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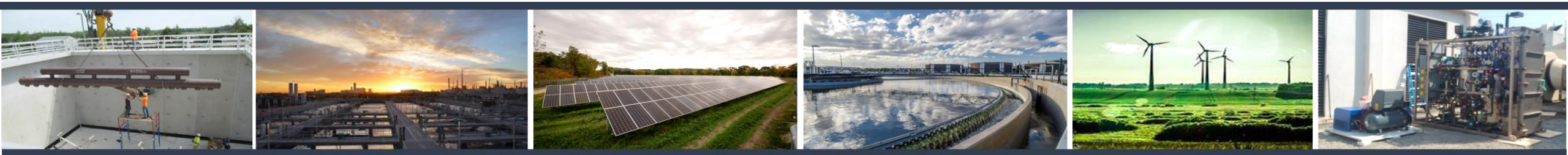
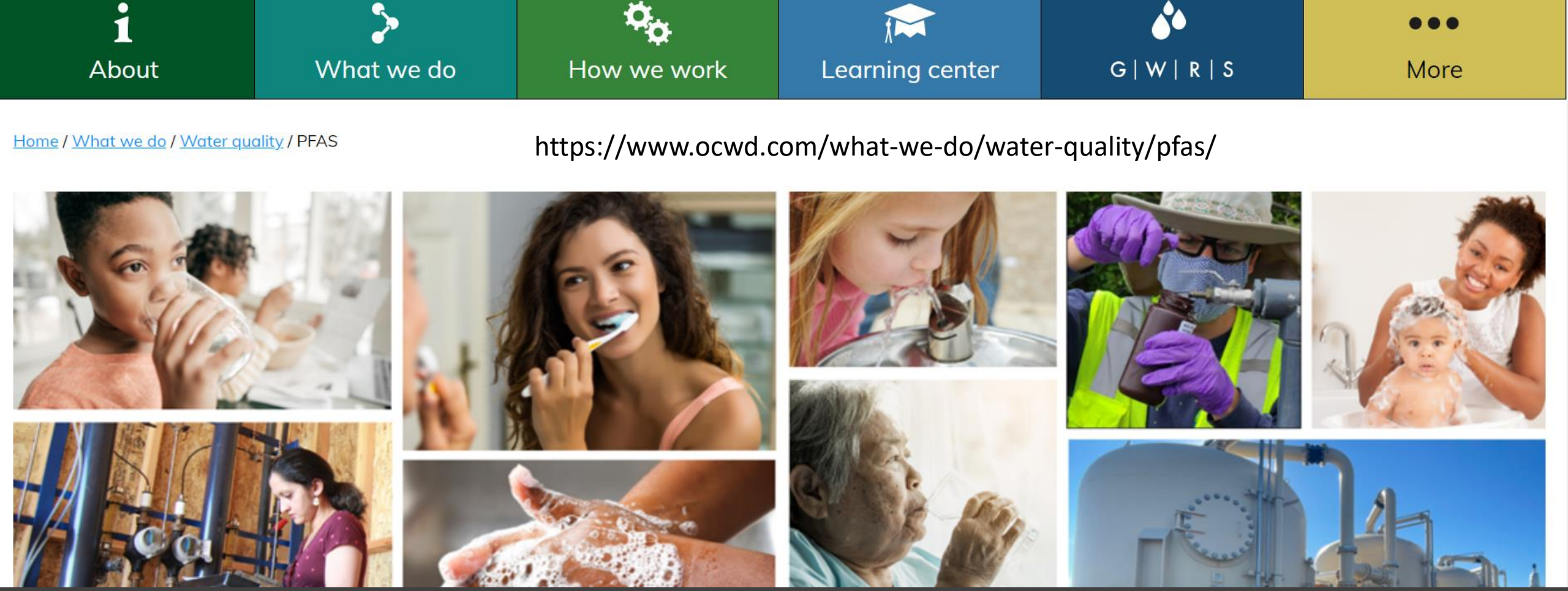
LA DWP Los Angeles Department of Water & Power

LOS ANGELES COUNTY SANITATION DISTRICTS
Converting Waste Into Resources

We will begin our presentation in a few minutes…





OCWD PFAS Treatment Study

Manmeet "Meeta" Pannu

March 23, 2022

Co-authors: Megan Plumlee, Christine Pham, Mike Hwang, Scott Grieco

Outline

- Introduction to OCWD and PFAS impact
- Study objectives
- Pilot test
- Lab-scale test
- Construction of treatment systems
- Phase II and III testing of adsorbents
- Related research underway

Acknowledgements

- OCWD R&D Dept team →
- OCWD Water Quality and Laboratory Departments
- Jacobs and Battelle
- Media providers for testing included:

ResinTech Inc. Innovations in Ion Exchange

evoqua Water Technologies

LANXESS Energizing Chemistry

CABOT

CalgonCarbon

ect2

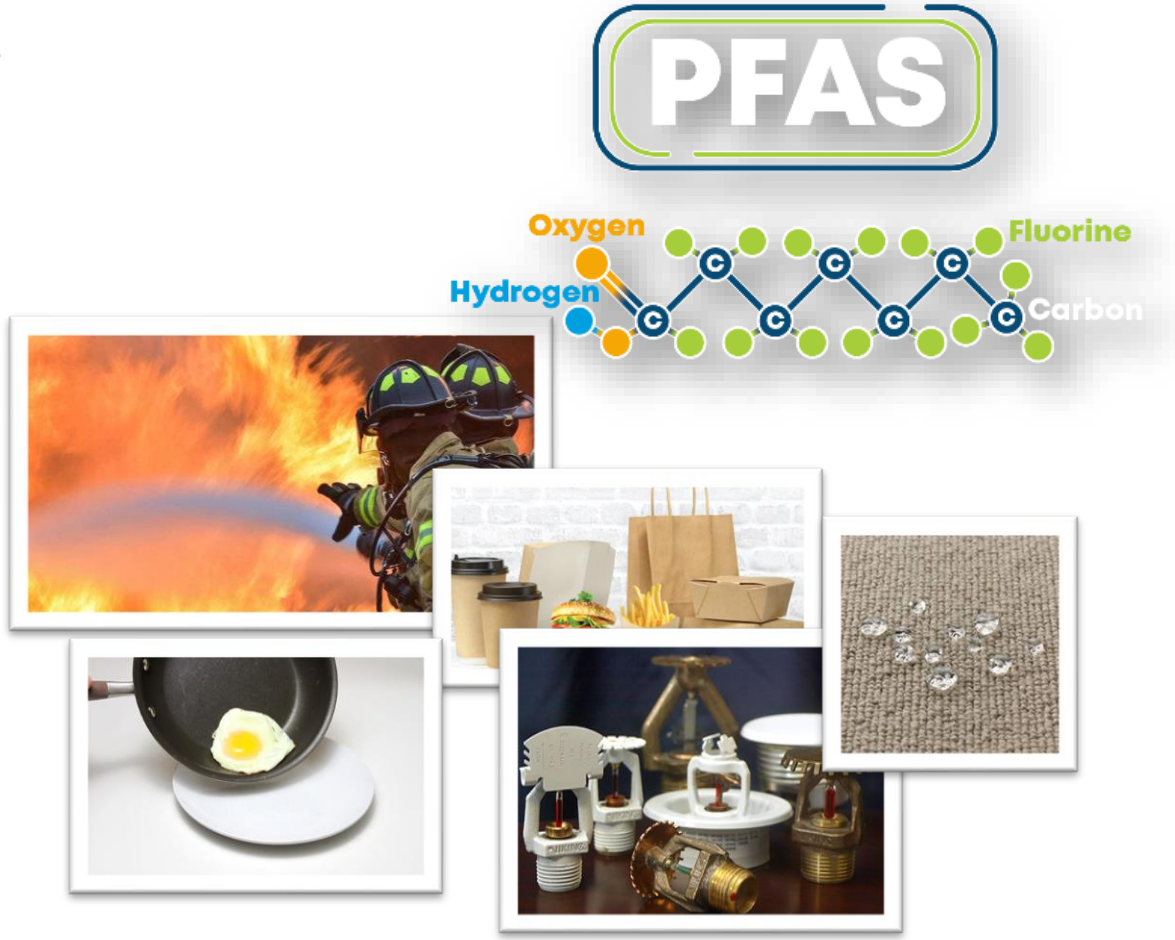
CETCO

Jacobi Carbons

Purolite

What Are PFAS?

- PFAS = Per- and Polyfluoroalkyl Substances **(family of 1000s of man-made chemicals)**
- Composed of multiple C-F bonds
- Often labelled as forever chemicals
- Resistant to degradation



Most common PFAS

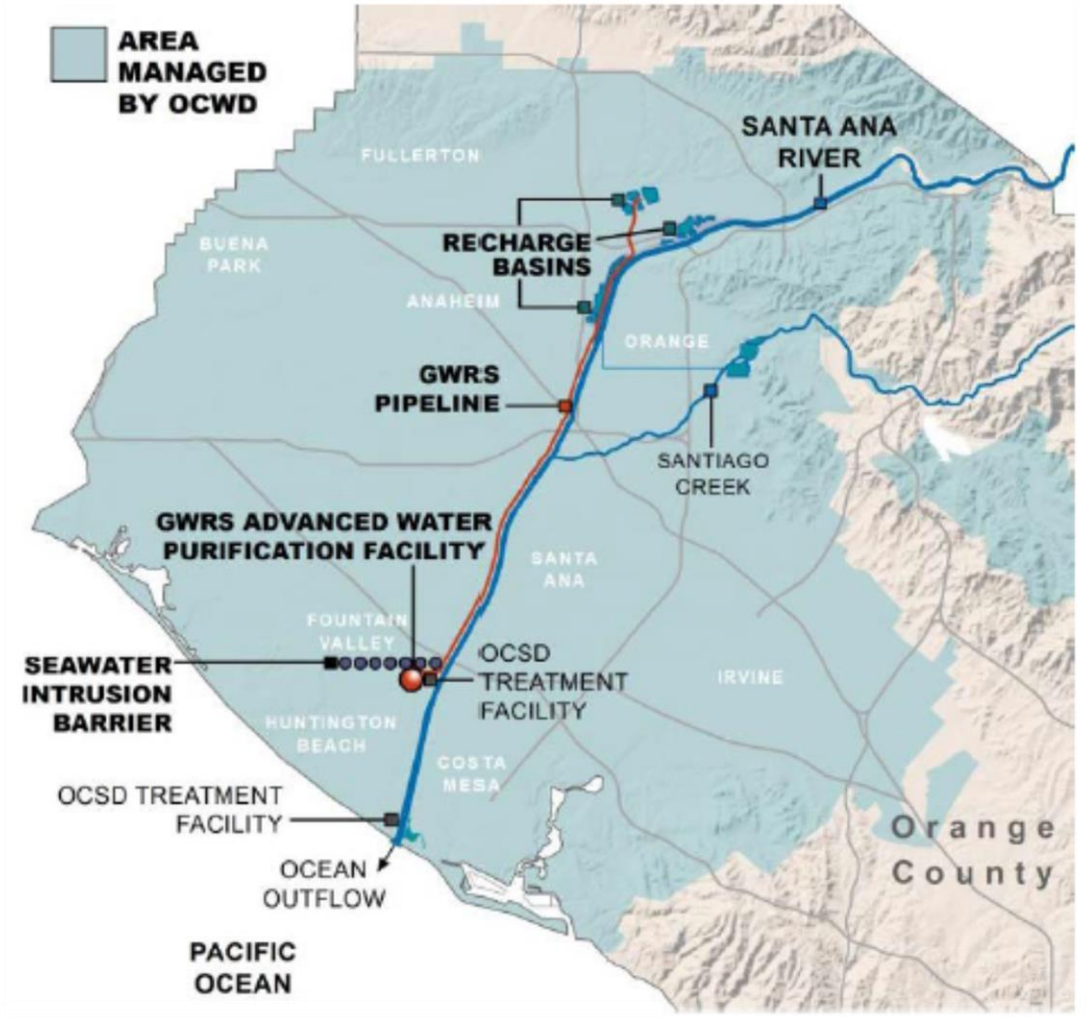
PFOA = Perfluorooctanoic Acid ($C_8HF_{15}O_2$)

