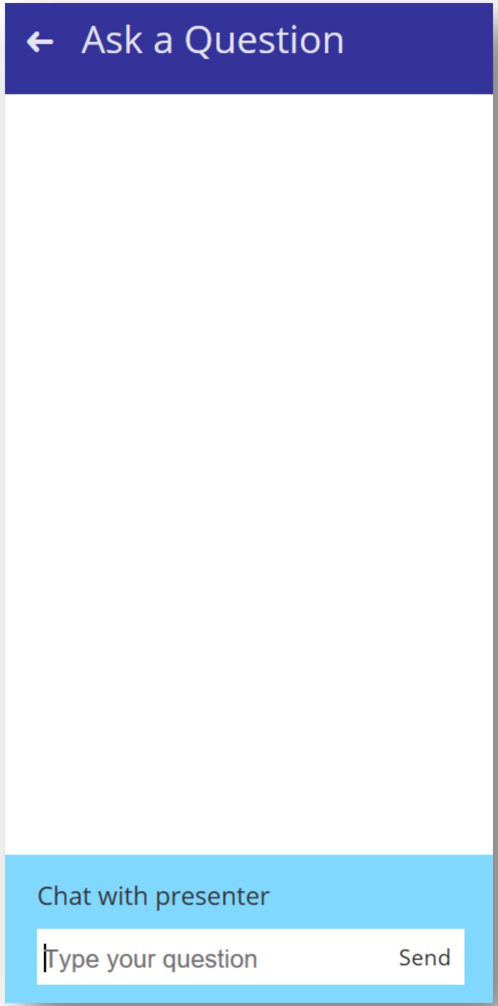
Potable Reuse Using Ozone-Biofiltration

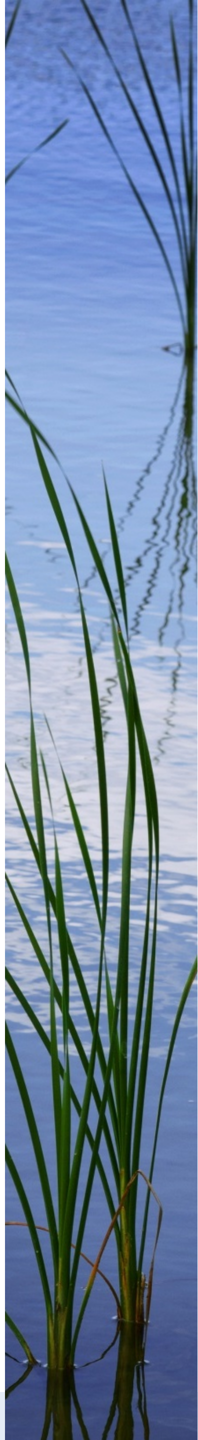
September 26, 2018

WateReuse Webcast Series

A Few Notes Before We Start…

- Today's webcast will be 90 minutes.
- A PDF of today's presentation can be downloaded when you complete the survey at the conclusion of this webcast.
- If you have questions for the presenters please send a message by typing it into the chat box located on the panel on the left side of your screen.





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Today's Presenters

Melissa Meeker
Water Innovation Center
Development Director
Gwinnett County
Water Resources

Denise Funk
Director of Research
Gwinnett County
Water Resources

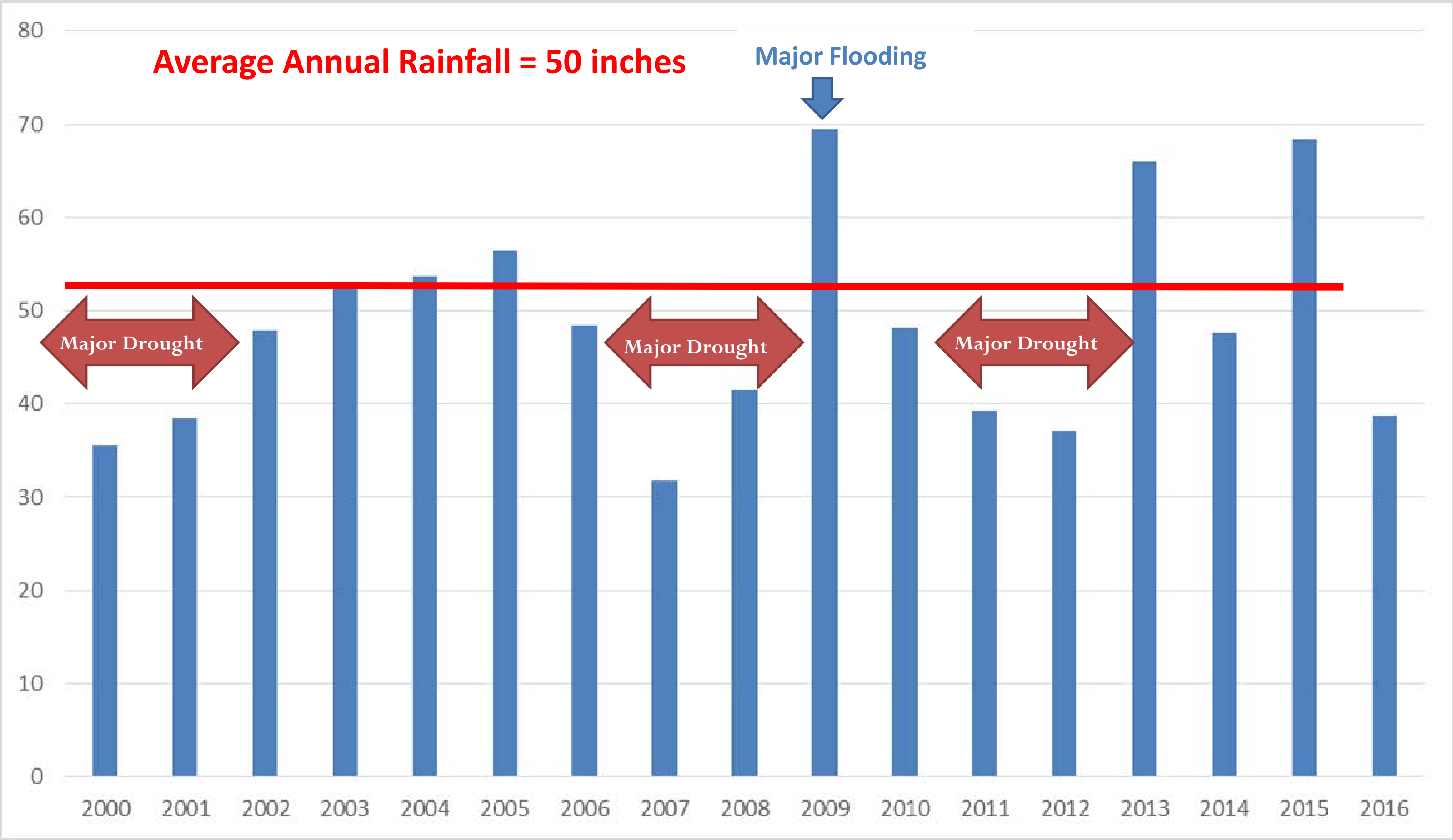
Kati Bell
Director of Water Strategy
Brown and Caldwell

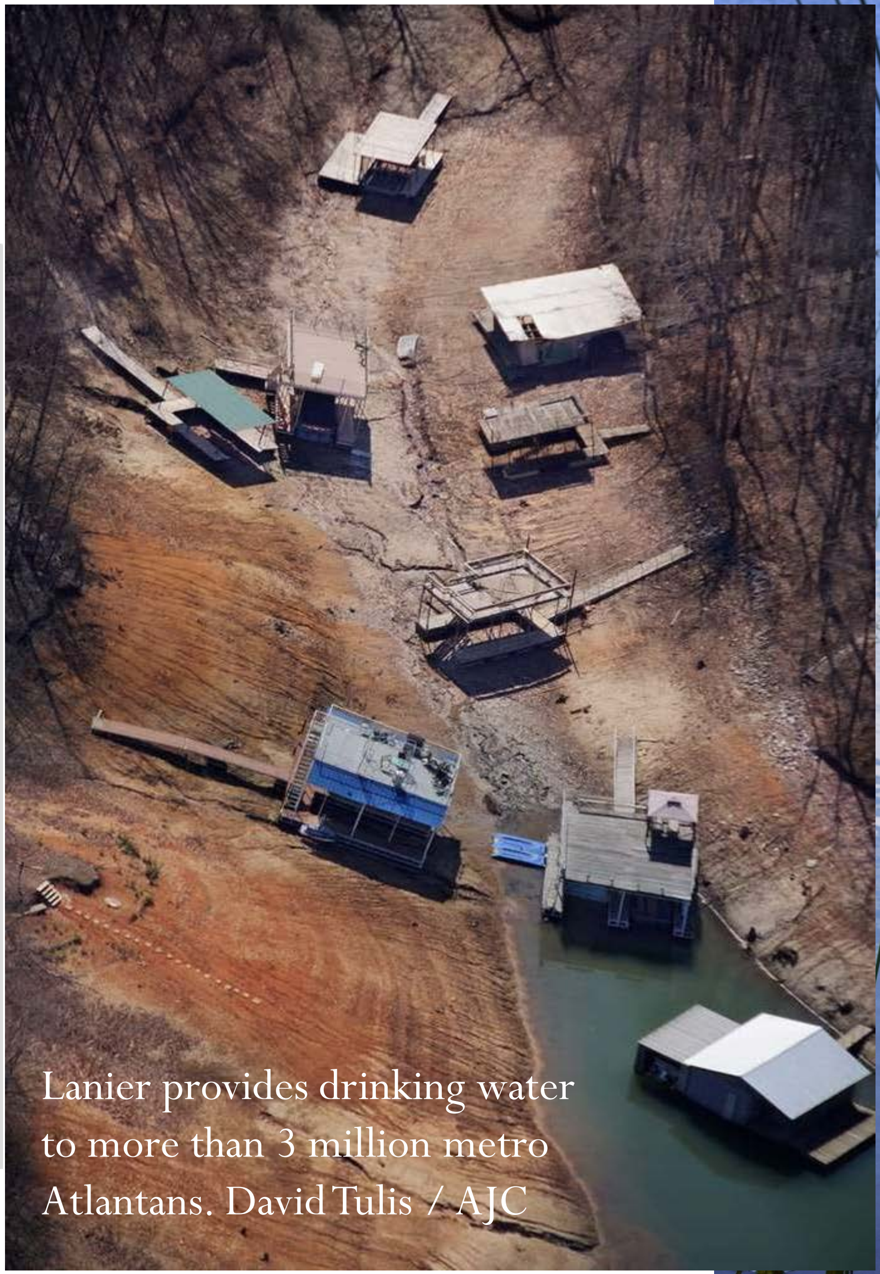
Jennifer Hooper
Senior Environmental Engineer
CDM Smith

Presentation Overview

- Background and Context
- Study Approach
- Research Results
- Cost Comparisons
- Key Findings and Conclusions
- Question and Answer Session

Averages Can Be Misleading





Lanier provides drinking water to more than 3 million metro Atlantans. David Tulis / AJC

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Competition for Water

- ACF Basin goes through three states
- Multiple uses including:
  - Power Generation
  - Drinking Water
  - Navigation
  - Recreation
  - Ecology
  - Fisheries and Agriculture
- 4.2 million people in Atlanta rely on water from the ACF Basin (72% of metro-Atlanta)
- Tri-state water wars ongoing since 1990

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Gwinnett County Pipes

Water Distribution System

3,800 miles

Sewer Collection System

3,000 miles

Storm Water System

1,500 miles

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Gwinnett County Pipes

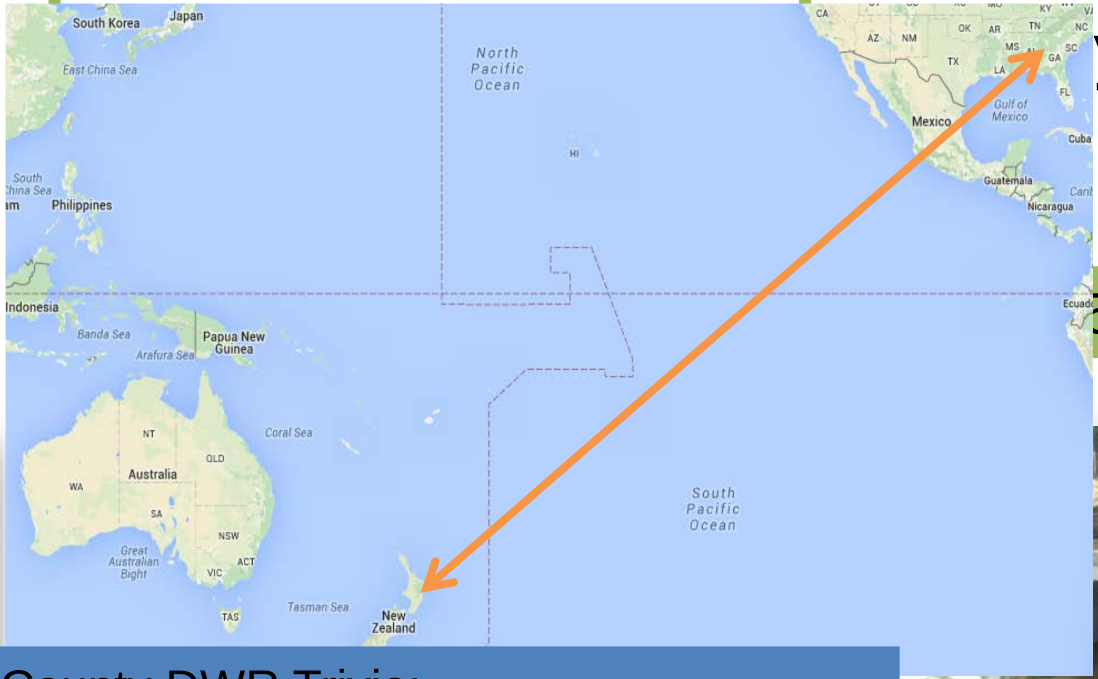
Water Distribution System

3,800 miles

Sewer

Storm Water ystem

500 miles



Gwinnett County DWR Trivia:
End to end all the pipes in Gwinnett County would stretch from Georgia to New Zealand

Gwinnett County Facilities

Water Production

Two Facilities
150 MG per Day
98 MG per Day

Water Reclamation

Three Facilities
60 MG per Day
22 MG per Day
16 MG per Day

Wastewater Pump Stations

220 Pump Stations

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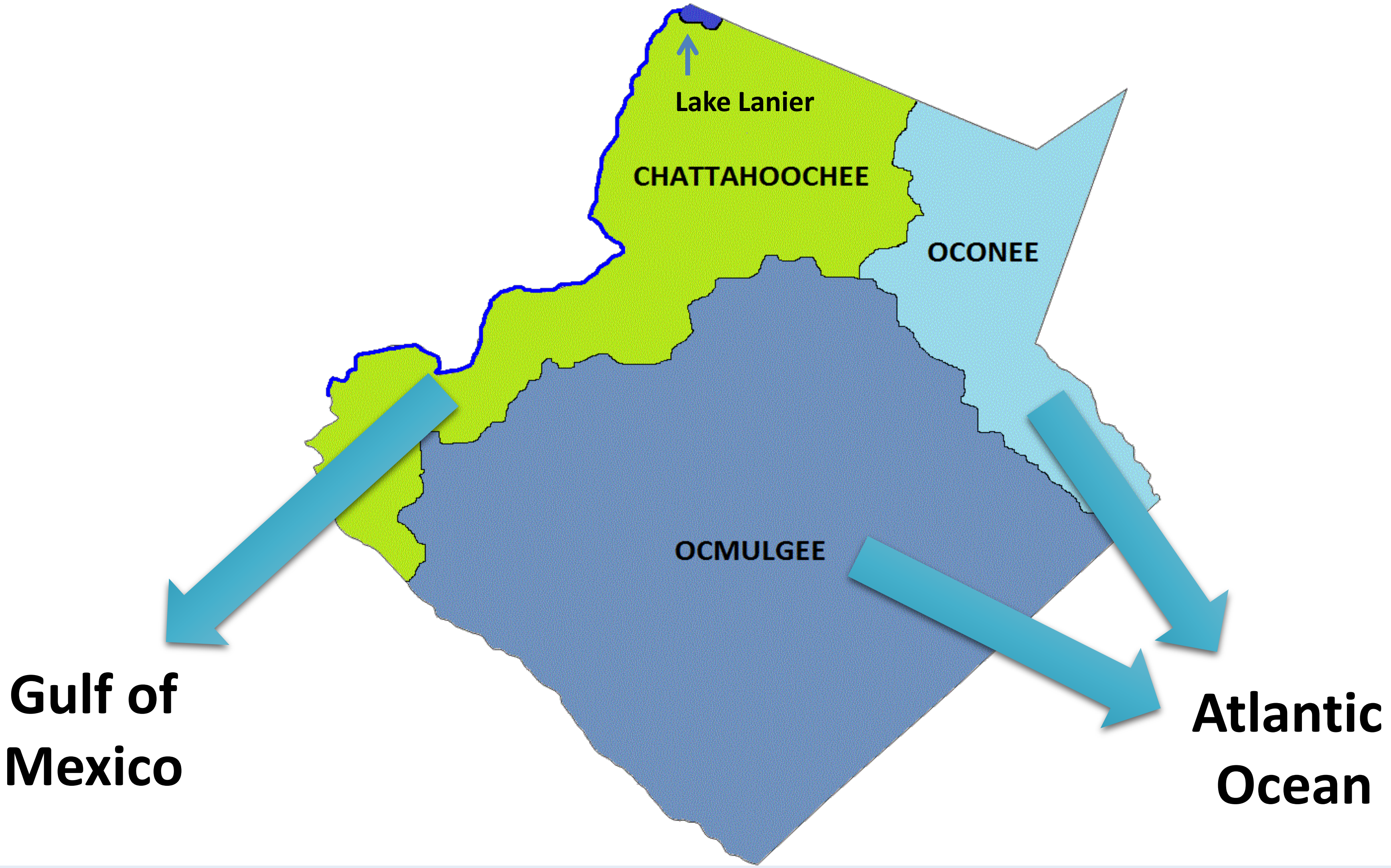
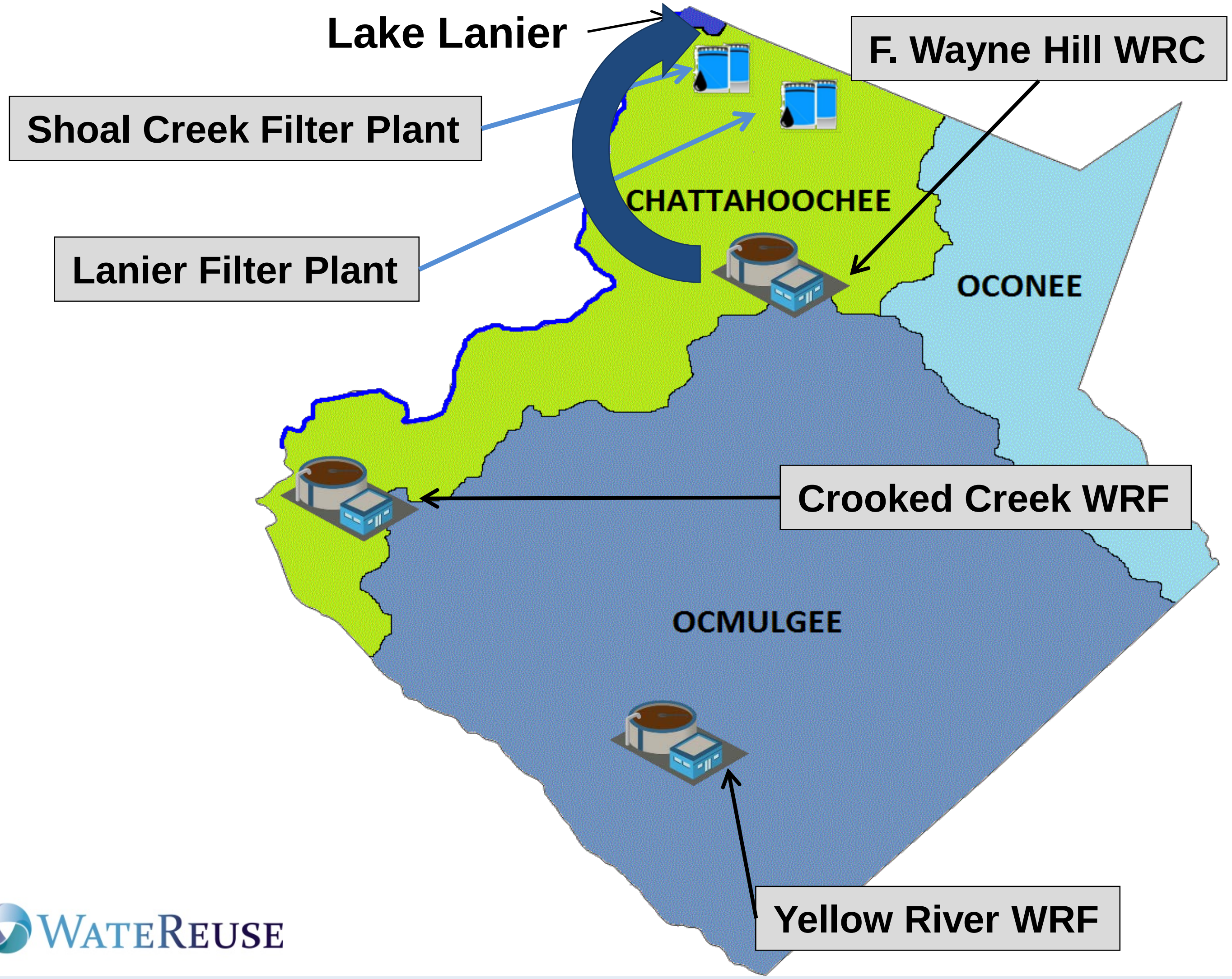
Gwinnett County – Challenge of Geography



Facility Locations within Watersheds



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Gwinnett County Water Returns and Withdrawals from Lake Lanier

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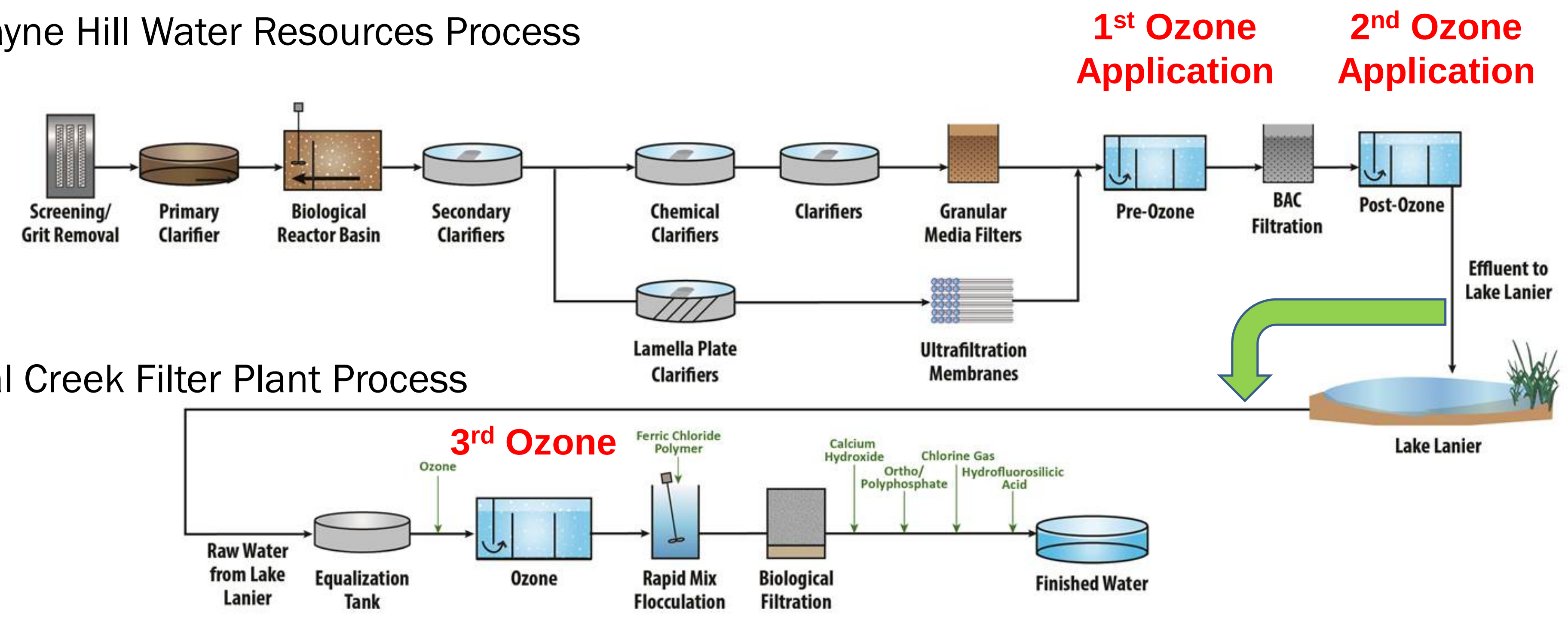
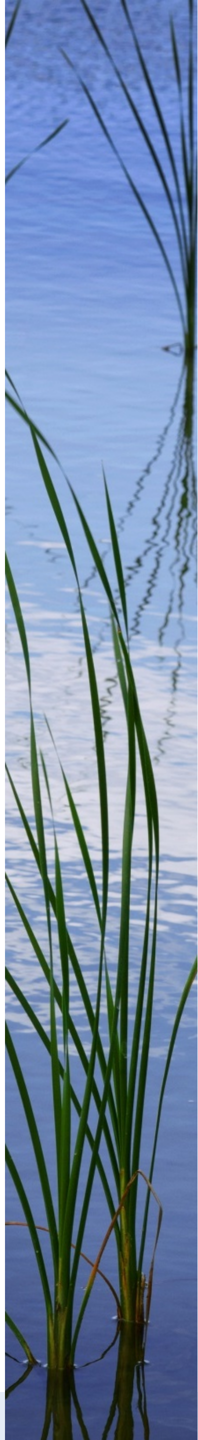
Gwinnett County Indirect Potable Reuse Treatment Trains

F. Wayne Hill Water Resources Process

Shoal Creek Filter Plant Process





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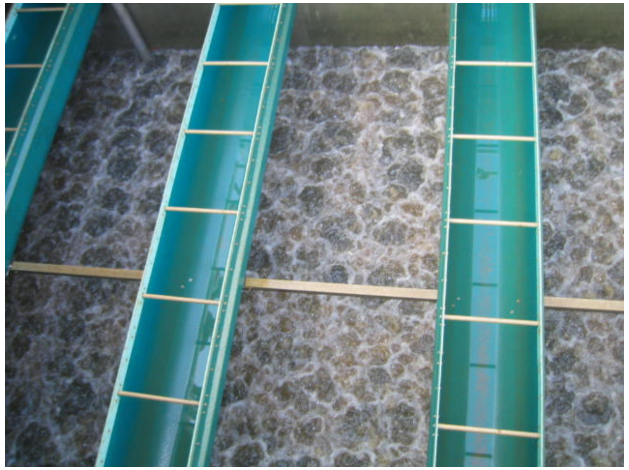
Why Study Direct Potable Reuse?

