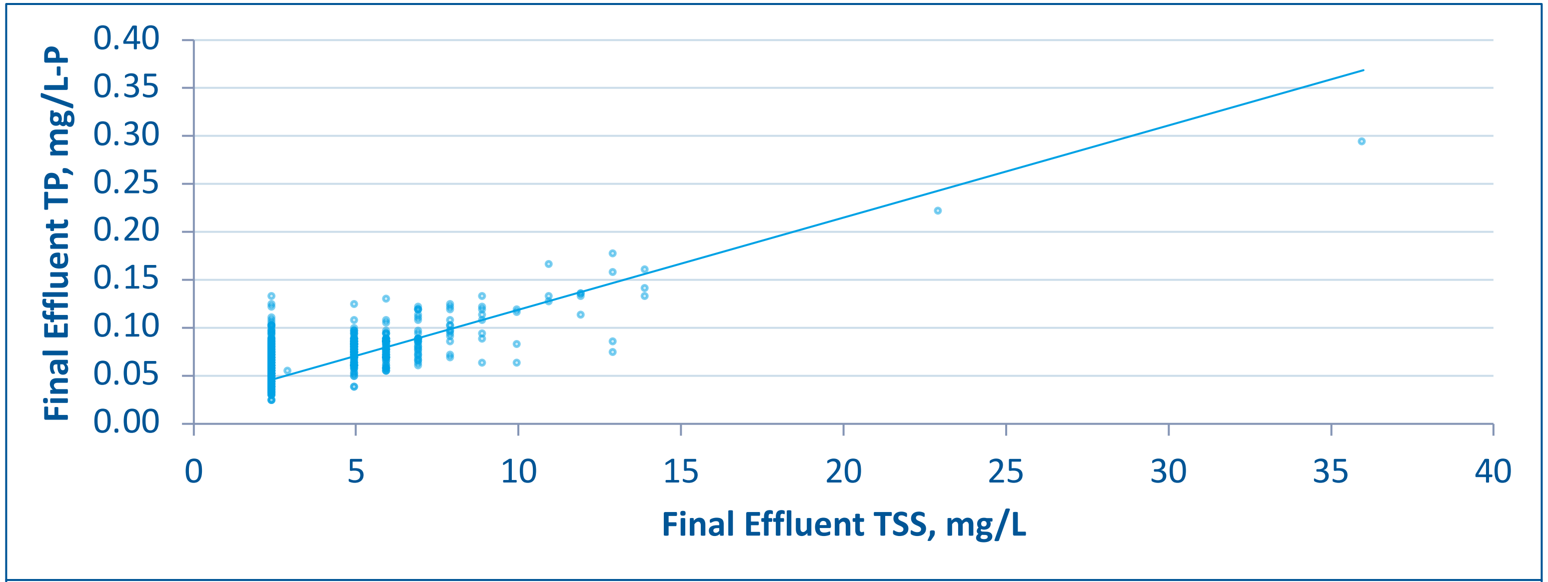
What was the cause of exceedances?