PFOS = Perfluorooctane Sulfonate ($C_8HF_{17}O_3S$)

PFBS = Perfluorobutanesulfonic acid ($C_4HF_9O_3S$)

Orange County Water District

- OCWD was formed in 1933 to
  - Manage the OC Groundwater Basin
  - Protect rights to Santa Ana River water
- Basin provides groundwater to
  - 19 municipal and special water districts
  - 2.5 million residents
- Basin provides 77% of the water supply for north & central OC



Extent of PFAS Impact in OCWD Service Area

Current California DDW NL/RLs:

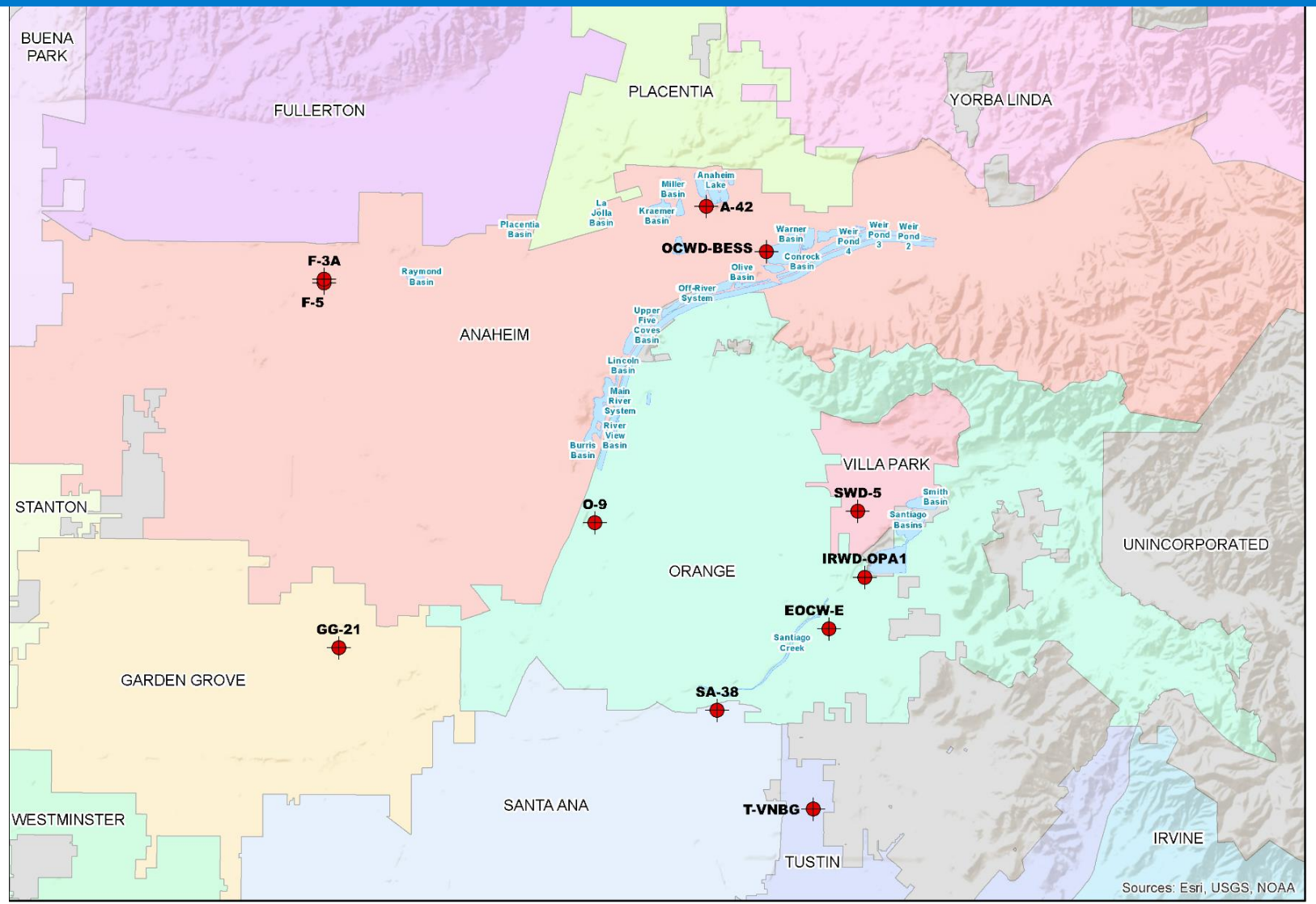
Notification Levels (NLs):
PFOA = 5.1 ng/L
PFOS = 6.5 ng/L
PFBS = 500 ng/L

Response Levels (RLs):
PFOA = 10 ng/L
PFOS = 40 ng/L
PFBS = 5,000 ng/L

*Public Health Goal (PHG) process has begun, as required initial step to develop Maximum Contaminant Level (MCL)

- **11 water retailers** (i.e., groundwater "Producers") in the OCWD service area impacted by 10 ng/L PFOA RL
- **Up to ~ 1/3 of groundwater basin** production (100,000 afy) unable to be served
- **Closure of wells and ~ >$50 million/year** treated *imported* surface water
- **Solution** is to find an adsorbent based technology to remove PFAS and bring local groundwater supplies back online

Wells Impacted by PFAS Regulations



0 2,500 5,000 Feet

PFAS is not present in advanced treated, recycled water from OCWD's GWRS

GWRS
GROUNDWATER REPLENISHMENT SYSTEM

- GWRS generates purified water for groundwater augmentation ('indirect potable reuse' or IPR)
- Removal of PFAS by reverse osmosis (RO) is known to be highly effective

https://www.ocwd.com/gwrs/

GWRS - new water you can count on

The GWRS is the world's largest water purification system for indirect potable reuse. The system takes highly treated wastewater that would have previously been discharged into the Pacific Ocean and purifies it using a three-step advanced treatment process consisting of microfiltration, reverse osmosis and ultraviolet light with hydrogen peroxide. The process produces high-quality water that meets or exceeds all state and federal drinking water standards.

OBJECTIVE

Granular Activated Carbon (GAC)

Ion Exchange (IX) Resin

Alternative Adsorbents

- What adsorbent should be used to best remove PFAS, and for best value?
- Treatment Study: Test various products at ***pilot*** and ***lab*** scale
- Products tested were GAC, IX and Alternative adsorbents

Adsorbents Tested at Pilot and Lab scale Tests

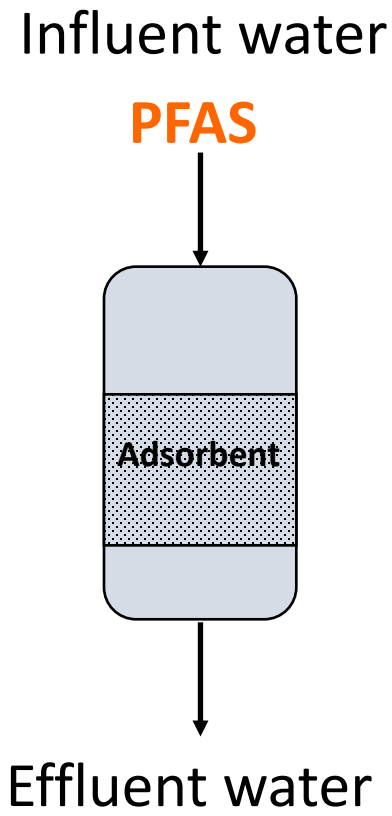
Pilot Adsorbents	# of Products Tested	Empty Bed Contact Time (EBCT)	Supplier(s)/ Manufacturers	Lab (RSSCT)	Pilot	Regenerable?
GAC	8	10 min	Cabot Norit, Calgon, Evoqua, Jacobi	✓	✓	Yes
IX	4	2 min	Calgon, ECT2, Evoqua, Purolite		✓	No
Alternative Adsorbent	1	5 min	Confidential	✓	✓	Yes
Alternative Adsorbent Surface-modified bentonite (FLUORO-SORB® 200)	1	2 min	CETCO	✓	✓	No

