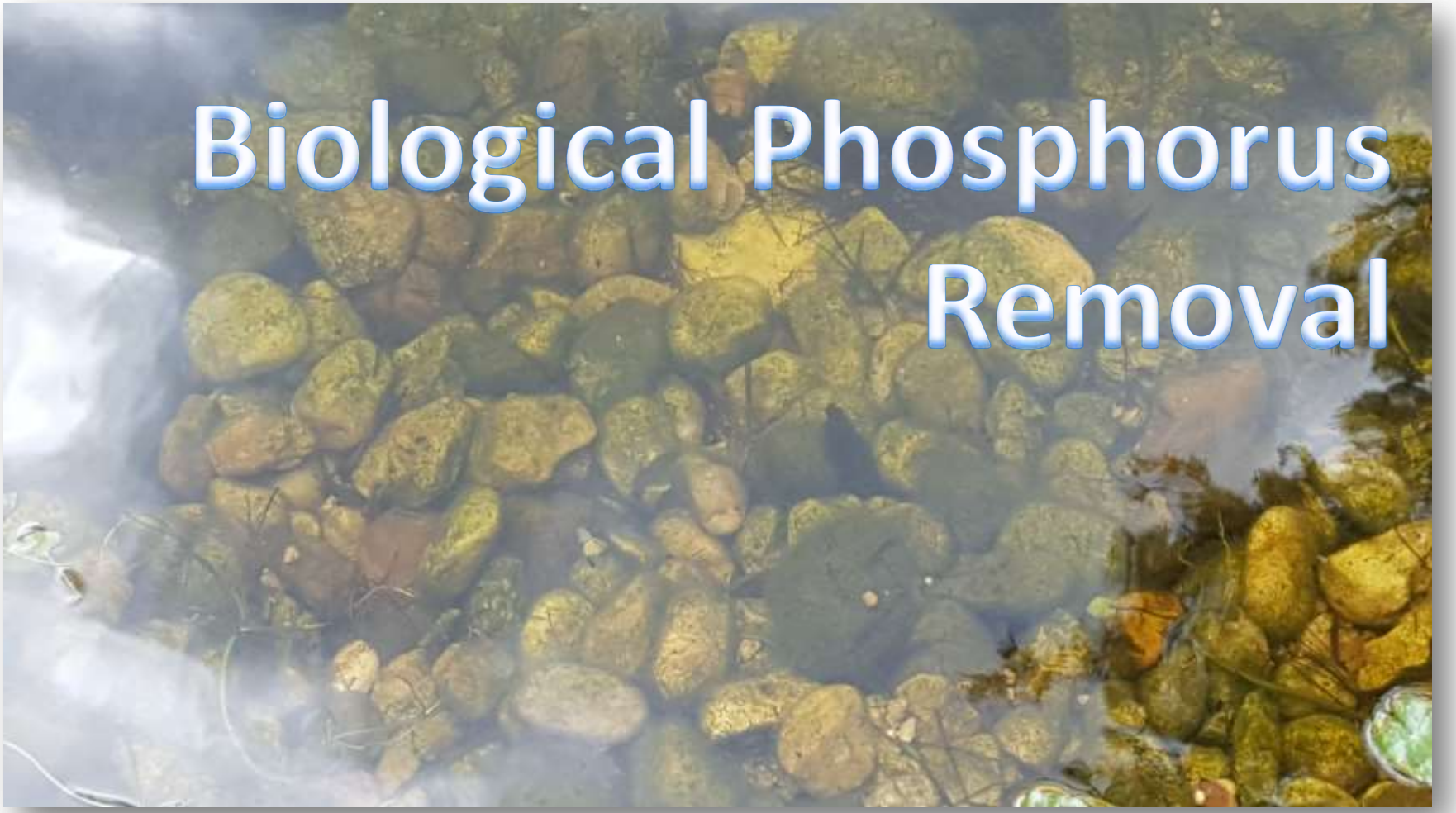


Biological Phosphorus Removal

By Op2Myz, LLC

Greg Paul

Why Fractionalize P ?

- We want to understand how to approach phosphorus treatment
- Best way is to understand each fraction and its make up
- Once know that treatment options become more clear

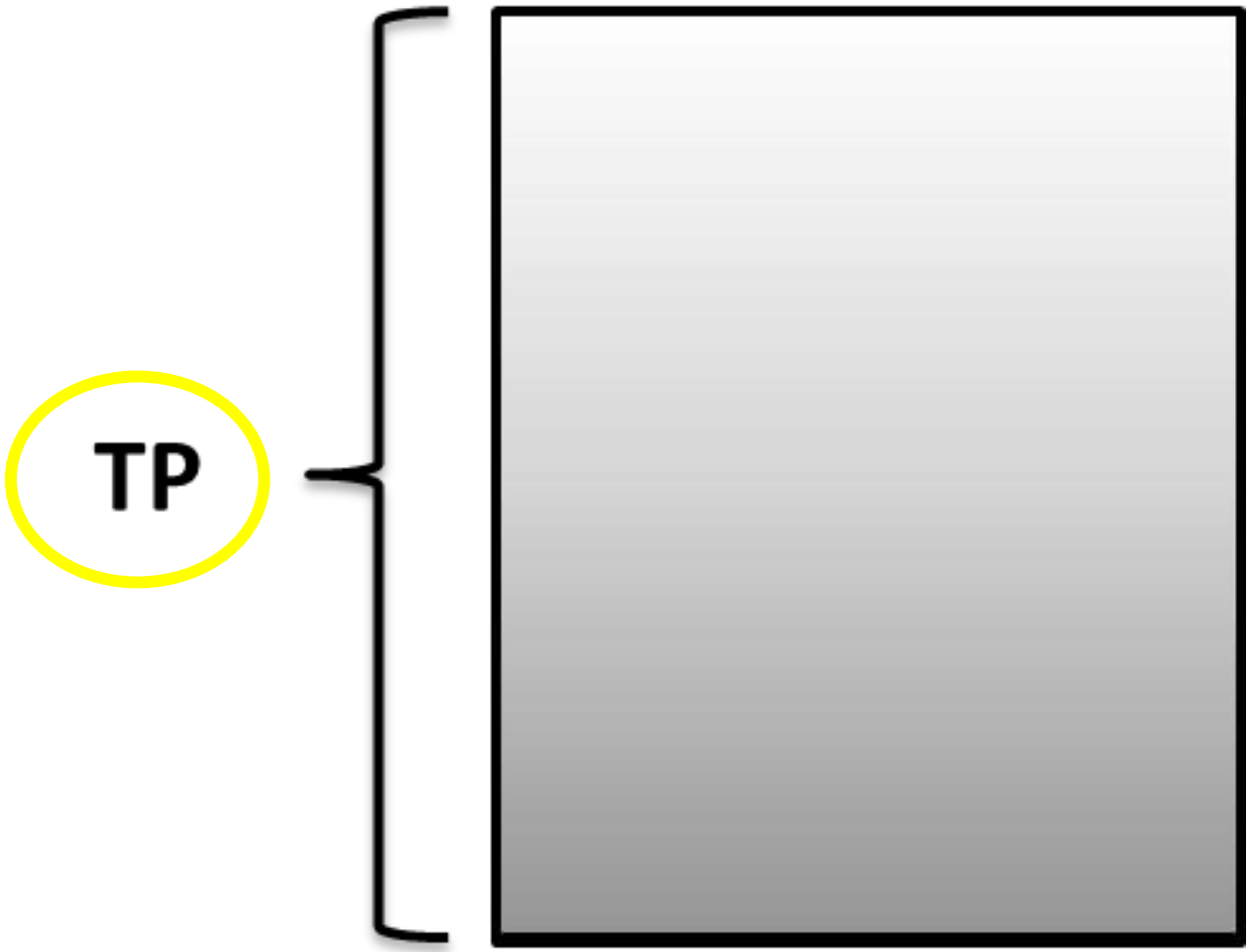
Three Main Basic Fractions of P and Their General Treatment Pathway

- SOLUBLE or dissolved REACTIVE or orthophosphate **sRP**
  - Chemical & BPR
- SOLUBLE or dissolved NON-REACTIVE P or orthophosphate that does react well **sNRP**
  - Most difficult to remove
- PARTICULATE or the solids in the water **pTP**
  - Enhanced Settling & Filtration

Total Phosphorus

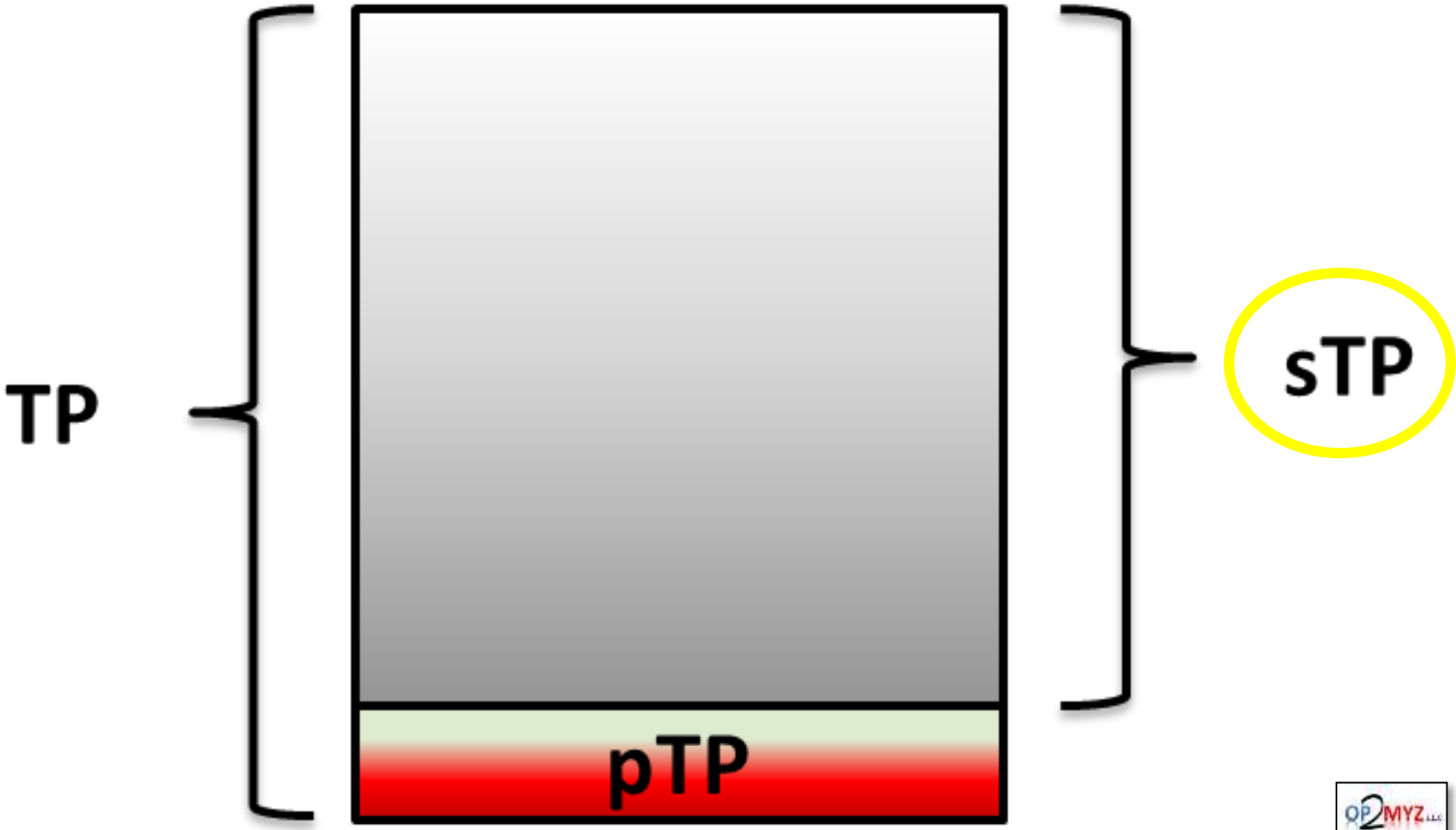
Persulfate Digestion

Direct Colorimetric Method



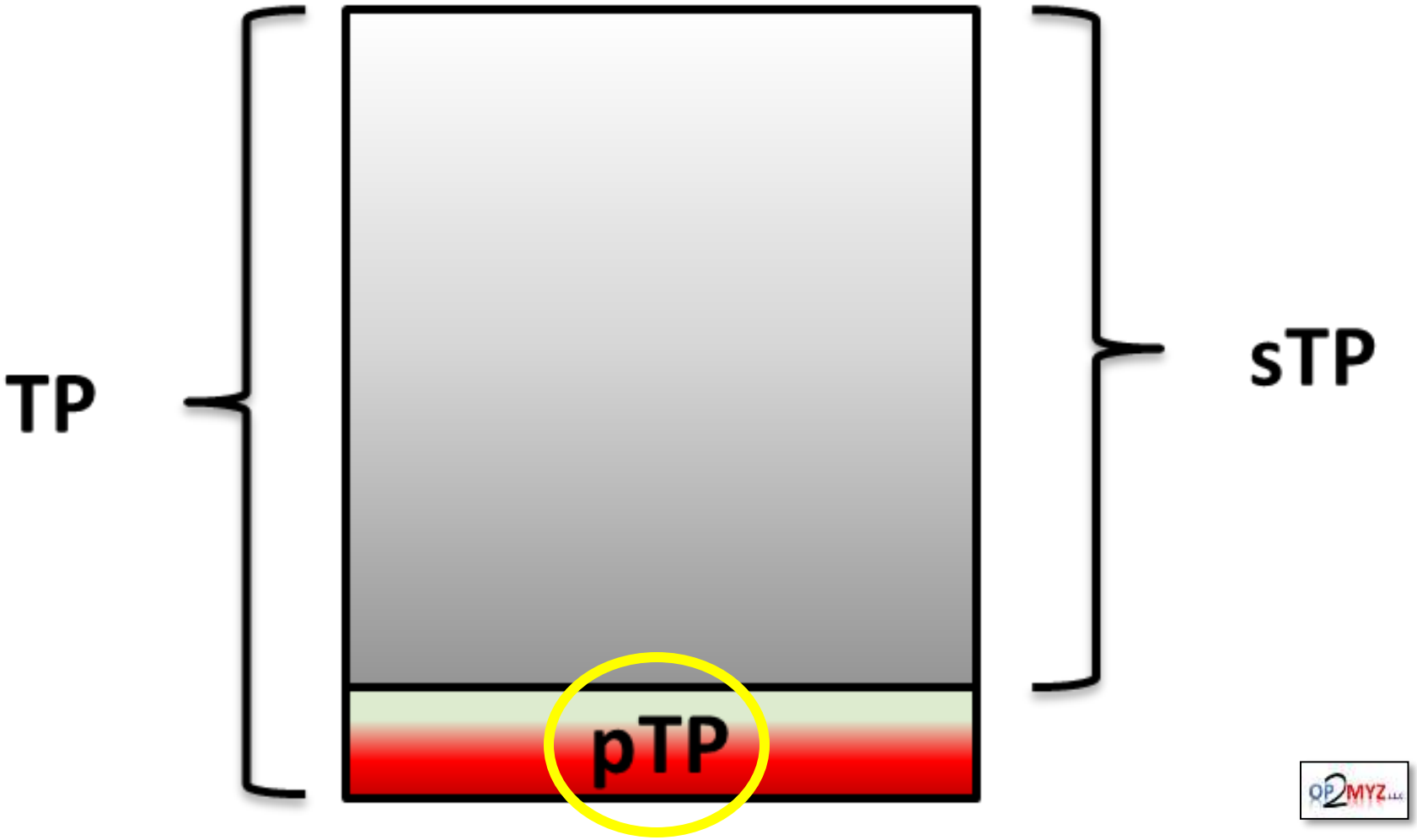
Total Soluble Phosphorus

Filter (04.5 Micron)/Persulfate Digestion
Direct Colorimetric Method



Total Particulate Phosphorus

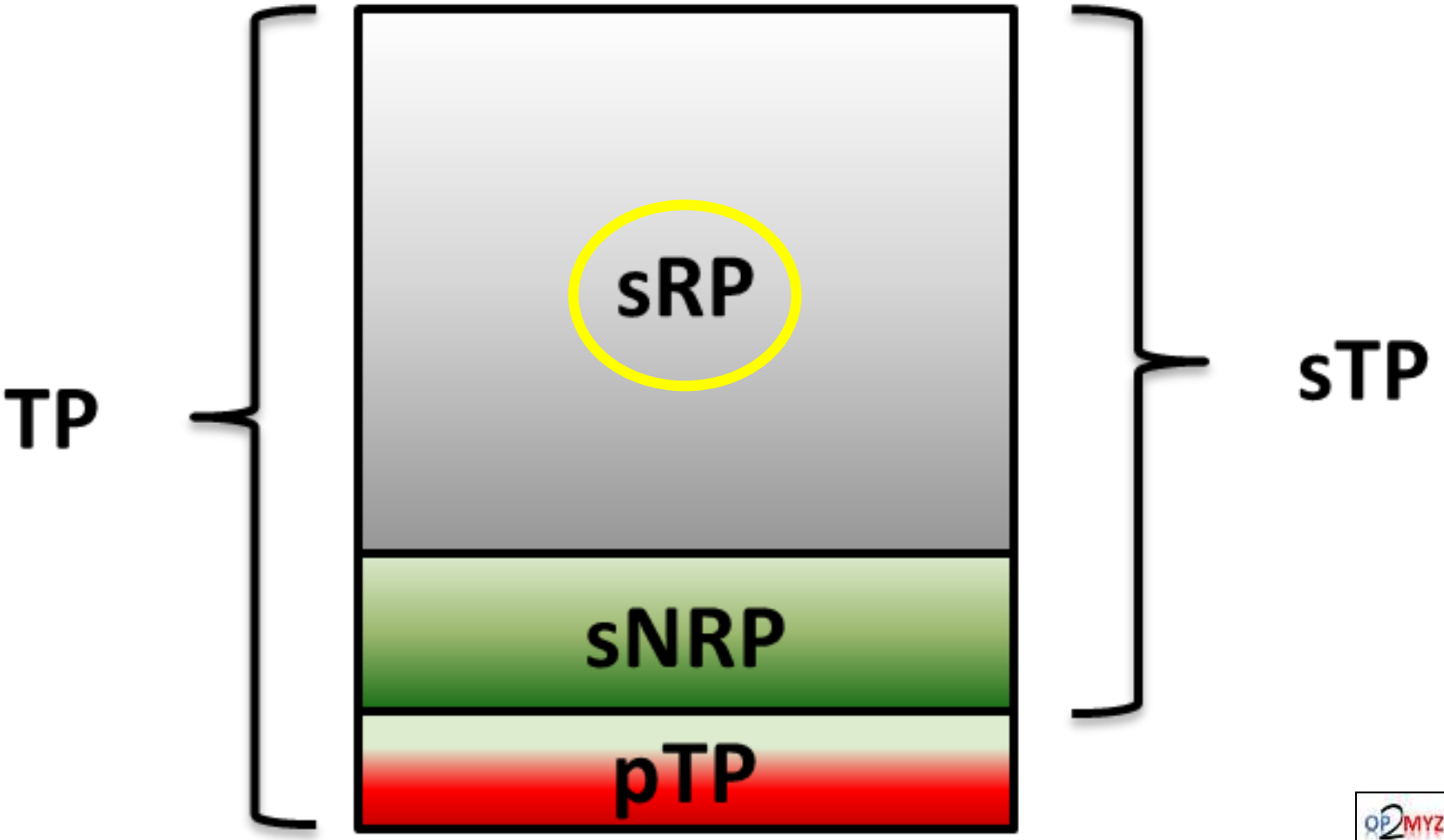
TP minus sTP



Soluble Reactive Phosphorus

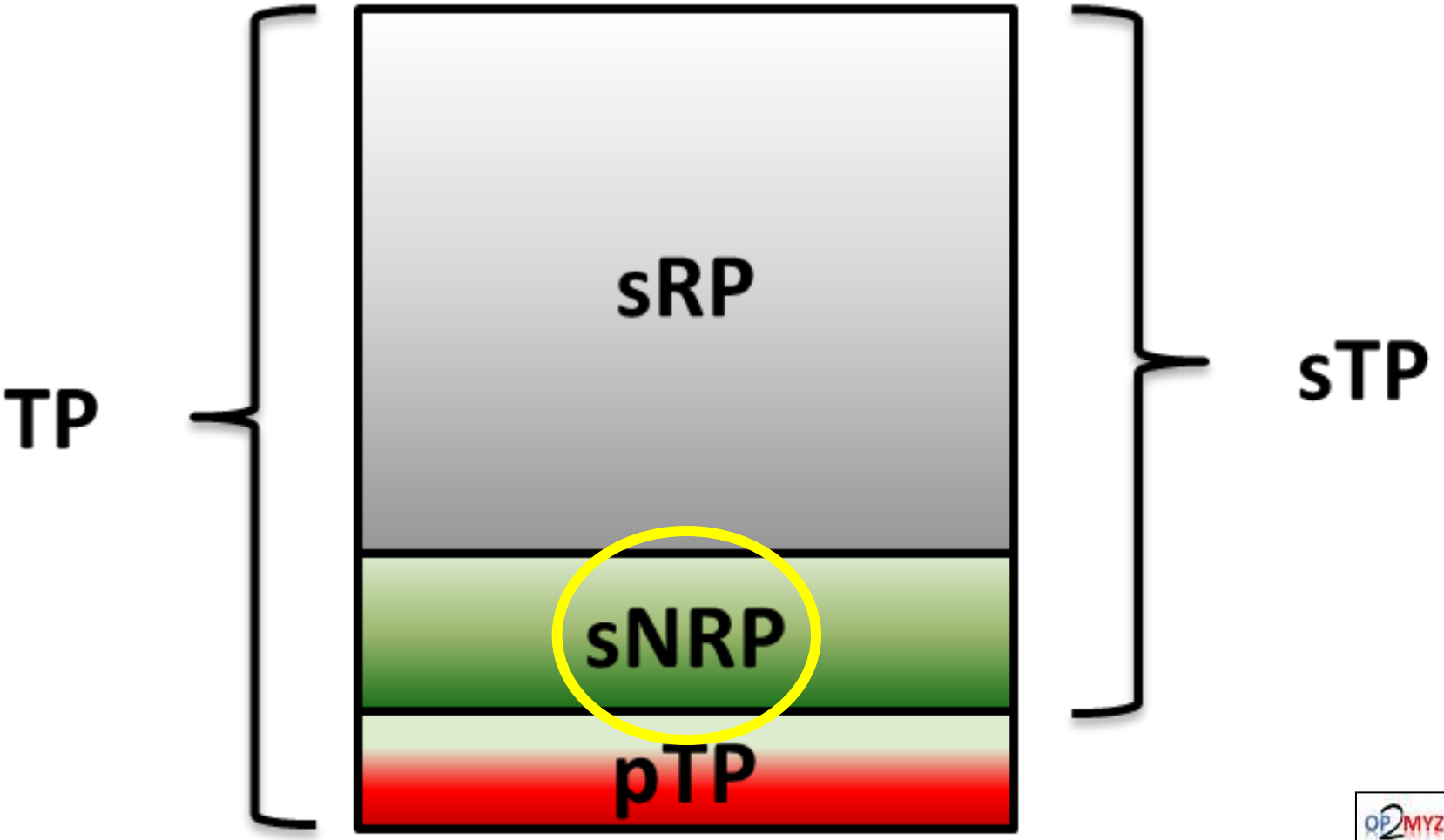
Filter (0.45 Micron)