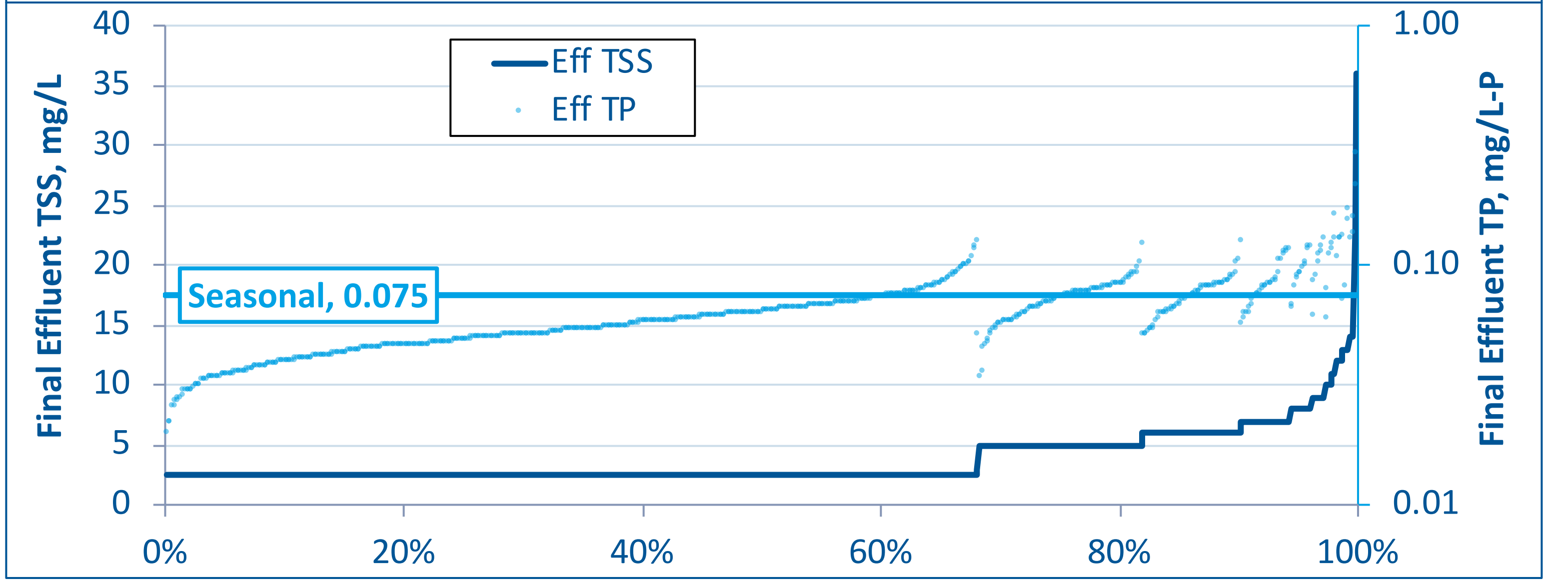


Facility 1 – ACTIFLO w/ 2° Chem P Removal



Facility 1 – ACTIFLO w/ 2° Chem P Removal

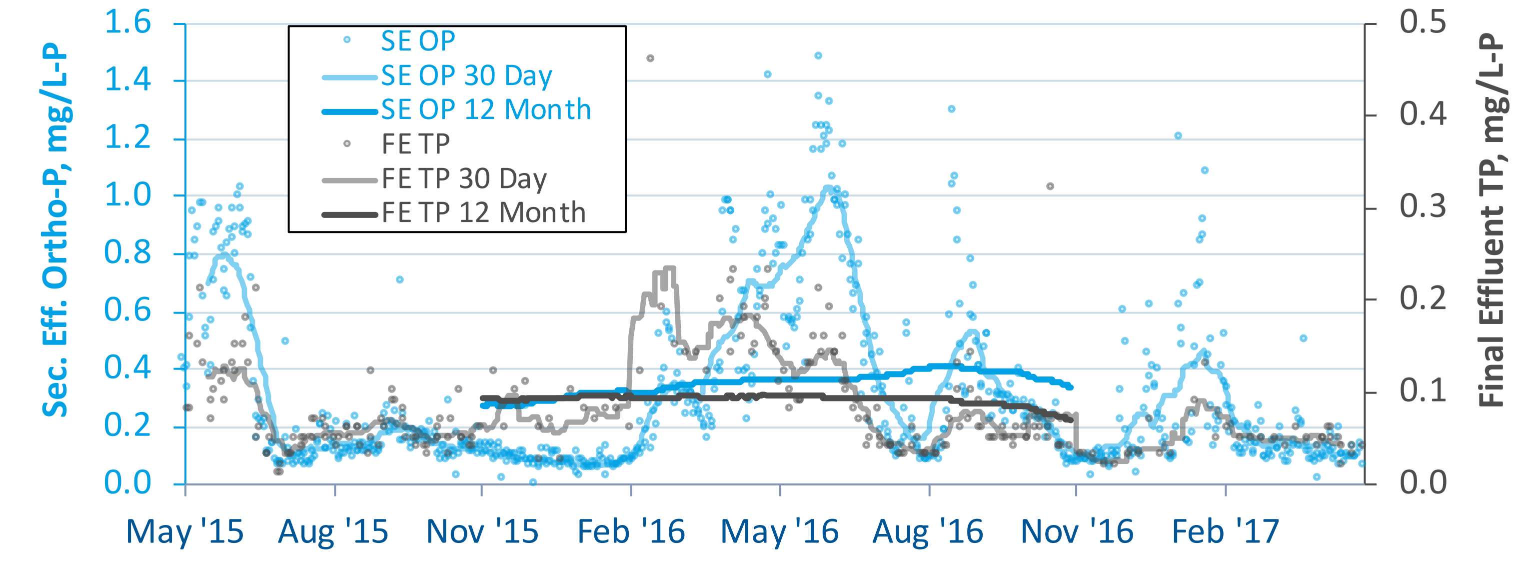


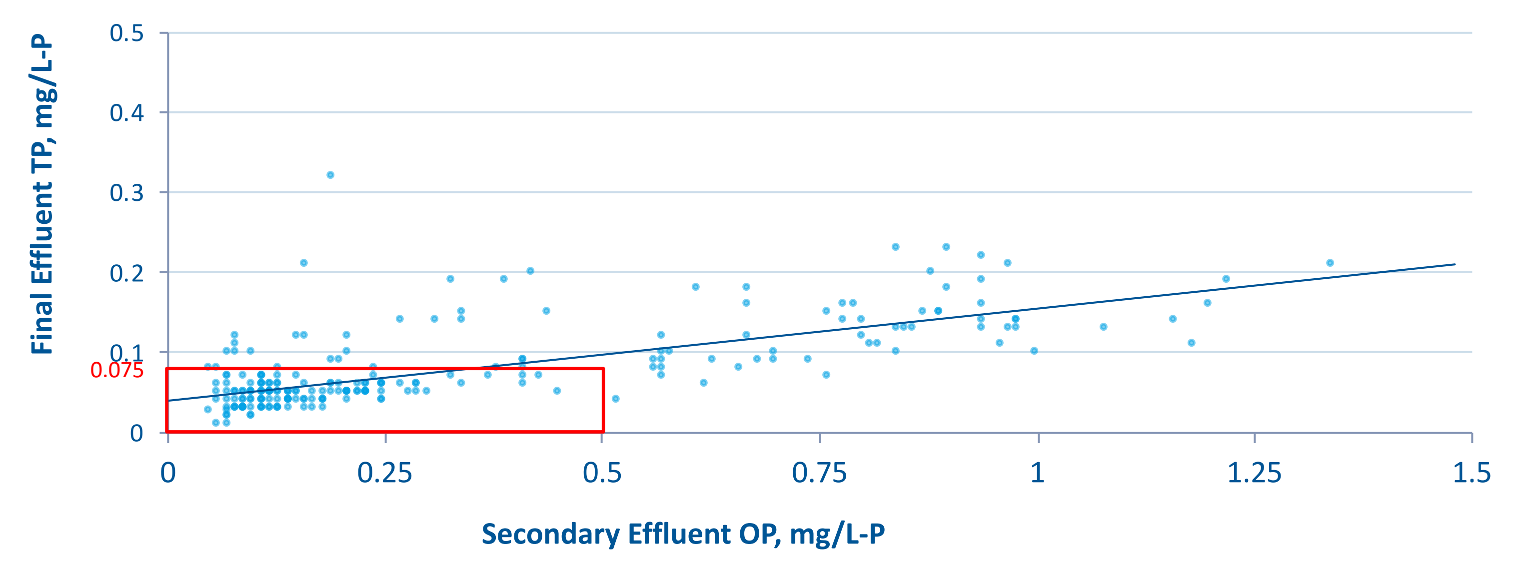


Facility 1

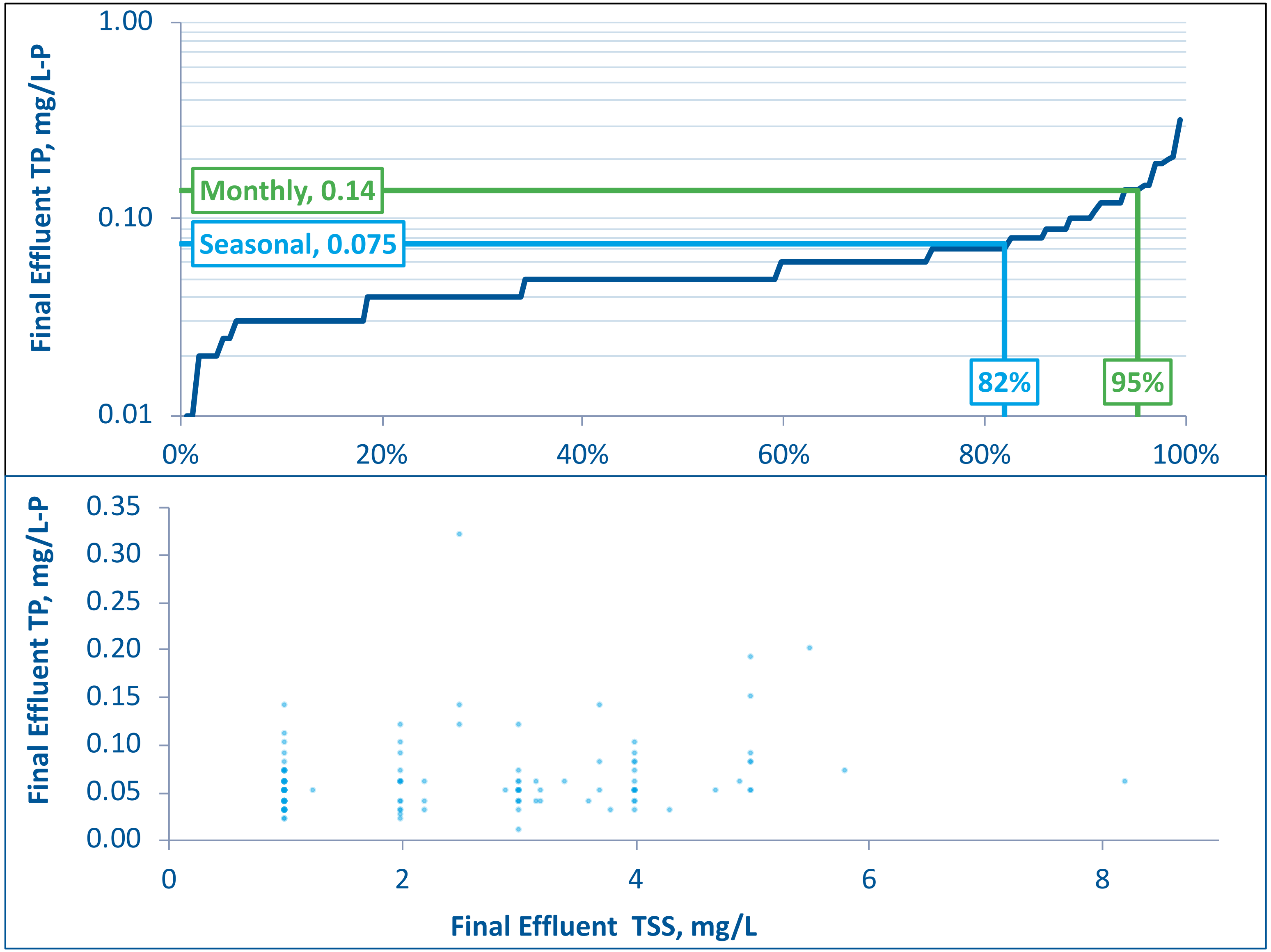
- Chemical P Removal Secondary Process maintaining a consistent SE TP concentration ~0.5 mg/L-P
- Various problems lead to periods of FE TSS > 5.0 mg/L-P which drives FE TP concentration
  - High loading & poor tertiary flow spitting at high flows
  - Polymer system failures
- Regular cleaning of Lamellas & polymer system preventative maintenance important to maintaining TSS removal performance

Facility 2 – ACTIFLO w/ 2° Bio-P Removal





Facility 2 – 2° EBPR (for SE OP < 0.5 mg/L)