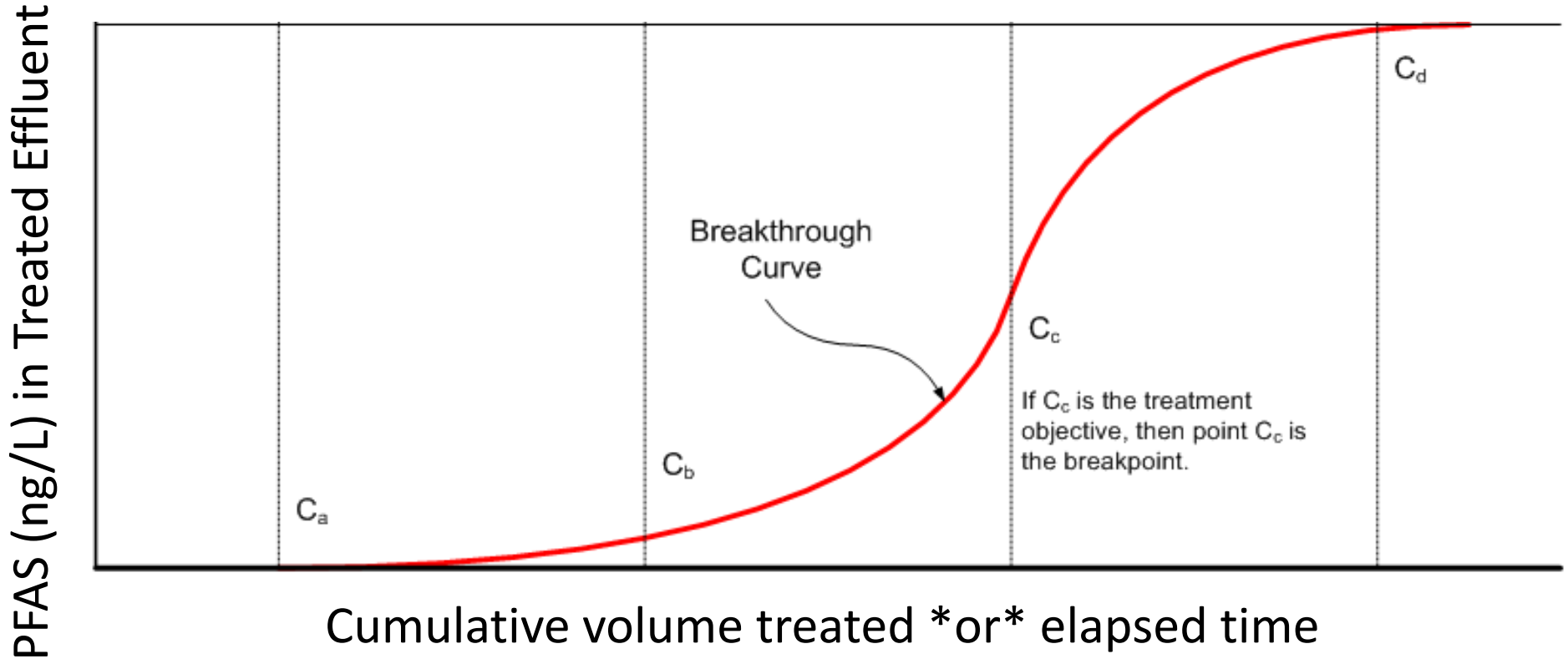

GAC


IX


Alternative

How does adsorbent technology work? Breakthrough Curve





OCWD Pilot Program

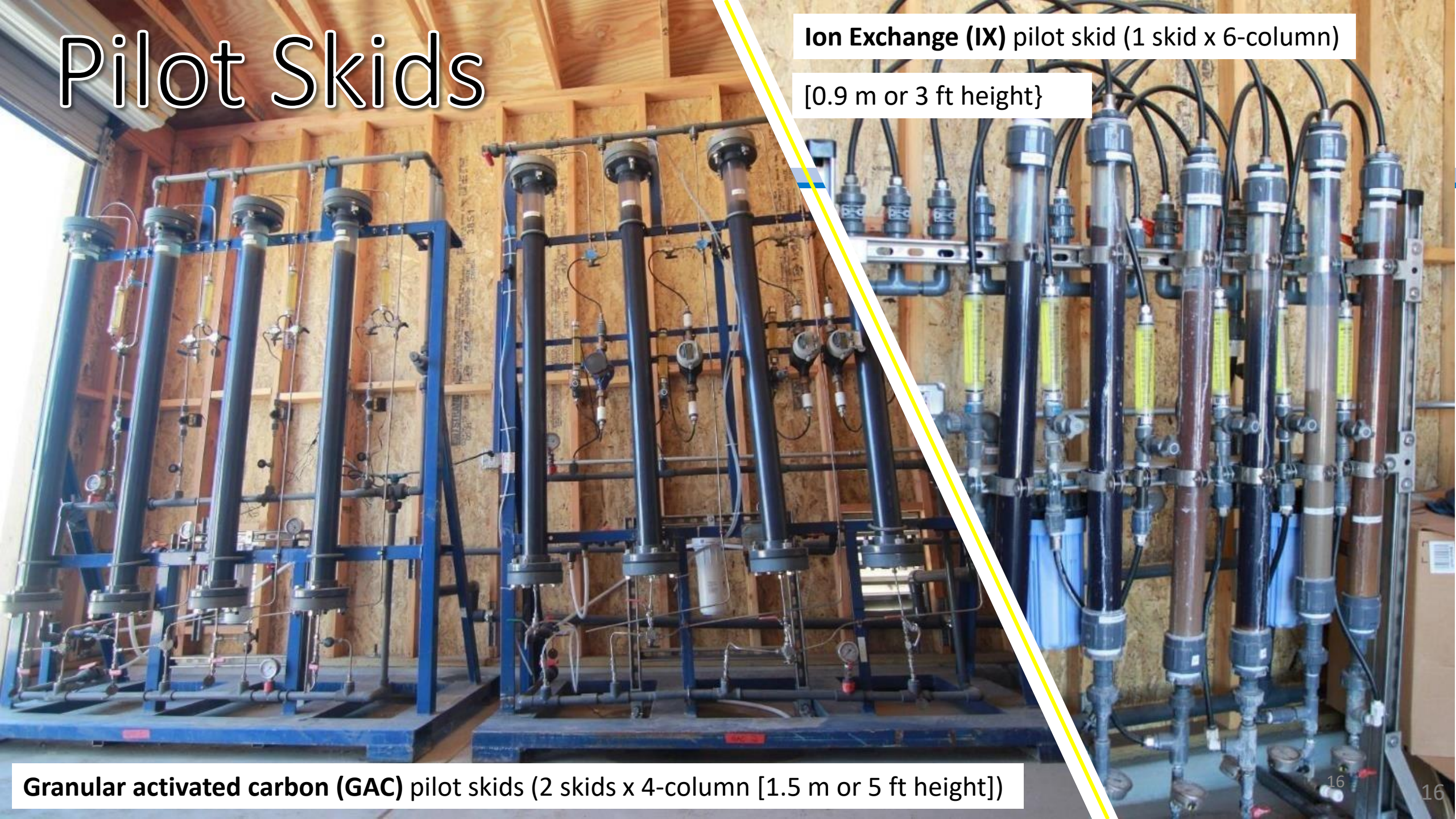
- Pilot ★ water supplied by OCWD-owned non-potable well in Anaheim
- PFAS in pilot influent:

PFAS (EPA 537.1)	Mean (ng/L)
PFOA (long-chain)	16
PFOS (long-chain)	23
PFHxS (long-chain)	11
PFBS (short-chain)	15
PFHxA (short-chain)	3

OCWD Pilot Program

Installed pre-fab building to house pilot

Pilot Skids



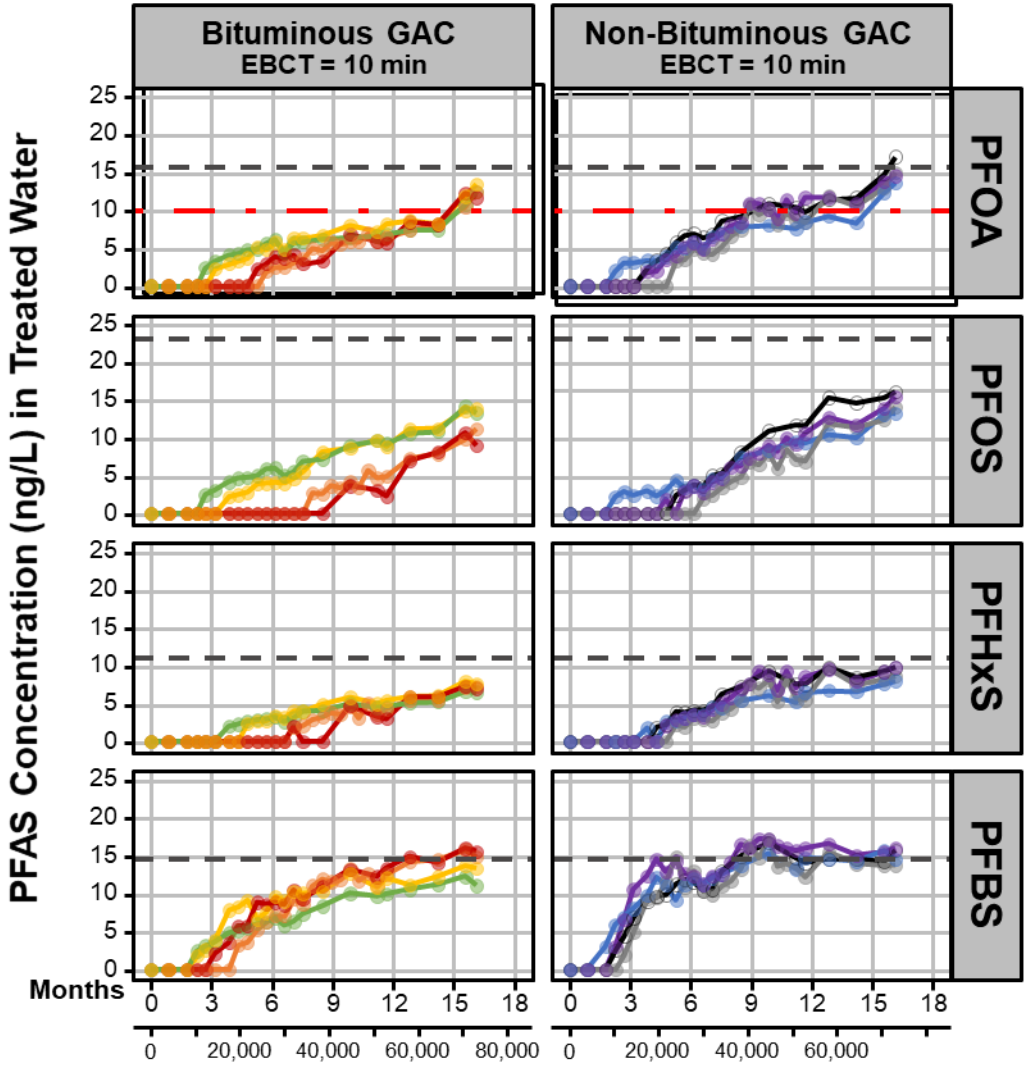
Ion Exchange (IX) pilot skid (1 skid x 6-column)

[0.9 m or 3 ft height}

Granular activated carbon (GAC) pilot skids (2 skids x 4-column [1.5 m or 5 ft height])

16

GAC Performance Pilot Results



- **GACs:** Bituminous GACs **(e.g., Calgon F400)** performed better than non-bituminous or blended products. Overall, **Calgon F400** superior performance (taking into account PFOA + PFOS).