- Diversify water supply and resiliency
- Compare DPR to current IPR system
- Advance the science of Ozone-Biofiltration as an alternative to Reverse Osmosis (RO)-based treatment



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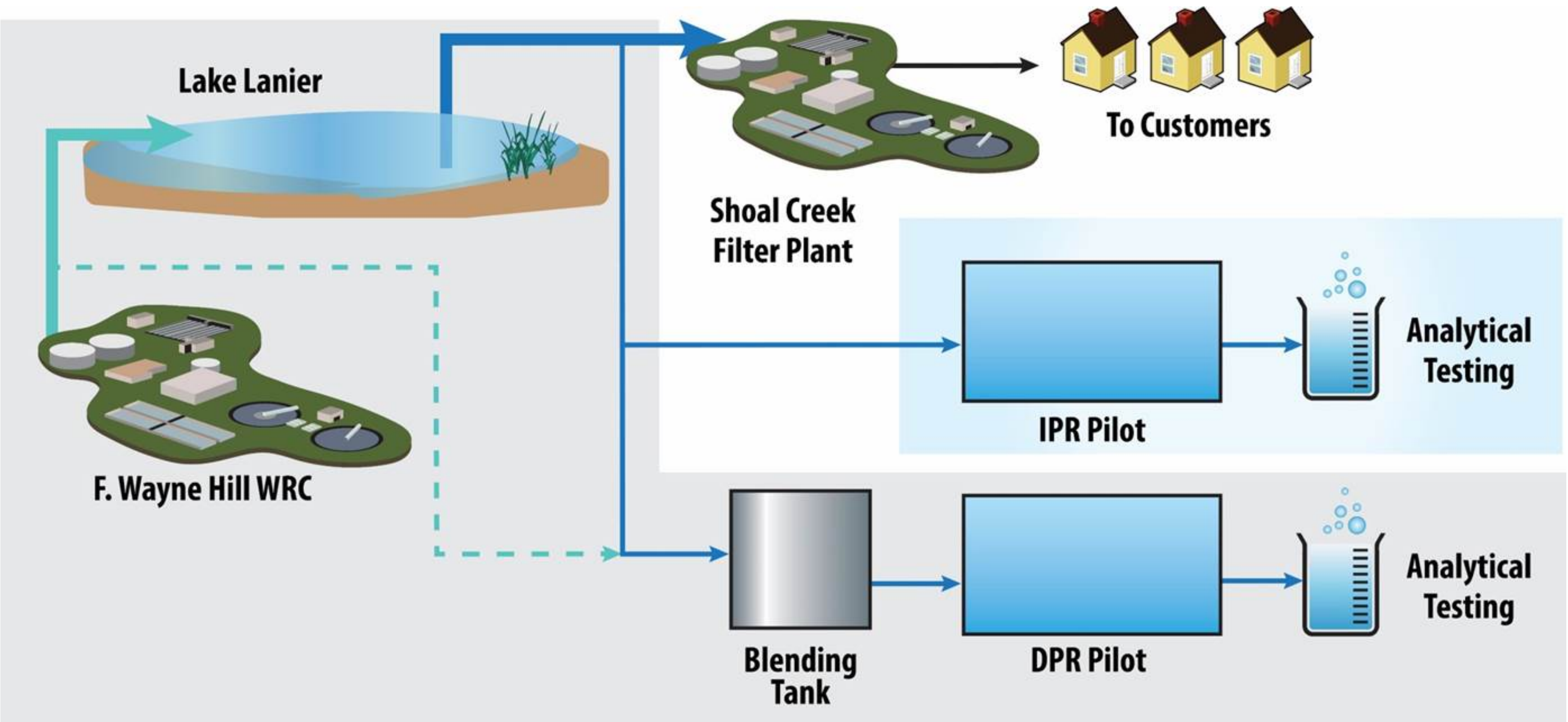
WRF Reuse 15-11 Study Approach



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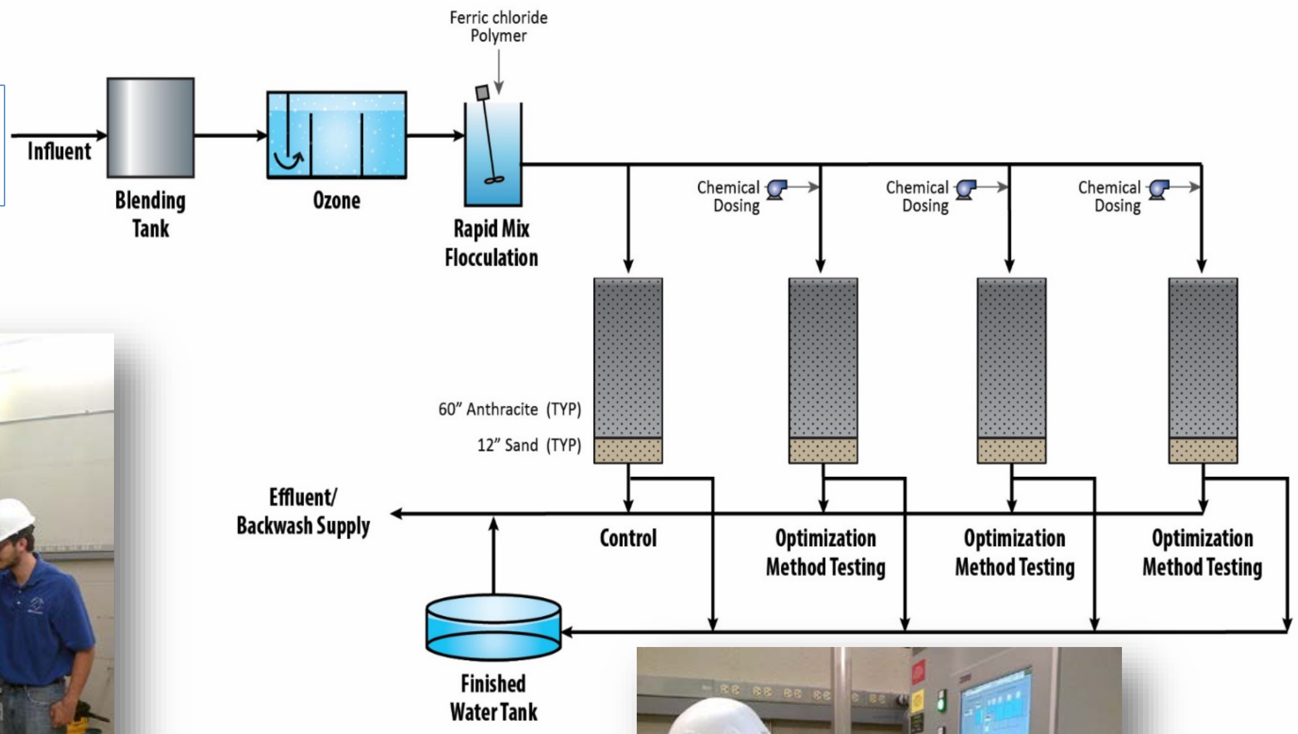
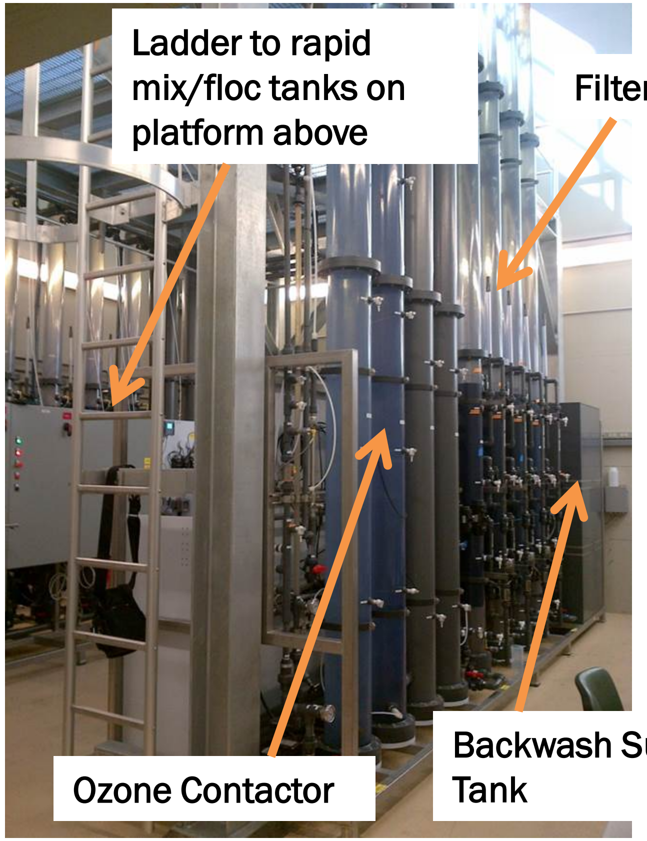
Pilot Plant Treatment Train

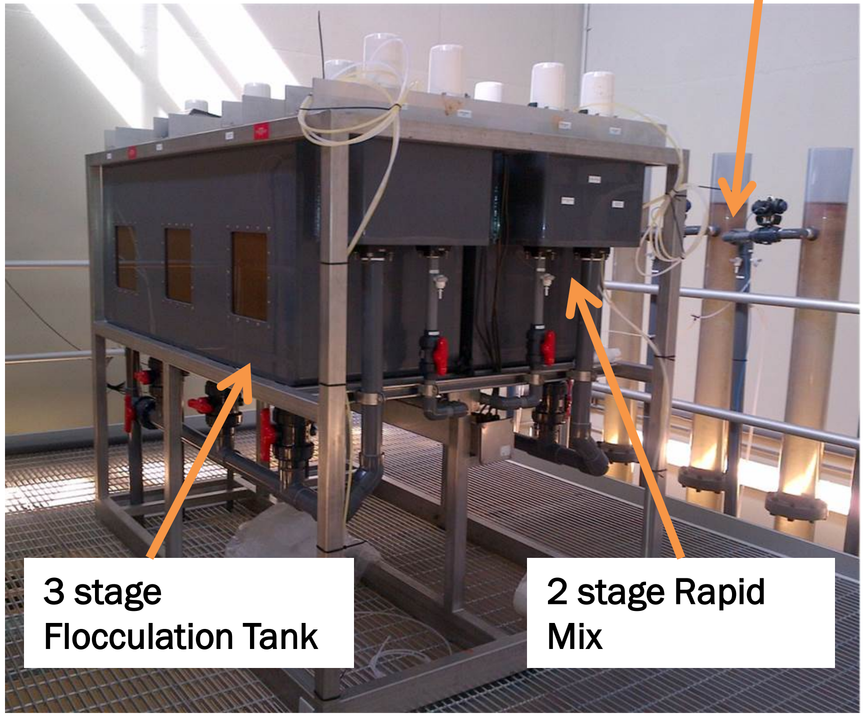
Lake Lanier

F. Wayne Hill WRC Advanced Treated Water



Pilot Plant Facilities





Pilot Plant Controls, Chemicals, and Instruments

HMI for control
and data logging

Chemical
Tanks

Ozone
Panel

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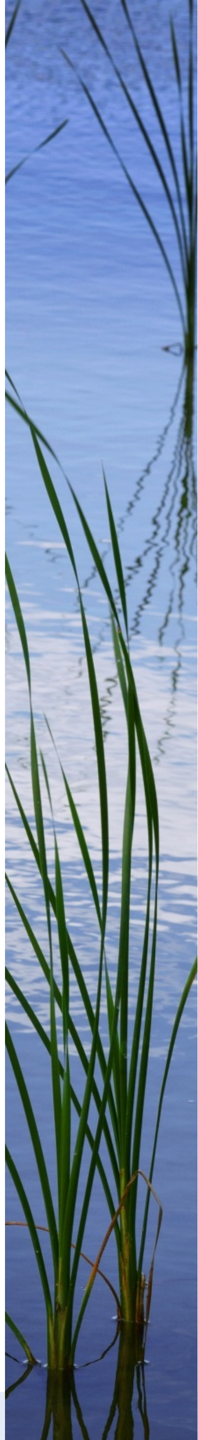
Pilot Operational Phases

Phase	Duration	Objectives/Conditions
Baseline	1 month	• Characterize with 100% Lake Lanier influent • Compare performance with full scale operations • Acclimate biofilters
DPR Testing of Blending Ratios	6 months	• Test blending ratios • 15, 25, 50, and 100% F. Wayne Hill effluent
Robustness	3 months	• Autumn lake water quality challenges • Characterize performance over process challenges (e.g. loading rate fluctuation, extended filter run time)

Pilot Analytical Matrix

Parameter	Baseline						
	Influent	Ozone Effluent	Coag/Flocc Effluent	Biofilter Effluent	Biofilter Media	Finished Water	Backwash Water
Biological Indicators	●		●	●	●	●	
Organic Characteristics	●	●	●	●		●	
Trace Chemical Constituents	●					●	
DBPs/DBP-FP	●	●		●		●	
General Water Quality	●	●	●	●		●	●
Inorganic Chemicals						●	
Operational Parameters	●	●	●	●	●	●	●



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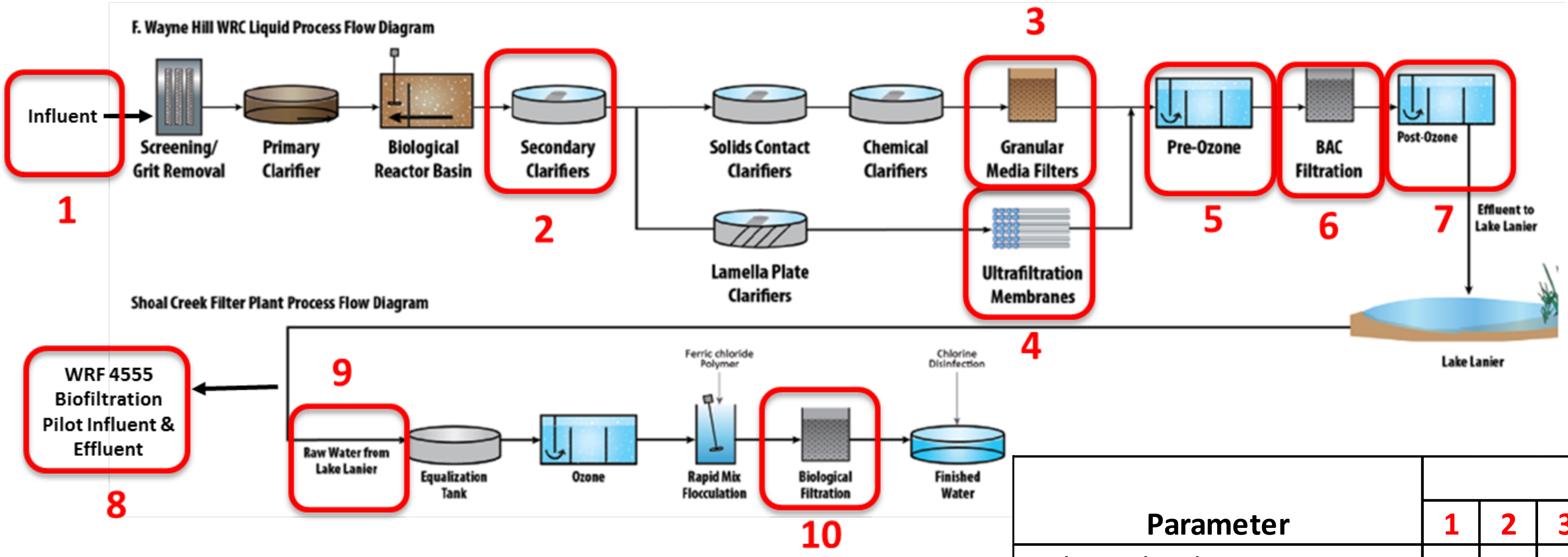
Quarterly Benchmark Sampling Analytical Matrix



Parameter	Location ID									
	1	2	3	4	5	6	7	8	9	10
Biological Indicators	●		●	●		●	●	●	●	●
Organic Characteristics	●		●	●	●	●	●	●	●	
Trace Chemical Constituents	●				●	●	●	●	●	
DBPs/DBP-FP	●		●	●	●	●	●	●	●	
General Water Quality	●	●	●	●	●	●	●	●	●	
Inorganic Chemicals	●	●	●	●			●	●	●	
Operational Parameters	●	●	●	●	●	●	●	●	●	●

Sampling Events

6 laboratories

+

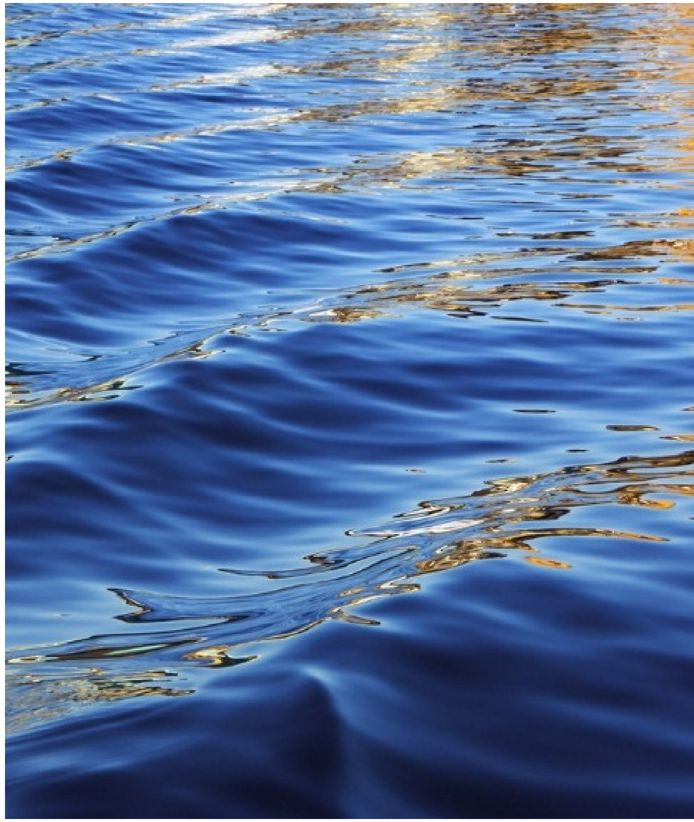
300 analytical methods

=

Lots of sample bottles

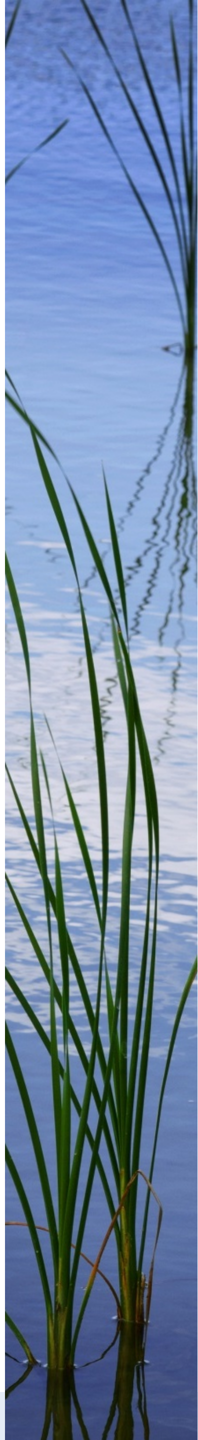
F Wayne Hill WRC Results

Dr. Kati Bell

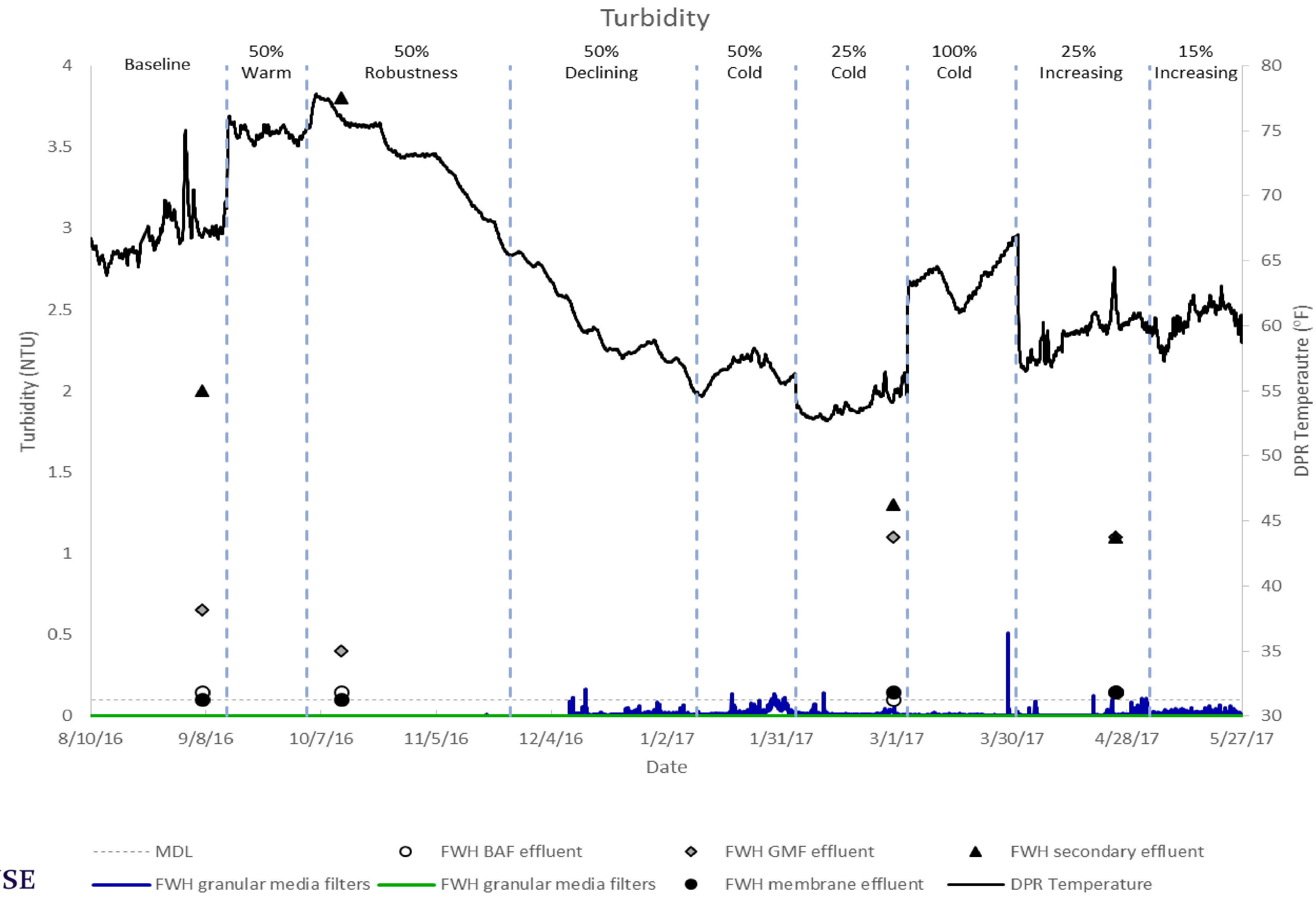


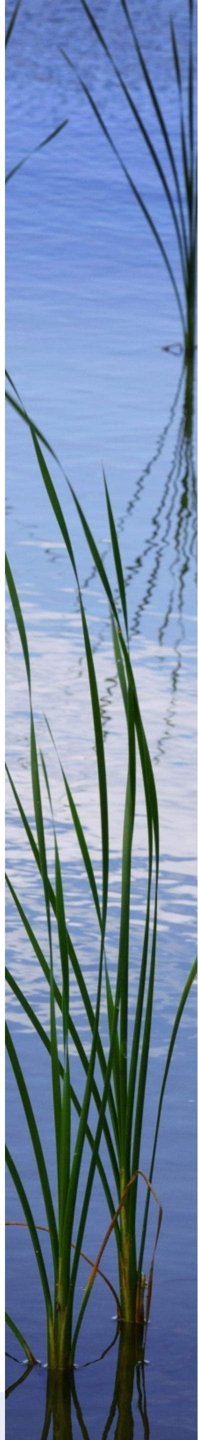
FWH WRC Discharge Permit Limits

Parameter (Unit)	Permit to Discharge (monthly limits)
Flow (MGD)	60
COD (mg/L)	18
Total Suspended Solids (mg/L)	3
Fecal Coliform (CFU/100 mL)	2 (geometric mean)
Ammonia (mg-N/L)	0.4
Phosphorus, Total (mg/L)	0.08
Turbidity (NTU)	0.5



Turbidity performance





Operational conditions at FWH

Operational Parameter	Sept 6 – 8	Oct 10 – 12	Nov 15 – 16	Dec 12 – 14	Jan 30 – Feb 1	Feb 27 – Mar 1	Mar 27–29	Apr 24–26	May 23–24
Alum (mg/L)	20-35	10	10	10	35	30	10	10	10
Ferric (mg/L)	45-50	20	30	20	40	45	25	25	25
Bio-P upset*	Y	N	N	N	Y	Y	N	N	N
2° effluent P	0.7 to 5	0.5	0.8	0.3	<0.1	<0.1	0.2	0.1	<0.1
NRCY	No nitrate recycle (NRCY) and limited dN, occurring only in 2° clarifiers							NRCY on to bio 2&8 (limited dN in 2° clarifiers)	
Nitrate		~20	~20	~20	~19	~18	~20	14-18	~20 in bios w/o NRCY; bio 2&8 ~9
Other	• GAC/BAC and UF membrane operations were normal throughout the study • Pre-ozone dose was consistently 2.5 mg/L; post-ozone dose was consistently 1.5 mg/L • Mean cell retention time (MCRT) changed from 10 to 11 days on 1/25/17 • On 5/8/17 pre-ozone dose increased to 3.0 mg/L; and $Mg(OH)_2$ at plant reduced from 30 to 25 mg/L • On 5/8/17 the NRCY turned on to bio 2&8 for bio-P study (plus limited dN in 2° clarifiers); GAC cells were swapped, 17 and 18 taken offline to bring new carbon cells online; additionally, effluent from old and new carbon cells was separated in the effluent channel.								

