Date: Wednesday, January 29, 2025

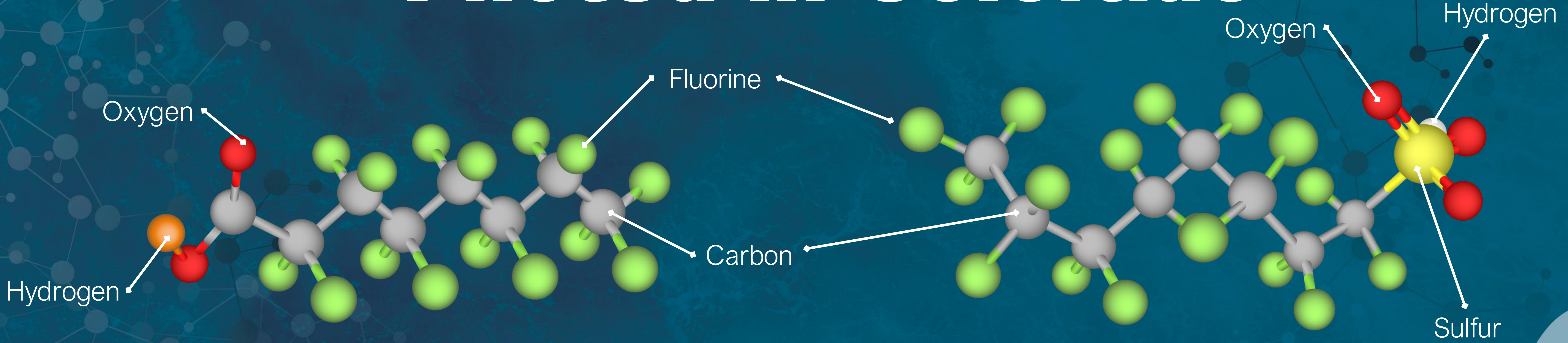
2025 FWEA SOUTH FLORIDA CHAPTER TECHNICAL SEMINAR

**PFAS IN WATER AND WASTEWATER: SOLUTIONS FOR A HEALTHIER TOMORROW**

6 PDHs - PDH Course No. 0002710

Kimley»Horn

# A Mile High Tale of 3 PFAS Treatment Technologies Piloted in Colorado




Perfluorooctanoic Acid (PFOA)

Perfluorooctane sulfonic acid (PFOS)

# AGENDA

- The Problem
- Our Team
- Approach
- A Background of the Technologies Tested
- Deep Dive into EC + CUF
- Pilot Trailer Design

# The Problem

# The Problem

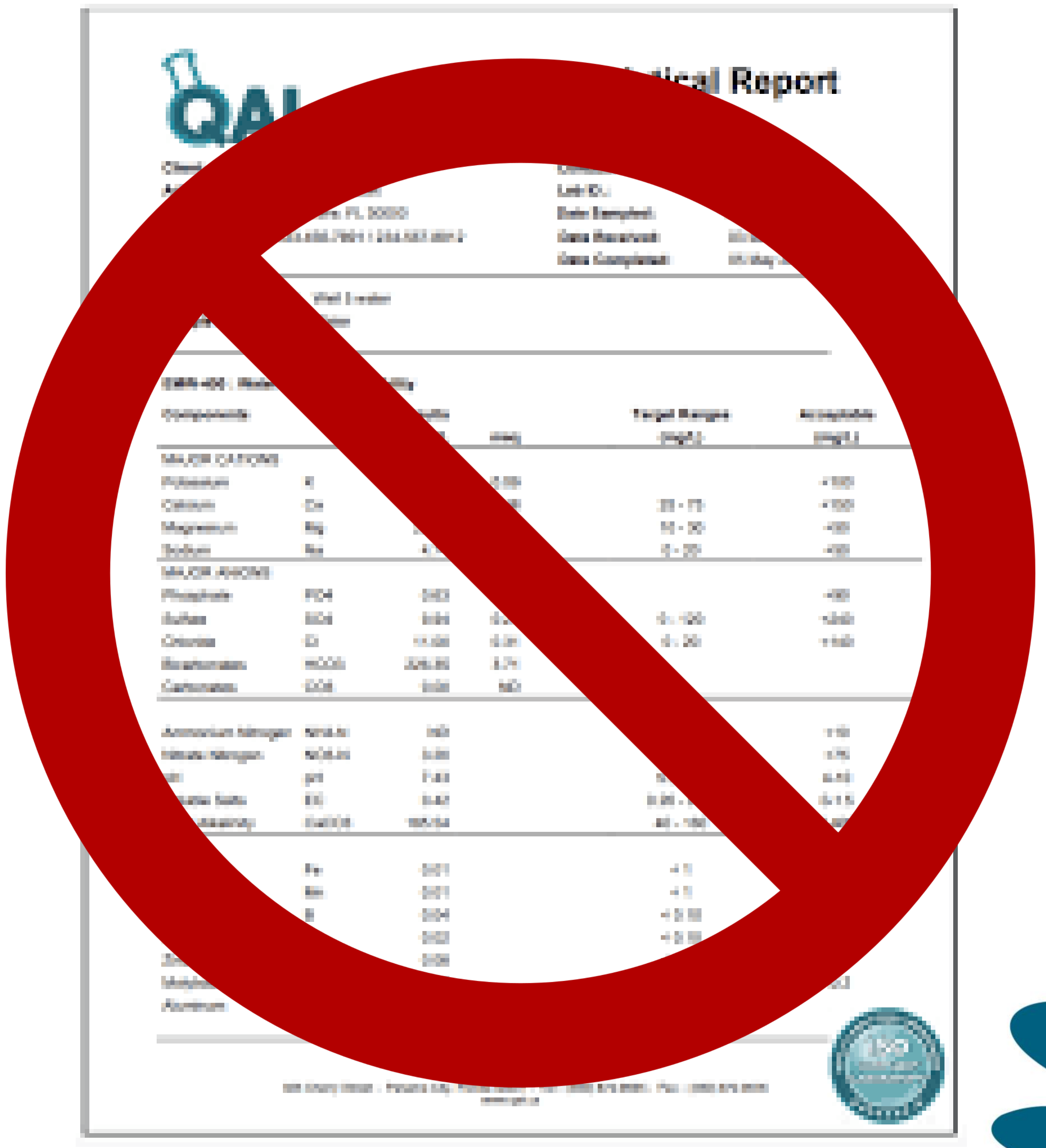
- Nearby Fort Carson Army Base polluted shallow aquifer with AFFF
- WMWC 120 gpm well supplies water to customers from this aquifer
- PFAS concentrations from well for **PFOS, PFOA** and **PFHXs** exceed EPA MCL
- EC was only technology tested to date at site and achieved ND both times
- EC is not permitted by CDPHE as DW BAT and requires piloting

| Analyte | Chemical Formula | Concentration (ppt) | MCL (ppt) |
|---|---|---|---|
| **PFOS** | **C8HF17O3S** | **23** | 4 |
| PFHxA | C6HF11O2 | 20 | -- |
| **PFOA** | **C8HF15O2** | **17** | 4 |
| **PFHxS** | **C6HF13O3S** | **32** | 10 |
| PFBS | C4HF9O3S | 32 | -- |
| PFHpA | C7HF13O2 | 5.6 | -- |

Grab Sample collected in August 2023

# The Problem…But wait, there's more

- Limited water quality data to project SBA or GAC performance
  - Determine if pre-treatment is needed
- EC does not have computer model to project performance and requires bench testing
- What we do know is the water is very hard
  - **513 mg/L TH as CaCO3 + excessive Fe levels**
  - Could pose performance issues
- Current chlorine gas disinfection dosing point is at the well shroud / intake
  - Relocate to alternative location downstream of pilot
  - Use abandoned well ~30-ft away as alternative pilot supply source



# Our Team

# Team

**MOONSHOT MISSIONS / WMWC**

## Co-PI

Andrew Dixon, PE

## Primary Investigator (PI) | EC, IX, GAC Subject Matter Expert

Eric Dole, PE, PSAP

## Principal-in-Charge

Joel Price, PE, LEED AP

## Pilot Design Lead | Process Mechanical Engineer

Jeremy Beard, PE

### Civil Designer

Megan Doty, EIT

### BIM | Drafting

Bob Lupo

### Electrical | I&C

Dustin Colwell, PE

### Operator

Cory Gettinger, EIT

**SUBCONSULTANTS**

1: Mickley & Associates

2: Colorado School of Mines

**KEY**

Key Personnel:

**SUPPORT SPECIALISTS**

### QA/QC Managers

Dr. Mike Mickley [1]
Dr. Chris Bellona [2]

### Funding Specialist

Rachael Kiser, PE

### Groundwater Modeling

Jason Sheasley, PG

# Our Approach

# Our Approach

*Compare existing PFAS BATs (GAC and SBA) to an emerging "electrified" treatment technology called electro-coagulation (EC) to see which performs the best on the well water and….*

***Determine if EC destroys the covalent C-F bond***

# Our Approach

**Phase 1**

Background Data Review

**Phase 2**

Bench Testing

**Phase 3**

Pilot Testing

**Phase 4**

Final Report Writing and Various CDPHE Form Submittals

# Phase 1 - Background Data Review

- Thorough review of water quality analysis (WQA) required
- Identify GAP analysis on available WQ parameters
- GAC and IX performance can be modeled with MFR proprietary software to determine pilot performance and optimal configuration
- Immediately develop sampling plan to acquire at least 8 data sets for
  - all PFAS compounds
  - Competing ions per IX and GAC MFR

Sample Identification: ........................

Feed Source: ........................

Conductivity: ........................ pH: ........................ Temperature (°C): ........................

Feedwater Analysis:

Please give units (mg/L as ion or ppm as $CaCO_3$ or meq/L)

| | | | | |
|---|---|---|---|---|
| | $NH_4^+$ | ........................ | $CO_2$ | ........................ |
| | $K^+$ | ........................ | $CO_3^{2-}$ | ........................ |
| | $Na^+$ | ........................ | $HCO_3^-$ | ........................ |
| | $Mg^{2+}$ | ........................ | $NO_3^-$ | ........................ |
| | $Ca^{2+}$ | ........................ | $Cl^-$ | ........................ |
| PFOA | $Ba^{2+}$ | ........................ | $F^-$ | ........................ |
| PFOS | $Sr^{2+}$ | ........................ | $SO_4^{2-}$ | ........................ |
| PFBS | $Fe^{2+}$ | ........................ | $PO_4^{3-}$ | ........................ |
| GneX | Fe (tot) | ........................ | $S^{2-}$ | ........................ |
| PFNA | $Mn^{2+}$ | ........................ | $SiO_2$ (colloidal) | ........................ |
| PFHxS | Boron | ........................ | $SiO_2$ (soluble) | ........................ |
| | $Al^{3+}$ | ........................ | | |

Other Ions: ........................

TDS (by method): ........................

TOC: ........................

BOD: ........................

COD: ........................

AOC: ........................

BDOC: ........................

Total Alkalinity (m-value): ........................

Carbonate Alkalinity (p-value): ........................

Total Hardness: ........................

Turbidity (NTU): ........................

Silt Density Index (SDI): ........................

Bacteria (count/ml): ........................

Free Chlorine: ........................

Remarks: ........................

(odor, smell, color, biological activity, etc.) ........................

........................

........................

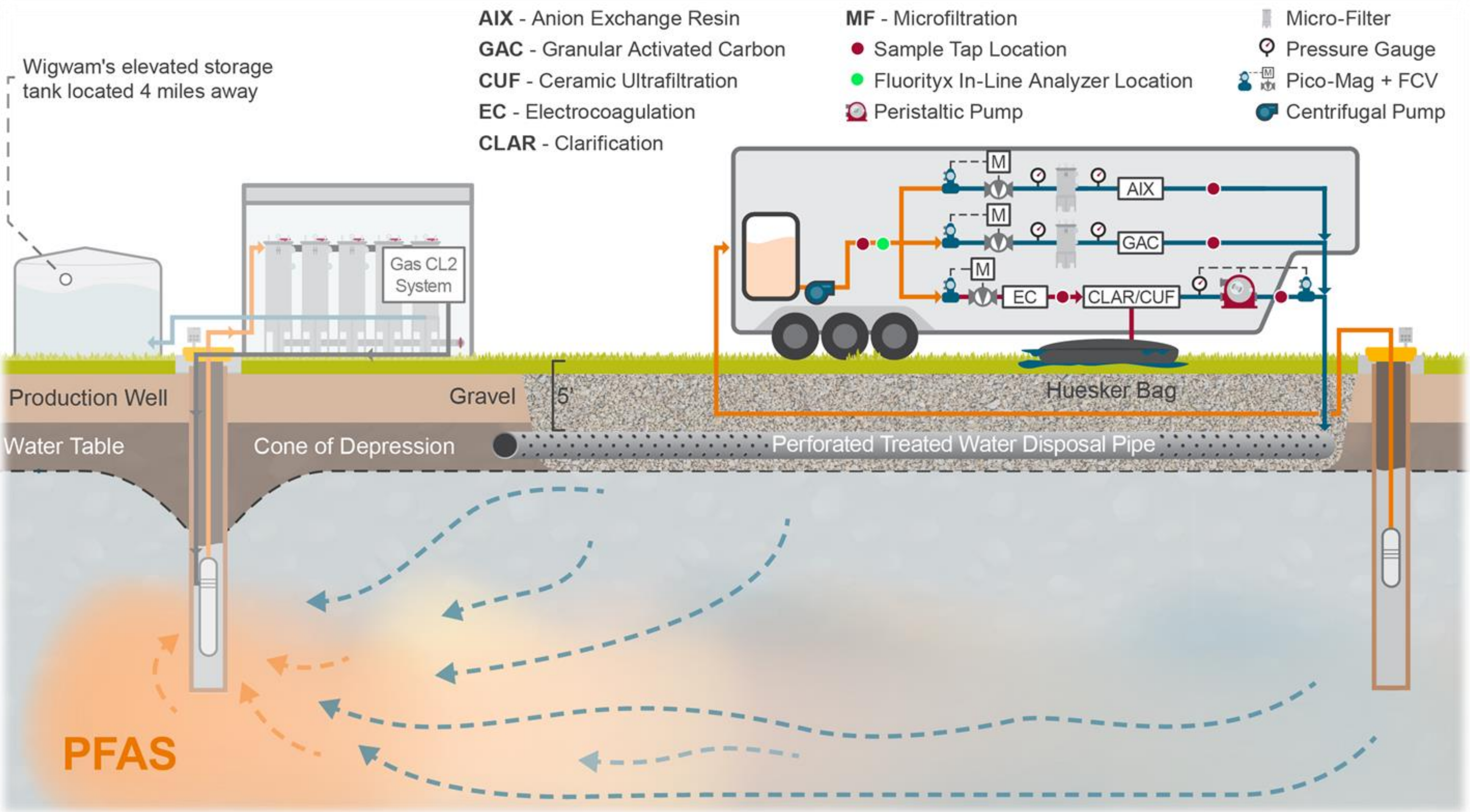
Analysis By: ........................

Date: ........................

# Phase 2 – Bench Testing


- EC does not have a modeling software and requires field testing
- Develop a bench testing protocol that will
  - outline how EC will be evaluated
  - Identify field parameters to be collected, configurations, and water quality analyses
- Development of a bench testing technical memorandum so pilot testing can be configured per optimal bench config
- **Use EPA 1633 and 1621 to prove / disprove EC defluorination capability**
- Include Primary and Secondary MCL's

# Phase 3 – Pilot Testing



# **Phase 3 –** Pilot Testing

## Goals

- Affirm the removal efficiency achieved from bench tests (EC only) and model projections (SBA and GAC)
- Fine-tune design constraints and testing configuration
- Give staff opportunity to become familiar with the technology
- Determine best performing technology and associated budgetary capital and O&M costs
- **Determine if EC destroys PFAS?**

# Phase 3 – Pilot Testing


Deliverables

- Update and automate trailer to include SBA, GAC and CUF
- Civil, mechanical, EI&C, and process drawings with specifications on drawings
- Pilot test protocol development
- PFAS technology comparison matrix to qualitatively compare each technology
- Seri

# **Phase 5 –** Final Report Writing and Various CDPHE Form Submittals

- TM's at each milestone that summarize the "what, why, and how" as well as lessons learned will be compiled into the Final Report
- Preparation of necessary CDPHE forms

CDPHE CO COLORADO Department of Public Health & Environment

**APPENDIX D: Alternative Technology Acceptance Application**
**Safe Drinking Water Program**
**Implementation Policy #5**

4300 Cherry Creek Drive South, B2
Denver, Colorado 80246-1530
CDPHE.WQEngReview@state.co.us, 303-692-6298

### Alternative Technology Acceptance Application

In accordance with the *Colorado Primary Drinking Water Regulations (Regulation 11)*, the Water Quality Control Division (Division) may accept alternative filtration technologies to meet the requirements of Regulation 11. The Division also elects to review technologies that do not meet or are not addressed by the *State of Colorado Design Criteria for Potable Water Systems*. The alternative technology review process does not need to have an associated project to apply however the applicant must have information to support the application (e.g., third party testing reports)

Please note that review and approval for the design of any Public Water System proposing to use an accepted alternative technology will be handled on a case-by-case basis by the Division as required by Section 11.4(1) of Regulation 11.

| A. Applicant Information | | | |
|---|---|---|---|
| Applicant / Entity | | | |
| Representative Name/Title | | | |
| Address (include City, State, Zip Code) | | | |
| Email | | | |
| Phone | | Fax | |
| **B. Alternative Technology Information** | | | |
| Water quality parameter<br><br>Please discuss the targeted water quality parameter and the anticipated treatment level of the proposed technology | | | |
| Alternative technology general description<br><br>Please provide a discussion of proposed alternative technology. | | | |
| Theory and calculations:<br><br>Please provide a discussion of the background theory and backup calculations demonstrating how the proposed technology functions, unless such information is specifically documented as proprietary, e.g. the basis of a patent. | | | |
| Warranty<br><br>Please discuss any applicable manufacturer's warranty and/or performance warranty. | | | |
| Product specifications:<br><br>Please provide model numbers and cut-sheets for all proposed treatment components. Provide specific information for technical components (e.g., flowrates, materials). State any requested treatment removal credits. | | | |