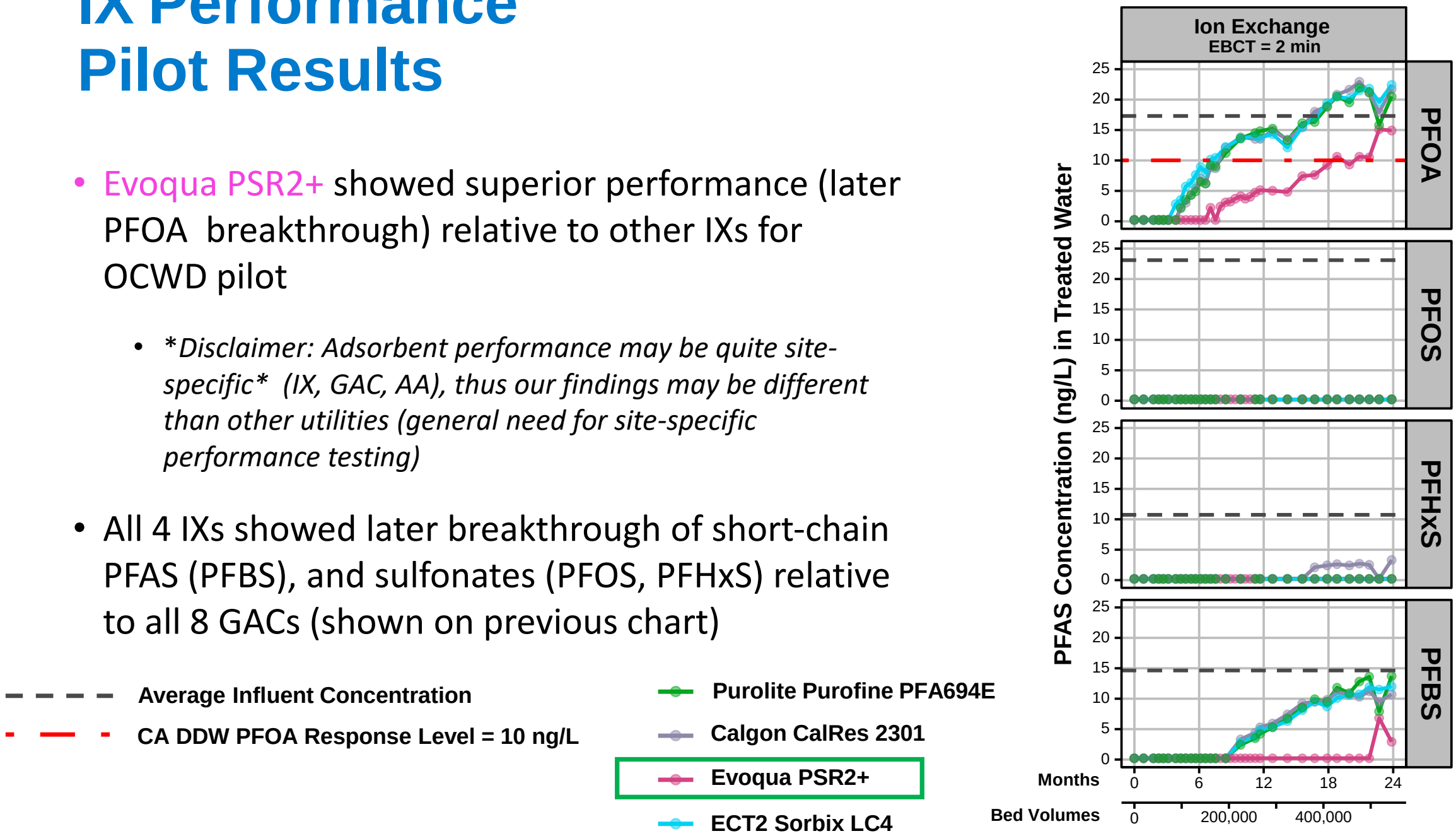
Average Influent Concentration

CA DDW PFOA Response Level = 10 ng/L

- Cabot Norit GAC400
- Calgon F400V (Virgin)
- Calgon F400R (Reactivated)
- Calgon F600
- Evoqua UltraCarb 1240LD
- Evoqua AquaCarb 1230CX
- Cabot Norit HYDRODARCO 4000
- Jacobi AquaSorb F23

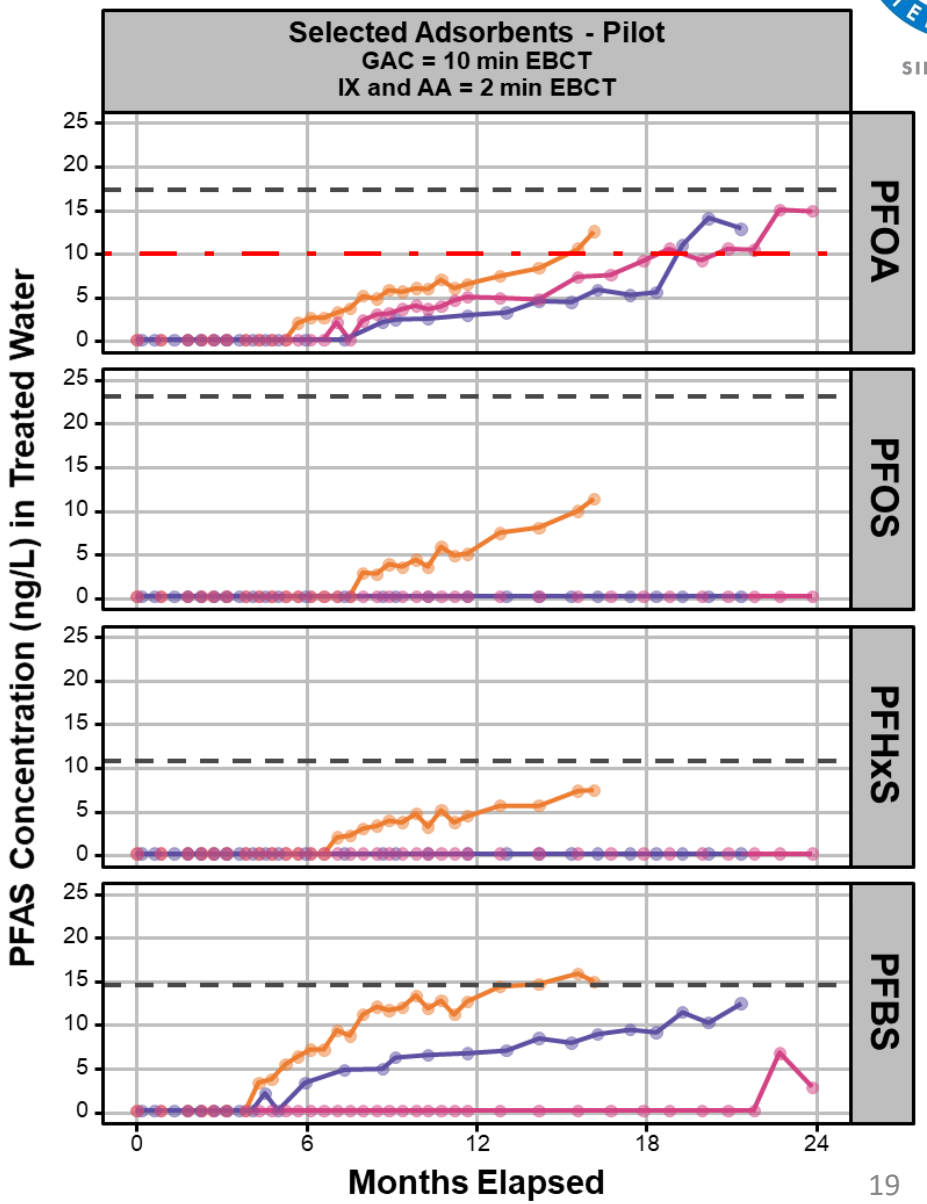
IX Performance Pilot Results

- Evoqua PSR2+ showed superior performance (later PFOA breakthrough) relative to other IXs for OCWD pilot
    - **Disclaimer: Adsorbent performance may be quite site-specific* (IX, GAC, AA), thus our findings may be different than other utilities (general need for site-specific performance testing)*
- All 4 IXs showed later breakthrough of short-chain PFAS (PFBS), and sulfonates (PFOS, PFHxS) relative to all 8 GACs (shown on previous chart)



GAC vs IX vs Alt. Adsorbents (AA)

- Encouraging results for alternative adsorbent **CETCO FLUORO-SORB® 200** showing similar performance for PFOA as pilot's best-performing IX *(at same low-footprint 2-min EBCT!)*
- Merits consideration for full-scale treatment
- This AA is new to the drinking water market; OCWD and other water agencies currently reviewing with regulators



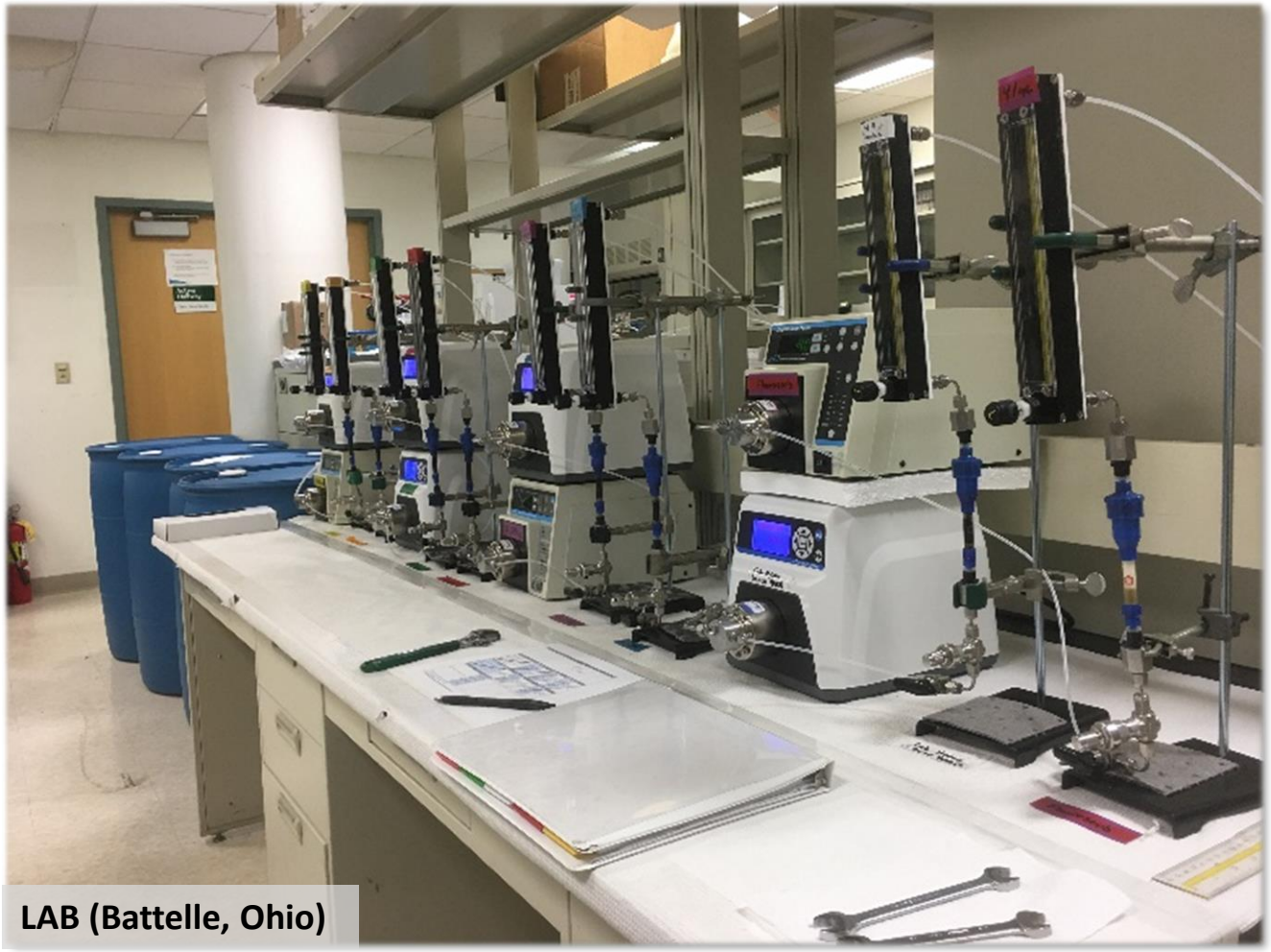
Rapid Small Scale Column Testing (RSSCT) in Lab