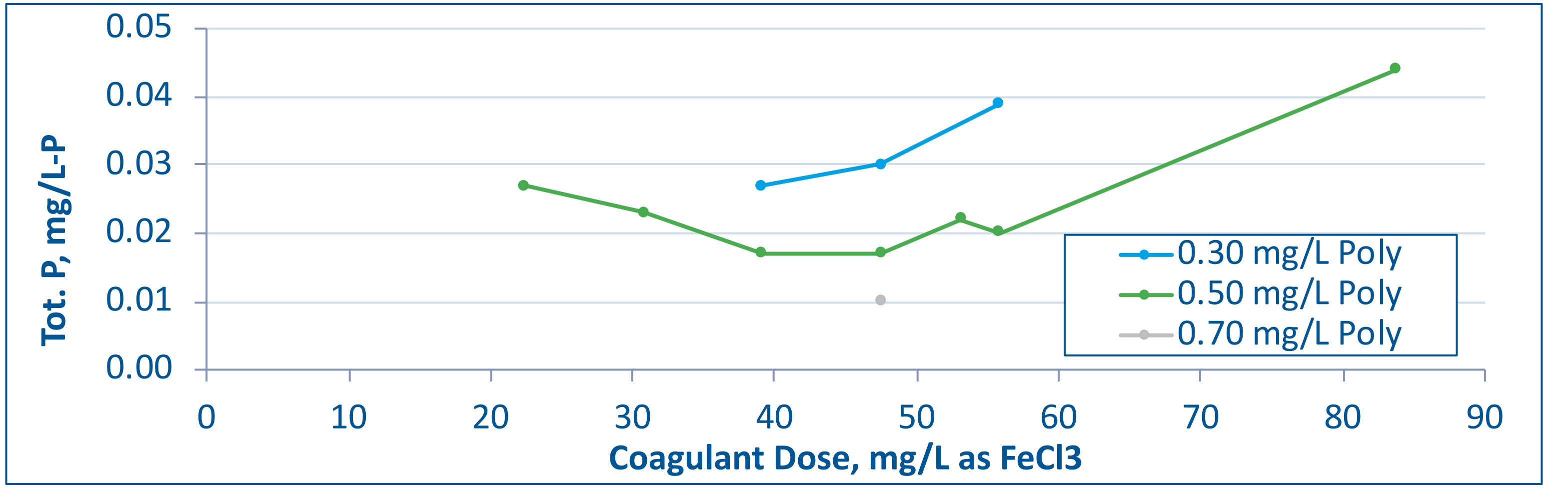


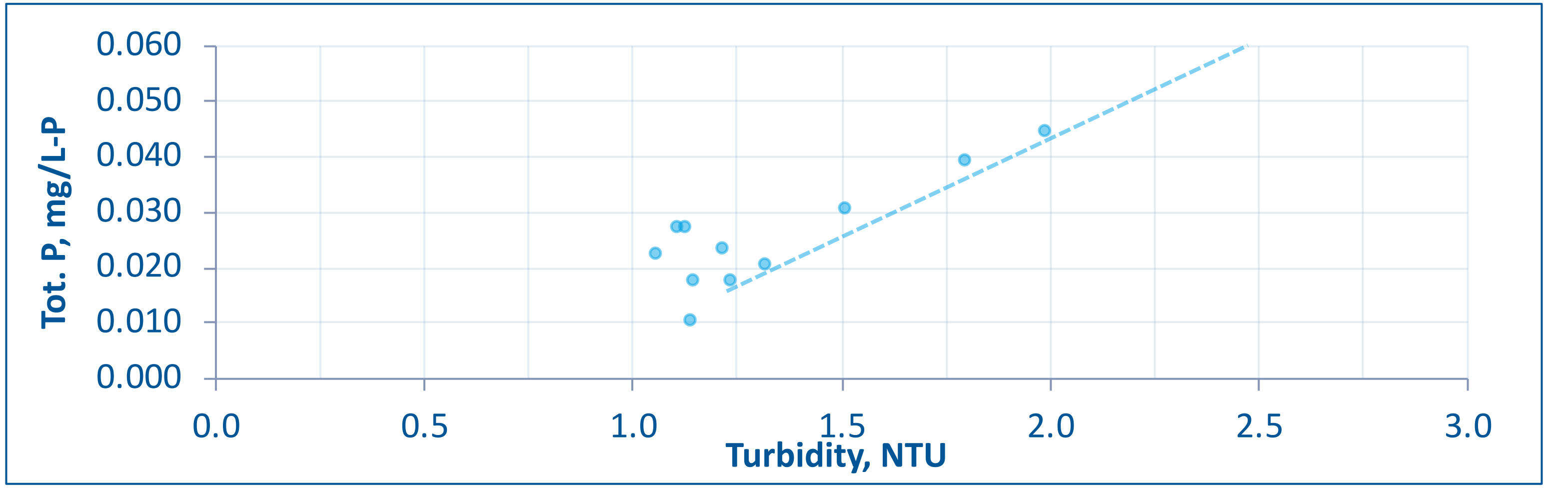
Facility 2

- Secondary effluent TP varies to >1.0 mg/L-P which is major determinant of FE P Concentration
- Limit is 0.2 or 1.0 mg/L-P depending on seasons but tertiary treatment is used year-round for metals limits
- Effluent TSS < 5.0 mg/L 95% of the time
- When SE OP is controlled to <0.5 mg/L-P (as at Danbury) Danbury effluent P goals are achieved

SITE SPECIFIC CONSIDERATIONS

Danbury Jar Testing (SE TP ~0.55 mg/L-P)

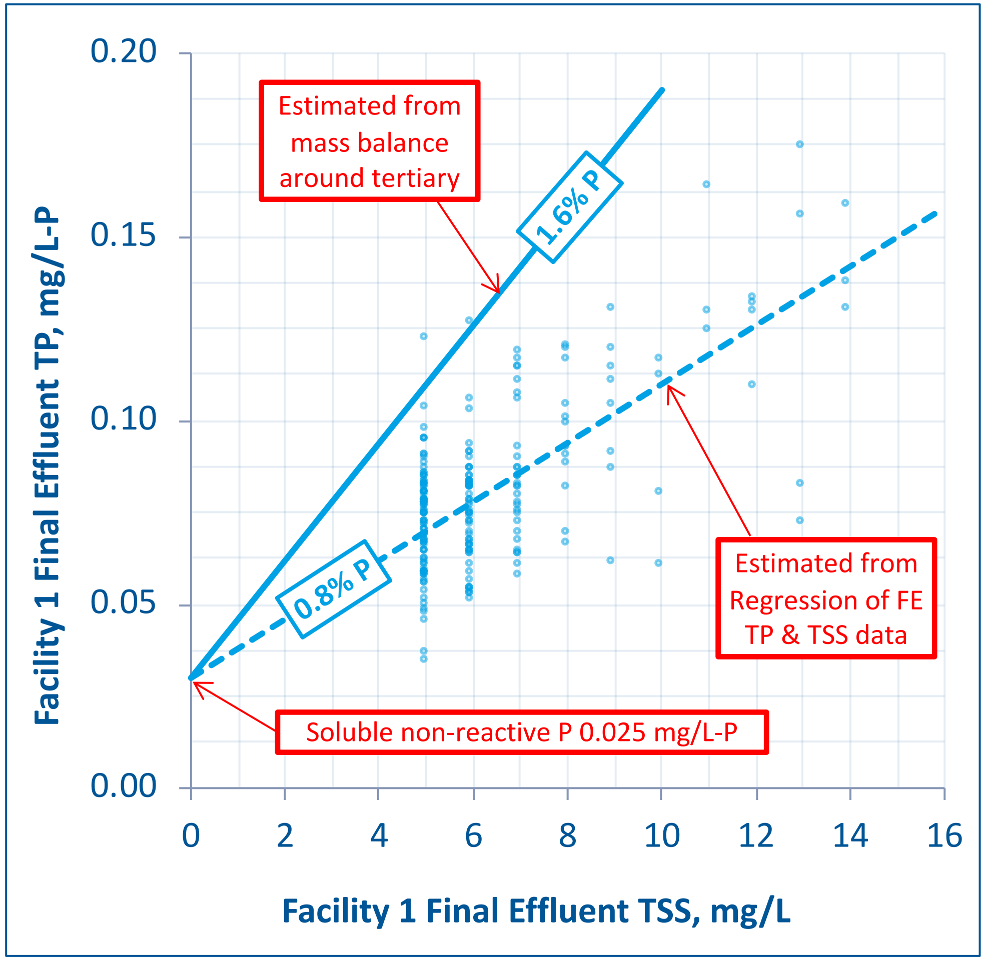




At optimal dose settled TP ~20 ppb

Spec. Samplings indicate sNRP 5-15 ppb

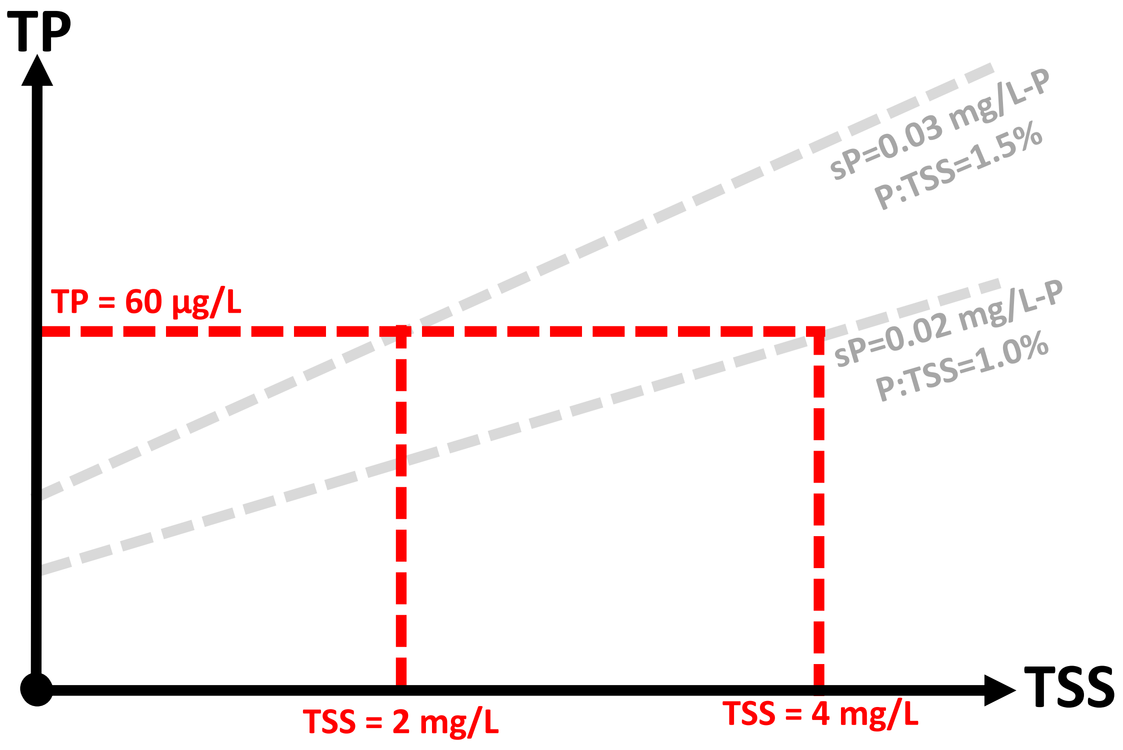
Selective Removal of Precipitates?