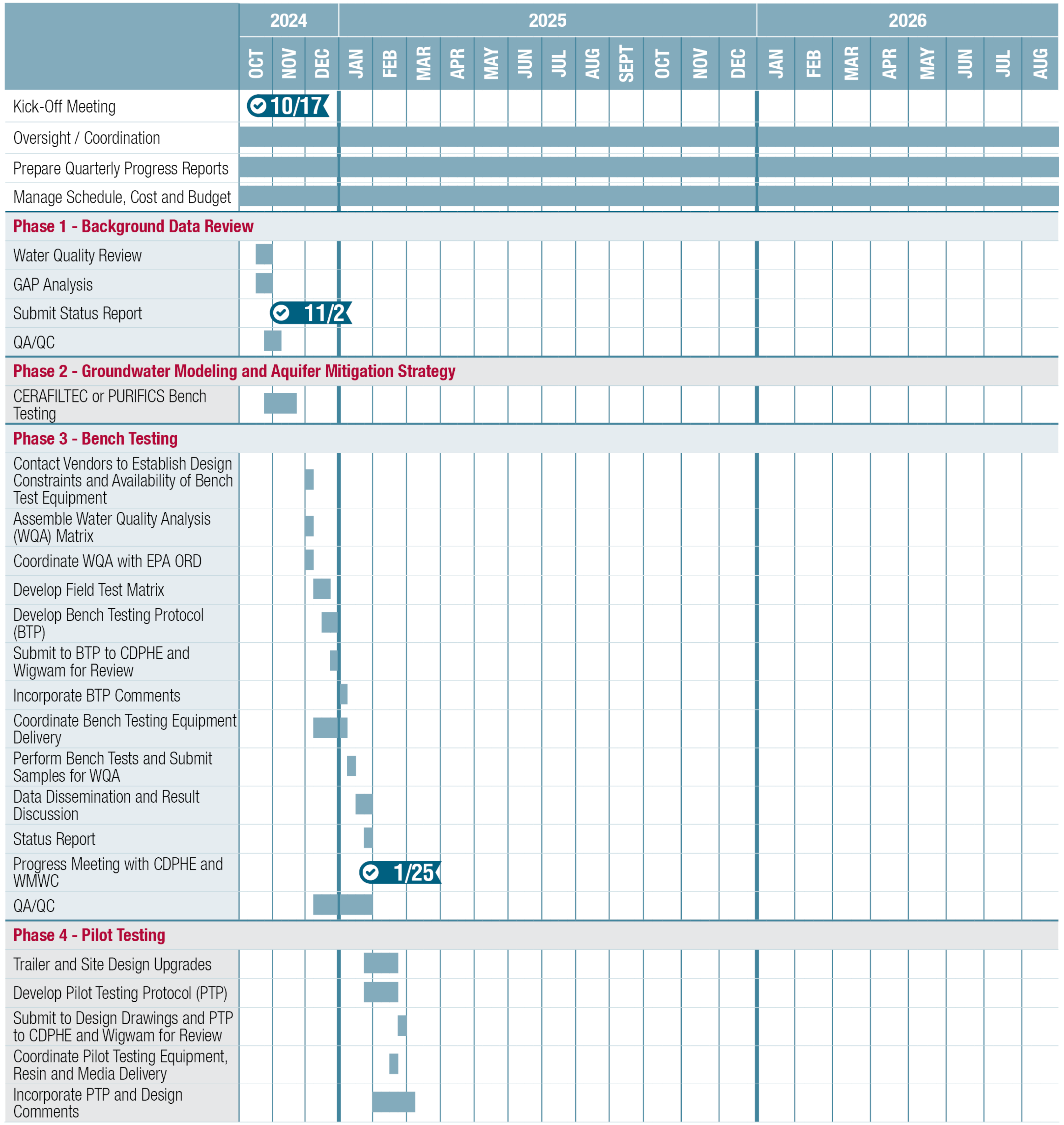
CDPHE COLORADO Department of Public Health & Environment

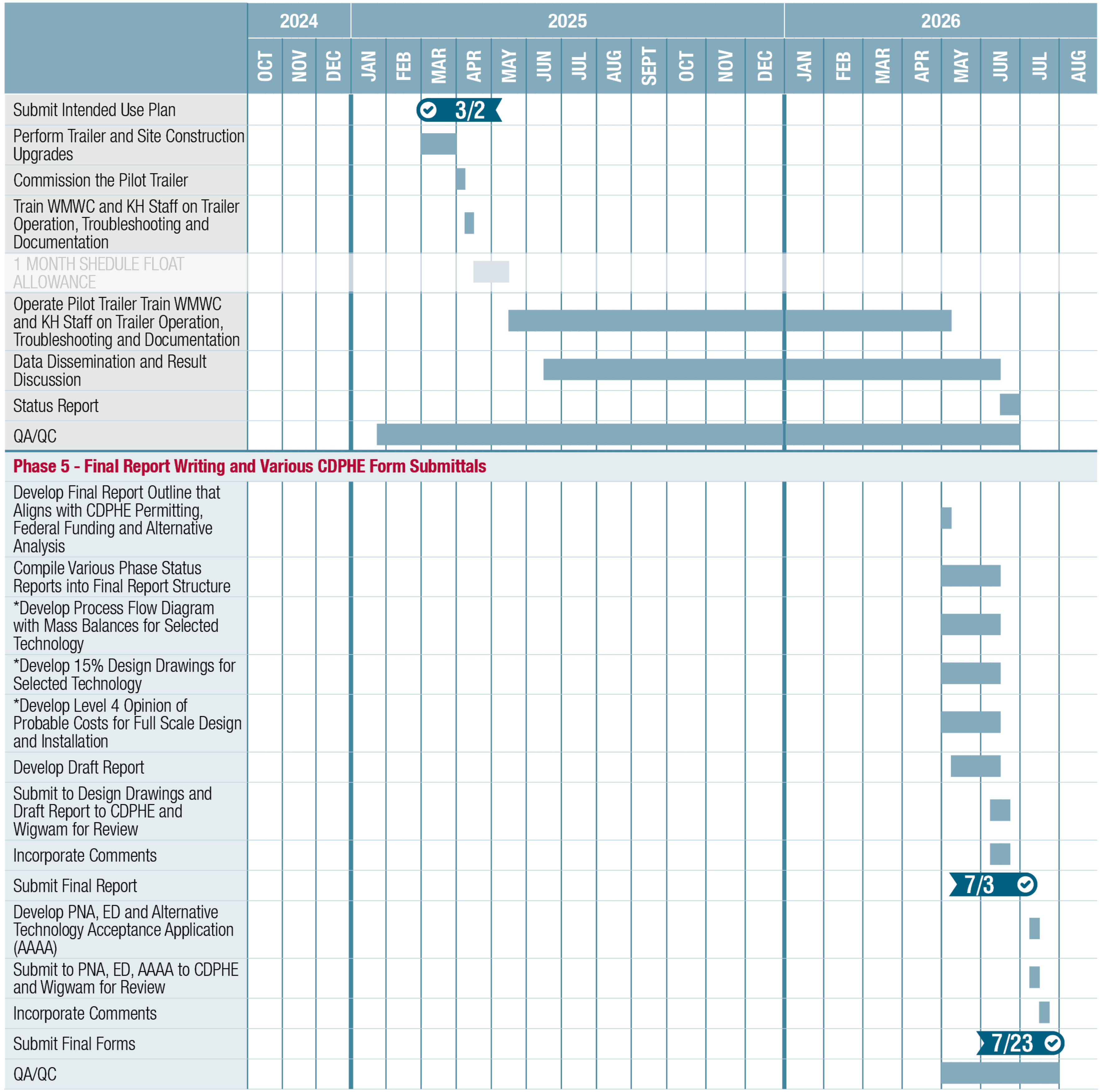
### ENVIRONMENTAL CHECKLIST

Use the Discussion and References space at the end of each section to document your responses. For example, explain how you determined the level of impact and document the reasoning if checking PA (possible adverse) for any resource. Attach additional pages if necessary.

1. Brief project description, including identification of selected alternative:
2. Describe if the project will improve or maintain water quality, and if the project addresses a TMDL, and/or Watershed Management Plan.
3. Provide latitude and longitude of the proposed project (if a transmission / distribution / collection line identify the center point not the whole line):
4. Provide discharge (WW) or source (DW) information: N/A ☐
5. Provide NPDES/PWSID number:
6. Provide primary waterbody name and waterbody ID, secondary name (if available), and State designated surface water use:

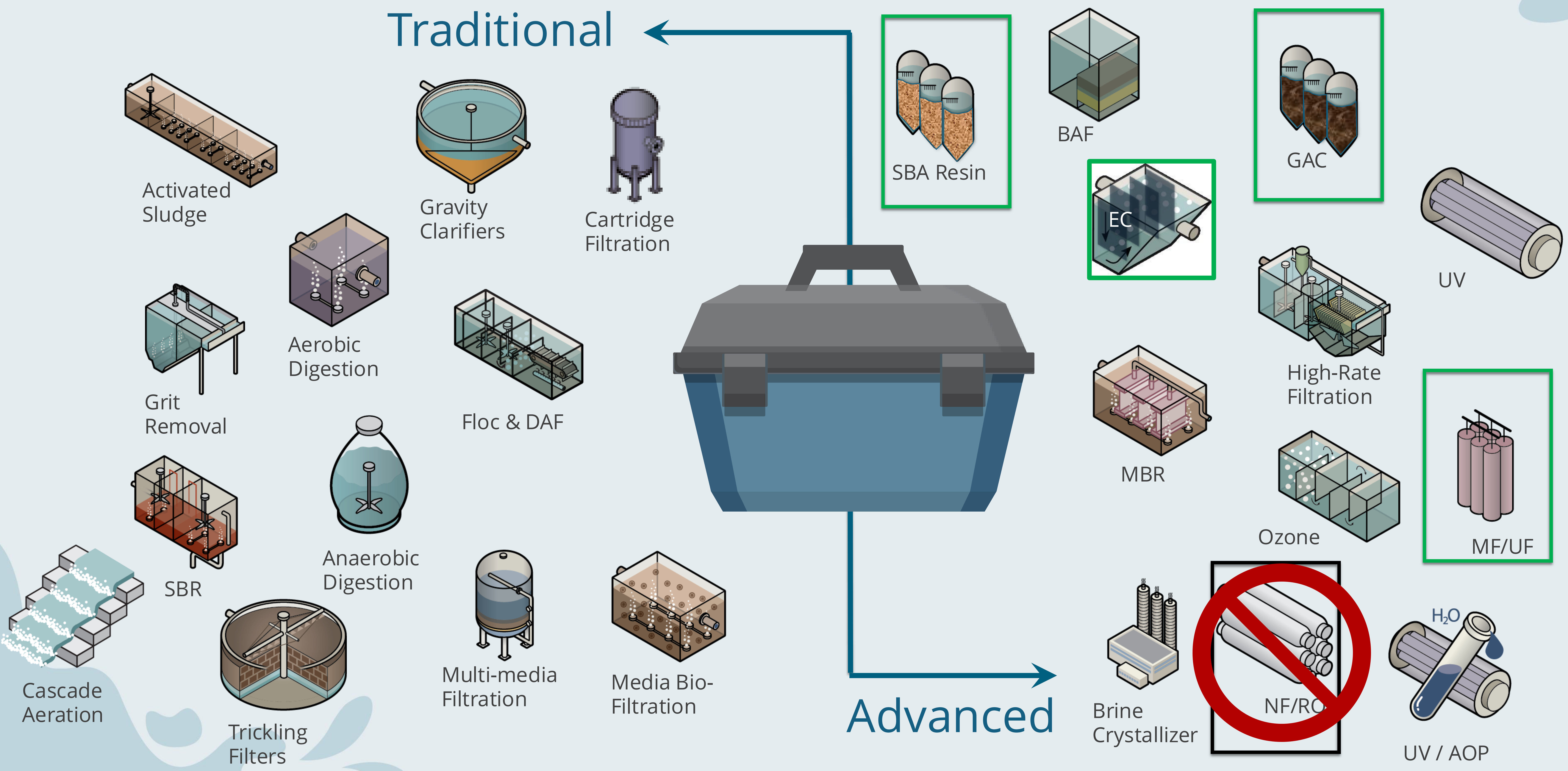
# SCHEDULE


2024
2025
2026
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
Kick-Off Meeting
10/17
Oversight / Coordination
Prepare Quarterly Progress Reports
Manage Schedule, Cost and Budget
Phase 1 - Background Data Review
Water Quality Review
GAP Analysis
Submit Status Report
11/2
QA/QC
Phase 2 - Groundwater Modeling and Aquifer Mitigation Strategy
CERAFILTEC or PURIFICS Bench Testing
Phase 3 - Bench Testing
Contact Vendors to Establish Design Constraints and Availability of Bench Test Equipment
Assemble Water Quality Analysis (WQA) Matrix
Coordinate WQA with EPA ORD
Develop Field Test Matrix
Develop Bench Testing Protocol (BTP)
Submit to BTP to CDPHE and Wigwam for Review
Incorporate BTP Comments
Coordinate Bench Testing Equipment Delivery
Perform Bench Tests and Submit Samples for WQA
Data Dissemination and Result Discussion
Status Report
Progress Meeting with CDPHE and WMWC
1/25
QA/QC
Phase 4 - Pilot Testing
Trailer and Site Design Upgrades
Develop Pilot Testing Protocol (PTP)
Submit to Design Drawings and PTP to CDPHE and Wigwam for Review
Coordinate Pilot Testing Equipment, Resin and Media Delivery
Incorporate PTP and Design Comments

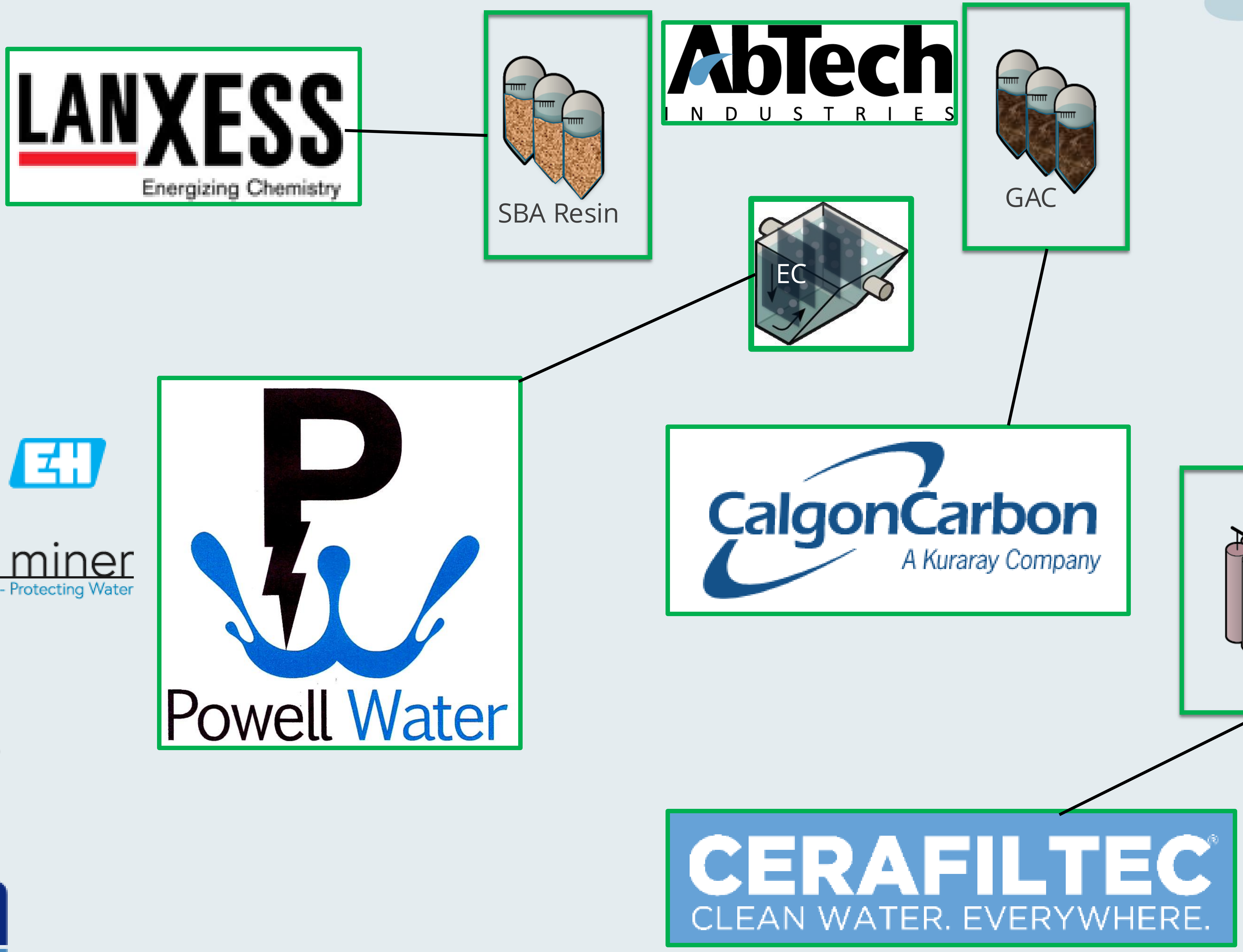

2024
2025
2026
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG
Submit Intended Use Plan
3/2
Perform Trailer and Site Construction Upgrades
Commission the Pilot Trailer
Train WMWC and KH Staff on Trailer Operation, Troubleshooting and Documentation
1 MONTH SHEDULE FLOAT ALLOWANCE
Operate Pilot Trailer Train WMWC and KH Staff on Trailer Operation, Troubleshooting and Documentation
Data Dissemination and Result Discussion
Status Report
QA/QC
Phase 5 - Final Report Writing and Various CDPHE Form Submittals
Develop Final Report Outline that Aligns with CDPHE Permitting, Federal Funding and Alternative Analysis
Compile Various Phase Status Reports into Final Report Structure
*Develop Process Flow Diagram with Mass Balances for Selected Technology
*Develop 15% Design Drawings for Selected Technology
*Develop Level 4 Opinion of Probable Costs for Full Scale Design and Installation
Develop Draft Report
Submit to Design Drawings and Draft Report to CDPHE and Wigwam for Review
Incorporate Comments
Submit Final Report
7/3
Develop PNA, ED and Alternative Technology Acceptance Application (AAAA)
Submit to PNA, ED, AAAA to CDPHE and Wigwam for Review
Incorporate Comments
Submit Final Forms
7/23
QA/QC