- RSSCT was performed at bench (lab) scale with GAC and alternative adsorbents
- RSSCT – Advantage (over pilot) is the ability to ***quickly*** screen ***multiple*** waters
- Tested water from 9 different producers (production wells in OC) plus OCWD pilot influent water ***(10 total waters)***
- RSSCT on CD (constant diffusivity) assumptions
- Only presenting results for PFOA

0.7 cm diameter
1.0 - 3.4 cm bed depth

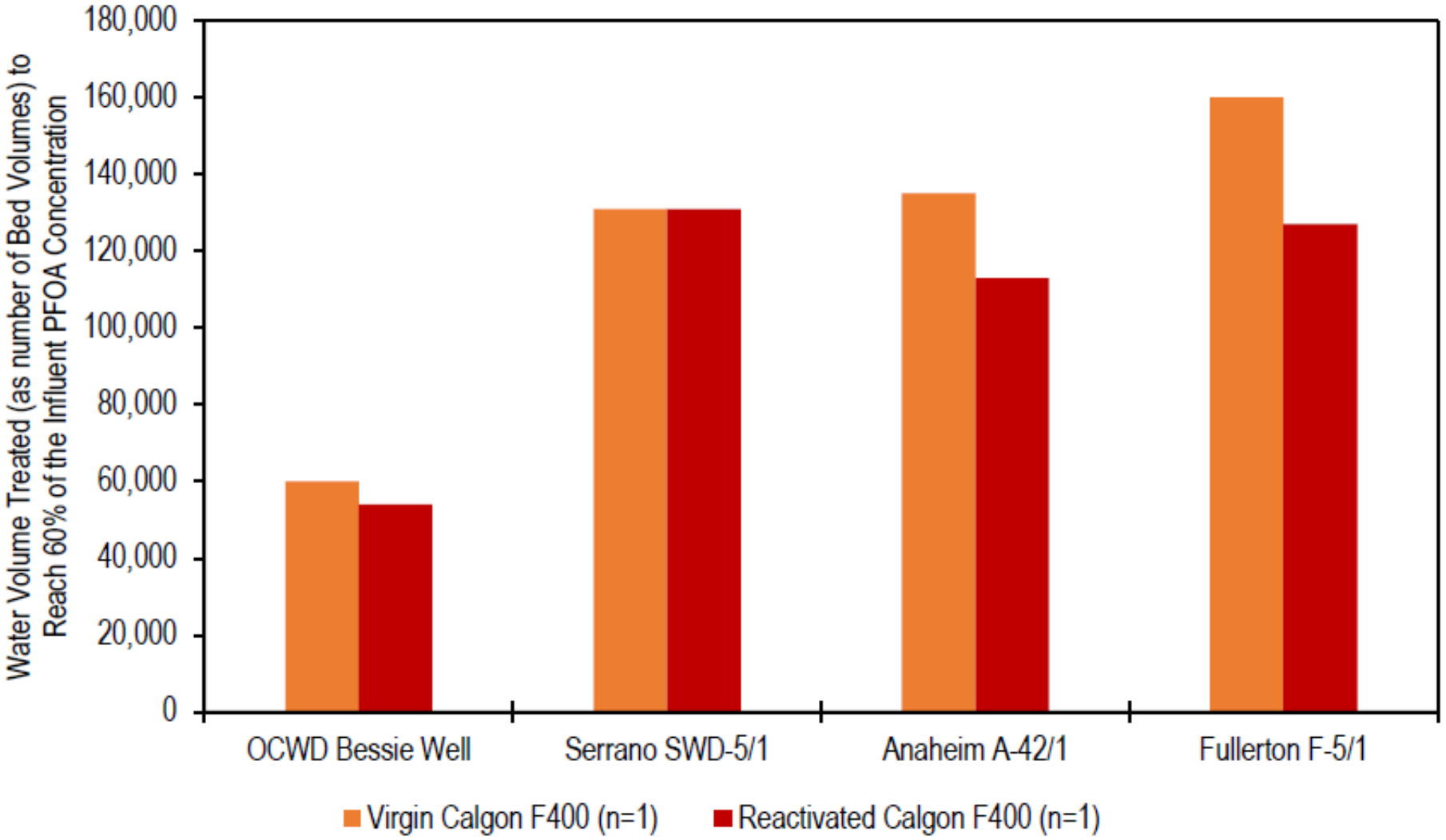
Drum Filling from different producers' for RSSCT Testing

RSSCT– Lab Testing



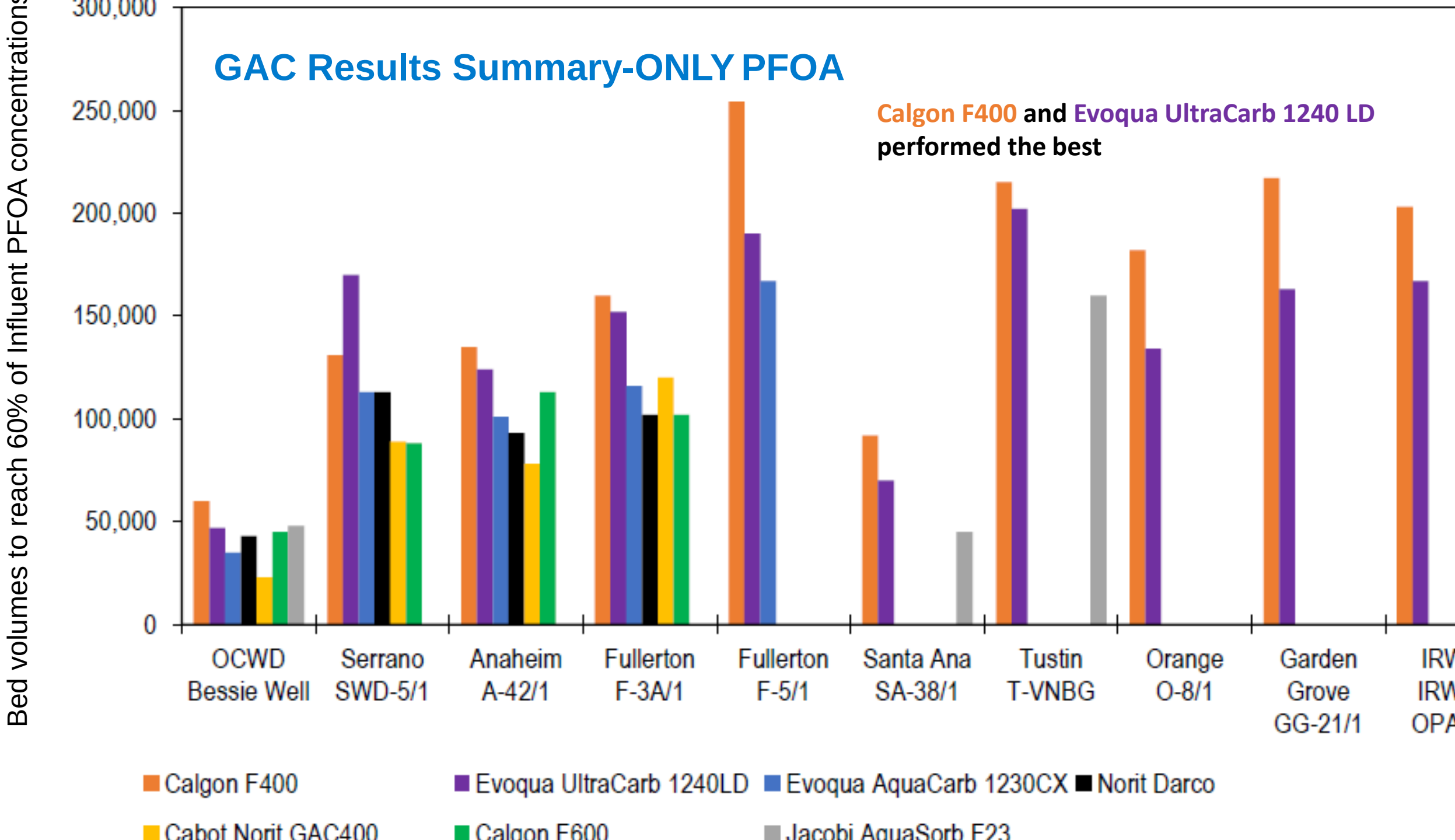
LAB (Battelle, Ohio)

Calgon F400: Virgin & Reactivated

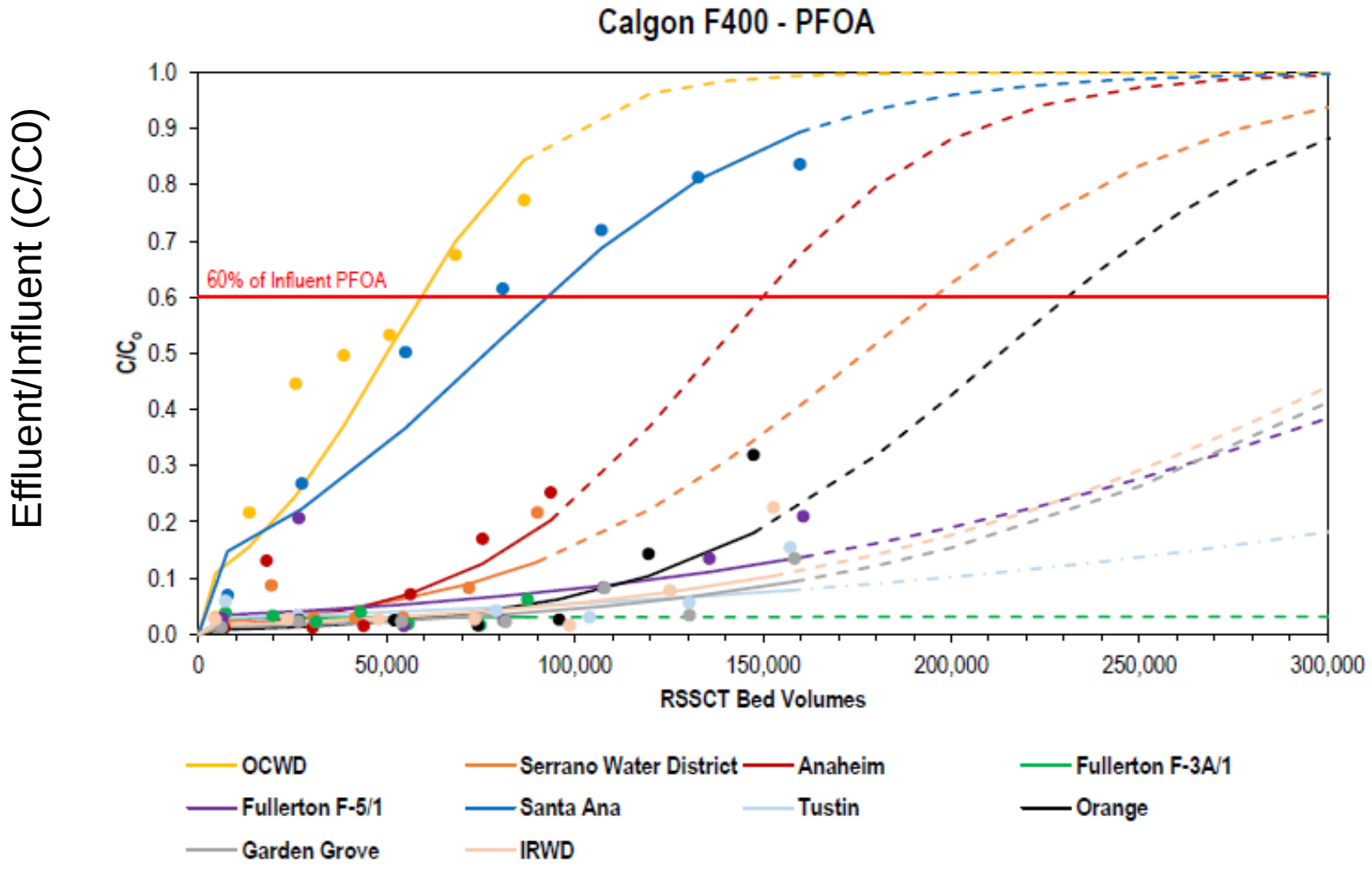


- Virgin GAC may provide longer life with lower DOC
- GAC performance varied by the water producer/water quality

