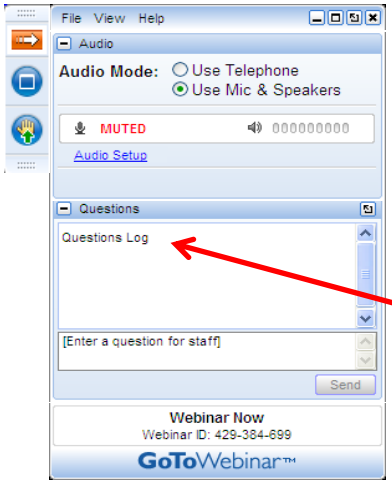
Ozone Applications at Inland Locations for Potable Reuse

Wednesday December 13, 2017

1:00 – 2:30 p.m. EDT

How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this web seminar.**

Today's Moderator

Justin Mattingly
WE&RF Research Manager

WE&RF and WRF Integration

- Represents the evolution of water research
  - 1,200 subscribers
  - 2,300 research studies
  - $700M integrated research portfolio
- Launches January 1, 2018

WE&RF and WRF Integration

- A more interconnected research agenda
- Access to an expanded collection of water research
- Leverages funding
- Communicates more effectively with government partners
- Strengthens relationships with water partners
- Creates a model for collaboration across the water community

Today's Speakers

Vijay Sundaram, P.E.
Regional Practice Leader,
Water Sustainability
Stantec

Denise Funk
Division Director, Research and
Development at Gwinnett County
Department of Water Resources

Ozone-BAC Technology Development and Demonstration in Reno Nevada

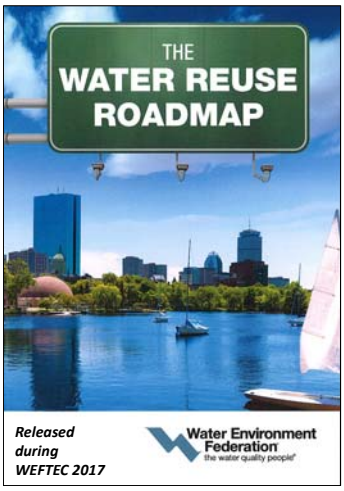
Vijay Sundaram, PE[1,2]

[1]Regional Practice Leader, Water Sustainability, Stantec

[2]PhD Candidate, University of Nevada, Reno

Potable Reuse Drivers

- Water scarcity
- Single-pipe system
- No cross connection concerns
- Allows for "One Water" management strategy
- Maximum utilization of the water resource



https://www.e-wef.org/Store/ProductDetails.aspx?productId=58436417

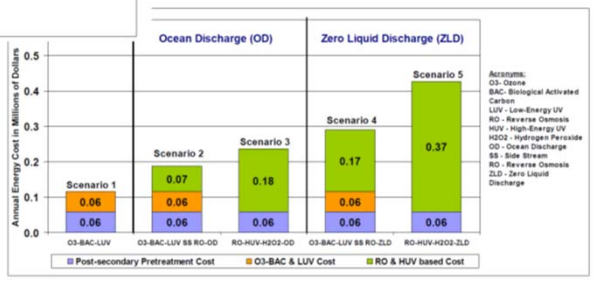
Why Ozone-based Trains for Inland Locations?

Technology	Preliminary Relative Capital Cost
O3-BAC-LUV	$ 1.0x
O3-BAC side-stream RO-OD	$ 1.4x
RO-H2O2-HUV-OD	$ 1.7x
O3-BAC-LUV side-stream RO-ZLD	$ 2.5x
RO-H2O2-HUV-ZLD	$ 3.3x

Acronyms:
O3: Ozone
BAC: Biological activated carbon
LUV: Low-energy UV
RO: Reverse Osmosis
H2O2: Hydrogen Peroxide
HUV: High-energy UV
OD: Ocean discharge
ZLD: Zero liquid discharge

MF-RO-AOP based treatment trains are widely utilized in potable reuse (PR) applications.

Annual Energy Cost Per MGD (Unit Power Cost = $0.14/kWh)



Northern Nevada Potable Reuse Initiative

2007 – 2010

- Ozone-BAC technology development
- 20-month continuous field testing
- Findings presentation to Nevada Division of Environmental Protection (NDEP)

2015 – Present

- WE&RF 15-10 Ozone-BAC technology optimization project underway in South Truckee Meadows Water Reclamation Facility in Reno
- State of Nevada approved IPR regulations (December 2016)
- Advanced Water Treatment Technologies Demonstration Project – Ongoing Regional IPR Feasibility Study

Ozone-BAC Technology Development & Demonstration

2007 - 2010 — Reno-Stead WRF Ozone-BAC Pilot Project

City of Reno/ Stantec/ WE&RF 08-05 team demonstrated Ozone-BAC as an equally effective alternative to RO for CEC and regulated contaminant removal.

2015 - 2018 — WE&RF 15-10 Ozone-BAC Optimization Project

Stantec/ American Water/WE&RF/ Washoe County team is investigating DBP formation of Ozone-BAC effluent and BAC EBCT Optimization.

2016 - 2020 — UNR Project – Demonstration of IPR Treatment Trains

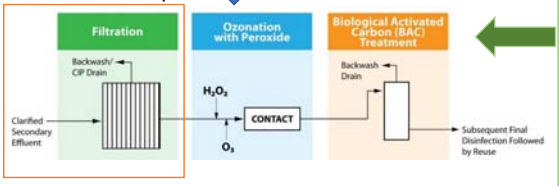
University of Nevada Reno (UNR) and Regional Team will conduct "Membrane Free" IPR demonstration projects based on Nevada IPR Regulations.

Ozone-BAC Introduction

Ozone

- A strong oxidant
- Widely utilized in drinking water treatment
- Generated onsite (Air, O_2, Liquid Oxygen)
- Typical contact time: 3 – 20 minutes

Pretreatment Steps



Biological Activated Carbon (BAC)

- Activated carbon colonized by microbes
- Empty bed contact time (EBCT) 10 - 30 minutes
- Backwashed regularly to:
  - Control biomass
  - Remove suspended solids

Ozone Pros & Cons

Pros	Cons
• CEC and Refractory Organics Oxidation • Virus Inactivation • DO Replenishment • Taste, Odor, & Color Improvement	• Bromate Formation Potential • Biodegradable Organic Byproducts Formation • NDMA Generation Potential • Incomplete Flame Retardant Removal

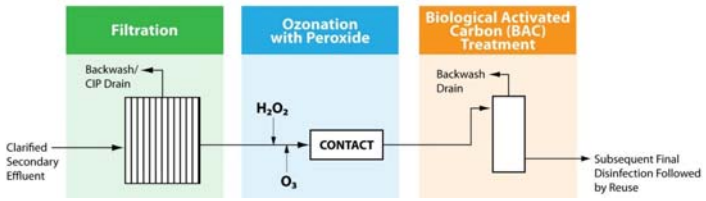
Reno-Stead WRF Ozone-BAC Pilot Testing

Stantec

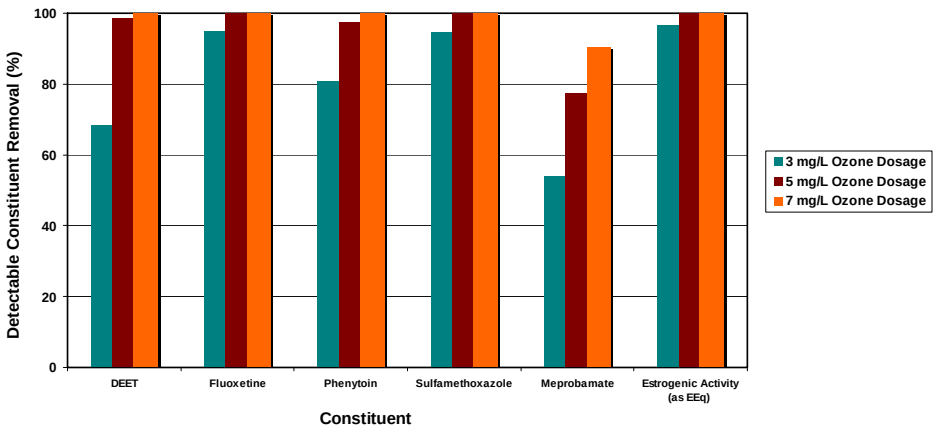
Reno-Stead WRF Project | WE&RF 15-10 | Regional Project

Reno-Stead Ozone-BAC Pilot Testing

- WWTP Site: Reno-Stead WRF (RSWRF)
  - Average flowrate = 1.5 Mgal/d
  - Mean cell residence time (MCRT) = 17 to 25 days
  - Average bromide = 240 µg/L
  - Average TDS = 350 mg/L
- Ozone-BAC Continuous Operation
  - Pretreatment:
    - Membrane Filtered (MF) Effluent (10 months)
    - Sand Filtered (SF) Effluent (5 months)
  - Flowrate = 10.7 gpm; BAC Empty Bed Contact Time (EBCT) = 30 minutes



CEC Ozone Oxidation



Ozone Disinfection Performance

Ozonation of Membrane Filtered Effluent

Sample Location	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)	MS2 (pfu/100 mL)
Secondary Effluent	>2400	>2400	Not Measured
Membrane Effluent	<0.9	<0.9	1.1 X 10^8
After Ozonation with 5 mg/L O_3 & 3.5 mg/L H_2O_2	<0.9	<0.9	1- 6 X 10^0

Ozonation of Sand Filtered Effluent

Sample Location	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)
Secondary Effluent	>2400	>2400
Sand Filtered Effluent	>2400	>2400
After Ozonation with 5 mg/L O_3 & 3.5 mg/L H_2O_2	2 – 5	140 – 280*

* Of concern in some effluent uses and regulatory jurisdictions.