# A Background of the Technologies Tested

# The Treatment Toolbox



# Our partners donated their PFAS technology for testing


Rockwell Automation

Endress+Hauser

the salt miner
Preventing Salt Pollution - Protecting Water

INDUSTRIAL CONTROL

PCL CONSTRUCTION

HARRINGTON
Process Solutions since 1959

Rexel

# Our design constraints for SBA, GAC and Abtech media is listed below.

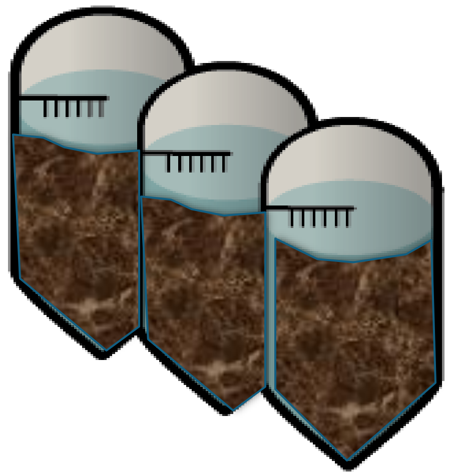
Design Calculations for WMWC PFAS Pilot for One Clear PVC Vessel (Downflow Configuration)

| Parameter | Units | LANXESS | CALRes | GAC | Abtech | Total |
|---|---|---|---|---|---|---|
| Service Flow Rate | gpm | 1.9 | 1.9 | 0.85 | 1.5 | 6.2 gpm |
| EBCT | min | 2.10 | 2.10 | 6.00 | 2.00 | |
| Resin Volume | $ft^3$ | 0.5 | 0.5 | 0.7 | 0.4 | |
| Resin Volume | gal | 4.0 | 4.0 | 5.1 | 3.0 | |
| Vessel Diameter | ft | 0.50 | 0.50 | 0.50 | 0.33 | |
| Vessel Diameter | in | 6 | 6 | 6 | 4 | |
| Surface Area | $ft^2$ | 0.196 | 0.196 | 0.196 | 0.087 | |
| Height of resin in vessel | ft | 2.7 | 2.7 | 3.5 | 4.6 | |
| Height of resin in vessel | in | 32.6 | 32.6 | 41.7 | 55.2 | |
| Hydraulic Loading Rate (4 to 12 gpm/$ft^2$, except Abtech = 40) | gpm/$ft^2$ | 9.7 | 9.7 | 4.3 | 17.2 | |
| Expansion Volume | % | **50%** | **50%** | **30%** | **0%** | |
| Total Height for Initial Conditioning (X) | ft | 4.1 | 4.1 | 4.5 | 4.6 | |
| Total Height for Initial Conditioning | in | 48.9 | 48.9 | 54.2 | 55.2 | |
| Top and bottom headers + media support | % | **20%** | **20%** | **20%** | **20%** | |
| Total Height for Clear PVC Vessel | ft | 4.9 | 4.9 | 5.4 | 5.5 | |
| hL per ft of resin | psi/ft | | | | | |

Note: all **blue** cells are input variables

***…plus an additional 1.5 to 3 gpm to EC + CUF pilot train***

# Granular Activated Carbon



GAC

Destructive Technology

☐ YES

☒ NO

- Granular activated carbon (GAC) is a media-based treatment made from organic materials with high carbon contents such as wood, lignite, and coal
- One of the most studied technologies for PFAS removal and has been widely used for many years to adsorb organic compounds from drinking water treatment
- Effective at removing longer chain PFAS compounds from water
- Slower kinetics result in longer EBCTs (6 to 12 min)

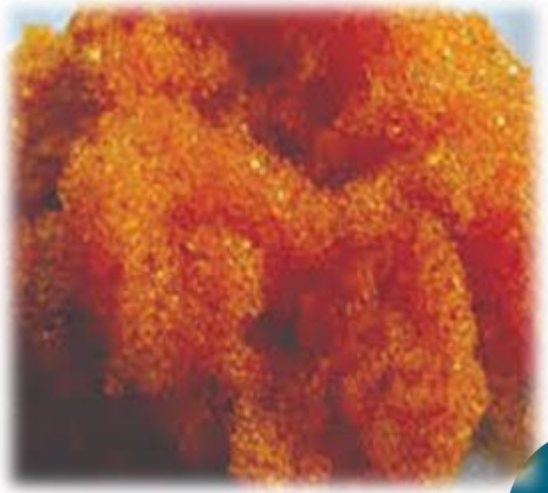
# Strong Base Anion (SBA) Resin


Destructive Technology

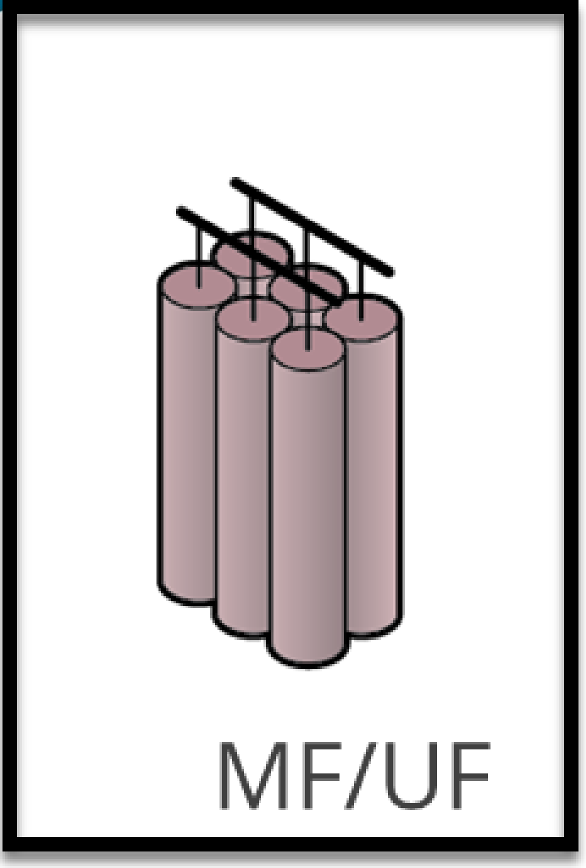
☐ YES

☒ NO

- Strong base anion (SBA) a type of resin that have a positive surface charge that binds negatively charged molecules such as PFAS to the resin surface
- Polystyrene-based polymer beads (0.5–1 mm diameter) that have positive adsorption sites that attract anionic PFAS by a combination of electrostatic and hydrophobic mechanisms.
- Effective at removing longer and shorter chain PFAS compounds from water
- Quicker treatment kinetics result in shorter EBCTs (2 to 4 min)
- Shorter chains require longer EBCT



# Ceramic Ultrafilter (CUF)

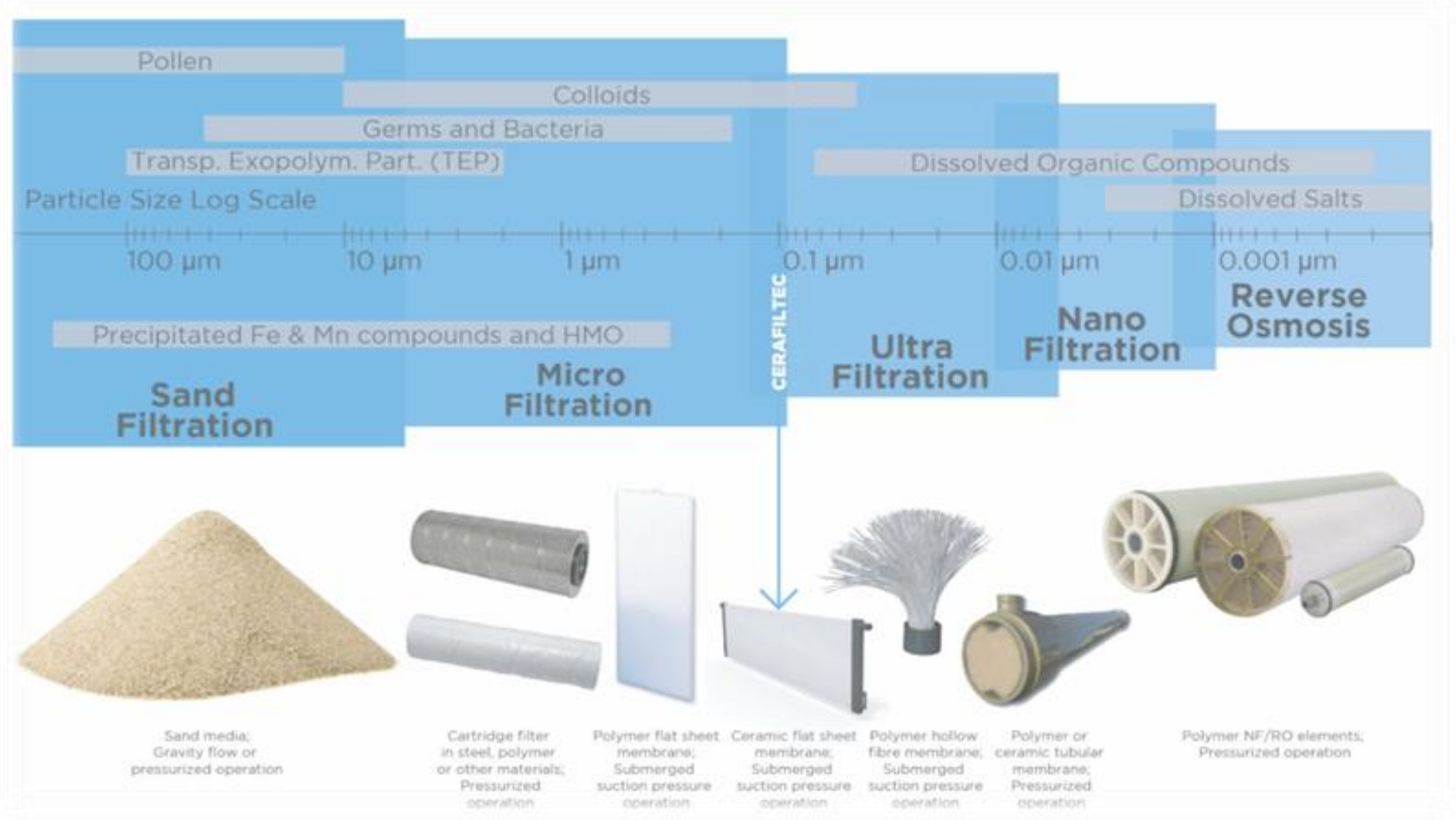



- Particle separation technique with pore size between 5-um and 0.01-um (outside – in)
- Will be tested to remove e-floc from EC unit and potentially in front of AIX and GAC as pre-filter
- Can remove PFAS if coated with PAC

Destructive Technology

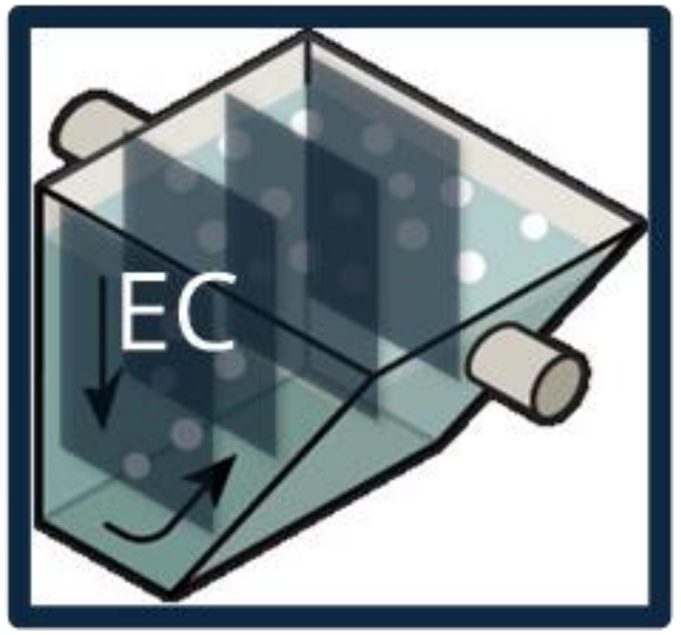
☐ YES

☒ NO




Courtesy: CERAFILTEC

# Electrocoagulation (EC)




- An alternative to traditional chemical coagulation that does not increase TDS
- Uses electricity + sacrificial metal blades to drive efficient chemical coagulation reactions w/out adding metal salts
- Negatively charged contaminants magnetically attracted to anode (+); opposite for cathode (-)
- Polarity reversal every minute prevents passivation
- Requires downstream particle separation

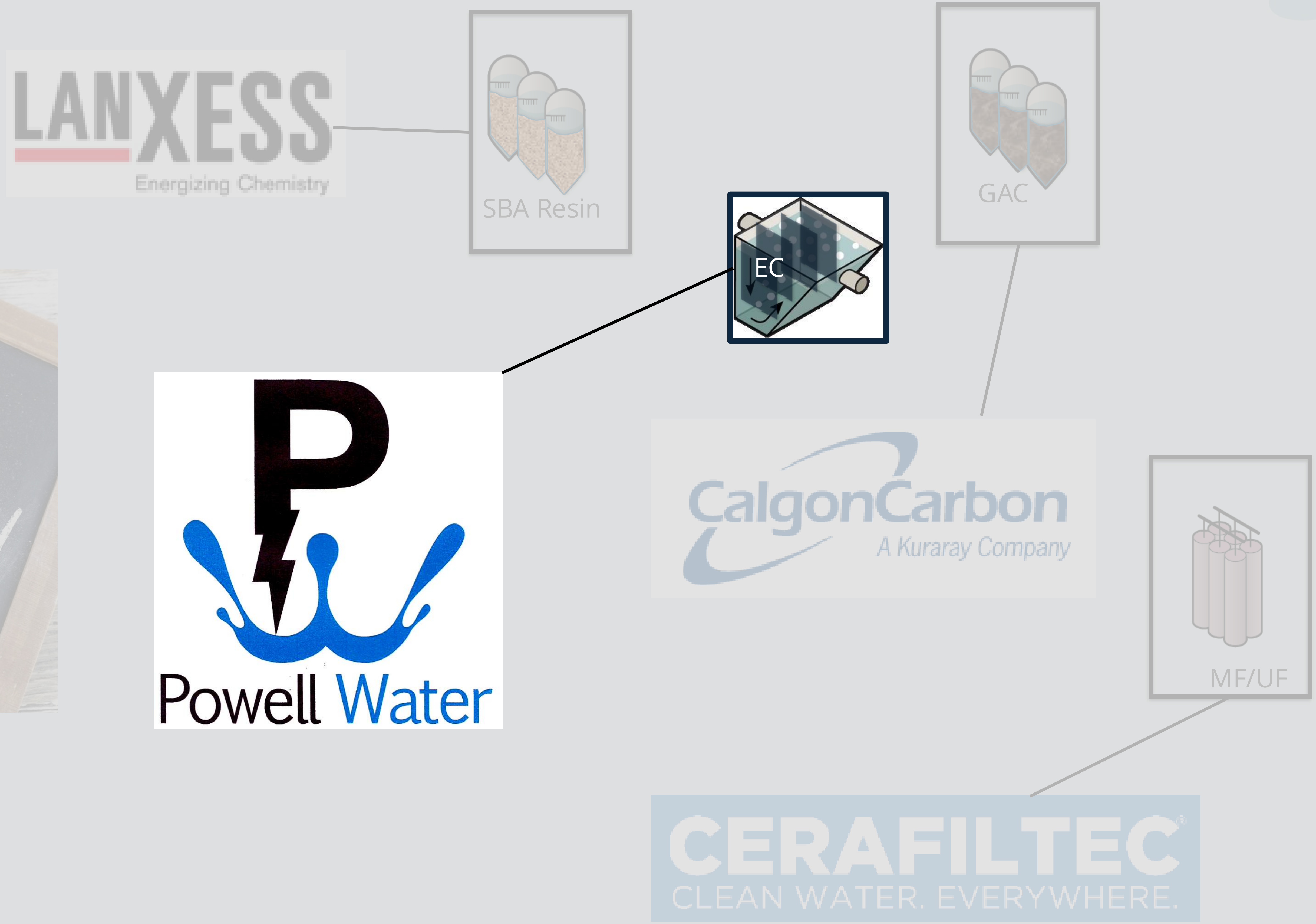
Destructive Technology

☑ YES

☒ NO

# Deep Dive into EC + CUF System

# Our partners donated their PFAS technology for testing

# What is Electro-Coagulation?

- Wide range of contaminants can be removed with EC + filtration

- Challenging contaminants (i.e., Selenium) require
  - Longer process time
  - Higher amps
  - **Tighter filtration**
  - Chemical catalyst