Direct Colorimetric Method



Soluble Non-Reactive Phosphorus

sTP minus sRP



FYI - Additional Fractions

List of Fractions of P

Fraction of P	Abbrev.	Source
Total Phosphorus	TP	Analyze
Total Reactive Phosphorus	tRP	Analyze
Total Acid Hydrolysable Phosphorus	tAHP	Analyze
Total Non Reactive Phosphorus	tNRP	TP - tRP
Total Polymerized Phosphorus	tPoly	tAHP - tRP
Total Organic Phosphorus	tOP	TP - tAHP
Total Particulate Phosphorus	pTP	TP - sTP
Particulate Reactive Phosphorus	pRP	tRP - sRP
Particulate Organic Phosphorus	pOP	tOP - sOP
Particulate Non Reactive Phosphorus	pNRP	tNRP - sNRP
Particulate Polymerized Phosphorus	pPoly	tPoly - sPoly
Particulate Acid Hydrolysable Phosphorus	pAHP	tAHP - sAHP
Total Soluble Phosphorus	sTP	Analyze after 0.45 um filter
Soluble Acid Hydrolysable Phosphorus	sAHP	Analyze after 0.45 um filter
Soluble Reactive Phosphorus	sRP	Analyze after 0.45 um filter
Soluble Organic Phosphorus	sOP	sTP - sAHP
Soluble Non Reactive Phosphorus	sNRP	sTP - sRP
Soluble Polymerized Phosphorus	sPoly	sAHP - sRP

So Many Different Names !!!

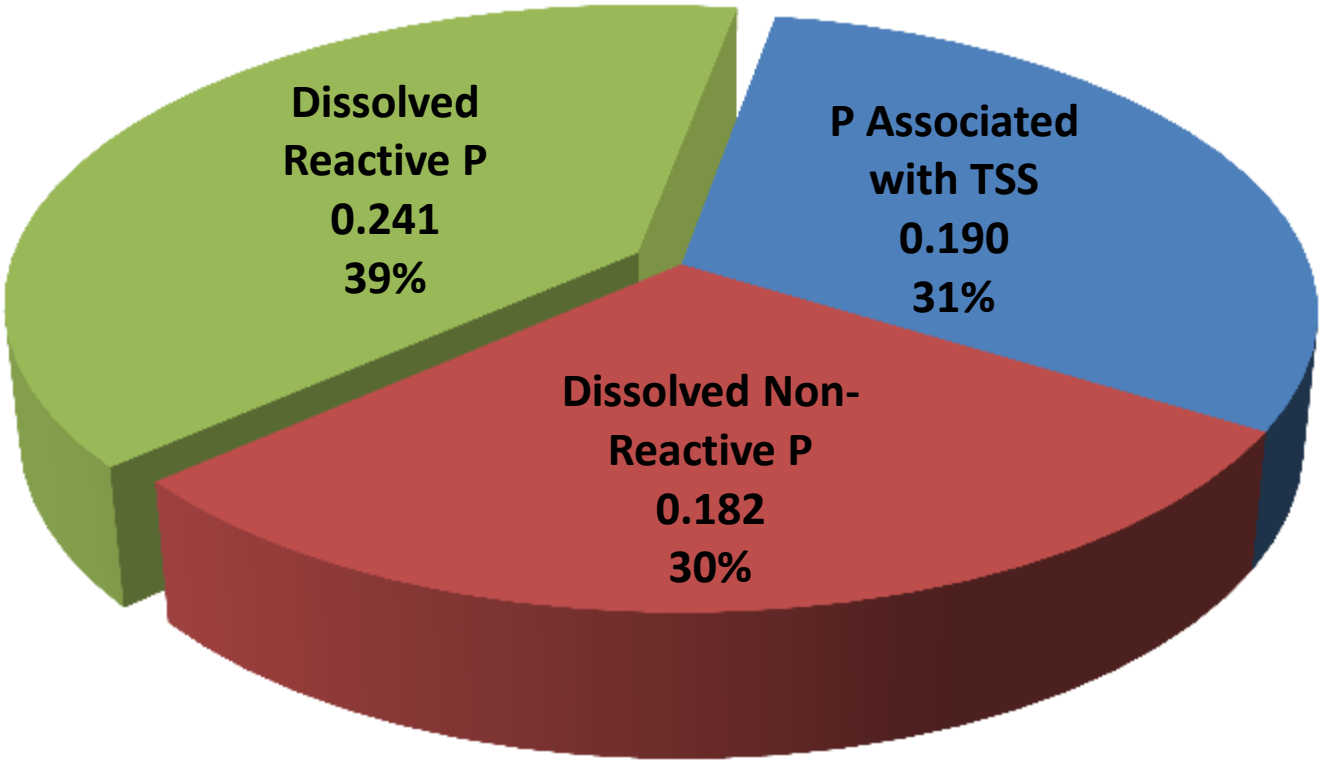
Fraction of P	Abbrev.	Other names
Total Phosphorus	TP	
Total Reactive Phosphorus	tRP	Total Ortho-P, Total Orthophosphate as P, Total PO_4-P
Total Acid Hydrolysable Phosphorus	tAHP	
Total Non Reactive Phosphorus	tNRP	
Total Polymerized Phosphorus	tPoly	
Total Organic Phosphorus	tOP	
Total Particulate Phosphorus	pTP	
Particulate Reactive Phosphorus	pRP	Particulate Orthophosphorus, Particulate Orthophosphate as P
Particulate Organic Phosphorus	pOP	
Particulate Non Reactive Phosphorus	pNRP	
Particulate Polymerized Phosphorus	pPoly	
Particulate Acid Hydrolysable Phosphorus	pAHP	
Total Soluble Phosphorus	sTP	Total Dissolved Phosphorus
Soluble Acid Hydrolysable Phosphorus	sAHP	
Soluble Reactive Phosphorus	sRP	Soluble Orthophosphorus, Soluble Orthophosphate as P, Dissolved Reactive Phosphorus, Dissolved Orthophosphate as P, Dissolved Orthophosphorus, Dissolved PO_4-P, Soluble PO_4-P
Soluble Organic Phosphorus	sOP	Dissolved Organic Phosphorus, DOP
Soluble Non Reactive Phosphorus	sNRP	Disssolve Non-Reactive Phosphorus
Soluble Polymerized Phosphorus	sPoly	

What do I do With the Results???

Using Fort Atkinson EFF. P Data What Happens IF?

Fort Atkinson - Fraction of Phosphorus in WWTP Effluent

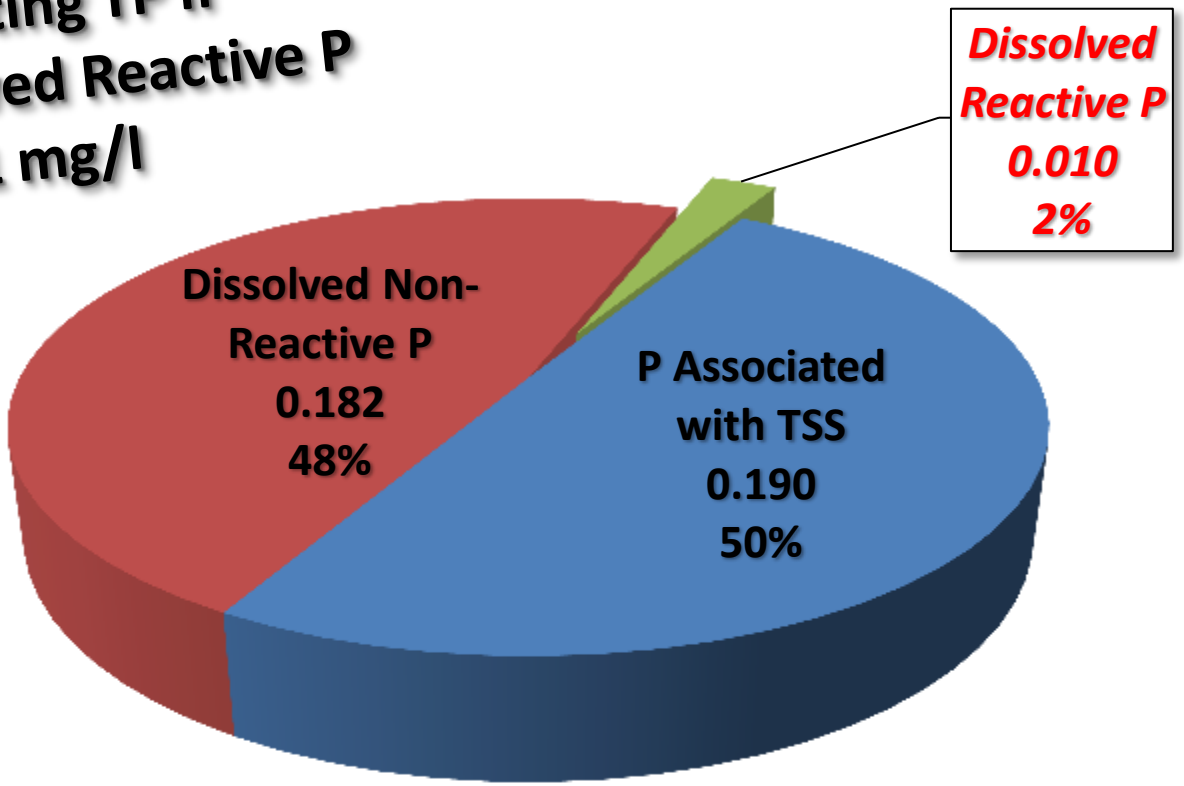
Data from Fall of 2011



Aug thru Oct 2011 - Average based on actual data

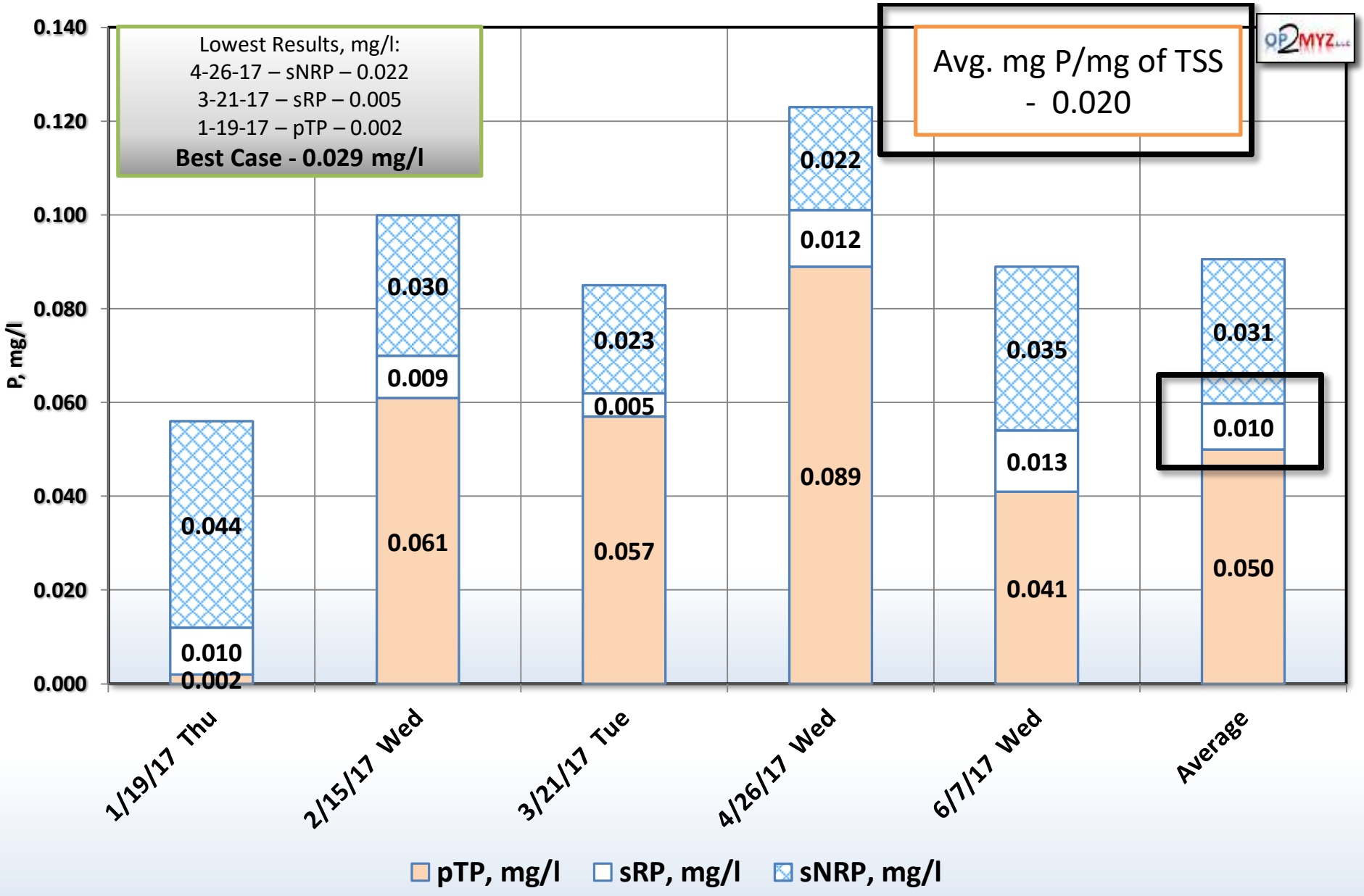
Fort Atkinson - Most Reactive P Removed by BNR

Estimating TP if Dissolved Reactive P at 0.01 mg/l



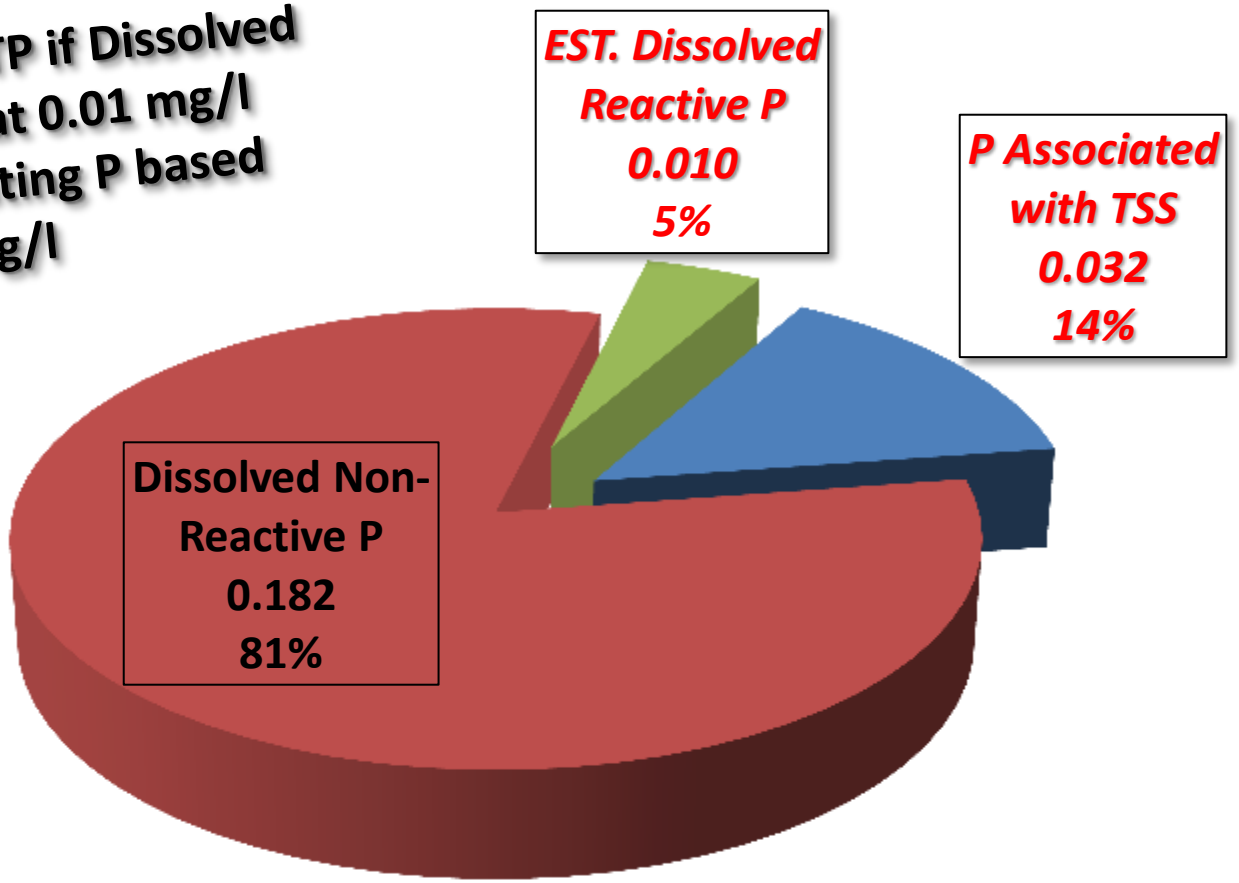
Estimated Total Phosphorus, mg/l - 0.382

Eleva-Strum - sRP Avg. 0.01



Fort Atkinson - Most Reactive P Removed by BNR and Effluent TSS Filtration

Estimating TP if Dissolved Reactive P at 0.01 mg/l And Estimating P based on TSS 1 mg/l



Estimated Total Phosphorus, mg/l - 0.224

The Problem Children
They Don't Play Nice!!!