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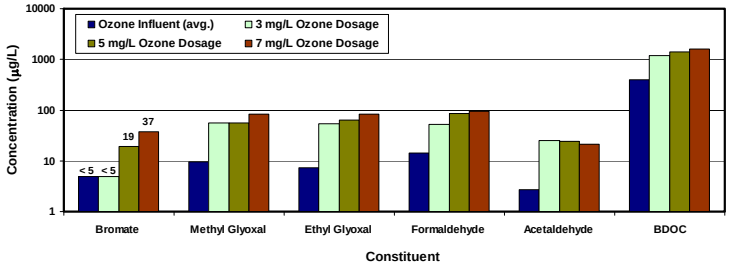
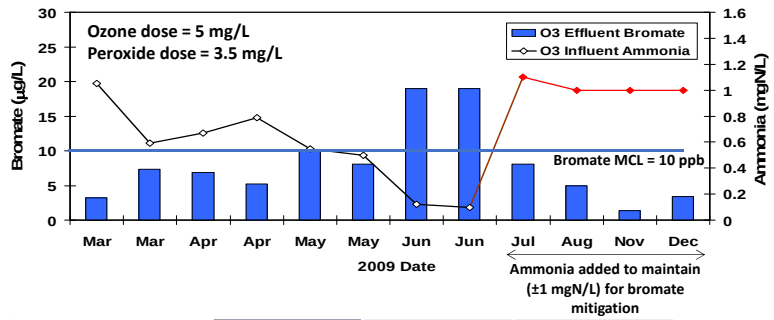
Ozonation Byproducts





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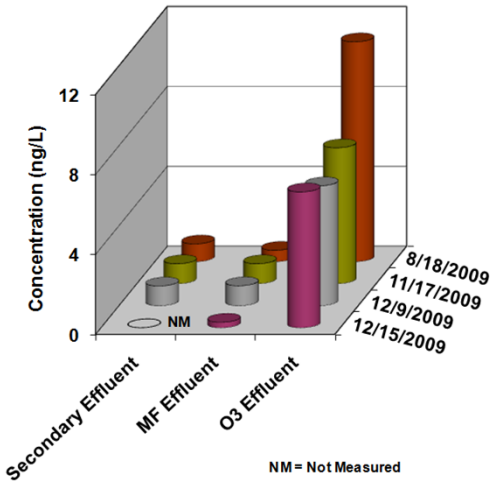
NDMA Formation during Ozonation



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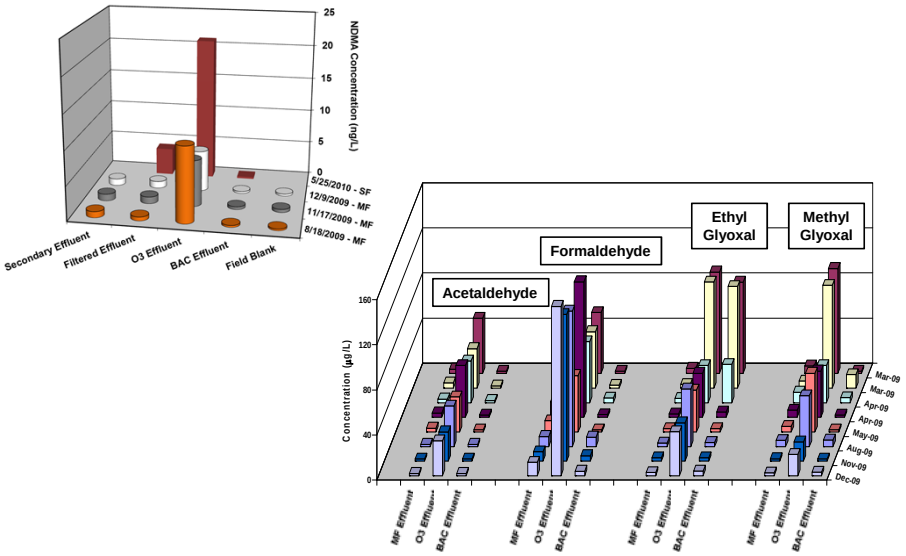
Role of BAC in Ozonation Byproducts Removal



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MF-Ozone-BAC CEC Removal

Group	Constituents	Units	Secondary Clarifier Effluent	Membrane Filter Effluent	Ozonation Effluent	BAC Effluent	Blank
Hormones	Estradiol	ng/l	5.9	3.4	1.9	1.8	2
	Estrone	ng/l	65	11.9	0.52	0.5	0.5
Pharmaceuticals	Gemfibrozil	ng/l	45.7	35.3	0.2	0.2	< 0.080
	Ibuprofen	ng/l	4.4	6.4	< 0.39	< 0.39	< 0.39
	Naproxen	ng/l	20.5	17.9	< 0.25	< 0.25	< 0.25
	Triclosan	ng/l	54.7	2.2	< 1.2	< 1.2	< 1.2
	Diazepam	ng/l	2.7	2.8	0.18	< 0.14	< 0.14
	Fluoxetine	ng/l	3.2	2.4	2	< 0.080	< 0.080
	Primidone	ng/l	140	129	4.6	< 0.6	< 0.6
	Trimethoprim	ng/l	270	130	< 2.4	< 2.4	< 2.4
	Atorvastatin	ng/l	14.3	5.5	< 0.11	< 0.11	< 0.11
	Azithromycin	ng/l	323	102	< 22	< 22	< 22
	Caffeine	ug/l	25	10.8	< 0.042	< 0.042	< 0.042
	Ciprofloxacin	ng/l	363	247	< 14	< 14	< 14
	Cotinine	ng/l	54.5	20.5	14	2.3	0.49
	Meprobamate	ng/l	385	343	43.5	3	< 1
	Sulfamethoxazole	ng/l	930	833	6.0	< 0.25	< 0.25
	Methadone	ng/l	65.3	33	0.3	0.13	< 0.4
	Atenolol	ng/l	953	890	10.6	< 1	< 1
	Carbamazepine	ng/l	258	247	0.98	0.8	0.8
	Dilantin	ng/l	253	150	3.1	< 1	< 1
	Diclofenac	ng/l	96	109	< 0.5	< 0.5	< 0.5
	Amoxicillin	ng/l	1633	1020	0.74	ND	ND
	Phenytoin	ng/l	390	343	3.9	ND	ND
	Salicylic Acid	ng/l	25	32.67	28	20.67	48.67
Flame Retardants	TCEP	ng/l	620	545	445	< 3.4	< 3.4
	TCPP	ng/l	2100	2400	1400	< 2.7	< 2.7
	TDCPP	ng/l	633	623	627	0.695	3.23
Industrial EDCs	Bisphenol A	ng/l	18	22	< 0.27	< 0.27	2200
	Octylphenol	ng/l	31	< 25	< 25	< 25	< 25
	Nonylphenol monoethoxylate	ug/l	1.1	0.87	< 0.87	< 0.87	< 0.87
Organics	DEET	ng/l	115	125	2.56	< 0.60	1.2
	Musk Ketone	ng/l	47	38	< 25	< 25	< 25
	BHA	ng/l	76	42	< 1	< 1	< 1
	Atrazine	ng/l	1.3	1.5	0.5	< 0.25	< 0.25
	Benzophenone	ng/l	203	173	< 50	< 50	< 50
	1,4-Dioxane	ug/l	1.53	1.5	0.3	0.4	< 0.13
Ozone Byproducts	Formaldehyde	ug/l	9.2	9.8	133.3	5.8	2.4
	Acetaldehyde	ug/l	3.5	2.1	31.0	< 1	< 1
	Ethyl Glyoxal	ug/l	3.3	3.1	41.3	3.9	< 1.1
	Methyl Glyoxal	ug/l	3.3	3.4	27.0	3.7	< 0.5
	Propanal	ug/l	<0.7	<0.7	3.5	< 0.7	< 0.7
	NDMA	ng/l	1	0.9	7.9	< 0.28	0.385

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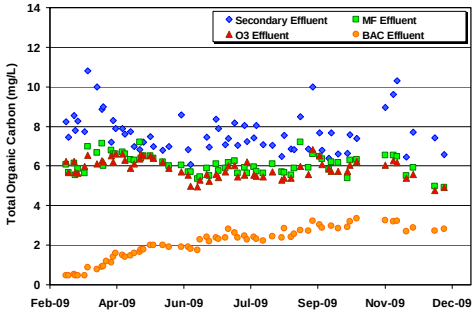
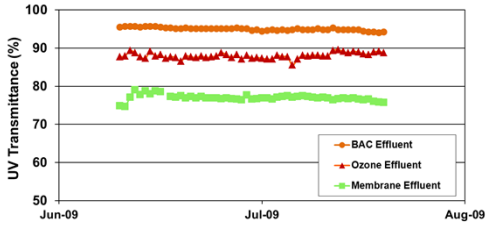
TOC Removal and UVT Improvement