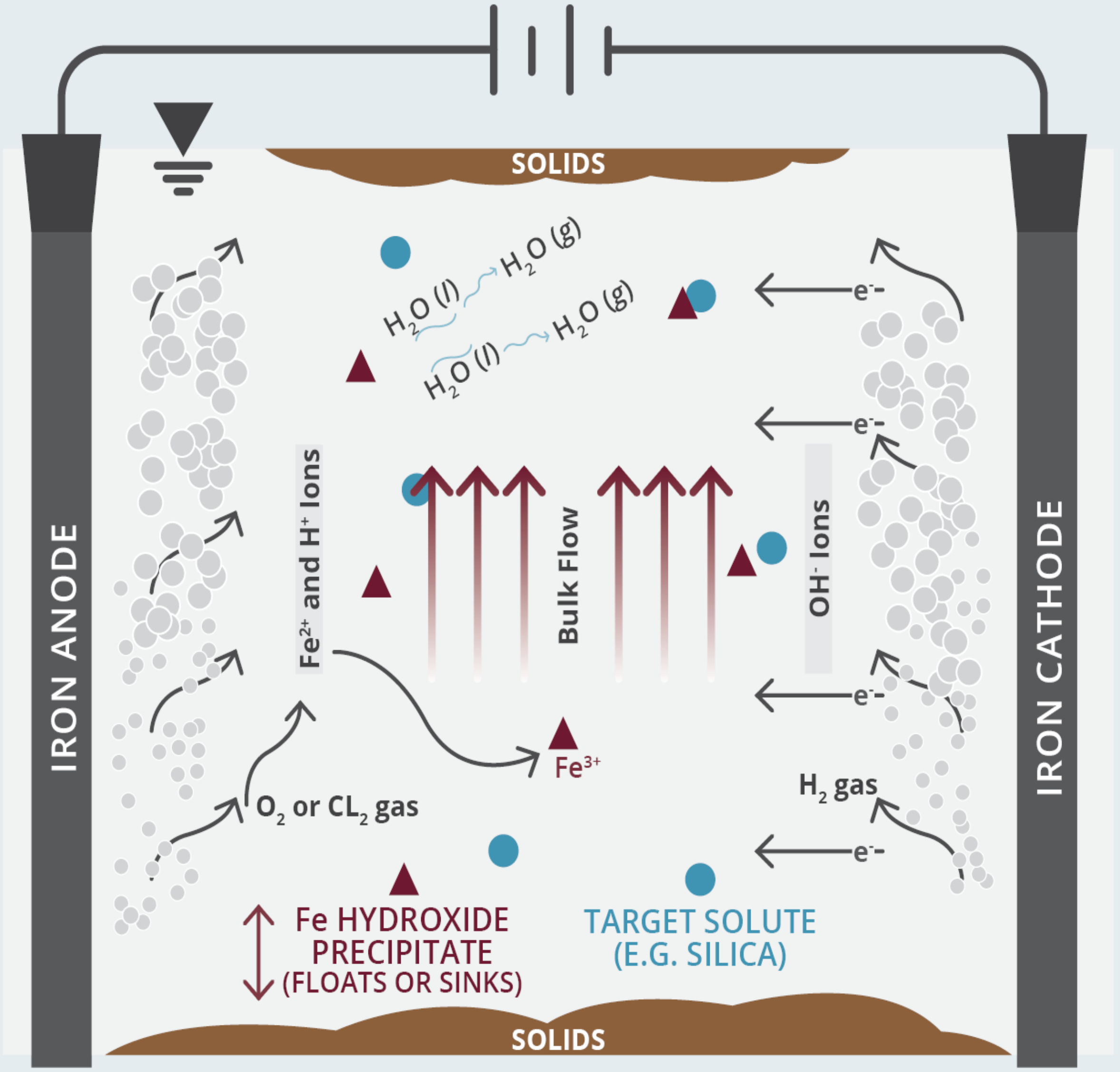
***Energy efficiency is a function of volts per gap, conductivity of water and EC chamber configuration***

# Electro-Coagulation vs. Chemical Coagulation

| | Potassium Alum $KAl(SO_4)_2 \cdot 12(H_2O)$ | Ferric Chloride $FeCl_3 \cdot 6(H_2O)$ | Electro-coagulation $Fe^{2+}$ or $Al^{3+}$ |
|---|---|---|---|
| | | | |
| | | | |

# EC Removal Mechanisms

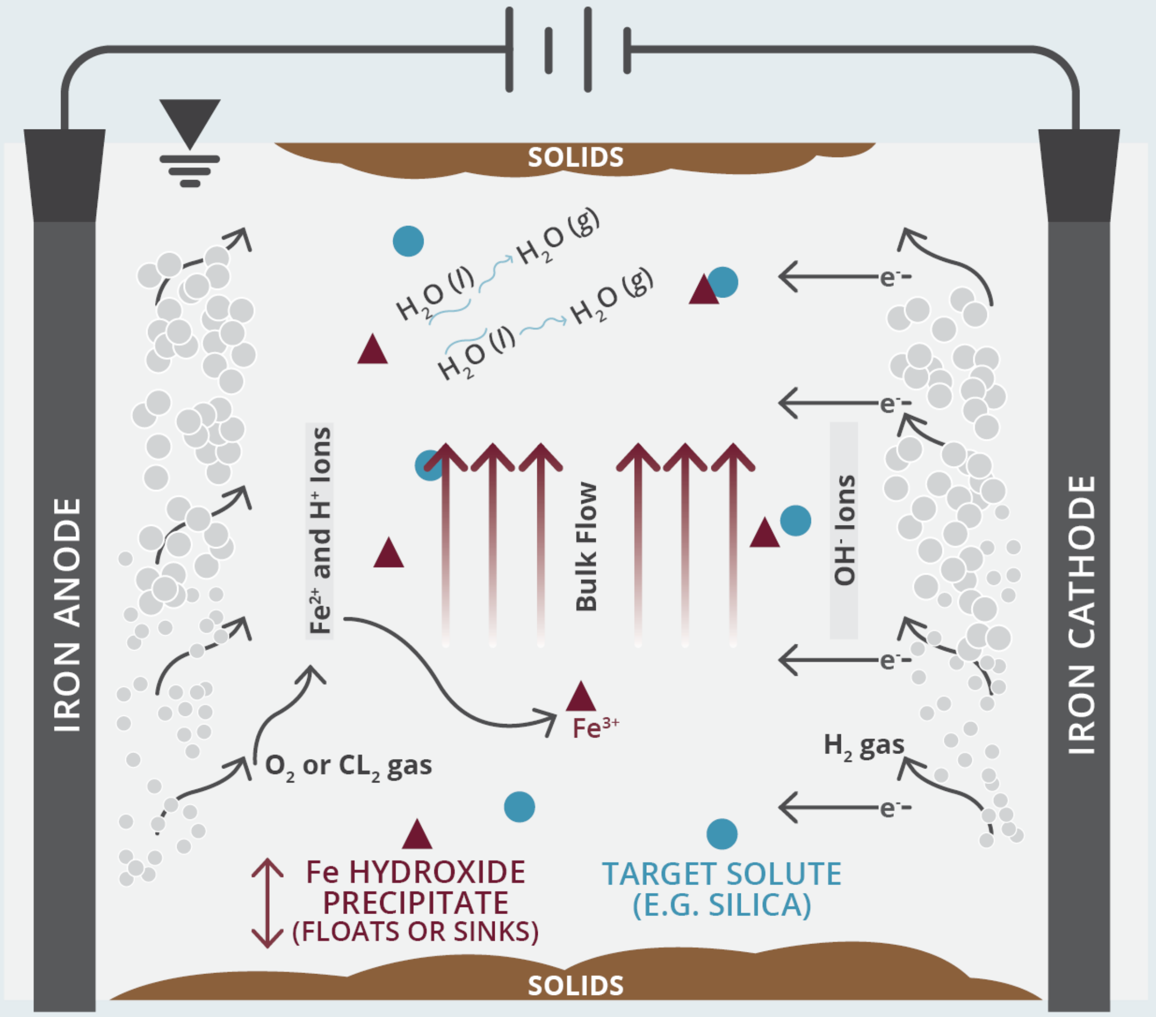
## EC Only (FE Blades)




| | |
|---|---|
| Al ($s$) + 3e- → $Al^{3+}$<br>Fe ($s$) + 2e- → **$Fe^{2+}$**<br>$2H_2O + 4e \rightarrow O_2(g) + 4H^+$ | Anodic reactions (Oxidation) |
| $2H_2O + 2e^- \rightarrow H_2(g)^* + 2OH^-$ | Cathodic reactions (Reduction) |

## EC Only (FE Blades) + Fenton ($H_2O_2$)

AOP




| | |
|---|---|
| Al ($s$) + 3e- → $Al^{3+}$<br>Fe ($s$) + 2e- → **$Fe^{2+}$**<br>$2H_2O + 4e \rightarrow O_2(g) + 4H^+$ | Anodic reactions (Oxidation) |
| $2H_2O + 2e^- \rightarrow H_2(g)^* + 2OH^-$ | Cathodic reactions (Reduction) |

*$H_2(g)$ only generated if:
1.) Salt bridge > 8%; 2.) Polarity duration > 1.5 minute;
3.) Platinum or titanium electrode used

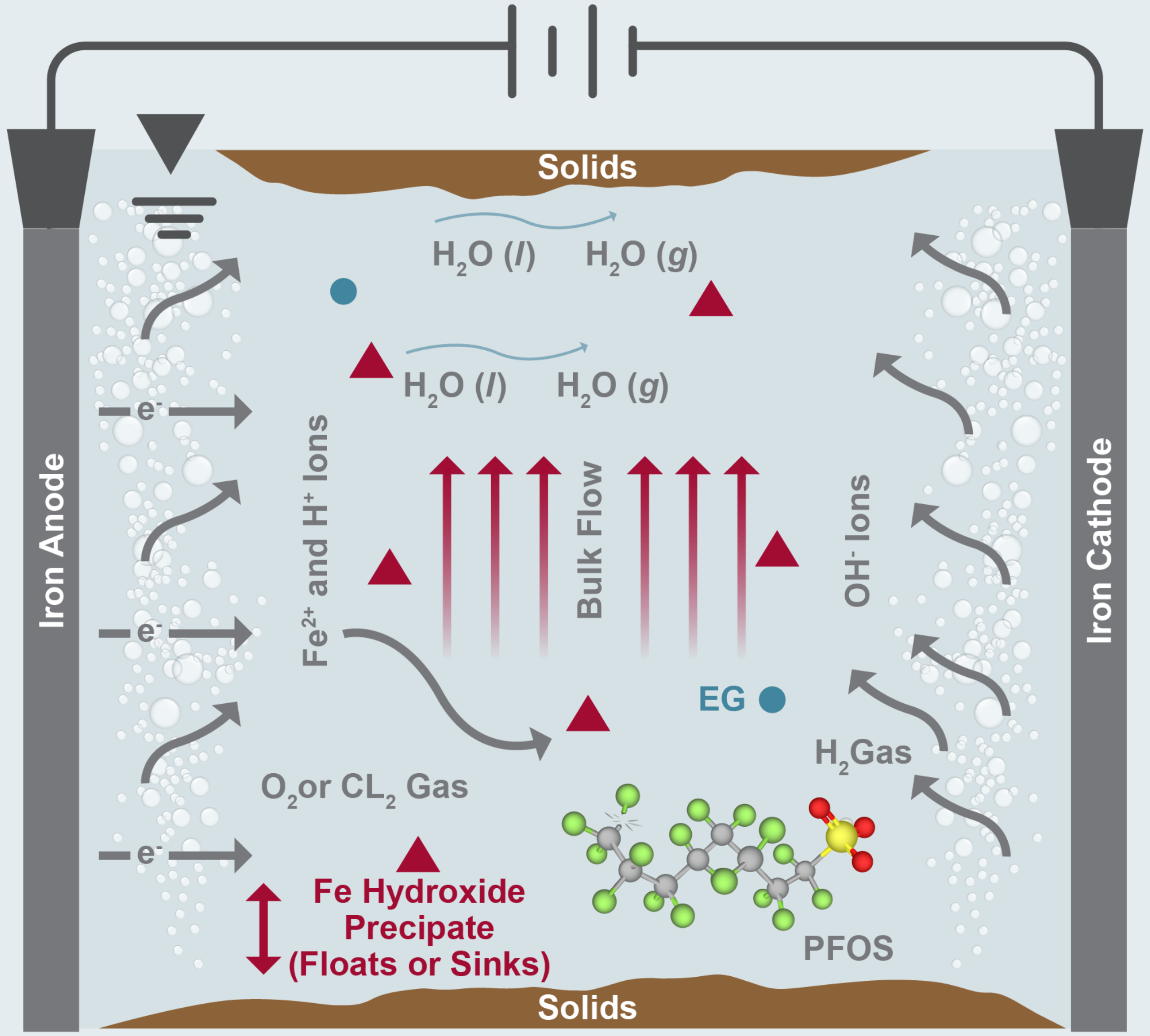
+

$$Fe^{2+} + H_2O_2 \longrightarrow Fe^{3+} + HO^{\bullet} + OH^-$$

$$Fe^{3+} + H_2O_2 \longrightarrow Fe^{2+} + HO^{\bullet}_2 + H^+$$

# PFAS Destruction Hypothesis

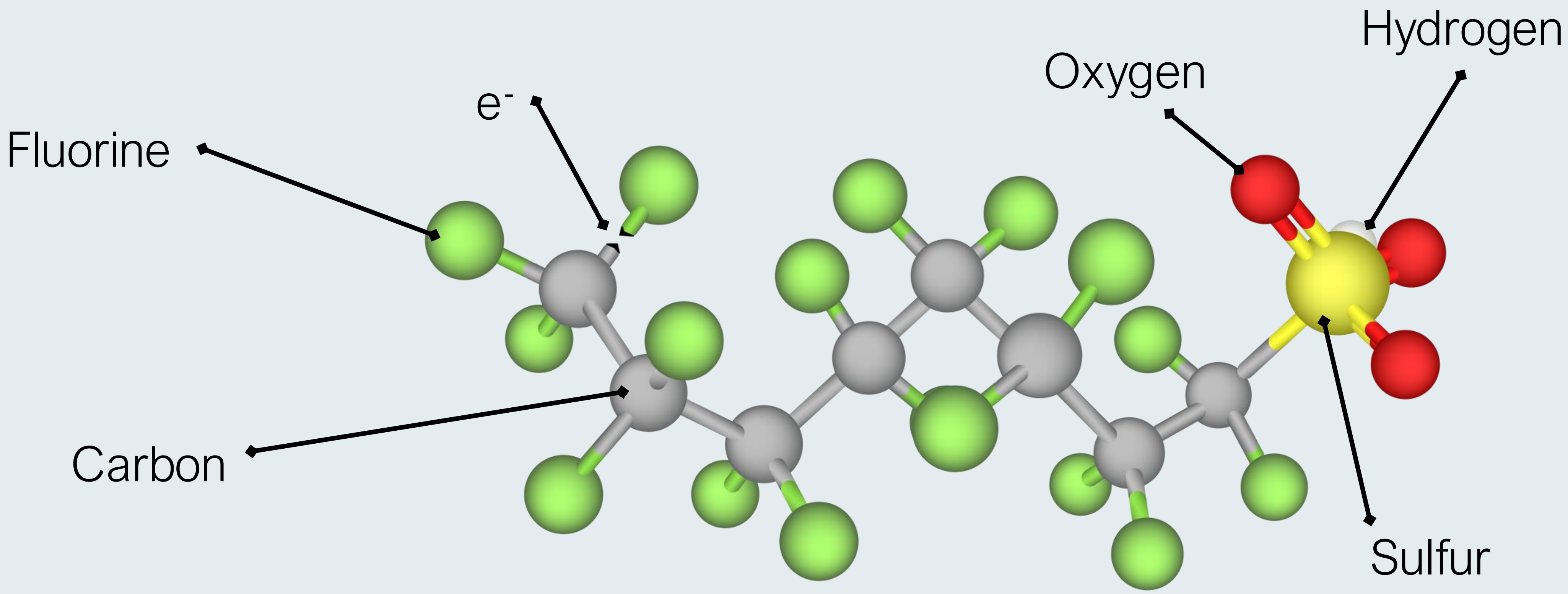
## EC Only (FE Blades)




| | |
|---|---|
| Al (*s*) + 3e- → $Al^{3+}$<br>Fe (*s*) + 2e- → **$Fe^{2+}$**<br>$2H_2O$ + 4e → $O_2$(*g*) + $4H^+$ | Anodic reactions (Oxidation) |
| $2H_2O + 2e^- \rightarrow H_2(g)^* + 2OH^-$ | Cathodic reactions (Reduction) |

| | |
|---|---|
| PFOS (g/mol) | 500.13 |
| PFOS (ng/L) | 23 |
| PFOS (g/L) | 0.000000023 |
| PFOS BDE (kJ/mol) | 485 |
| PFOS BDE (kWh/mol) | 0.13472233 |
| Sample Volume (L) | 2 |
| Total Energy (kWh) | 1.23912E-11 |

***Q…***
*How much energy does it take to break C-F covalent bond in PFOS?*
***A…***
*485 kJ/ mol or 0.135 kWh/mol*



# EC Removal Mechanisms

## Oxidation/Reduction Reactions

- Reduction @ cathode = OH generated; oxidation @ anode = H + metal dissolves
- Fe dose rate, bubble rate and mixing is function of amps

## Halogen Complexing

- Metal ions bind to chlorines in a chlorinated hydrocarbon molecule
- Results in a large insoluble complex

## Electron Flooding

- Drives zeta potential to zero promoting a sweep floc and efficient agglomeration
- The increase of electrons creates an osmotic pressure that ruptures algae, bacteria, cysts, and viruses

## Emulsion Breaking

- Oxygen and hydrogen ions bond into the water receptor sites of oil molecules
- Creates a water insoluble complex that separates water from oil

## Bleaching by Oxygen Ions

- Oxidizes dyes, cyanides, bacteria, viruses, endocrine disruptors, biohazards at anode

## Seeding

- Seeding results from the anode oxidation of metal ions and cathode reduction forming OH ions
- Forms insoluble sweep floc that precipitate as complex metal oxides

# What about the solids from EC?

- Solids generated
  - Often pass Toxicity Characteristic Leaching Procedure b/c contaminants are bound as metal oxides - do not leach at ambient landfill pH
    - Depends on concentration in solids (Uranium example)
    - Dissolve more Fe if rad mass %age causes LLRW issues
  - Hydrophobic solids – easy to dewater
  - "83% less solids generated than chemical coagulation" per *EPA/540/S-93/504 September 1993 Emerging Technology Summary, Superfund Innovative Technology Evaluation*

# University of South Florida ran tests with the Powell EC bench-top unit on raw domestic wastewater in 2010 and had this to say…

USF
UNIVERSITY OF SOUTH FLORIDA

College of Marine Science
140 Seventh Avenue South
St. Petersburg, Florida 33701
(727) 553-3520
mya@marine.usf.edu

August 7, 2010

Dear Mr. Hamilton,

The purpose of this letter is to inform you of the results we have recently obtained from our tests of the Powell Water Systems Electrocoagulation unit for removal of biological pathogens and indicators from sewage.