TP

sRP

sNRP

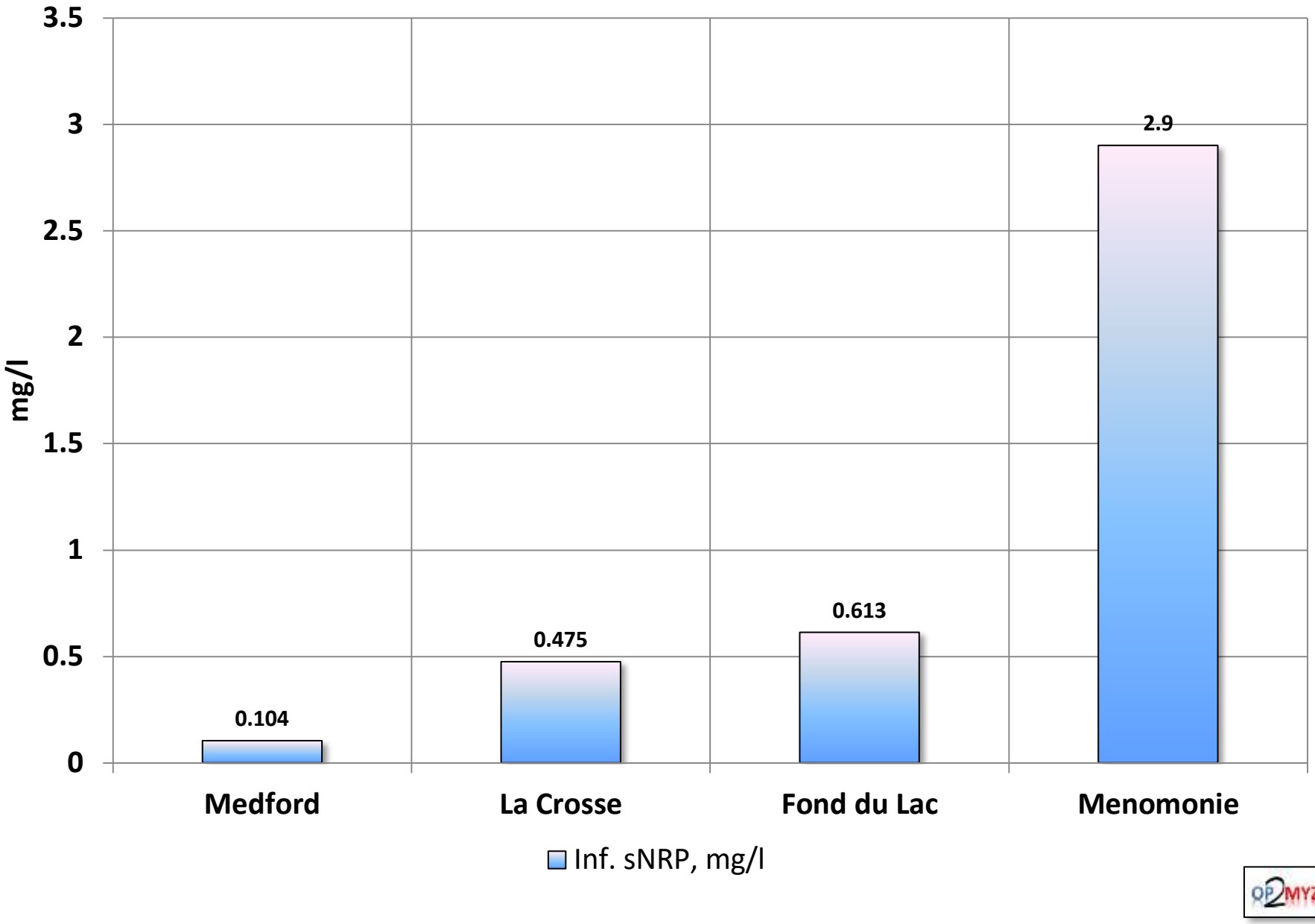
pRP

pNRP

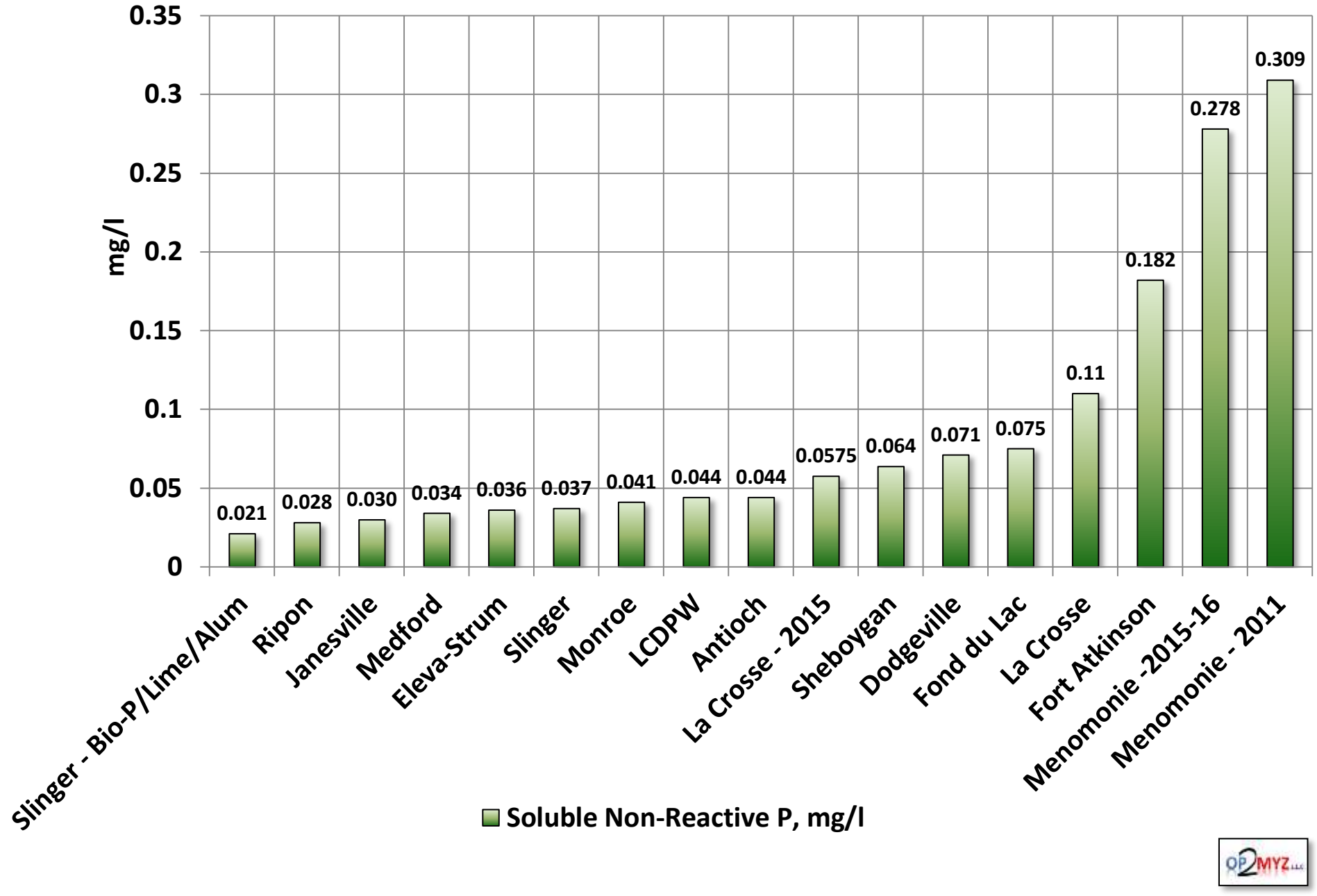
sTP

pTP

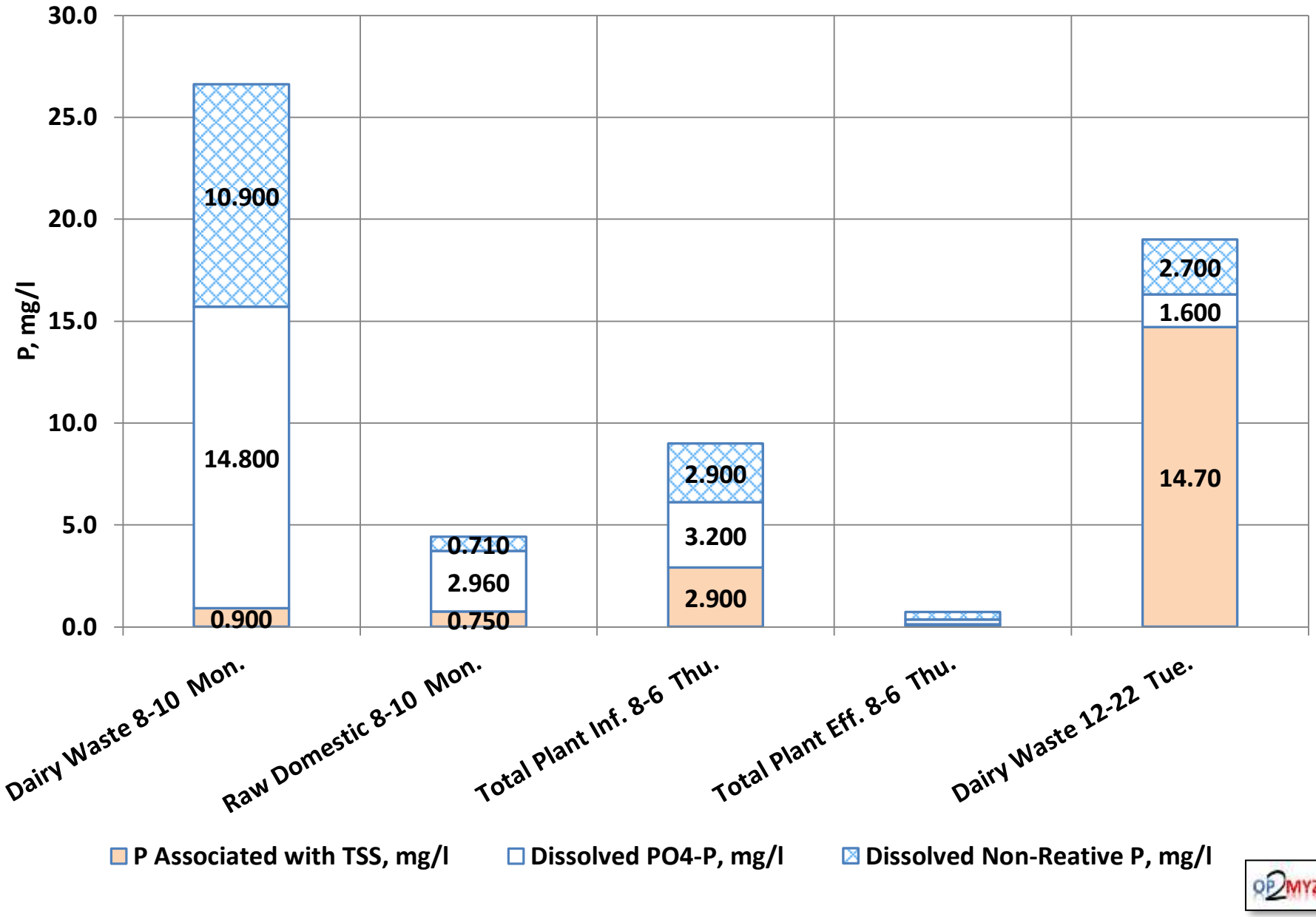
Inf. sNRP Survey

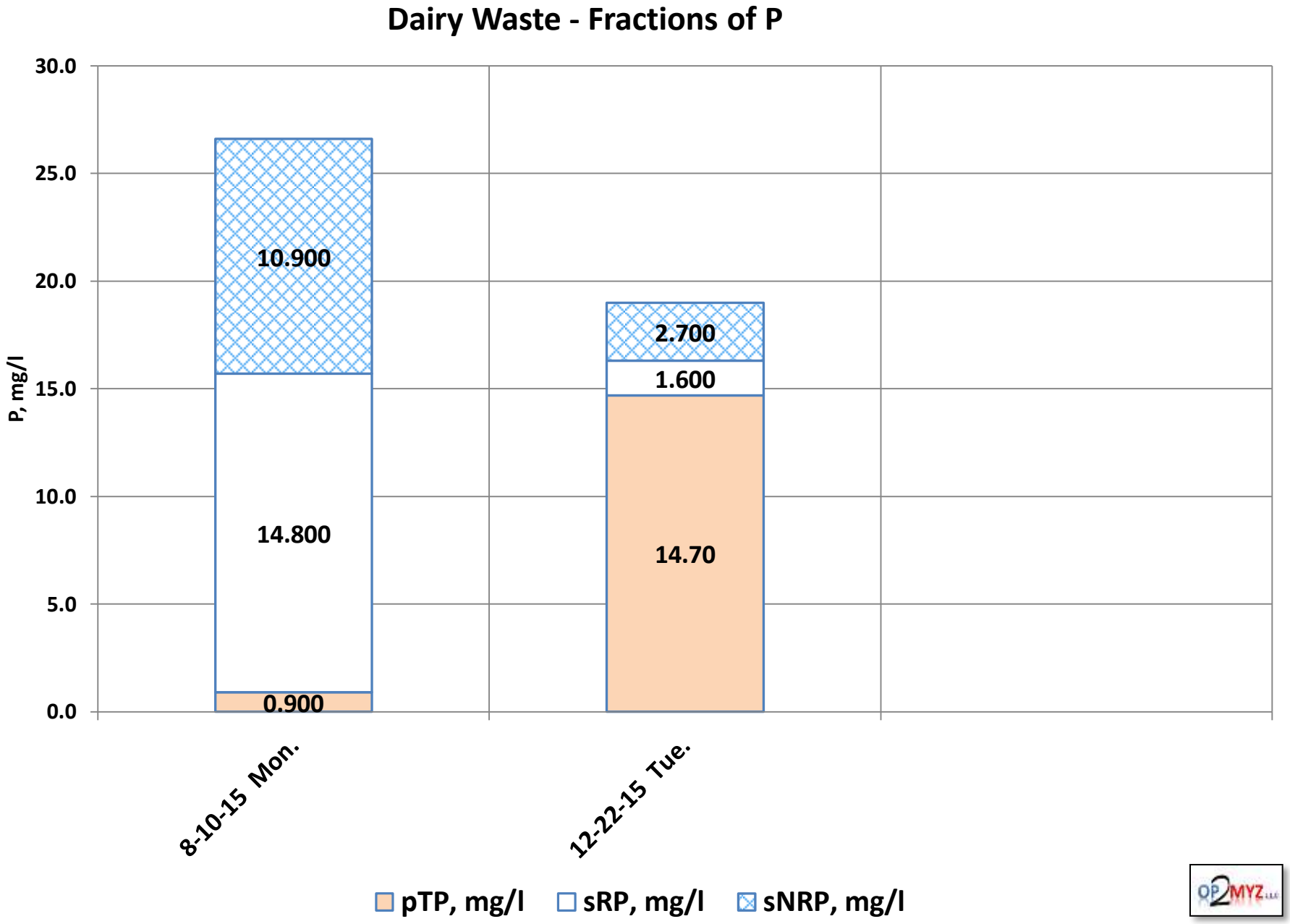


Eff - Soluble Non-Reactive P (sNRP) Survey

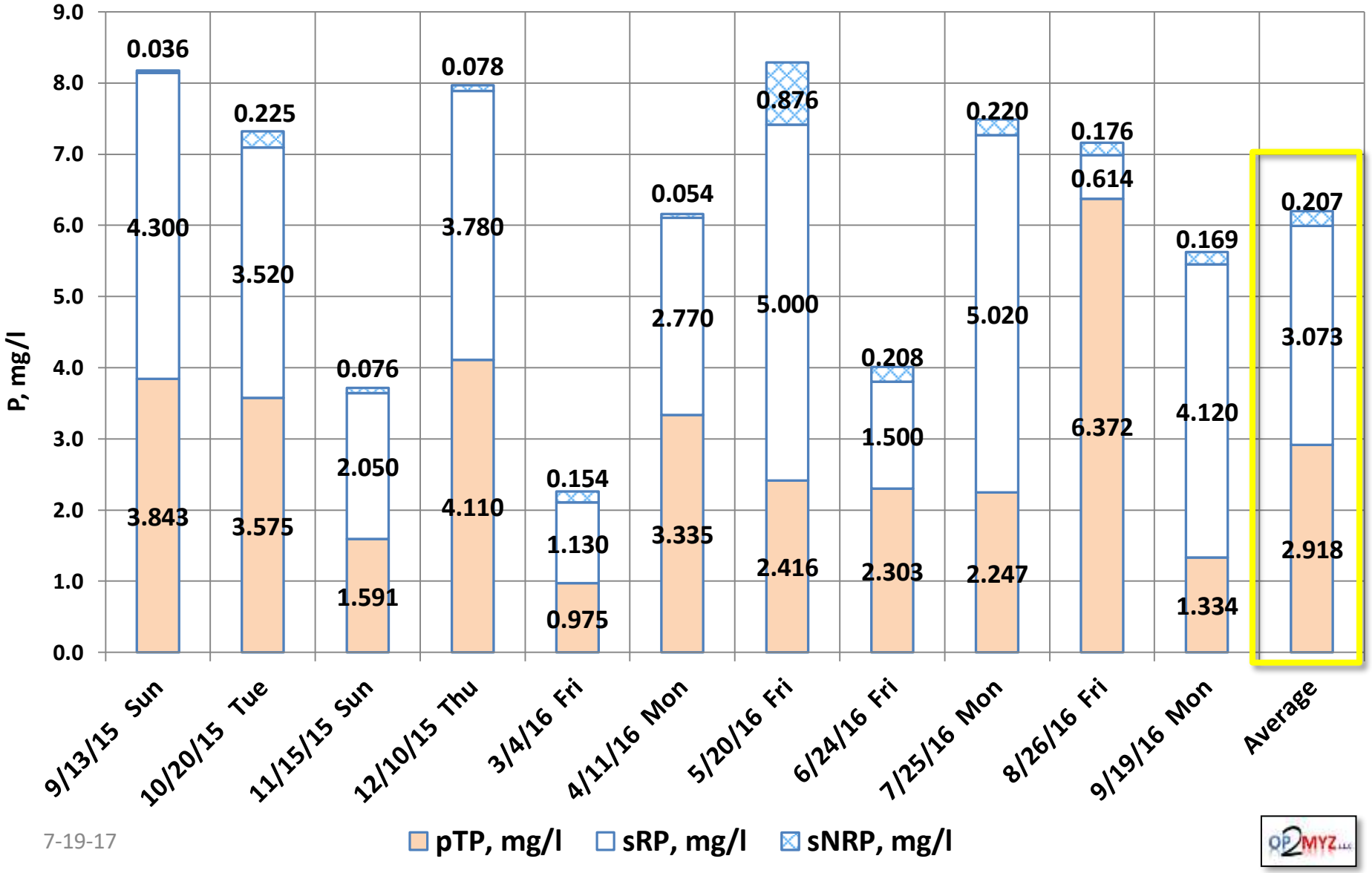


Menomonie WWTP - Fractions of P

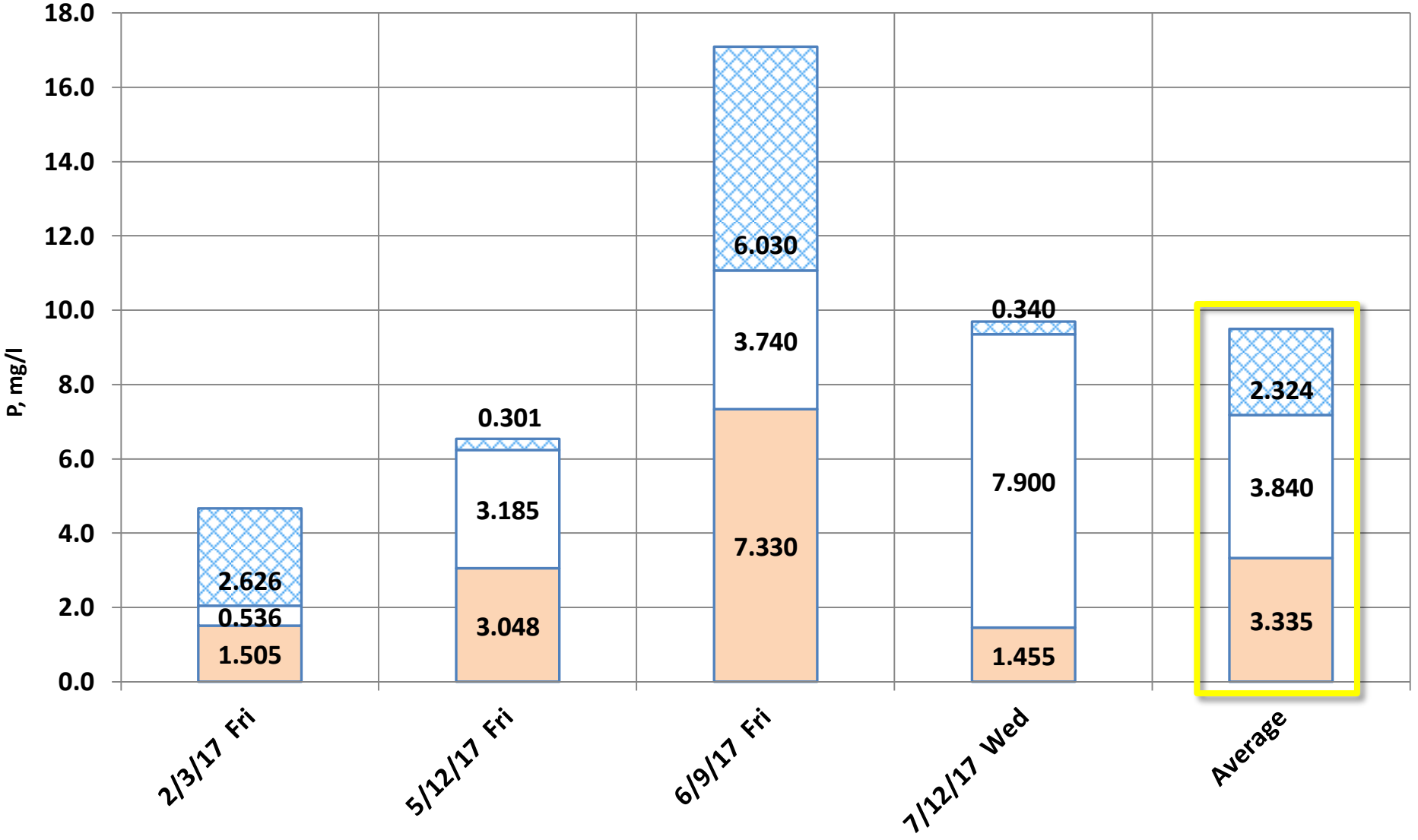



Dairy Waste - Fractions of P
30.0
25.0
20.0
15.0
10.0
5.0
0.0
P, mg/l
10.900
14.800
0.900
2.700
1.600
14.70
8-10-15 Mon.
12-22-15 Tue.
pTP, mg/l
sRP, mg/l
sNRP, mg/l