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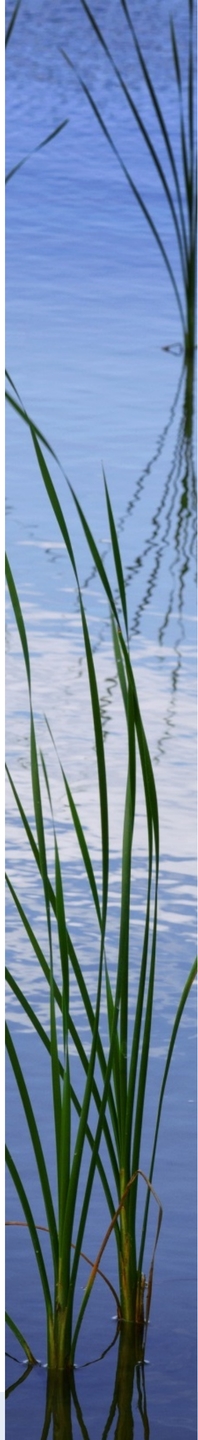
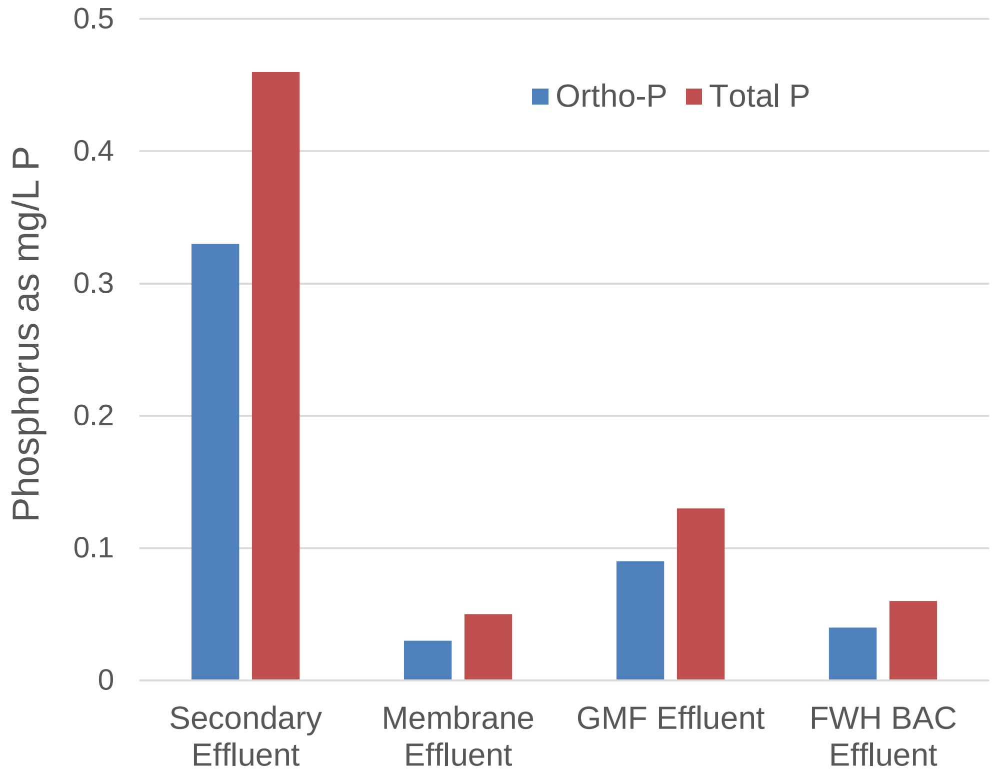
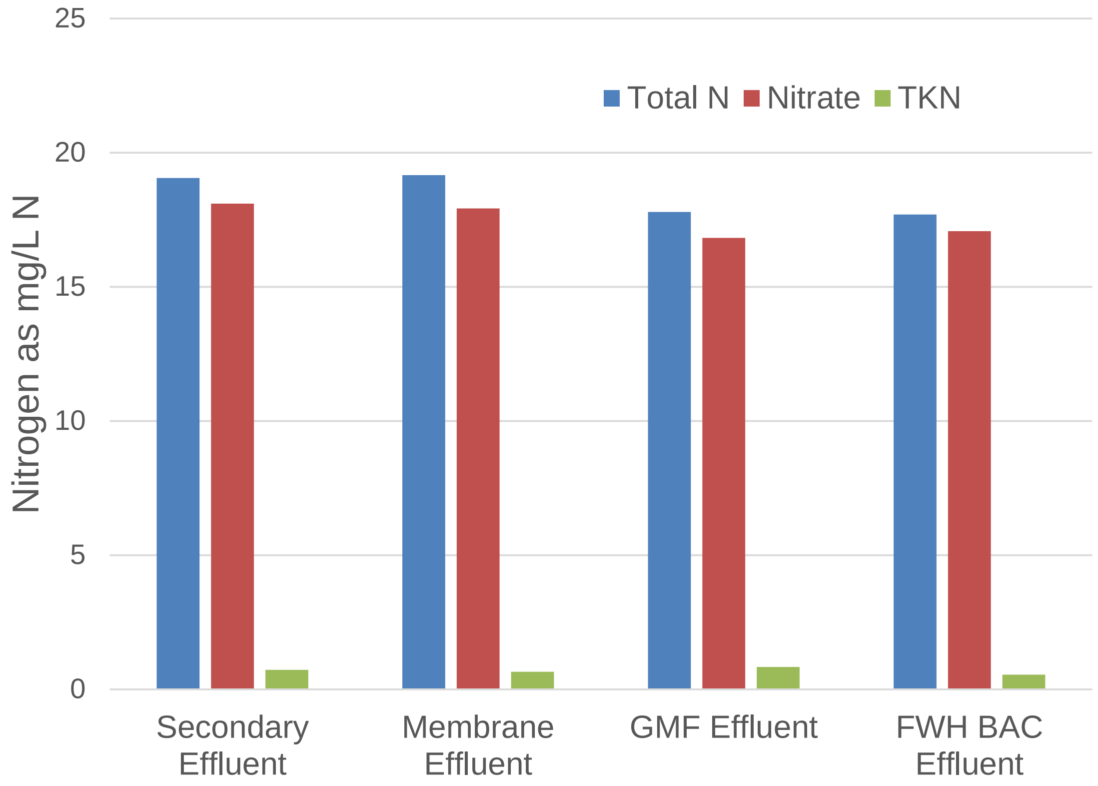


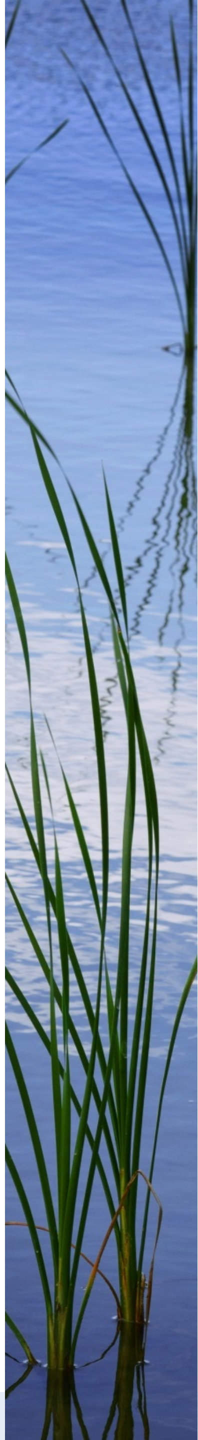
Nutrient removal performance

- Turbidity, very low,
  UF better than GMF



- pH (6.77 to 7.87)
- Nutrients and speciation





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Organic carbon

- Surrogates – TOC, DOC, COD
- Not all organic carbon is equal:
  - Phenolic and carboxylic acid derivatives
  - Proteinaceous compounds, amino acids
  - Fulvic and humic acids (or FA-, HA-like)
  - *Trace organic compounds and soluble microbial products are a minor component*
- Additional characterization
  - UV transmittance (UVT) for chromophores
  - Fluorescence EEM for fluorophores

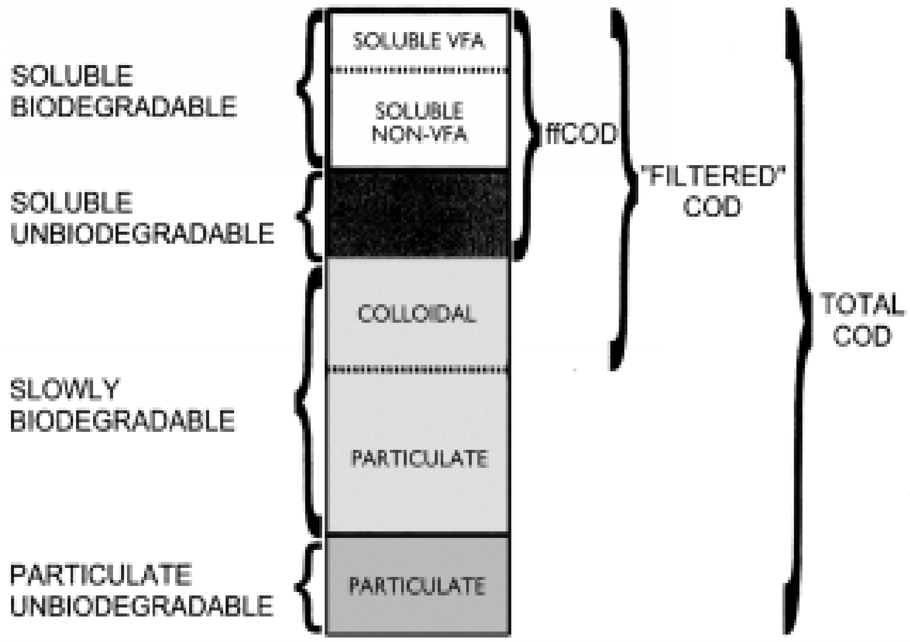

Figure 4-5. Schematic Representation of COD Components for Municipal Wastewater

(Melcer, et al., 2003)

99-WWF-3

METHODS FOR WASTEWATER CHARACTERIZATION IN ACTIVATED SLUDGE MODELING

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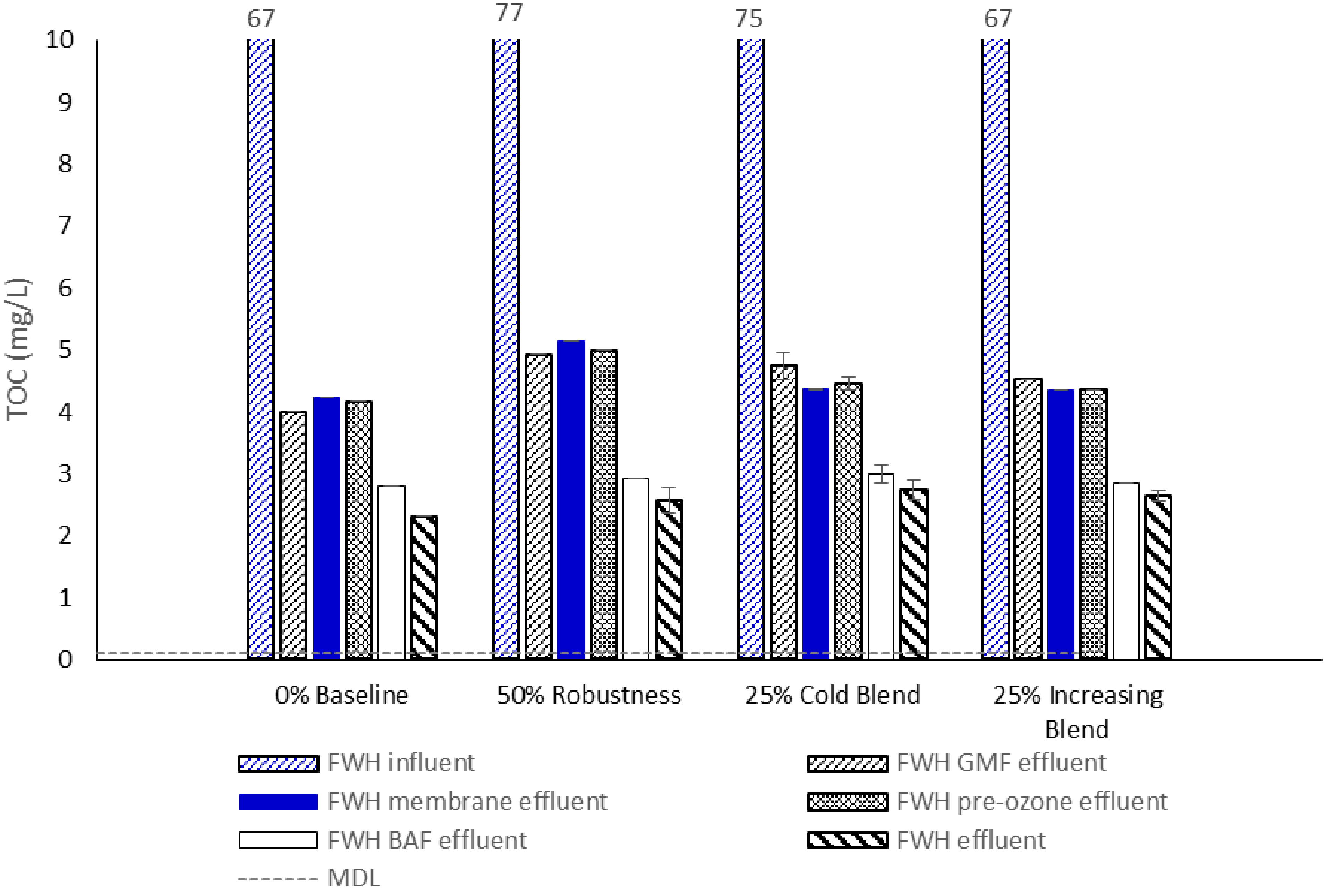
TOC performance



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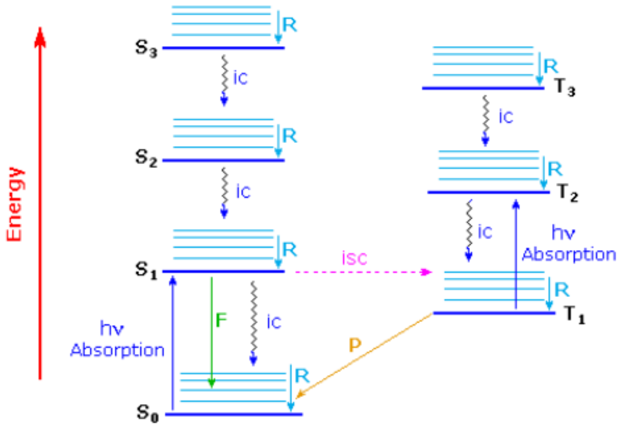
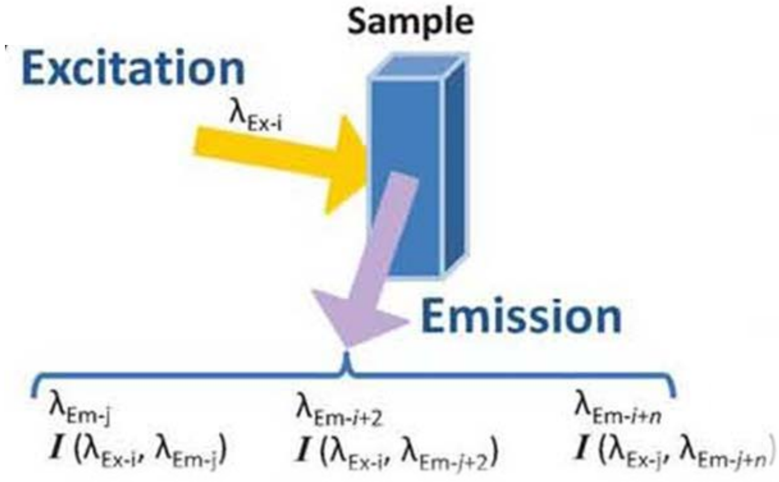
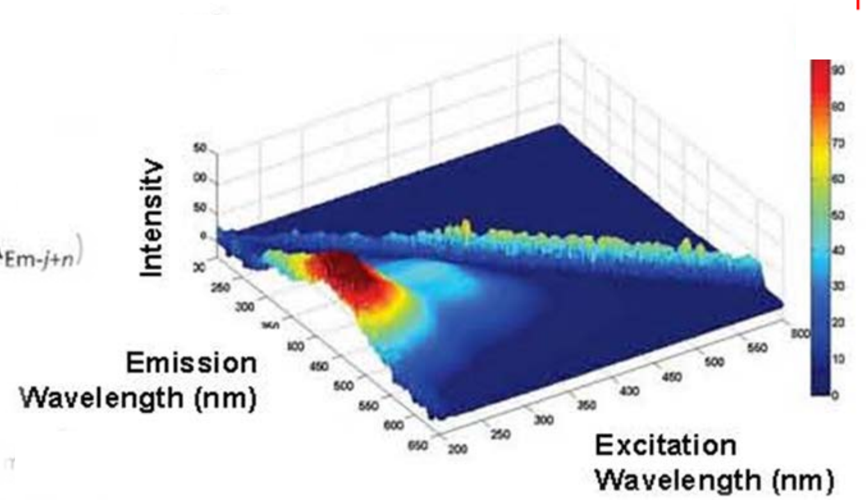
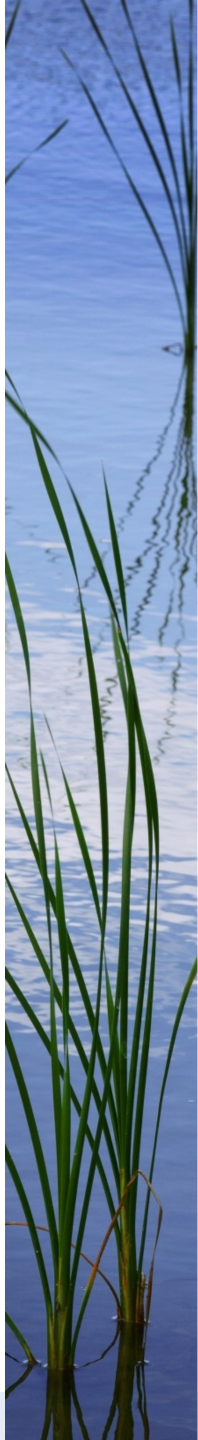
Fluorescence Excitation Emission Matrix Spectroscopy

- Organic matter can be electronically excited at particular wavelengths, but only part of the molecule may emit light (fluorescence), in response
- The resulting representation or "fingerprint" localizes fluorescence centers related to groups









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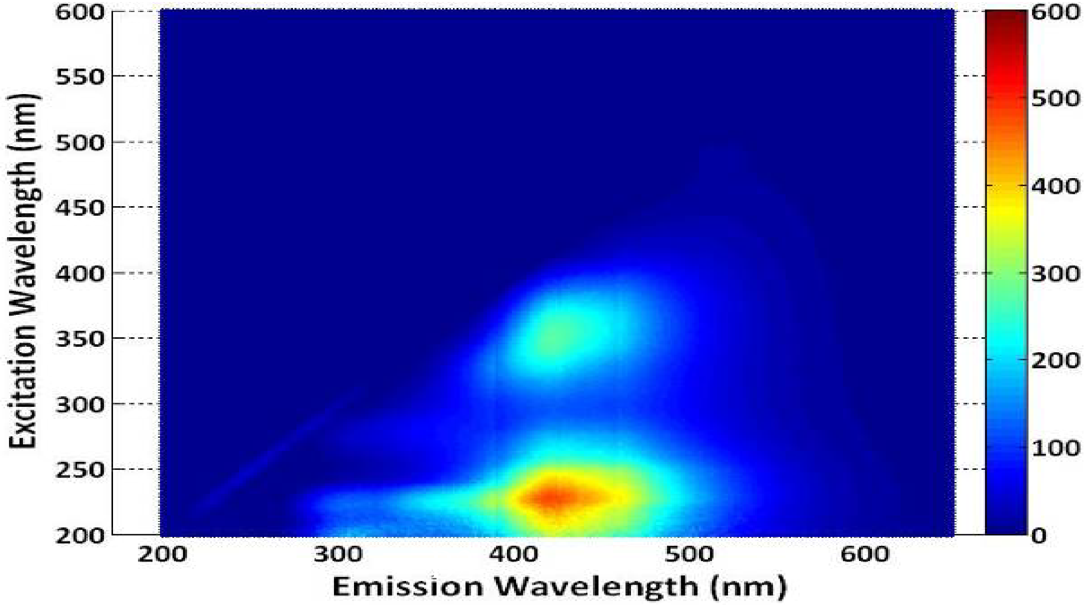
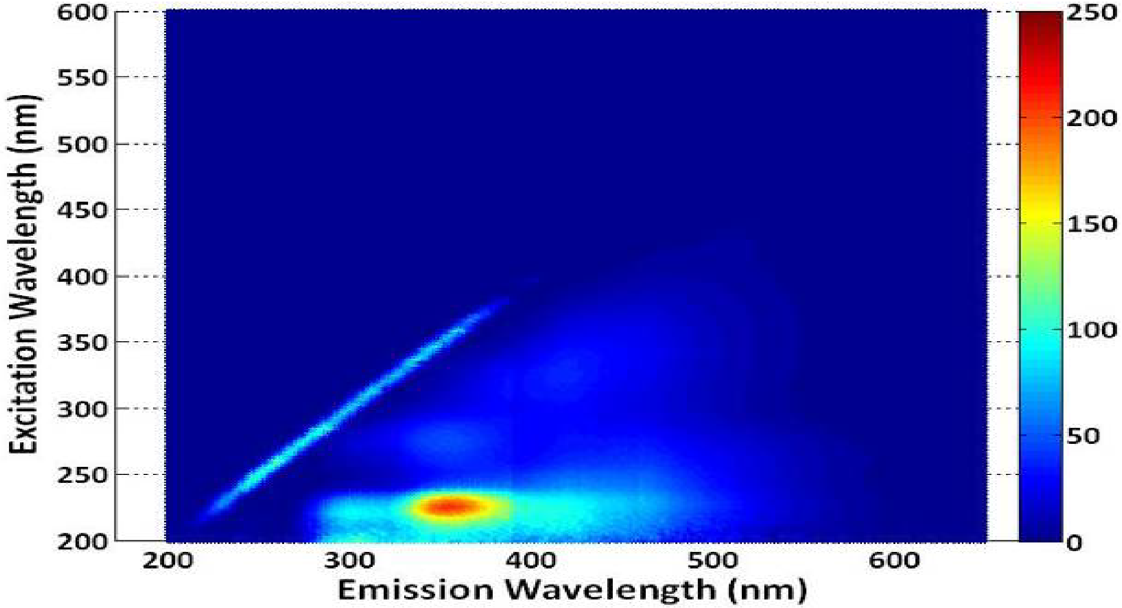
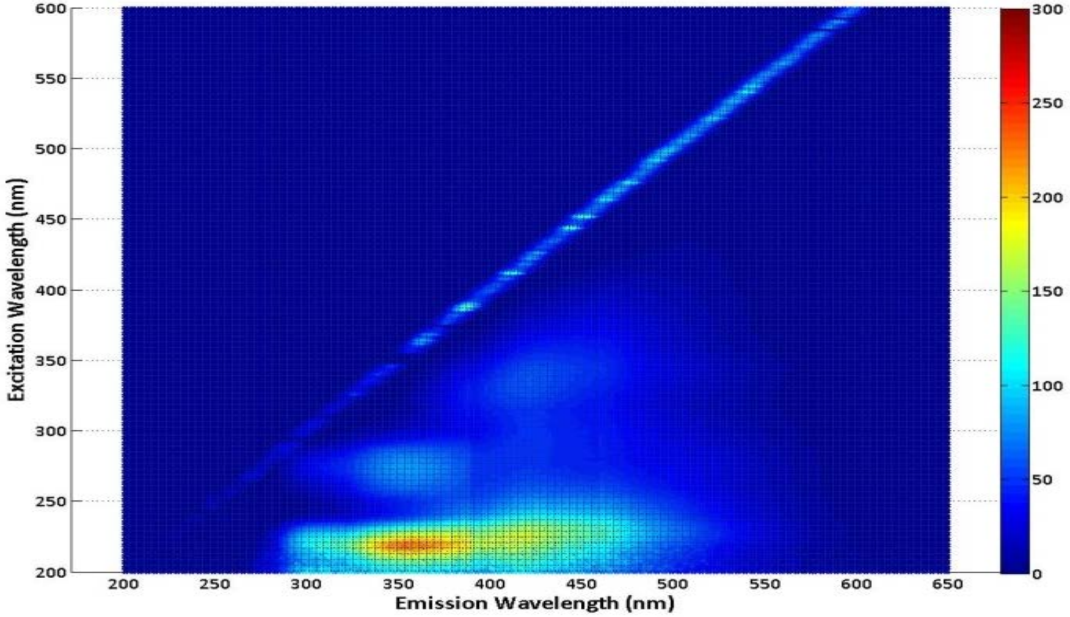
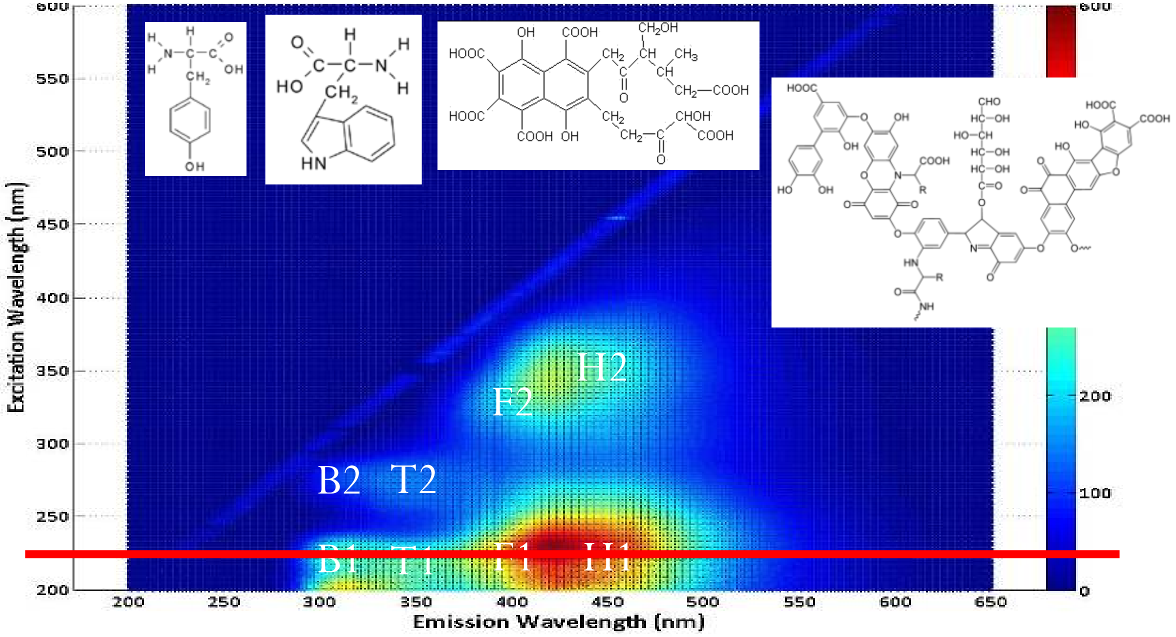
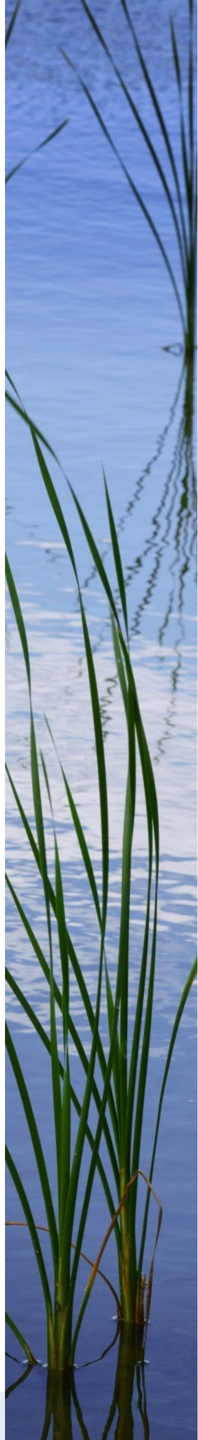