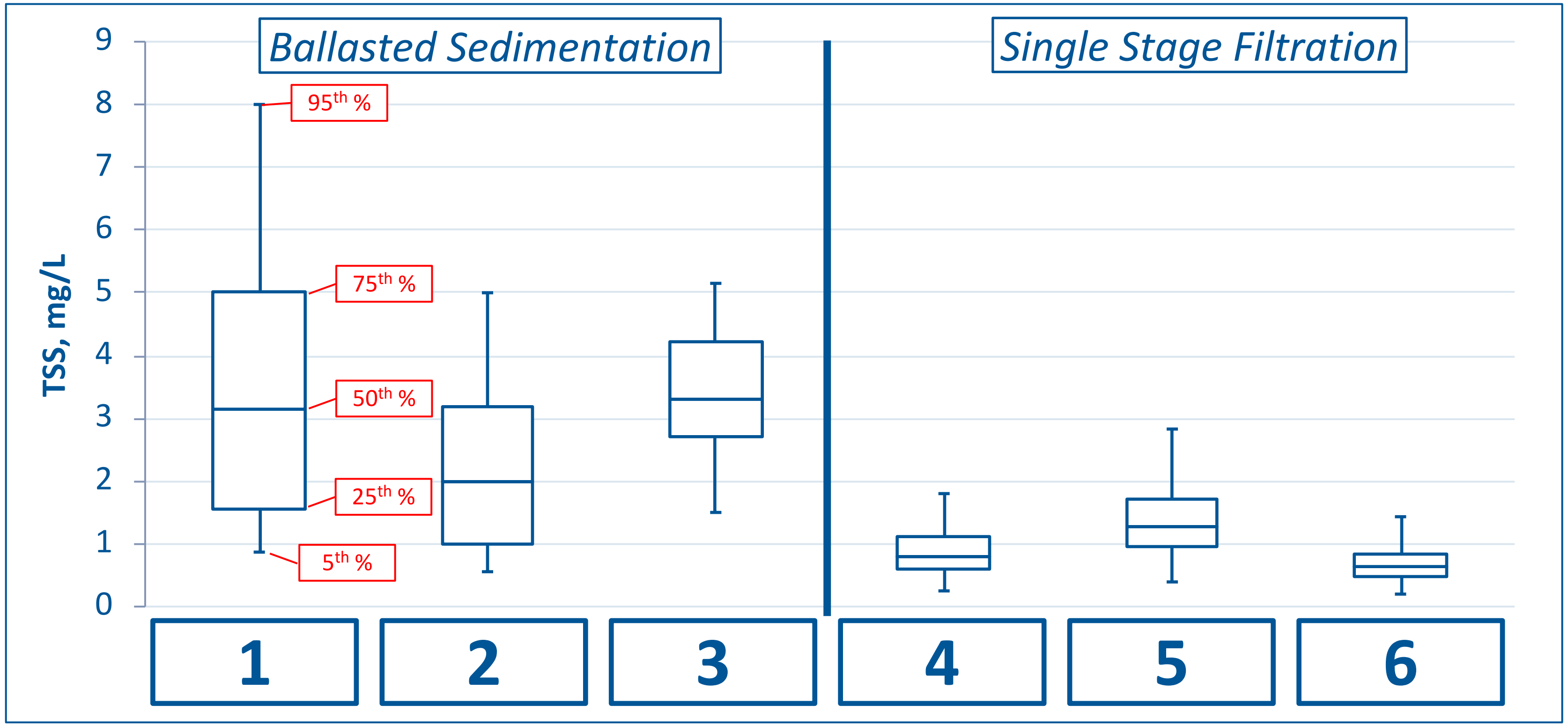
Relationship between Eff TSS and TP in Facility 1 Data suggests selective removal of solids with higher %P

Critical Factors to Achieve Seasonal Average P Limit of 0.075 mg/L-P

- sP < 0.02-0.03 mg/L-P
  - Soluble Reactive P almost fully removed
  - Soluble non-reactive P in typical range
- xP < 0.03-0.04 mg/L-P
  - TSS ~3.0 mg/L at 1.0-1.5% P by weight.



TSS Removal Comparison w/ Single Stage Deep Bed Granular Media Filtration



All things being equal filters could achieve 0.02-0.03 mg/L-P lower effluent TP through additional TSS removal

