# Advancing the Implementation of Potable Reuse

In partnership with California State Water Resources Control Board and Metropolitan Water District

April 20, 2023

# Housekeeping

- Submit questions through the question box at any time. We will do a Q&A at the end of the presentation(s).
- Slides and a recording of the webcast will be available at www.waterrf.org.
- You can download the slides and access a link to the grant projects under Event Resources on the left side of your screen.
- A certificate of completion will be automatically generated after the webcast. Any questions, please contact Michelle Suazo at msuazo@waterrf.org.
- Please stay until the end to fill out a quick survey.

# State Water Board Grants for Recycled Water Research with support from MWD

2018-2024

**California Legislation – AB 574 (2017):**
Established deadline for DPR legislation of 2023

## GRANT 1

FUNDING LEVEL: $1.4M

TIMELINE: 2018-2020

PROJECTS: 5
Recommended by the DRP Expert Panel for Developing Regulations in CA

## GRANT 2

FUNDING LEVEL: $3.1M

TIMELINE: 2019-2024

PROJECTS: 20
Recommended by WRF's Water Reuse Advisory Committee and SWB

***Leveraging of Grant Funds***

- **$975,000 from Metropolitan Water District (CA) for 7 projects**
- **$1M from other contributing utilities and firms**

# Water Reuse Projects – SWB / MWD partnership

| Proj # | Project Title |
|---|---|
| 4832 | Evaluation of CEC Removal by Ozone/BAF Treatment in Potable Reuse Applications |
| 4833 | Understanding Wastewater Treatment Performance on Advanced Water Treatment Processes and Finished Water Quality |
| 4953 | Considerations and Blending Strategies for Drinking Water System Integration with Alternative Water Supplies |
| 4954 | Integration of High Frequency Performance Data for Microbial and Contaminant Control in Potable Reuse Systems |
| 4955 | Indicator Viruses for Advanced Physical Treatment Process Performance Confirmation |
| 4956 | Addressing Impediments and Incentives for Agricultural Reuse |
| 4957 | Compiling Evidence of Pathogen Reduction through Managed Aquifer Recharge and Recovery |
| 4958 | New Techniques, Tools, and Validation Protocols for Achieving Log Removal Credit across NF and RO Membranes |
| 4959 | Evaluation of Tier 3 Validation Protocol for Membrane Bioreactors to Achieve Higher Pathogen Credit for Potable Reuse |
| 4960 | Review of Industrial Contaminants Associated with Water Quality or Adverse Performance Impacts for Potable Reuse Treatment |
| 4961 | The Use of Next Generation Sequencing (NGS) and Metagenomics Approaches to Evaluate Anti-Microbial Resistance, Plant Challenge, Biological Removal Processes |
| 4962 | Identifying the Amount of Wastewater that is Available and Feasible to Recycle in California |
| 4963 | Developing a New Foundational Understanding of SAR – Soil Structure Interactions to Provide Management Options for Reclaimed Water Use in Agriculture |
| 4964 | Assessing the State of Knowledge and Impacts of Recycled Water Irrigation on Agricultural Crops |
| 4993 | Potential of Oilfield Produced Water for Irrigation in California |
| 5047 | Guidelines for the Demonstration of Pathogen Log Removal Credits in Wastewater Treatment |
| 5048 | Integrating Real-Time Collection System Monitoring Approaches into Enhanced Source Control Programs for Potable Reuse |
| 5049 | Public Health Benefits and Challenges for Blending of Advanced Treate |
| 5050 | Applicability of the UV/Chlorine AOP: Assessment of Applicability, Ope |
| 5051 | Geochemical Considerations for Managed Aquifer Recharge (MAR) Im |
| 5052 | Standardizing Methods with QA/QC Standards for Investigating the Oc |

https://www.waterrf.org/sites/default/files/file/2022-09/SWB%20Grant%201%20and%20Grant%202%20Projects%20w%20obj_RAC%202020.pdf

# Speaker Introductions

- Laura McLellan, Senior Environmental Scientist, Recycled Water and Desalination Unit Chief, Division of Water Quality, State Water Resources Control Board
- Warren Teitz, ENV-SP, Resource Development Team Manager, Metropolitan Water District of Southern California
- Eva Steinle-Darling, PhD, PE, Water Reuse Technical Practice Director, Carollo Engineers
- Nicole Blute, PhD, PE, Vice President, Director of Drinking Water Process Technologies, Hazen and Sawyer
- Daniel Giammar, PhD, Walter E. Browne Professor of Environmental Engineering, Energy, Environmental & Chemical Engineering, Washington University in St. Louis

Laura McLellan

Senior Environmental Scientist, Recycled Water and Desalination Unit Chief, Division of Water Quality

State Water Resources Control Board

THE Water Research FOUNDATION

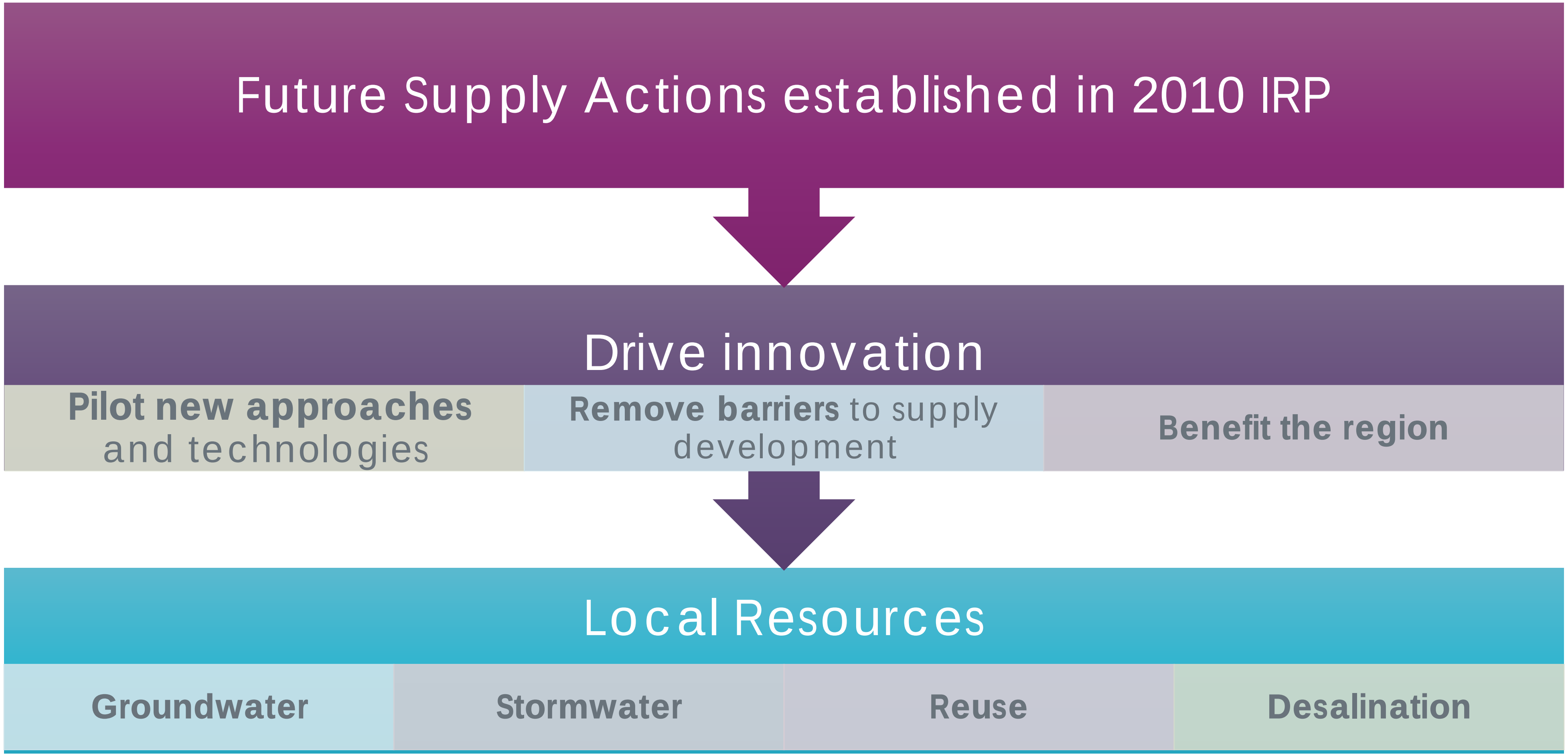
# Warren Teitz, ENV-SP
Resource Development Team Manager
Metropolitan Water District of Southern California

# The Metropolitan Water District of Southern California

- Nation’s largest wholesale water provider
- Service area: 19 million people/5,200 square miles/parts of six counties
- 26 member agencies
- Supports a $1 trillion regional economy
- Imports water from Northern Sierra and the Colorado River, invests in local projects

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

# Future Supply Actions Funding Program



Future Supply Actions established in 2010 IRP

Drive innovation

| | | |
|---|---|---|
| **Pilot new approaches** and technologies | **Remove barriers** to supply development | **Benefit the region** |

Local Resources

| | | | |
|---|---|---|---|
| **Groundwater** | **Stormwater** | **Reuse** | **Desalination** |

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

# Current Program

## Member Agency

- 14 studies
- $3.1 million

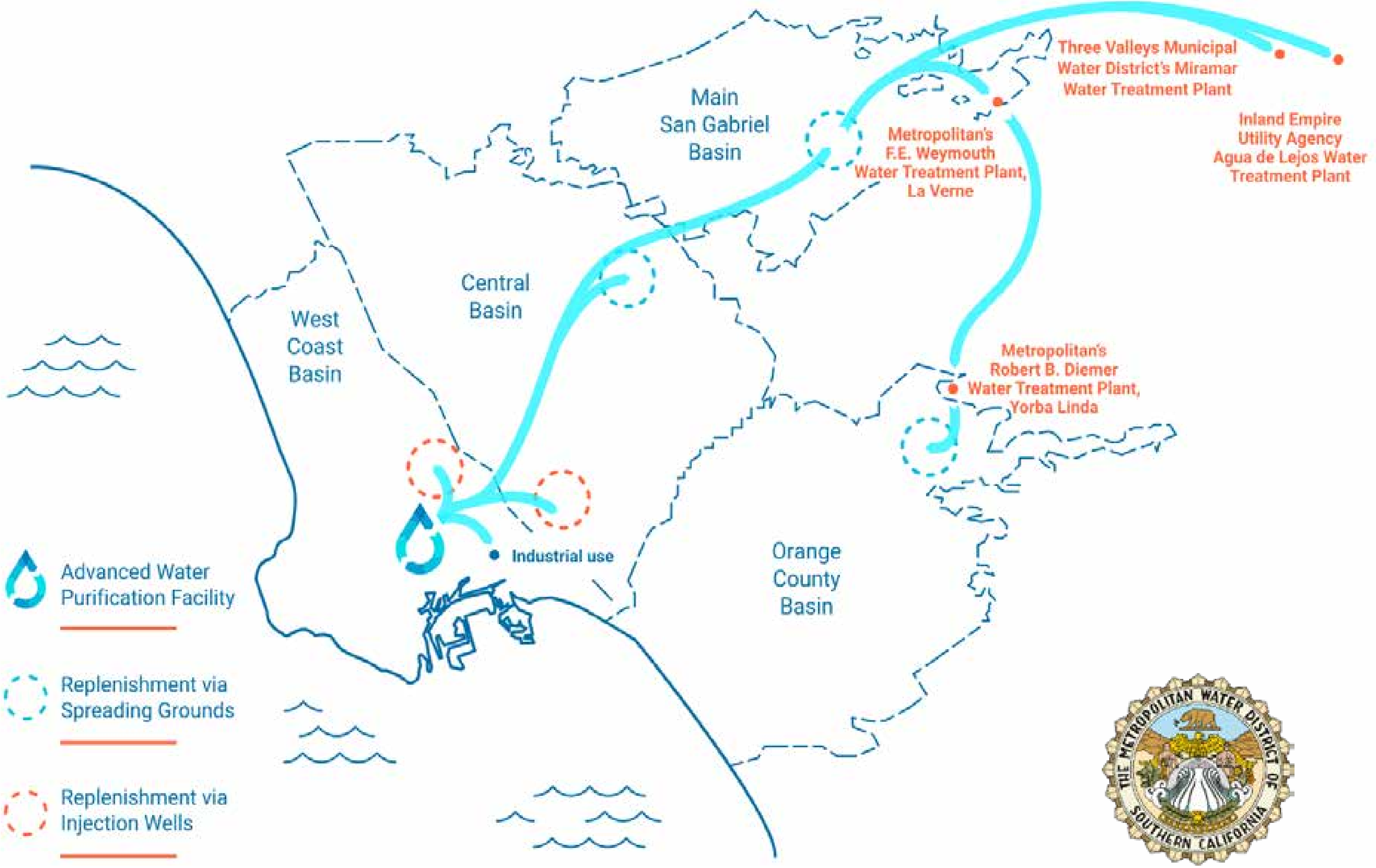
## Water Research Foundation

- 6 potable reuse studies
- 1 agricultural reuse study
- $975k

www.mwdh2o.com/FSA

PURE WATER
SOUTHERN CALIFORNIA

- 150 mgd AWP
- Initial IPR design
- Raw water augmentation DPR element planned



THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

THE Water Research FOUNDATION

# Eva Steinle-Darling, PhD, PE
Water Reuse Technical Practice Director
Carollo Engineers

# WRF 4833 (aka Reuse 15-05) Impacts of WW Performance on Advanced Treatment

Eva Steinle-Darling, PhD, PE

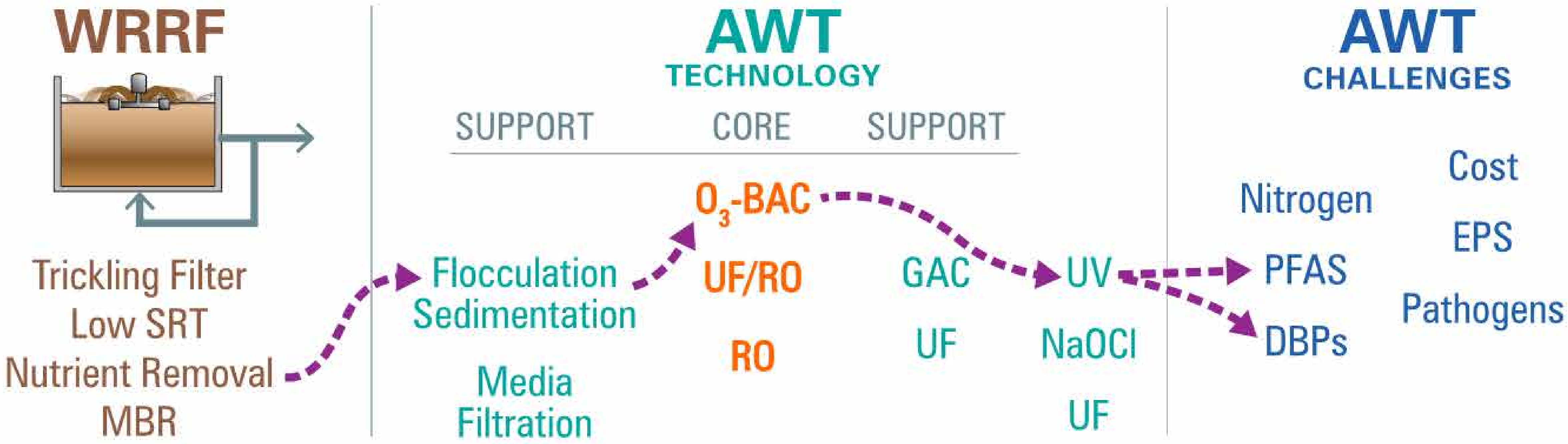
Webinar hosted by:
The Water Research Foundation | WateReuse Association | Metropolitan Water District of Southern California

20 April 2023

01

# WRF 4833
# Project Overview

# Project End Goal:
# Find the best path from any WRRF to Potable Reuse!



# Basic Premise:

- Any WRRF Effluent can be “Good Enough” for Potable reuse if…

1. Effluent water quality is well enough understood, and
2. Advanced water treatment is appropriately designed.

# Project Team:

carollo

Hazen

SOUTHERN NEVADA
WATER AUTHORITY

THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

# Project Overview and Acknowledgements

## The Water Research Foundation

### Principal Investigator: Eva Steinle-Darling

Module A:
**WRRF-Side**

Lead:

Wendell Khunjar, Hazen

Module B:
**CBAT**

Leads:

Eric Dickenson & Dan Gerrity

SNWA

Module C:
**RBAT**

Leads:

Eva Steinle-Darling, Carollo

Troy Walker, Hazen

Module D:
**MBR à RO**

Leads:

Sun Liang and Joyce Lehman, MWD

Andy Salveson, Carollo

Module E:
**MBR à CBAT**

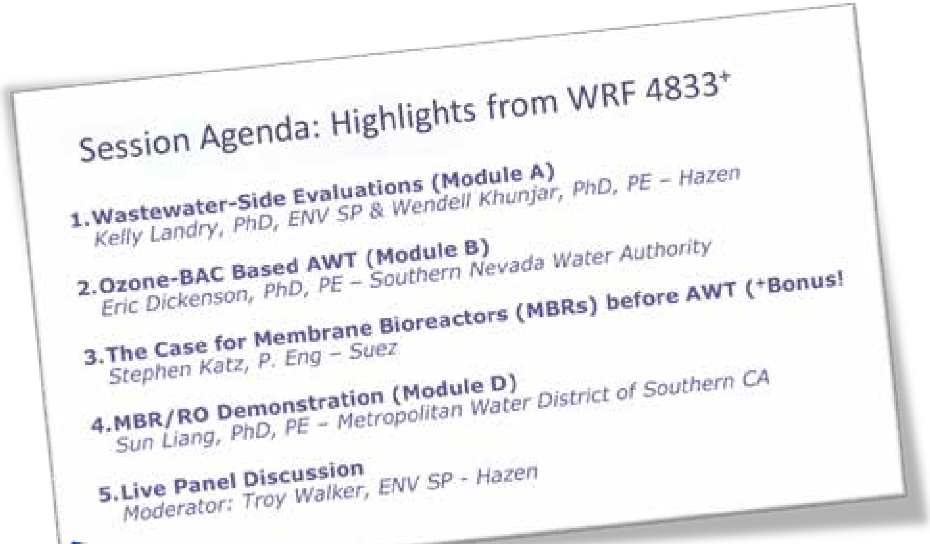
Lead:

Andy Salveson, Carollo

Case Studies & Cost Trade-Offs – Kelly Landry, Hazen and Eva Steinle-Darling, Carollo

FAQs and Myths – Eva Steinle-Darling & Rosa Yu, Carollo

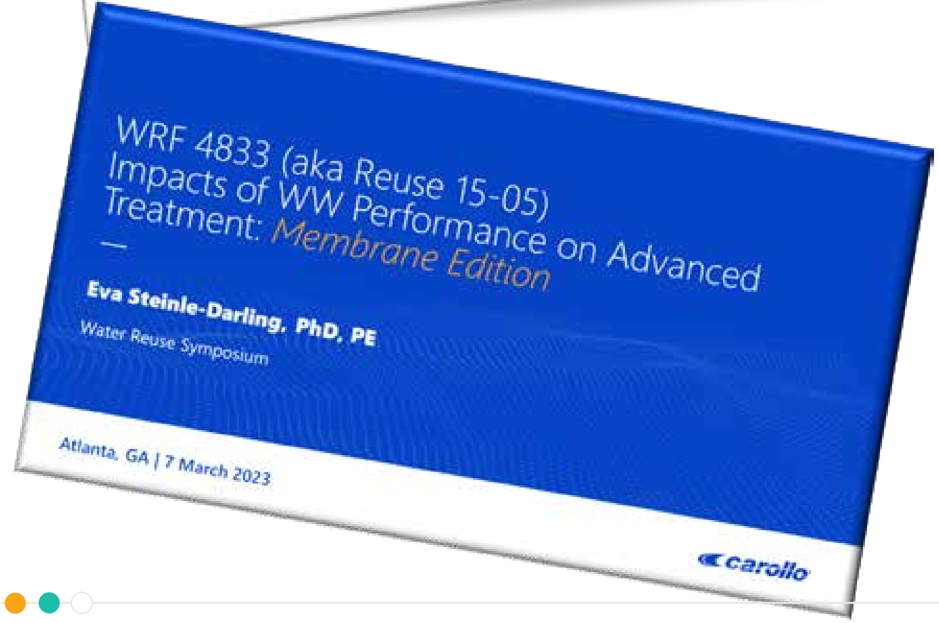
# Huh. This sounds familiar...?