We performed a trial using a single sample of raw sewage obtained from a municipal wastewater treatment facility in southwest Florida. Samples were tested to determine the abundance of two types of bacteria and four types of viruses before and after treatment with the electrocoagulation unit. The electrocoagulation process resulted in significant decreases in the concentration of all microorganisms tested, and in several cases reduced the concentration of the pathogens to below the detection limits of our assays. Electrocoagulation led to an approximately 4 log reduction in the concentrations of both fecal coliforms and Enterococci (approximately 99.999% decrease). Concentrations of phages (viruses that infect bacteria) infectious for *Eschericia coli* and *Bacillus subtilis* decreased from several thousand plaque forming units (pfu) per milliliter to less than one pful per milliliter. In addition, concentrations of human polyomaviruses were reduced from approximately 10,000 copies per milliliter to below assay detection limits, demonstrating that electrocoagulation removed human pathogenic viruses.

In addition, we determined the efficiency of electrocoagulation for removing *Pepper mild mottle virus* (PMMoV), which is a plant pathogen that has recently been found at extremely high concentrations in human sewage. PMMoV was found in the raw sewage at approximately 60,000 copies per milliliter and electrocoagulation reduced the PMMoV concentrations to below detection limits. This is extremely encouraging since we typically see PMMoV concentrations in excess of 10,000 copies per milliliter in final effluent from most commercial treatment plants.

My laboratory has spent several years studying the types of viruses and bacteria present in raw sewage and treated wastewater, with the goals of identifying pathogens that present a risk to public health as well as effective indicators that can be used for water quality testing. In our preliminary experiment, the Powell Electrocoagulation unit reduced all the tested biological agents (including both bacteria and viruses) with greater efficacy than current wastewater treatment practices.

Thank you for facilitating this trial, and I hope that we can continue to work together in the future to further evaluate this very promising treatment process.

Sincerely,

*Mya Breitbart*

Dr. Mya Breitbart

TAMPA ST. PETERSBURG SARASOTA LAKELAND



pathogens to below the detection limits of our assays. Electrocoagulation led to an approximately 4 log reduction in the concentrations of both fecal coliforms and Enterococci (approximately 99.999% decrease). Concentrations of phages (viruses that infect bacteria) infectious for *Eschericia coli* and *Bacillus subtilis* decreased from several thousand plaque forming units (pfu) per milliliter to less than one pful per milliliter. In addition, concentrations of human polyomaviruses were reduced from approximately 10,000 copies per milliliter to below assay detection limits, demonstrating that electrocoagulation removed human pathogenic viruses.

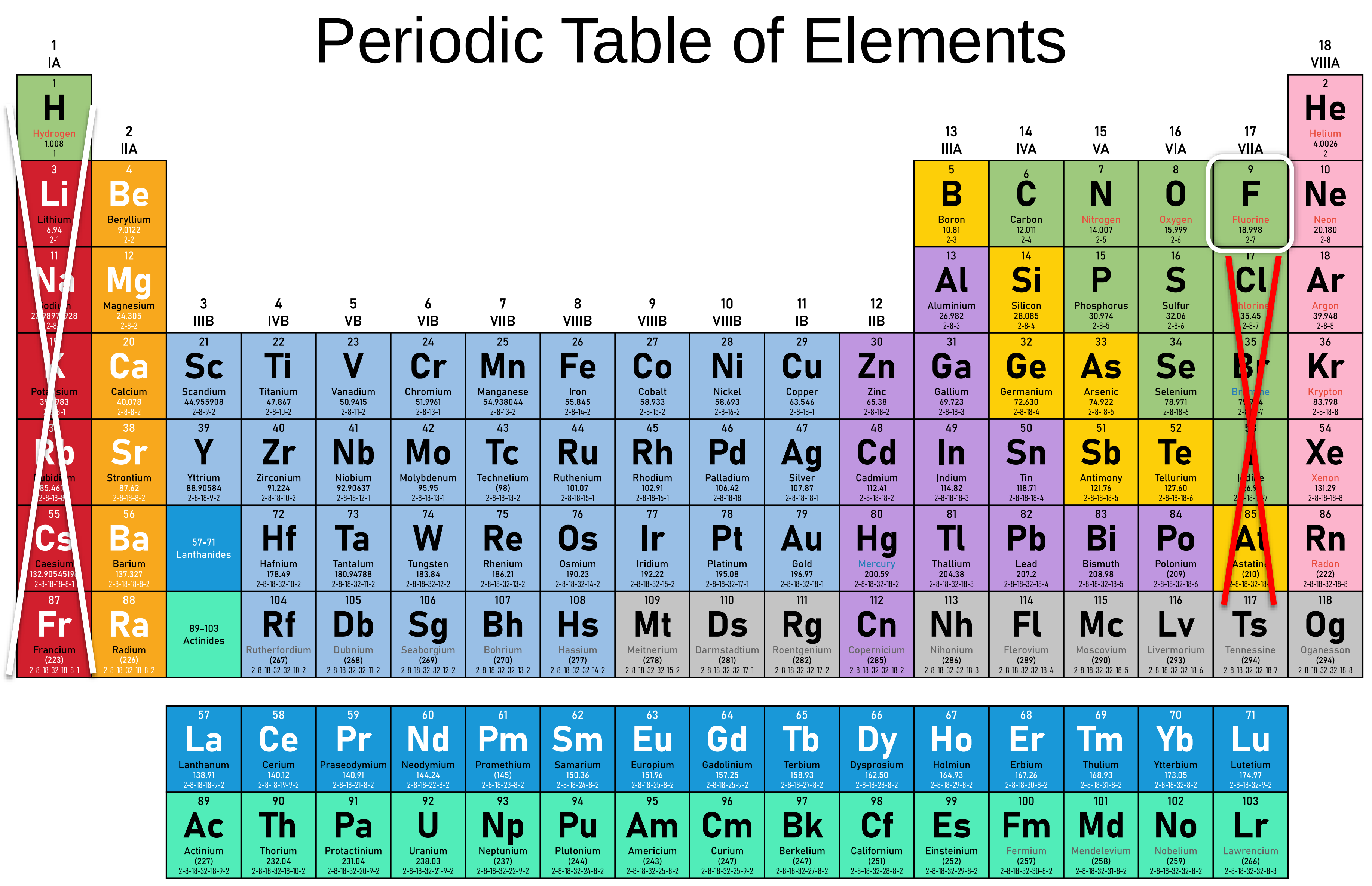
> ***"In our preliminary experiment, the Powell Electrocoagulation unit reduced all the tested biological agents (including both bacteria and viruses) with greater efficacy than current wastewater treatment practices."***
>
> Dr. Mya Breitbart | *University of South Florida*

# EC – A Clean Process

- No added chemicals except for periodic acid clean
  - Reuse acid
  - ~ 0.2#/1,000 gal iron blade consumption
  - Minimal chemicals to buy, store, manage, apply or dispose of in almost all applications
  - Some chemicals are necessary for aggressive WW
    - H2O2 for advanced Fenton reaction
    - Mg, P and NH3 source for struvite precipitation
- Reduced waste stream

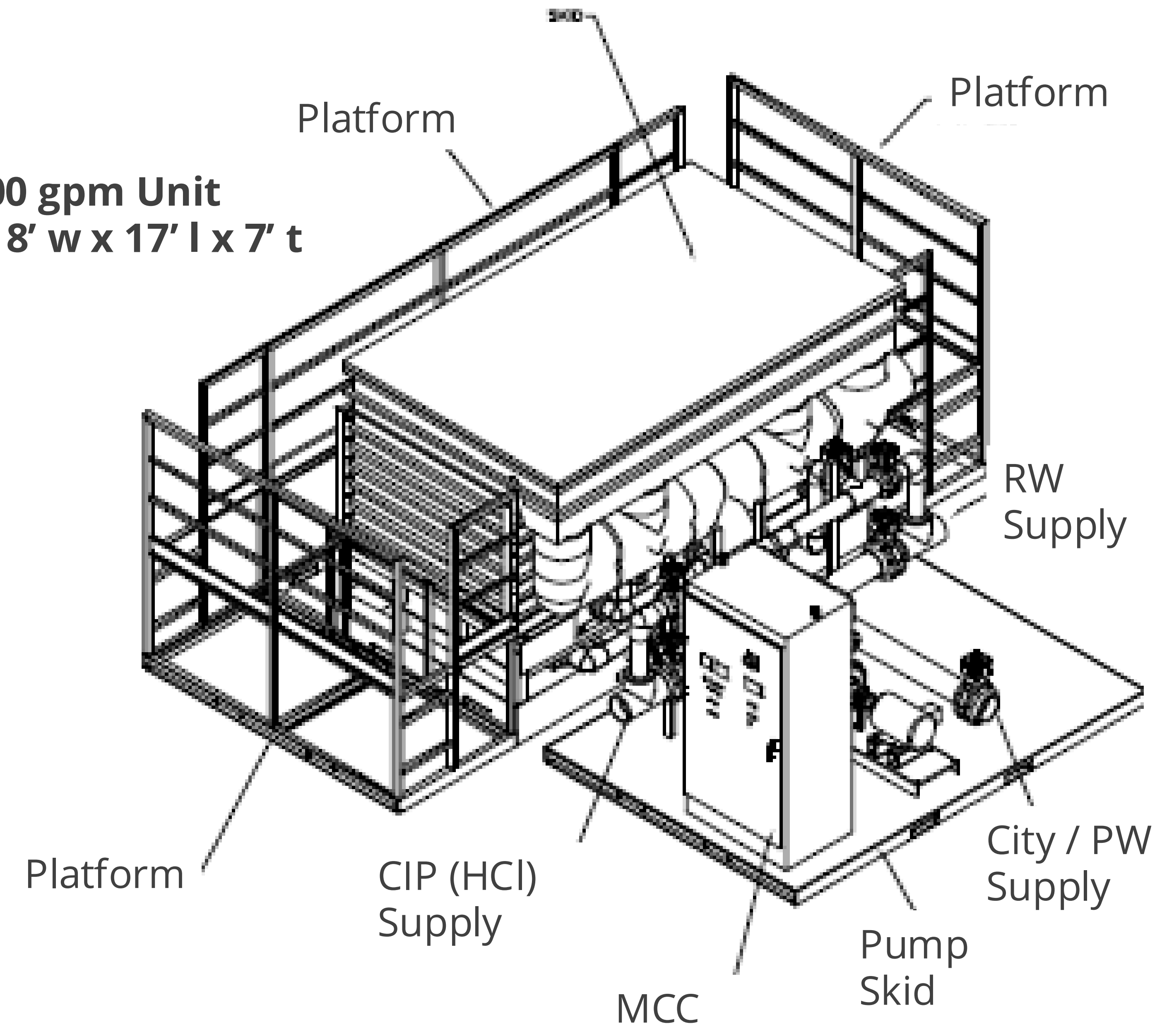
# EC Does not…

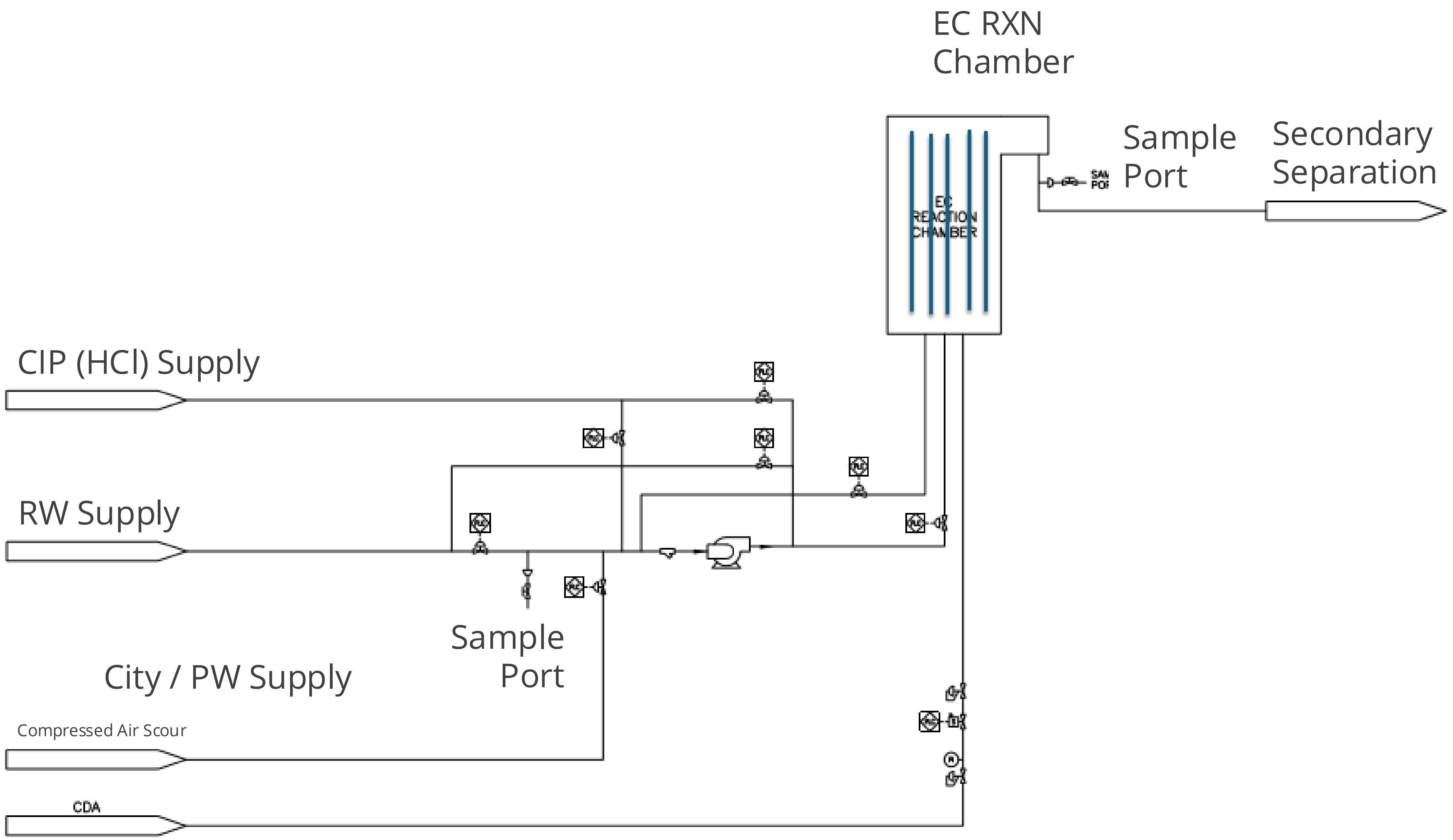
- Efficiently remove carbon chains < 6 OR Selenium w/out long residence times and/or chemical catalyst
- Use a lot of electricity
  - Typically 2-7 kWh/1,000 gal
  - Higher conductivity = lower power costs
- Require clean power
  - Only low voltage PLC and computer requires UPS
  - Easier to operate in countries with poor electric grid



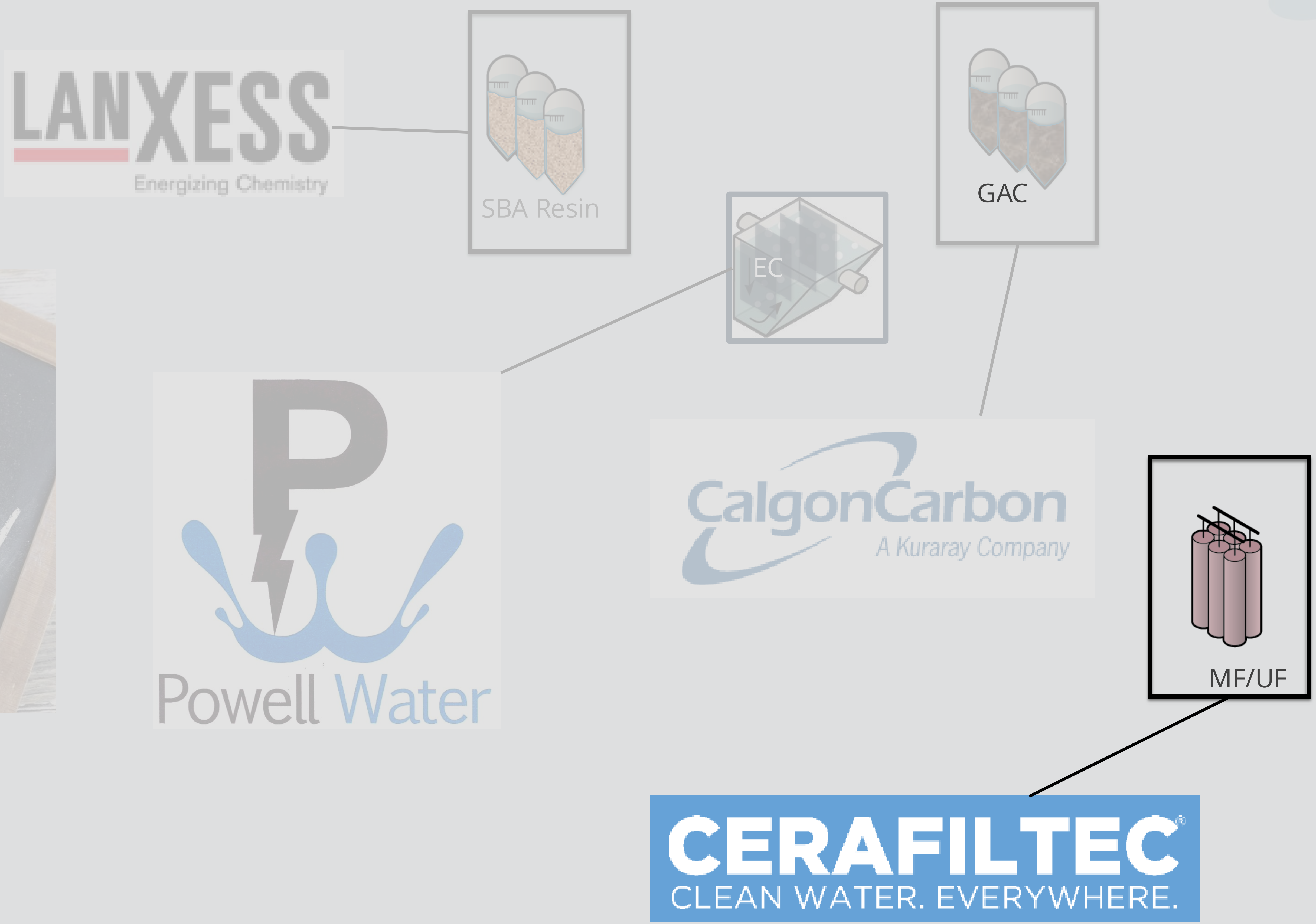
# EC – Typical Layout for Atmospheric Configuration

**600 gpm Unit**
**- 18’ w x 17’ l x 7’ t**



# Our partners donated their PFAS technology for testing

# Who is CERAFILTEC?

CERAFILTEC
CLEAN WATER. EVERYWHERE.