GAC Results Summary-ONLY PFOA



Calgon F400: Producer Differences due to DOC level

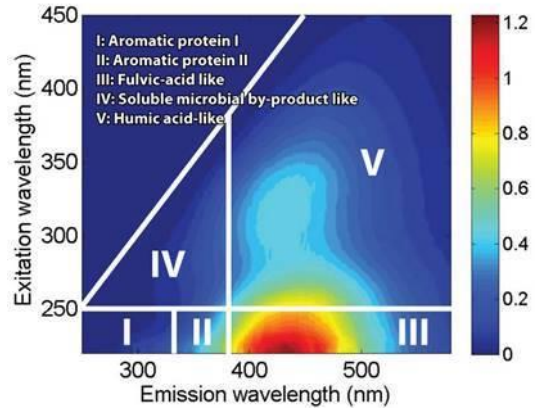


- Calgon F400 was the best performing based on our Pilot and Lab tests
- Large dependency of GAC performance on producer water quality (particularly DOC levels)
  - –Bessie (OCWD well) had the highest DOC
  - –DOC range is 0.2 to 1.6 mg/L

Influence of DOC Character

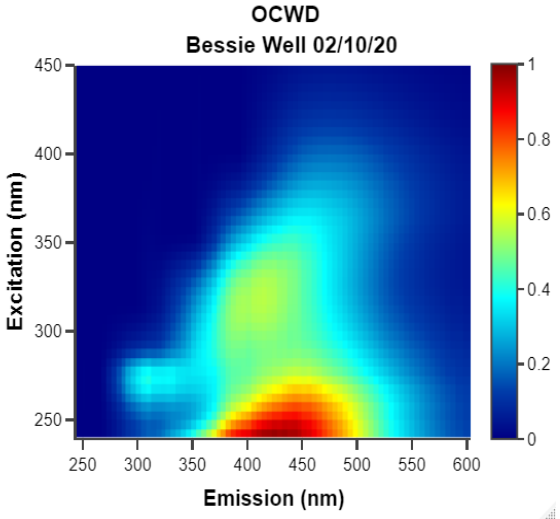
- Excitation Emission Matrix (EEM) Fluorescence Spectroscopy

Heat Maps

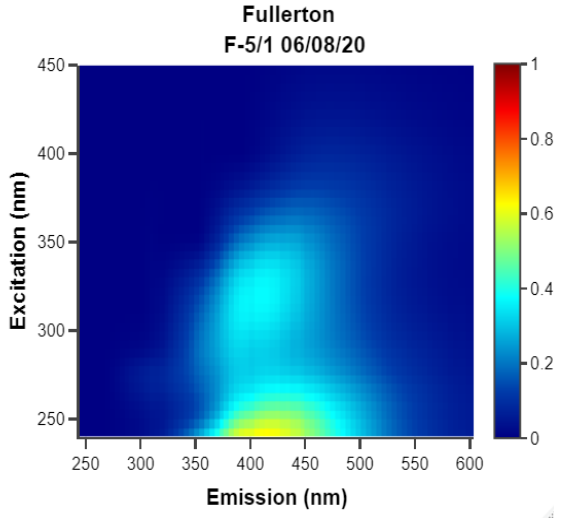


- Five excitation−emission regions:
  - –Aromatic proteins (I, II)
  - –Fulvic acids (III)
  - –Hydrophilic acids (IV)
  - –Humic acids (V)

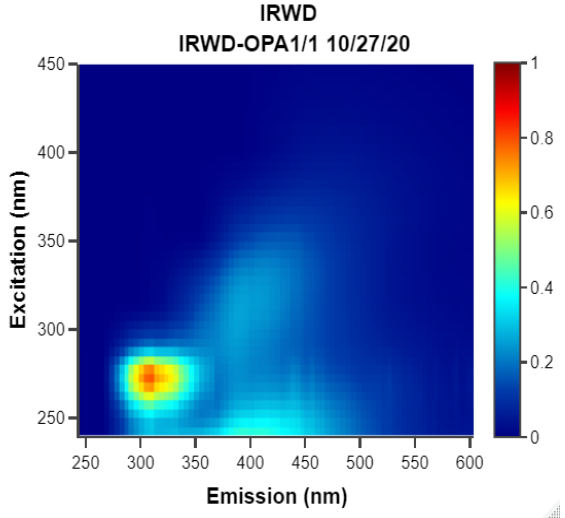
DOC=1.6 mg/L



DOC= 1.44 mg/L

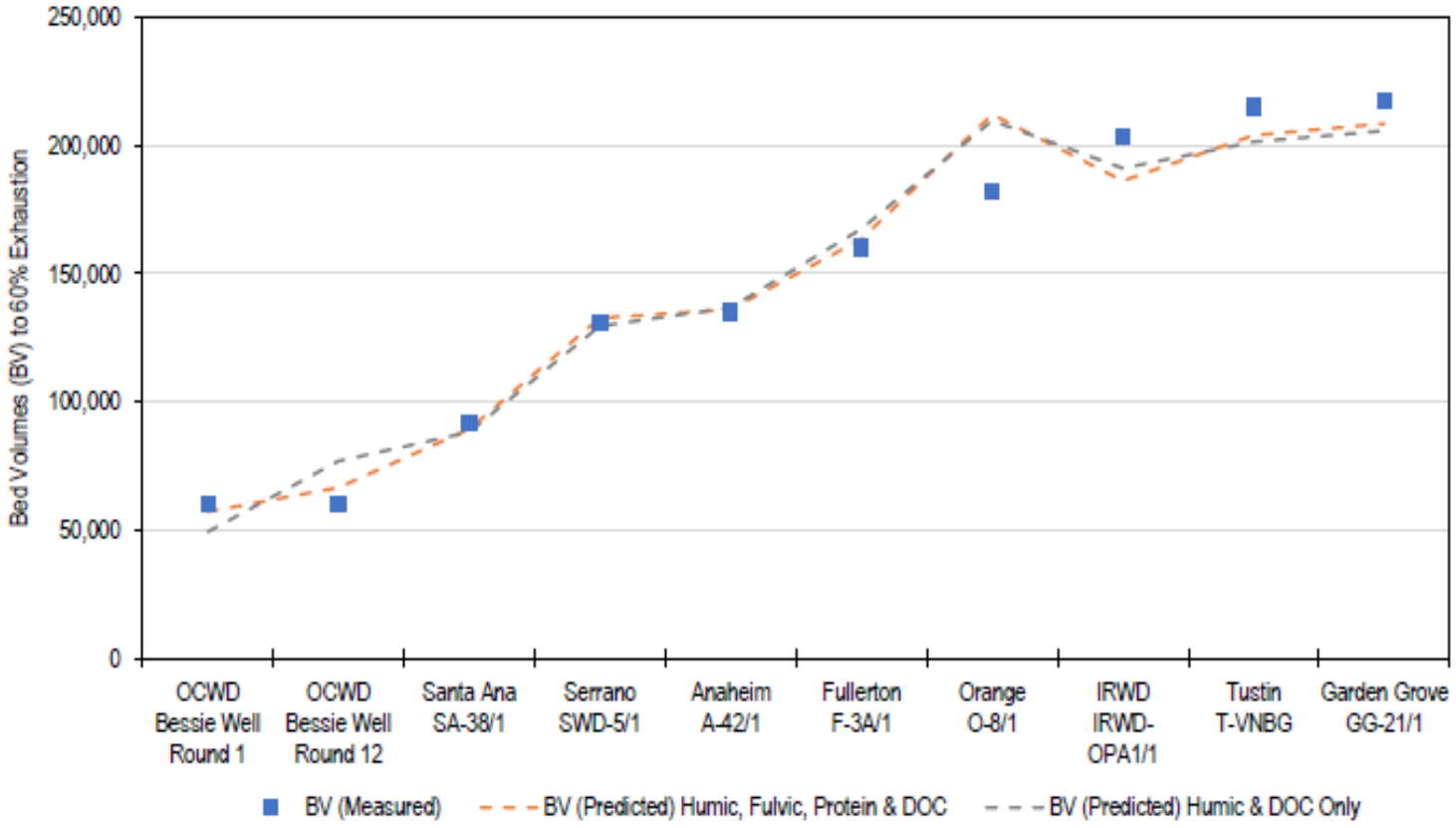


DOC= 0.47 mg/L



- Provided in fluorescence units (AFU)