## Session Agenda: Highlights from WRF 4833⁺

1. **Wastewater-Side Evaluations (Module A)**
   *Kelly Landry, PhD, ENV SP & Wendell Khunjar, PhD, PE – Hazen*
2. **Ozone-BAC Based AWT (Module B)**
   *Eric Dickenson, PhD, PE – Southern Nevada Water Authority*
3. **The Case for Membrane Bioreactors (MBRs) before AWT (⁺Bonus!**
   *Stephen Katz, P. Eng – Suez*
4. **MBR/RO Demonstration (Module D)**
   *Sun Liang, PhD, PE – Metropolitan Water District of Southern CA*
5. **Live Panel Discussion**
   *Moderator: Troy Walker, ENV SP - Hazen*

We had a session at WRA 2021...



WRF 4833 (aka Reuse 15-05) Impacts of WW Performance on Advanced Treatment: *Membrane Edition*

**Eva Steinle-Darling, PhD, PE**

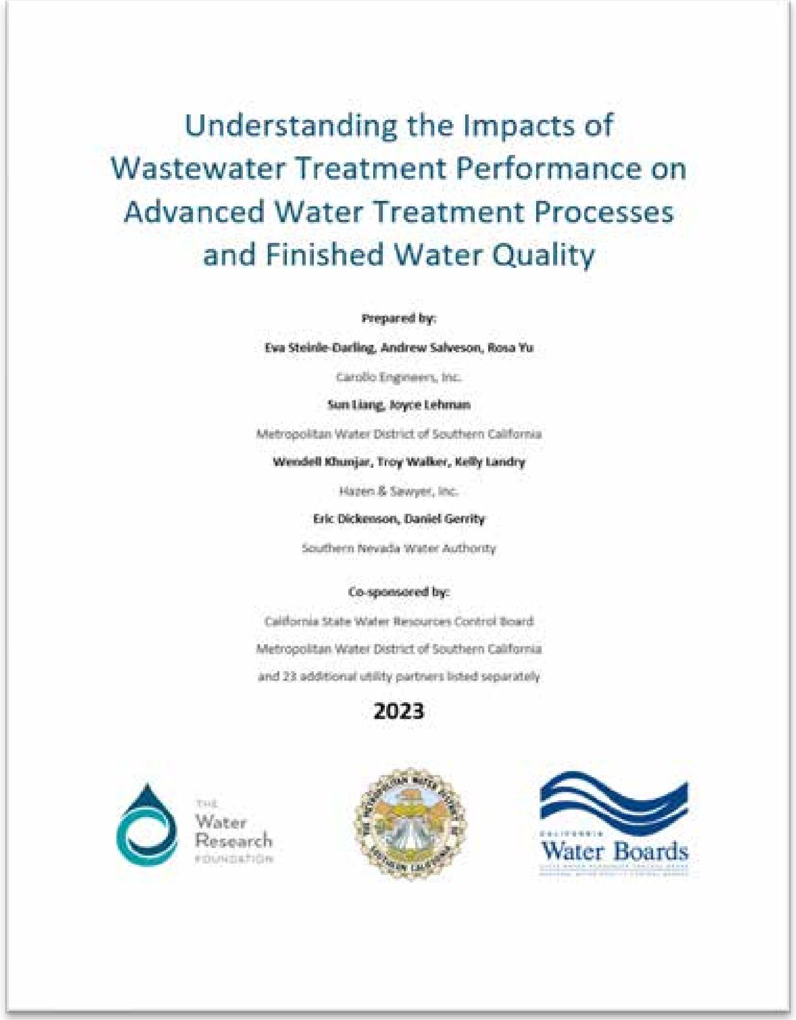
Water Reuse Symposium

Atlanta, GA | 7 March 2023

carollo

...
and a follow-up
on Module C
at WRA 2022!

- **Publication expected Summer 2023**



Understanding the Impacts of Wastewater Treatment Performance on Advanced Water Treatment Processes and Finished Water Quality

**Prepared by:**

**Eva Steinle-Darling, Andrew Salveson, Rosa Yu**

Carollo Engineers, Inc.

**Sun Liang, Joyce Lehman**

Metropolitan Water District of Southern California

**Wendell Khunjar, Troy Walker, Kelly Landry**

Hazen & Sawyer, Inc.

**Eric Dickenson, Daniel Gerrity**

Southern Nevada Water Authority

**Co-sponsored by:**

California State Water Resources Control Board

Metropolitan Water District of Southern California

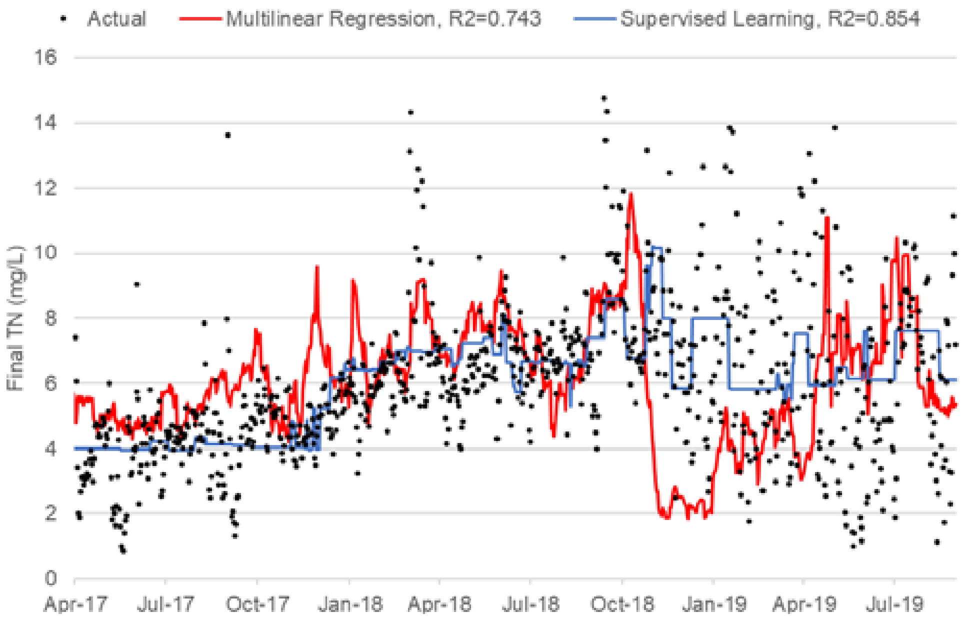
and 23 additional utility partners listed separately

**2023**

02

# Module Summaries:

# Module A: Focused on WRRF-Side with Big Data Analytics



AWT Effluent TN Data compared to two models

**Summary:**

- Large historical datasets evaluated
- Lookback averages used to assess impact of time lag btw WRRF and AWT
- Some intuitive correlations found, but still only site-specific.
- Work hindered by lack of data richness needed for machine learning based approaches.

**Is your facility machine-learning ready?**

Module led by: Hazen

# Module B: Carbon-Based Advanced Treatment (CBAT) (with conventional effluent)

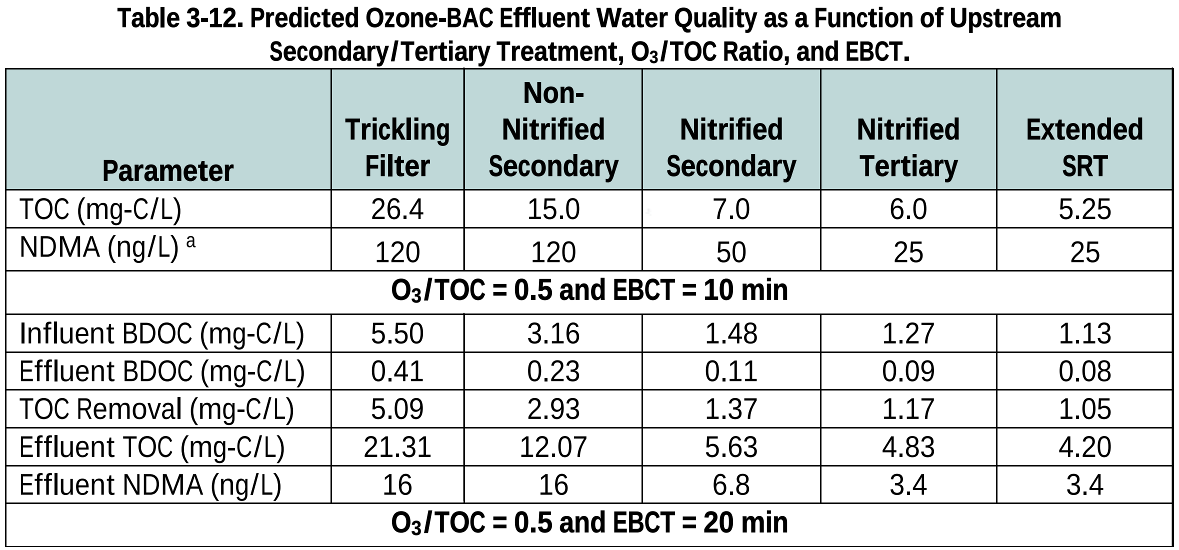


**Table 3-12. Predicted Ozone-BAC Effluent Water Quality as a Function of Upstream Secondary/Tertiary Treatment, $O_3$/TOC Ratio, and EBCT.**

| Parameter | Trickling Filter | Non-Nitrified Secondary | Nitrified Secondary | Nitrified Tertiary | Extended SRT |
|---|---|---|---|---|---|
| TOC (mg-C/L) | 26.4 | 15.0 | 7.0 | 6.0 | 5.25 |
| NDMA (ng/L) [a] | 120 | 120 | 50 | 25 | 25 |
| **$O_3$/TOC = 0.5 and EBCT = 10 min** | | | | | |
| Influent BDOC (mg-C/L) | 5.50 | 3.16 | 1.48 | 1.27 | 1.13 |
| Effluent BDOC (mg-C/L) | 0.41 | 0.23 | 0.11 | 0.09 | 0.08 |
| TOC Removal (mg-C/L) | 5.09 | 2.93 | 1.37 | 1.17 | 1.05 |
| Effluent TOC (mg-C/L) | 21.31 | 12.07 | 5.63 | 4.83 | 4.20 |
| Effluent NDMA (ng/L) | 16 | 16 | 6.8 | 3.4 | 3.4 |
| **$O_3$/TOC = 0.5 and EBCT = 20 min** | | | | | |

**Summary:**

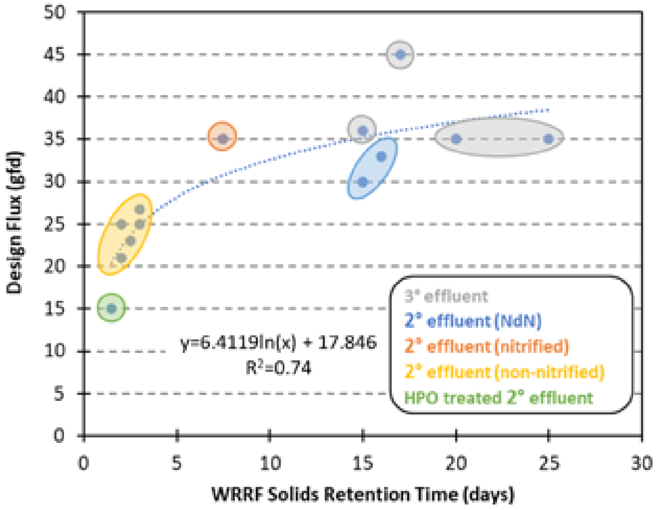
- CBAT core = ozone + biofiltration + GAC
- *Pass-through* constituents:
  - Bromide/bromate, nitrate, salinity
  - NMOR, short-chain PFAS, iohexal, 1,4-dioxane
- *Interfering* constituents:
  - Turbidity, free chlorine, nitrite, TOC
- Mitigate by:
  - Enhanced source control
  - Optimized secondary treatment
  - Additional AWT processes

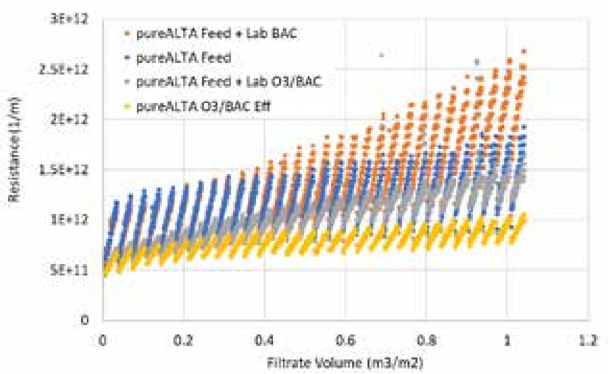
**Major cost factors**

***Many* factors and water quality parameters dictate success of CBAT.**

Module led by: Southern Nevada Water Authority

# Module C: Predicting MF/UF Flux; Art or Science?





**Summary:**

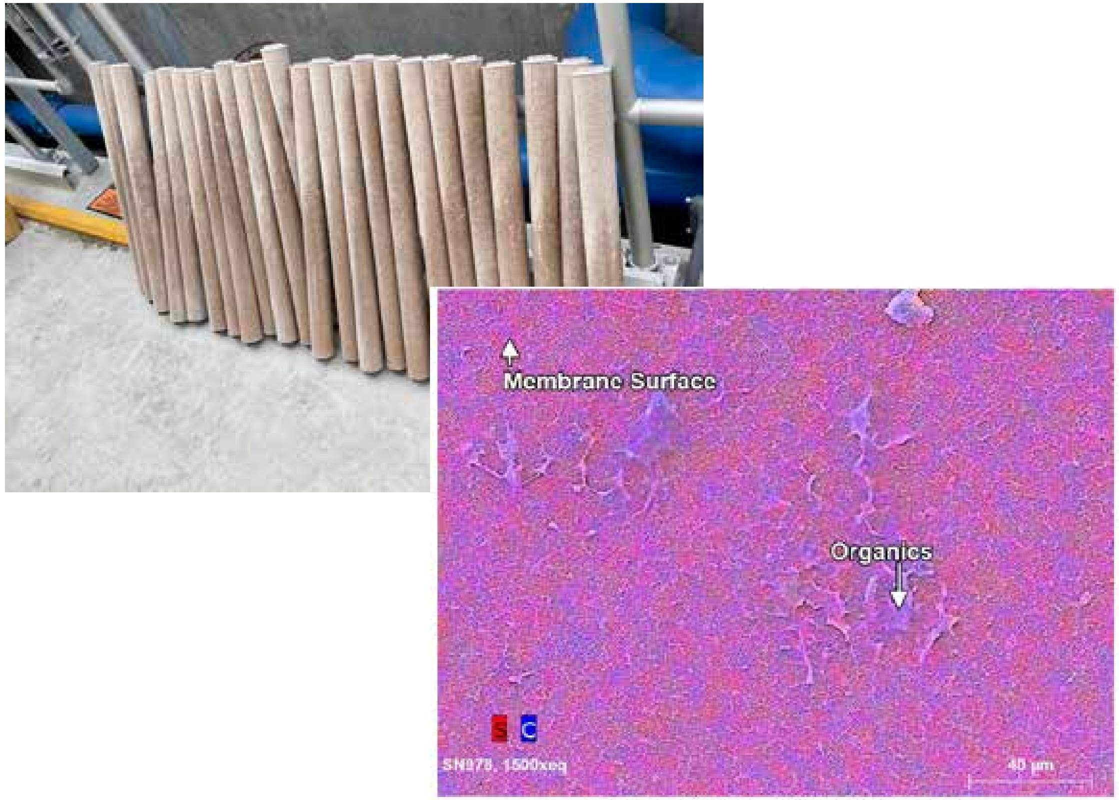
- Many correlations later, rediscovered *KISS* principle:
  - » Cost ∝ design flux!
  - » Correlates to SRT, effluent TOC & effluent ammonia
- Pencil module tests vs. pilot/full scale:
  - » Similar but not identical results
  - » Bench tests predicted non-obvious “challenging” vs. “easy” waters

**Bench testing potentially useful for *planning-level* MF/UF sizing & cost**

Module led by: Carollo and Hazen

# Module D: MBR ➡ RO. *Can* it be Done? *Should* it be done?

*Cartridge filters after change-out*



CEI image (1500x) of the membrane surface with labels

*Autopsy results and salt passage data confirm membrane integrity*

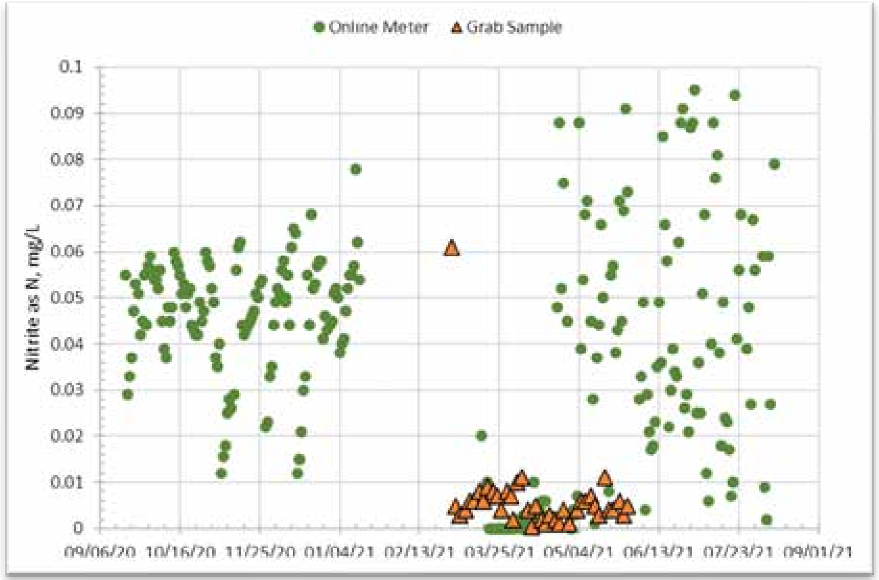
**Summary:**

- Incorporated summary of parallel ongoing efforts by MWD into project
- Mixed liquor breakthrough provided substantial "challenge test"
- Additional cleaning burden compared to tertiary UF à RO
- But RO integrity remained intact

**MBR à RO can obviously be done. But that wasn't so clear when we started!**

Module led by: Metropolitan Water District of Southern California with Carollo

# Module E: MBR ➡ CBAT works well... *when it works!*



What to believe? Online or grab data?