CERAFILTEC is a **submerged ceramic membrane** technology provider.

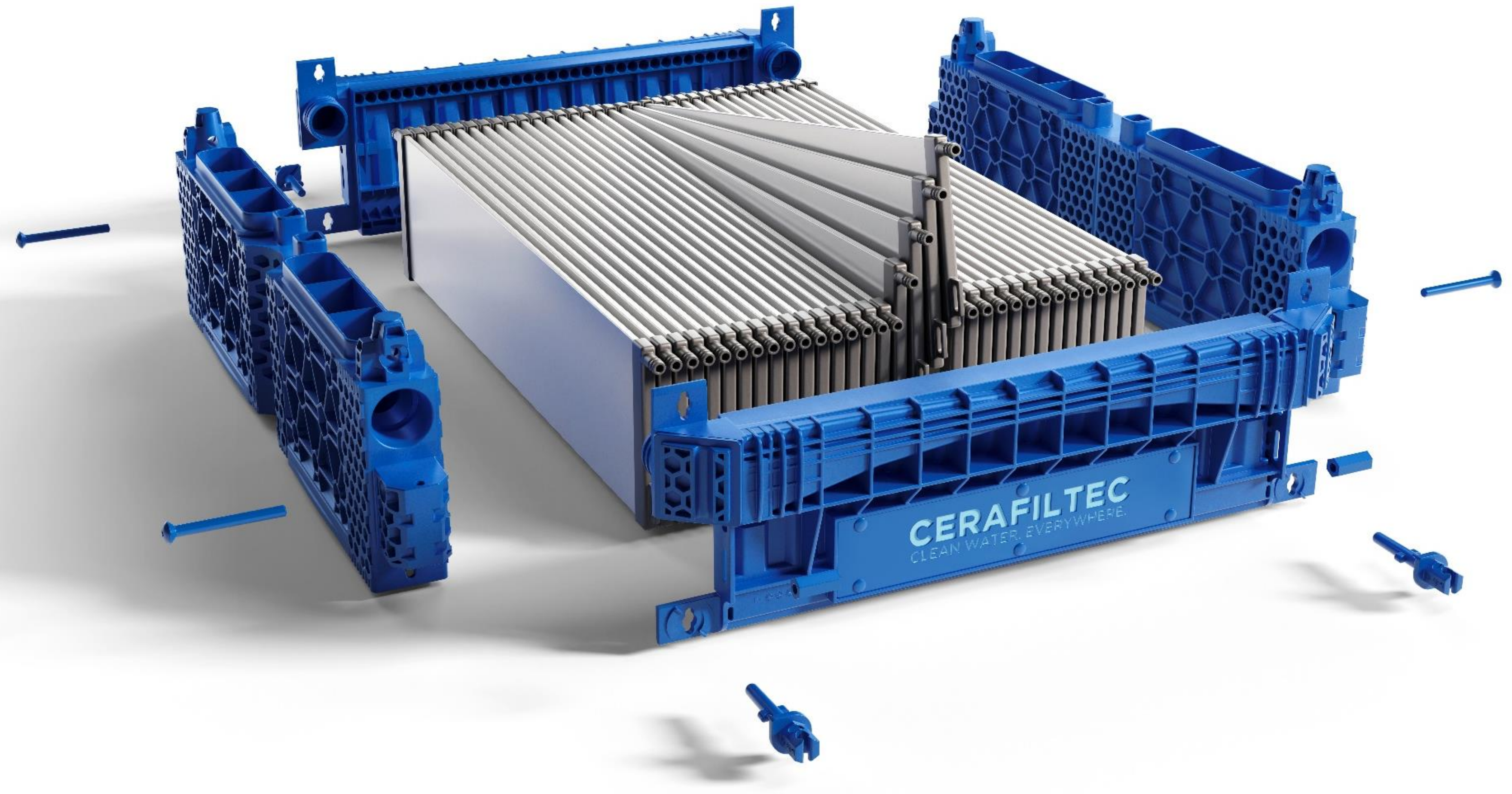
All modules are made in **Germany**.

We partner with a global network of **system integrators** to deliver turn-key systems.

**Core Applications**:

1. Drinking Water
2. Wastewater & Tertiary Reuse
3. Industrial Wastewater

**USA HQ**: Atlanta, Georgia
**Global HQ**: Saarbrücken, Germany



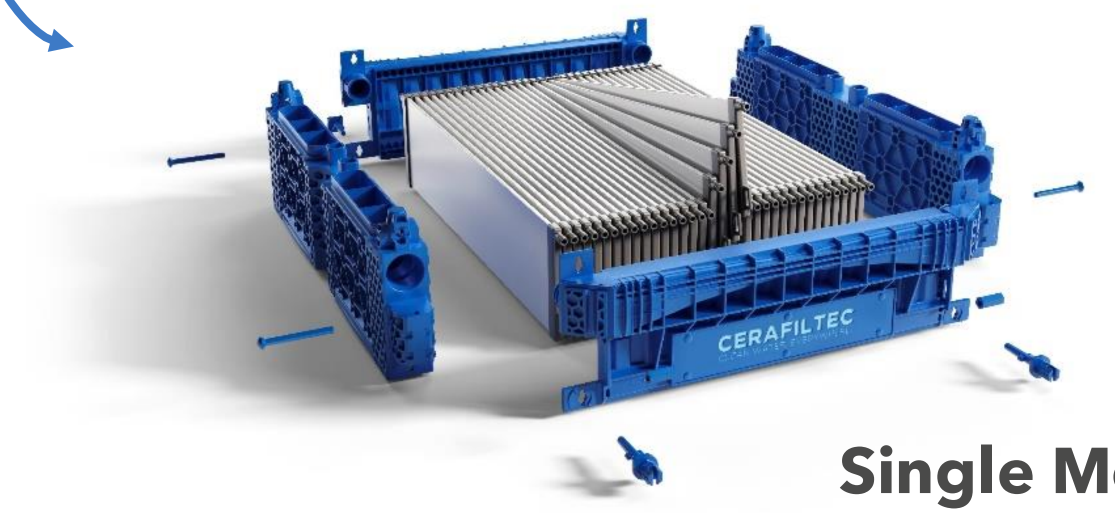

NSF Certified to NSF/ANSI 61

NSF Certified to NSF/ANSI 419

# Highly Modular Design

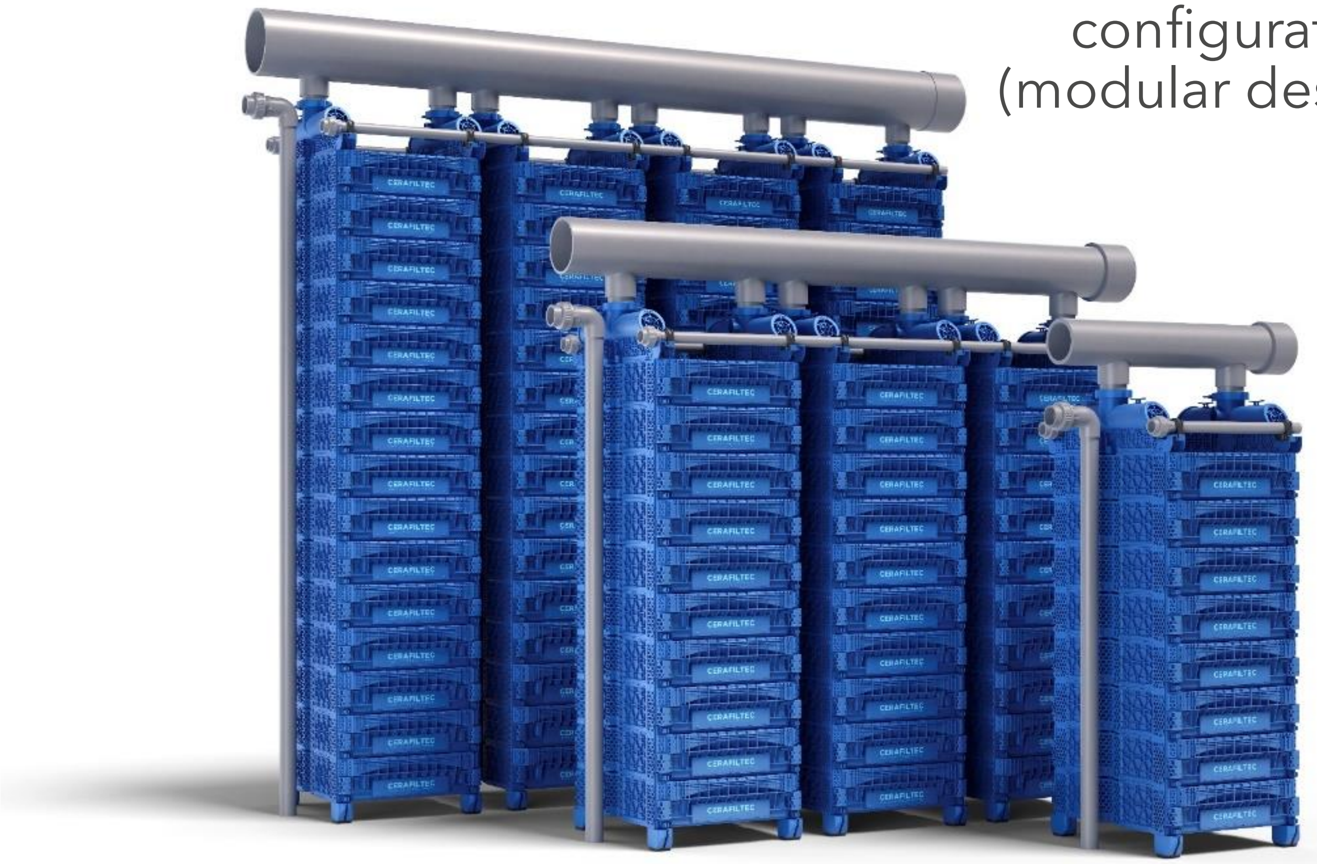
CERAFILTEC
CLEAN WATER. EVERYWHERE.

**Single**
**Ceramic Plate**




**Single Module**


**Single Tower**
with 5 modules



**Connected Towers**
in various
configurations
(modular design)

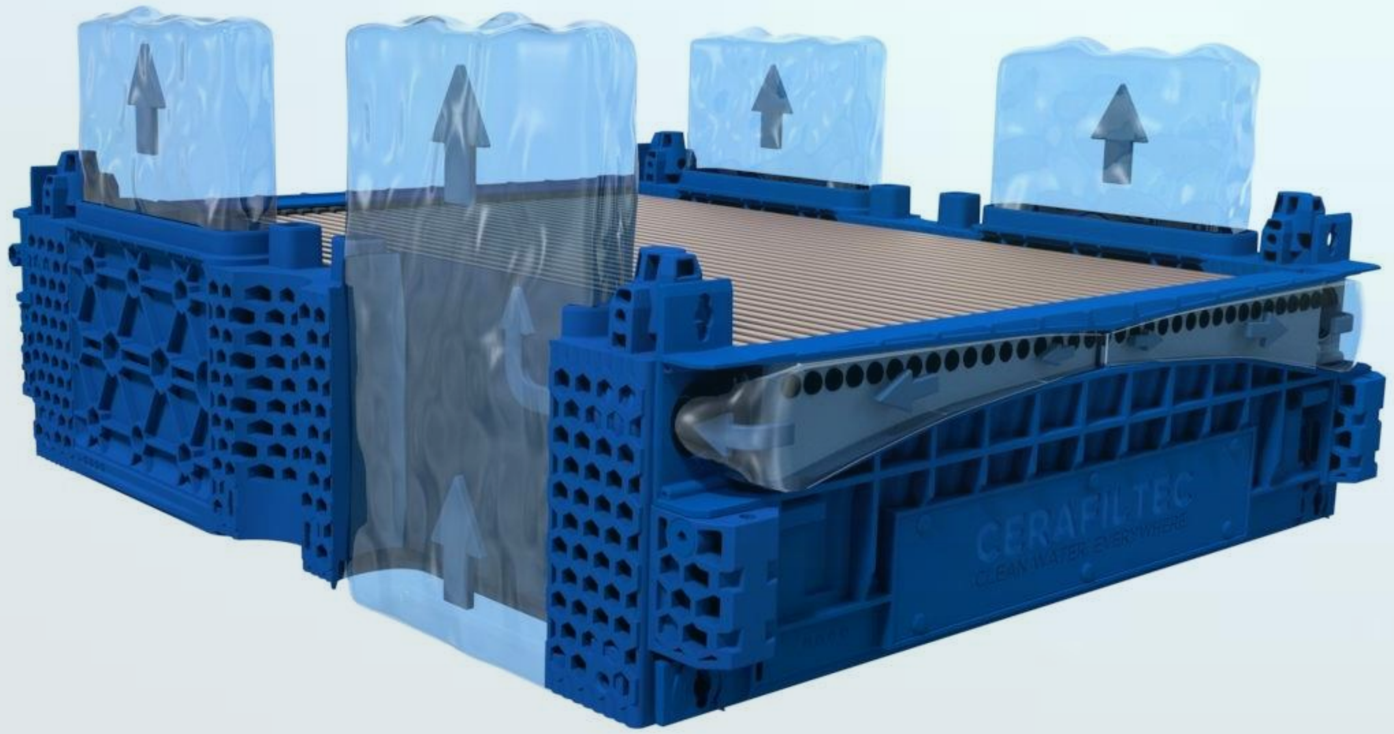
# How CERAFILTEC Works

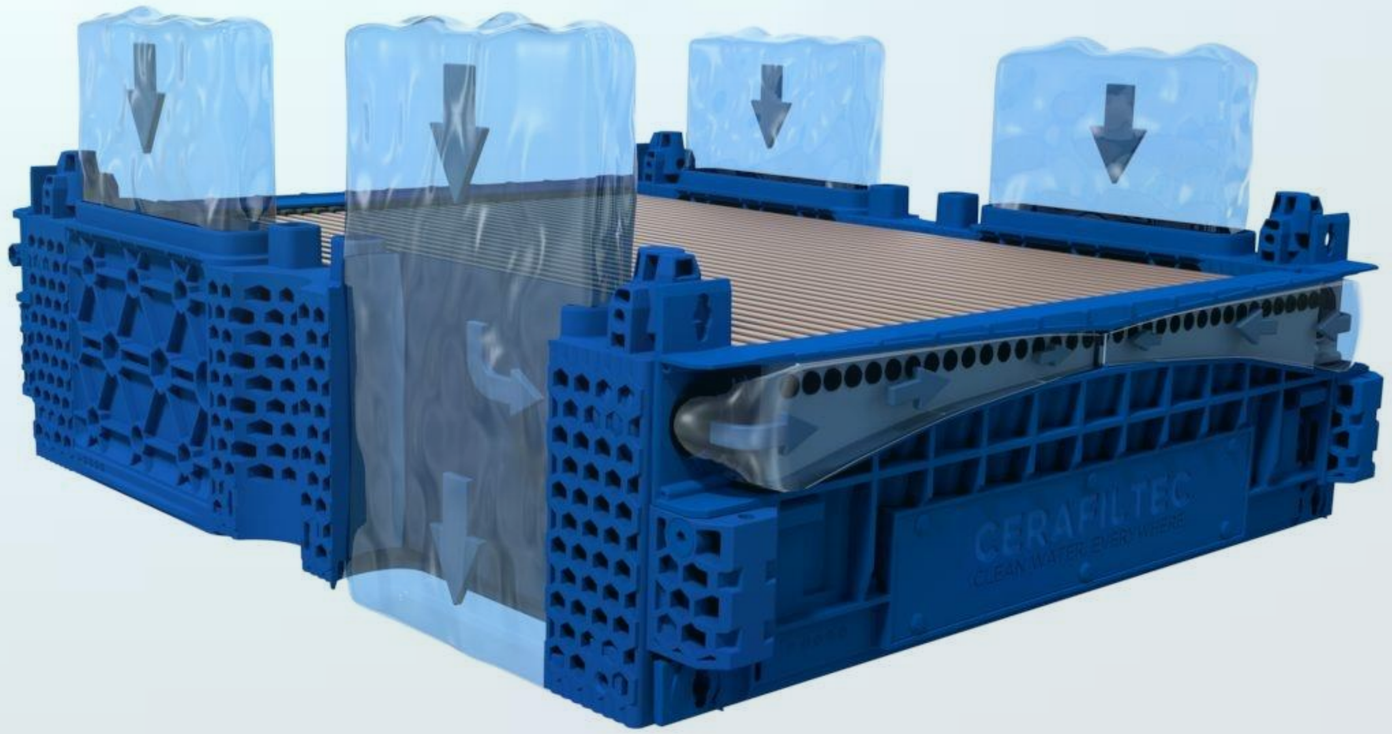
CERAFILTEC
CLEAN WATER. EVERYWHERE.