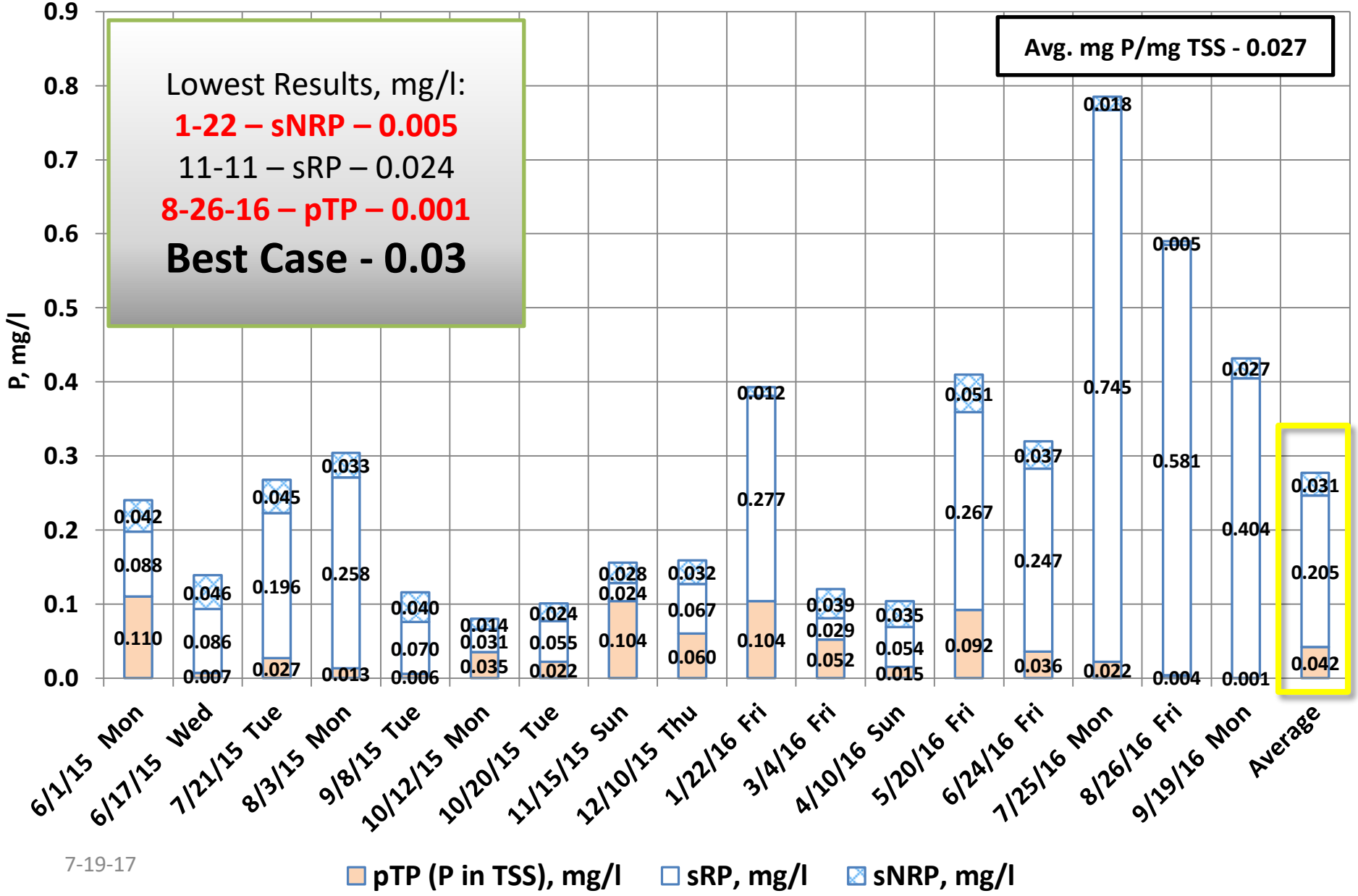
Fractions of P - Inf. 2015 & 2016



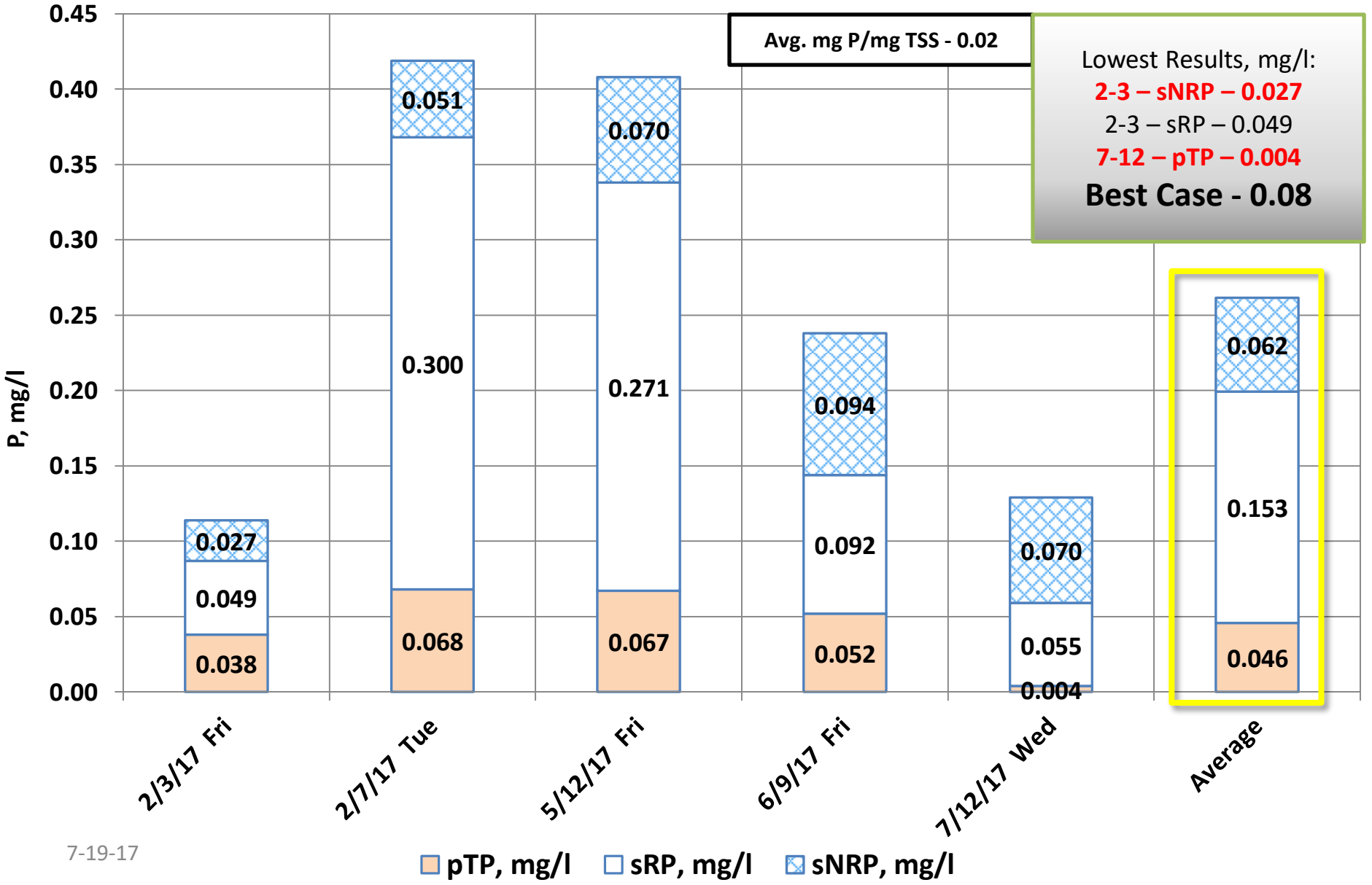
Fractions of P - **Inf.** 2017



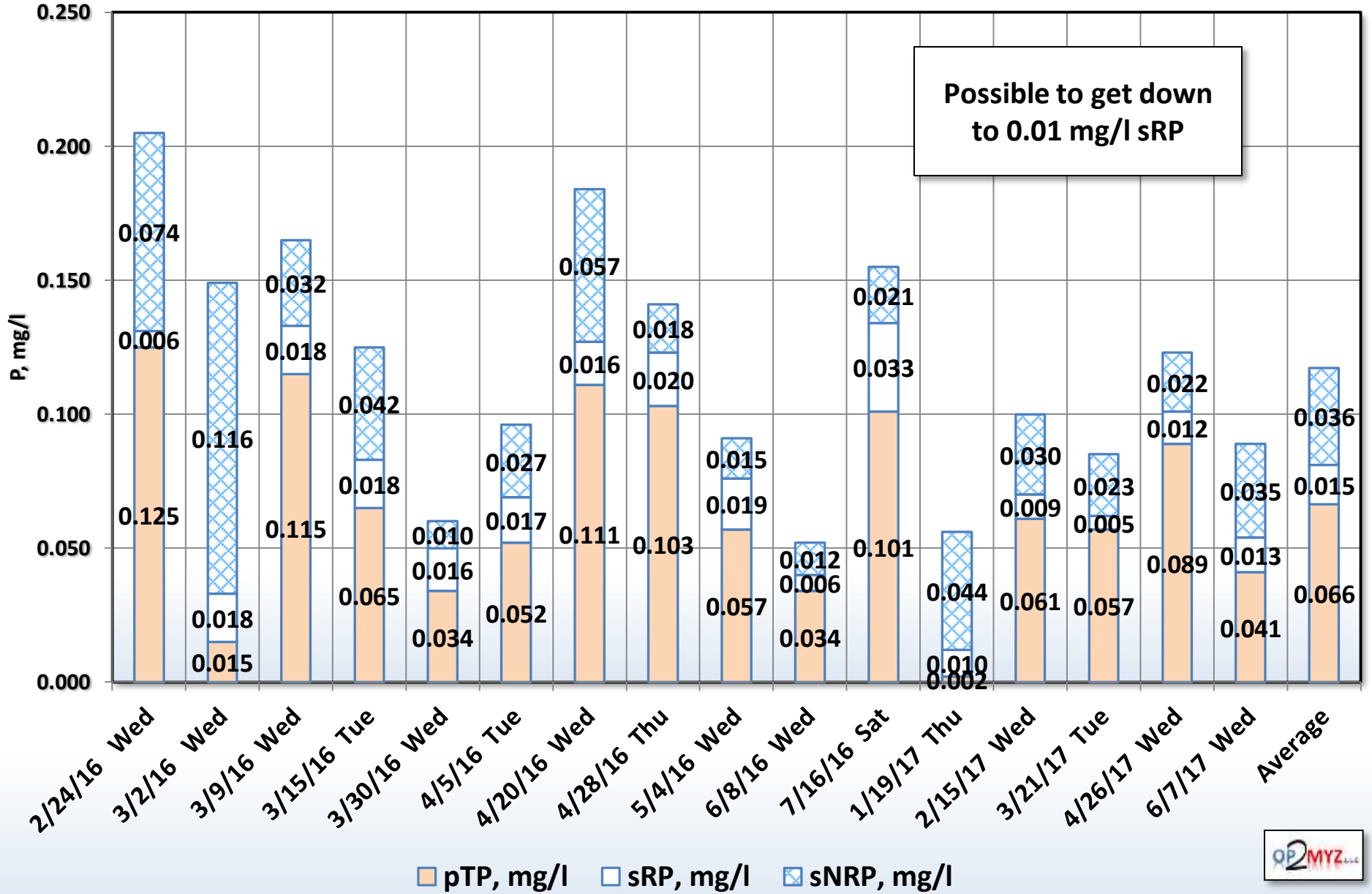
Fractions of P - **Eff.** 2015 & 2016



Fractions of P - **Eff.** 2017

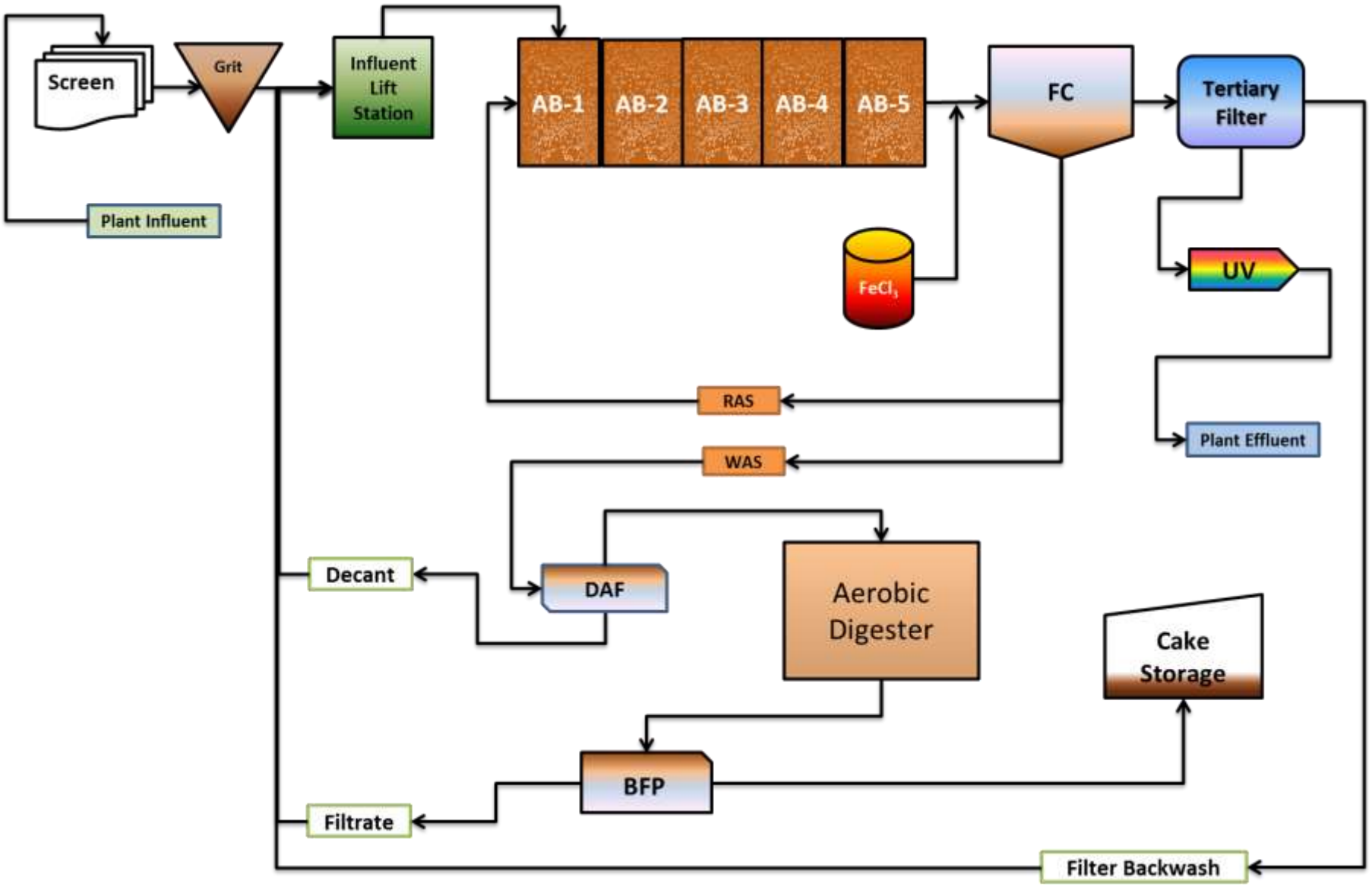


Eleva-Strum – Fractions of P



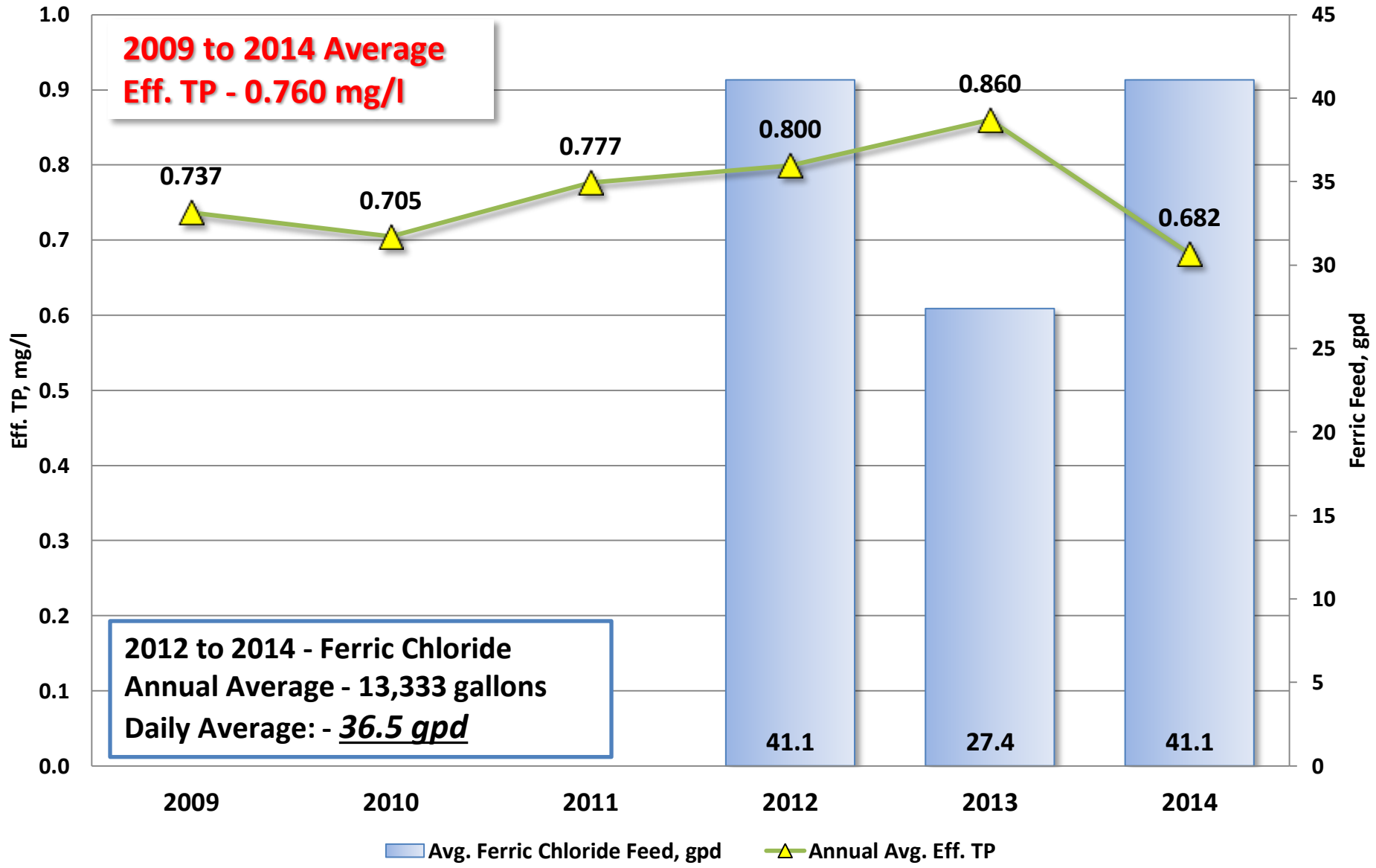
Medford EBPR - Optimization

Before Any Changes in Operation

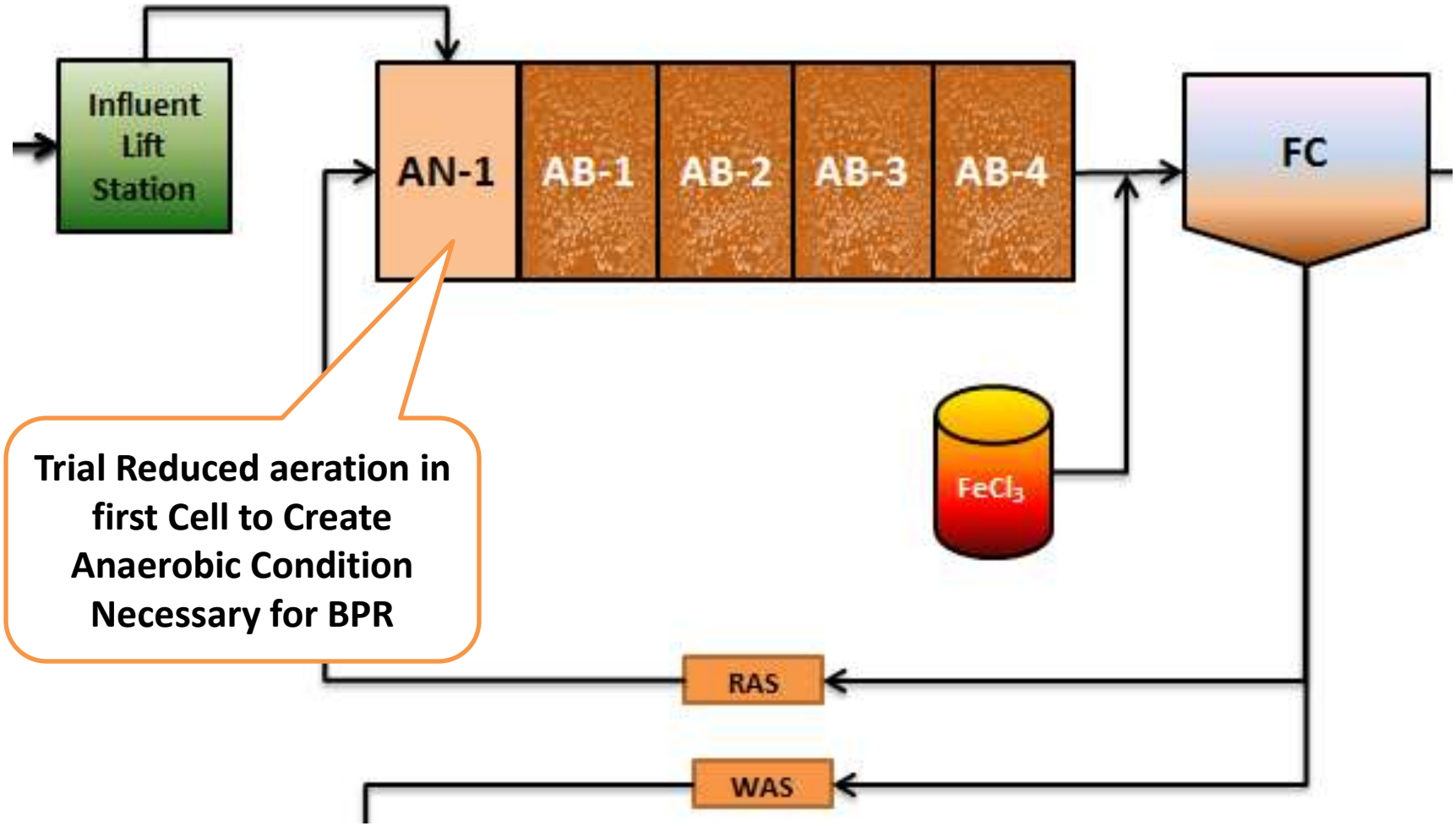


Design as Chemical Removal

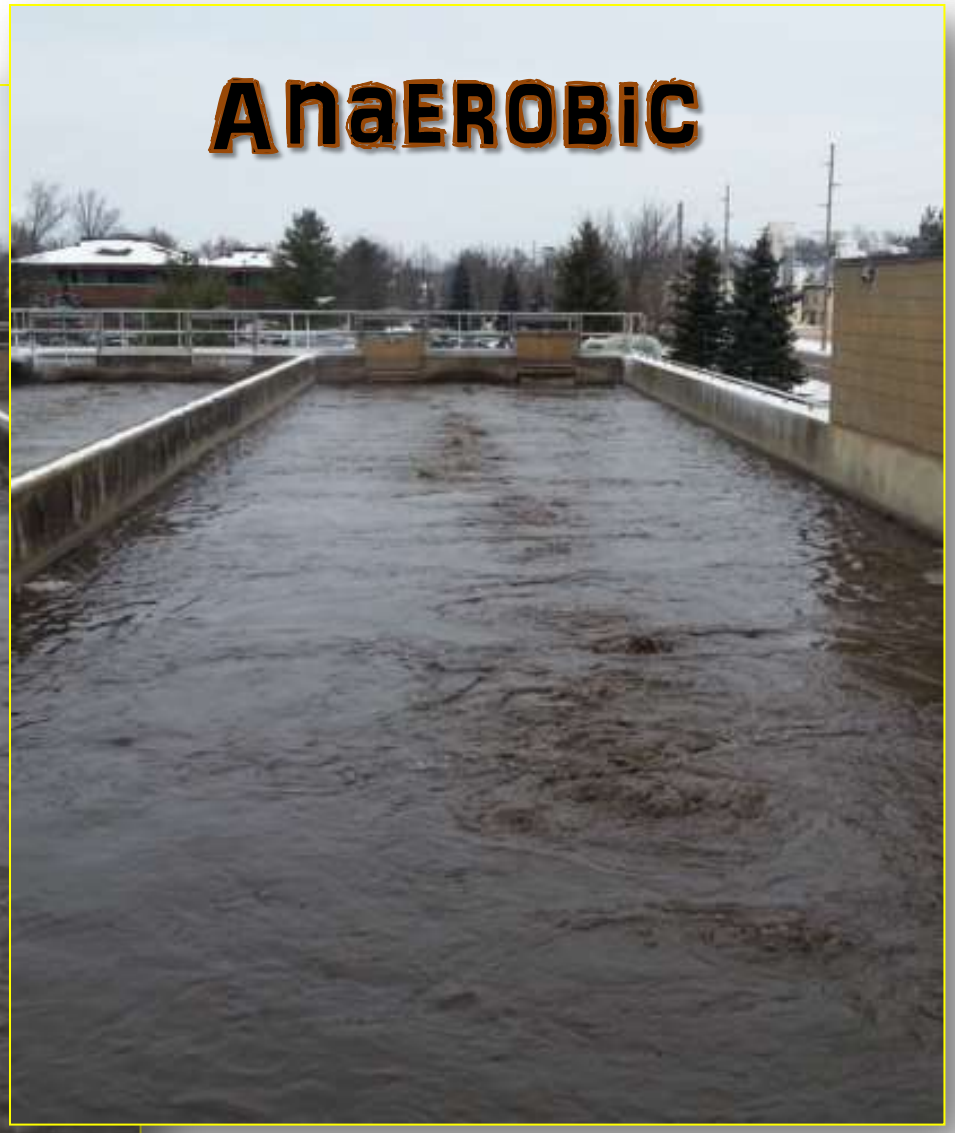
Ferric Chloride Performance/Effluent TP



Nutrient Removal Plan Suggestion




AEROBIC


AnaEROBIC

Improve Bio-P Performance by Getting to Know the System

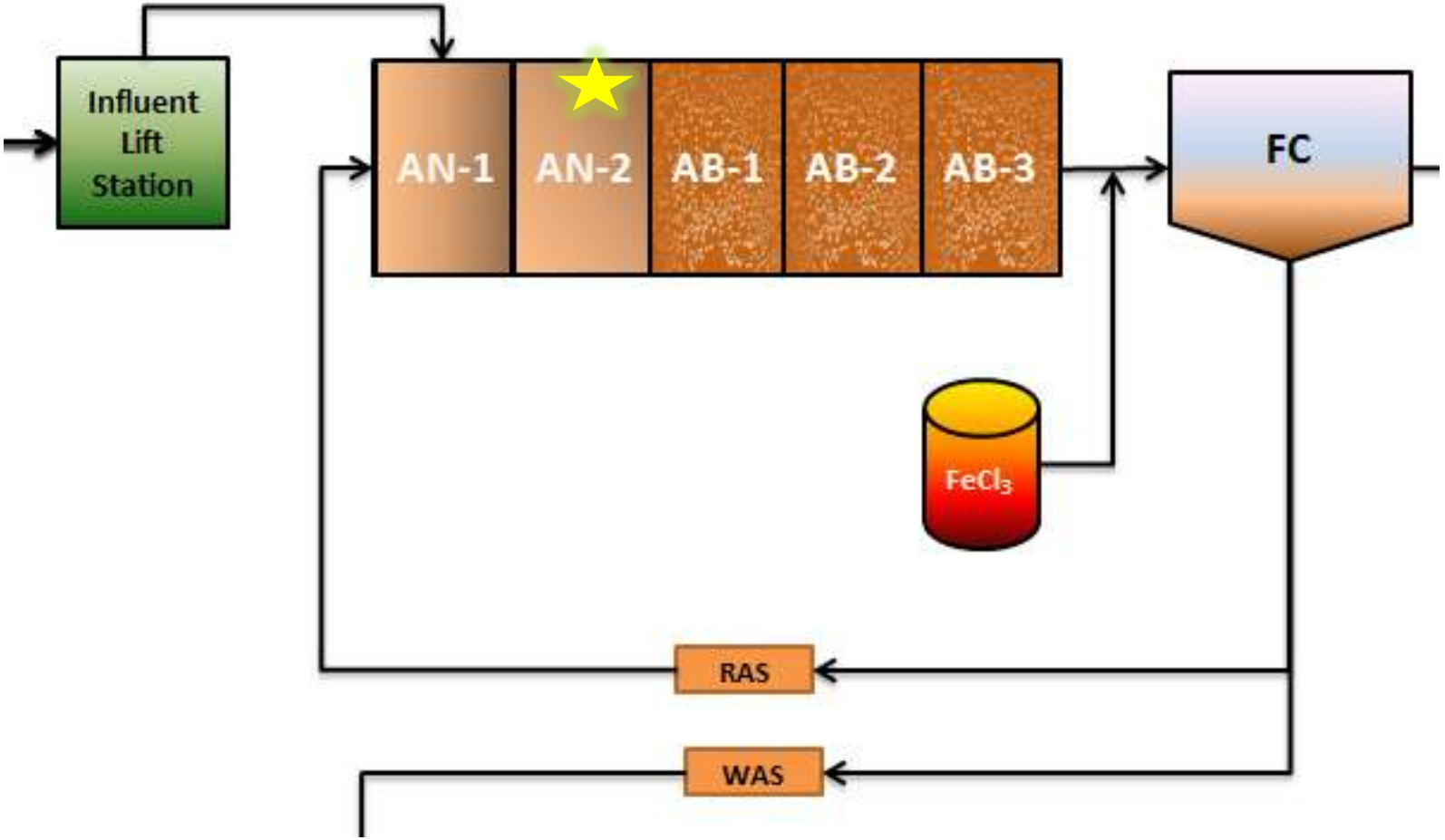
- Added online monitoring to better understand and track system performance
  - Soluble reactive phosphorus
  - ORP
  - D.O.

Eff. Ortho-P Online Analyzer

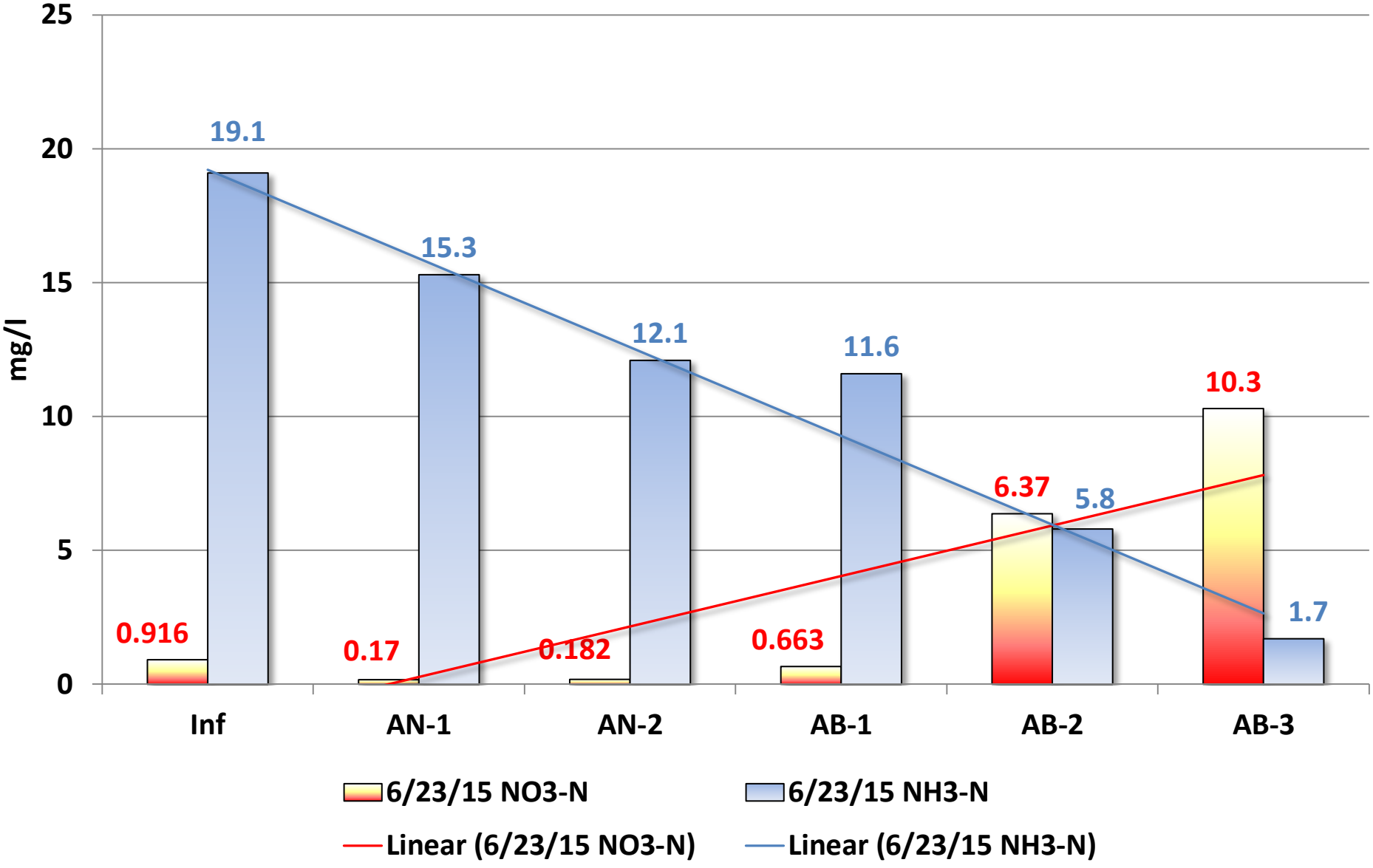
ORP Online Monitor

D.O. Online Monitor

Converted Cell #2 to Anaerobic Zone



NH_3-N/NO_3-N in System



Time Line

- Goal See if a EBPR System would work and then modify plant if it does