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WE&RF 15-10 Optimization of Ozone-BAC Processes for Potable Reuse Applications

- Zia Bukhari, PhD
- Ruth Marfil-Vega, PhD
- Patrick Jjemba, PhD
- Matt Surmeier

Reno Regional Agency Team

- Lydia Peri, Washoe County
- Rick Warner, PE, Washoe County

Stantec

- Vijay Sundaram, PE
- Jeff Curtis, PhD

- Stefani McGregor
- Project Advisory Committee

xylem Let's Solve Water

- David Foster

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WE&RF 15-10 Project Objectives

1. **Monitor DBPs and FP in Ozone-BAC and RO effluents**
   - Establish baselines for Total Trihalomethanes (TTHMs), Haloacetic Acids (HAAs), nitrosamines and their precursors in the effluents
   - Determine relationship between TOC level and DBP FP
2. **Optimize Ozone-BAC in pilot scale**
3. **Develop a guidance manual for the potable reuse industry on design and operational optimization of Ozone-BAC systems**

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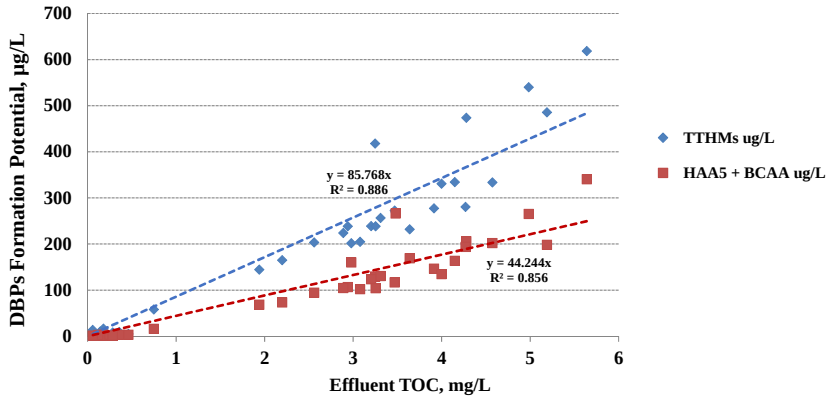
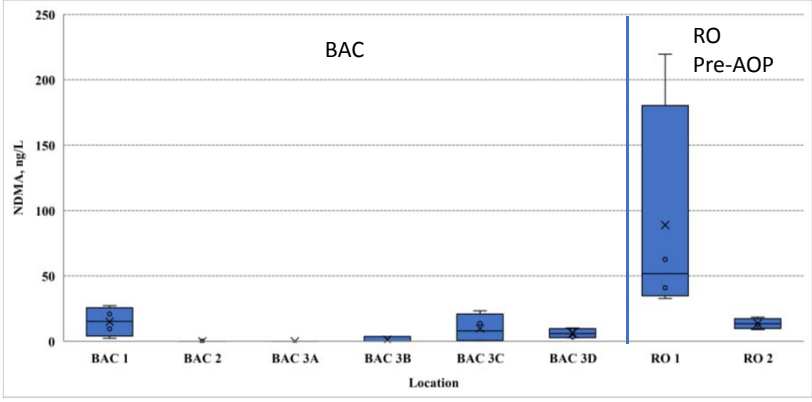
Full-Scale Monitoring

Facility ID	Sample ID	System Type	Age, years (at start of monitoring)
BAC 1	BAC 1	Ozone-BAC	GAC Media - 9.0
BAC 2	BAC 2	Ozone-BAC	GAC Media - 1.1
BAC 3	BAC 3A	BAC	GAC Media - 2.7
	BAC 3B	BAC	GAC Media - 2.3
	BAC 3C	Ozone-BAC	GAC Media - 2.3
	BAC 3D	Ozone-BAC	GAC Media - 0.0
RO 1	RO 1	(O3+MF) RO	RO Membrane - 2.3
RO 2	RO 2	(MF) RO	RO Membrane - 2.8

THM and HAA Formation Potential



Effluent NDMA Concentration



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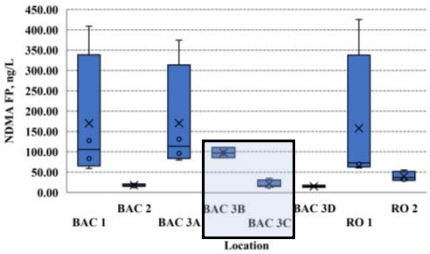
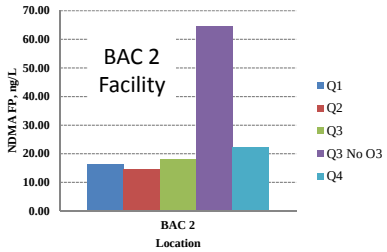
Impact of Ozone on Effluent NDMA Precursors





Sample ID	System Type	Ozone:TOC	Average Ozone:TOC	BAC Media Age (Years)
BAC 3B	BAC	-	-	2.3
BAC 3C	Ozone-BAC	0.5 – 0.6	0.5	2.3

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South Truckee Meadows WRF Pilot Testing

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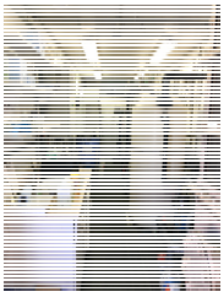

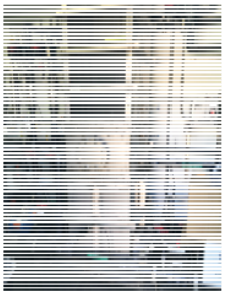

Goal: Optimize Ozone-BAC for DBP FP mitigation and CEC removal

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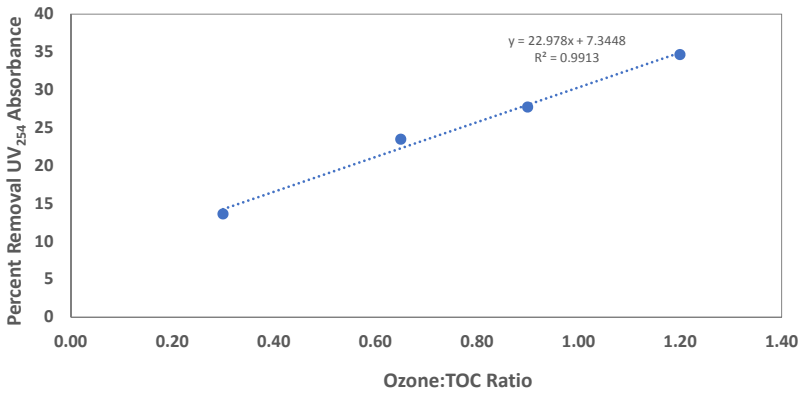
Impact of Ozone:TOC Ratio on UV Absorbance



UV_{254} absorbance is a reliable field verification parameter for ozonation

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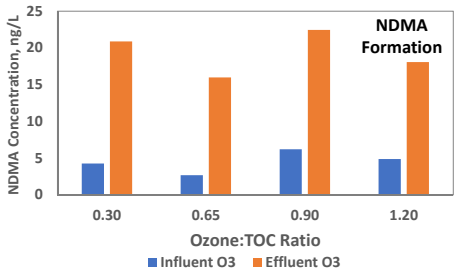
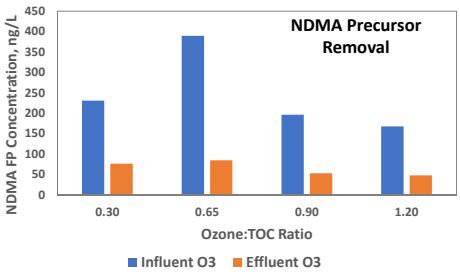
Impact of Ozone:TOC Ratio on NDMA Formation and Precursor Removal