## Out-to-In Filtration

## In-to-Out Backwash

Submerged vacuum-driven (negative pressure) filtration and positive backwash pressure





# How CERAFILTEC Works

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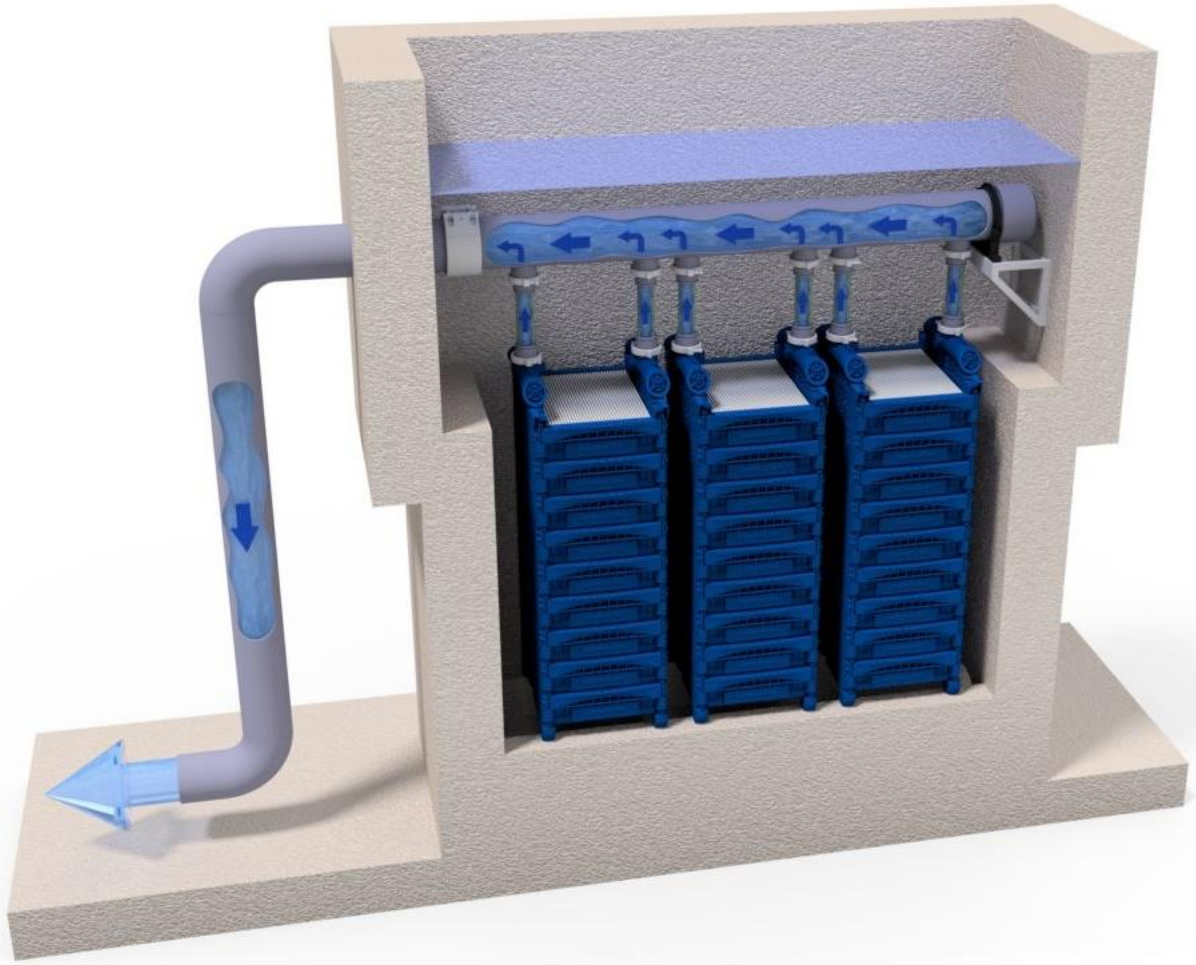
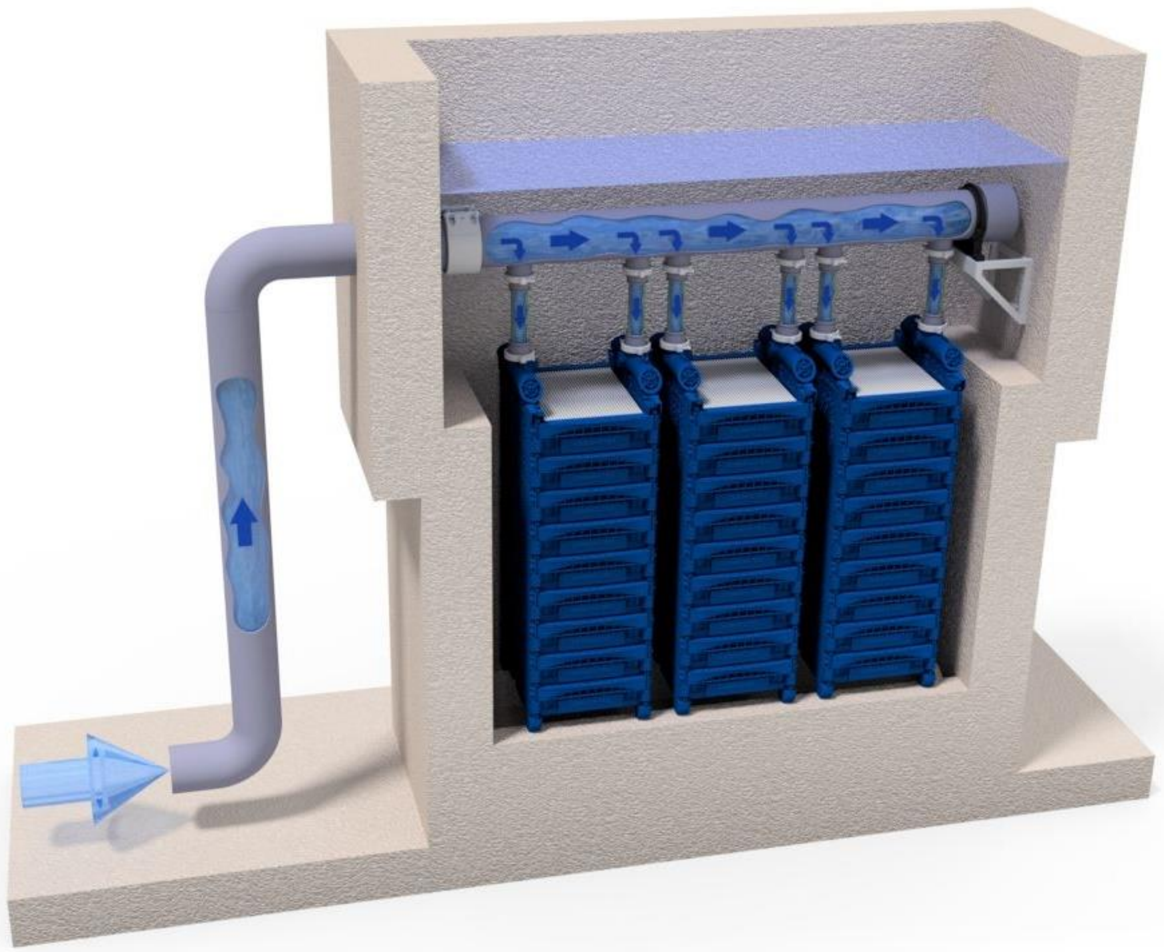




**Typical operations:**

100 – 400mbar (1.5 – 6 psi) suction pressure

2-12 hours filtration cycles between backwashes

Using typical chemicals (NaOCl, Citric Acid, HCl)

# Adsorbent Dosing for Dissolved Contaminant Polishing

CERAFILTEC
CLEAN WATER. EVERYWHERE.


**Ceramic UF**

+

**Powder Activated Carbon**

=

PAC Coated Membranes
Active Cake Layer filtration (ACLF)


**Removing Dissolved Contaminants**

# Active Cake Layer Filtration (ACLF)

CERAFILTEC®
CLEAN WATER. EVERYWHERE.

## Highly Efficient Removal of:

- PFAS
- Dissolved TOC
- Taste, Color, Odor
- Pharmaceutical compounds
- Pesticides
- Radium


# Superior Filtration Technology

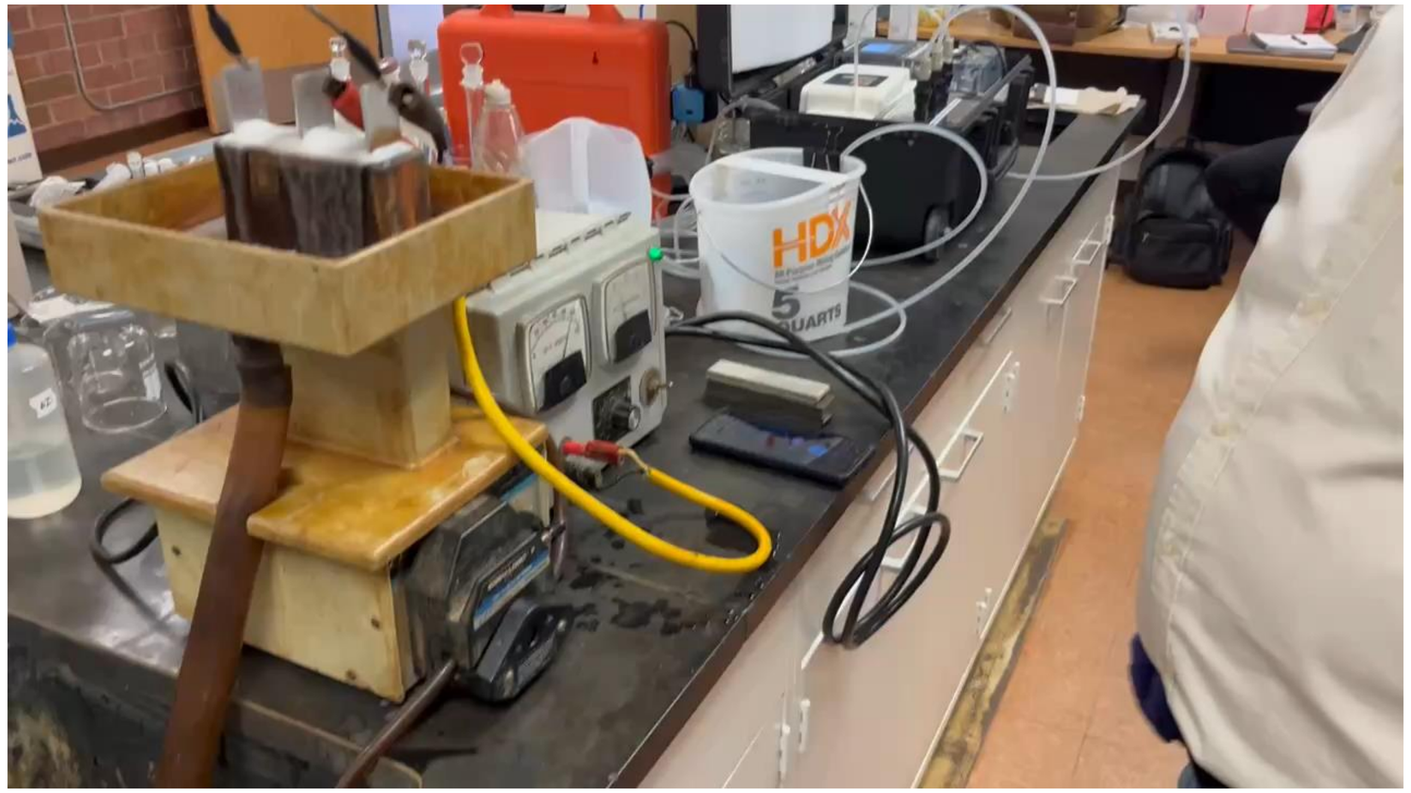
CERAFILTEC®
CLEAN WATER. EVERYWHERE.

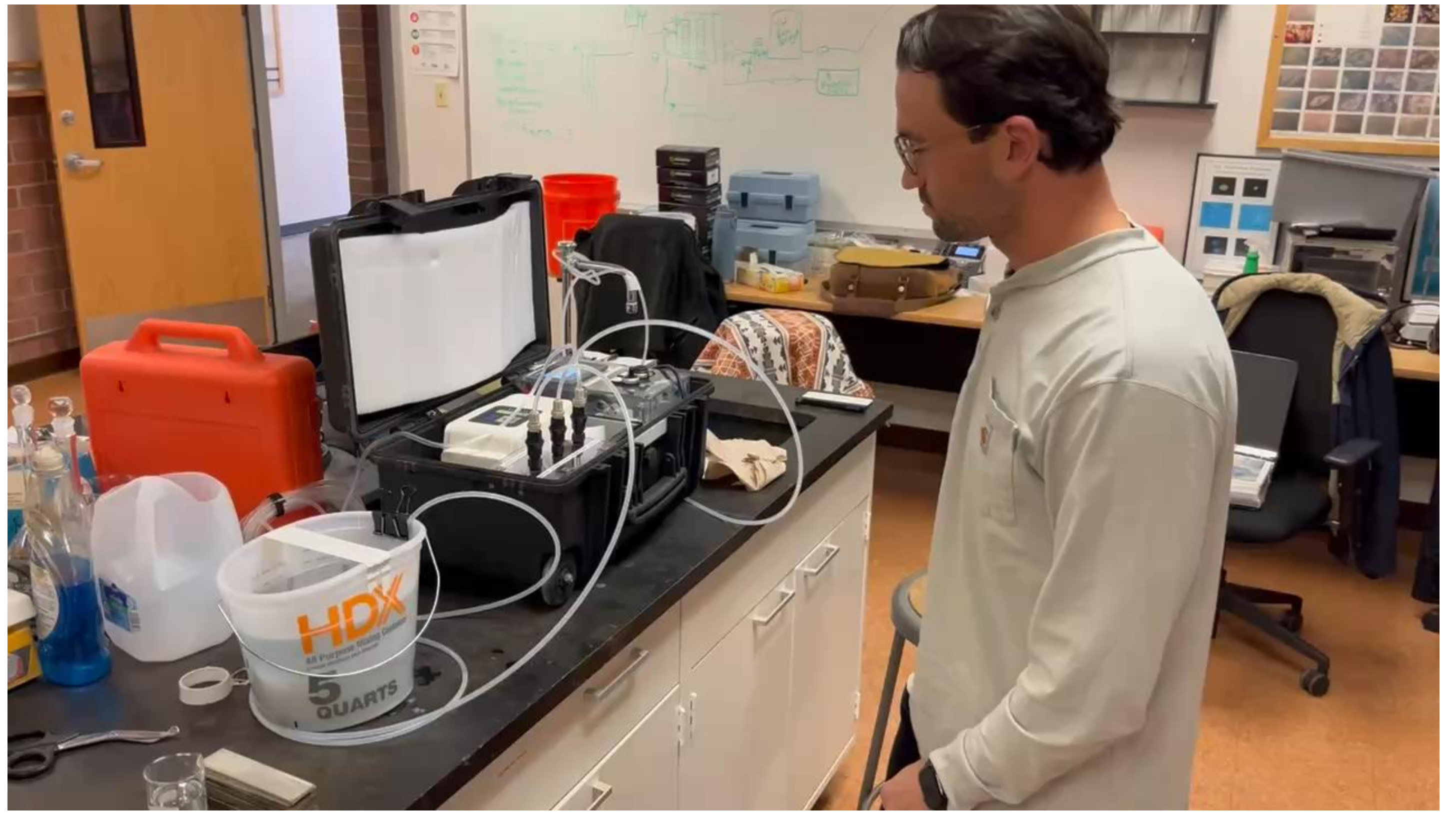
**Ceramic membranes provide the following advantages over conventional filters:**

1. Robust & Reliable
2. Resilient to Dynamic Feed Waters
3. Superior Cleaning
4. No Fiber Breakages & Low Maintenance
5. Long Life (~20 years)
6. Ease of Operation
7. Lower Total Cost of Ownership (TCO)