Excitation Wavelength (nm)
Emission Wavelength (nm)


Excitation Wavelength (nm)
Emission Wavelength (nm)


Excitation Wavelength (nm)
Emission Wavelength (nm)


Excitation Wavelength (nm)
Emission Wavelength (nm)
H2
F2
B2
T2
B1
T1
F1
H1



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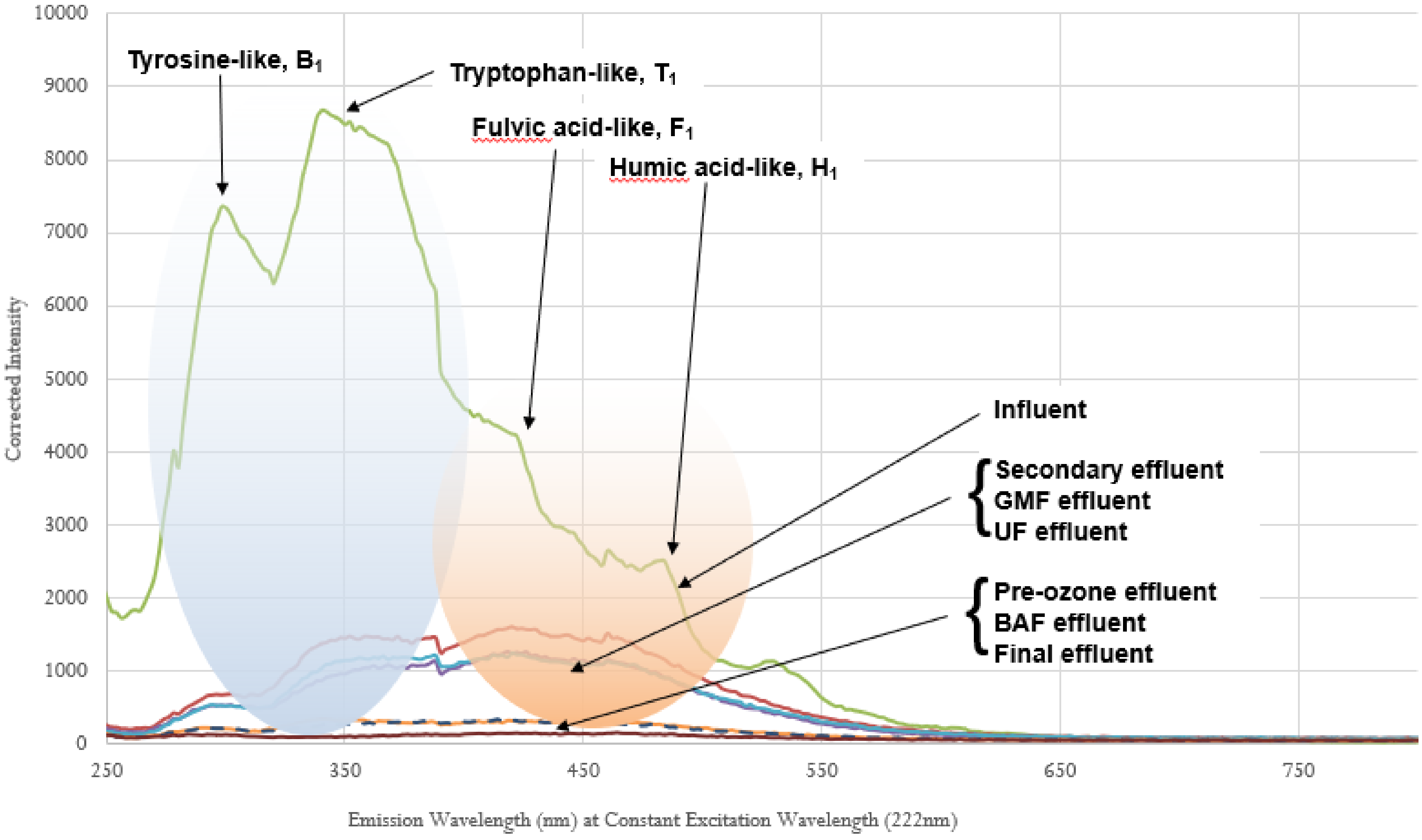
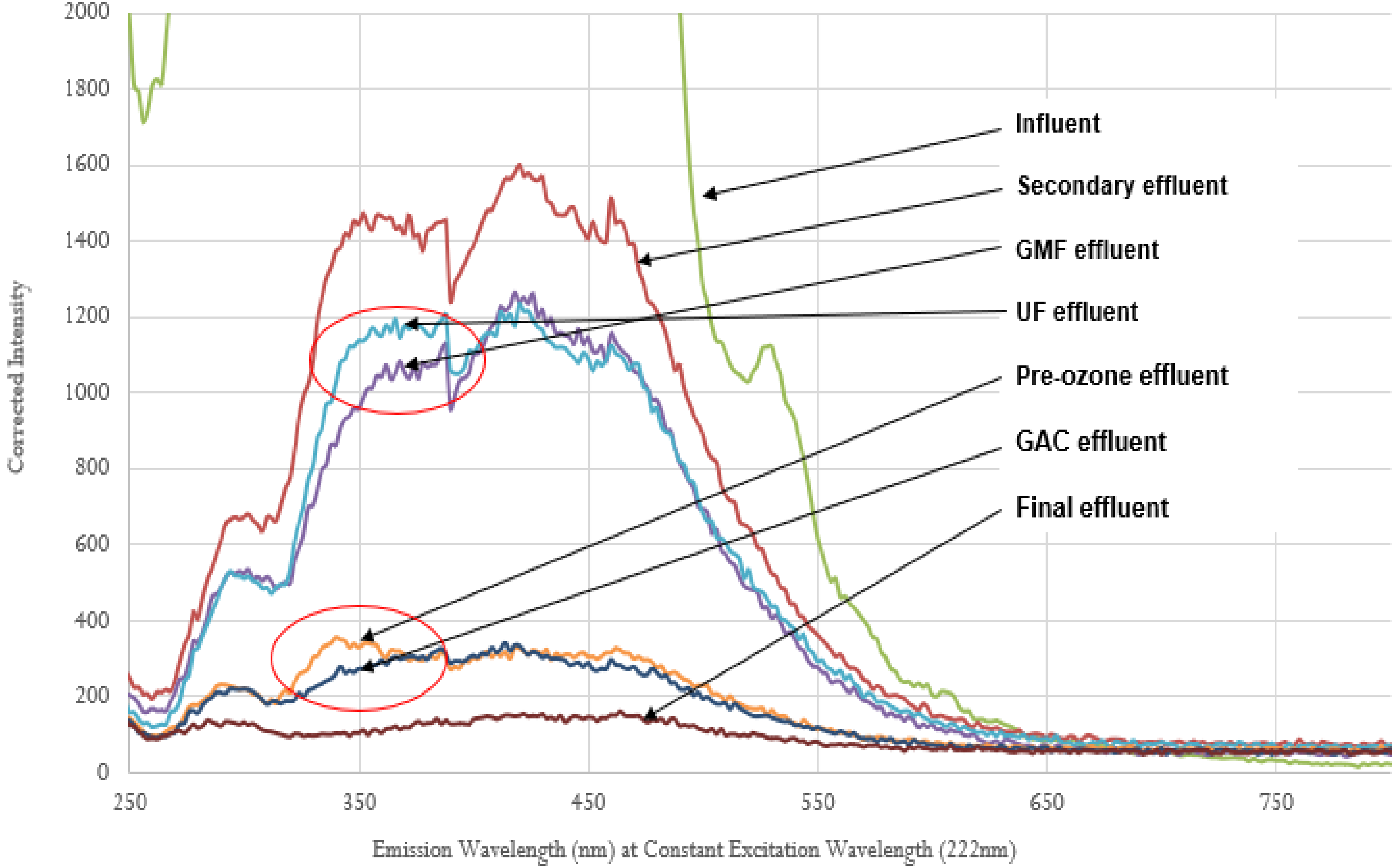
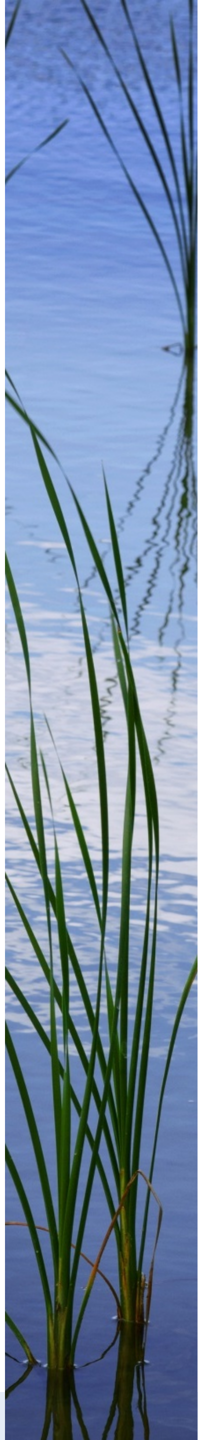
fEEM results for FWH WRC



fEEM results for FWH WRC





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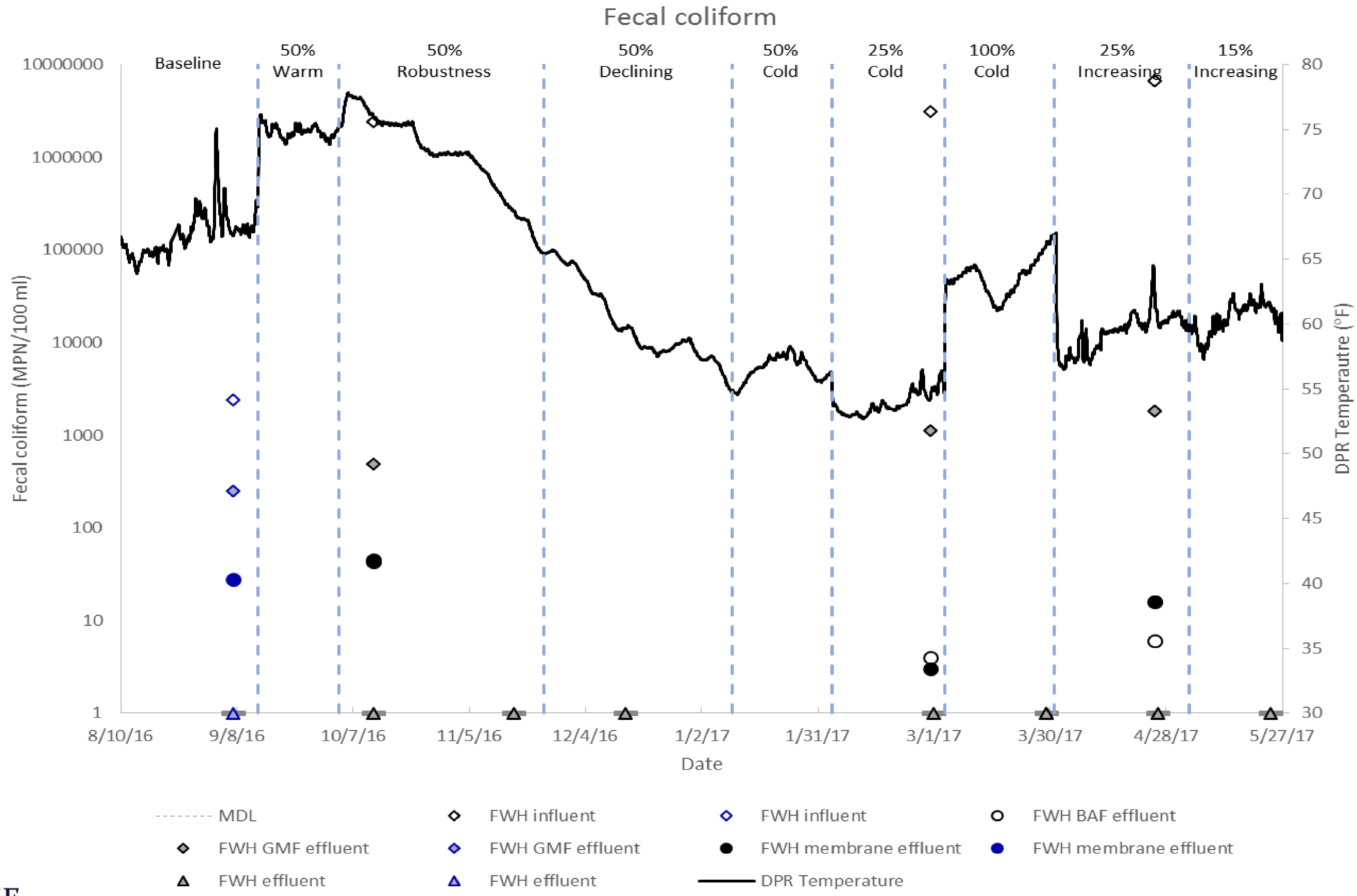
Microbial removal performance



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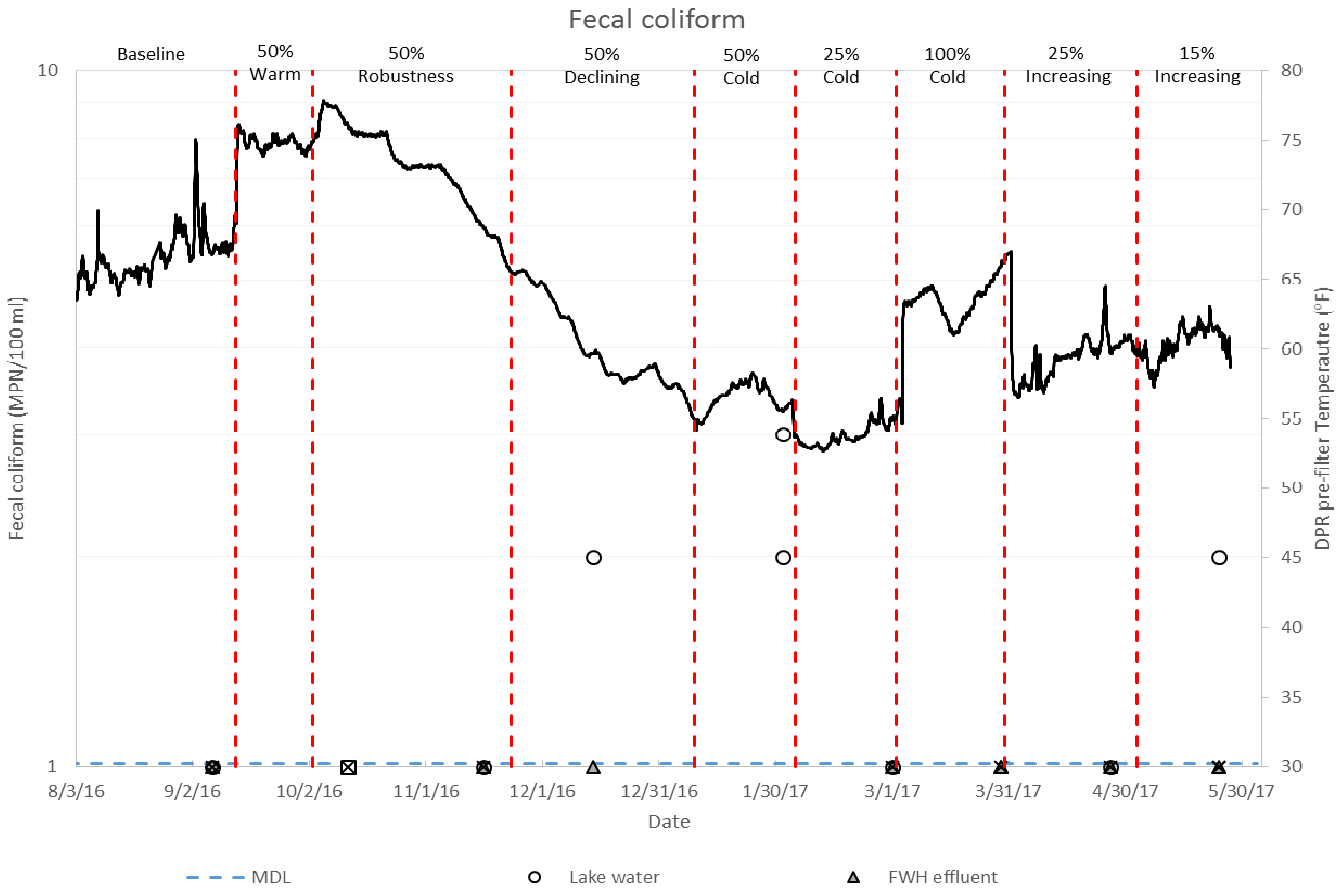
Microbial quality comparison



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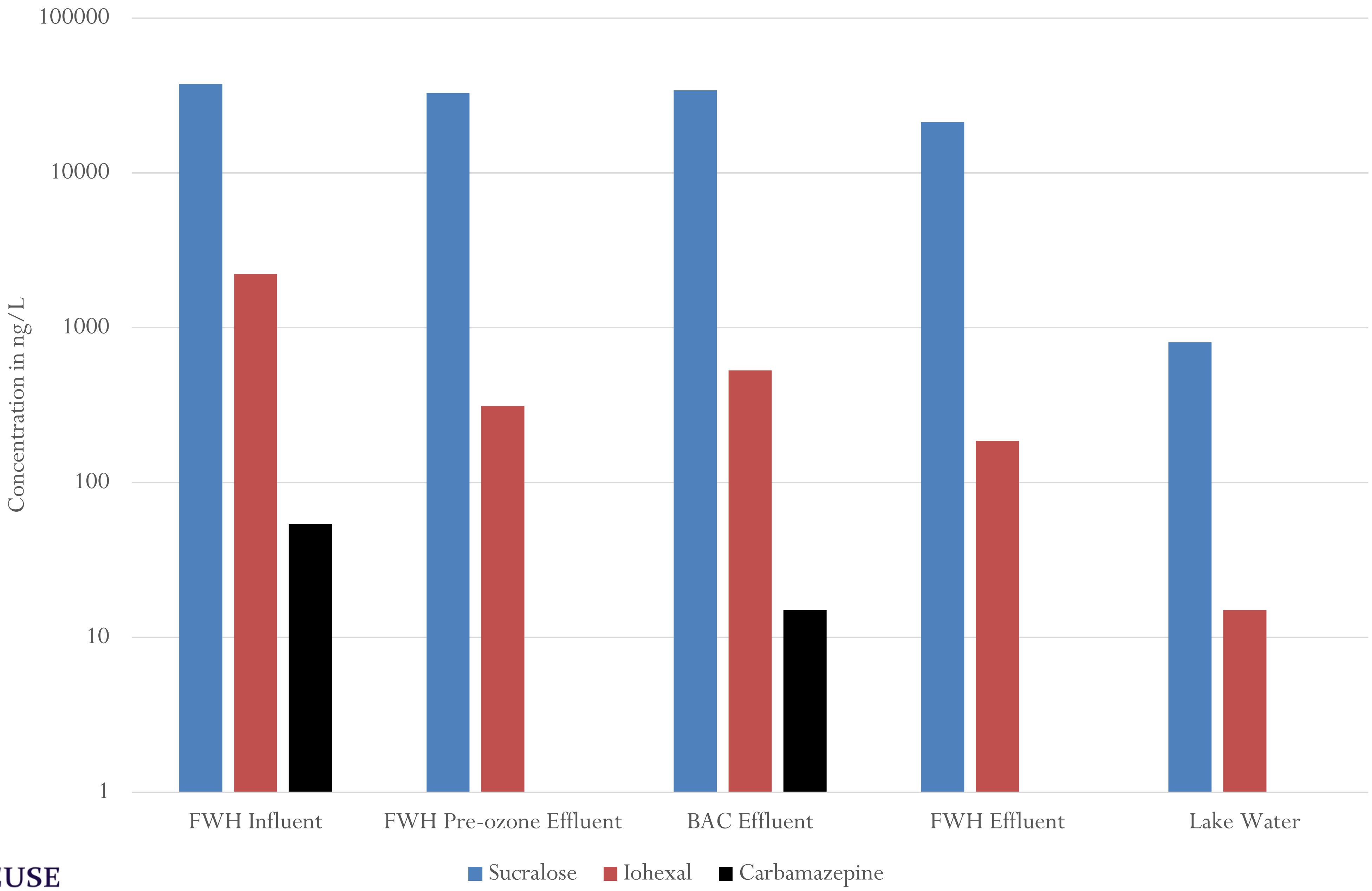
TrOCs compounds in FWH WRC



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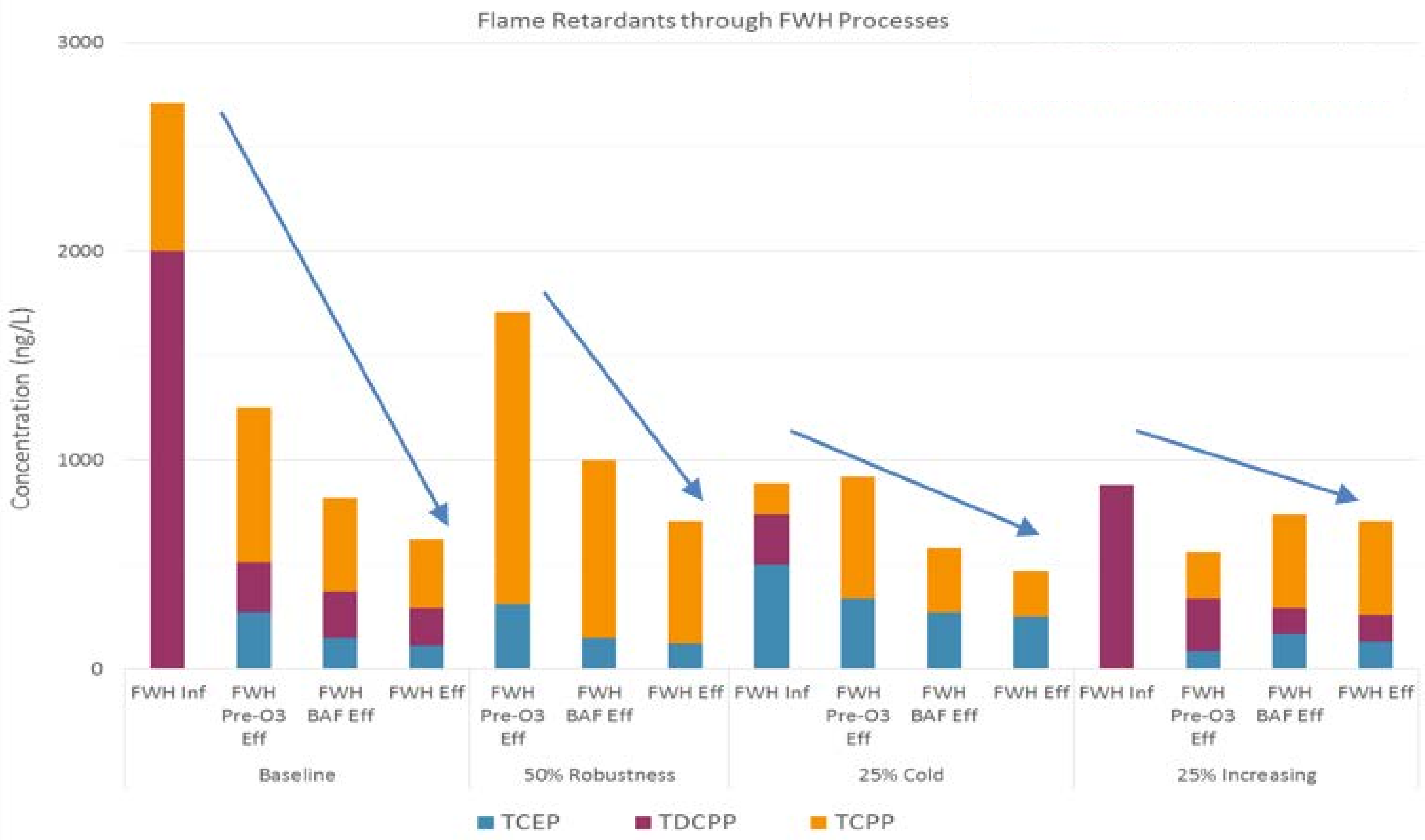
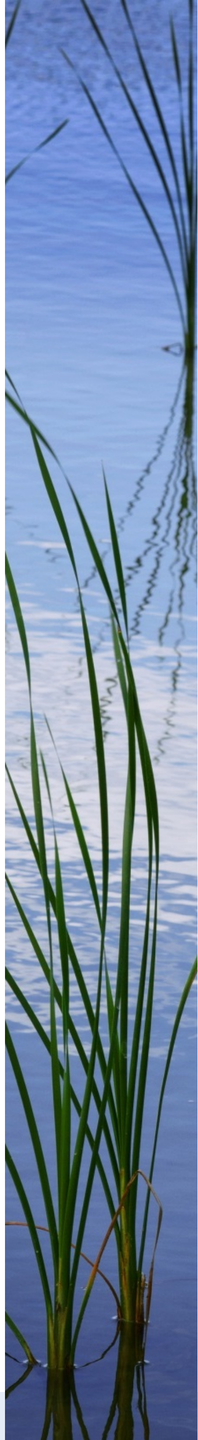
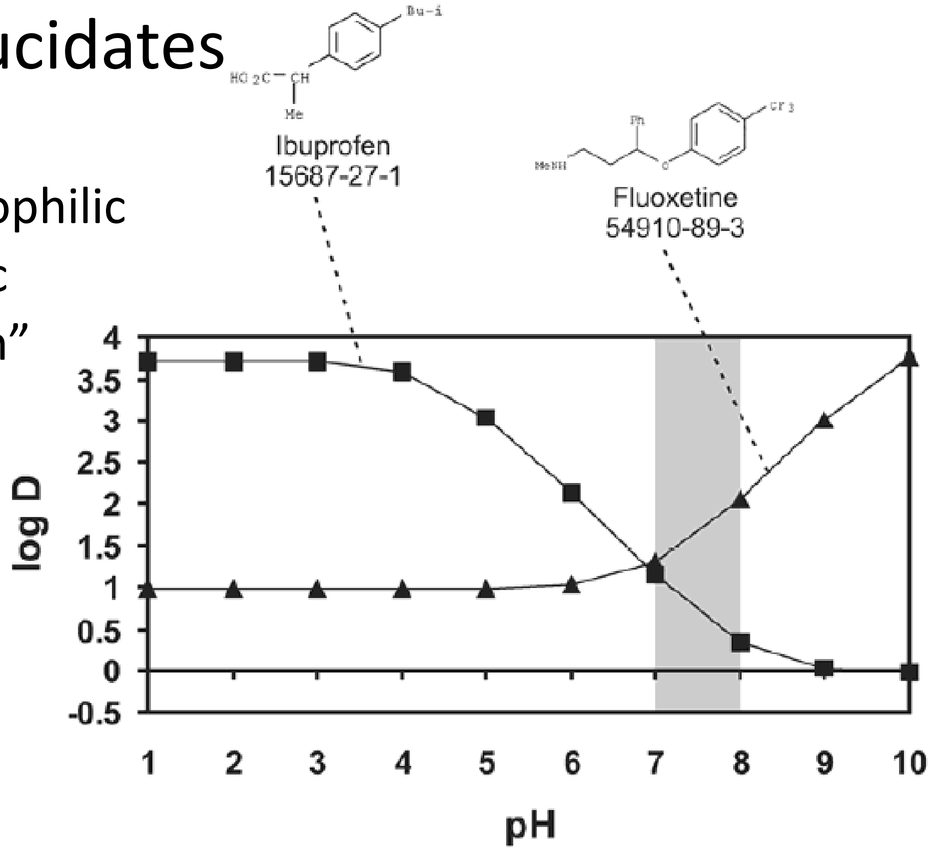
Flame retardants in FWH WRC





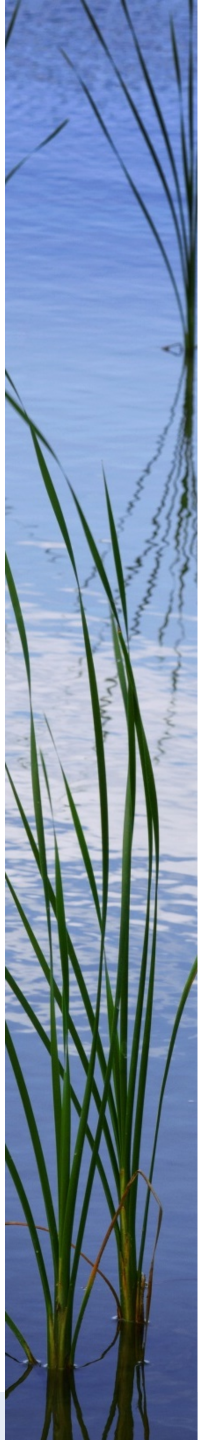
Targeted PPCP removal by minor pH adjustments?