- Late Fall/Winter 2014 – Create anaerobic zone by turning air down in Cell #1
- Spring 2015 – Turned air down even farther to improve anaerobic zone performance
- Summer 2015 – Improve anaerobic zone performance more by extending to include two Cells 1&2

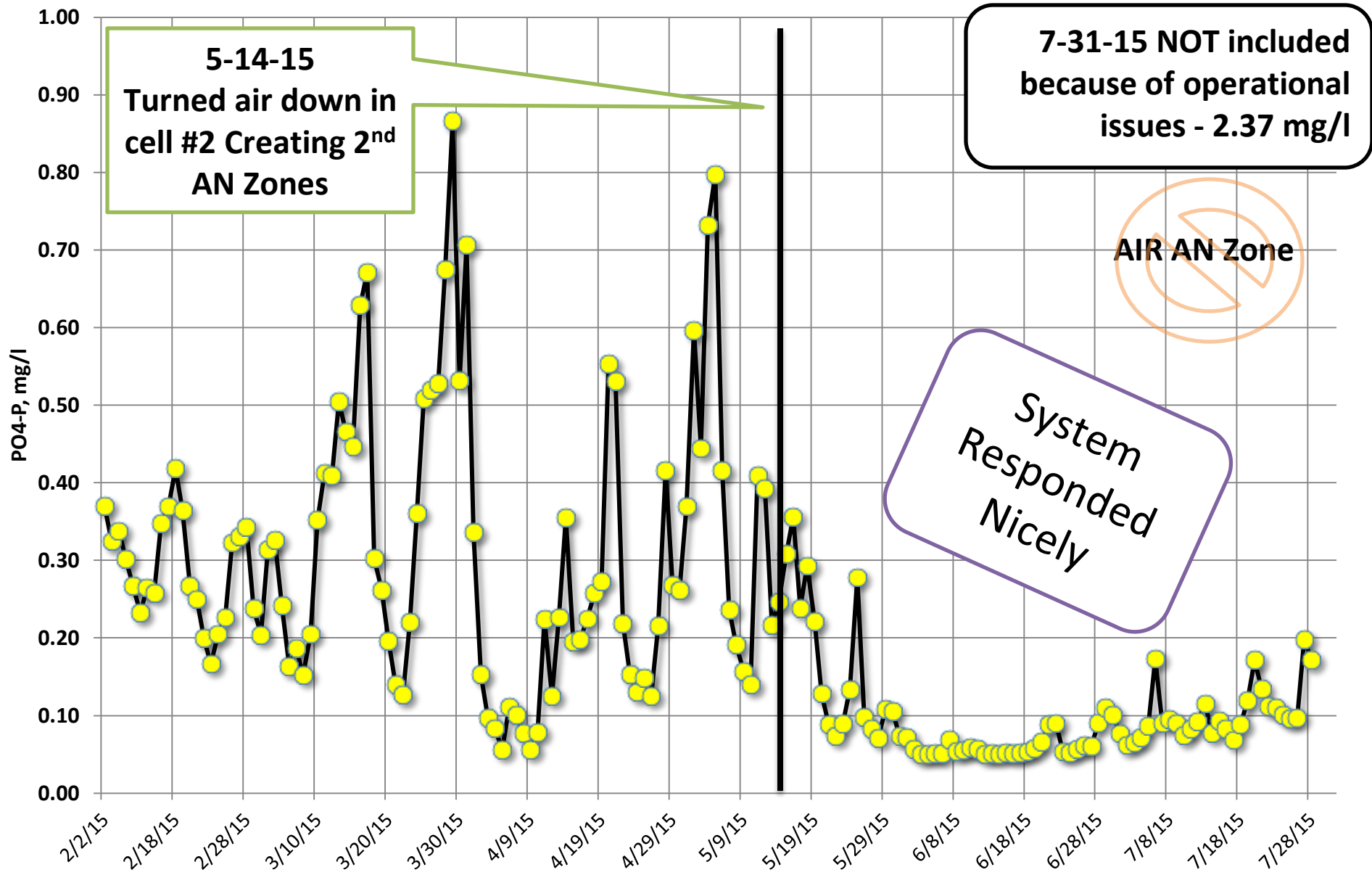
Time Line

- Late Summer early Fall 2015 reduced D.O. in aeration basins
- Fall 2015 reduced ferric
- Winter/Spring 2016 increased MLSS and reduced RAS flow
- Summer 2016 Industry changed production schedule, very little on weekends and most during the week – EBPR system lost performance

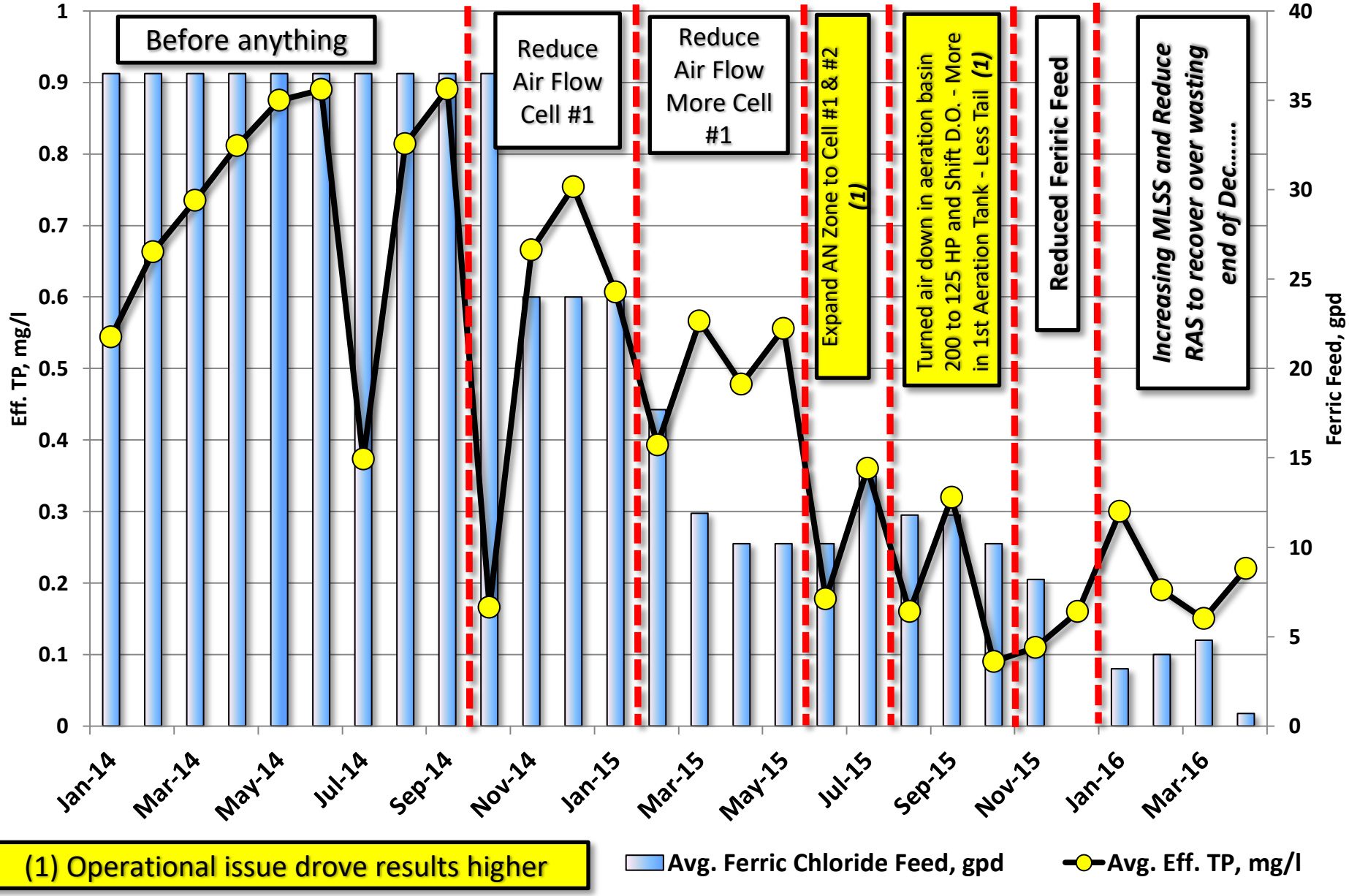
Time Line

- Late Summer early Fall prepping for installation of permanent anaerobic zone mixers in Cell #1
- Late Fall anaerobic zone mixers installation and startup
- Winter 2017 – Trialed feeding QLF as a sewage substitute on the weekends when the industrial loadings are very low
- Winter/Spring 2017 - Learned about clarifier seal leaks and how they impact EBPR
- Spring 2017 - Learned about the impact of accepting cooperative molasses waste
- Spring/Summer 2017 - Worked at recovering from the impacts of the molasses