**Summary:**

- MBRs provide excellent starting point
- In depth testing of operational alternatives at Rio Rancho AWTF
- Observed interference of nitrite, challenges with sensor data
- Well-operated WRRF is prerequisite for successful potable reuse.

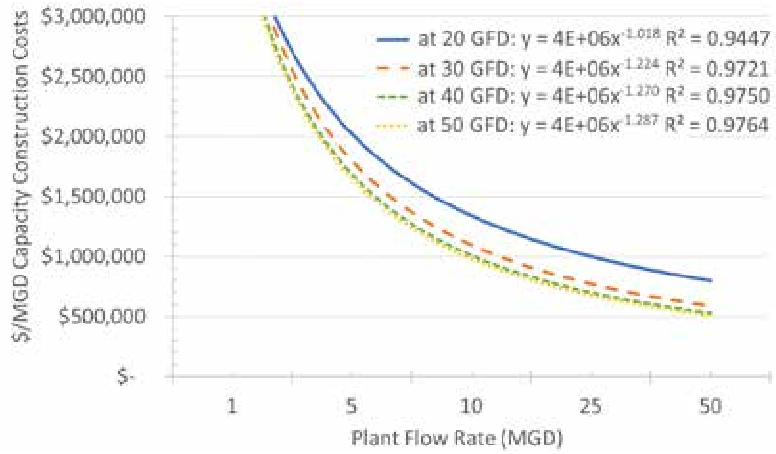
**“I do not think [these data] mean what you think they mean.”**

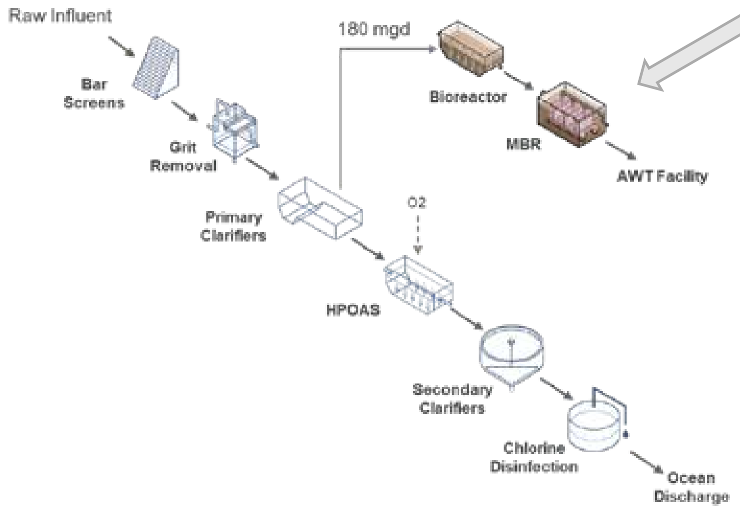
Module led by Carollo with support from City of Rio Rancho, NM

03

# Cost Trade-Offs

# Cost information is a necessary step to making trade-offs





**Summary:**

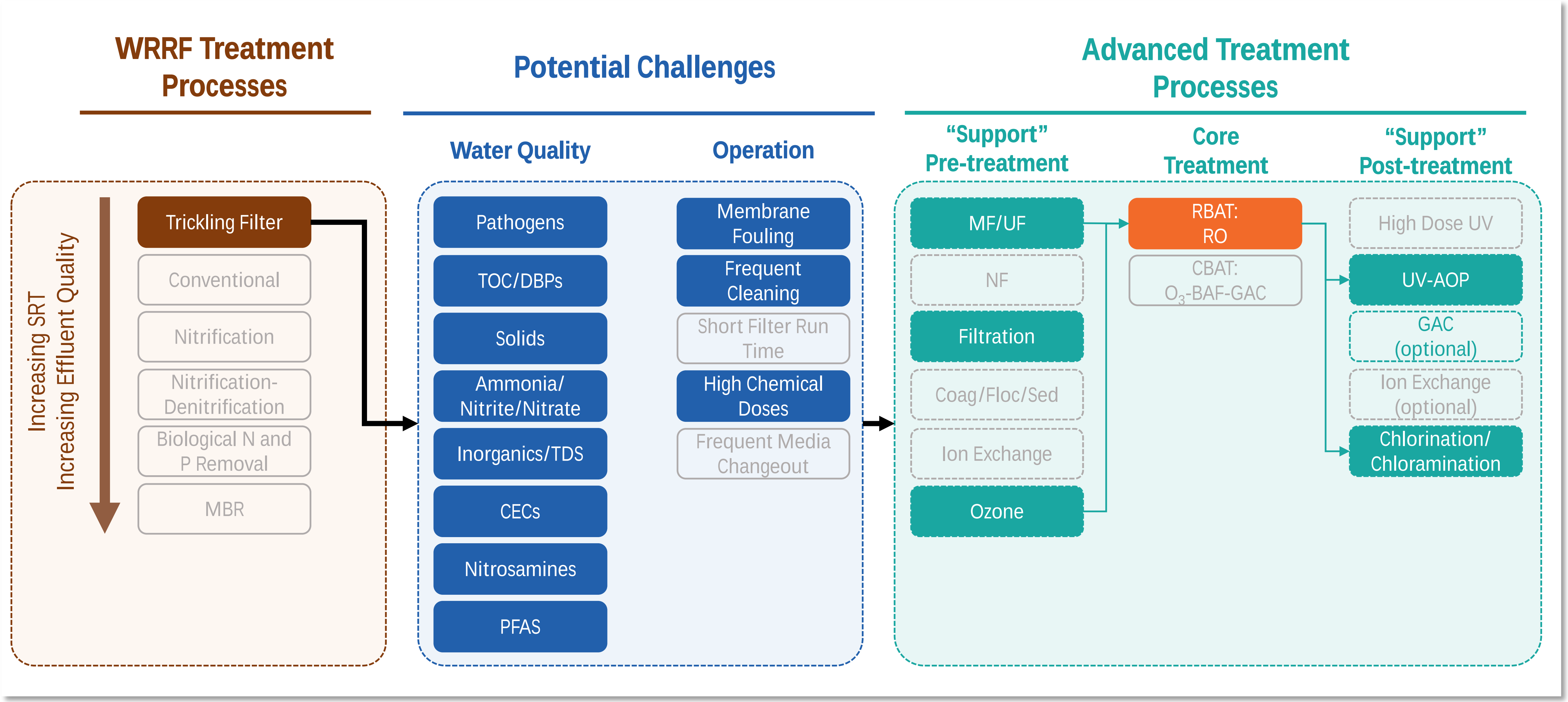
- If you have an MBR and can skip the MF/UF, the cost savings can be substantial.
- But building MBRs for AWT pretreatment ***alone*** doesn't make financial sense.

- Generally, taking WRRF effluent as-is and building on AWT to match is the most cost-effective approach. Why?
  - Relative flows: Typically, $Q_{WRRF} > Q_{AWT}$ Plus peaking factors on WRRF design
  - Marginal improvements in new AWT cost $$, but *retrofitting* existing WRRF processes costs $$$$$ -- even at the same flows.

04

# Communicating WRF Results Differently: Graphical Scenarios and Fact Sheets

# Example Scenario #1: Trickling Filter ➡ RBAT



**WRRF Treatment Processes**

Increasing SRT
Increasing Effluent Quality

- Trickling Filter
- Conventional
- Nitrification
- Nitrification-Denitrification
- Biological N and P Removal
- MBR

**Potential Challenges**

**Water Quality**

- Pathogens
- TOC/DBPs
- Solids
- Ammonia/ Nitrite/Nitrate
- Inorganics/TDS
- CECs
- Nitrosamines
- PFAS

**Operation**

- Membrane Fouling
- Frequent Cleaning
- Short Filter Run Time
- High Chemical Doses
- Frequent Media Changeout

**Advanced Treatment Processes**

**"Support" Pre-treatment**

- MF/UF
- NF
- Filtration
- Coag/Floc/Sed
- Ion Exchange
- Ozone

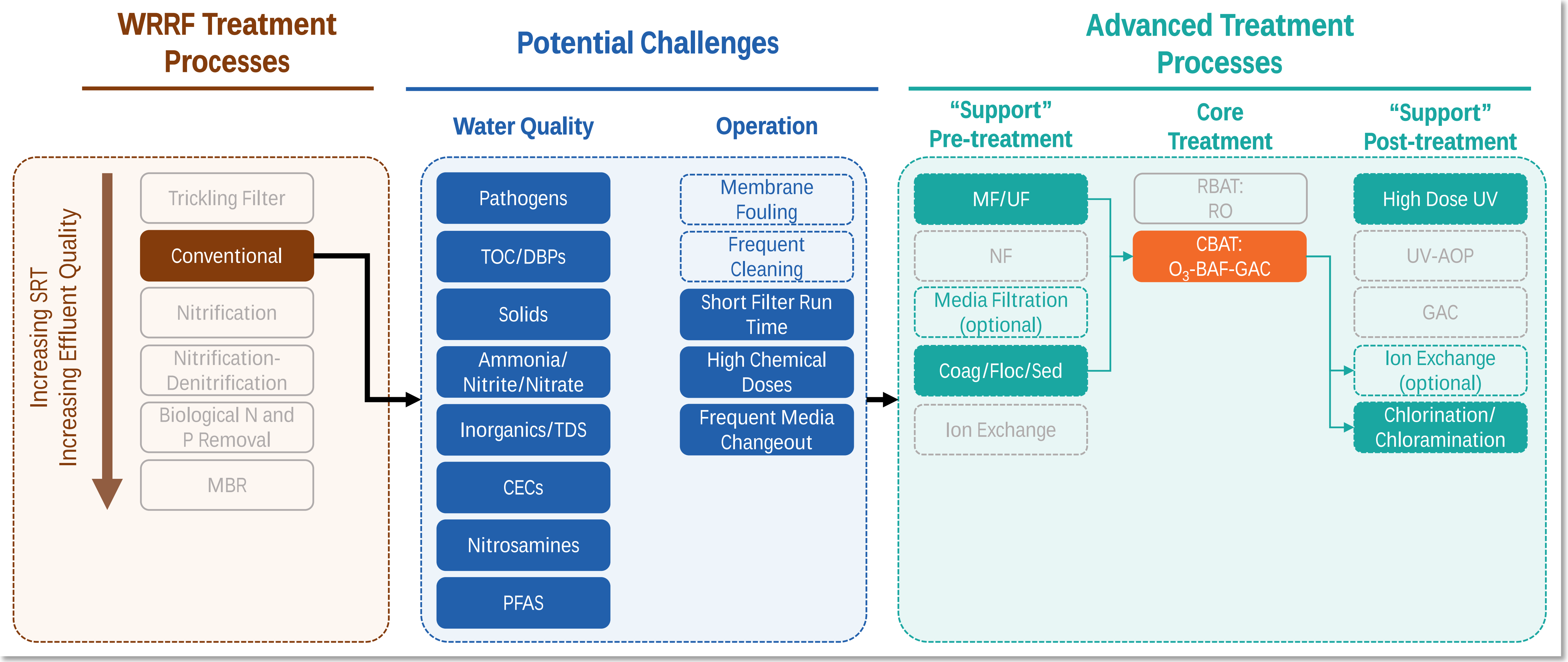
**Core Treatment**

- RBAT: RO
- CBAT: $O_3$-BAF-GAC

**"Support" Post-treatment**

- High Dose UV
- UV-AOP
- GAC (optional)
- Ion Exchange (optional)
- Chlorination/ Chloramination

# Example Scenario #2: Conventional WRRF ➡ CBAT



**WRRF Treatment Processes**

Increasing SRT
Increasing Effluent Quality

- Trickling Filter
- Conventional
- Nitrification
- Nitrification-Denitrification
- Biological N and P Removal
- MBR

**Potential Challenges**

**Water Quality**

- Pathogens
- TOC/DBPs
- Solids
- Ammonia/Nitrite/Nitrate
- Inorganics/TDS
- CECs
- Nitrosamines
- PFAS

**Operation**

- Membrane Fouling
- Frequent Cleaning
- Short Filter Run Time
- High Chemical Doses
- Frequent Media Changeout

**Advanced Treatment Processes**

**"Support" Pre-treatment**

- MF/UF
- NF
- Media Filtration (optional)
- Coag/Floc/Sed
- Ion Exchange

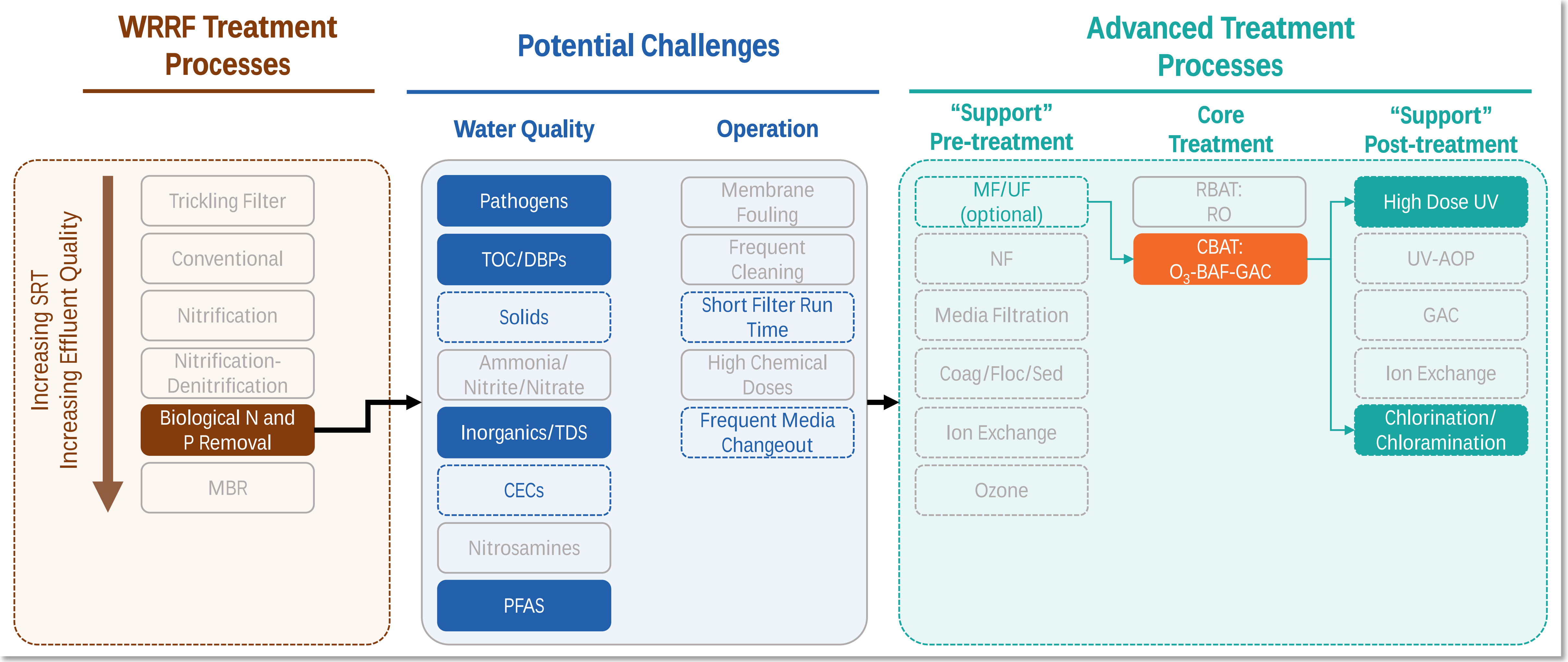
**Core Treatment**

- RBAT: RO
- CBAT: $O_3$-BAF-GAC

**"Support" Post-treatment**

- High Dose UV
- UV-AOP
- GAC
- Ion Exchange (optional)
- Chlorination/ Chloramination

# Example Scenario #3: BNR WRRF ➡ CBAT



**WRRF Treatment Processes**

Increasing SRT
Increasing Effluent Quality

- Trickling Filter
- Conventional
- Nitrification
- Nitrification-Denitrification
- **Biological N and P Removal**
- MBR

**Potential Challenges**

| Water Quality | Operation |
|---|---|
| Pathogens | Membrane Fouling |
| TOC/DBPs | Frequent Cleaning |
| Solids | Short Filter Run Time |
| Ammonia/ Nitrite/Nitrate | High Chemical Doses |
| Inorganics/TDS | Frequent Media Changeout |
| CECs | |
| Nitrosamines | |
| PFAS | |

**Advanced Treatment Processes**

| "Support" Pre-treatment | Core Treatment | "Support" Post-treatment |
|---|---|---|
| MF/UF (optional) | RBAT: RO | High Dose UV |
| NF | CBAT: $O_3$-BAF-GAC | UV-AOP |
| Media Filtration | | GAC |
| Coag/Floc/Sed | | Ion Exchange |
| Ion Exchange | | Chlorination/ Chloramination |
| Ozone | | |