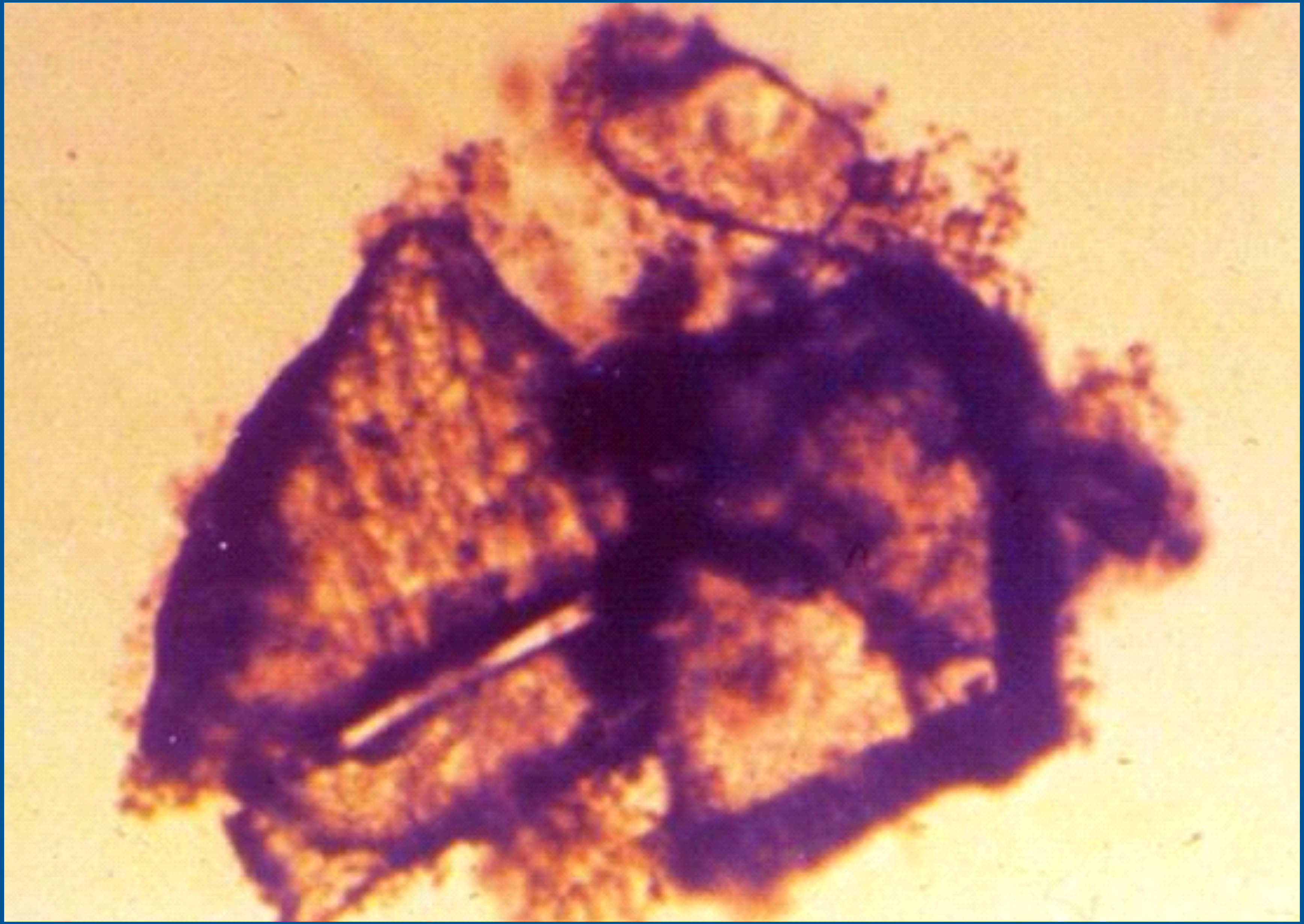
Design / Ops Considerations

- Hydraulic Loading < 30 gpd/sf at Peak flow w/ n-1 units
- Particle formation best practices (rapid mix/ flocculation zone HRT & mixing intensity) from WTPs
- Easy to maintain and robust poly feed system
- Frequent Cleaning of Lamella Plate
- Well defined dry & wet weather SOPs
- Soluble Reactive P removal by continuing to control SE TP at current levels

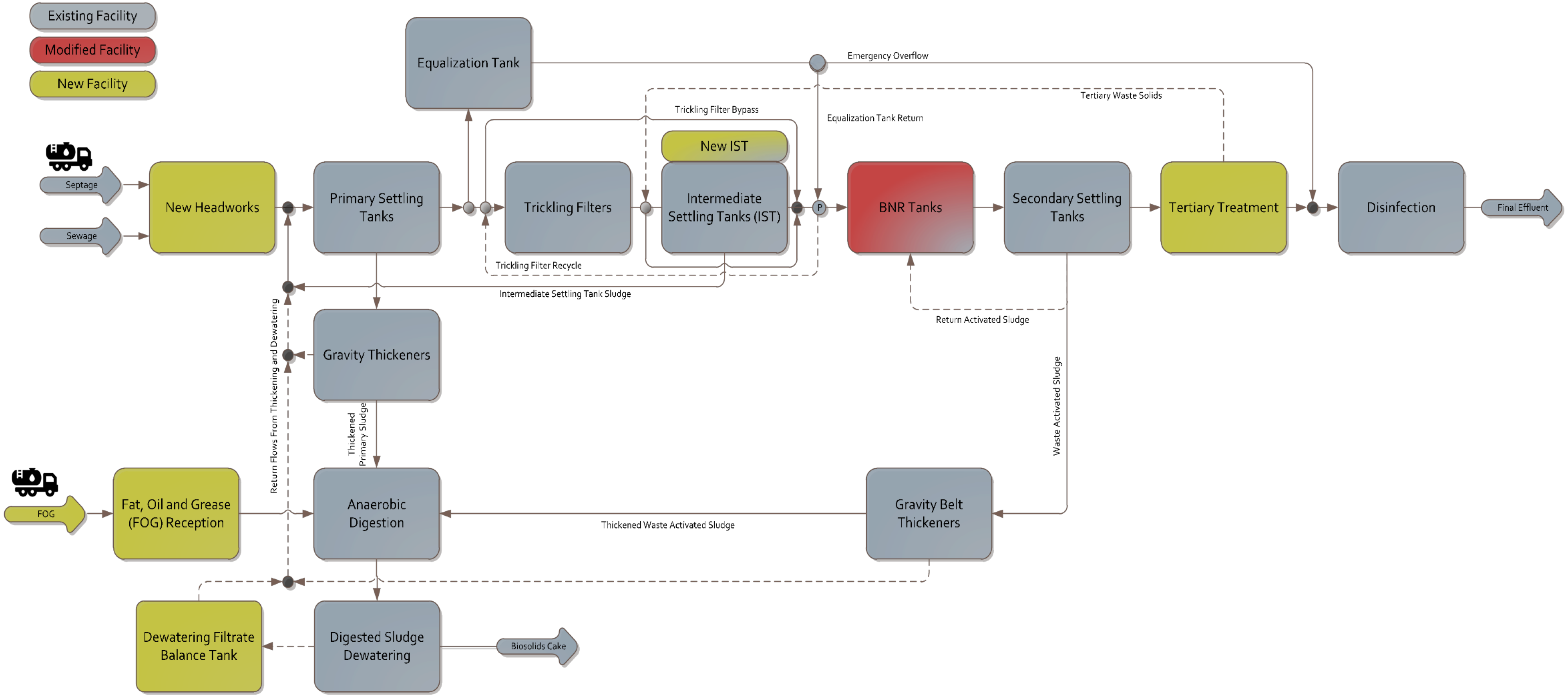
Risks and Mitigations Strategies

- Risks
  - sNRP spikes
  - Lower P limits
    - Pop. exceeds projected
    - More stringent load limit
- Mitigation
  - Higher upstream P removal
  - Source control if sNRP is unusually high
  - Earlier implementation of 2^{nd} stage of tertiary treatment
    - Filtration or coagulation/filtration depending on limit