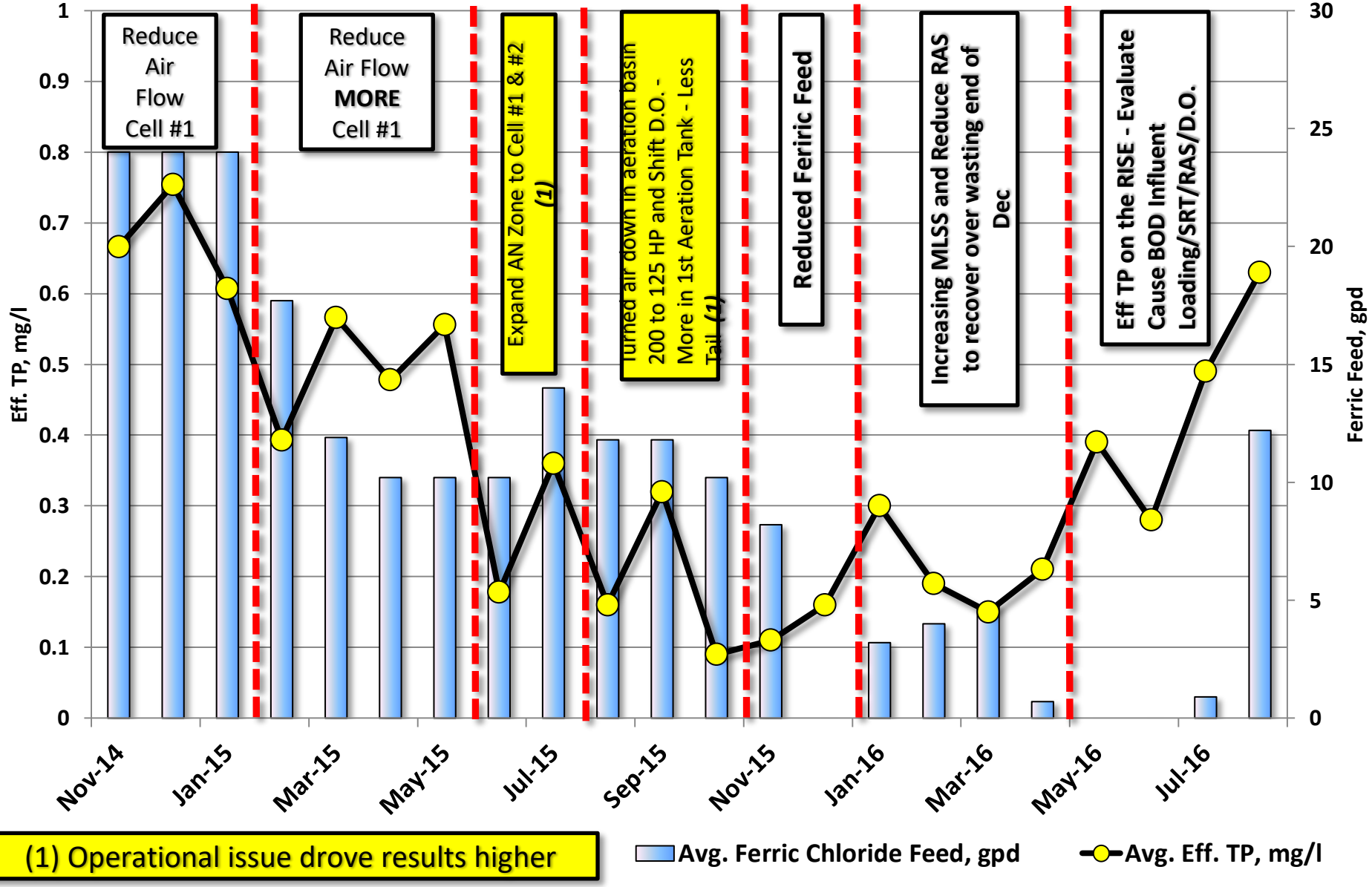
Effluent PO_4-P Inline Analyzer - Daily Avg
Unit Samples Every 15 minutes (94 times/day)



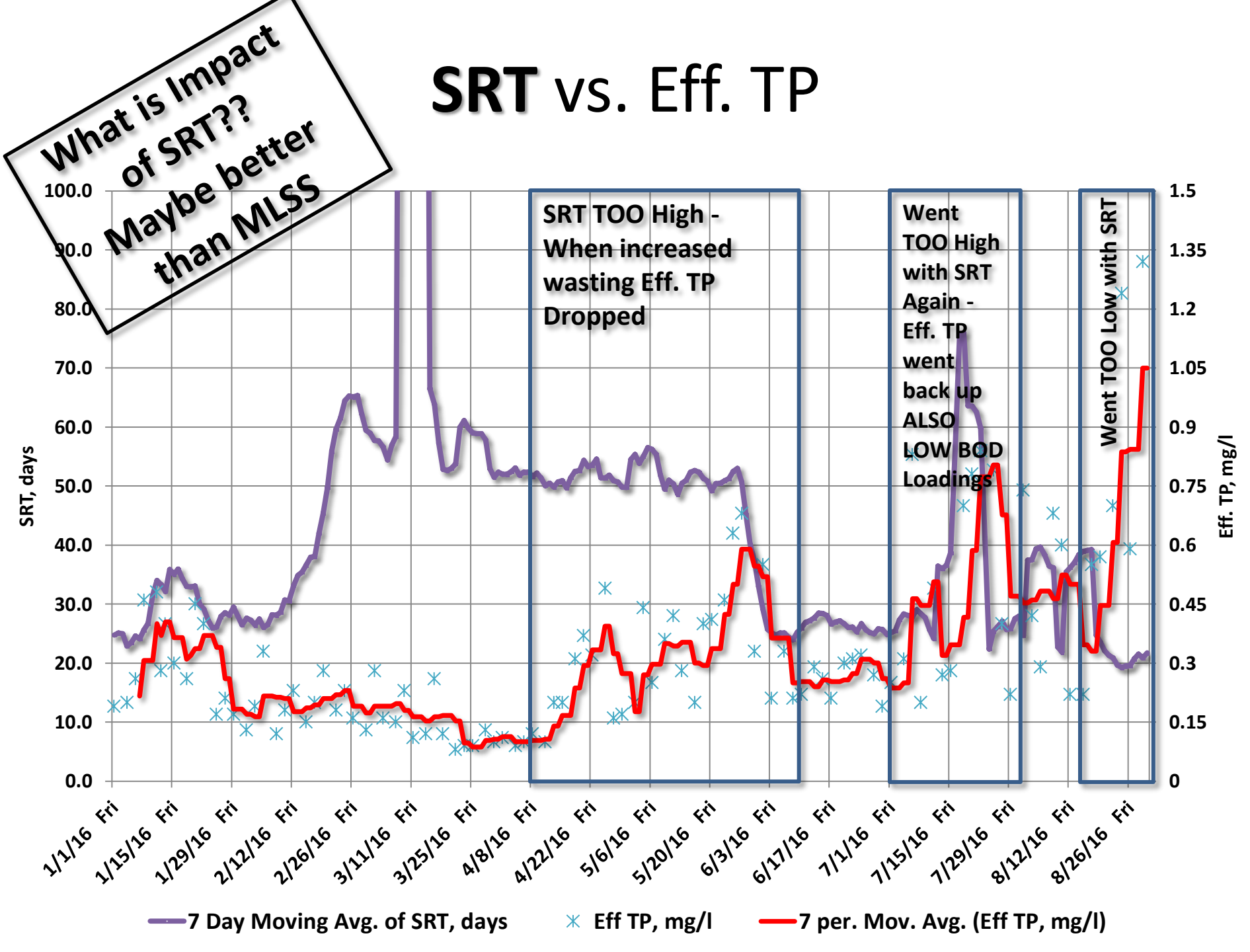
Results – MLSS/RAS Control



Results of Declining Inf. BOD

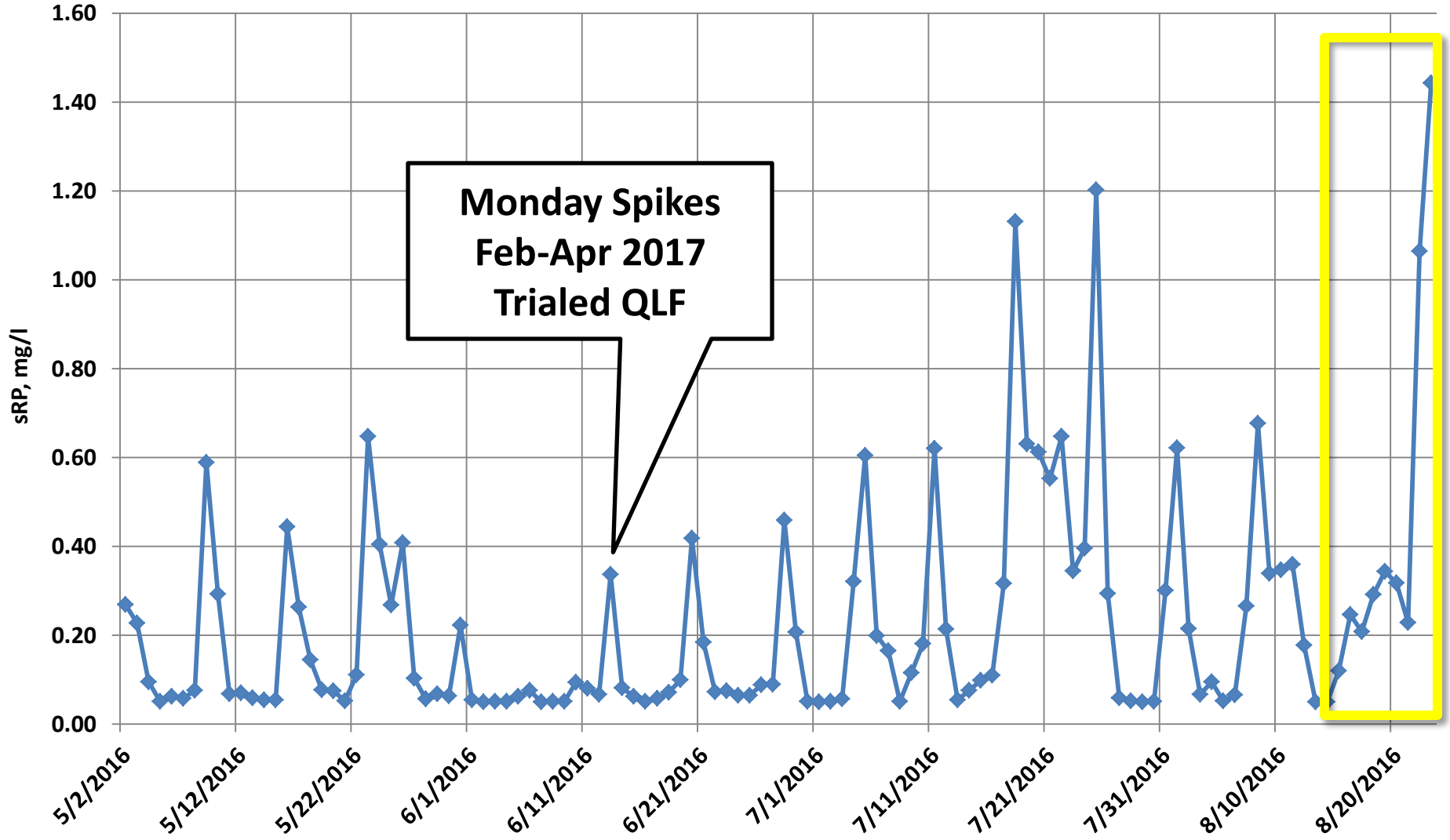


SRT vs. Eff. TP

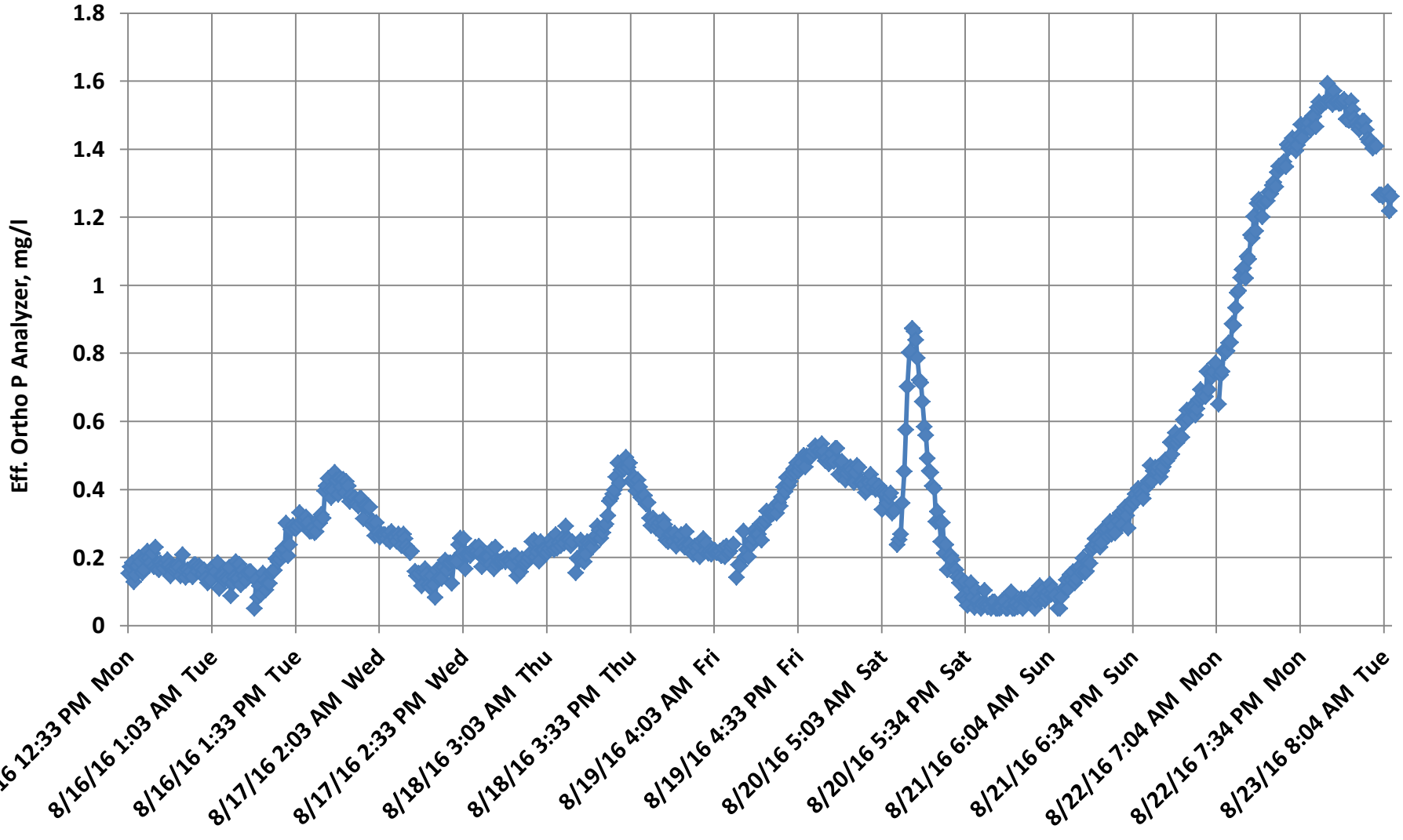

What is Impact of SRT?? Maybe better than MLSS
SRT TOO High - When increased wasting Eff. TP Dropped
Went TOO High with SRT Again - Eff. TP went back up ALSO LOW BOD Loadings
Went TOO Low with SRT
SRT, days
Eff. TP, mg/l
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1.5
1.35
1.2
1.05
0.9
0.75
0.6
0.45
0.3
0.15
0
1/1/16 Fri
1/15/16 Fri
1/29/16 Fri
2/12/16 Fri
2/26/16 Fri
3/11/16 Fri
3/25/16 Fri
4/8/16 Fri
4/22/16 Fri
5/6/16 Fri
5/20/16 Fri
6/3/16 Fri
6/17/16 Fri
7/1/16 Fri
7/15/16 Fri
7/29/16 Fri
8/12/16 Fri
8/26/16 Fri
7 Day Moving Avg. of SRT, days
Eff TP, mg/l
7 per. Mov. Avg. (Eff TP, mg/l)