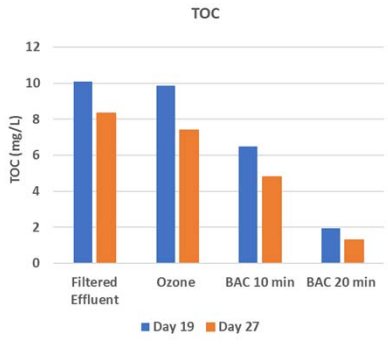


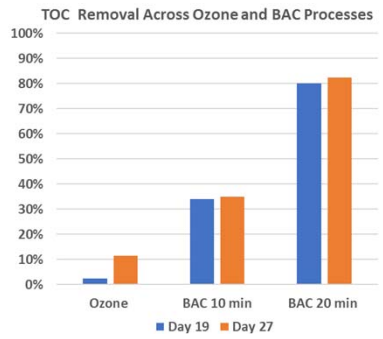


NDMA FP reduction with ozone appears to be independent of Ozone:TOC ratio

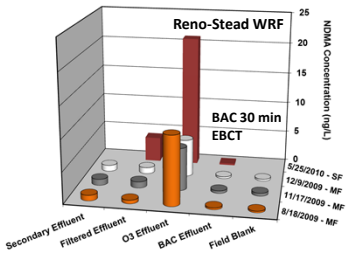
Steady State Operation

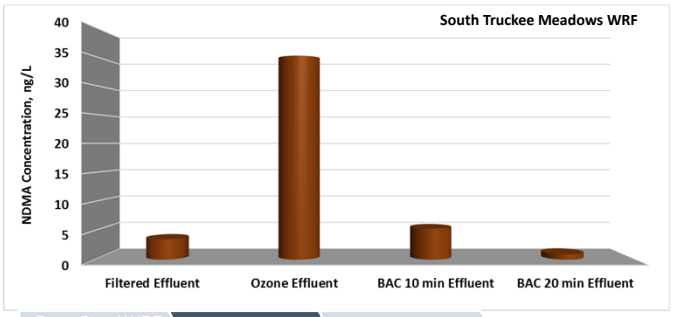
- Ozone:TOC Ratio maintained at 0.9 (no peroxide addition)
- Two parallel BAC units: EBCTs maintained at 10 and 20 minutes
- Steady state operation was initiated end of September
- Sampling events span from October 2017 to February 2018





NDMA Generation and Removal





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Truckee Meadows Advanced Technology Demonstration Project

University of Nevada, Reno

Vijay Sundaram, Laura Haak, Lydia Peri, and Krishna Pagilla

Regional Agency Team

Rick Warner and Lydia Peri, Washoe County; Dave Kershaw and Keri Lanza, City of Reno; Andy Hummel, City of Sparks; John Enloe, Truckee Meadows Water Authority; Michael Drinkwater, Truckee Meadows Water Reclamation Facility; Jim Smitherman, Northern Nevada Water Planning Commission

Independent Advisory Panel (IAP)

Led by NWRI

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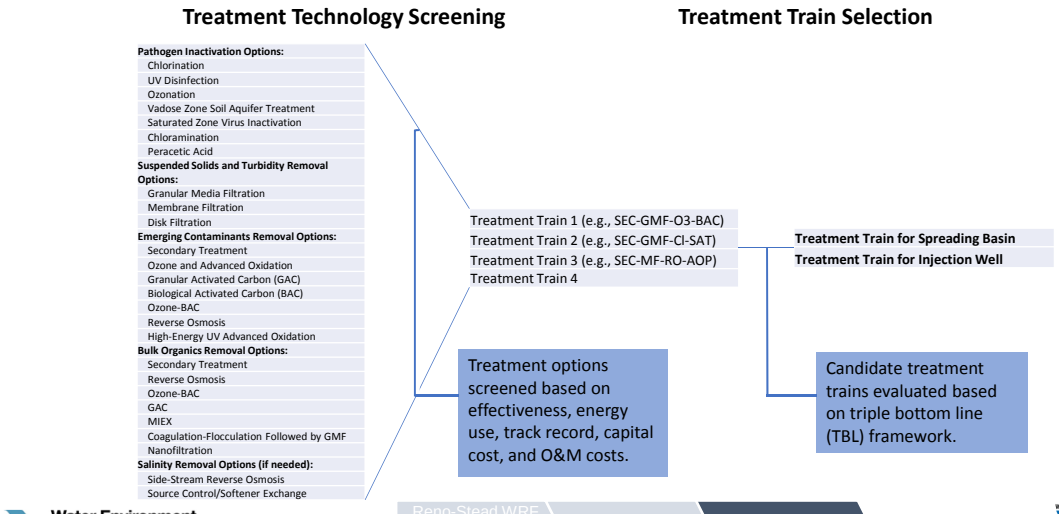
Truckee Meadows Advanced Technology Demonstration Project

- Demonstrate the feasibility of IPR in Nevada based on Nevada IPR Regulations
- Two IPR Methodologies:
  - Spreading Basin
  - Injection Well

Treatment Train Selection Methodology



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"Membrane Free" IPR Treatment Trains Recommended

Spreading Basin Project Train (Category A Effluent + Vadose Zone Treatment)	Injection Well Project Train (Ozone-BAC AWTF Category A+ Effluent)
Secondary Treatment	Secondary Treatment
Granular Media Filtration with Pretreatment	Coagulation-Flocculation-Clarification Granular Media Filtration (CFC GMF)
UV Disinfection	Ozone-BAC
Residual Disinfectant (if needed)	UV Disinfection
Spreading	Effluent Polishing
Vadose Zone/Soil Aquifer Treatment	Residual Disinfectant (if needed)
Saturated Zone Travel Time	Injection
	Saturated Zone Travel Time

Both Spreading Basin and Injection Well Project trains achieve Category A+ Effluent Pathogen Log Reduction Requirements

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WATER ENVIRONMENT + REUSE FOUNDATION WE&RF

Present State-of-the-Art

- Ozone-BAC is effective at removing CECs
- Effluent TOC and its characteristics correlate with regulated DBP formation potential
- Ozonation provides significant NDMA precursor removal
- BAC EBCT is an important design parameter
- Ozone-BAC treatment is currently being implemented in various inland locations, concurrent with ongoing optimization research

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Demonstration of Direct Potable Reuse Using Multi-Stage Ozone-Biological Filtration (BAF)

Denise Funk[1], PE, BCEE
Jennifer Hooper[2], PE
Kati Bell[3], PhD, PE, BCEE
Eddie Machek[4]

[1]Gwinnett County Water Resources
[2]CDM Smith
[3]Stantec
[4]PhD student, Georgia Tech

Presentation Overview

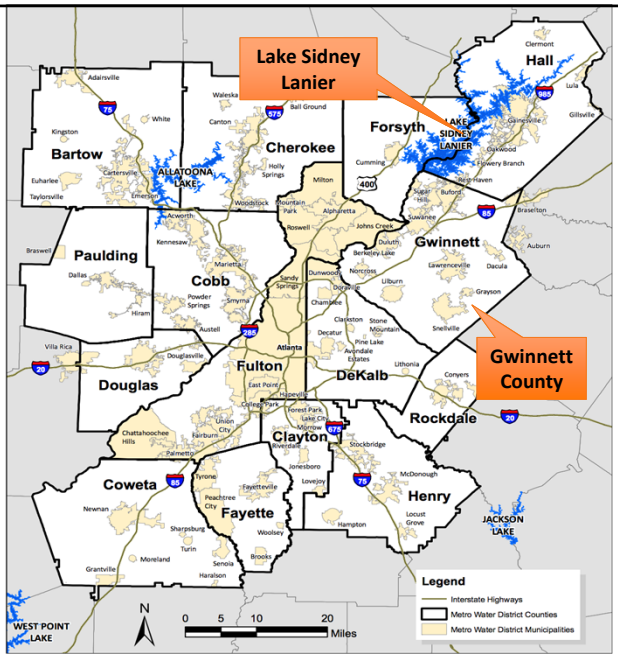
- Background on Gwinnett County
- Research Objectives
- Pilot Plants
- Select Results
- Next Steps

Atlanta Metropolitan Region

- 6 million people
- 15 counties

Gwinnett County

- 900,000 people



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Gwinnett County Water Resources Pipes

Water Distribution System	Sewer Collection System	Storm Water System
3,700 miles	3,000 miles	1,500 miles

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Gwinnett County Water Resources 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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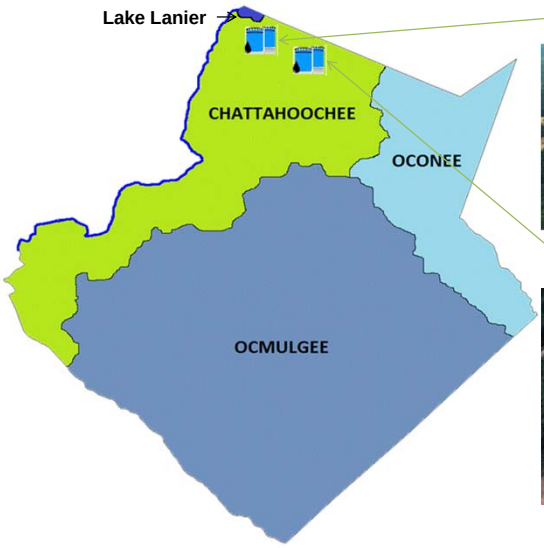
Gwinnett County Drinking Water Facilities



Shoal Creek Filter Plant

Lanier Filter Plant

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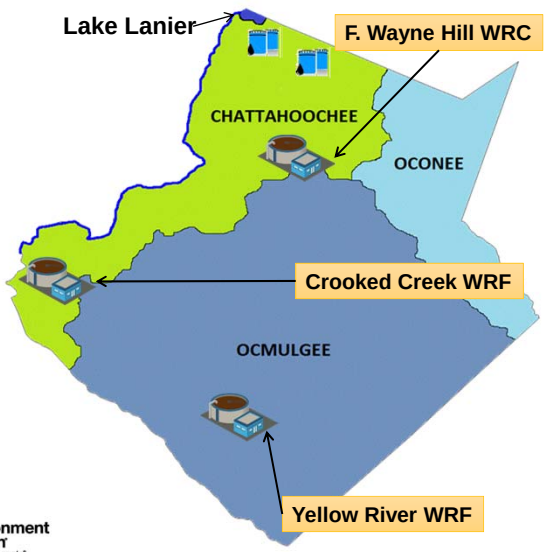
Gwinnett County
Water Reclamation Facilities