From the WRF 4833 Series: *Considering Potable Reuse?*

## Carbon-Based Advanced Treatment

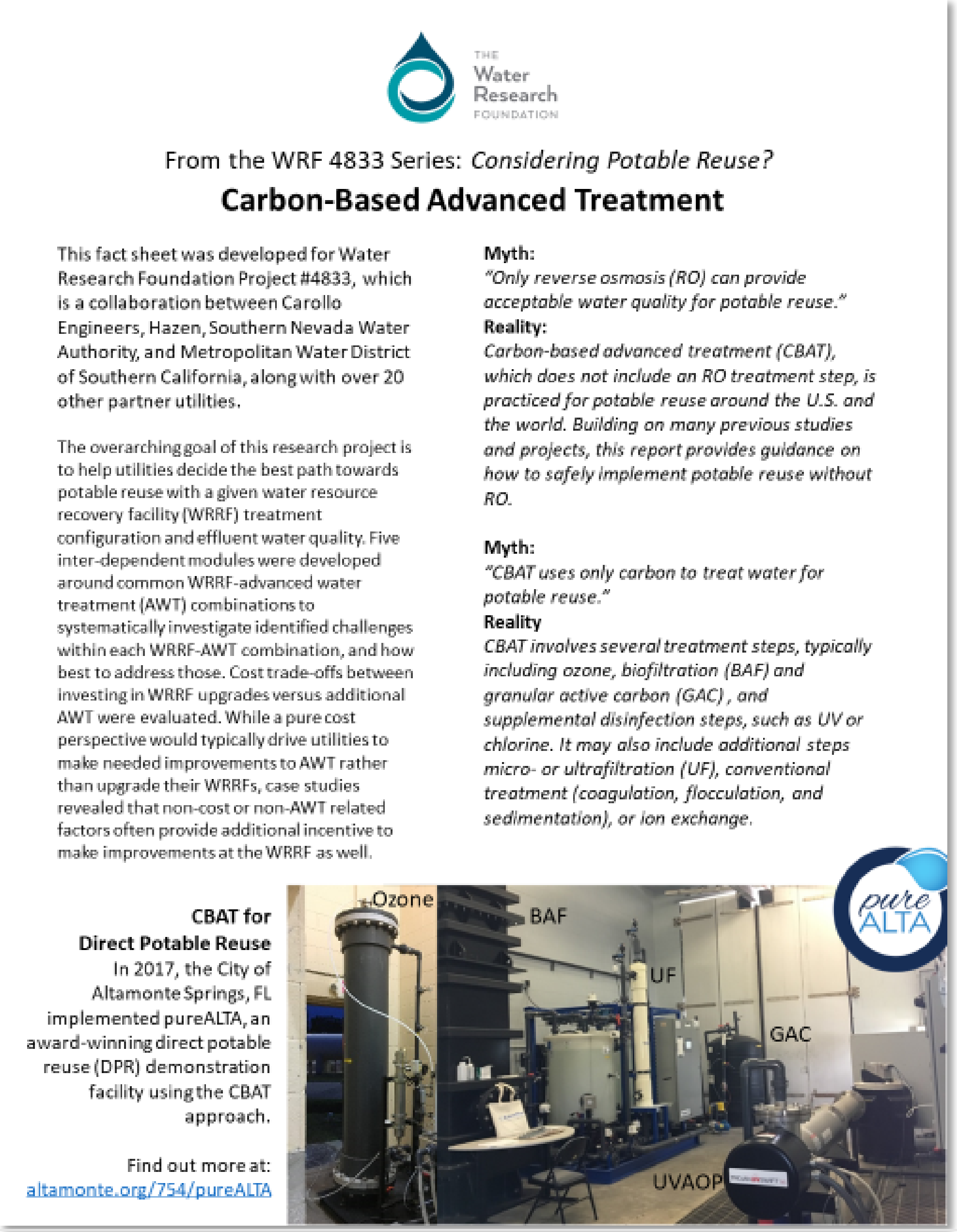
**Is CBAT for potable reuse right for my utility?**
Carbon based advanced treatment or CBAT uses core processes consisting of ozone, biofiltration (BAF) and granular activated carbon (GAC), and supporting processes, including disinfection (UV and chlorine), to address chemical and microbial contaminants of concern in potable reuse. Whether CBAT is right for your utility depends on several regulatory and technical factors. If CBAT does not face regulatory barriers in your state and your existing water resource recovery facility (WRRF) produces a high-quality, low salinity, and denitrified effluent, this approach can provide a safe, high-quality purified water at substantial cost savings over reverse osmosis-based treatment.

Even if your WRRF effluent quality is not as high, the core CBAT treatment approach can be augmented by any number of additional treatment steps that can improve water quality and provide additional pathogen barriers. The graphic below illustrates the core CBAT processes, and some additional processes that can help address potential water challenges.

### CBAT Treatment: Core and Support Processes

**CBAT at Scale**
The 60 mgd F. Wayne Hill Water Resources Center in Gwinnett County, GA has been purifying wastewater with the CBAT approach for introduction into Lake Lanier since 2010.

Find out more at:
vimeo.com/389473017



From the WRF 4833 Series: *Considering Potable Reuse?*

## Carbon-Based Advanced Treatment

This fact sheet was developed for Water Research Foundation Project #4833, which is a collaboration between Carollo Engineers, Hazen, Southern Nevada Water Authority, and Metropolitan Water District of Southern California, along with over 20 other partner utilities.

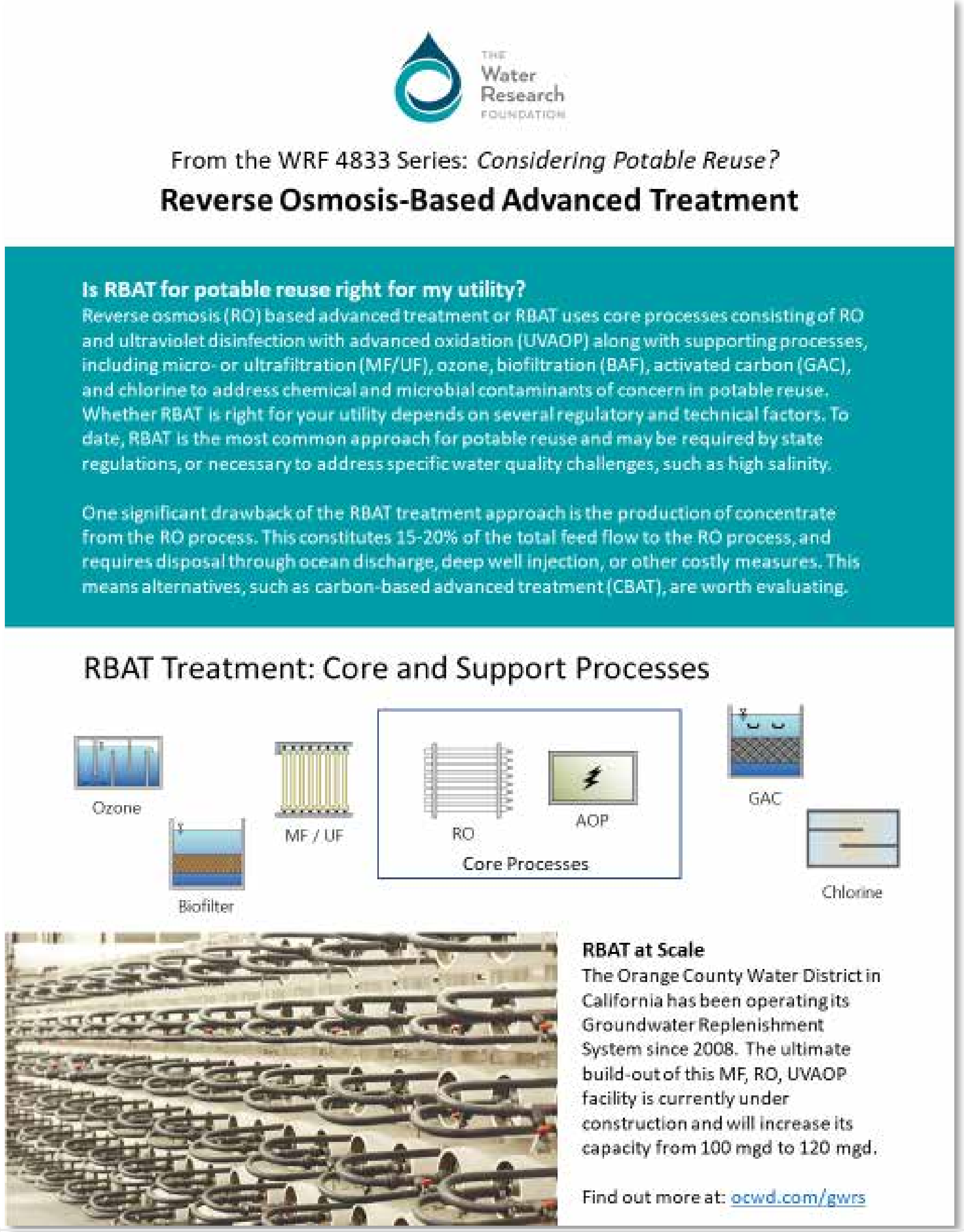
The overarching goal of this research project is to help utilities decide the best path towards potable reuse with a given water resource recovery facility (WRRF) treatment configuration and effluent water quality. Five inter-dependent modules were developed around common WRRF-advanced water treatment (AWT) combinations to systematically investigate identified challenges within each WRRF-AWT combination, and how best to address those. Cost trade-offs between investing in WRRF upgrades versus additional AWT were evaluated. While a pure cost perspective would typically drive utilities to make needed improvements to AWT rather than upgrade their WRRFs, case studies revealed that non-cost or non-AWT related factors often provide additional incentive to make improvements at the WRRF as well.

**Myth:**
*"Only reverse osmosis (RO) can provide acceptable water quality for potable reuse."*
**Reality:**
*Carbon-based advanced treatment (CBAT), which does not include an RO treatment step, is practiced for potable reuse around the U.S. and the world. Building on many previous studies and projects, this report provides guidance on how to safely implement potable reuse without RO.*

**Myth:**
*"CBAT uses only carbon to treat water for potable reuse."*
**Reality**
*CBAT involves several treatment steps, typically including ozone, biofiltration (BAF) and granular active carbon (GAC), and supplemental disinfection steps, such as UV or chlorine. It may also include additional steps micro- or ultrafiltration (UF), conventional treatment (coagulation, flocculation, and sedimentation), or ion exchange.*

**CBAT for Direct Potable Reuse**
In 2017, the City of Altamonte Springs, FL implemented pureALTA, an award-winning direct potable reuse (DPR) demonstration facility using the CBAT approach.

Find out more at:
altamonte.org/754/pureALTA



From the WRF 4833 Series: *Considering Potable Reuse?*

## Reverse Osmosis-Based Advanced Treatment

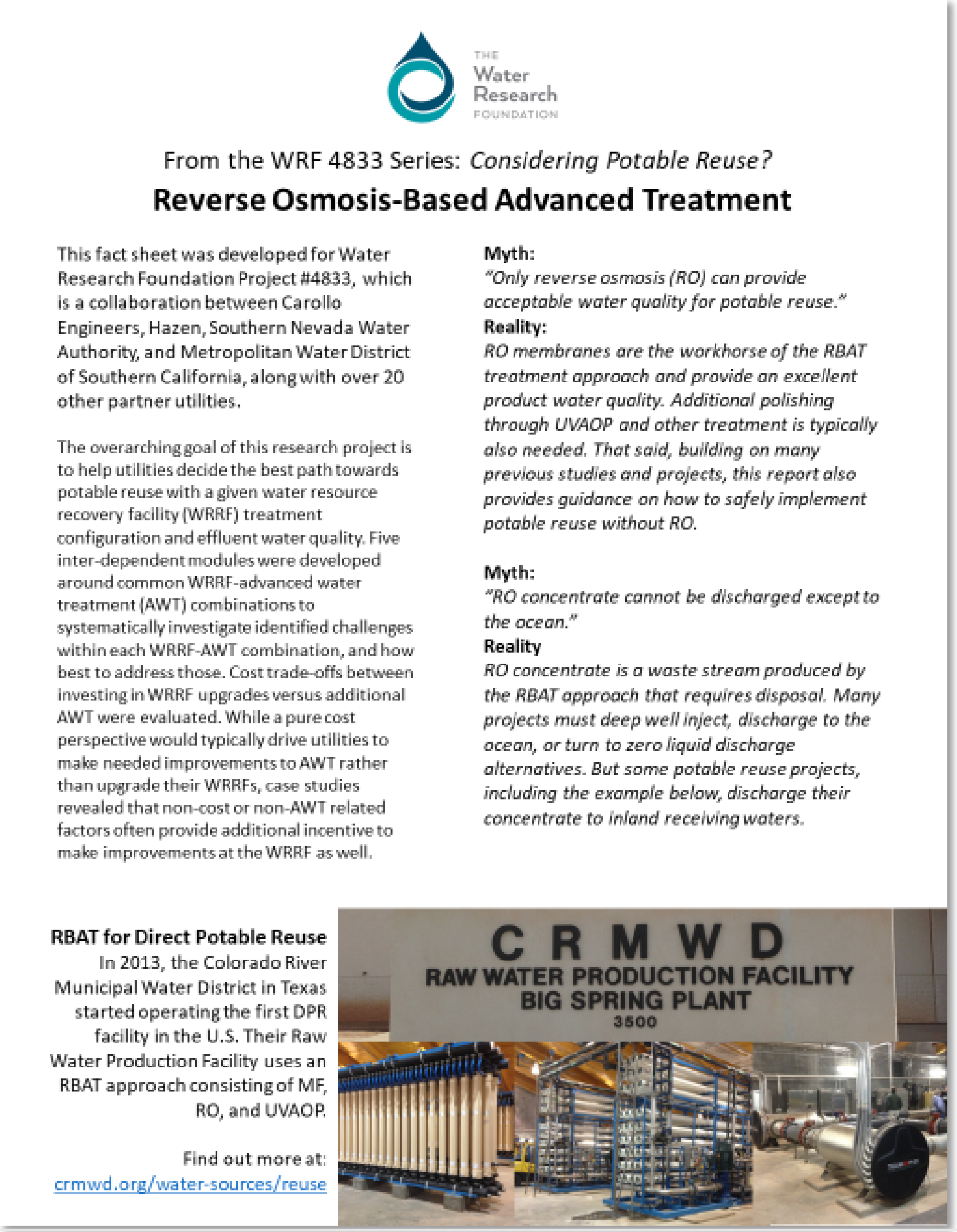
**Is RBAT for potable reuse right for my utility?**
Reverse osmosis (RO) based advanced treatment or RBAT uses core processes consisting of RO and ultraviolet disinfection with advanced oxidation (UVAOP) along with supporting processes, including micro- or ultrafiltration (MF/UF), ozone, biofiltration (BAF), activated carbon (GAC), and chlorine to address chemical and microbial contaminants of concern in potable reuse. Whether RBAT is right for your utility depends on several regulatory and technical factors. To date, RBAT is the most common approach for potable reuse and may be required by state regulations, or necessary to address specific water quality challenges, such as high salinity.

One significant drawback of the RBAT treatment approach is the production of concentrate from the RO process. This constitutes 15-20% of the total feed flow to the RO process, and requires disposal through ocean discharge, deep well injection, or other costly measures. This means alternatives, such as carbon-based advanced treatment (CBAT), are worth evaluating.

### RBAT Treatment: Core and Support Processes

**RBAT at Scale**
The Orange County Water District in California has been operating its Groundwater Replenishment System since 2008. The ultimate build-out of this MF, RO, UVAOP facility is currently under construction and will increase its capacity from 100 mgd to 120 mgd.

Find out more at: ocwd.com/gwrs



From the WRF 4833 Series: *Considering Potable Reuse?*

## Reverse Osmosis-Based Advanced Treatment

This fact sheet was developed for Water Research Foundation Project #4833, which is a collaboration between Carollo Engineers, Hazen, Southern Nevada Water Authority, and Metropolitan Water District of Southern California, along with over 20 other partner utilities.

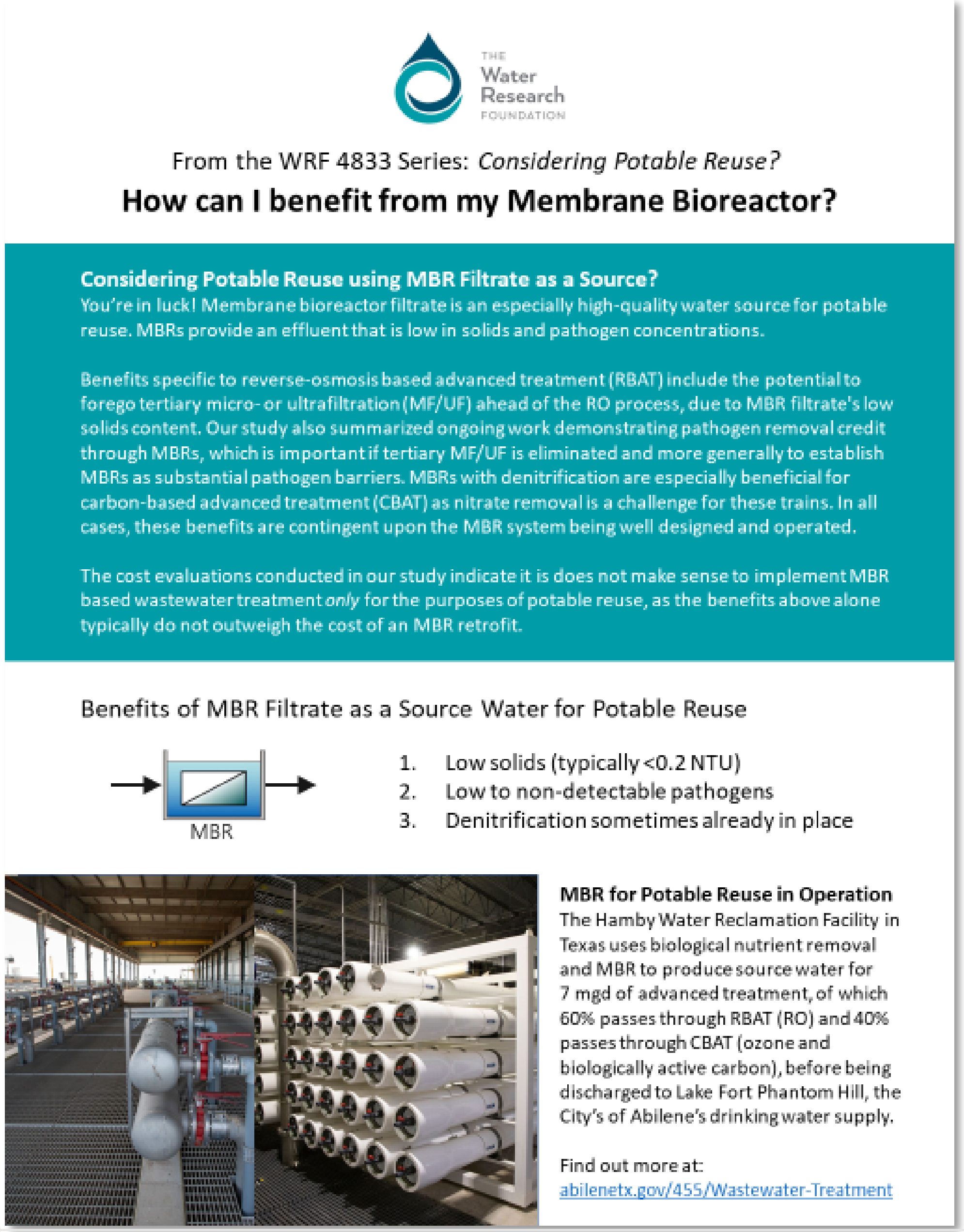
The overarching goal of this research project is to help utilities decide the best path towards potable reuse with a given water resource recovery facility (WRRF) treatment configuration and effluent water quality. Five inter-dependent modules were developed around common WRRF-advanced water treatment (AWT) combinations to systematically investigate identified challenges within each WRRF-AWT combination, and how best to address those. Cost trade-offs between investing in WRRF upgrades versus additional AWT were evaluated. While a pure cost perspective would typically drive utilities to make needed improvements to AWT rather than upgrade their WRRFs, case studies revealed that non-cost or non-AWT related factors often provide additional incentive to make improvements at the WRRF as well.