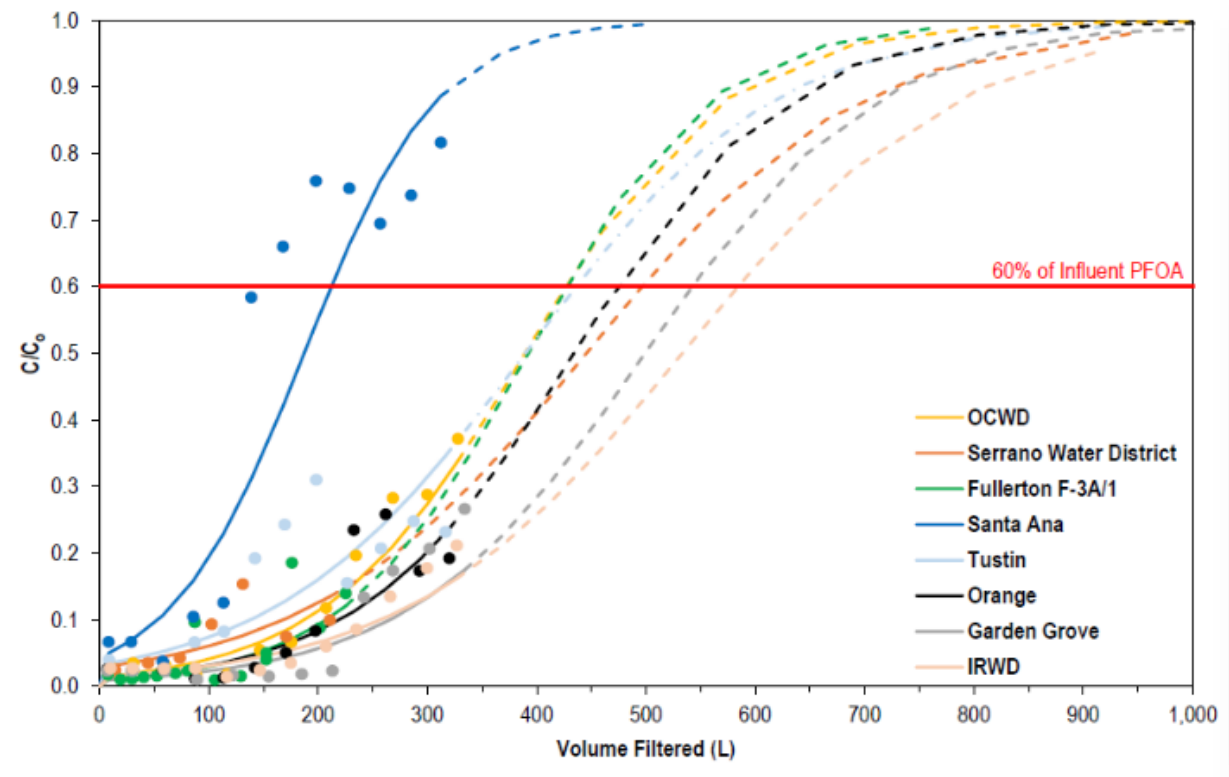
Multi-variable Regression

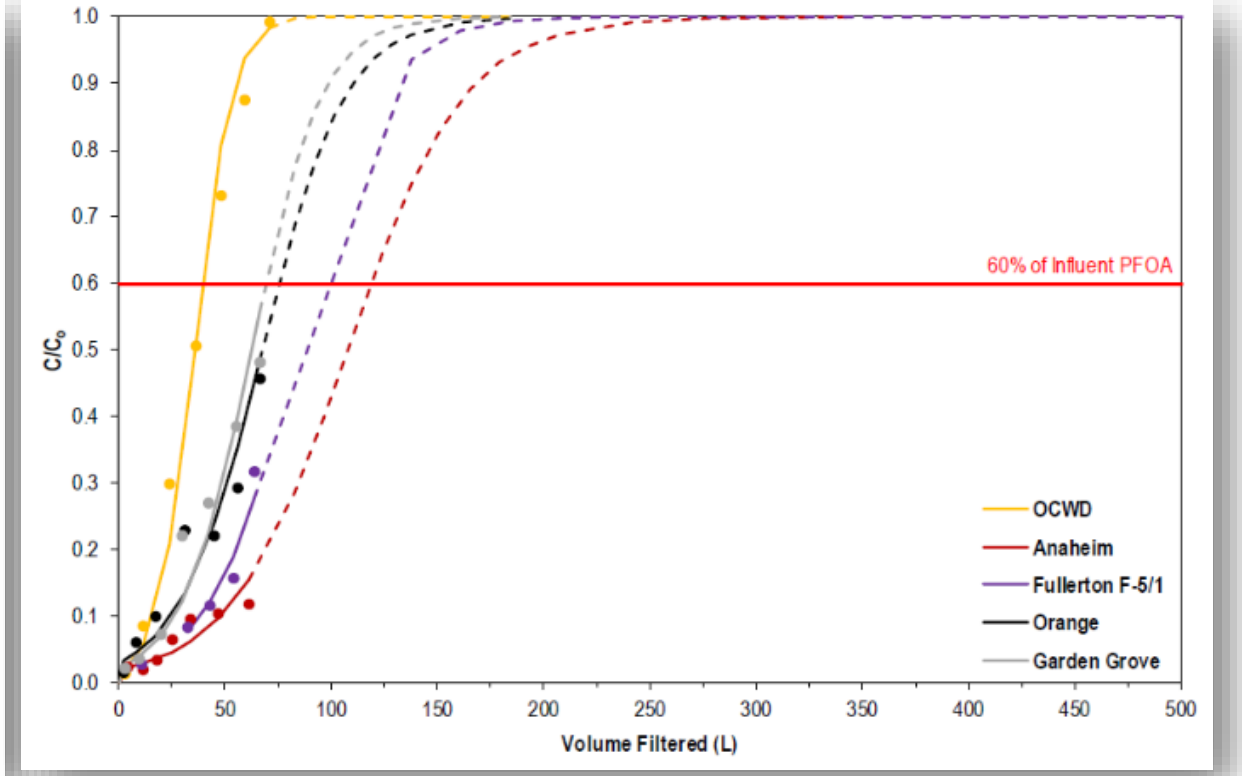


- Evaluated influence of
  - DOC
  - Humic acids
  - Fulvic acids
  - Aromatic proteins
- DOC and Humic acids were significantly corelated with the data ($p<0.05$)
- GAC performance can be predicted based on DOC and Humics ONLY

$$BV60\% = 241748 - 9772(HA{:}\ AFU) - 69482(DOC{:}\frac{mg}{L})$$

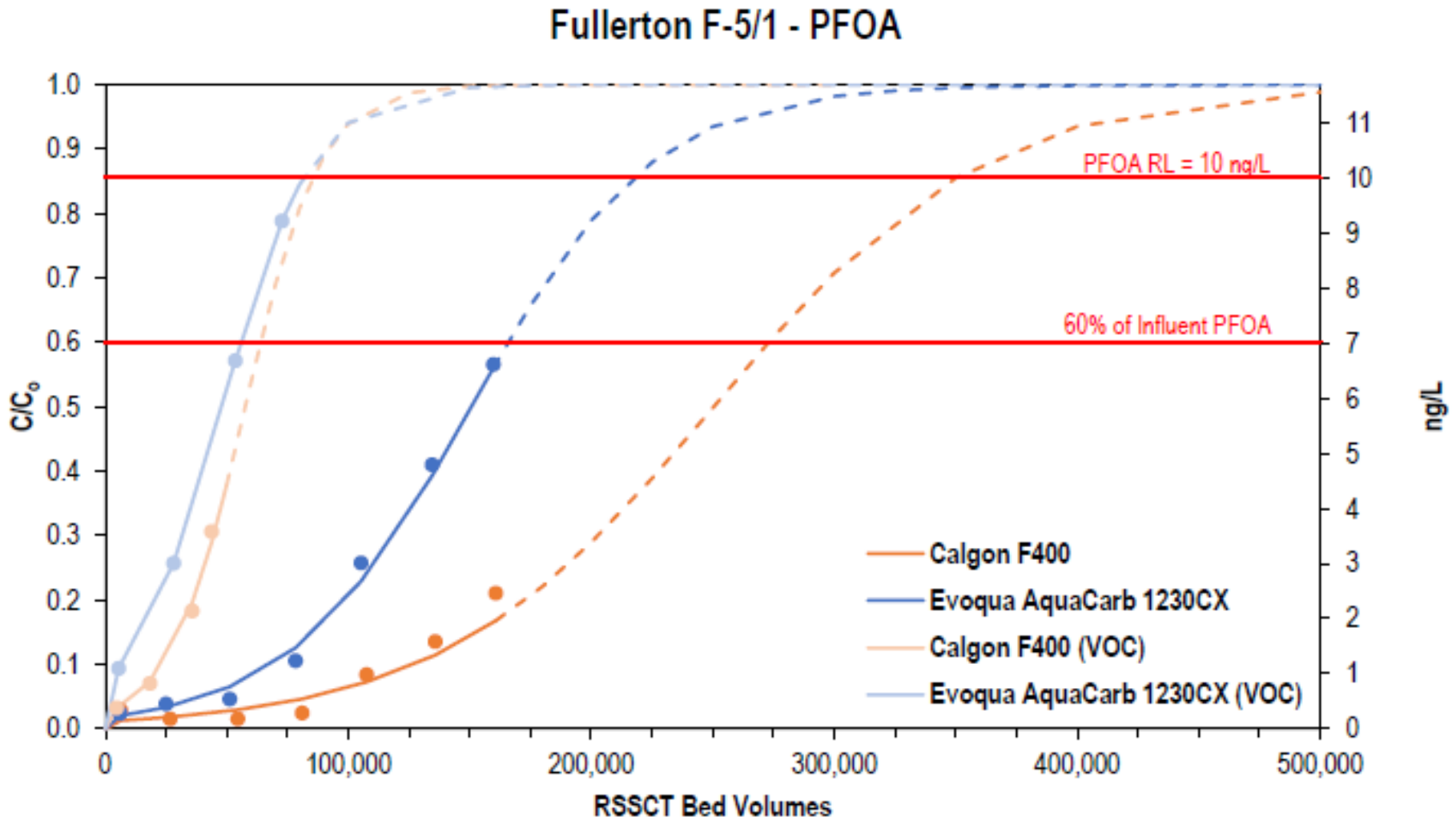
Alternative Adsorbents (Left; Cetco FS200)