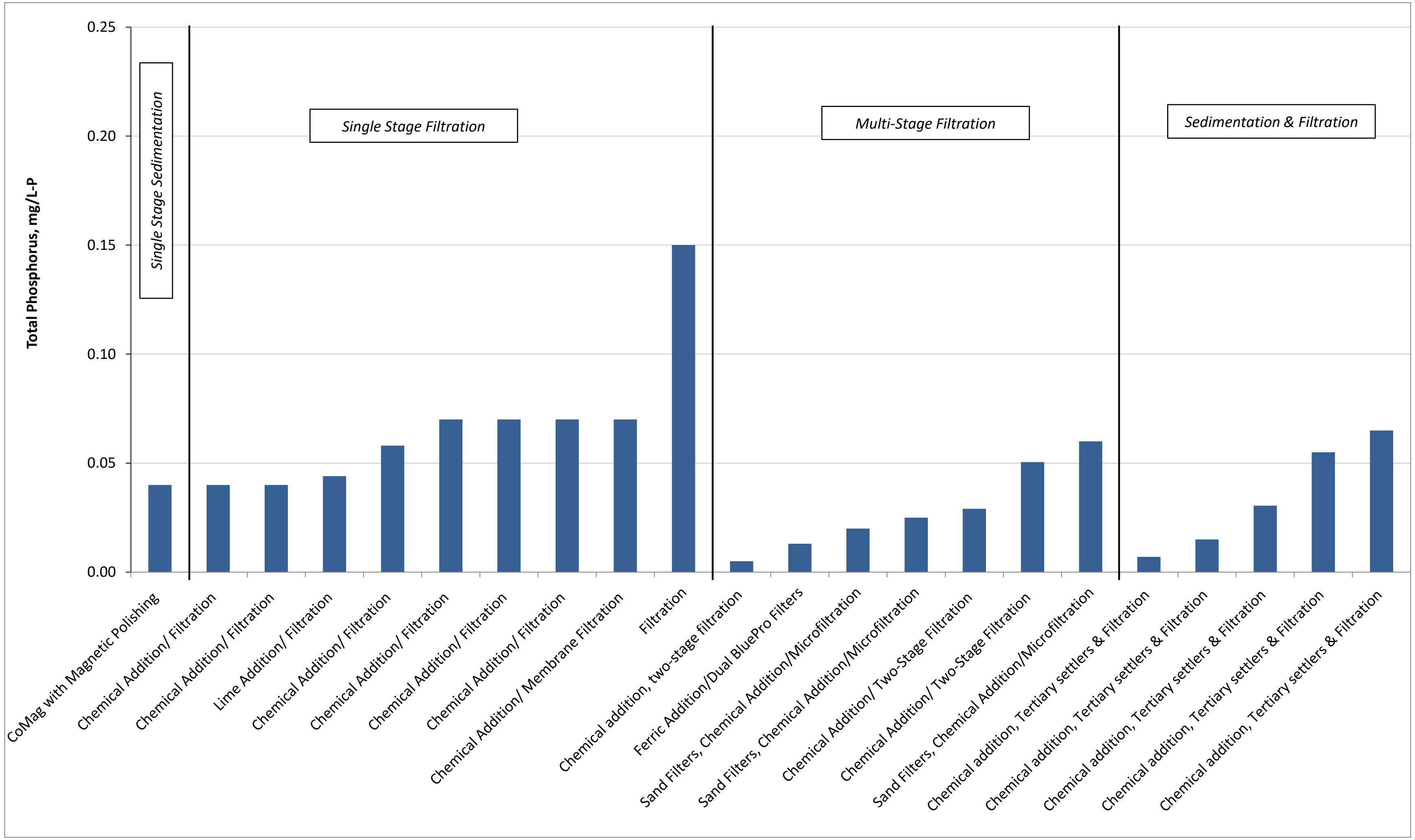
Questions



Danbury WPCF



EPA (2007) Evaluation



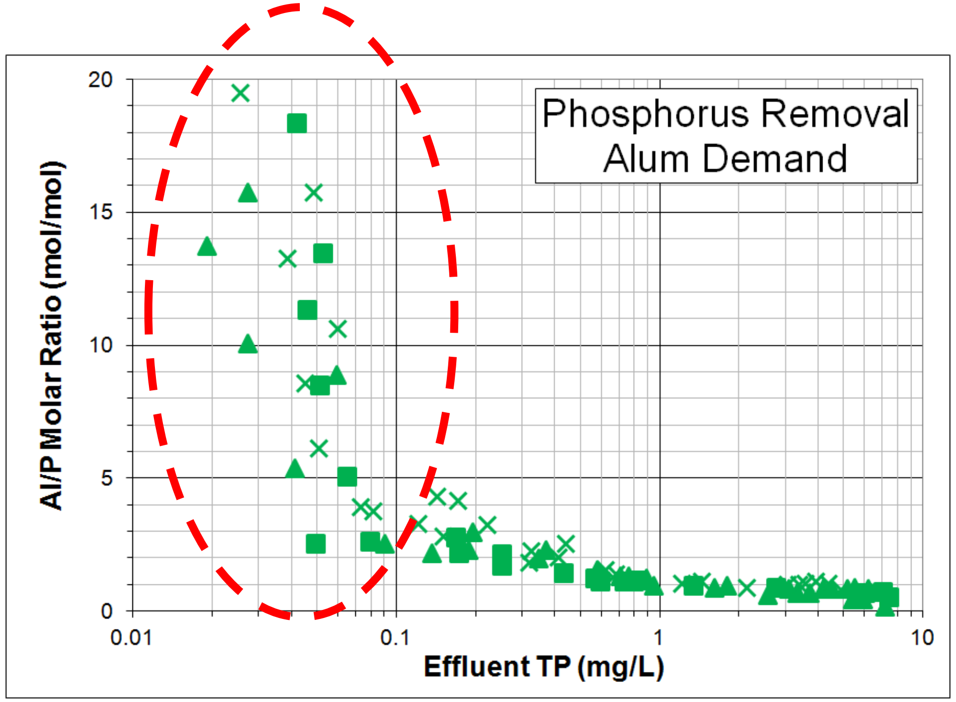
DESCRIPTION	VALUE
Number of Treatment Trains	3 (2 duty, 1 standby)
Maximum Capacity per Train	14.0 mgd
Rapid Mix (per train)	
HRT at 14.0 mgd	2.1 minutes
Mixing velocity gradient (G)	300 to 320 s^{-1}
Injection (per train)	
HRT at 14.0 mgd	2.1 minutes
Mixing velocity gradient (G)	250 to 290 s^{-1}
Flocculation (per train)	
HRT at 14.0 mgd	4.7 minutes
Mixing velocity gradient (G)	100 to 200 s^{-1}
Settling (per train)	
Maximum HLR at 14 mgd (1)	28.8 gpm/ft^2
Microsand Recirculation (per train)	
Number of pumps	1 duty + 1 standby
Flow rate at 14 mgd	290 gpm per pump
De-sanded Sludge Generation (per train)	
Flow rate at 14 mgd	232 gpm (without sludge recirculation)
Sludge solids concentration	0.05 - 0.5 percent TS
Sludge Recirculation (per train)	
Flow rate at 14 mgd(2)	115 gpm