**Myth:**
*"Only reverse osmosis (RO) can provide acceptable water quality for potable reuse."*
**Reality:**
*RO membranes are the workhorse of the RBAT treatment approach and provide an excellent product water quality. Additional polishing through UVAOP and other treatment is typically also needed. That said, building on many previous studies and projects, this report also provides guidance on how to safely implement potable reuse without RO.*

**Myth:**
*"RO concentrate cannot be discharged except to the ocean."*
**Reality**
*RO concentrate is a waste stream produced by the RBAT approach that requires disposal. Many projects must deep well inject, discharge to the ocean, or turn to zero liquid discharge alternatives. But some potable reuse projects, including the example below, discharge their concentrate to inland receiving waters.*

**RBAT for Direct Potable Reuse**
In 2013, the Colorado River Municipal Water District in Texas started operating the first DPR facility in the U.S. Their Raw Water Production Facility uses an RBAT approach consisting of MF, RO, and UVAOP.

Find out more at:
crmwd.org/water-sources/reuse



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## How can I benefit from my Membrane Bioreactor?

**Considering Potable Reuse using MBR Filtrate as a Source?**
You're in luck! Membrane bioreactor filtrate is an especially high-quality water source for potable reuse. MBRs provide an effluent that is low in solids and pathogen concentrations.

Benefits specific to reverse-osmosis based advanced treatment (RBAT) include the potential to forego tertiary micro- or ultrafiltration (MF/UF) ahead of the RO process, due to MBR filtrate's low solids content. Our study also summarized ongoing work demonstrating pathogen removal credit through MBRs, which is important if tertiary MF/UF is eliminated and more generally to establish MBRs as substantial pathogen barriers. MBRs with denitrification are especially beneficial for carbon-based advanced treatment (CBAT) as nitrate removal is a challenge for these trains. In all cases, these benefits are contingent upon the MBR system being well designed and operated.

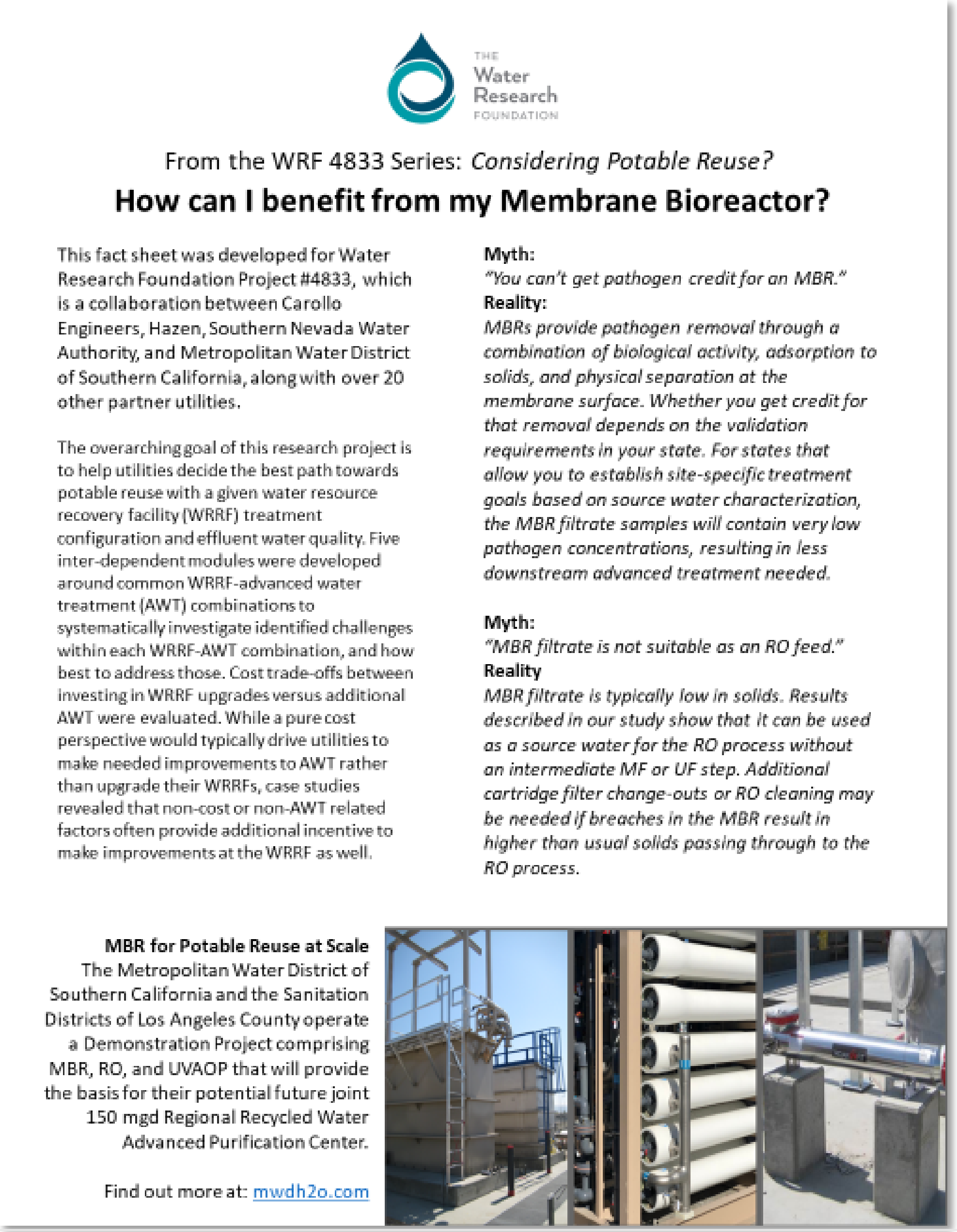
The cost evaluations conducted in our study indicate it is does not make sense to implement MBR based wastewater treatment *only* for the purposes of potable reuse, as the benefits above alone typically do not outweigh the cost of an MBR retrofit.

### Benefits of MBR Filtrate as a Source Water for Potable Reuse

1. Low solids (typically <0.2 NTU)
2. Low to non-detectable pathogens
3. Denitrification sometimes already in place

**MBR for Potable Reuse in Operation**
The Hamby Water Reclamation Facility in Texas uses biological nutrient removal and MBR to produce source water for 7 mgd of advanced treatment, of which 60% passes through RBAT (RO) and 40% passes through CBAT (ozone and biologically active carbon), before being discharged to Lake Fort Phantom Hill, the City's of Abilene's drinking water supply.

Find out more at:
abilenetx.gov/455/Wastewater-Treatment



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**Myth:**
*"You can't get pathogen credit for an MBR."*
**Reality:**
*MBRs provide pathogen removal through a combination of biological activity, adsorption to solids, and physical separation at the membrane surface. Whether you get credit for that removal depends on the validation requirements in your state. For states that allow you to establish site-specific treatment goals based on source water characterization, the MBR filtrate samples will contain very low pathogen concentrations, resulting in less downstream advanced treatment needed.*

**Myth:**
*"MBR filtrate is not suitable as an RO feed."*
**Reality**
*MBR filtrate is typically low in solids. Results described in our study show that it can be used as a source water for the RO process without an intermediate MF or UF step. Additional cartridge filter change-outs or RO cleaning may be needed if breaches in the MBR result in higher than usual solids passing through to the RO process.*

**MBR for Potable Reuse at Scale**
The Metropolitan Water District of Southern California and the Sanitation Districts of Los Angeles County operate a Demonstration Project comprising MBR, RO, and UVAOP that will provide the basis for their potential future joint 150 mgd Regional Recycled Water Advanced Purification Center.

Find out more at: mwdh2o.com

# Questions about
# WRF 4833 (aka Reuse 15-05) Impacts of WW Performance on Advanced Treatment ?

Eva Steinle-Darling, PhD, PE | esd@carollo.com

Webinar hosted by:
The Water Research Foundation | WateReuse Association | Metropolitan Water District of Southern California

20 April 2023

# WRF 4953: Considerations and Blending Strategies for Drinking Water Integration with Alternative Water Supplies

**Nicole Blute, PhD, PE and Daniel Giammar, PhD, PE**

Co-Authors: Anushka Mishrra, PhD, Janelle Junior, and Jacqueline Rhoades, PE

# Study Objectives

- Evaluate impacts of direct potable reuse water on the quality of the end users’ existing drinking water systems that have known issues with tuberculation
- Understand impacts of blending ratios of alternative water supplies for integration into existing pipes
- Develop management strategies and options to mitigate adverse impacts

# Study Tasks

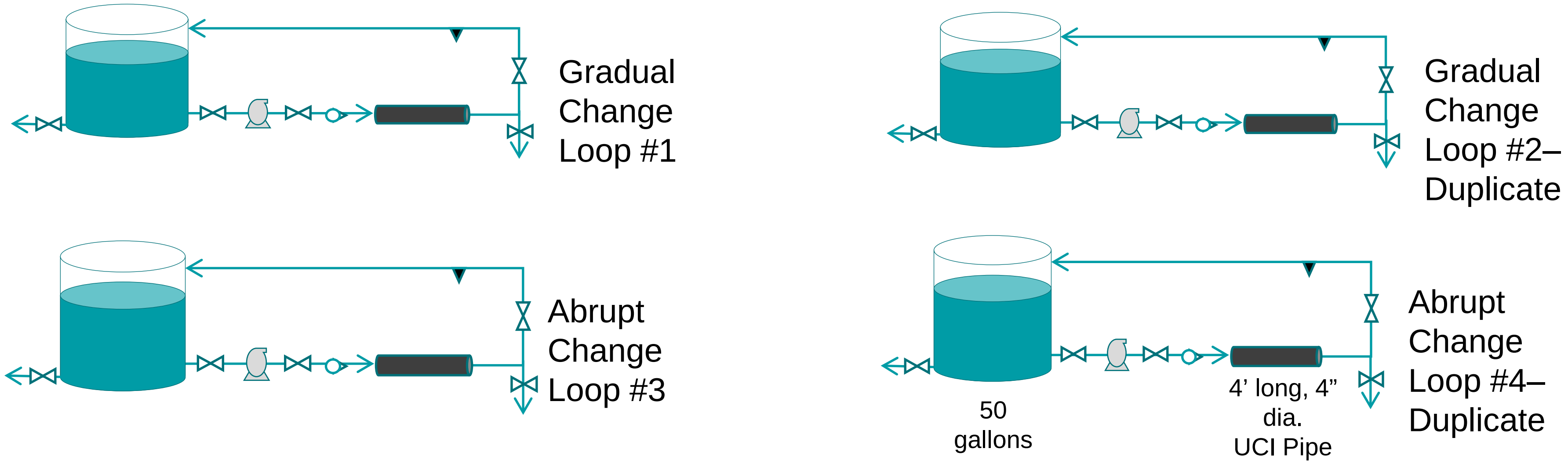
- Task 1 - Literature review
- Task 2 – Water quality review and coordination with participating utilities
- Task 3 – Distribution system pipe loops
- Task 4 – Premise plumbing pipe loops

Participating Utilities:
LADWP
Golden State
OCWD
Loudoun Water
WRD
West Basin
MWDOC
Pasadena
South Coast WD
Santa Monica
Suburban
Tampa Bay Water
Aurora Water
EBMUD

Funding through WRF:
MWD and CA WaterBoards

# Task 3 – Distribution Pipes

- Unlined Cast Iron Pipe Loops



Gradual Change Loop #1

Gradual Change Loop #2– Duplicate

Abrupt Change Loop #3

Abrupt Change Loop #4– Duplicate

50 gallons

4' long, 4" dia. UCI Pipe

# Task 3 – Distribution Pipes

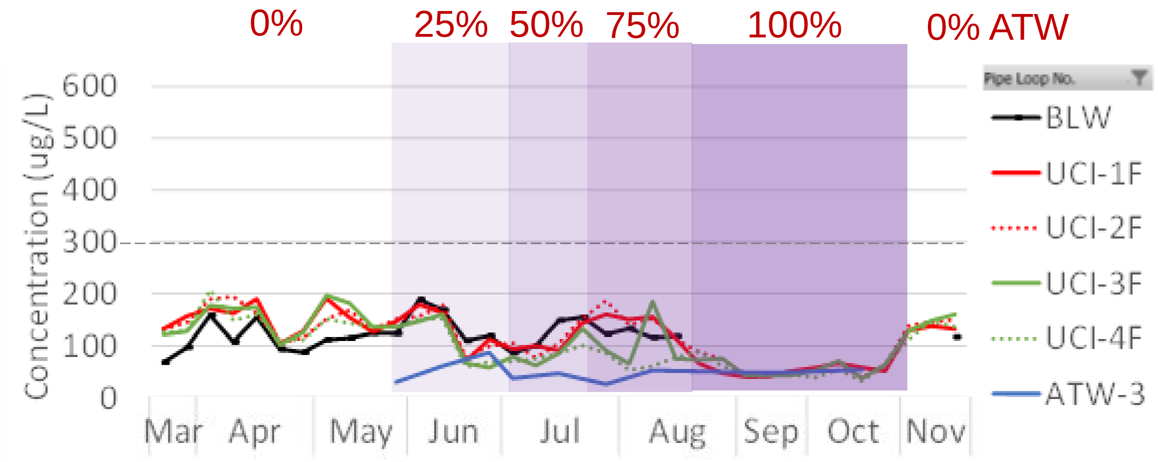
# Task 3 – Distribution Pipes: Schedule

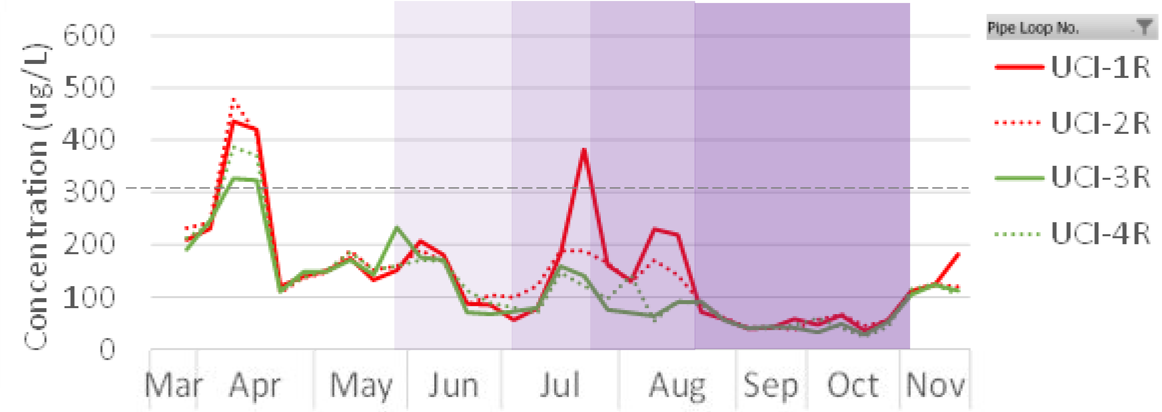
| **Timeline** | Iron Pipes | | | |
|---|---|---|---|---|
| | **Gradual** | **Duplicate – Gradual** | **Abrupt** | **Duplicate - Abrupt** |
| 2 months | Baseline | Baseline | Baseline | Baseline |
| 1 months | 25% ATW | 25% ATW | | |
| 1 months | 50% ATW | 50% ATW | | |
| 1 months | 75% ATW | 75% ATW | | |
| 3 months | 100% ATW stabilized | 100% ATW stabilized | 100% ATW stabilized | 100% ATW stabilized |
| 2 months | Baseline | Baseline | Baseline | Baseline |

# Task 3 – Distribution Pipes: Water Quality

| | Baseline Range | Baseline Avg | ATW Range | ATW Avg |
|---|---|---|---|---|
| Alkalinity (mg/L as $CaCO_3$) | 76 - 279 | 131 | 60 – 117 | 82 |
| Calcium (mg/L as $CaCO_3$) | 64 – 282 | 169 | 68 – 158 | 79 |
| Chloride (mg/L) | 77 – 105 | 82 | 5.7 – 13.7 | 9.9 |
| Conductivity (uS/cm) | 578 – 1012 | 880 | 163 – 663 | 250 |
| ORP (mV) | 280 – 406 | 346 | 278 – 409 | 357 |
| pH | 7.99– 8.4 | 8.12 | 7.63 – 8.37 | 8.10 |
| Sulfate (mg/L) | 102 – 238 | 178 | 0.1 – 0.42 | 0.31 |
| Temperature (deg. C) | 19.5 – 31.6 | 24.9 | 25 – 33.8 | 28.6 |
| TOC (mg/L) | 0.5 – 6.2 | 4.5 | 0.1 – 1.1 | 0.76 |
| Total Chlorine (mg/L) | 0.06 – 3.88 | 1.8 | 0.45 – 2.74 | 1.9 |
| Total Ammonia (mg/L as N) | 0.14 – 0.59 | 0.44 | 0.31 – 0.56 | 0.44 |
| Nitrite (mg/L as N) | 0 – 0.057 | 0.025 | 0.017 – 0.080 | 0.030 |