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F. Wayne Hill
Water Resources Center

60 MGD Capacity

- Phase 1 completed in 2000
- Phase 2 completed in 2006

One of World's Largest Membrane and Ozone Facility

Produces Highest Quality Reuse Water Return to Lake Lanier

Provides Wastewater Treatment for over 50% of Gwinnett County's Residents

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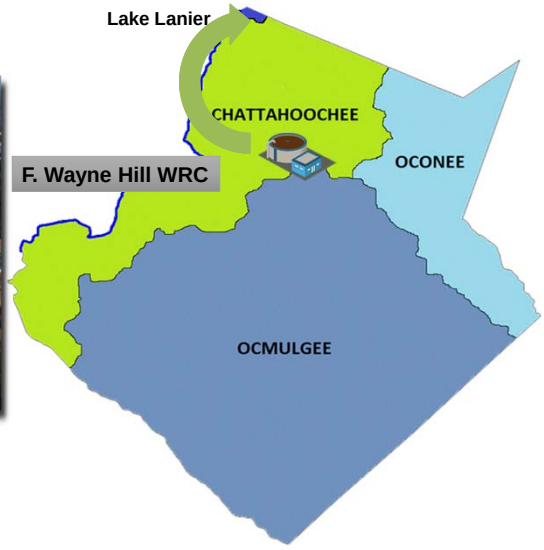
F. Wayne Hill Water Resources Center



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Gwinnett County Water Returns and Withdrawals from Lake Lanier

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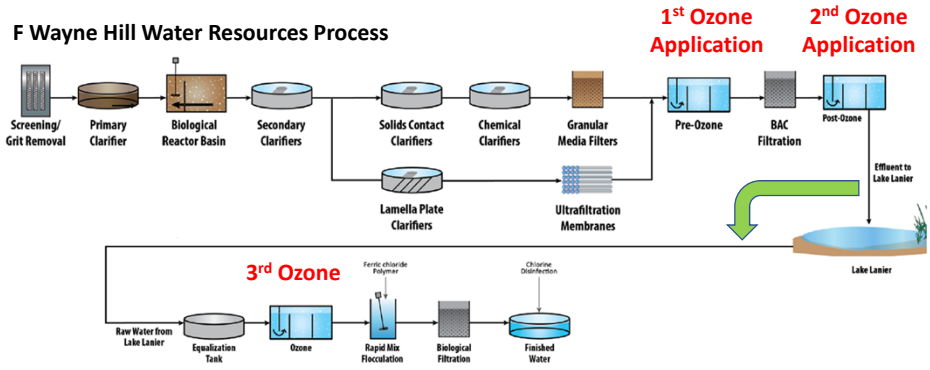
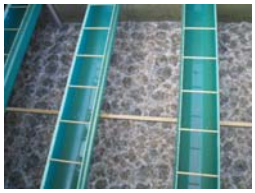
Gwinnett County
Indirect Potable Reuse Treatment Trains



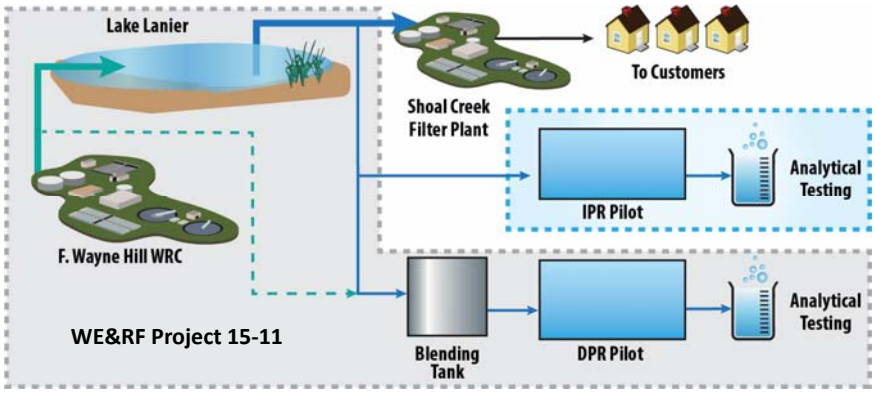
Shoal Creek Filter Plant Process

Why Study Direct Potable Reuse?

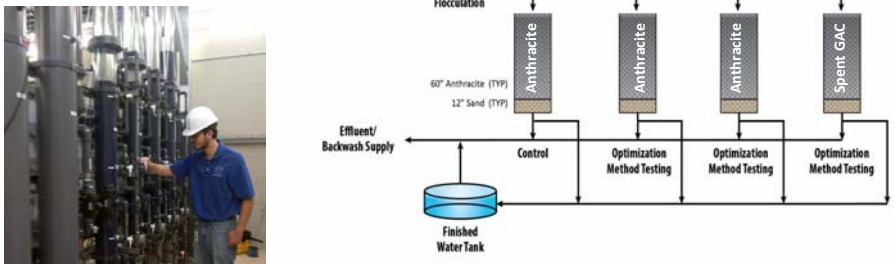
- Diversify water supply and resiliency
- Compare DPR to current IPR practice
- Advance the science of Ozone-Biofiltration as an alternative to Reverse Osmosis (RO) based treatment



Pilot Plant Configuration



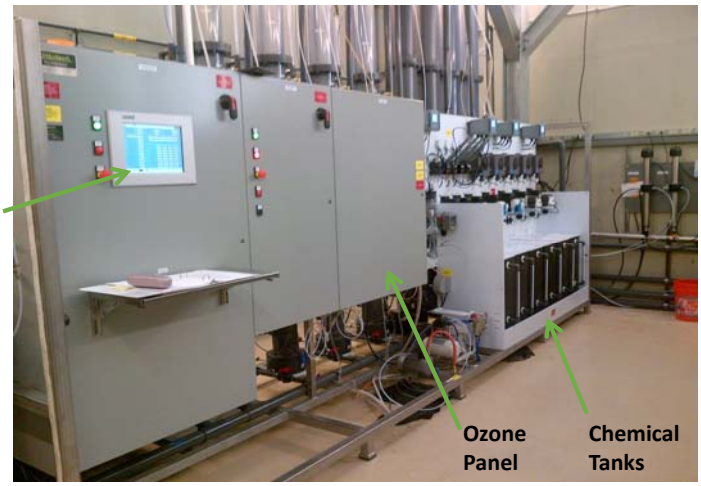
Pilot Plant Treatment Train



Pilot Plant Facilities

Pilot Plant Coagulation/Flocculation

Pilot Plant Controls, Chemicals and Instruments



Pilot Operational Phases

Phase	Duration	Objectives/Conditions
Baseline	1-2 months	• Characterize with 100% Lake Lanier influent • Compare performance with full scale operations • Acclimate biofilters
DPR Testing of Blending Ratios	5-6 months	• Test blending ratios • 15, 25, 50, and 100% F. Wayne Hill effluent
Robustness	1-2 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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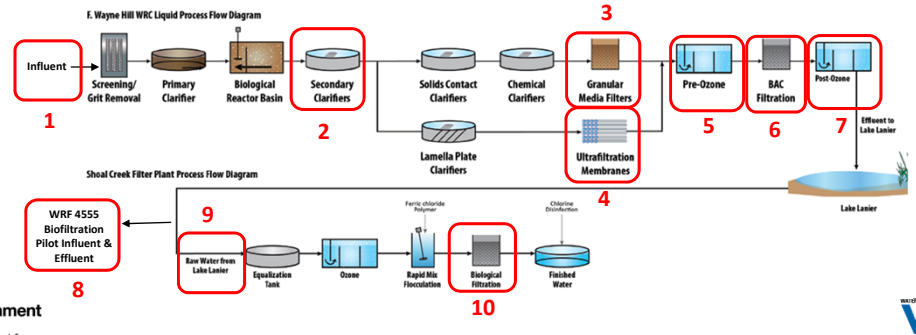
Quarterly Benchmark Sampling Analytical Matrix