- K_{ow} (octanol/water coefficient) is typically used to describe behavior, but does not account for the ionogenicity
- A log D_{ow} (K_{ow} at pH) approach elucidates mechanisms of removal
  - *log D_{OW}* of 1 (D_{OW} = 10 = 10/1) is highly hydrophilic
  - > 1 is less hydrophilic, < 1 is more hydrophilic
  - Hydrophobicity is an indicator of “adsorption” characteristics (e.g., to biosolids)
  - Hydrophilicity indicates bioavailability
- The link between nitrification/ denitrification and pH is key



Trace Organic Compound Detections	RL	FWH Effluent Range	FWH Effluent n	FWH Effluent n > RL	Lake Lanier Range	Lake Lanier n	Lake Lanier n > RL
1,4-Dioxane (µg/L)	0.07	0.2 - 0.62	9	9	0.07 - 0.07	8	0
2,4-D (ng/L)	5	5 - 50.2	13	3	5 - 5.4	8	1
2,4-D (µg/L)	0.1	0.1 - 0.1	10	0	0.1 - 0.1	7	0
4-Methyl-2-Pentanone (µg/L)	5	5 - 6.4	9	1	5 - 5	8	0
4-nonylphenol (ng/L)	100	100 - 626	13	10	100 - 700	8	4
Acesulfame-K (ng/L)	20	20 - 290	13	10	21 - 42	8	8
Albuterol (ng/L)	5	5 - 32	11	2	5 - 5	8	0
Atenolol (ng/L)	5	5 - 53	11	1	5 - 5	8	0
Azithromycin (ng/L)	20	20 - 48	2	1	20 - 20	1	0
BPA (ng/L)	10	10 - 14	11	1	10 - 30	8	1
Butalbital (ng/L)	5	5 - 68.8	13	2	5 - 5	8	0
Butylbenzylphthalate (µg/L)	0.5	0.5 - 0.5	11	0	0.5 - 0.57	7	1
Caffeine (ng/L)	5	5 - 8.9	11	2	5 - 25	8	3
Carbadox (ng/L)	5	5 - 28	11	2	5 - 7.5	8	1
Carbon disulfide (µg/L)	0.5	0.5 - 0.5	9	0	0.5 - 0.5	8	0
Carisoprodol (ng/L)	5	5 - 50	11	5	5 - 5	8	0
Chloridazon (ng/L)	5	5 - 12	11	1	5 - 5	8	0
Cimetidine (ng/L)	5	5 - 360	9	1	5 - 310	7	1
Cotinine (ng/L)	10	10 - 14	11	1	10 - 10	8	0
Cyanazine (ng/L)	5	5 - 6.5	11	1	5 - 5	8	0
DACT (ng/L)	5	5 - 16	11	6	5 - 5	8	0
DEET (ng/L)	10	10 - 10	11	0	10 - 25	8	2
Dehydronifedipine (ng/L)	5	5 - 6.1	11	2	5 - 5	8	0
Di(2-ethylhexyl) phthalate (µg/L)	0.6	0.6 - 0.6	11	0	0.6 - 0.6	7	0
DIA (ng/L)	5	5 - 16	11	8	5 - 15	8	2
Dilantin (ng/L)	20	20 - 71	11	1	20 - 480	8	1
Diltiazem (ng/L)	5	5 - 5	11	0	5 - 10	8	2
Diuron (ng/L)	5	5 - 5	11	0	5 - 5.4	8	1
Erythromycin (ng/L)	10	10 - 10	11	0	10 - 24	8	1
Estrone (LC-MS-MS) (ng/L)	5	5 - 113	13	2	5 - 5.8	8	2

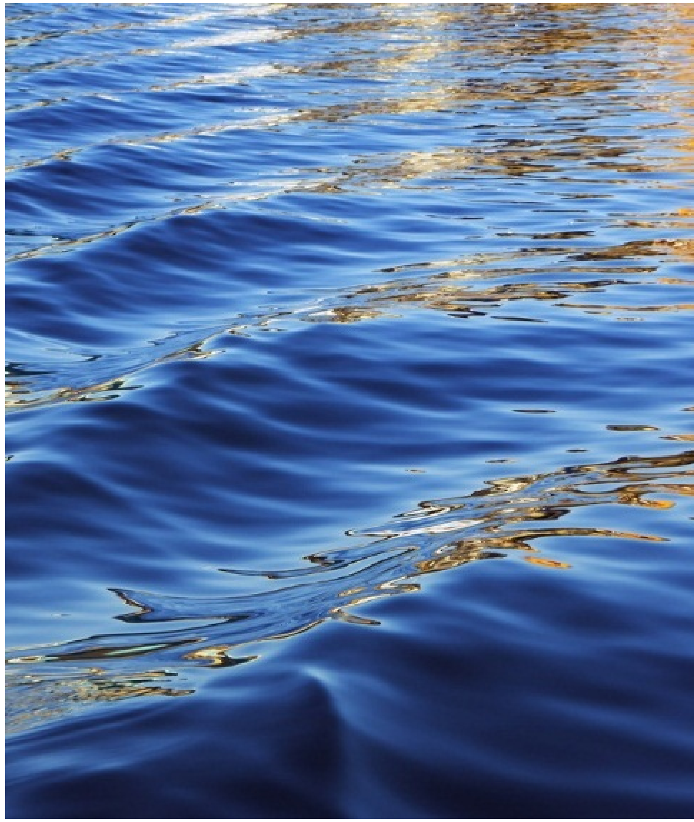
Trace Organic Compound Detections	RL	FWH Effluent Range	FWH Effluent n	FWH Effluent n > RL	Lake Lanier Range	Lake Lanier n	Lake Lanier n > RL
Ethylparaben (ng/L)	20	20 - 523	13	2	20 - 20	8	0
Flumequine (ng/L)	10	10 - 10	11	0	10 - 16	8	1
Ibuprofen (ng/L)	10	10 - 178	13	3	10 - 16	8	1
Iodide (µg/L)	1	1 - 1.6	4	1	-	0	0
Iohexal (ng/L)	10	43 - 560	13	13	10 - 43	8	3
Iopromide (ng/L)	5	5 - 130	13	3	5 - 5	8	0
m,p-Xylenes (µg/L)	0.5	0.5 - 0.61	9	1	0.5 - 0.5	8	0
Meprobamate (ng/L)	5	5 - 77	11	7	5 - 5	8	0
Metazachlor (ng/L)	5	5 - 5	11	0	5 - 5	8	0
Methylparaben (ng/L)	20	20 - 312	13	3	20 - 20	8	0
Perfluoro butanoic acid (PFBA) (ng/L)	10	10 - 12	11	2	10 - 10	7	0
PFOS (ng/L)	5	5 - 7	11	3	5 - 5	7	0
PFOA (ng/L)	5	8.4 - 16	11	11	5 - 5	7	0
Perfluoro-1-butanesulfonic acid (ng/L)	5	8.1 - 17	11	11	5 - 5	7	0
Perfluoro-n-hexanoic acid (ng/L)	5	19 - 49	11	11	5 - 5	7	0
Perfluoropentanoic acid (ng/L)	5	19 - 50	11	11	5 - 5	7	0
Primidone (ng/L)	5	5 - 11	11	3	5 - 5	8	0
Propylparaben (ng/L)	5	5 - 122	13	8	5 - 9.1	8	4
Quinoline (ng/L)	5	5 - 22	11	2	5 - 14	8	2
Salicylic Acid (ng/L)	100	100 - 2010	13	5	100 - 100	8	0
Simazine (ng/L)	5	5 - 20	11	9	7.1 - 24	8	8
Sucralose (ng/L)	100	100 - 43000	13	11	400 - 1600	8	8
TCEP (ng/L)	10	95 - 250	11	11	10 - 10	8	0
TDCPP (ng/L)	100	100 - 180	11	6	100 - 100	8	0
Testosterone (ng/L)	5	5 - 7.9	11	1	5 - 5	8	0
Theobromine (ng/L)	10	10 - 10	11	0	10 - 49	8	1
Theophylline (ng/L)	20	20 - 20	9	0	20 - 25	7	1
TCPP (ng/L)	100	170 - 670	11	11	100 - 100	8	0
Xylenes (total) (µg/L)	0.5	0.5 - 0.61	9	1	0.5 - 0.5	8	0



WateReuse

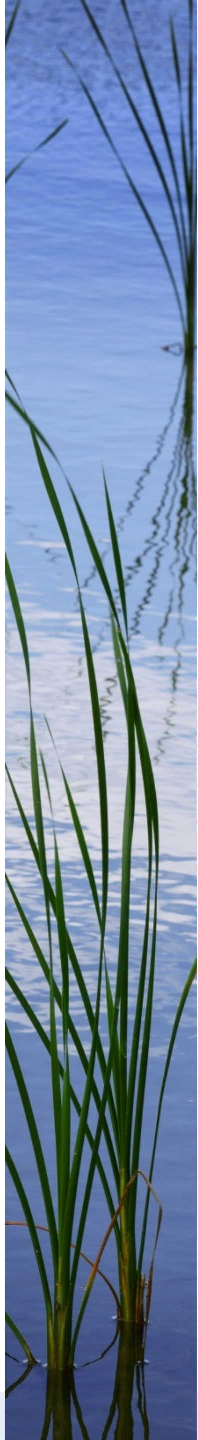
DPR Pilot Results

Jen Hooper



Pilot Effluent Water Quality

- All blends
  - Biological parameters were below detection
    - Total coliform, fecal coliform, *E. Coli*, coliphage (somatic and male-specific/F+- specific coliphage, MS2), *Clostridium perfringens, Enterococcus, Legionella, Cryptosporidium,* and *Giardia*
  - DBPs were low
    - HAA5 (< 22 µg/L)
    - TTHMs (< 13 µg/L)
    - Nitrogenous DBPs (sum of quantifiable detects <9.5 µg/L)
    - NDMA was generally low (average of 3.3 ng/L)
      - Increased to 41 ng/L after ozone, then biofiltration removed NDMA to an average of 14 ng/L
    - Haloquinones (average of 84 ng/L)
- 15% blend met all primary and secondary MCLs and action levels evaluated



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Pilot Effluent Water Quality

15% FWH WRC Blend

- **Met ALL Primary and Secondary MCLs evaluated**

25% FWH WRC Blend

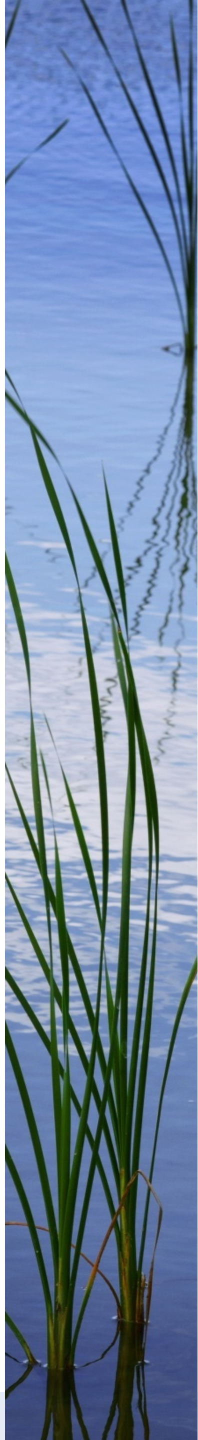
- **Cyanide**: 0.29 mg/L > 0.2 mg/L MCL
- **NDMA**: 25 ng/L > 10 ng/L CA&MA action levels

50% FWH WRC Blend

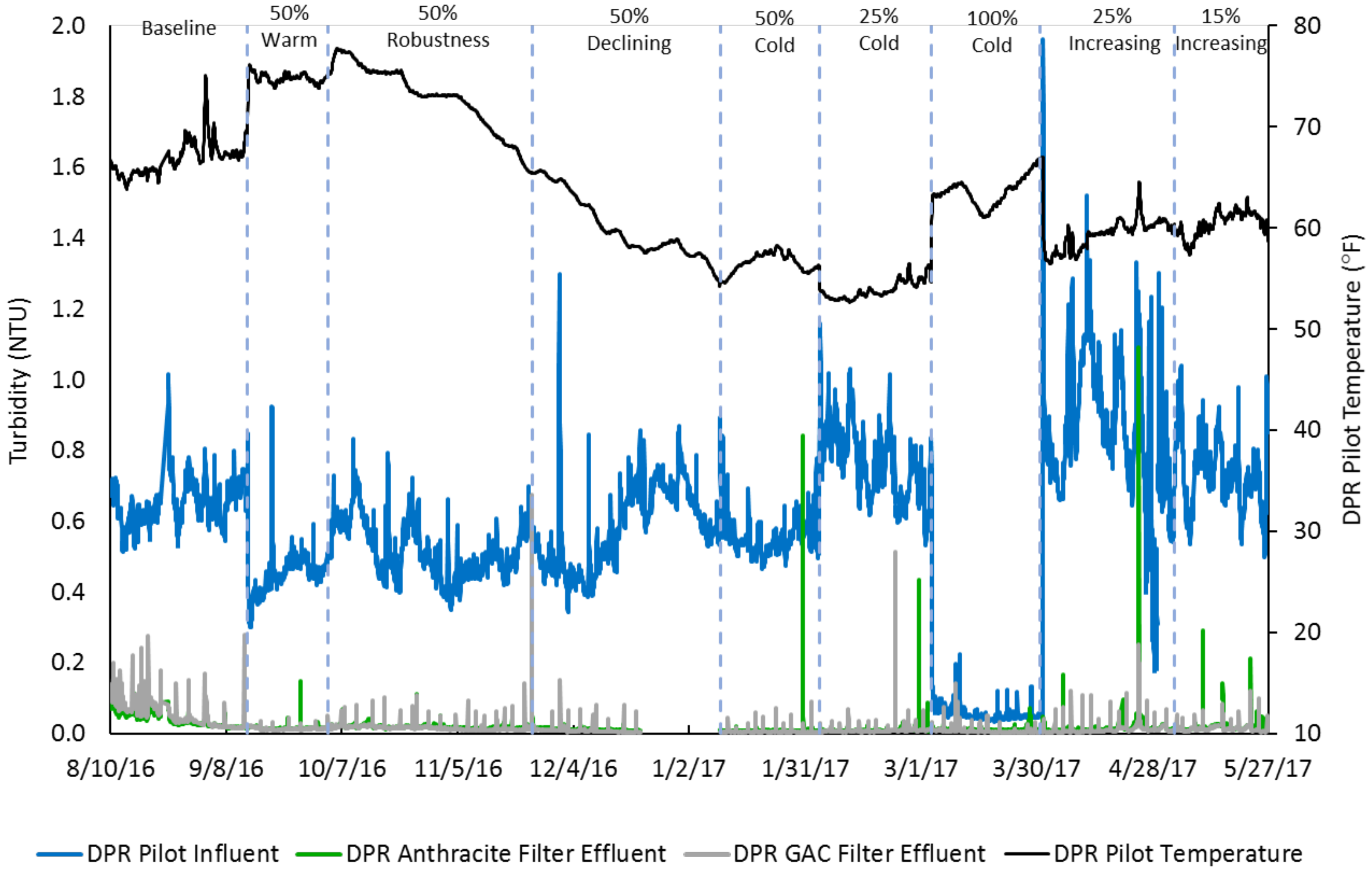
- **Nitrate**: 8.20 ± 3.87 mg-N/L, 5/17 samples > 10 mg-N/L MCL
- **Bromate:** 13 µg/L > 10 µg/L MCL
- **Di(2-ethylhexyl) phthalate:** 8 µg/L > 6 µg/L MCL
- **Color:** 166 CU > 15 CU SMCL *(robustness only)*
- **Manganese:** 0.06 mg/L > 0.05 mg/L SMCL
- **NDMA:** 11 ng/L > 10 ng/L CA&MA action level

100% FWH WRC Blend

- **Nitrate:** 14.3±9.5 mg-N/L > 10 mg-N/L MCL
- **Bromate:** 11 µg/L > 10 µg/L MCL
- **Cyanide:** 0.27 mg/L > 0.2 mg/L MCL

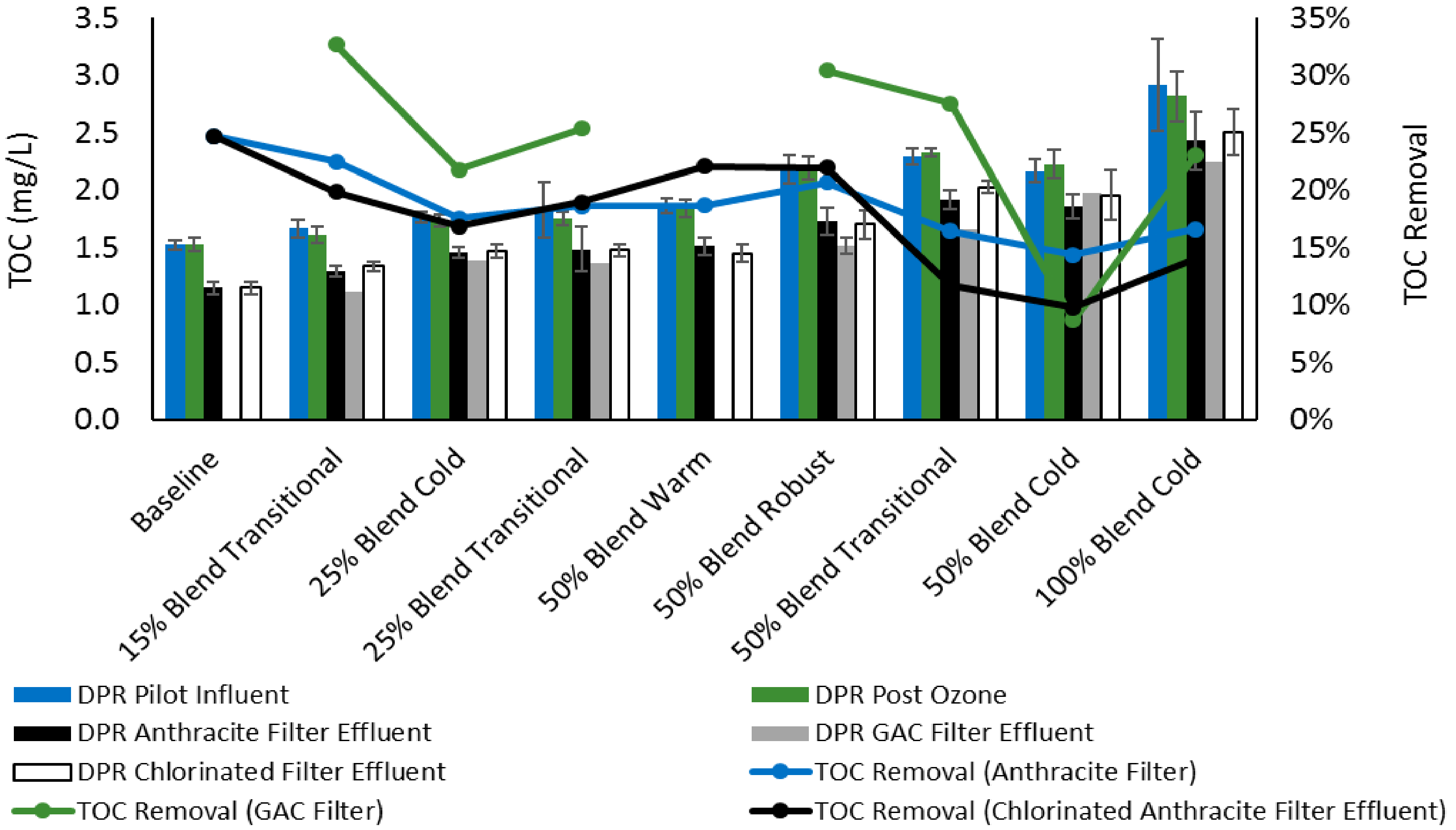


Turbidity



Baseline
50% Warm
50% Robustness
50% Declining
50% Cold
25% Cold
100% Cold
25% Increasing
15% Increasing
Turbidity (NTU)
DPR Pilot Temperature (°F)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
80
70
60
50
40
30
20
10
8/10/16
9/8/16
10/7/16
11/5/16
12/4/16
1/2/17
1/31/17
3/1/17
3/30/17
4/28/17
5/27/17
DPR Pilot Influent
DPR Anthracite Filter Effluent
DPR GAC Filter Effluent
DPR Pilot Temperature

TOC



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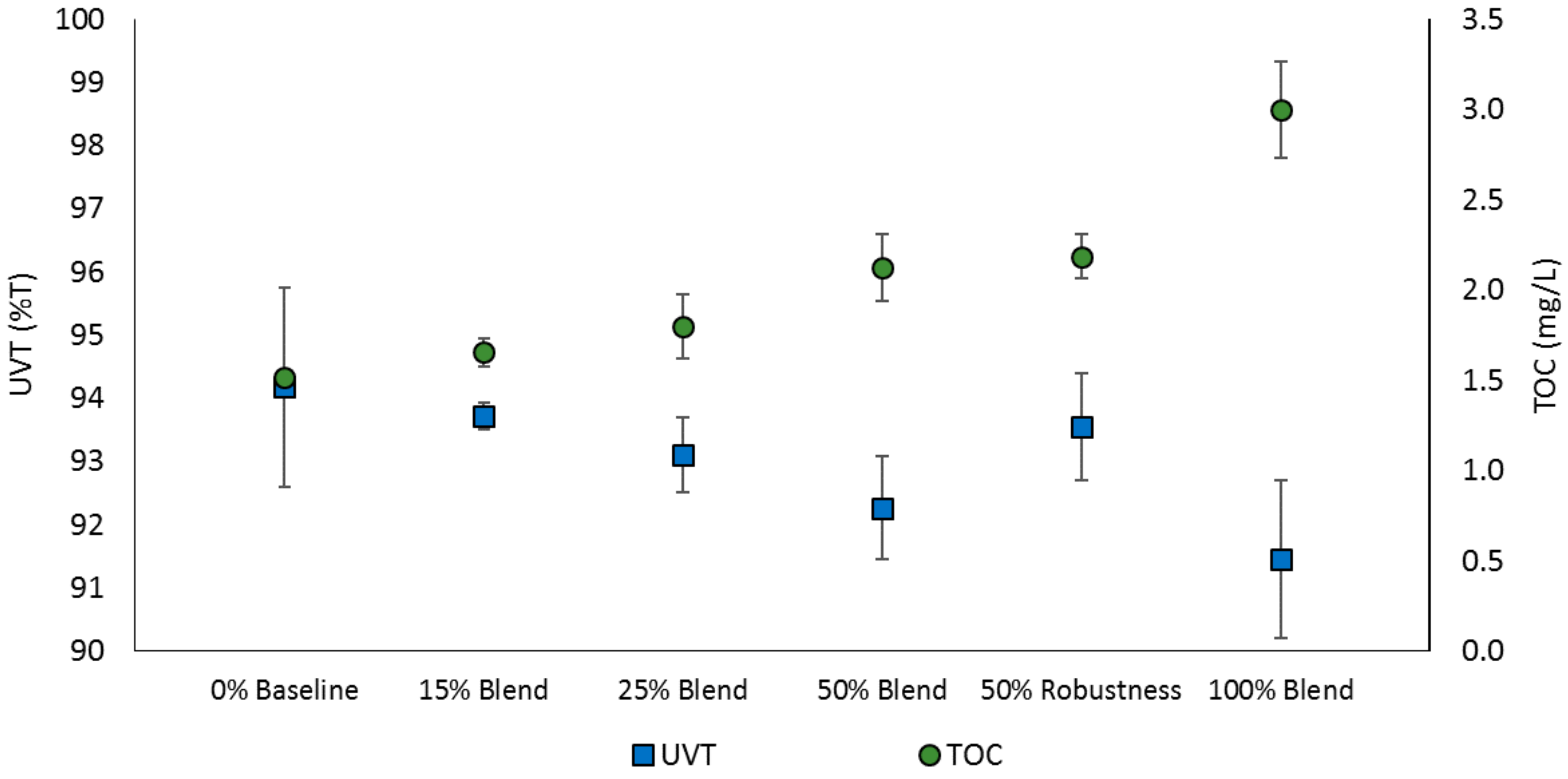
Organic Carbon Compounds