Spiking Soluble Reactive P

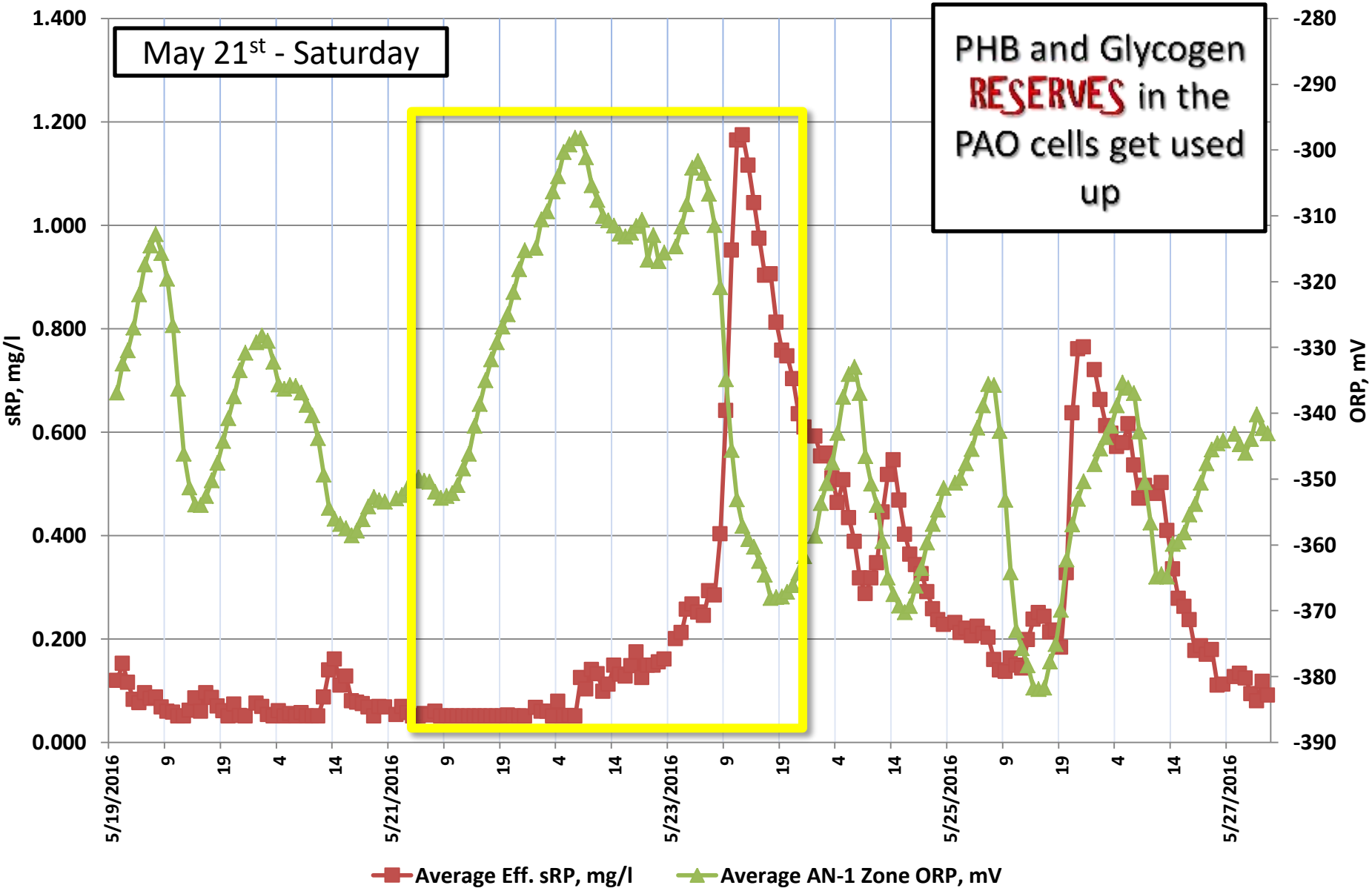
Eff. Analyzer Daily Average

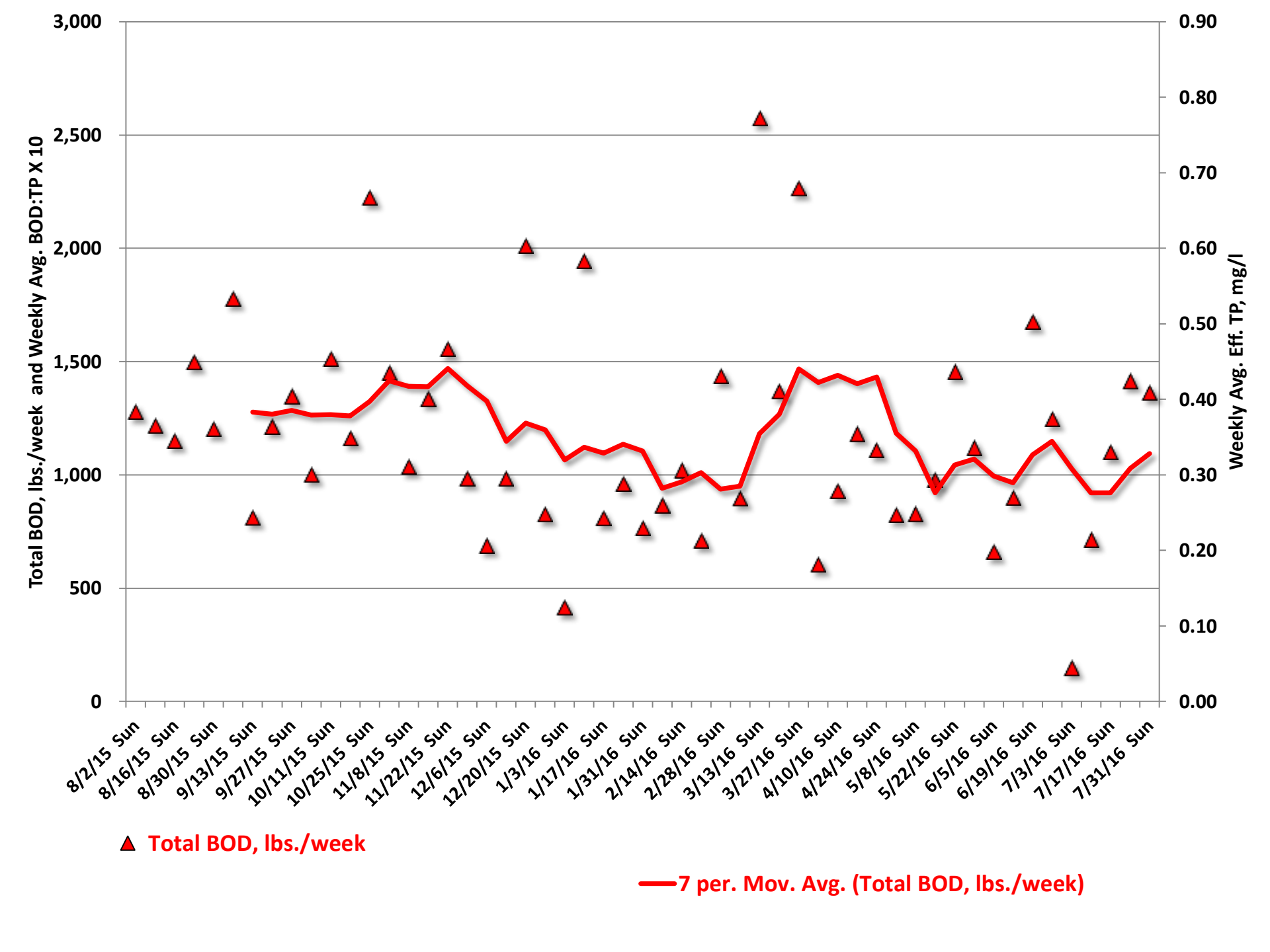


Close up – Beginning of the Week And Daily Spiking



AN-1 Zone ORP vs. Eff. sRP - Hourly

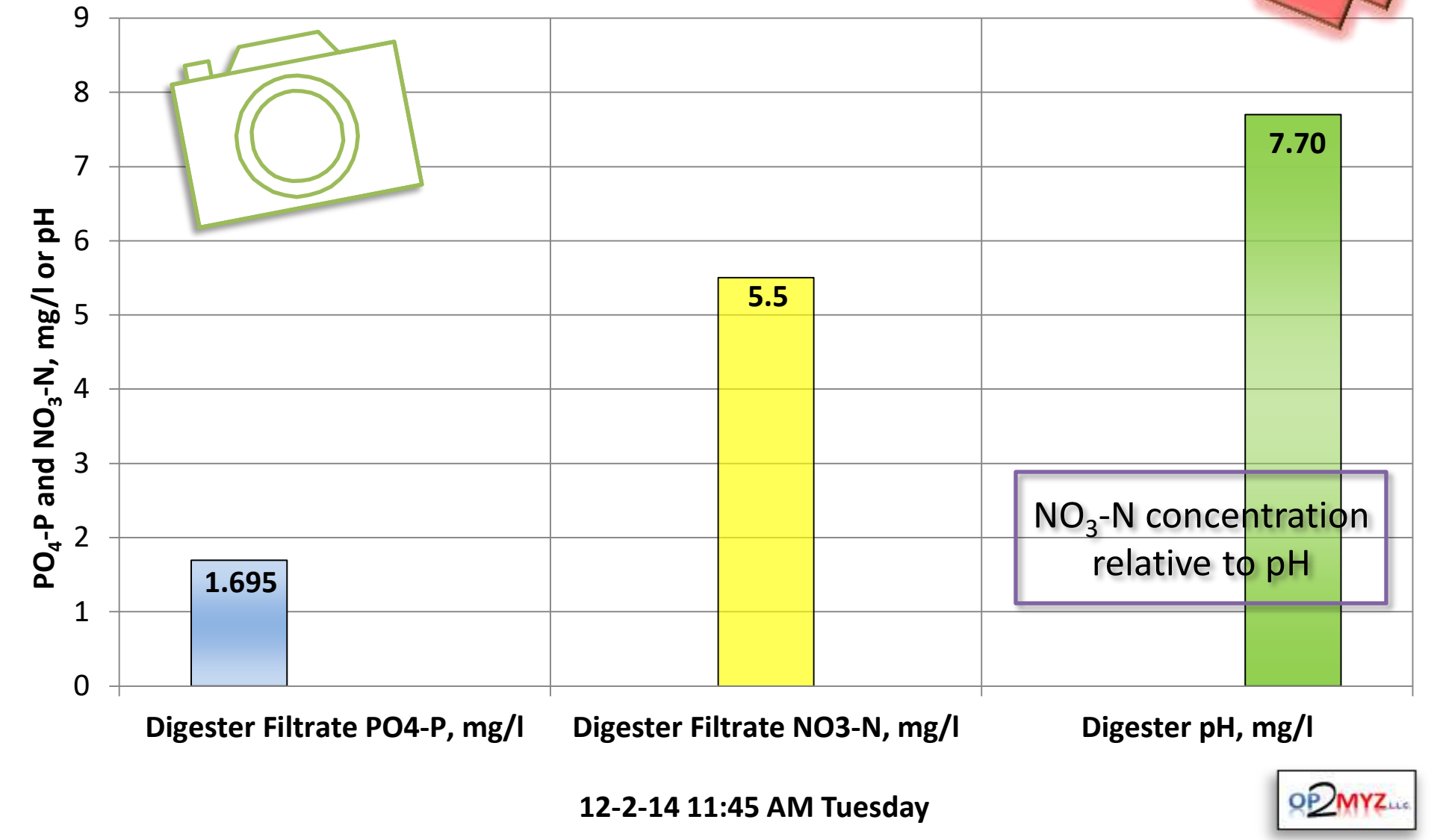



Total BOD, lbs./week and Weekly Avg. BOD:TP X 10
Weekly Avg. Eff. TP, mg/l
3,000
2,500
2,000
1,500
1,000
500
0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
8/2/15 Sun
8/16/15 Sun
8/30/15 Sun
9/13/15 Sun
9/27/15 Sun
10/11/15 Sun
10/25/15 Sun
11/8/15 Sun
11/22/15 Sun
12/6/15 Sun
12/20/15 Sun
1/3/16 Sun
1/17/16 Sun
1/31/16 Sun
2/14/16 Sun
2/28/16 Sun
3/13/16 Sun
3/27/16 Sun
4/10/16 Sun
4/24/16 Sun
5/8/16 Sun
5/22/16 Sun
6/5/16 Sun
6/19/16 Sun
7/3/16 Sun
7/17/16 Sun
7/31/16 Sun
Total BOD, lbs./week
7 per. Mov. Avg. (Total BOD, lbs./week)

Recycle Side Streams

- Low N & P in side stream
  - Unusual – but VERY helpful for BPR
- Why?
  - Well operated aerobic digesters
- NOTE - Heavy Industrial BOD during the dayshift offsets side stream impact

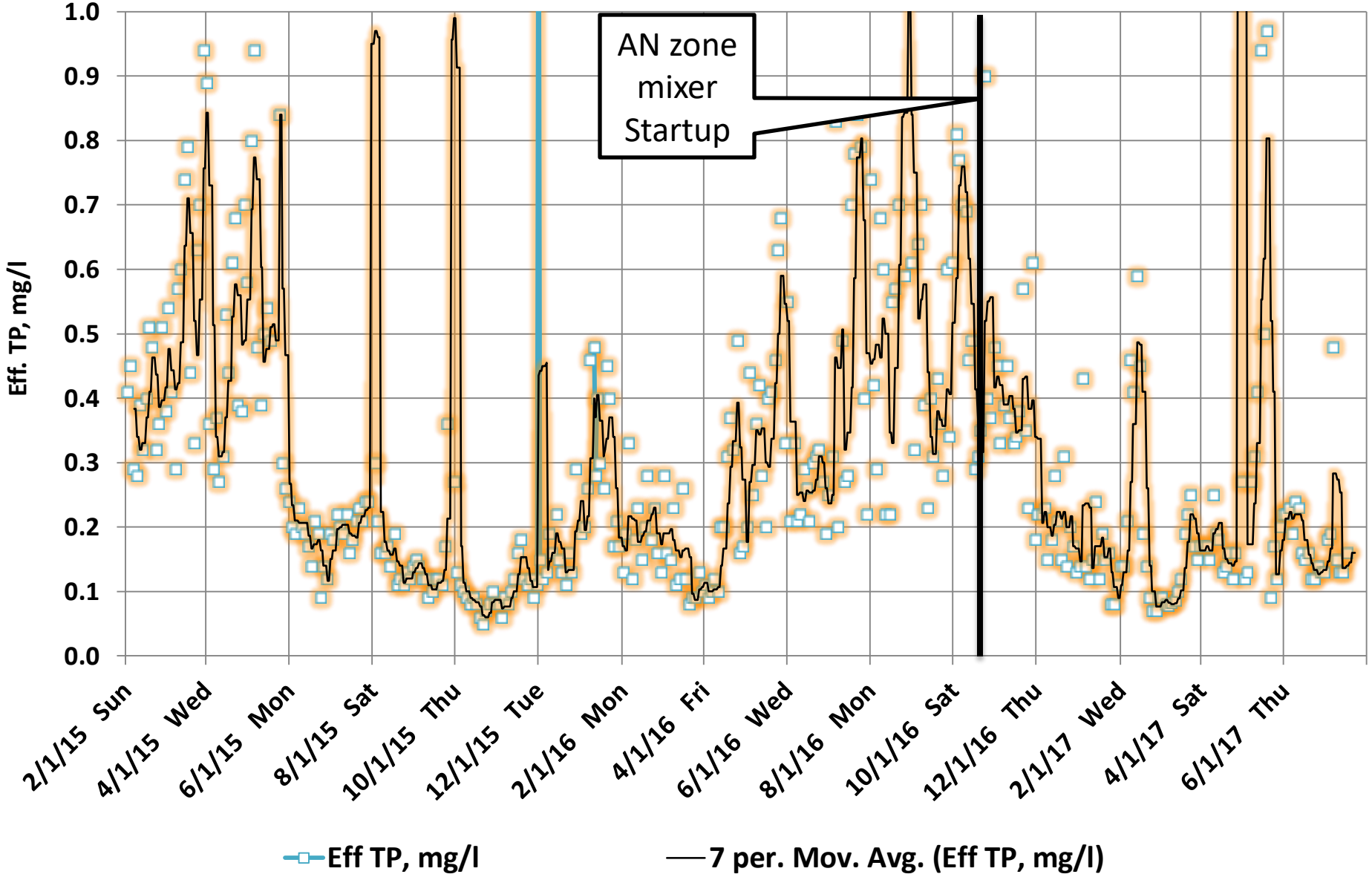
Side Stream - Aerobic Digester



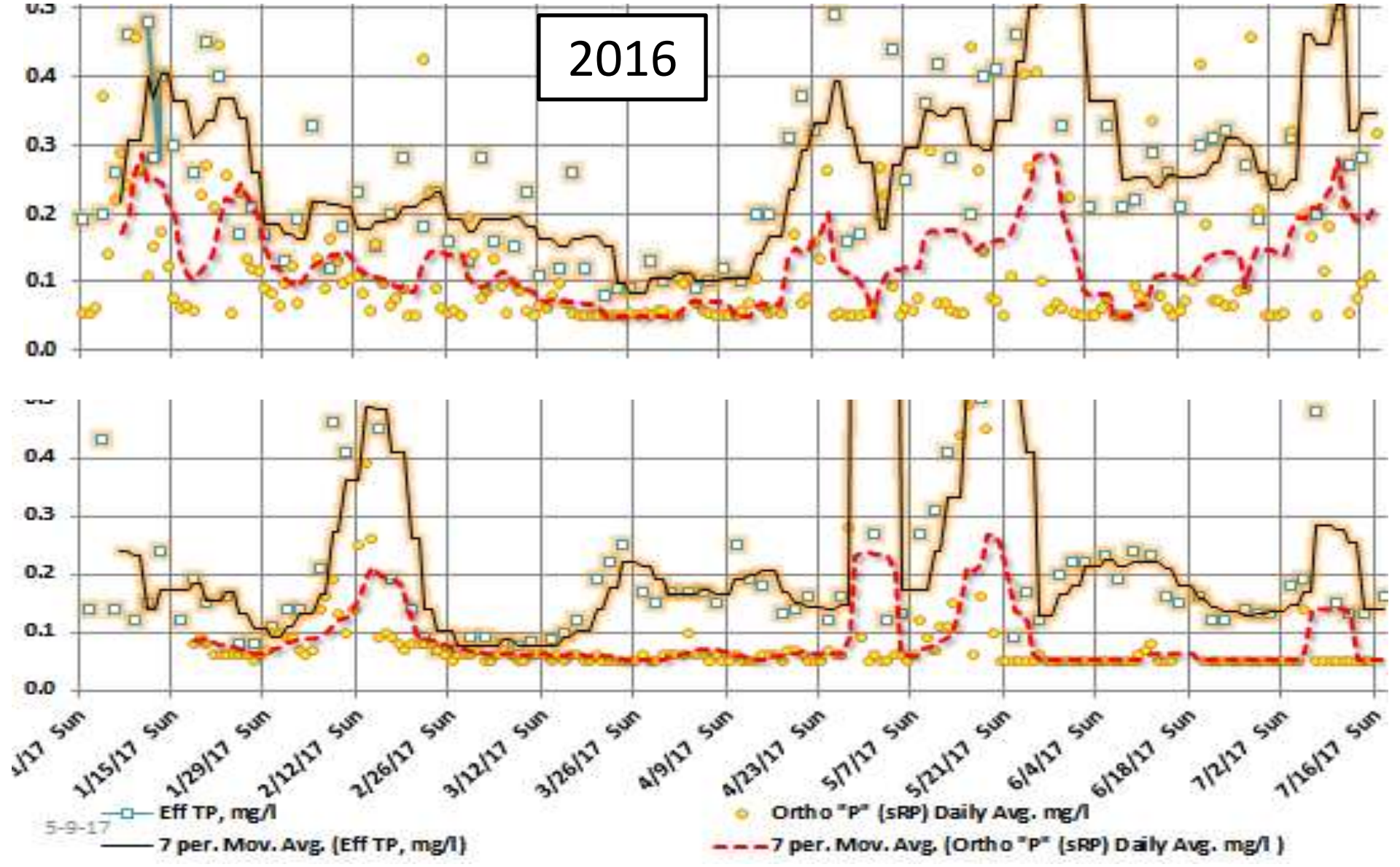
12-2-14 11:45 AM Tuesday

New Anaerobic Zone Mixers
October 2016

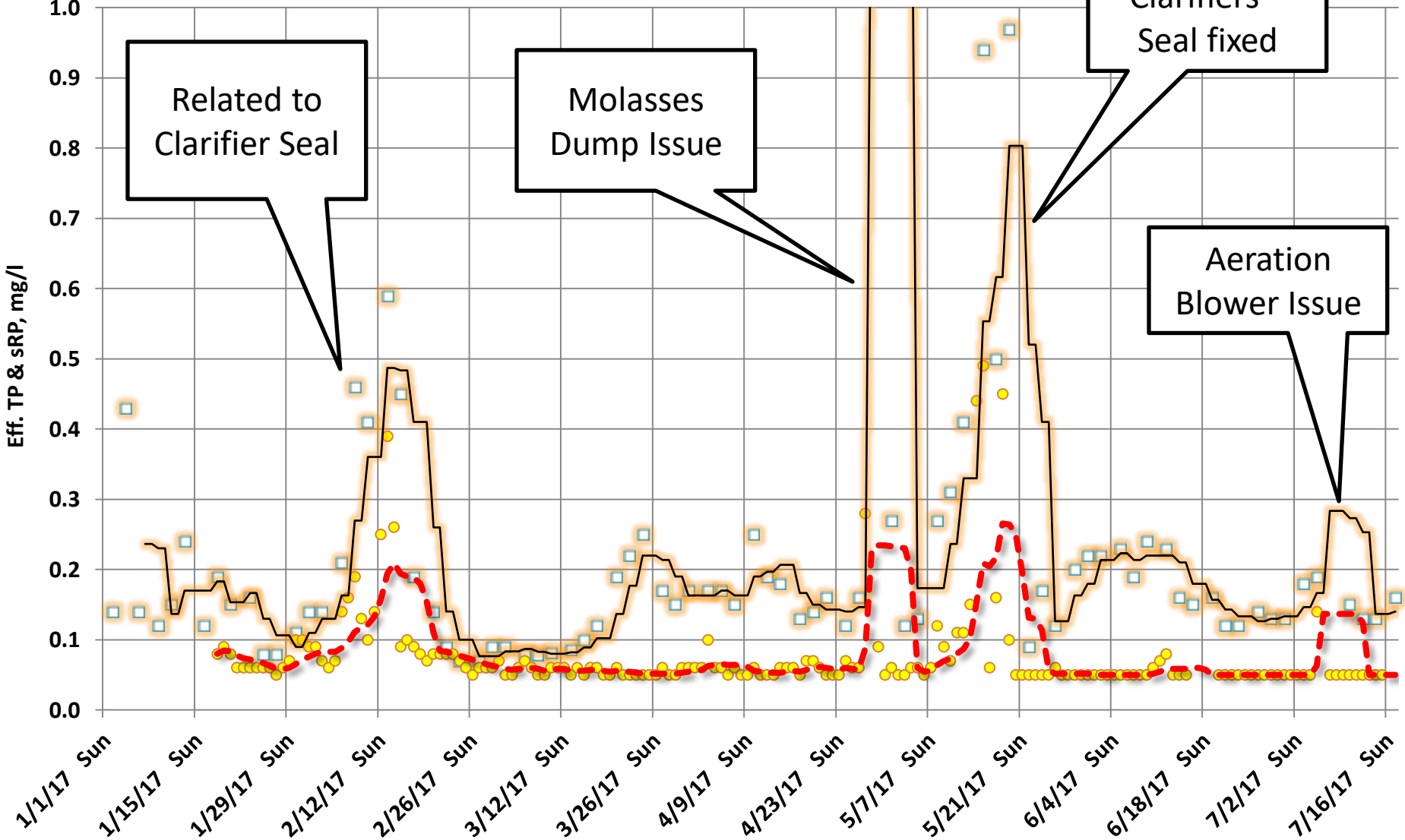
Eff. TP - Feb ‘15 to June 17’