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	●	●	●	●	●	●	●	●	●	●



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Sampling Events

6 laboratories
+
70 analytical methods
+
290 analytes
=
Lots of sample bottles

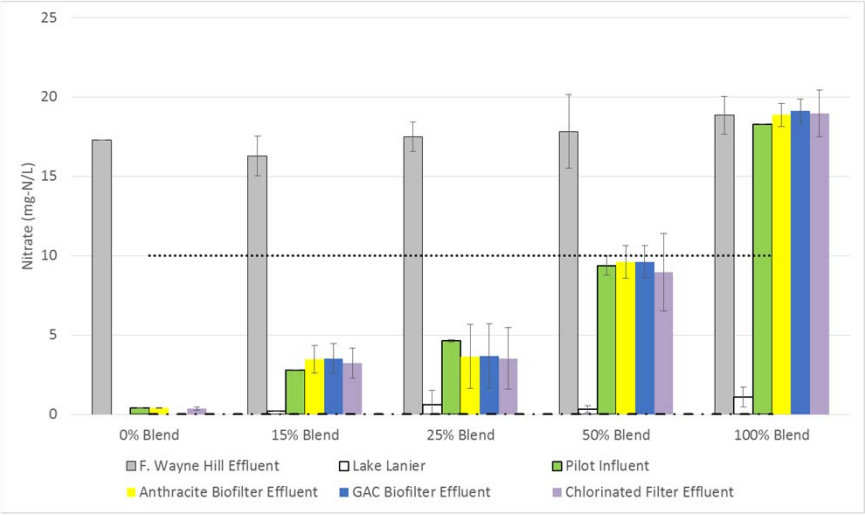
Results – Drinking Water Standards

- 15% Blend – met all primary and secondary standards evaluated
- 25% Blend – exceptions
  - Cyanide (one sample 0.29 mg/L)
  - NDMA (one sample 14 ng/L above CA/MA action level)
- 50% Blend – exceptions
  - Nitrate
  - Bromate (one sample 13 µg/L)
  - Di (2-ethylhexyl) phthalate (one sample 8 µg/L)
  - Color (during robustness only)
  - Manganese (one sample 0.06 mg/L)
  - NDMA (one sample 11 ng/L above CA/MA action level)

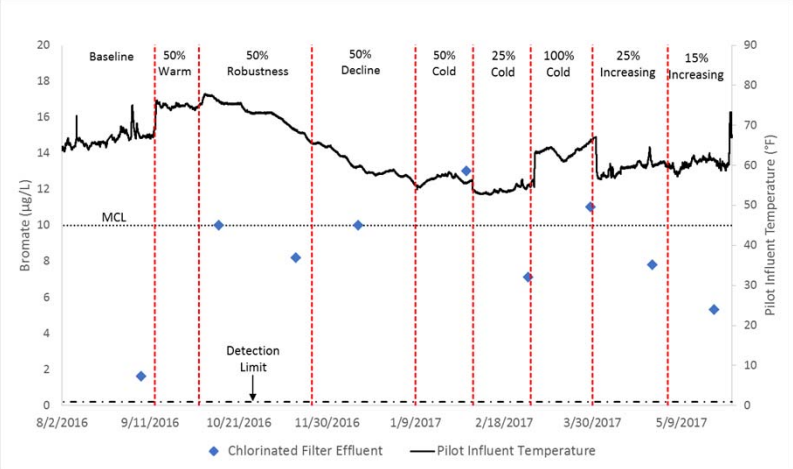
Results - Continued

- 100% FWH – exceptions
  - Nitrate
  - Bromate (one sample 11 µg/L)
  - Cyanide (one sample 0.27 mg/L)
- ALL BLENDS
  - HAA5 (< 22 µg/L)
  - TTHMs (< 13 µg/L)
  - Biological parameters all below detection limits (total coliform, fecal coliform, coliphage (somatic and male-specific/F+-specific coliphage, MS2), *enterococcus*, *Legionella*, *Cryptosporidium*, and *Giardia)*

DPR Pilot Nitrate Results



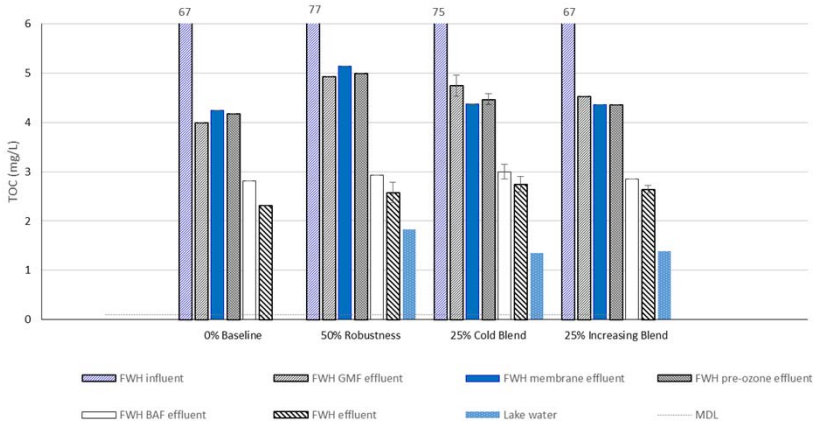
DPR Pilot Bromate Results



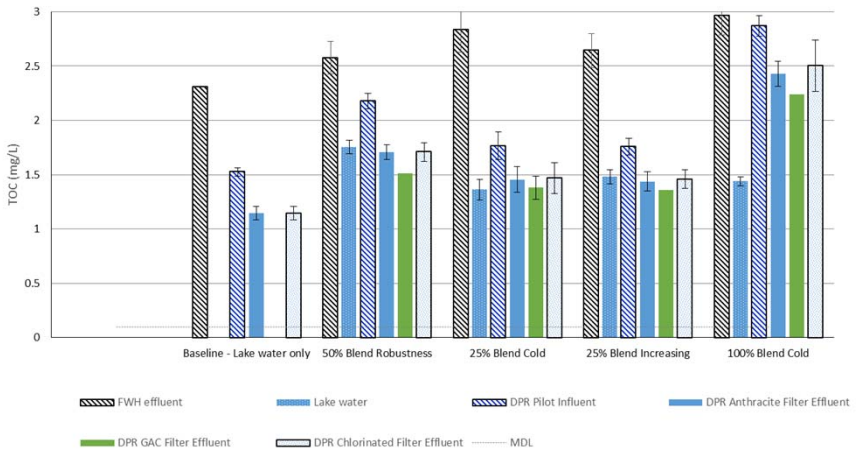
Bromide - Lake Lanier (average of 54±21 µg/L) and FWH effluent (average of 55±39 µg/L)

FWH Effluent Bromate ranged between 2.6 µg/L and 17 µg/L

TOC Removal through the FWH Treatment Process



TOC Removal through the DPR Pilot



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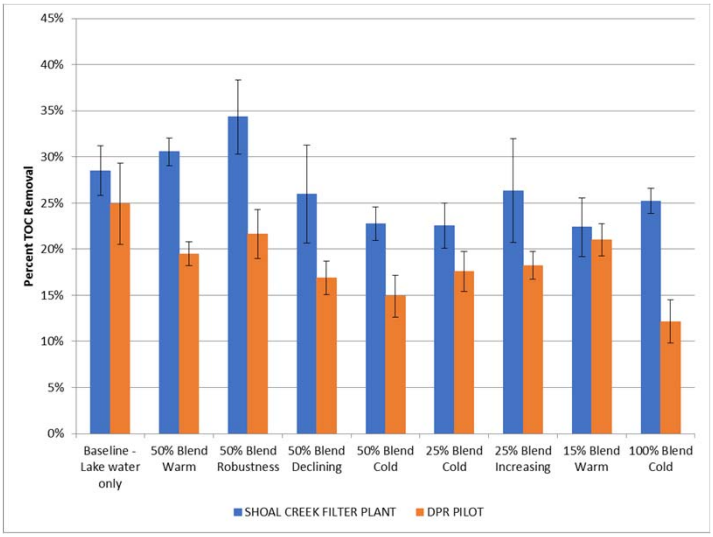
Comparing Full Scale Plant IPR to DPR Pilot Percent TOC Removal



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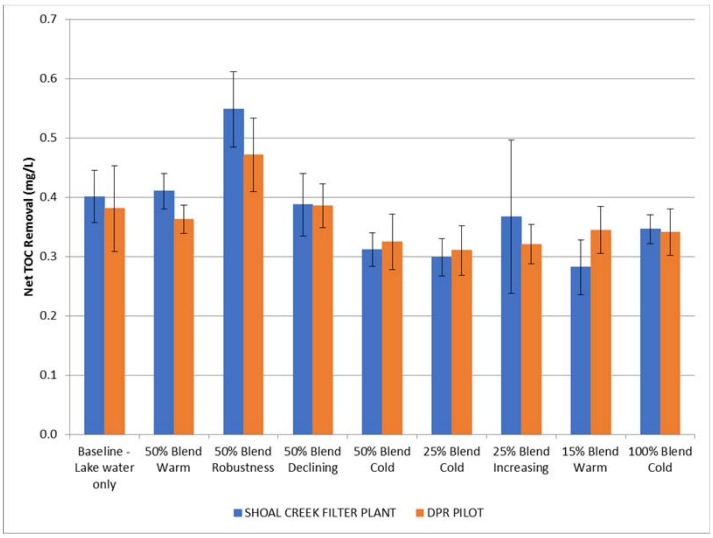
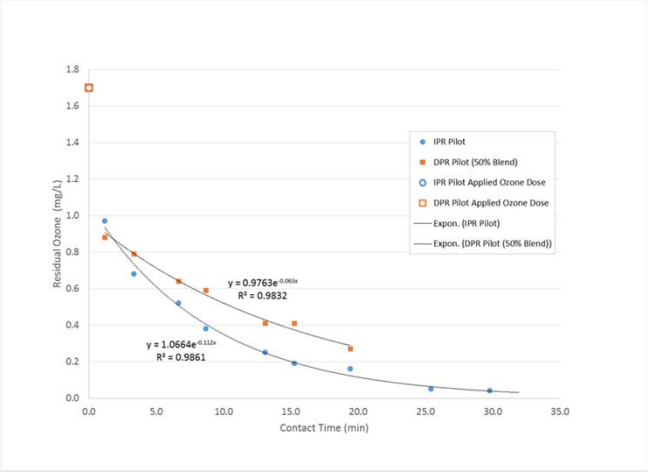
Comparing Full Scale Plant IPR to DPR Pilot Net TOC Removal