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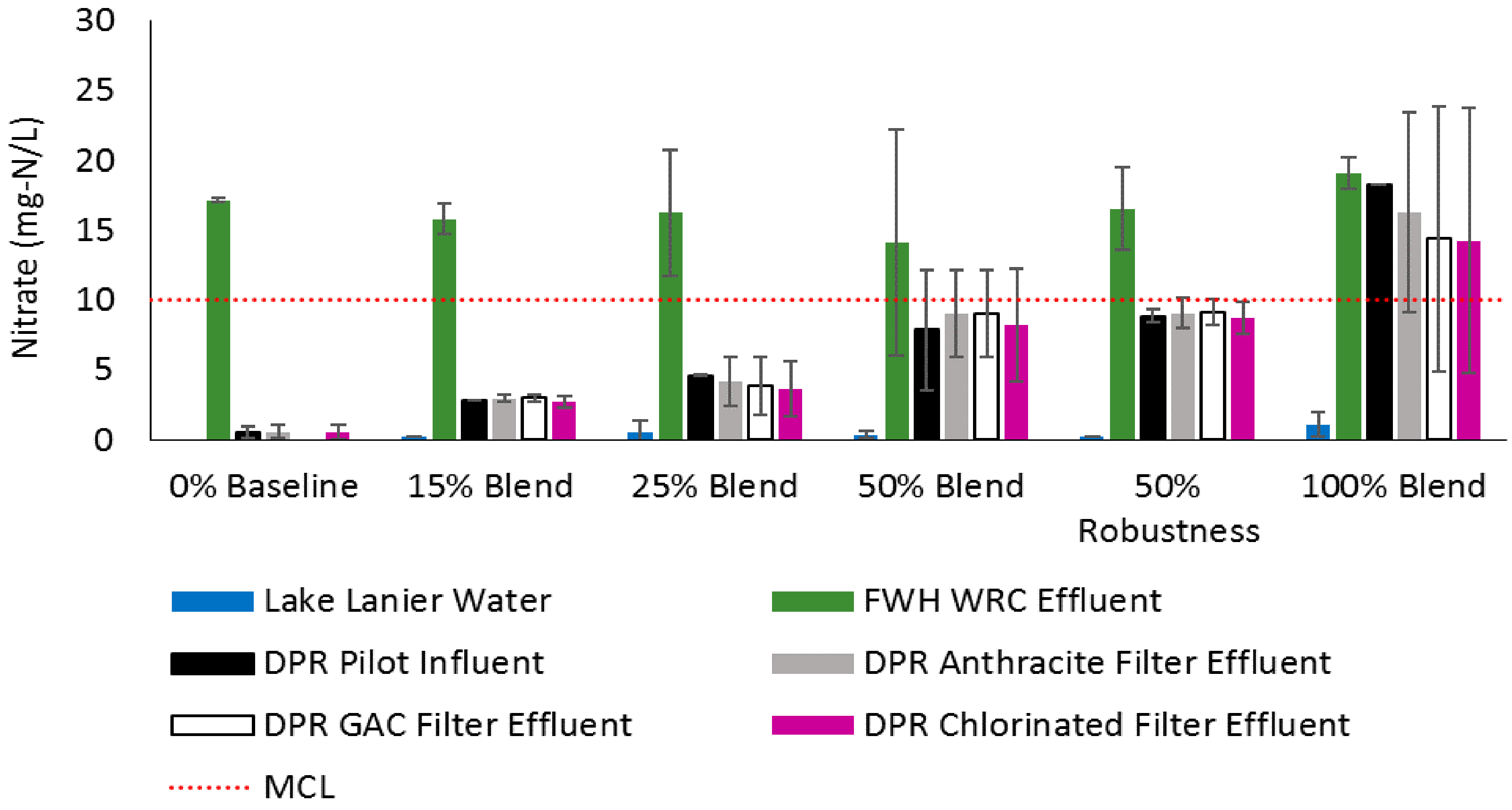
Nitrate



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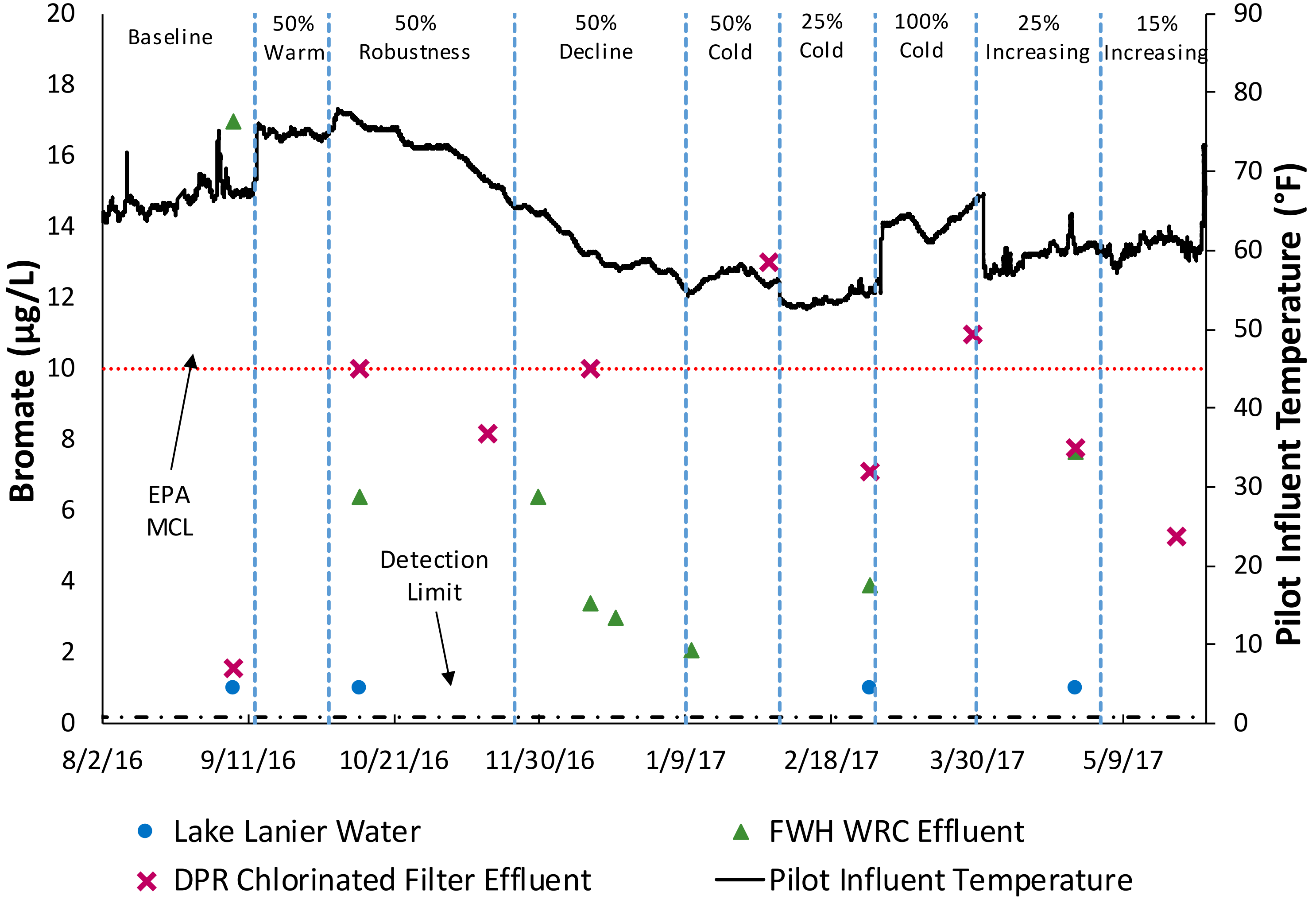
Bromate



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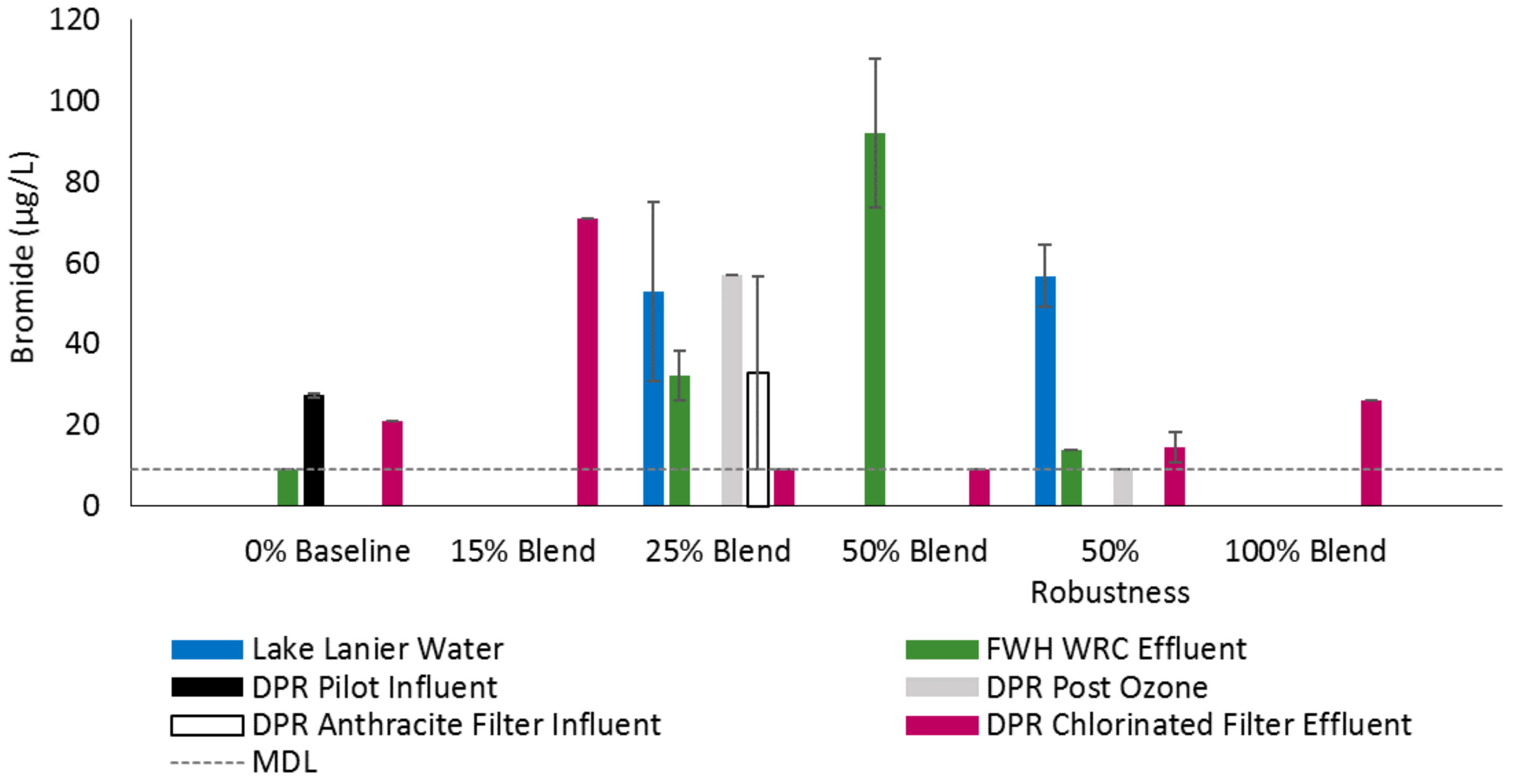
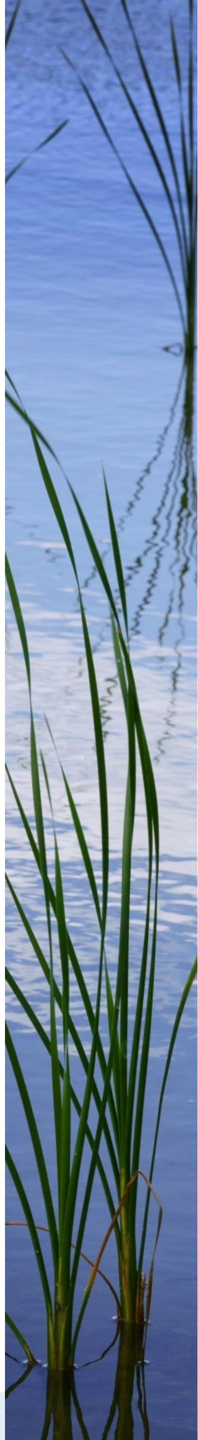
Bromide





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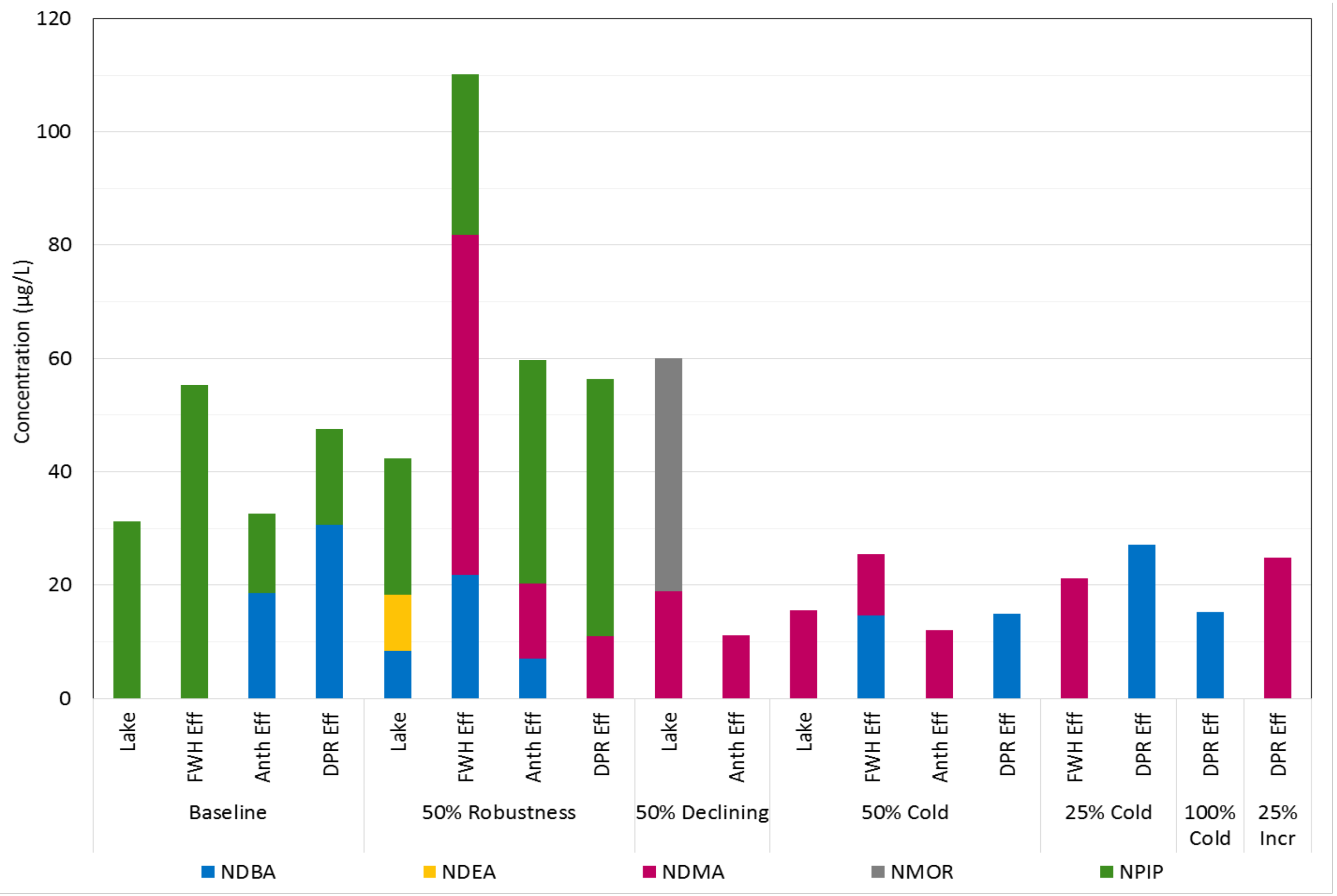
Nitrosamines



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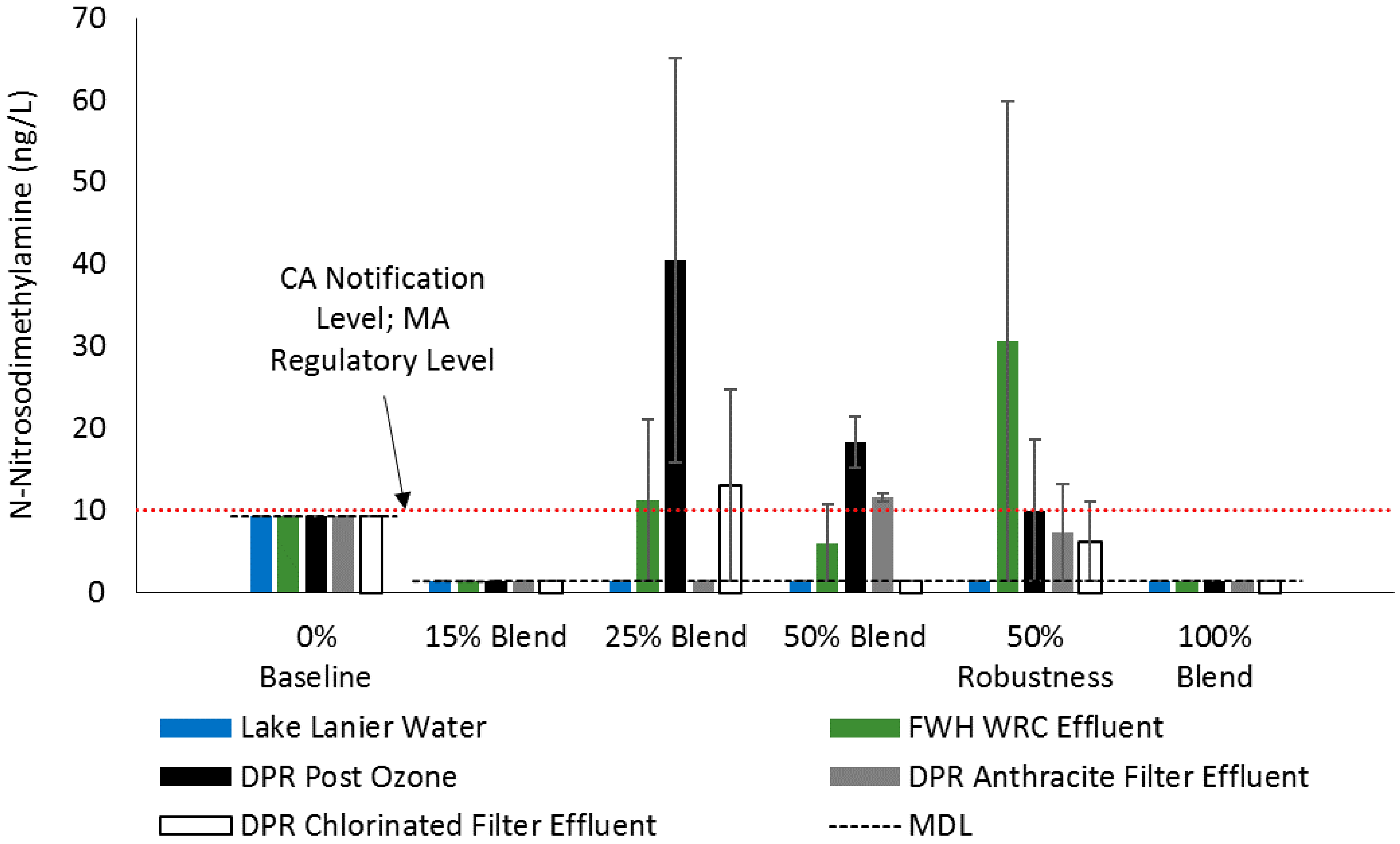
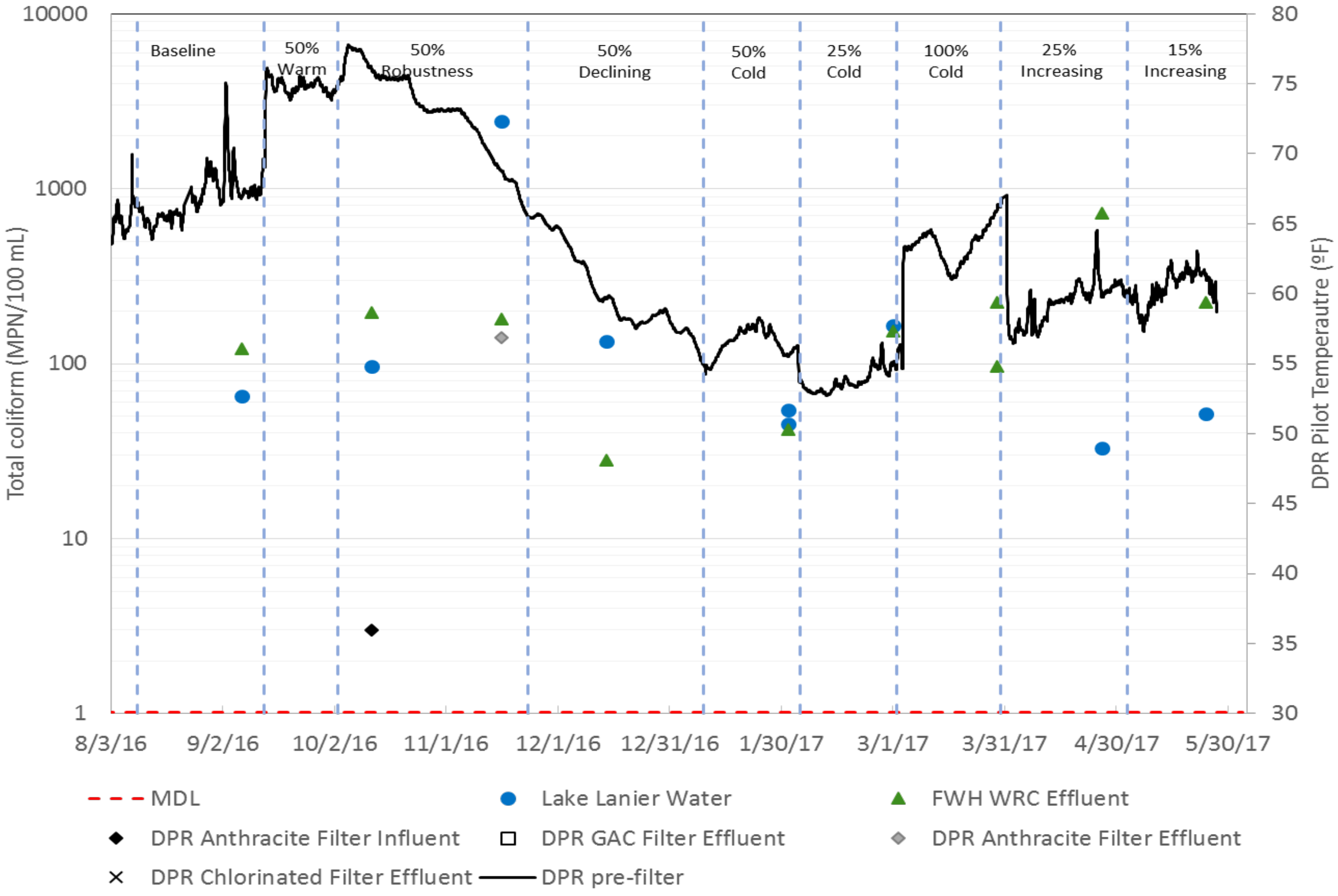
NDMA



70
60
50
40
30
20
10
0
N-Nitrosodimethylamine (ng/L)
CA Notification Level; MA Regulatory Level
0% Baseline
15% Blend
25% Blend
50% Blend
50% Robustness
100% Blend
Lake Lanier Water
FWH WRC Effluent
DPR Post Ozone
DPR Anthracite Filter Effluent
DPR Chlorinated Filter Effluent
MDL