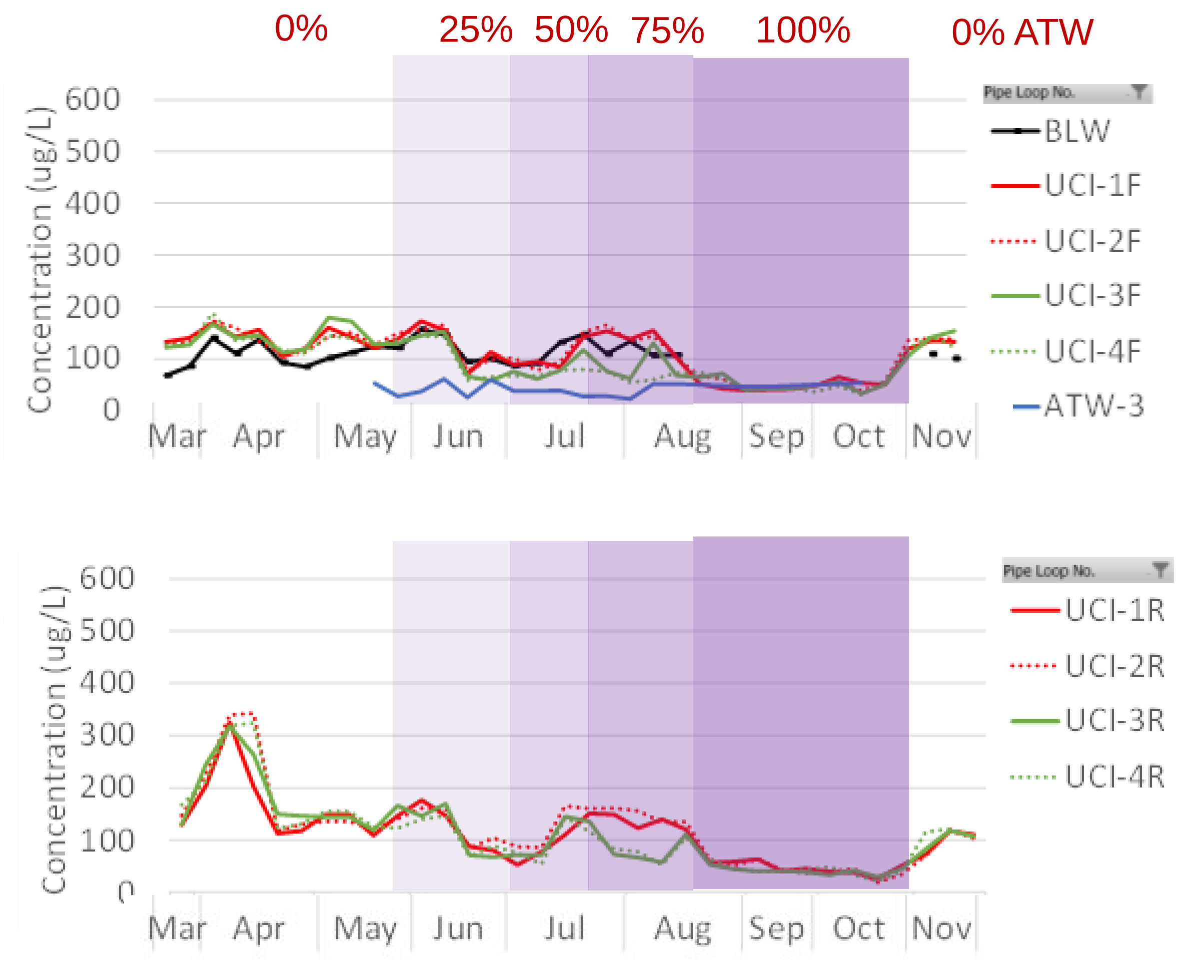
# Task 3 – Distribution Pipes: Total Iron





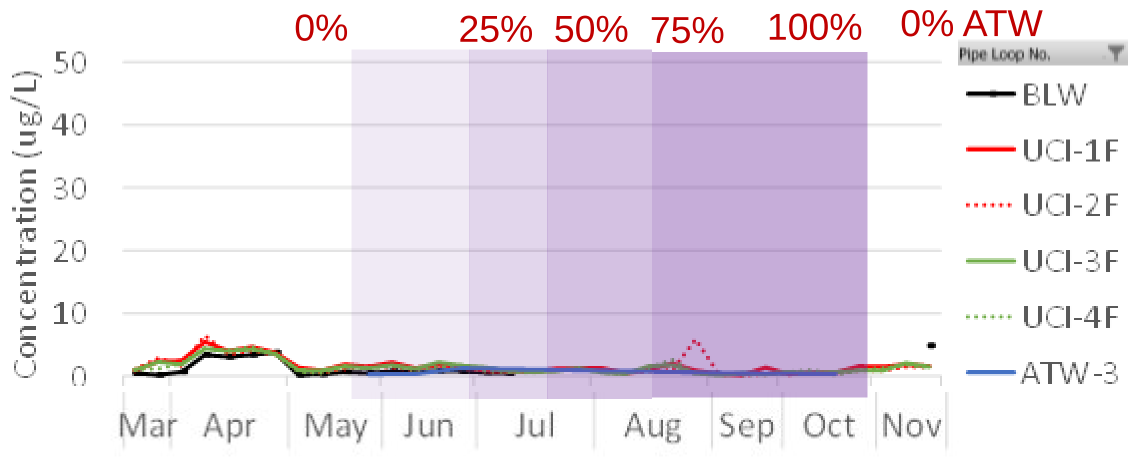
- Similar patterns observed with gradual or abrupt ATW introduction – freshly filled vs. recirculated water and over time
- Lower iron concentrations observed with more ATW, reflecting source water quality

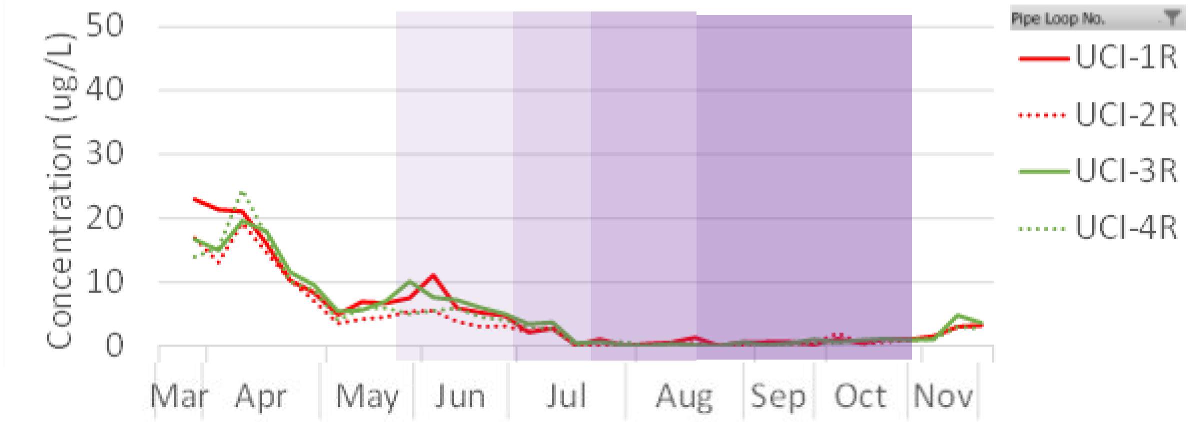
# Task 3 – Distribution Pipes: Dissolved Iron



- Dissolved iron concentrations were similar to total iron

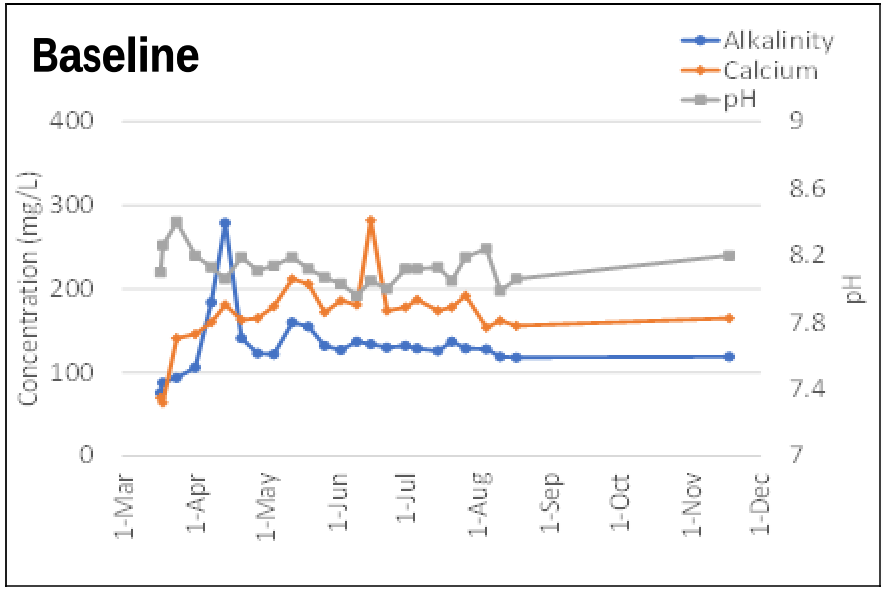
# Task 3 – Distribution Pipes: Dissolved Mn

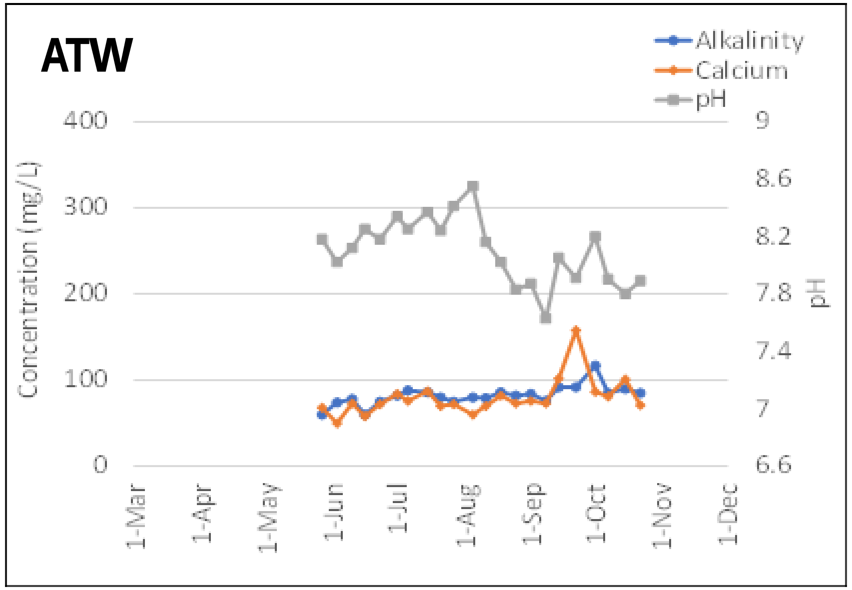


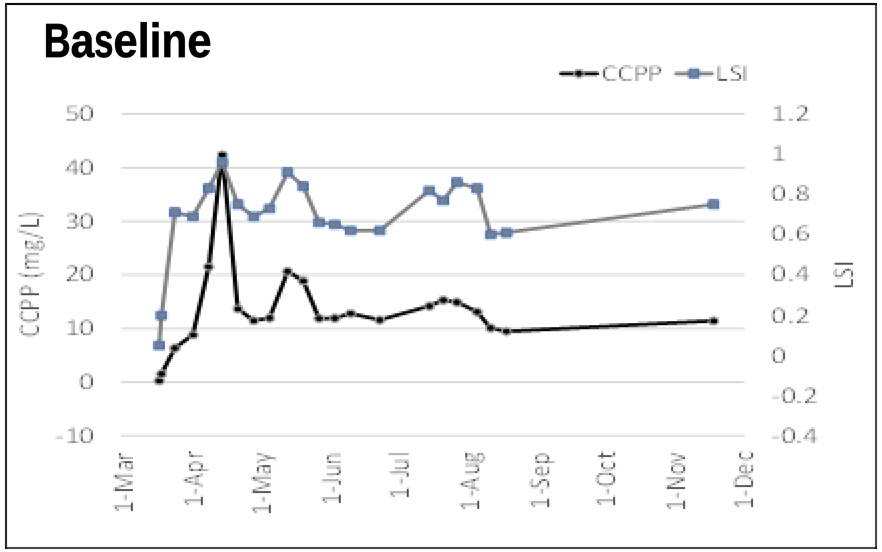


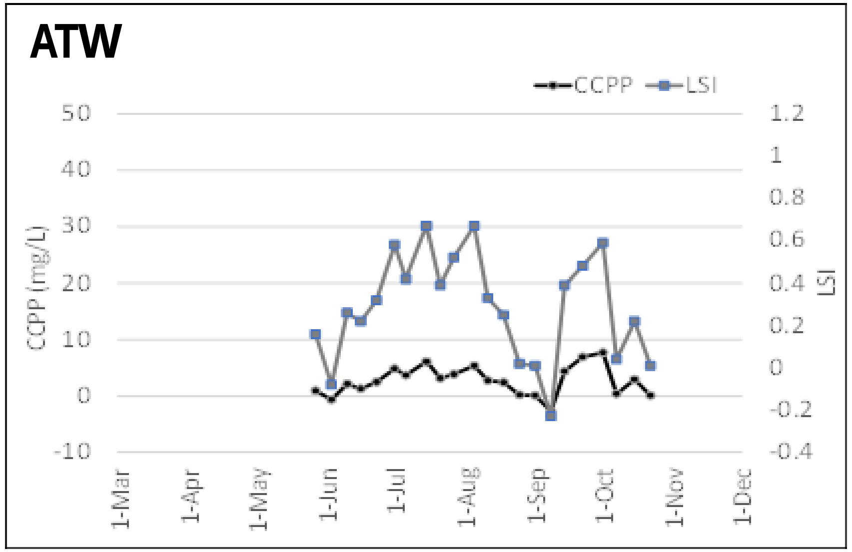
- Little total manganese release observed with introduction of ATW

# Task 3 – Water Sources: CCPP and LSI


Baseline

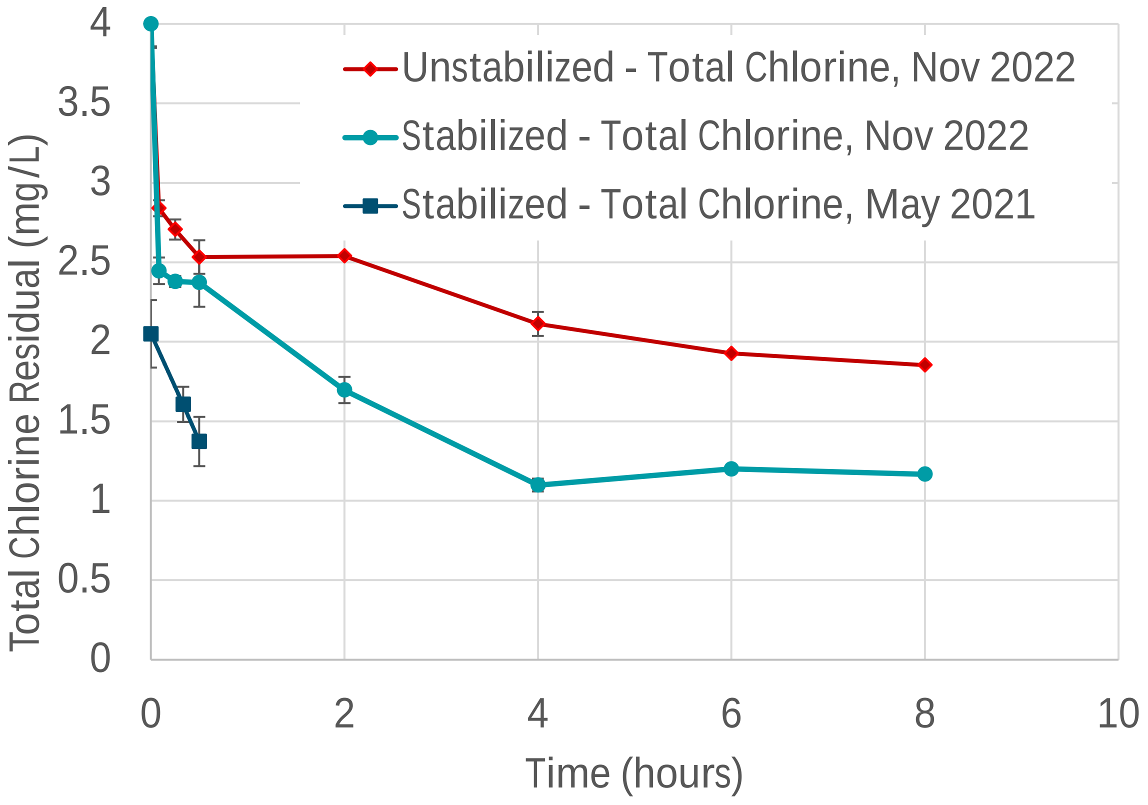

ATW


Baseline


ATW

# Chloramine Formation in ATW

- Large drop in total chlorine concentrations observed in ATW
- To achieve targets in the pipe loop study, 2.3x the total chlorine target was necessary.
- Water was found to hold a more stable chloramine residual if held overnight before addition of ammonia.
- Follow-up testing at Wash U on shipped water found stable formation of chloramines as expected, leading to the question of timing
- Additional testing conducted, showing dependence on water quality and/or treatment



# Key Distribution Pipe Findings

1. Iron and manganese were released into the water during the conditioning period after pipe harvesting, as expected.

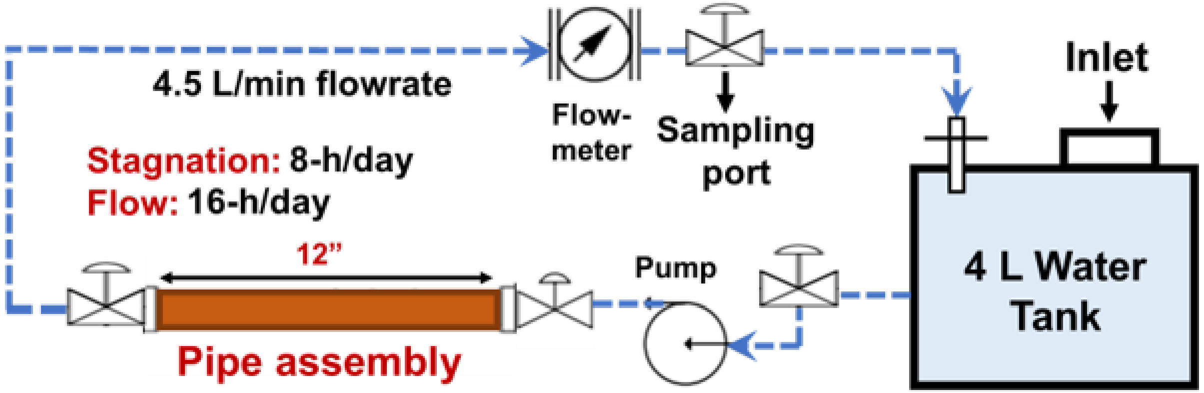
2. Good reproducibility observed for the pipes (i.e., no major outlier).