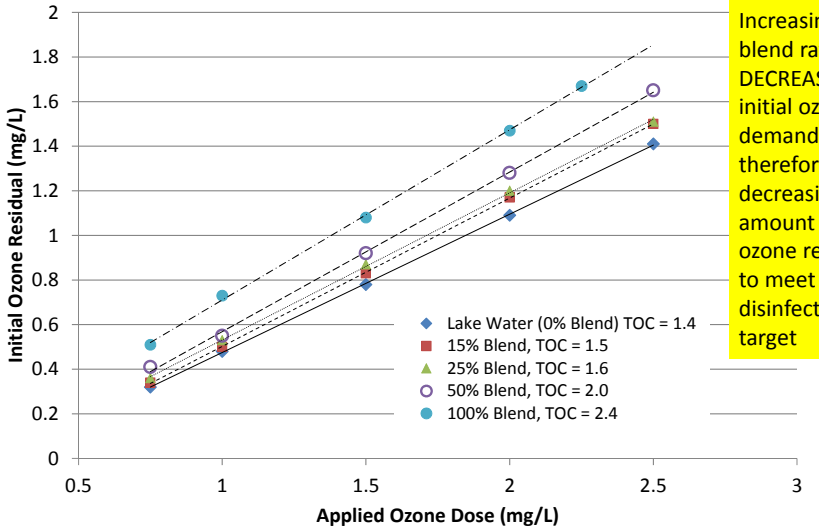


Operational Benefits of DPR

- Reduced ozone demand/decay
- Mitigation of lake source water quality excursions
- Lower filter headloss accumulation rates

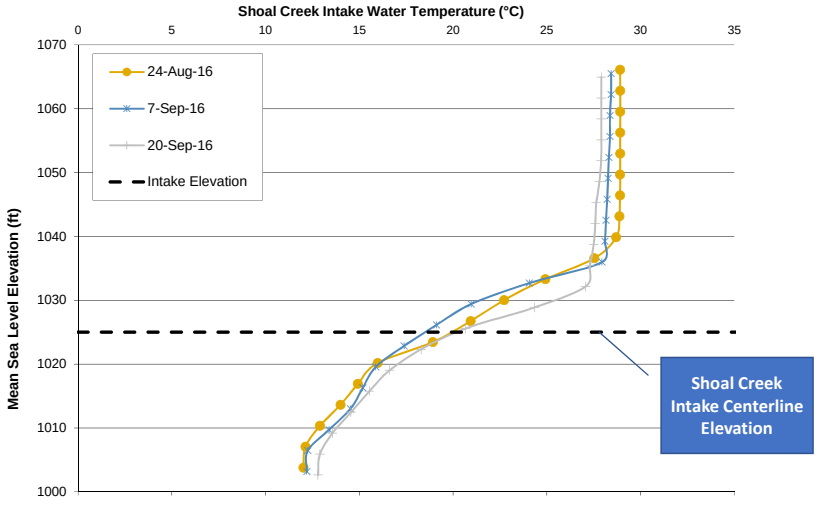


Ozone Dose Response by Blend

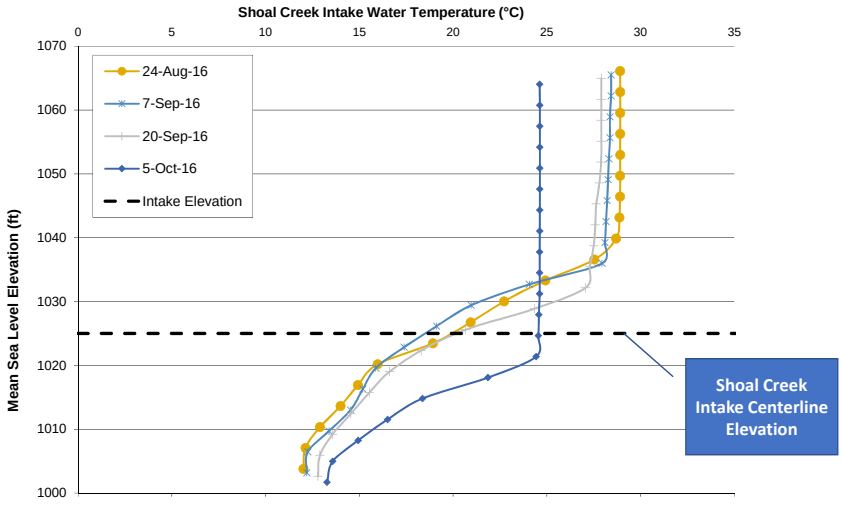


Increasing blend ratio DECREASES the initial ozone demand, therefore decreasing the amount of ozone required to meet a disinfection target

Performance During Seasonal Water Quality Challenges



Lake Temperature Profiles



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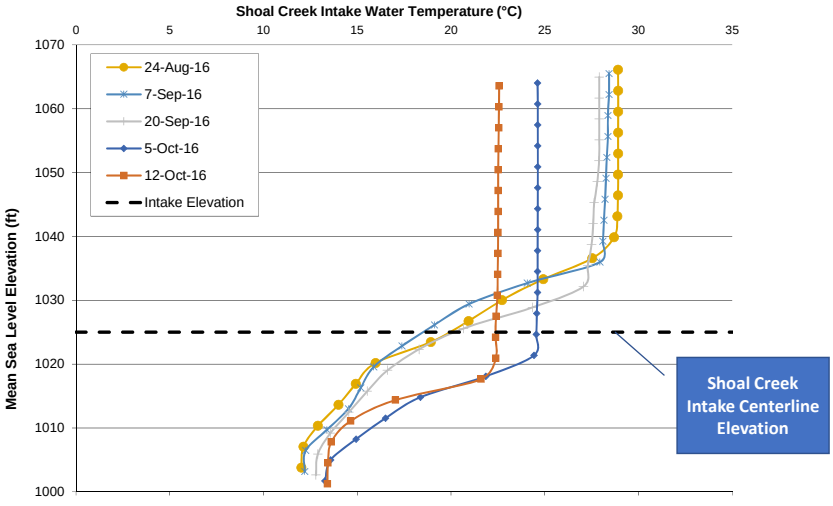
Lake Temperature Profiles



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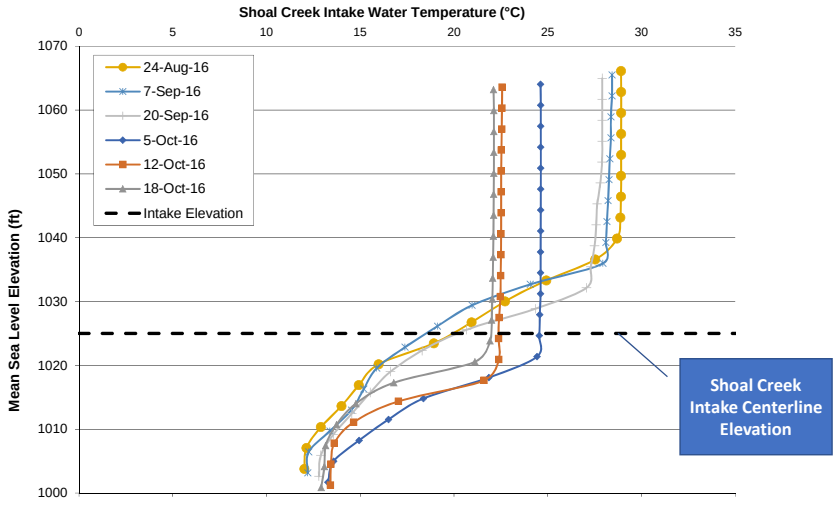
Lake Temperature Profiles



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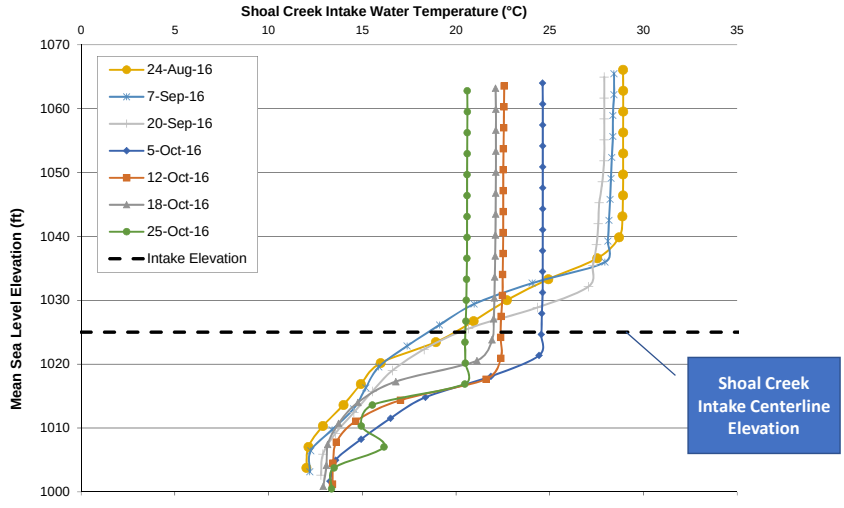
Lake Temperature Profiles