Microbial Parameters



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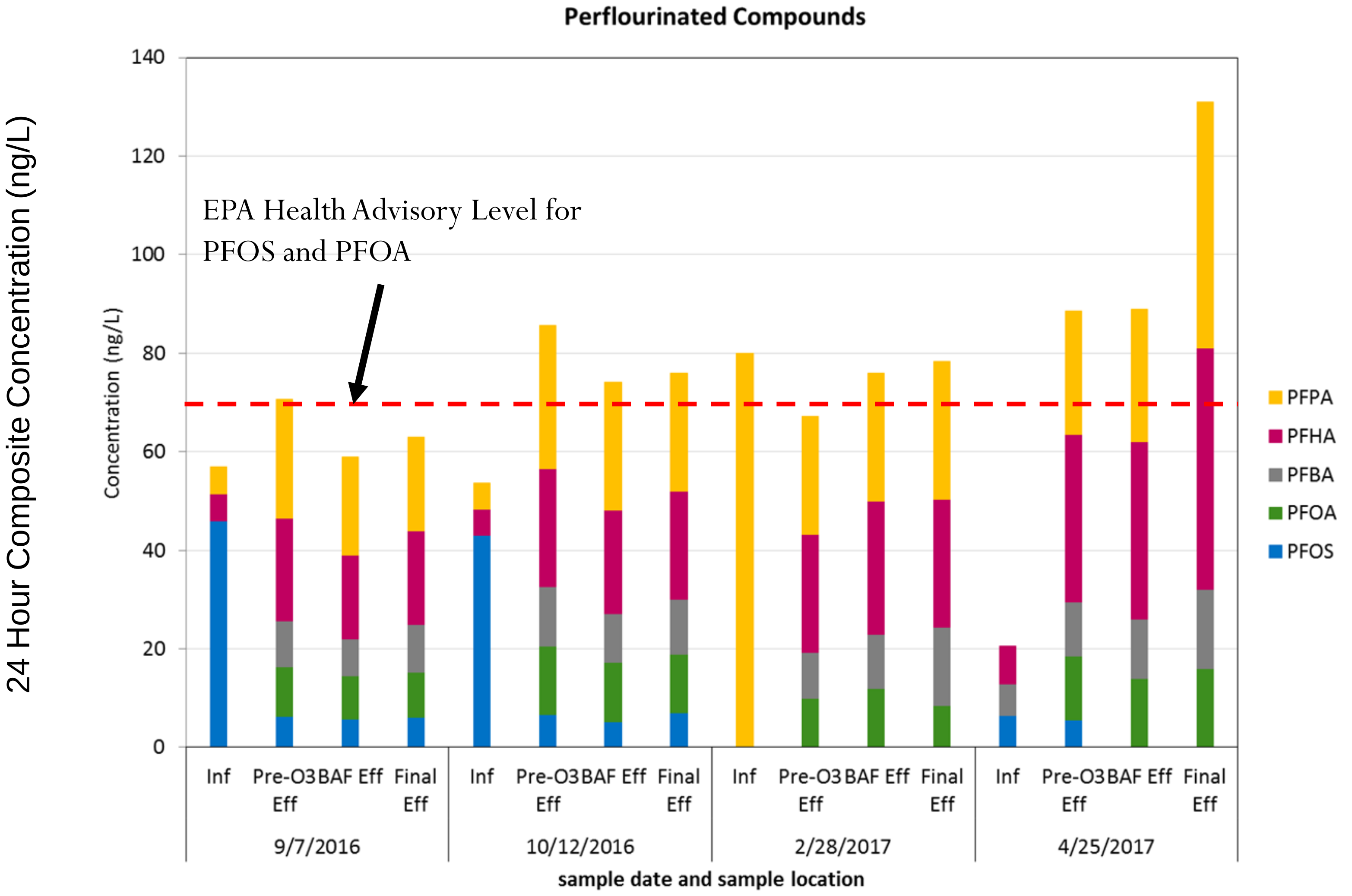
Perfluorinated Compounds – FWH Results



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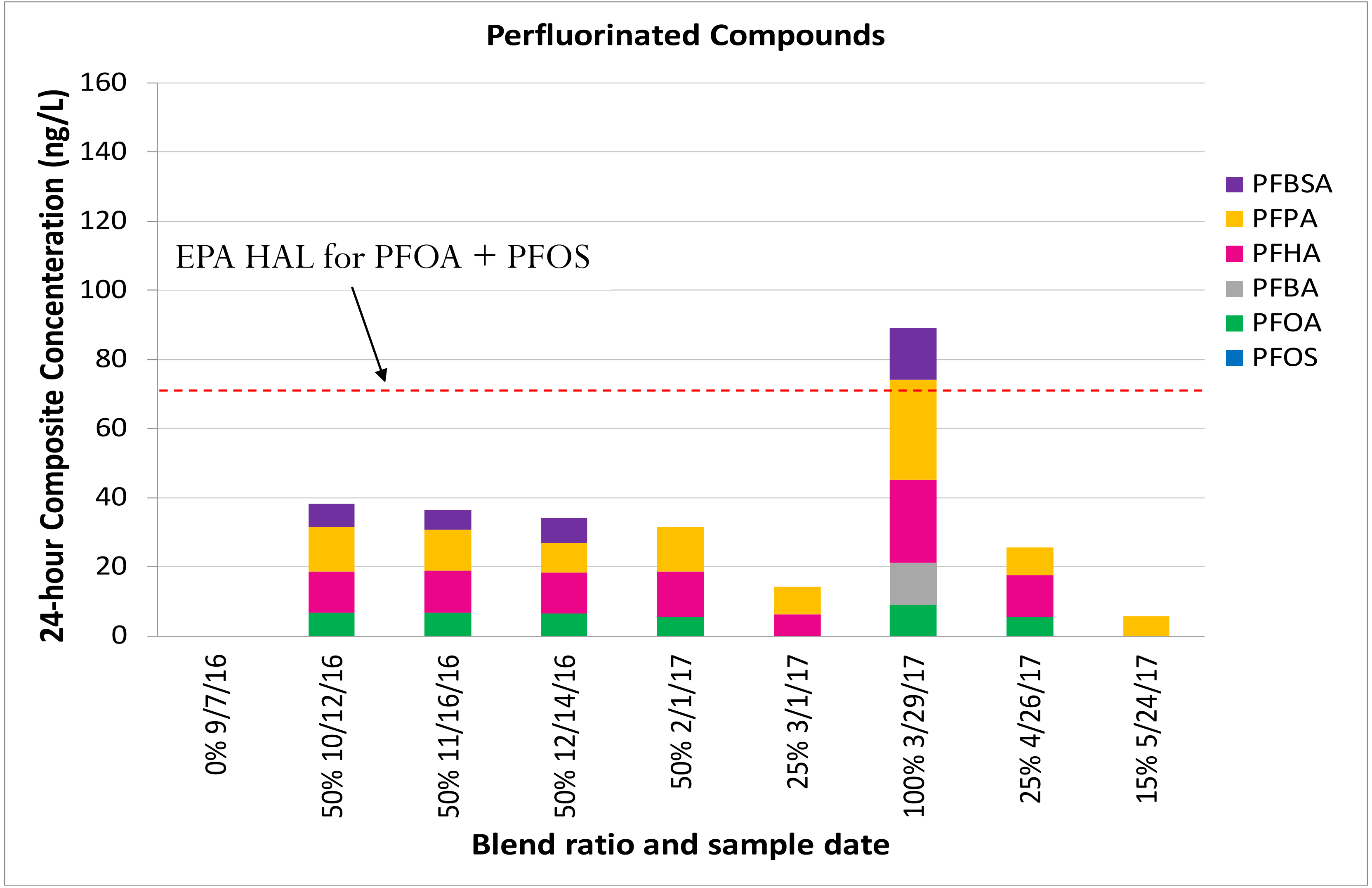
Perfluorinated Compounds - DPR Pilot Results



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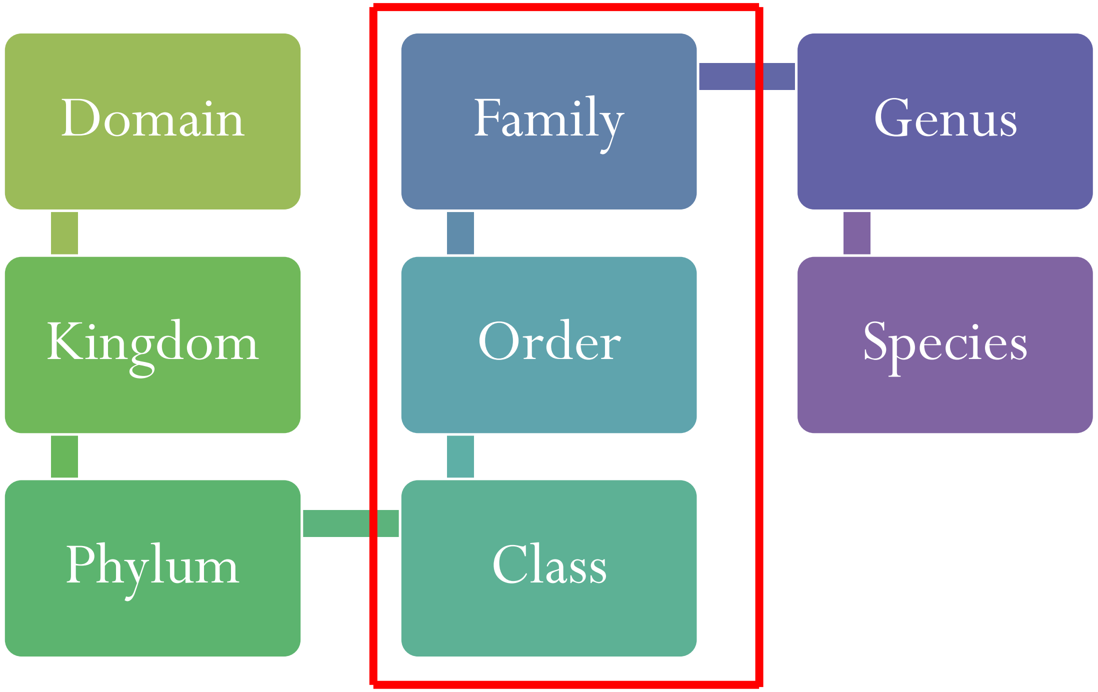
Microbial community analysis

- Collected biofilter samples in April 2017
  - FWH Old GAC
  - FWH New GAC
  - SCFP anthracite
  - DPR pilot anthracite
- Measured the 16S rRNA using Next Generation Sequencing
- Class to family-level information
  - Phylum – Proteobacteria
  - Genus – *Escherichia*
  - Species – *E. coli*
- Operational Taxonomic Units (OTUs) are used *in lieu* of species to evaluate diversity



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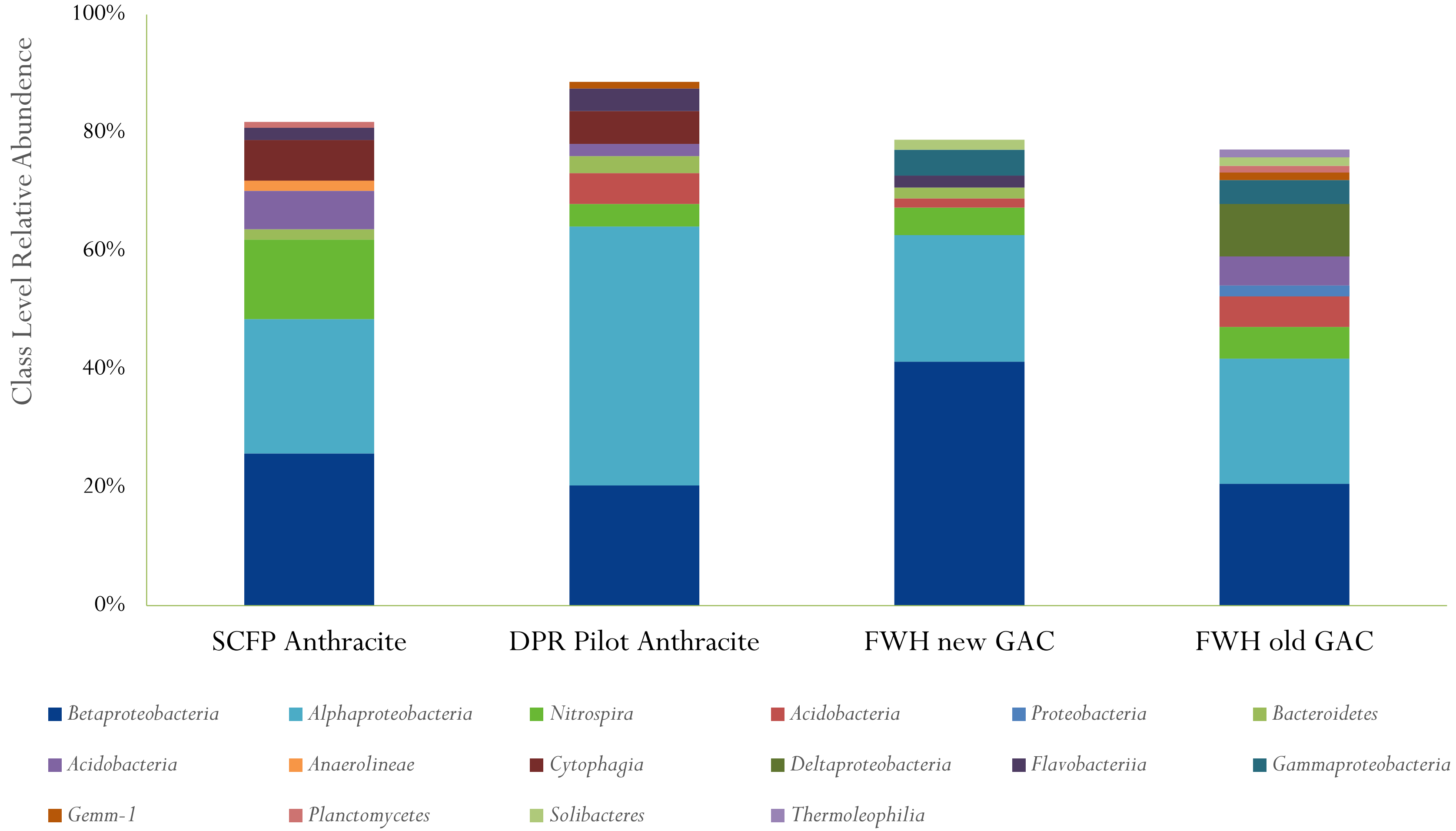
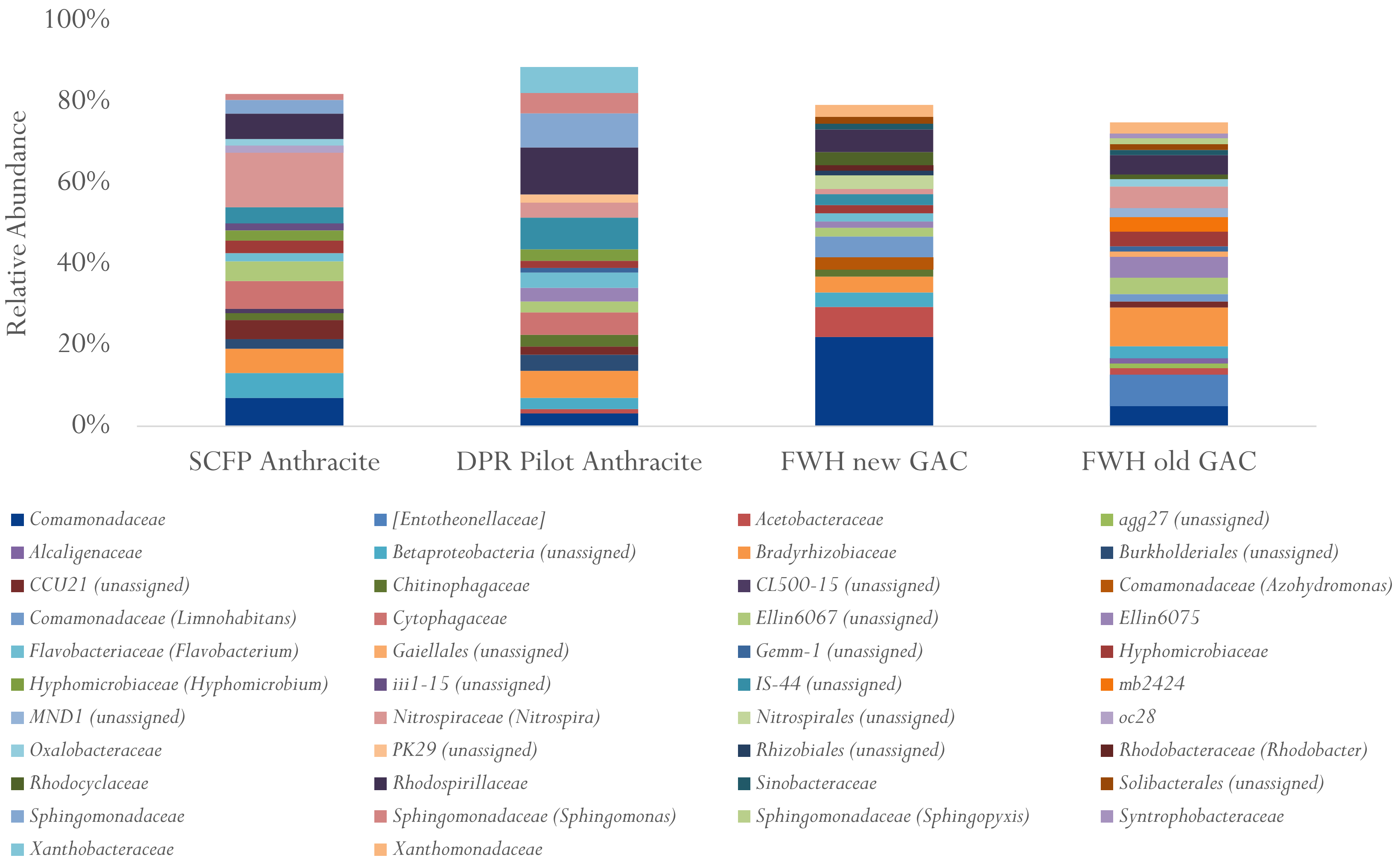
Classes present at >1% relative abundance



Families present at >1% relative abundance



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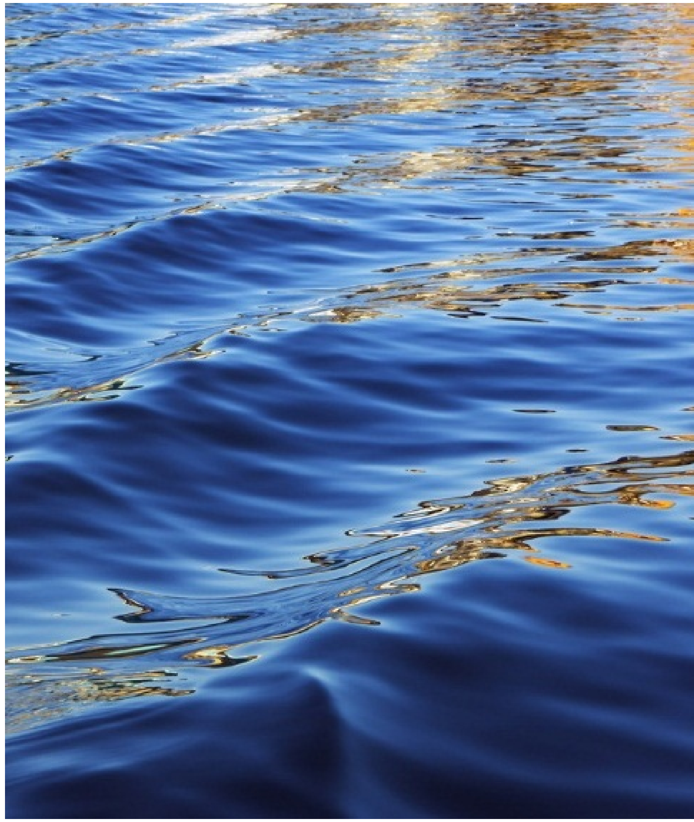
Comparison of DPR and IPR

Denise Funk



Source Water Quality Summary

Parameter	FWH Advanced Treated Water	Lake Lanier – Shoal Creek Intake
Maximum Temperature (^{o}C)	27.1	24.0
Minimum Temperature (^{o}C)	13.7	11.0
Average Turbidity (NTU)	**0.14**	**0.87**
Turbidity Range (NTU)	0.01 to 0.45	0.34 to 6.58
pH Range	6.5 to 7.8	6.0 to 7.3
Average TOC (mg/L)	**3.81**	**1.47**
TOC Range (mg/L)	1.8 to 8.0	1.3 to 2.2
Average Nitrate-Nitrite (mg-N/L)	**13.9**	**Very low**
Nitrate-Nitrite Range (mg-N/L)	0 to 23.2	<0.2 to 0.87

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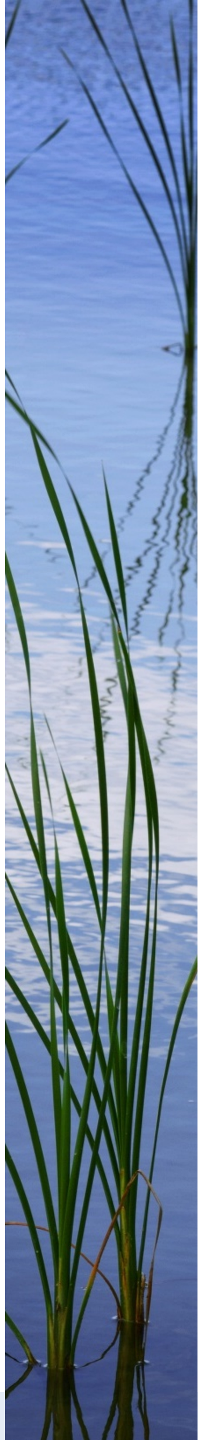
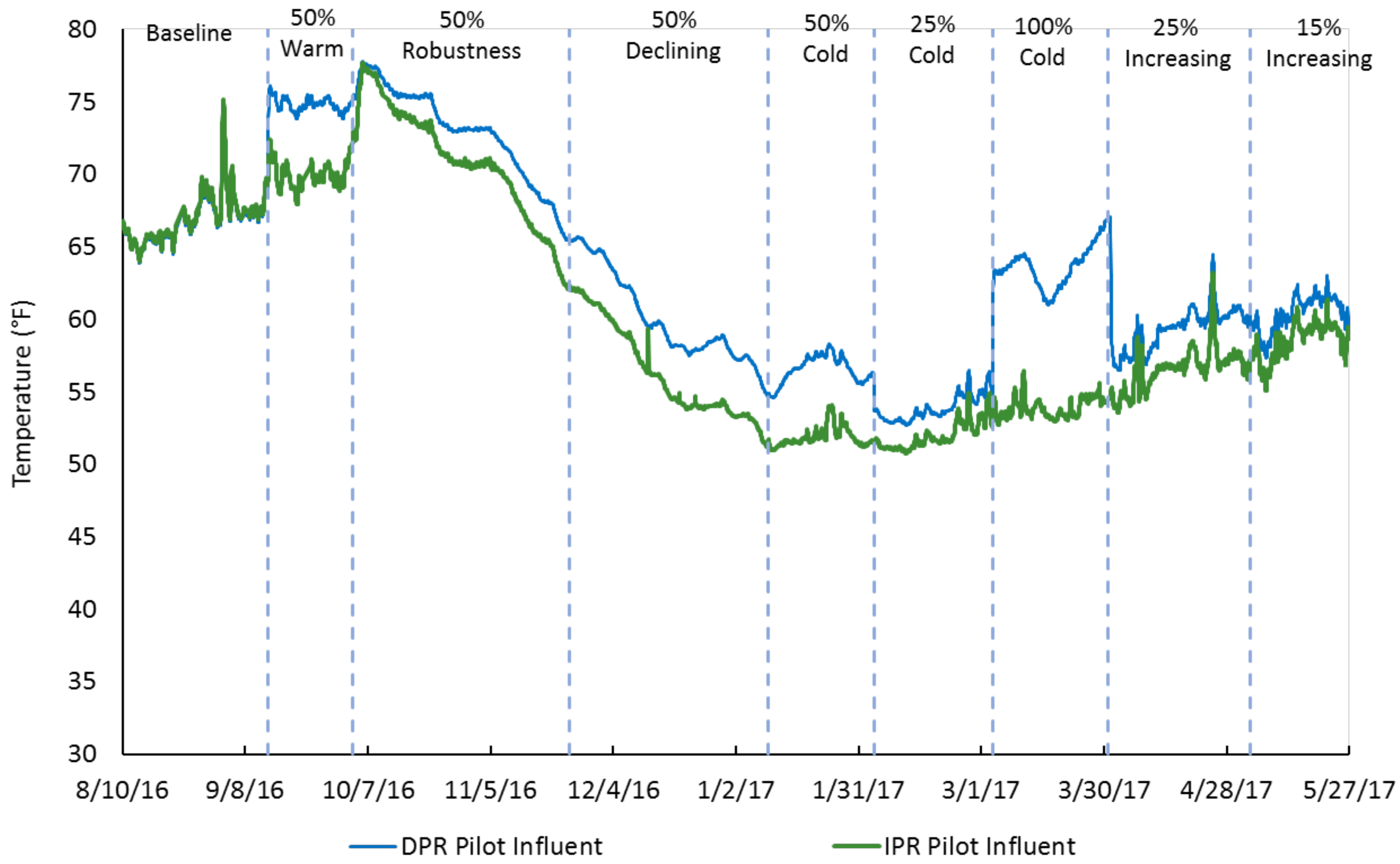