# Pilot Trailer Design

# EC + CUF Bench Tests – 1st date went well




# Preliminary Site Layout

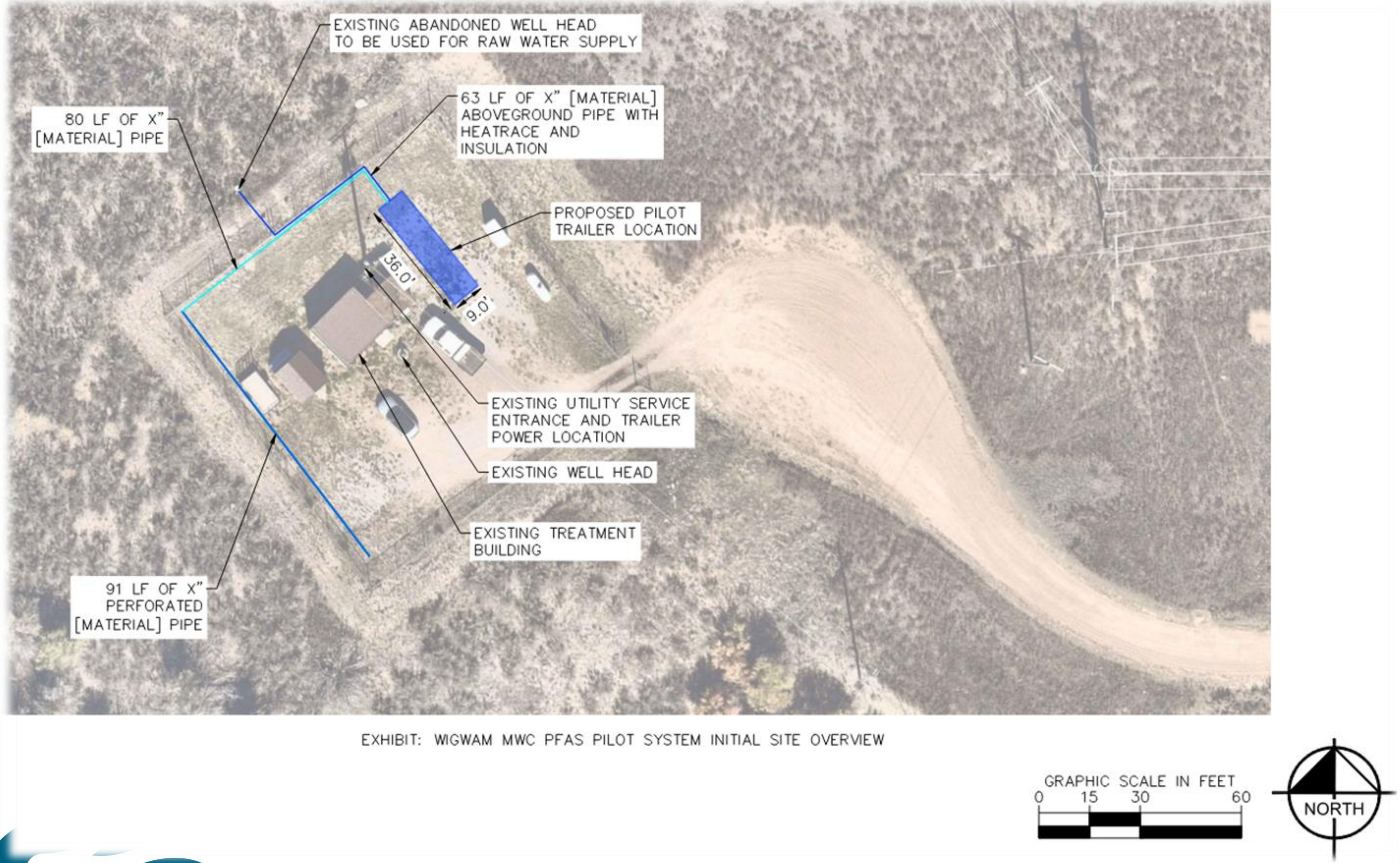
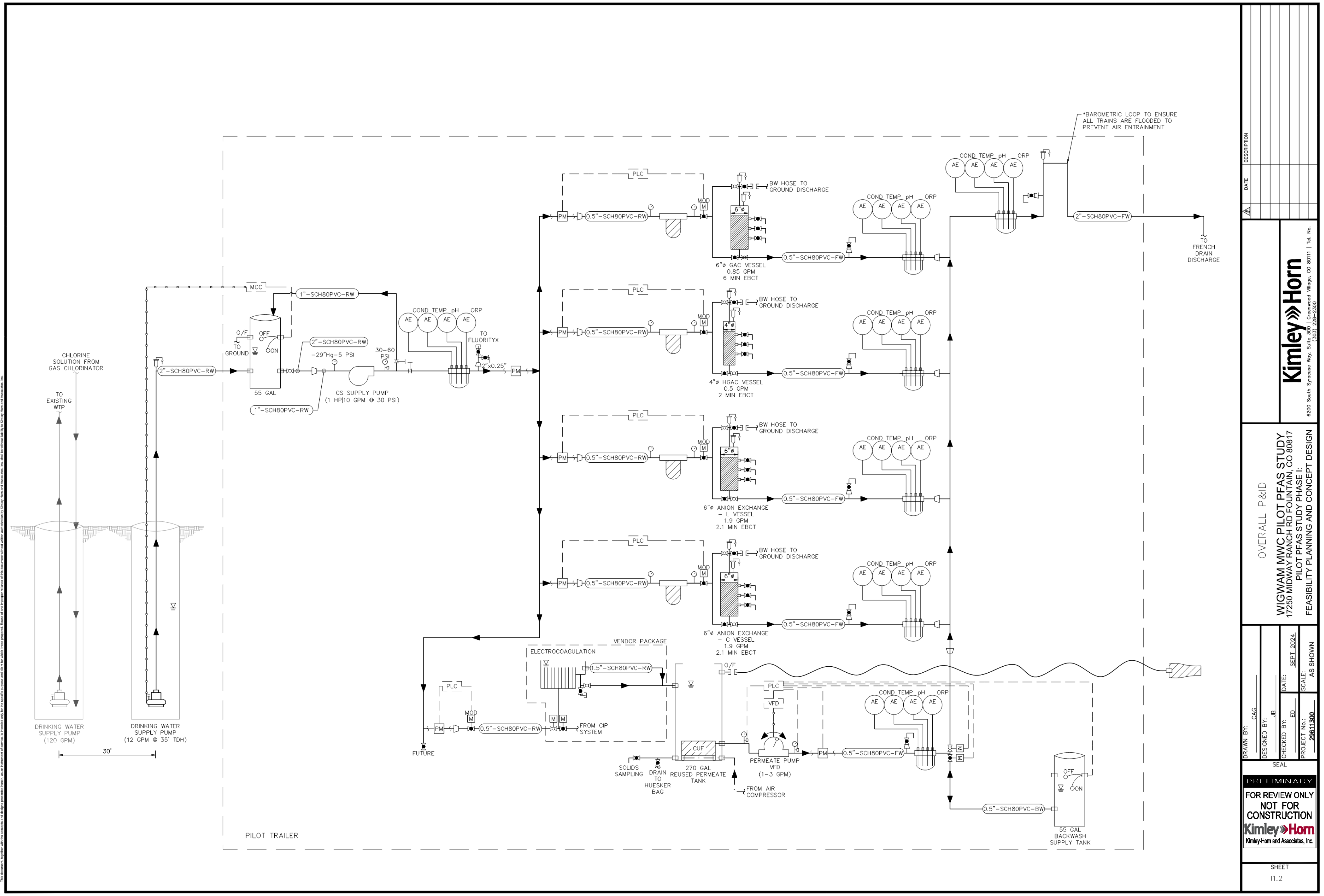
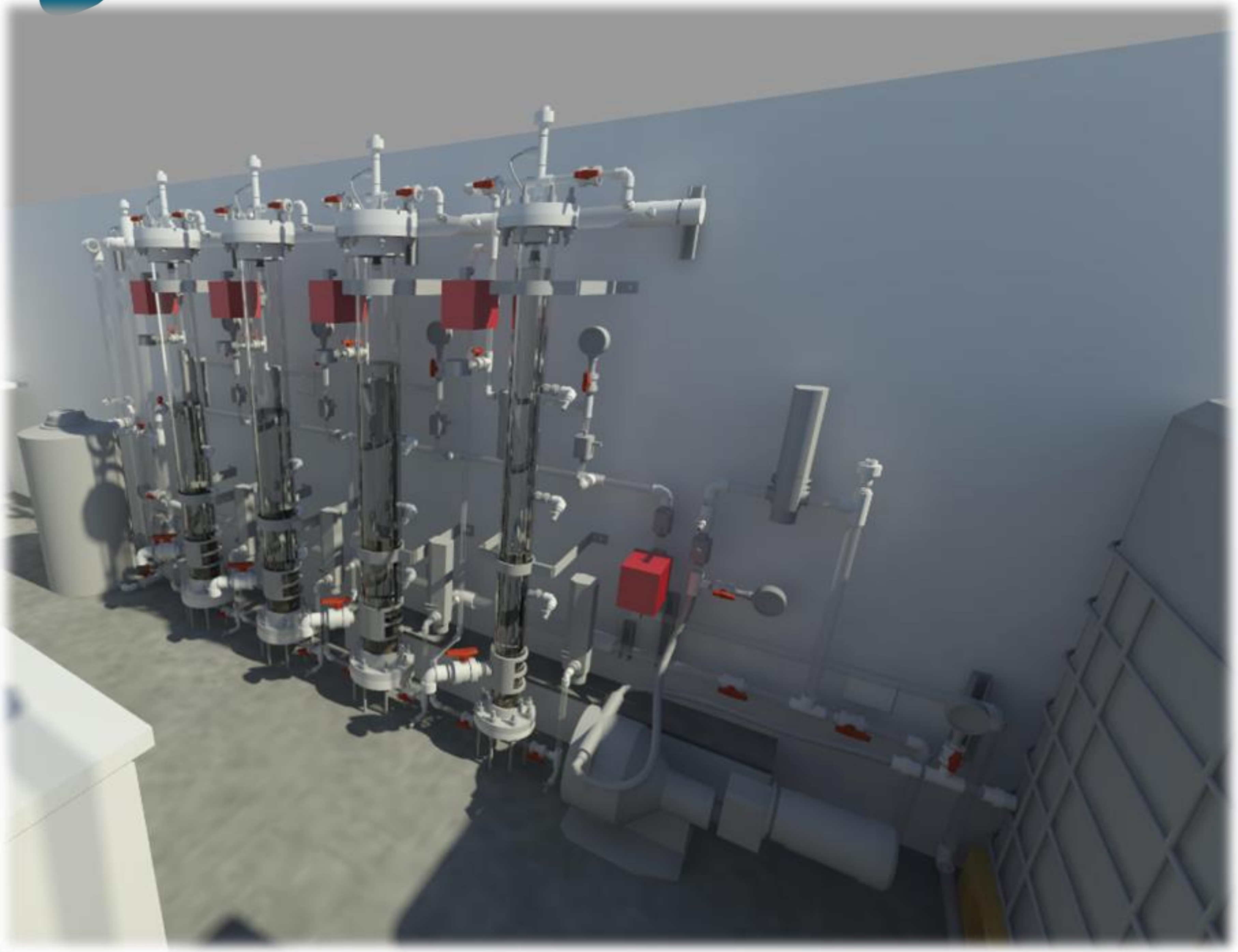


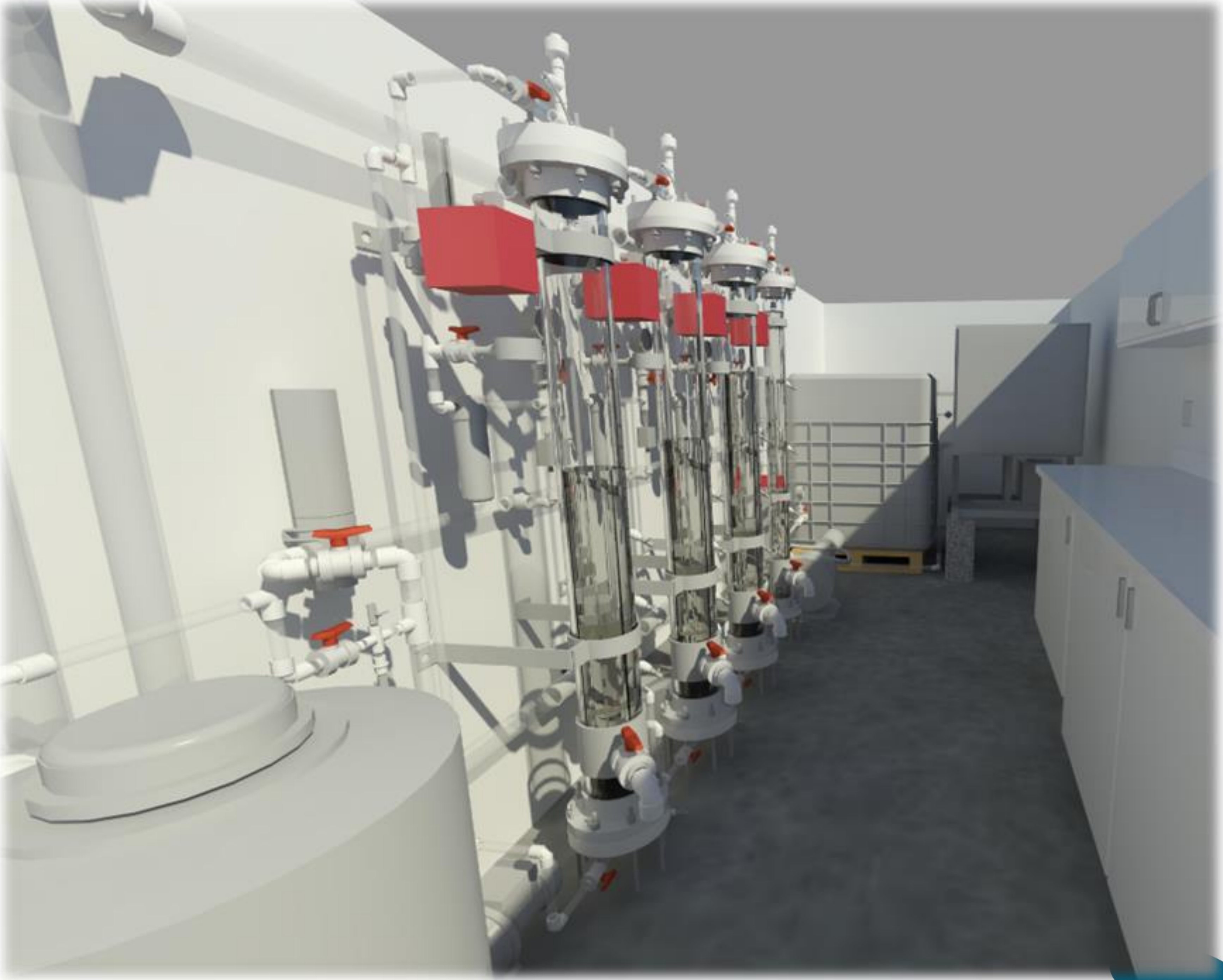

EXHIBIT: WIGWAM MWC PFAS PILOT SYSTEM INITIAL SITE OVERVIEW

# Preliminary P&ID

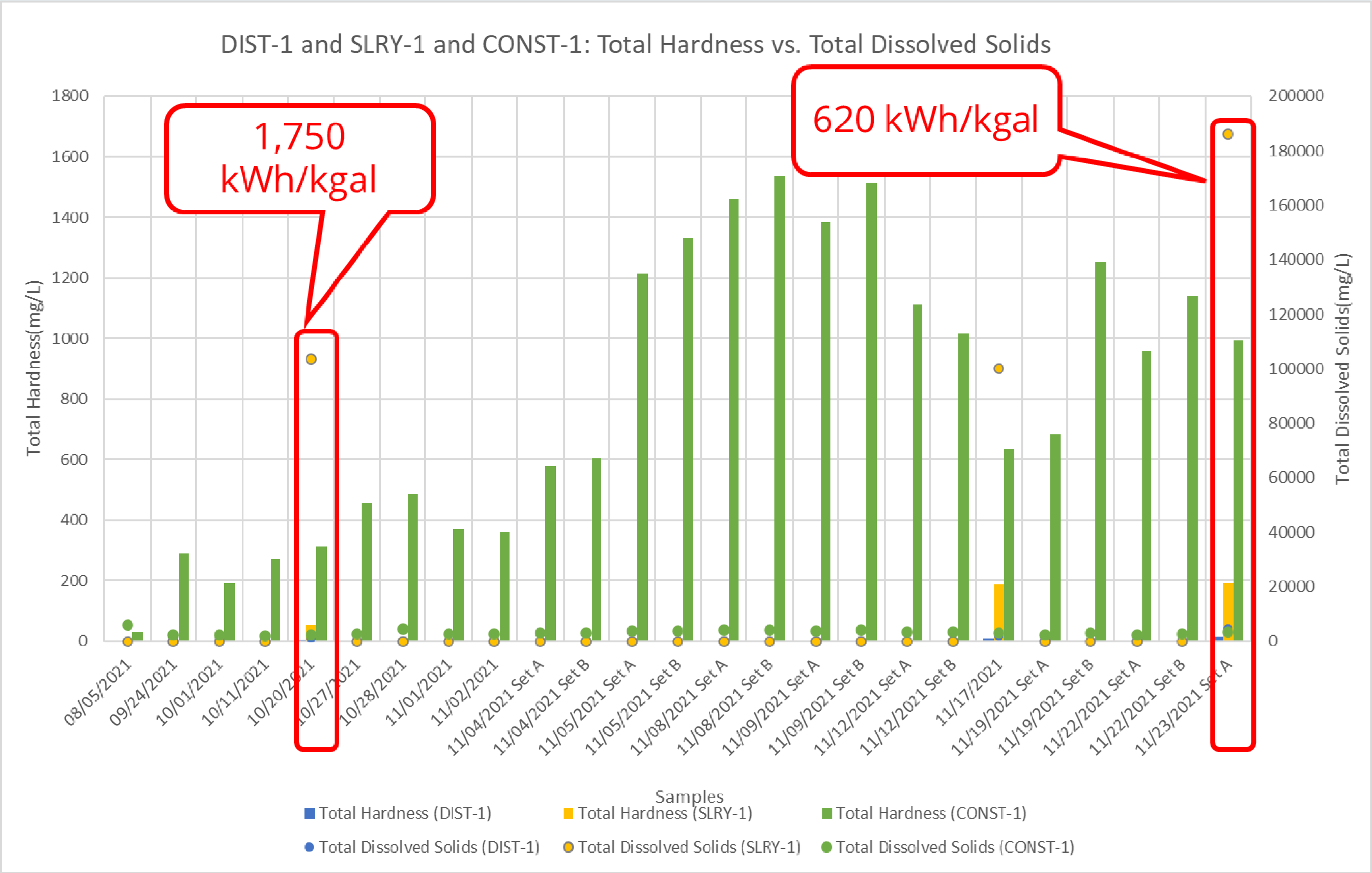


# 3D Rendering





# DURING FMA, WE WILL USE VAED TO REGENERATE SPENT AIX RESIN AND GAC…AND SEE WHAT HAPPENS




# Questions?

Eric Dole, PE, PSAP

Water & Energy Practice Builder

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