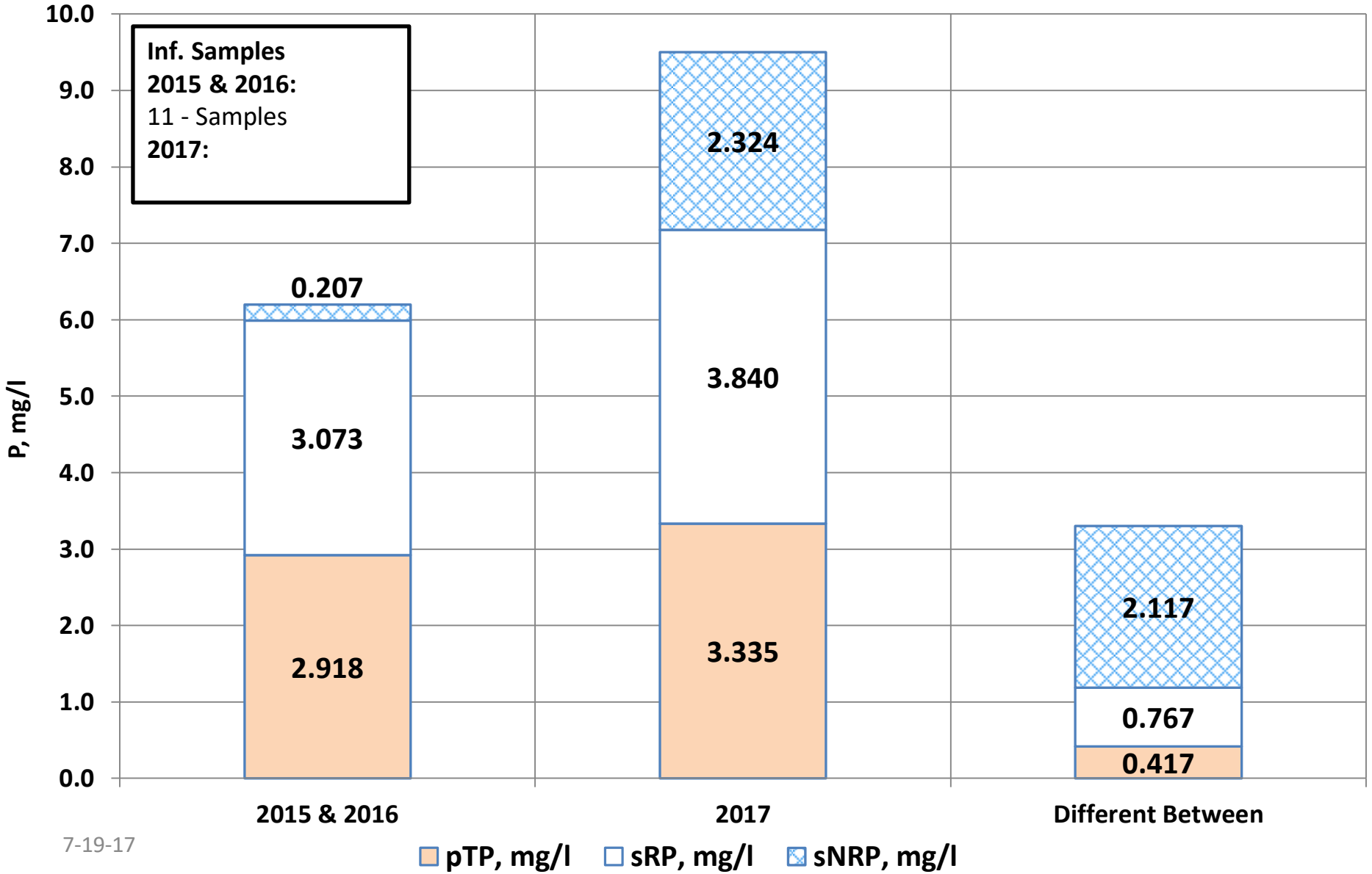
BNR Performance - 1st 7 Month 2016/2017



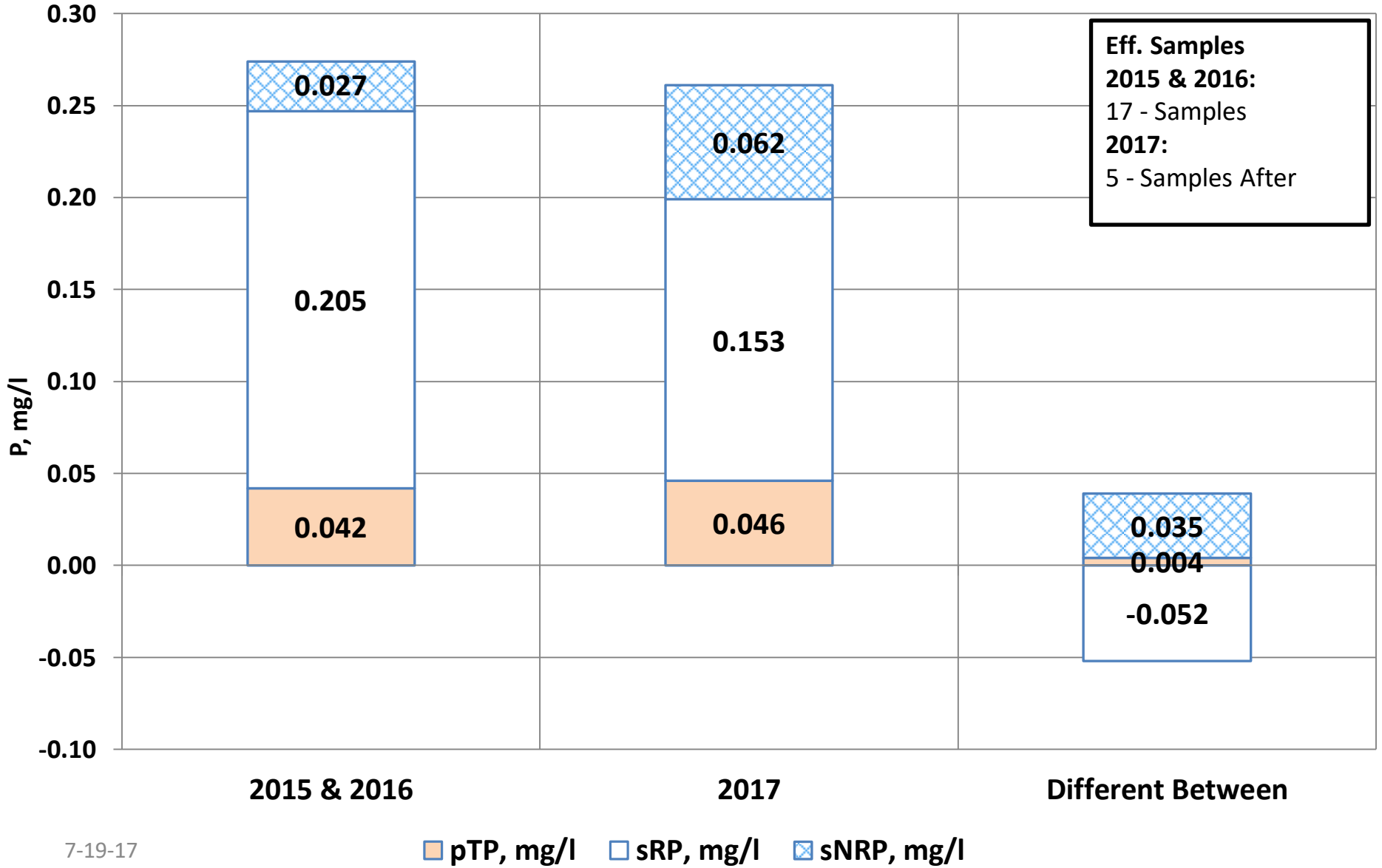
BNR Performance - 2017



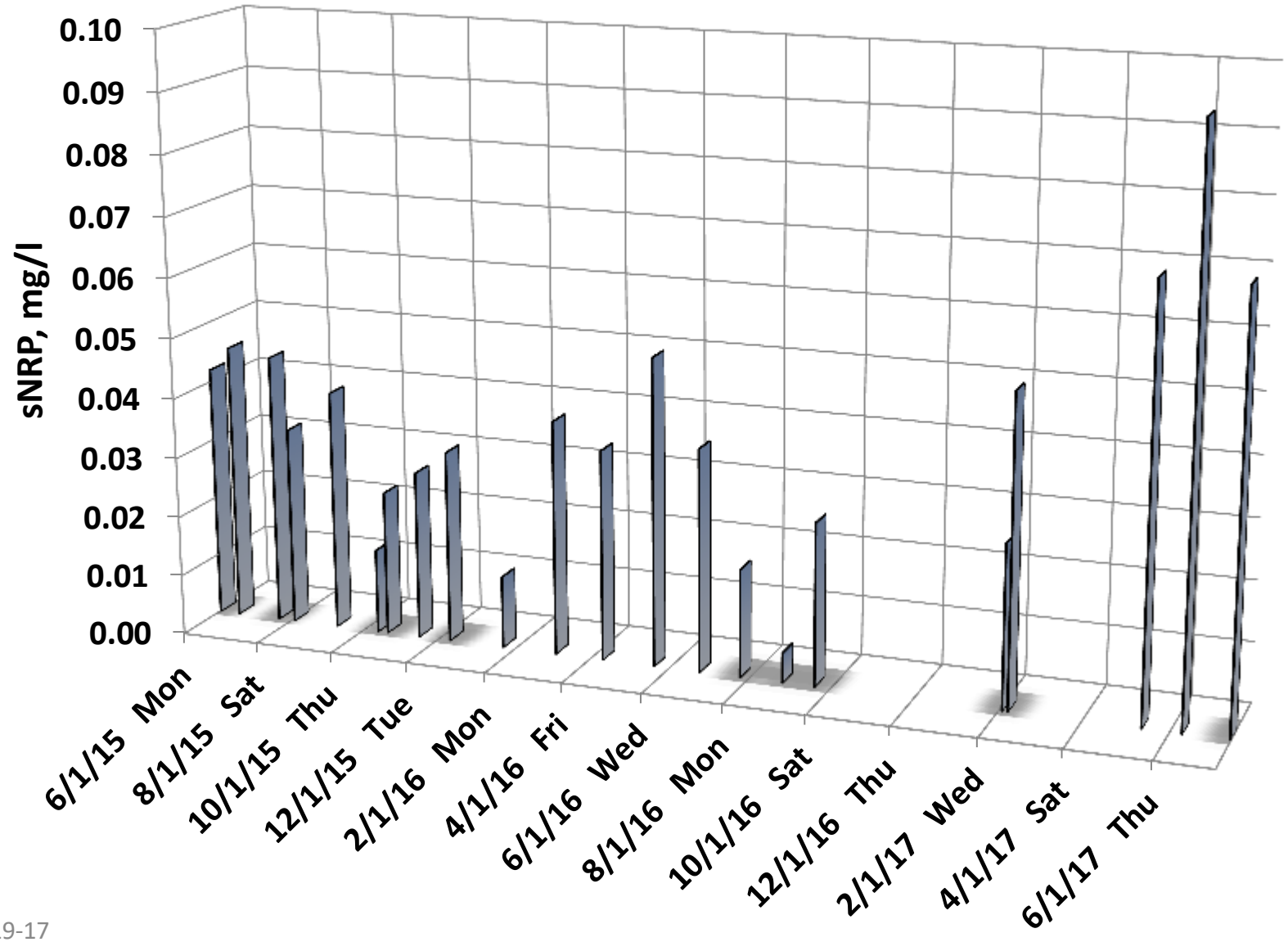
Fractions of P – Avg. **Inf.** 2015 & 2016 Compared to 2017



Fractions of P – Avg. **Eff.** 2015 & 2016 Compared to 2017



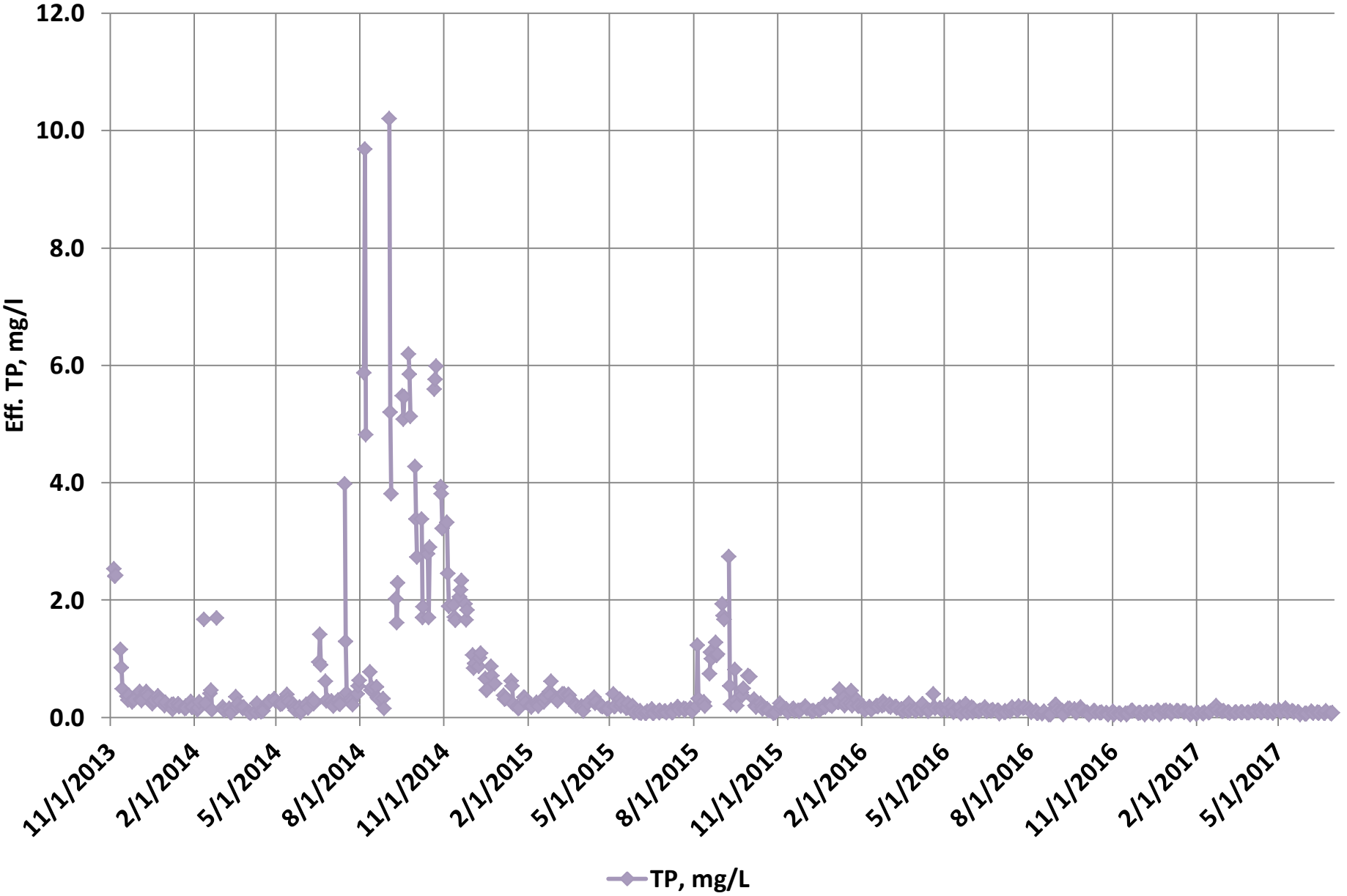
Fractions of P – sNRP Increase



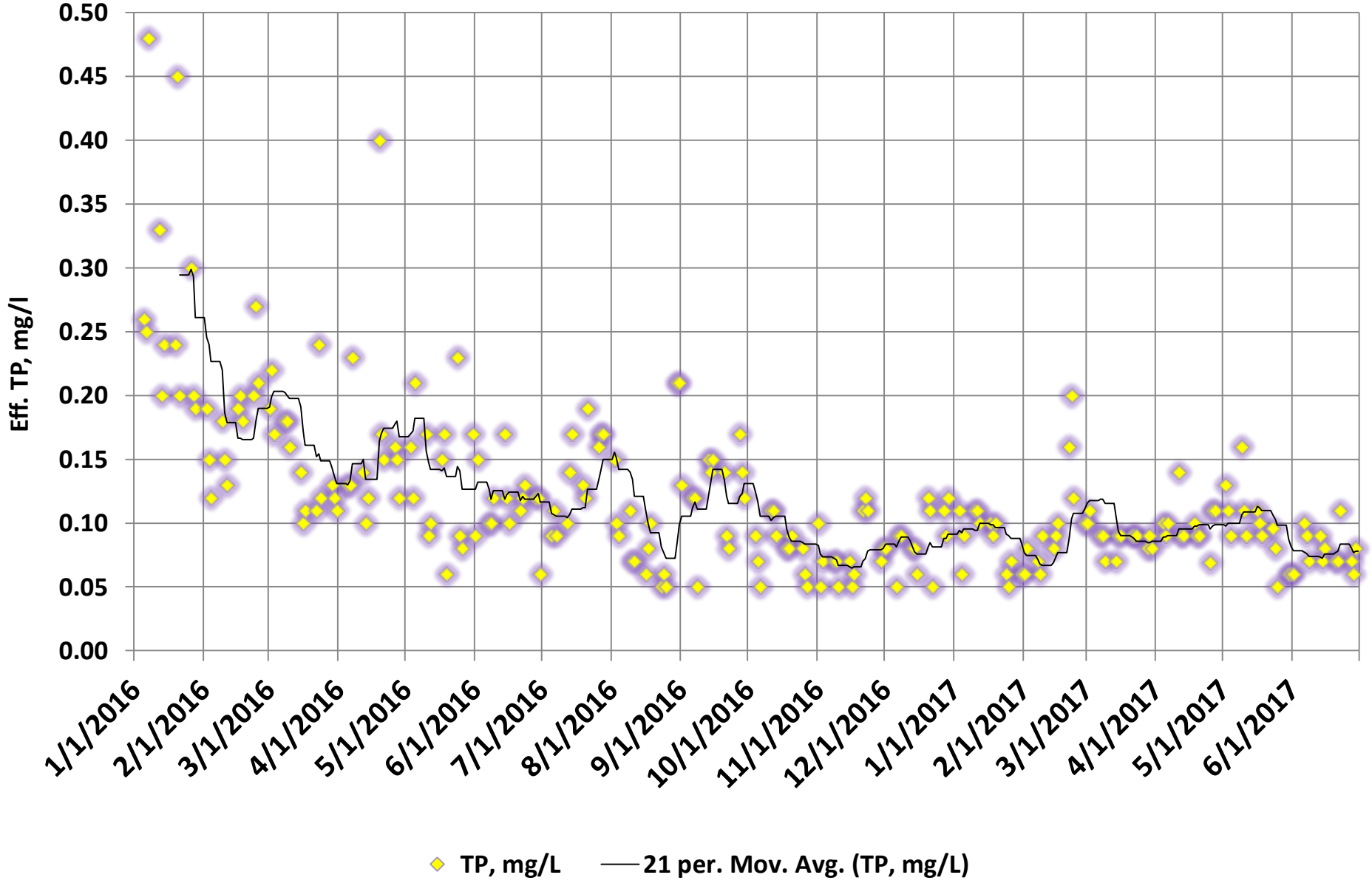
Where to go from here?

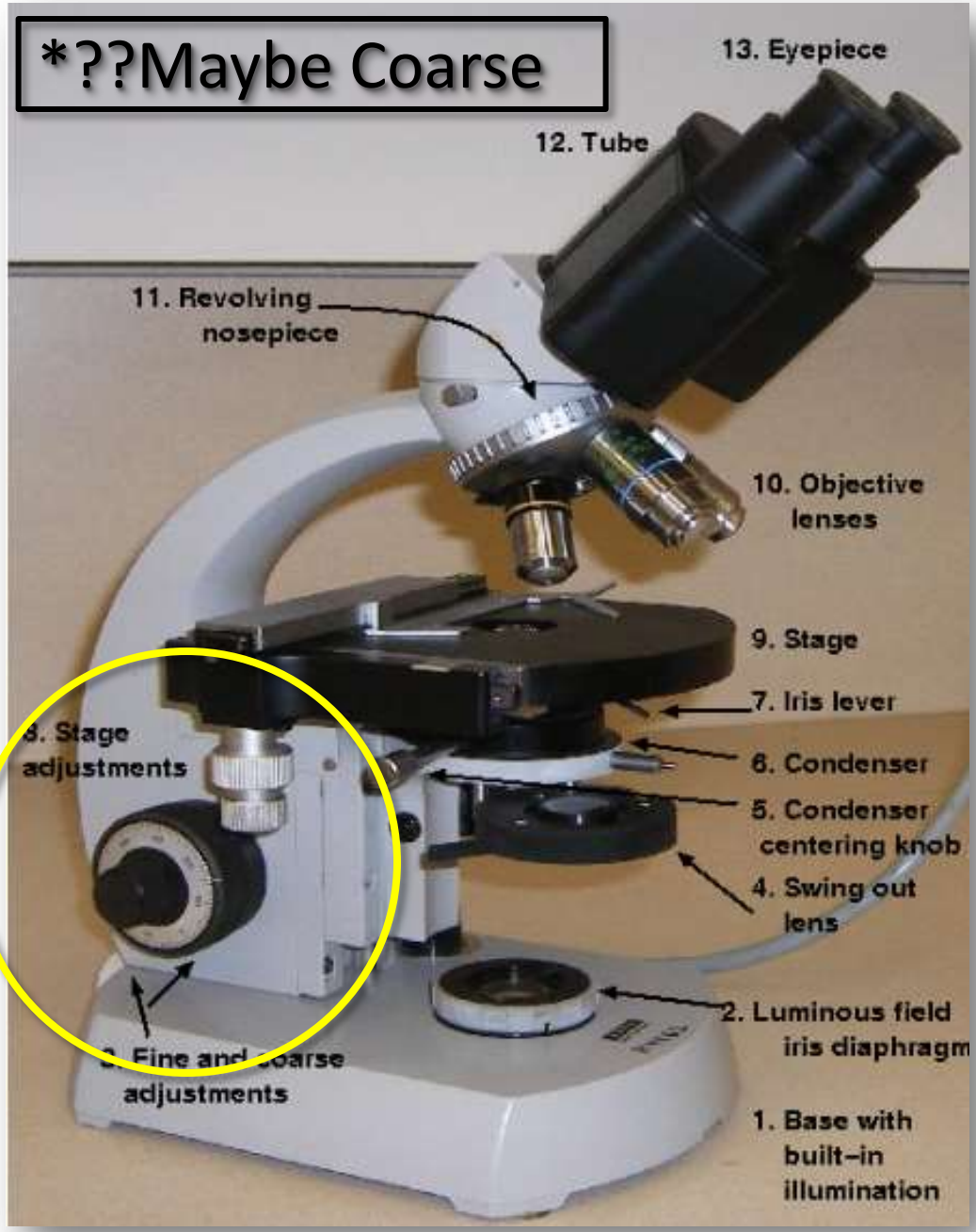
- Investigate/confirm/fix sNRP increase
- Investigating constant low dose QLF vs. just weekends
- Investigate alkalinity of system
- Decide whether to have a second Anaerobic Zone
- Looking at possible eff. filter upgrade
- Possible future blower/diffuser upgrade, including D.O. control – will help improve/stabilize P uptake and eff. TP

What is the Goal?



What is the Goal?





Fine & Coarse Adjustment

EBPR ADJUSTMENTS

Coarse Control:

BOD:TP

Truly Anaerobic

Inline Fermentation

Fine Control:

SRT*/RAS/D.O.

Work in progress

Concluding Thoughts

- BOD(VFAs) are ESSENTIAL to achieving very low level of effluent sRP
- Can inline fermentation produce enough VFAs to overcome limited influent BOD?
- Remember – this is an EXTENDED AERATION system not CONVENTIONAL ACTIVATED SLUDGE system.
- RAS/D.O./SRT Play their Role
- Optimization **tactics** will **change** somewhat with mixers in anaerobic zone vs. inefficient & minimal controllable air mixing

P.S. - Medford's Big Advantages in Converting to BPR

- Long **narrow** tanks
- **High** Industrial **BOD** loadings
- **Coarse** bubble diffusers – (Temp An Zone)
- Very friendly **side streams** – low in N & P

THANK YOU

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