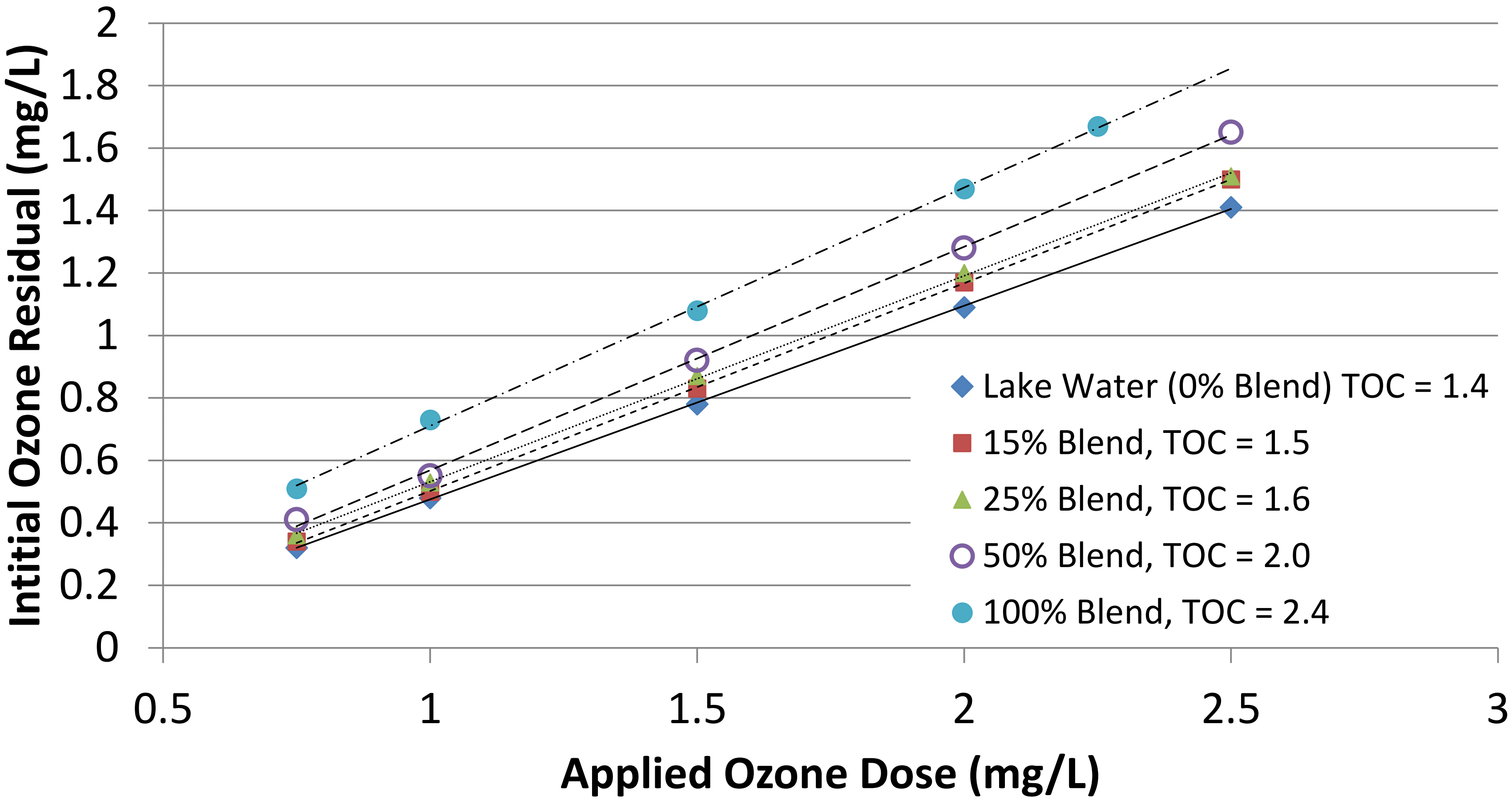
Temperature



Trace Organic Compounds

CEC Detections	Reporting Limit	DPR Pilot			IPR Pilot		
		Pilot Effluent			Pilot Effluent		
		Range	n	n > RL	Range	n	n > RL
1,4-Dioxane (µg/L)	0.07	0.07 - 0.22	10	6	0.07 - 0.07	4	0
4-nonylphenol - semi quantitative (ng/L)	100	100 - 690	10	3	100 - 100	2	0
Albuterol (ng/L)	5	5 - 160	10	2	5 - 5	2	0
Azithromycin (ng/L)	20	20 - 850	2	1	750 - 750	1	1
Butalbital (ng/L)	5	5 - 7.5	10	1	5 - 5	2	0
Caffeine (ng/L)	5	5 - 11	10	1	5 - 5	2	0
Carbadox (ng/L)	5	5 - 7.7	10	1	5 - 5	2	0
Di(2-ethylhexyl) phthalate (µg/L)	0.6	0.6 - 8	10	4	0.6 - 0.6	3	0
Diltiazem (ng/L)	5	5 - 5.4	10	1	5 - 5	2	0
Erythromycin (ng/L)	10	10 - 10	10	0	10 - 11	2	1
Ethylparaben (ng/L)	20	20 - 27	10	1	20 - 20	2	0
Iohexal (ng/L)	10	10 - 41	10	4	10 - 10	2	0
Meprobamate (ng/L)	5	5 - 11	10	2	5 - 5	2	0
Propylparaben (ng/L)	5	5 - 30	10	2	5 - 7	2	1
Salicylic Acid (ng/L)	100	100 - 150	10	3	100 - 100	2	0
Sucralose (ng/L)	100	240 - 41000	10	10	100 - 100	2	0
TCEP (ng/L)	10	10 - 160	10	9	10 - 10	2	0
Testosterone (ng/L)	5	5 - 7	10	1	5 - 5	2	0
Tris(chloroisopropyl)phosphate (TCPP) (ng/L)	100	100 - 220	10	6	100 - 100	2	0

Ozone Dose Response by Blend



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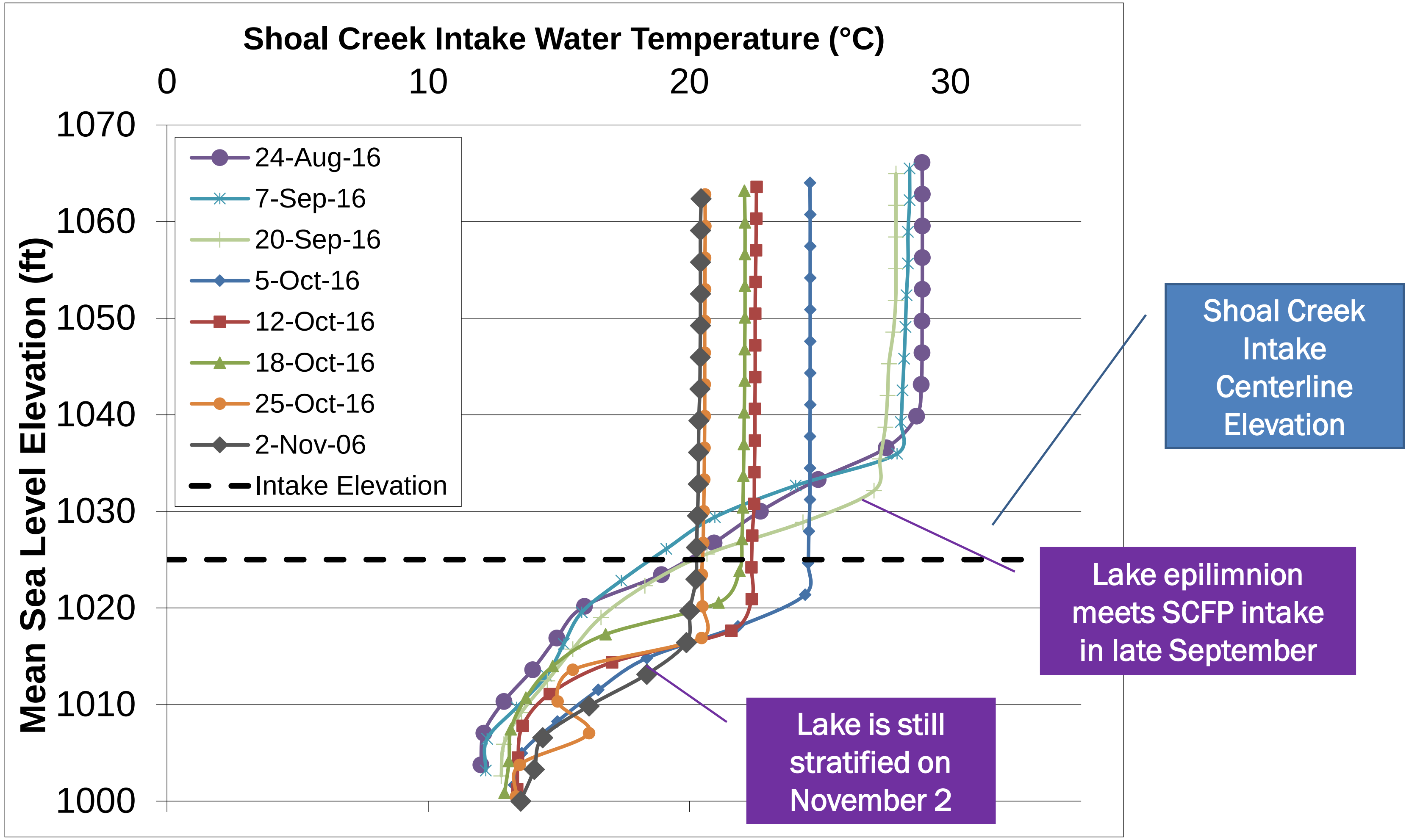
Lake Lanier Temperature Profiles



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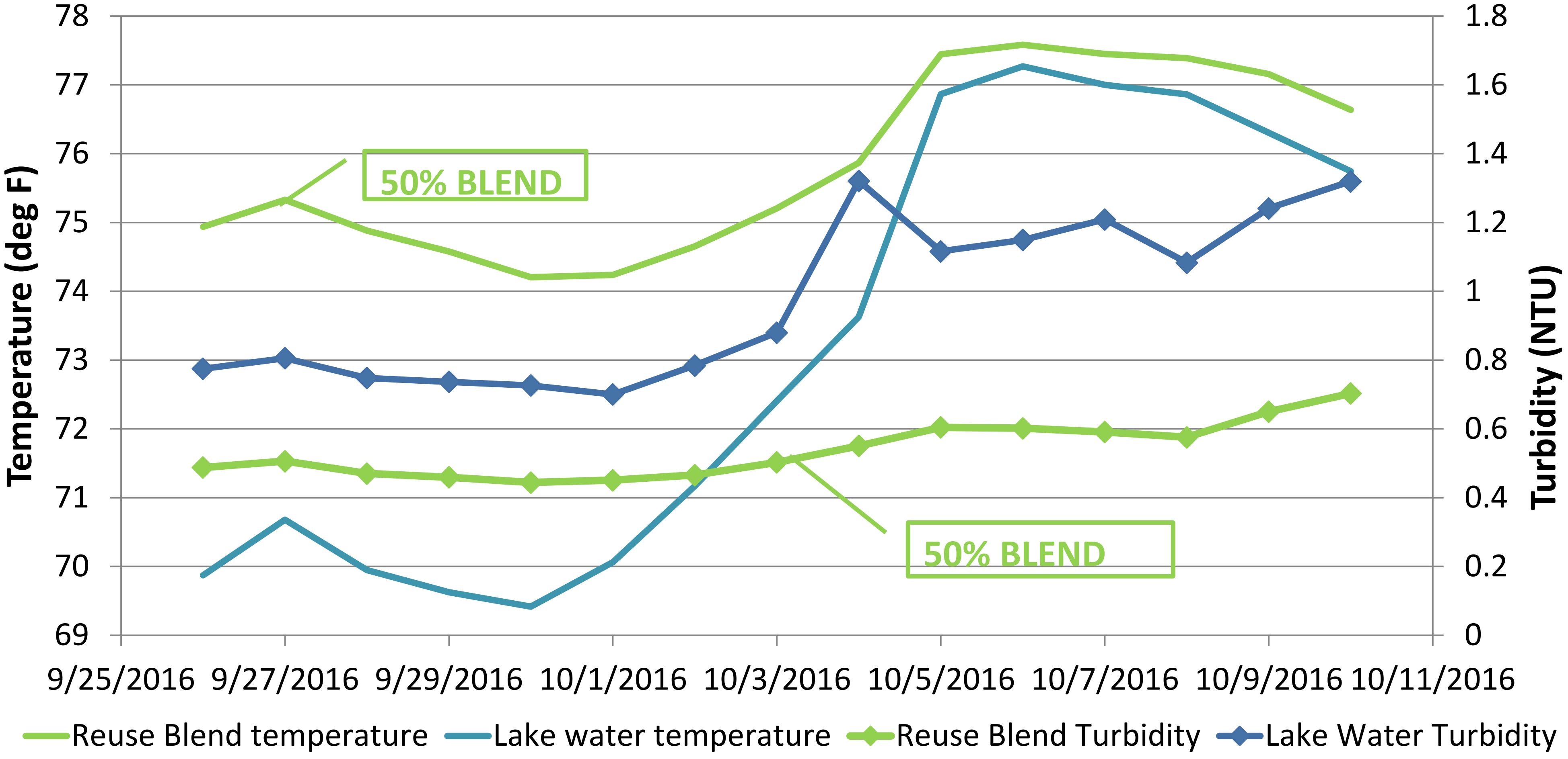
Comparing Raw Temp and Turbidity during Seasonal Water Quality Challenge



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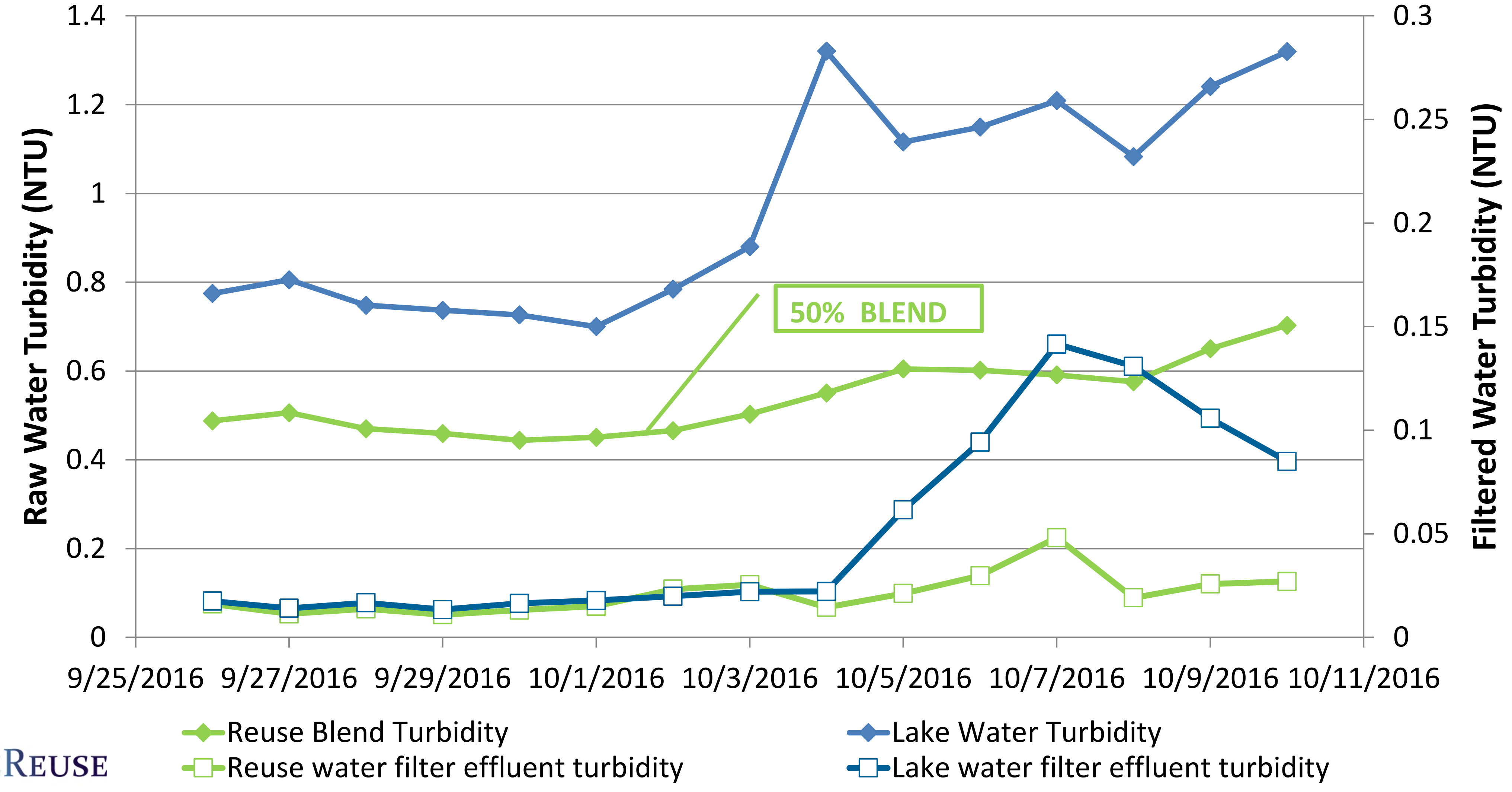
DPR Filter Effluent Performance Exceeds IPR During Seasonal Water Quality Challenge



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Filter Headloss Accumulation Rate

Scenario	Anthracite (ft/hr)	GAC (ft/hr)
Before Robustness		
DPR Pilot (50%)	0.03±0.01	0.07±0.01
IPR Pilot	0.04±0.02	0.09±0.01
During Robustness		
DPR Pilot (50%)	0.04±0.01	0.10±0.01
IPR Pilot	0.08±0.03	0.15±0.04

100 hours longer filter run time

35 hours longer filter run time

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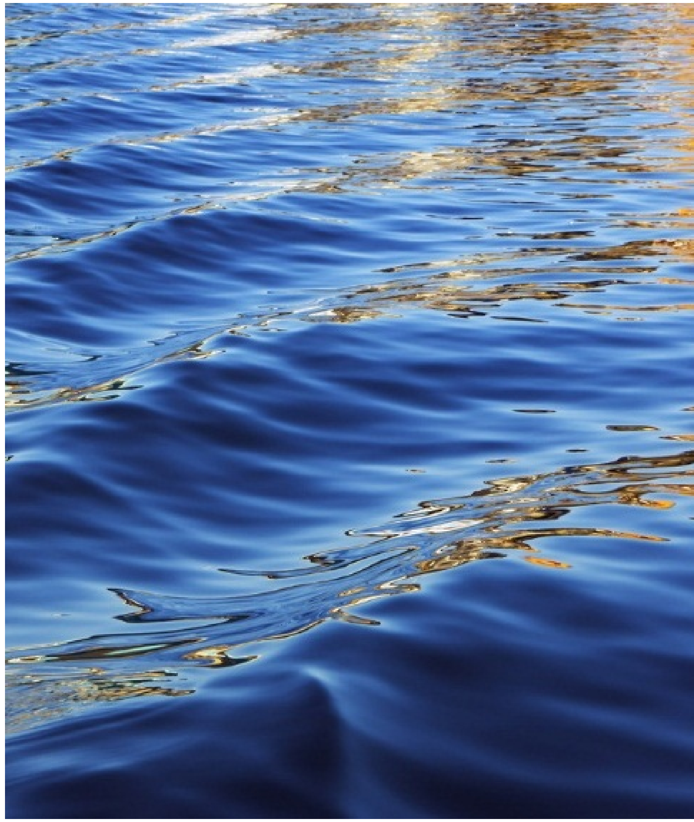
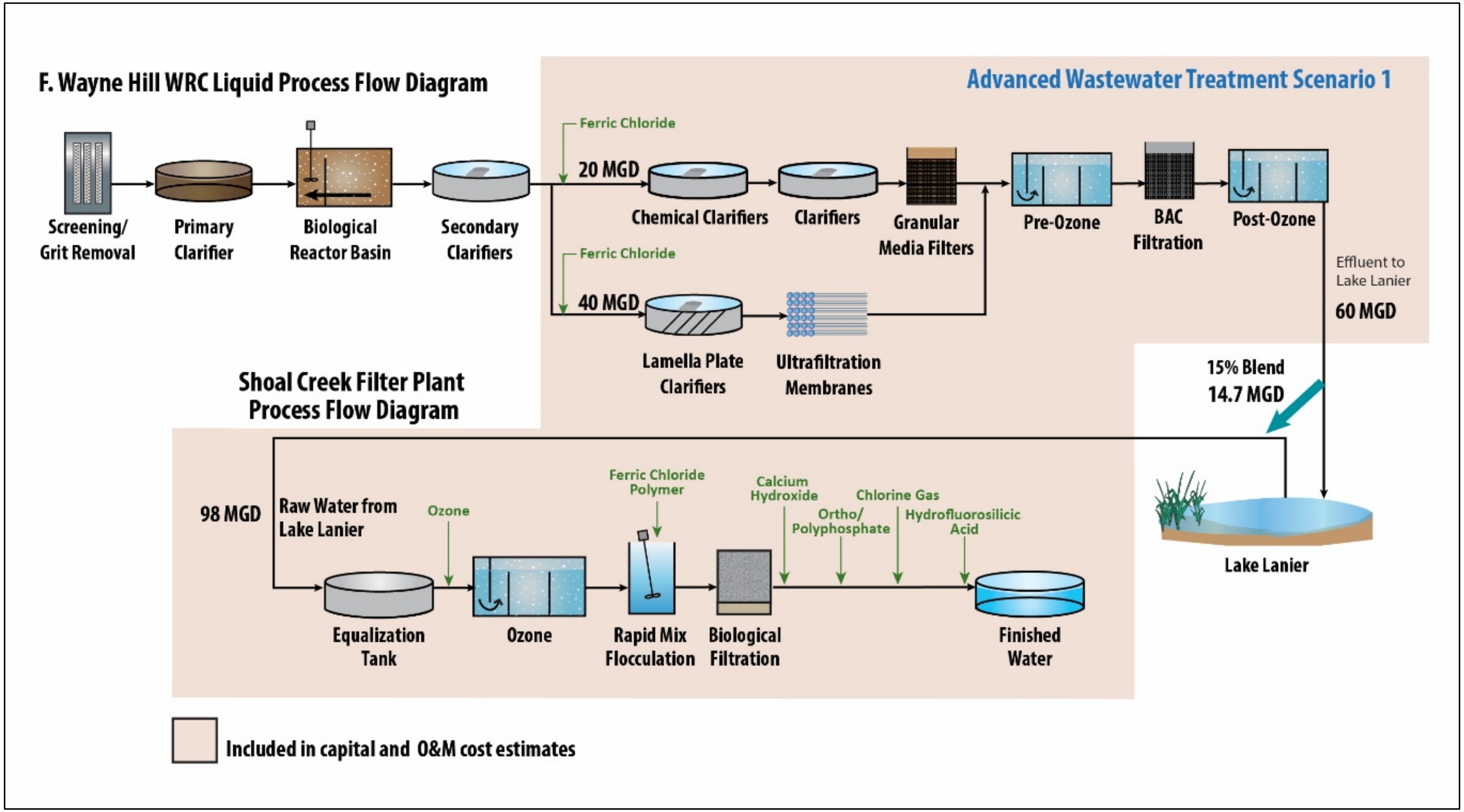
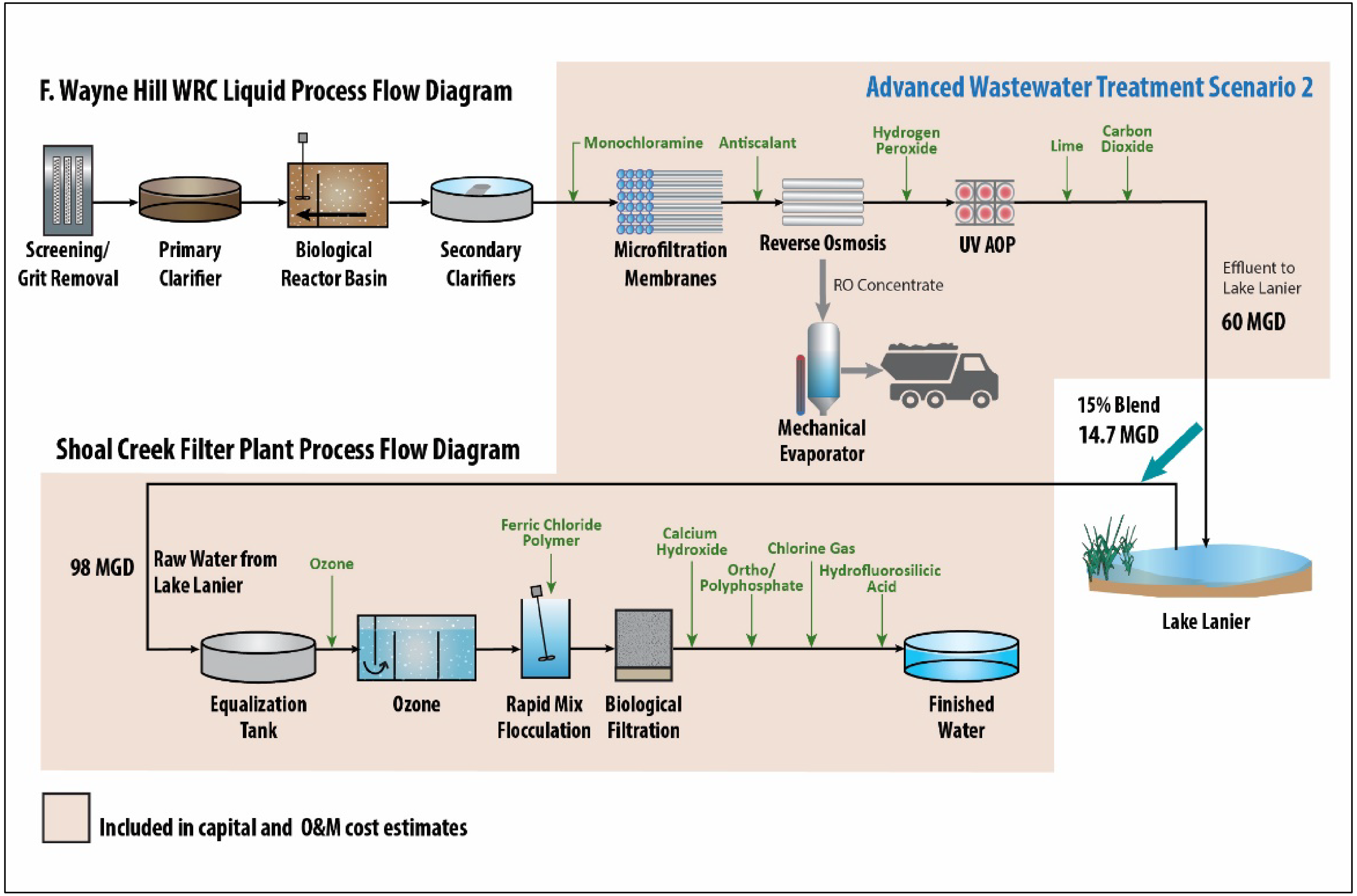
Cost Comparison



Economic Analysis – Scenario 1



Economic Analysis – Scenario 2



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Economic Analysis – Cost Comparison

Cost Element	Scenario 1 Advanced Wastewater Treatment (GMF-UF/Pre-O3/BAC/Post-O3)	Scenario 2 Advanced Wastewater Treatment (MF/RO/UV-AOP, RO Brine Mechanical Evaporation)	Potable Water Treatment (O3/BAF/Cl2)	Scenario 1 DPR Treatment	Scenario 2 DPR Treatment
Capital Cost, 30-Year Amortized	$10.8M	$30.4M	$7.01M	$17.8M	$37.4M
Average Annual O&M Cost	$3.38M	$16.7M	$7.02M	$10.4M	$23.7M
Total Cost, $/MG Treated	**$780**	**$2,820**	**$680**	**$1,460**	**$3,500**

More than double the cost!!

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Key Findings

- DPR as a source water supply provided potable water quality at a 15% blend using two-stage ozone/biofiltration *without* RO
- Advanced treated water from FWH WRC was of equal or higher quality than Lake Lanier for all biological parameters with *no detections* in the pilot finished water
- Of the 300 analytes measured, nitrate, bromate, and cyanide were the primary contaminants that exceeded potable water quality criteria
- DPR had operational benefits during challenging source water supply conditions including lower ozone demand and lower filter headloss accumulation rates
- The two-stage ozone/biofiltration process was less than *half* the cost of full advanced treatment

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Acknowledgements

Project Team

- Denise Funk, PE, BCEE (PI)
- Dr. Kati Bell, PE, BCEE (co-PI)
- Jen Hooper, PE (co-PI)
- Dr. Ben Stanford
- Dr. Ching-Hua Huang
- Eddie Machek
- Georgia Tech co-ops and interns
- Morayo Noibi

Project Advisory Committee

- Kelly Comstock
- Dr. Dan Gerrity
- Dr. Chance Lauderdale
- Alex Mofidi

Water Research Foundation

- Justin Mattingly

Questions?

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