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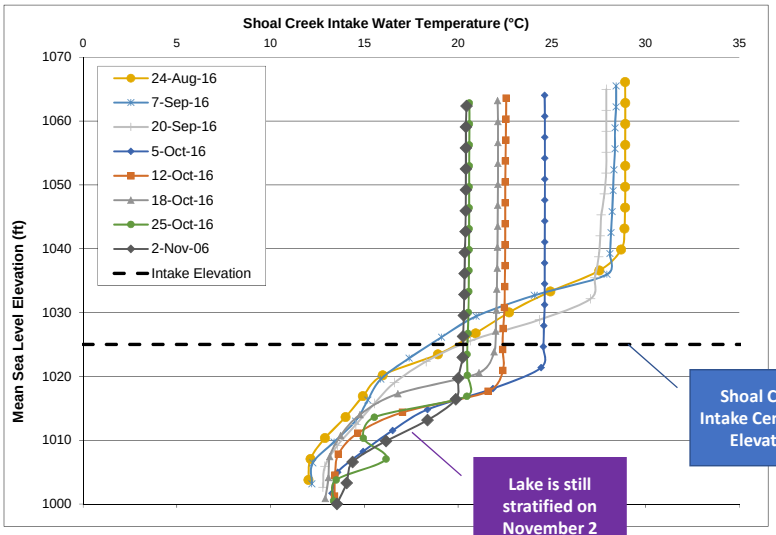
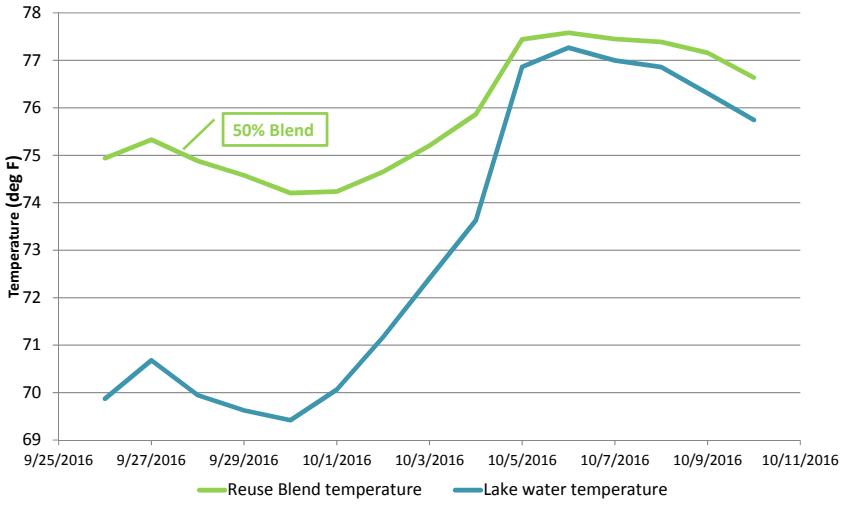
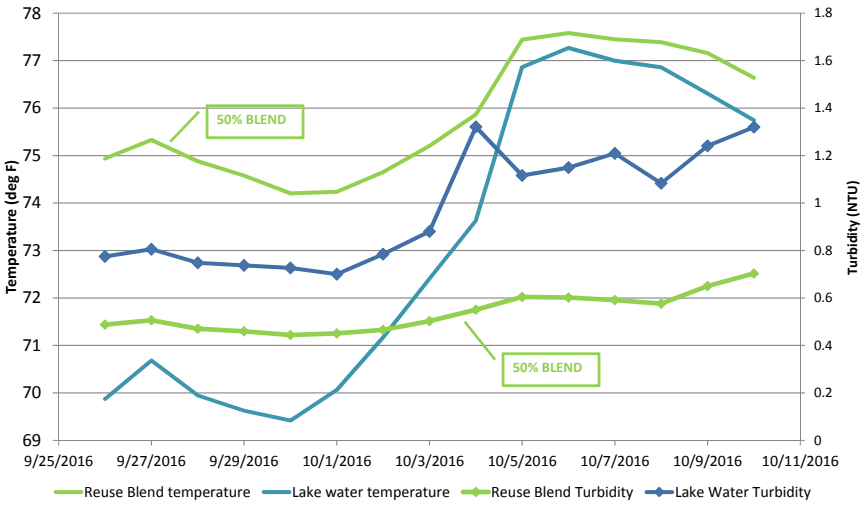
Lake Temperature Profiles



Comparing Raw Water Temperature during Seasonal Water Quality Challenge



Comparing Raw Temp and Turbidity during Seasonal Water Quality Challenge



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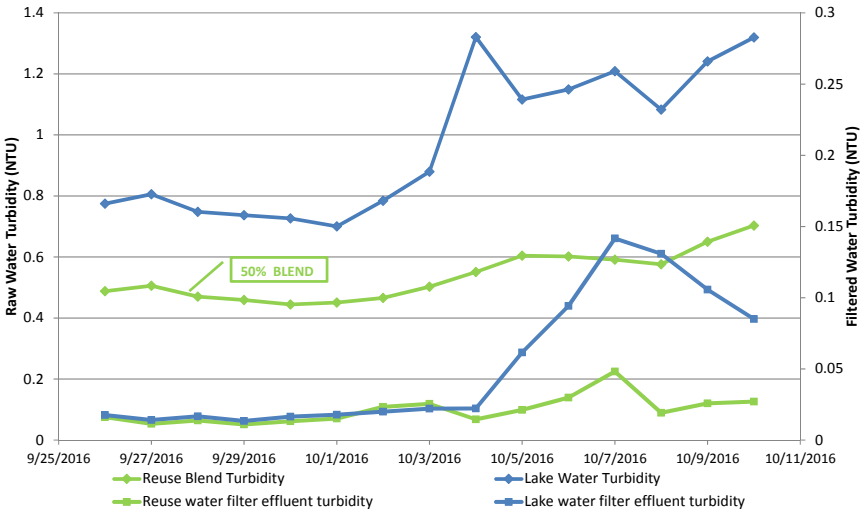
DPR Filter Effluent Performance Exceeds IPR During Seasonal Water Quality Challenge



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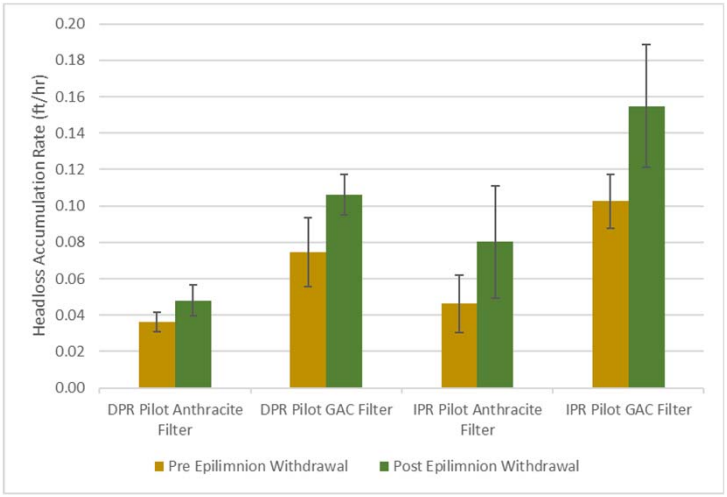
Comparing Headloss Accumulation Rates – IPR vs DPR



Next Steps for Gwinnett County

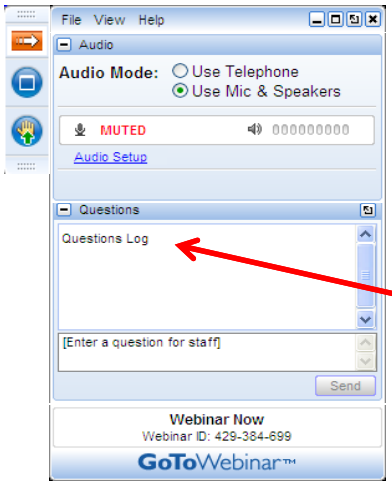
- WERF Project 15-11
  - Draft Report submitted Nov 7, 2017
  - Final Report mid-2018
- Ongoing research projects to optimize service in all areas
- Water Innovation Center

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
- Water Environment & Reuse Foundation
  - Justin Mattingly
- Project Advisory Committee
  - Brian Bernados
  - Kelly Comstock
  - Dr. Dan Gerrity
  - Dr. Chance Lauderdale
  - Alex Mofidi

Questions?

Questions for Our Speakers?



- **Submit your questions using the Questions Pane.**

Thank You