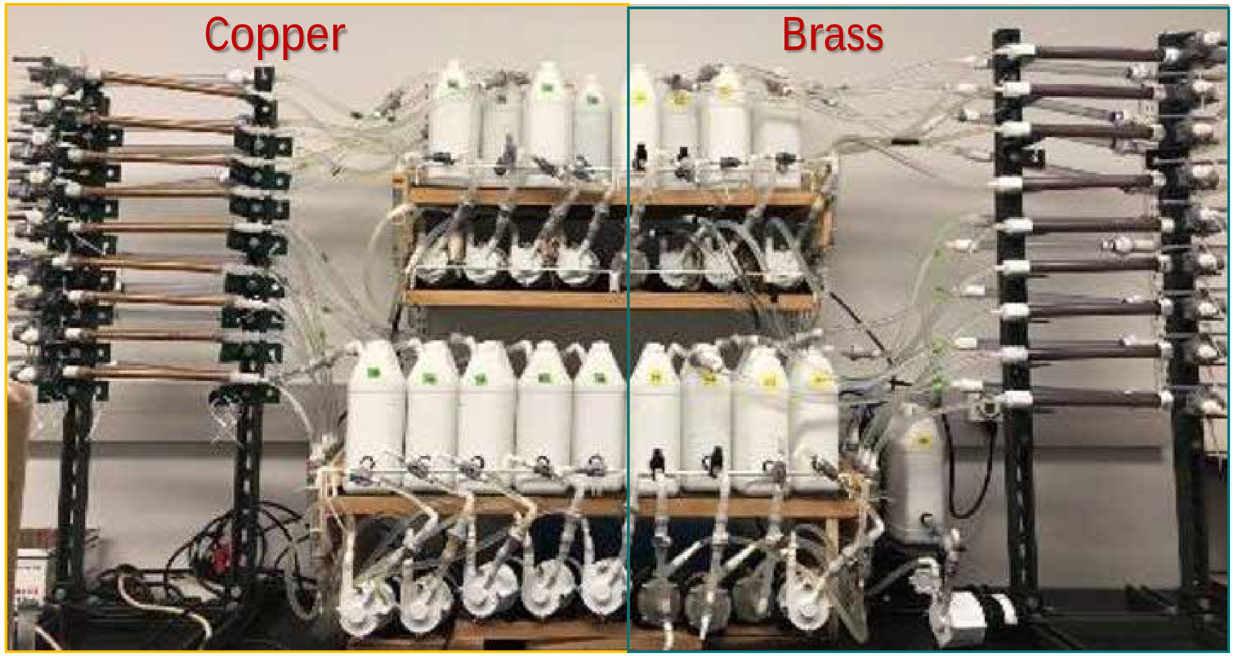
3. ATW conditioning with calcite filters achieved the targets for alkalinity, calcium, and pH without need for additional chemical addition.

4. Challenges observed in producing a stable disinfectant residual for the ATW.

5. Introduction of ATW, which varied significantly from Baseline water (groundwater), did not result in higher release of iron and manganese either for gradual addition or abrupt addition.

# Task 4 – Premise Plumbing



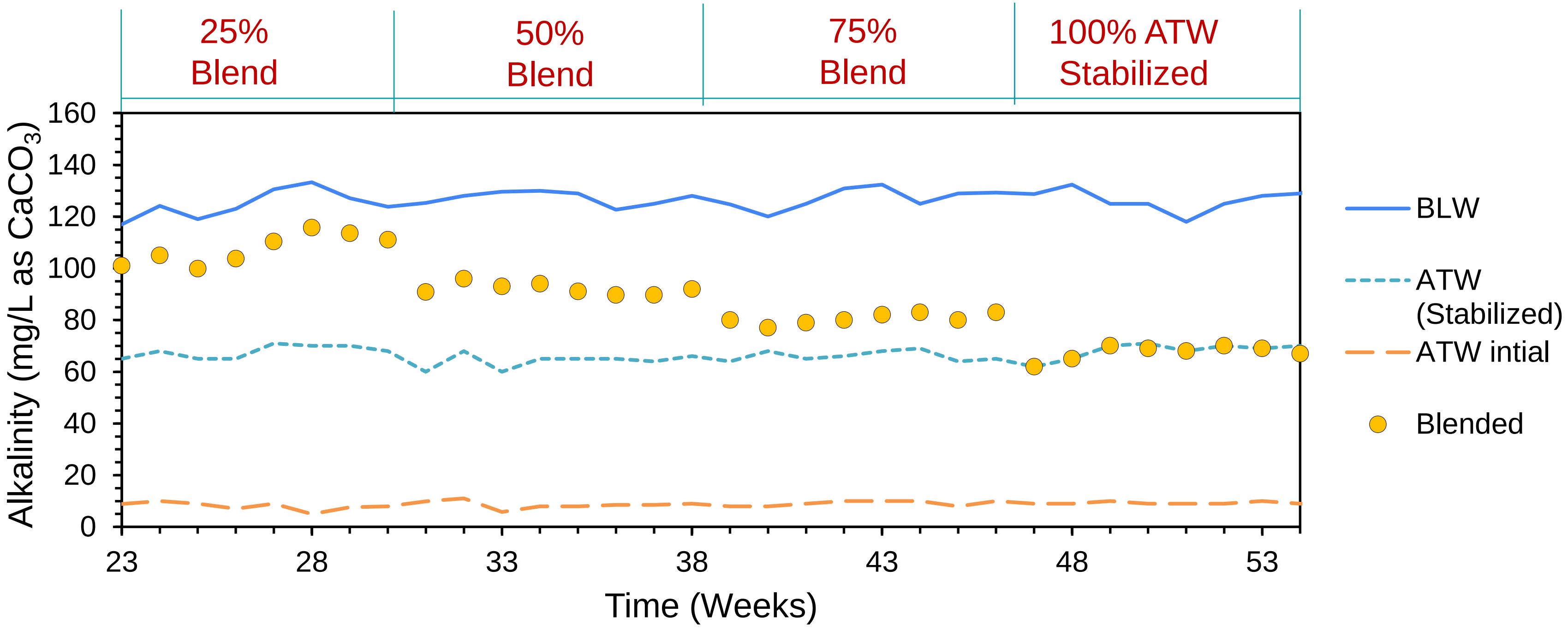


# Task 4 – Premise Plumbing: Schedule

| Timeline | Copper Pipes | | | Brass rods | | |
|---|---|---|---|---|---|---|
| | **Baseline** | **Gradual ATW** | **Abrupt ATW** | **Baseline** | **Gradual ATW** | **Abrupt ATW** |
| 5 months* | Baseline | Baseline | Baseline | Baseline | Baseline | Baseline |
| 2 months | Baseline | 25% ATW | | Baseline | 25% ATW | |
| 2 months | Baseline | 50% ATW | | Baseline | 50% ATW | |
| 2 months | Baseline | 75% ATW | | Baseline | 75% ATW | |
| 2 months | Baseline | 100% ATW stabilized | 100% ATW stabilized | Baseline | 100% ATW stabilized | 100% ATW stabilized |

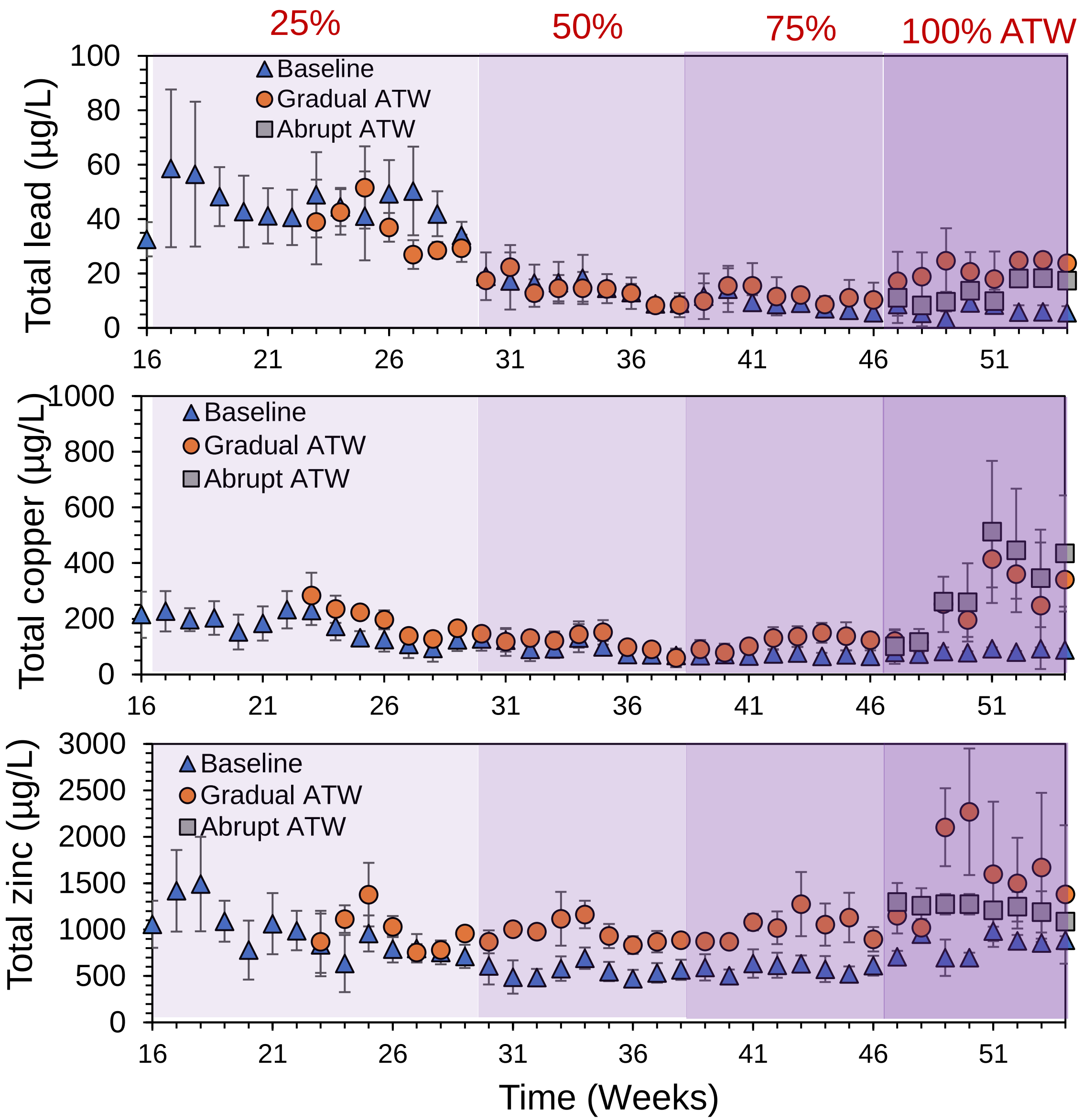
*Initial period of conditioning was decided based on stability of metal release.

# Task 4 – Average Alkalinity



- Alkalinity of stabilized ATW was 65 to 75 mg/L as $CaCO_3$.
- Alkalinity of the influent and effluent water remained same.

# Task 4 – Brass Rods: Pb, Cu, and Zn Release

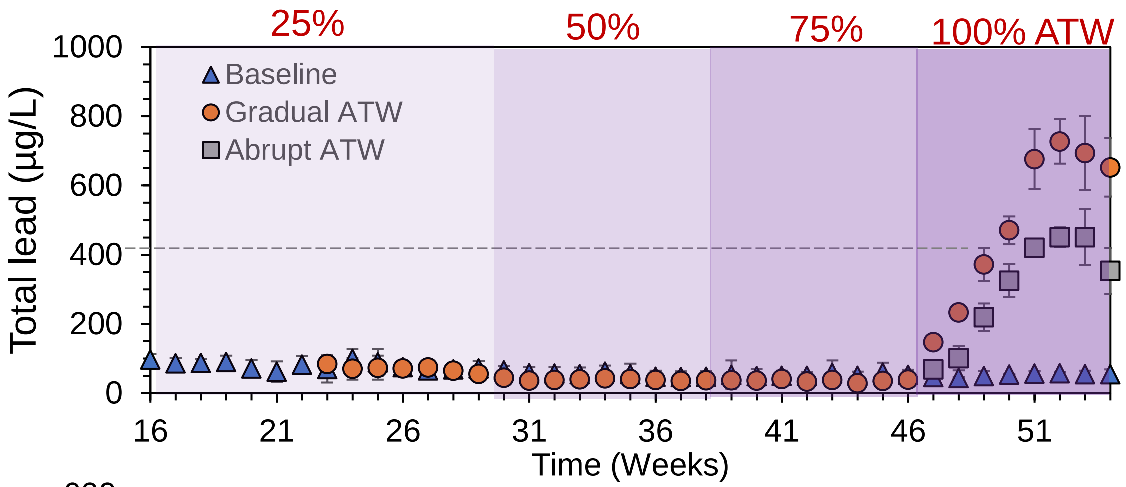


- Increase in total lead during of 100% stabilized ATW

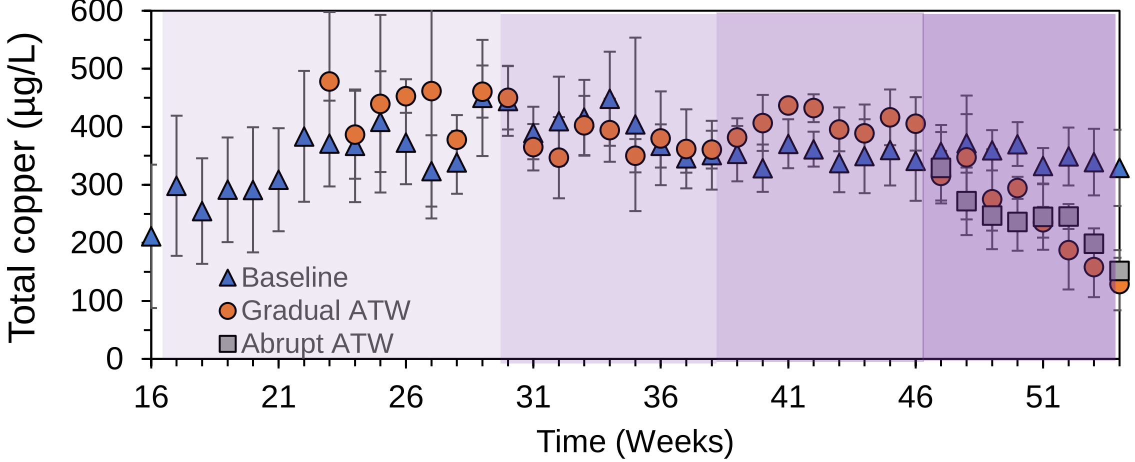
- Increase in total copper during 100% Stabilized ATW

- Increase in total zinc during 100% stabilized ATW
- MCL Zn: 5 mg/L

# Task 4 – Copper Pipes: Pb and Cu Release

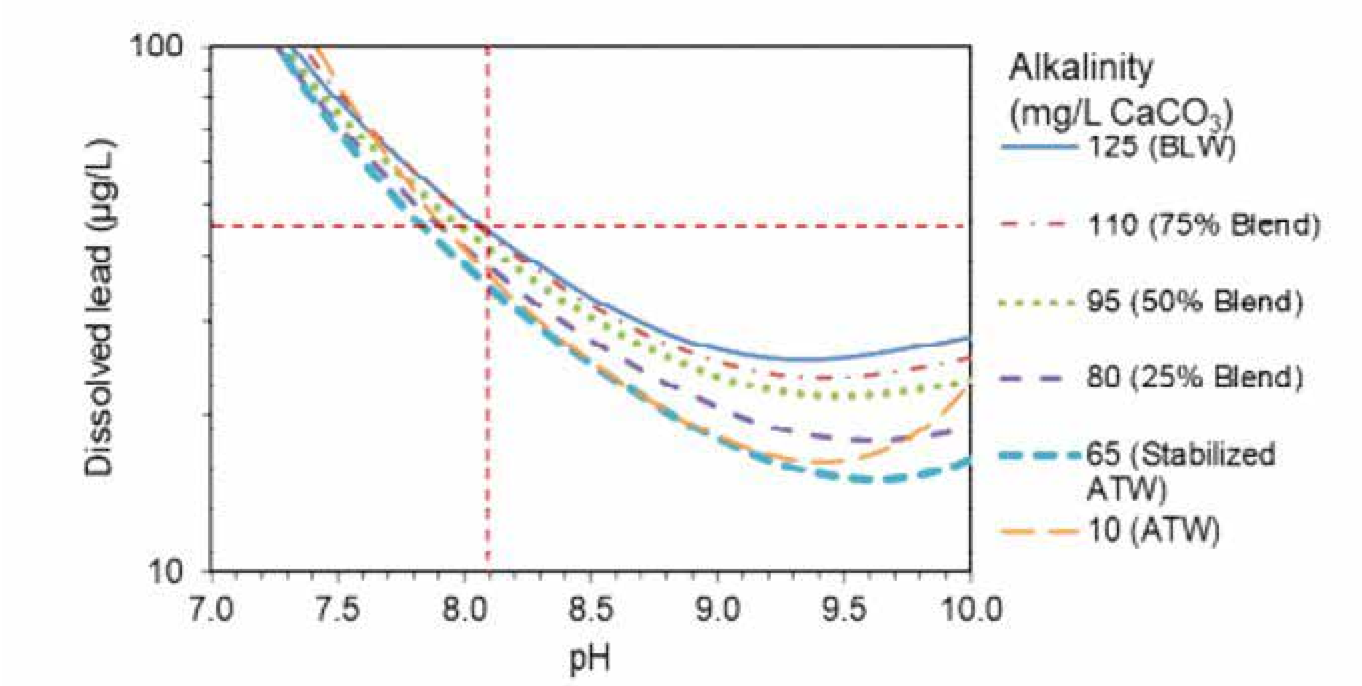


- No change in total lead upon gradual blending of ATW
- Increase in total lead at the introduction of 100% Stabilized ATW
- Action level Pb: 15 µg/L