Notes:

1. Hydraulic loading rate is based on the surface area of settling tank equipped with lamella settling tubes or plates.
2. Sludge recirculation rate assumed to be 50% of the de-sanded sludge generated by the hydrocyclones. The sludge recirculation rate will be confirmed during detailed design.
3. Refer to Chapter 3 for preliminary design criteria for the coagulant, polymer, and micro-sand feed systems. Jar testing of secondary effluent from the Danbury WWTP is needed to confirm coagulant and polymer type and to determine minimum, average, and maximum design dosages.

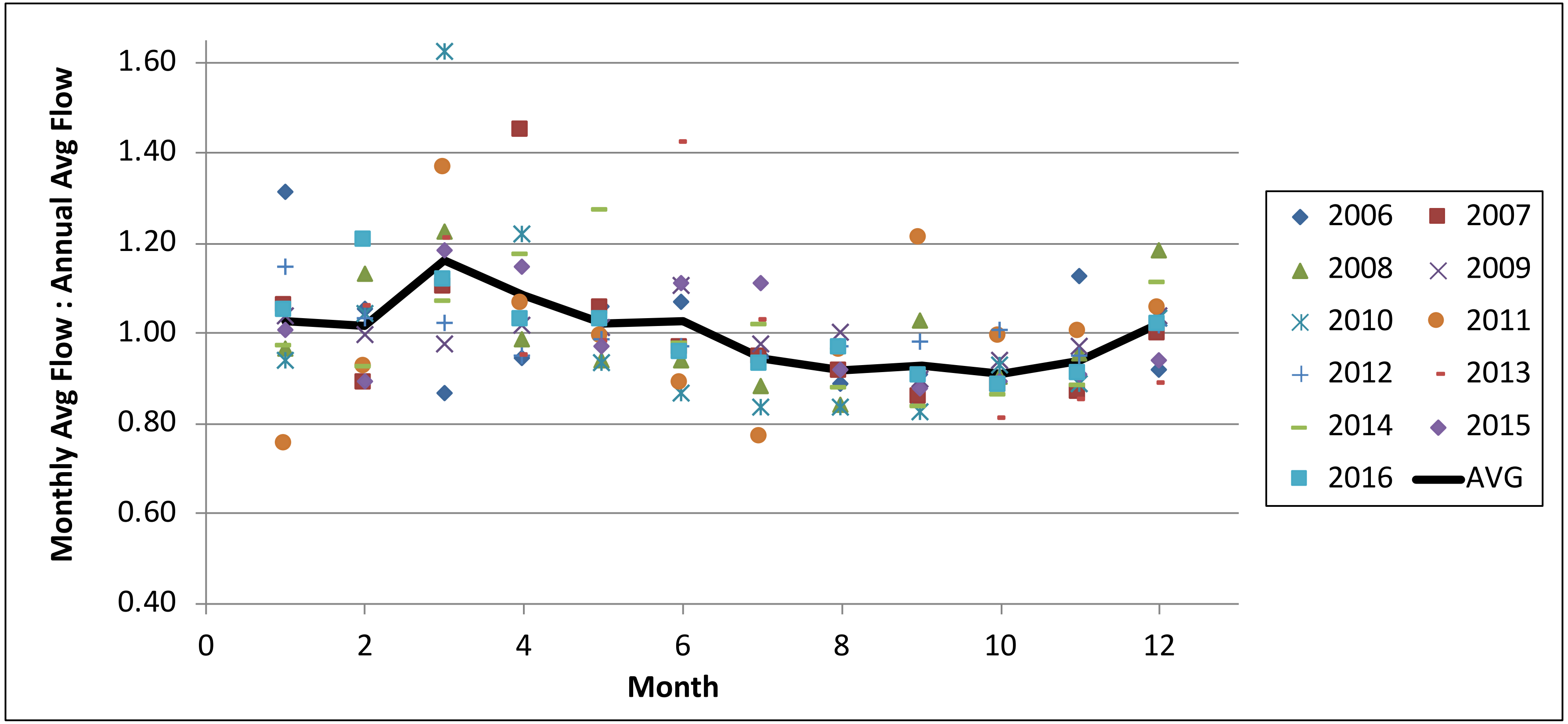
Steps 1-3 Determine Success

- Coagulation
  - $Al^{3+}/Fe^{3+}/Ca^{2+}$ dose
  - Alkalinity/pH
  - Rapid mixing criteria
- Flocculation
  - Polymer type and dose
  - Rapid mixing criteria
  - Slow mixing criteria
  - Sludge recirculation



- Coagulant dose higher than PO_4 precipitation alone
- Metal hydroxyl floc formation
  - pH/alkalinity
  - Deflocculation from monovalent cations

10 Years of Monthly Flow Factors



Clarification Mechanisms

Gravimetric

Particle Conditioning

Surface Charge Neutralization

Coagulation Co-precipitation

Flocculation Adsorption

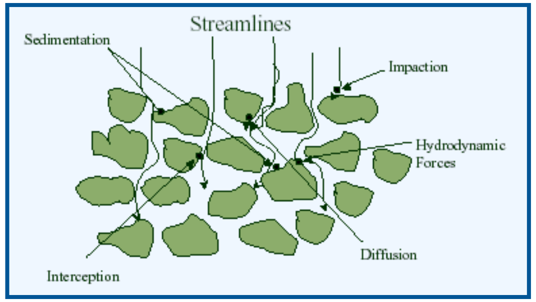
Flotation

Settling

Filtration*

Sieving (Surface)

Adsorption (Depth)



* Generally requires particle conditioning, depends upon waste and filter type.