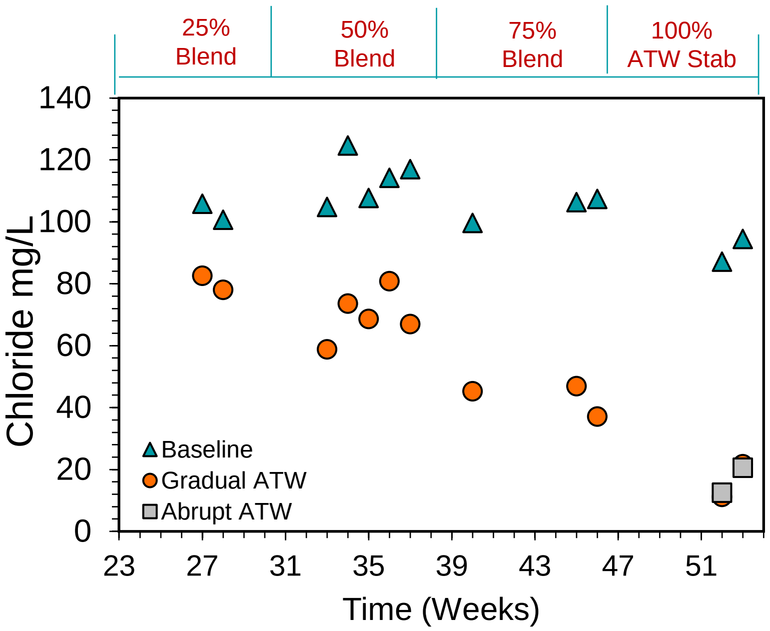
- No change in copper release upon gradual blending of ATW
- Decrease in copper release at the introduction of 100% Stabilized ATW
- Action level Cu: 1.3 mg/L

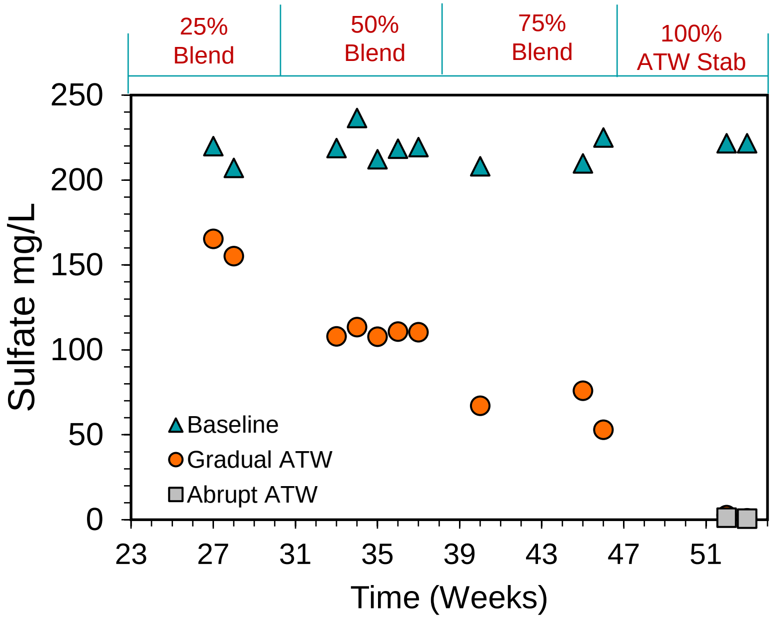
# Evaluation of Lead Precipitates



- SEM-EDX and XRD analysis showed that the predominant lead compound was hydrocerussite ($Pb_3(CO_3)_2(OH)_2$).
- Concentrations of 30-50 ug/L were predicted from solubility calculations, which agreed with results until 100% ATW was introduced.

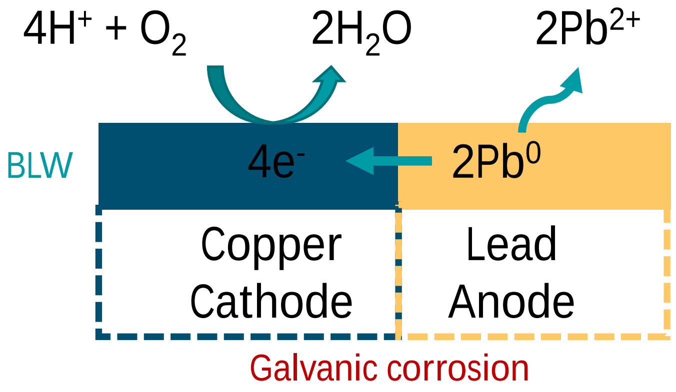
# Task 4 – Chloride and Sulfate





- Chloride and sulfate in ATW are much lower than those in baseline
- However, sulfate concentration is much lower in the ATW

# Lead Release in Copper Pipes with Solder



$4H^+ + O_2$

$2H_2O$

$2Pb^{2+}$

BLW

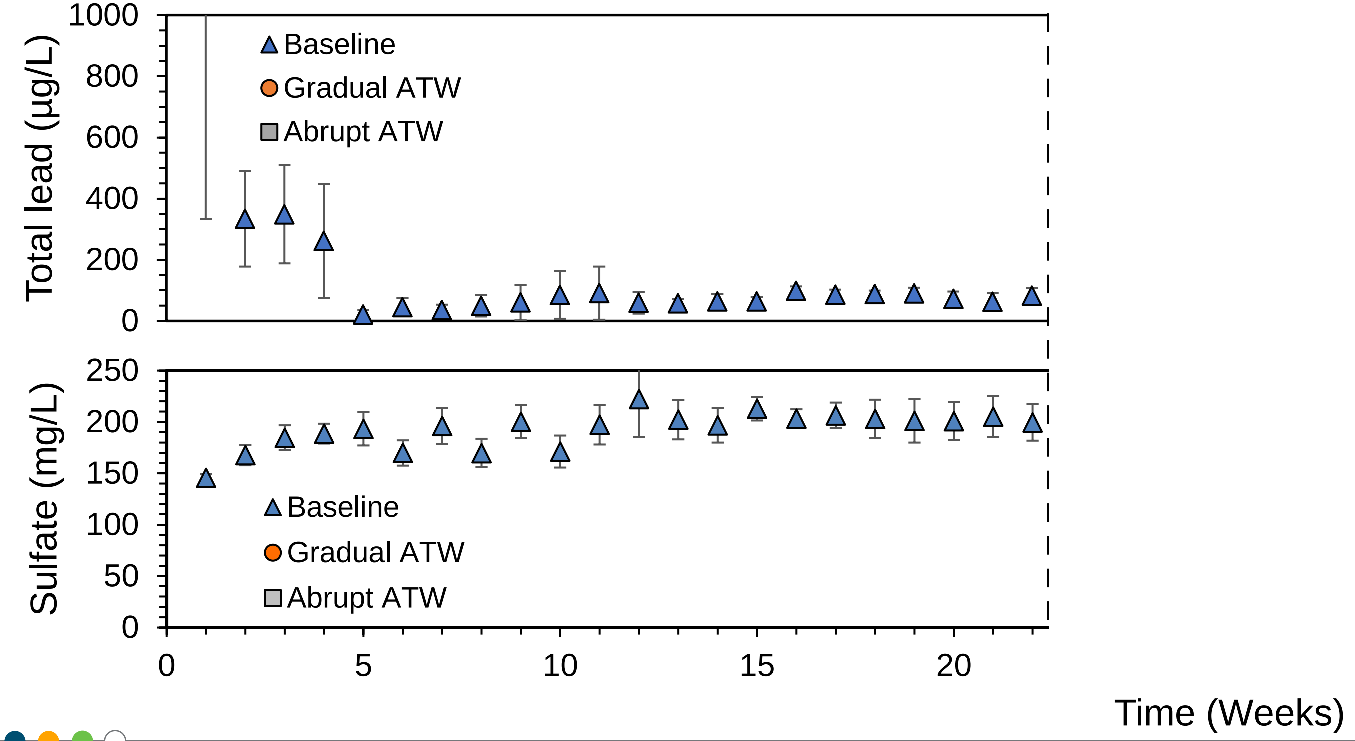
$4e^-$

$2Pb^0$

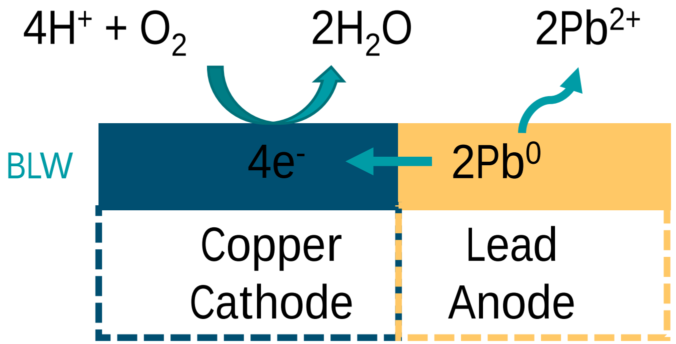
Copper Cathode

Lead Anode

Galvanic corrosion



# Lead Release in Copper Pipes with Solder



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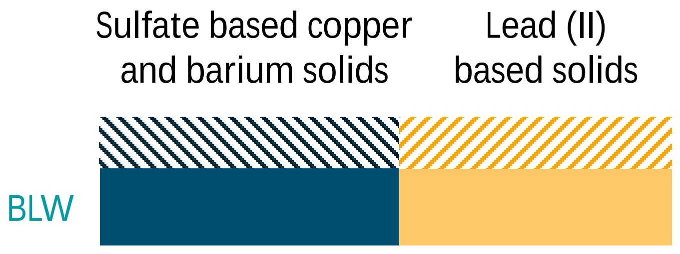
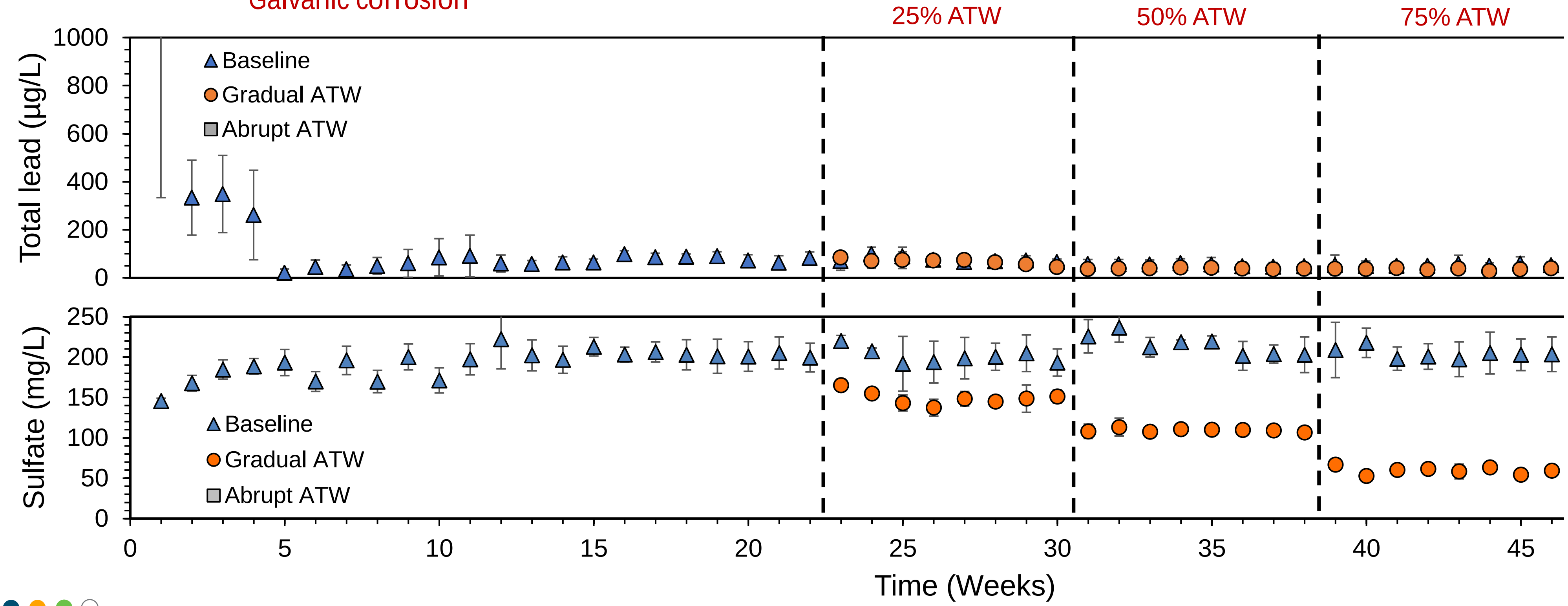


Sulfate based copper and barium solids

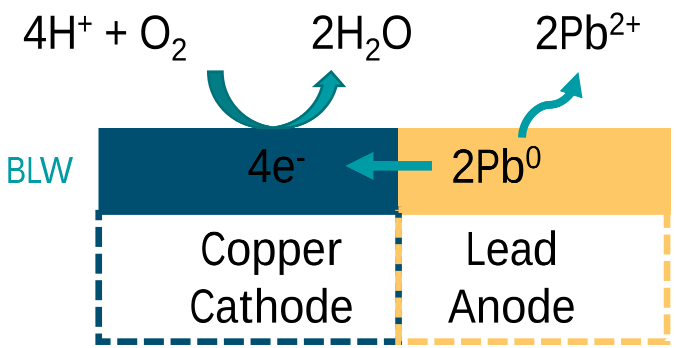
Lead (II) based solids

BLW

Passivation in the presence of sulfate



# Lead Release in Copper Pipes with Solder


$4H^+ + O_2$

$2H_2O$

$2Pb^{2+}$

BLW

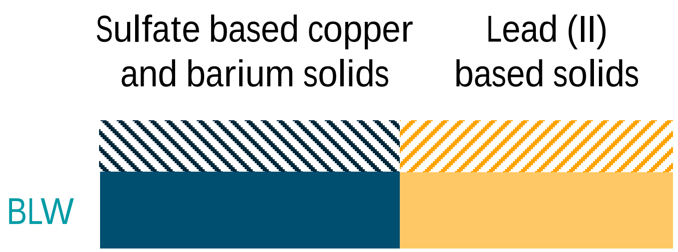
$4e^-$

$2Pb^0$

Copper Cathode

Lead Anode

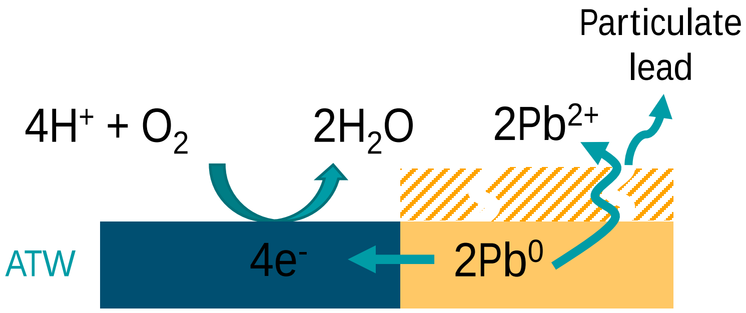
Galvanic corrosion


Sulfate based copper and barium solids

Lead (II) based solids

BLW

Passivation in the presence of sulfate


Particulate lead

$4H^+ + O_2$

$2H_2O$

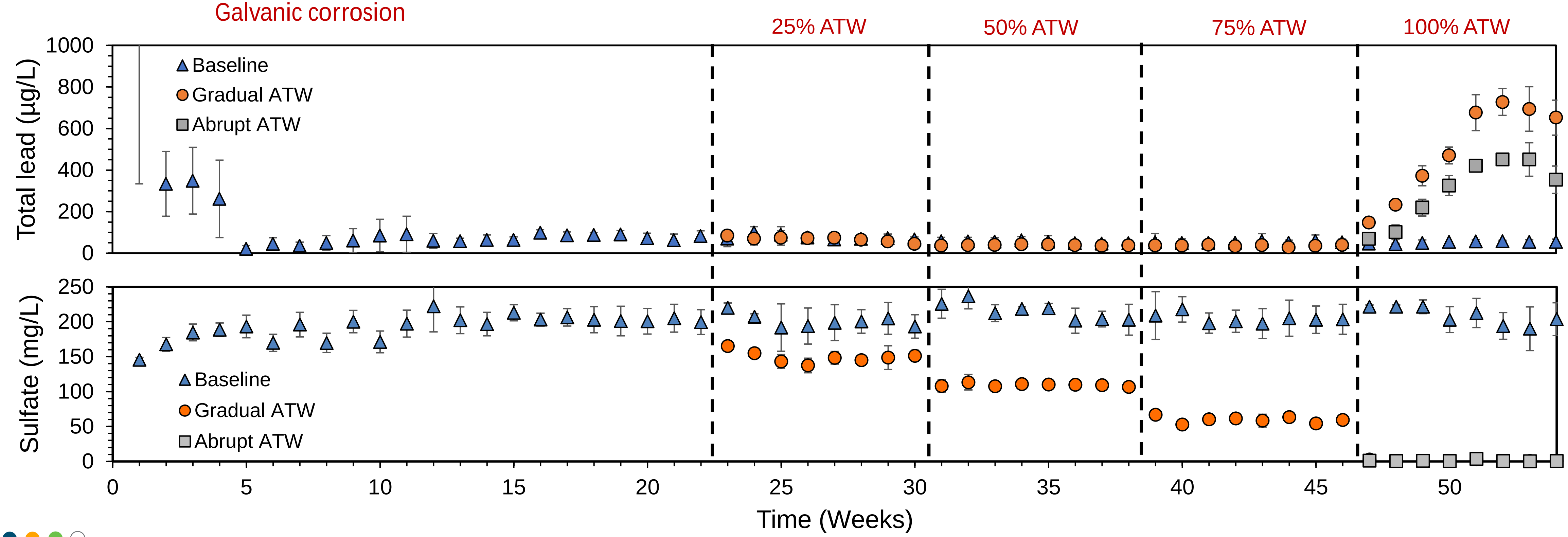
$2Pb^{2+}$

ATW

$4e^-$

$2Pb^0$

Galvanic corrosion induced due to dissolution of sulfate solids in the absence of sulfate



# Key Premise Plumbing Findings

1. Blending of 25 - 75 % ATW with conventional treated water did not affect lead and copper release from lead solder in copper pipes and brass rods.

2. Introducing 100% advanced treated water in the copper pipes with lead solder:
    * Increased lead release significantly.
    * Decreased copper release significantly.

3. These observations can be correlated to the dramatic decrease in sulfate concentration that made the lead more susceptible to galvanic corrosion.

4. Introducing 100% advanced treated water in brass pipes increased lead, copper and zinc release.

# Concluding Remarks

- Stabilization of ATW and blending with relatively well-buffered water resulted in negligible impacts to Fe/Mn tuberculation and water quality
- Changes in anion balance (chloride, sulfate) appear to increase lead release and decrease copper release by galvanic corrosion in copper pipe with lead solder

# Q&A

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# Thank you

Comments or questions, please contact:

Julie Minton: jminton@waterrf.org

For more information, visit www.waterrf.org