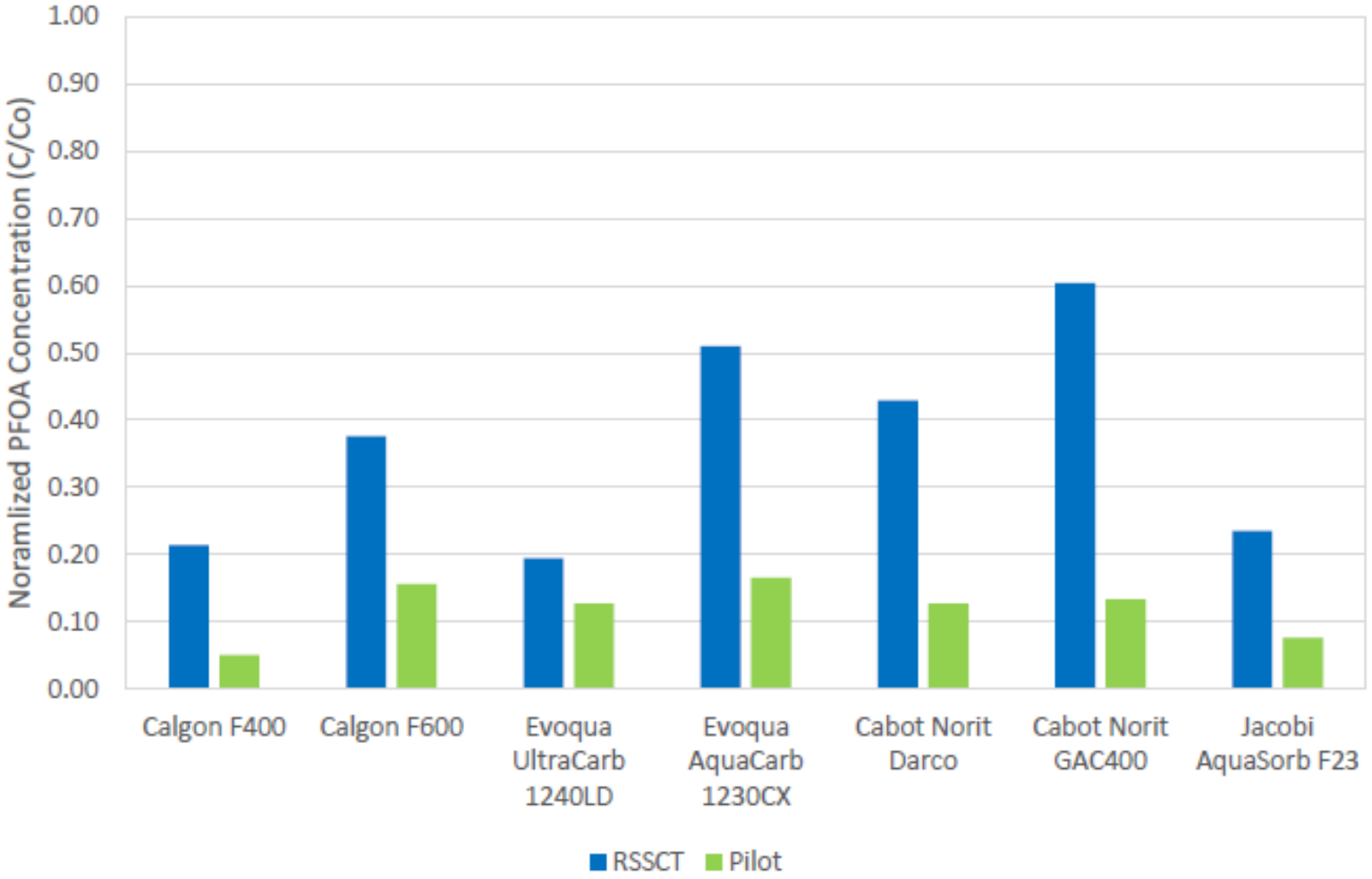


- Fluoro-Sorb 200 performed superior to another alternative adsorbent with later PFOA breakthrough
- Little difference among different producers except Santa Ana
- Alternative adsorbent performance is less impacted by DOC as compared to GAC
- FS200 had same superior results in the pilot

Addition of VOCs

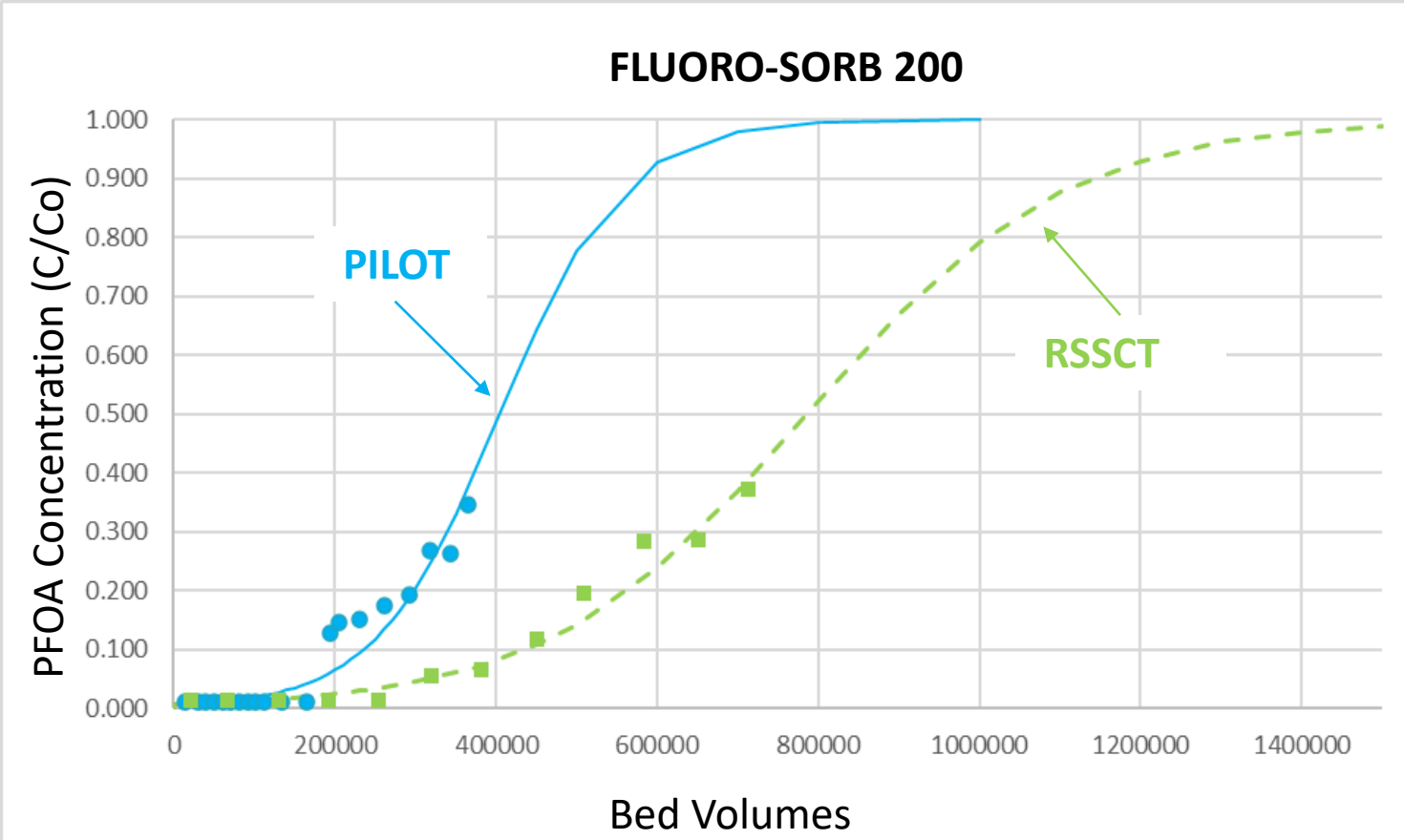


RSSCT to Field-Scale Comparison for GAC



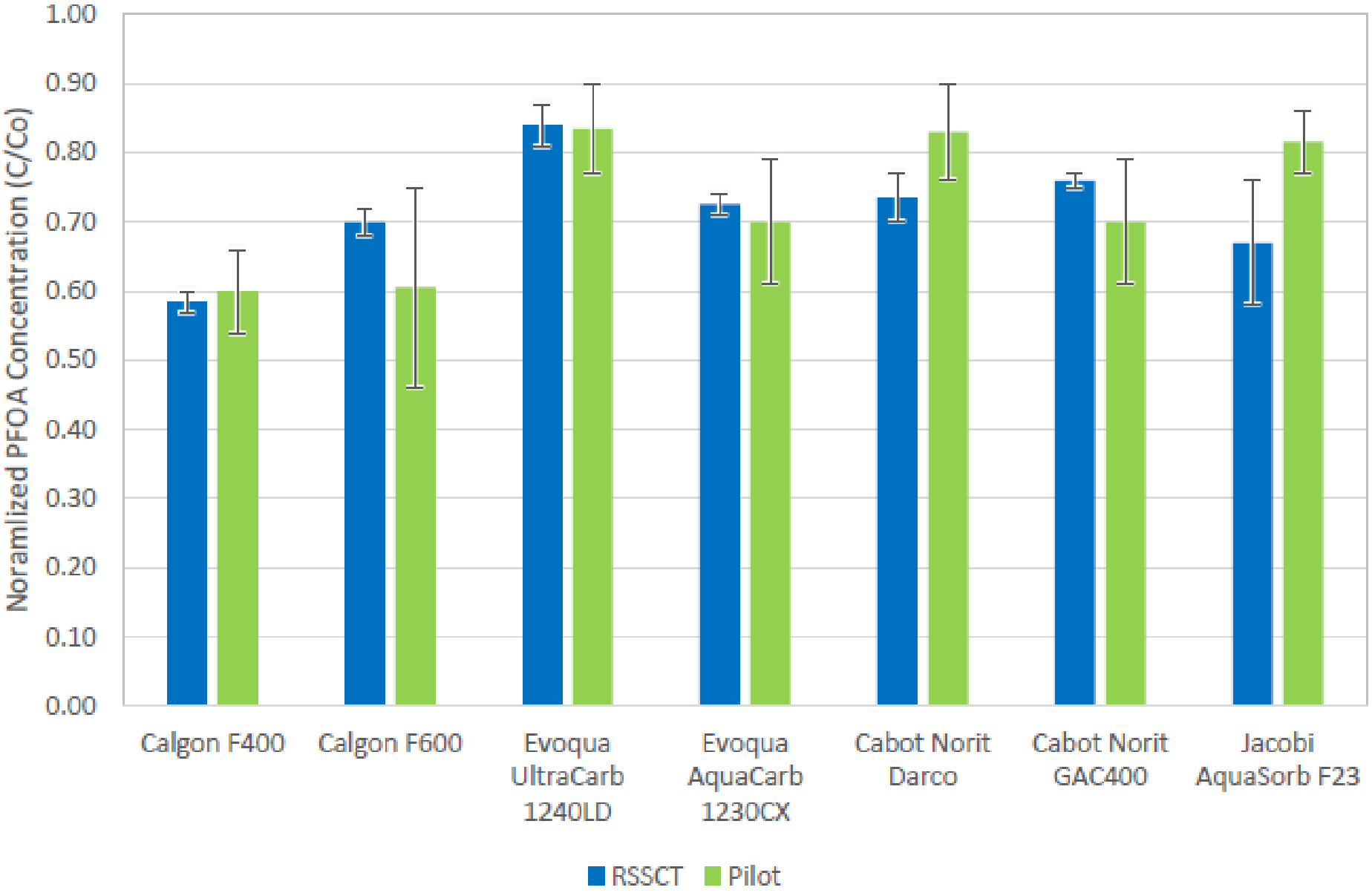
- Systems evaluated at 150 days of operation (~21,600 BV)
- RSSCT exhibits faster breakthrough in every product
  - –Conservative when assessing initial breakthrough

RSSCT to Field-Scale Comparison for FLUORO-SORB



- CETCO FLUORO-SORB 200 RSSCT showed much later PFOA breakthrough than pilot (*not conservative!*)
  - RSSCT data predicted ~2x greater runtime than actual from pilot

RSSCT to Field-Scale Comparison (cont.)



- Systems evaluated at <u>390 days</u> of operation (~56,000 BV)
- RSSCT predictive of full-scale at typical lead bed changeout exhaustion
- F600, GAC400 greater C/C_o for RSSCT
  - –Within estimated margin of error of testing

Generalized Cost Evaluation

- Costs for the 2 best GACs (Calgon F400 and Evoqua UC1240LD) were similar across sites within ~10%
  - Longer media life for lower DOC water
- Class IV estimates indicate total unit cost ($/acre-ft) for water treatment (capital + O&M) were GAC > IX >> FS200
- Nanofiltration projected to have the highest total unit water costs compared to all media technologies

Conclusions

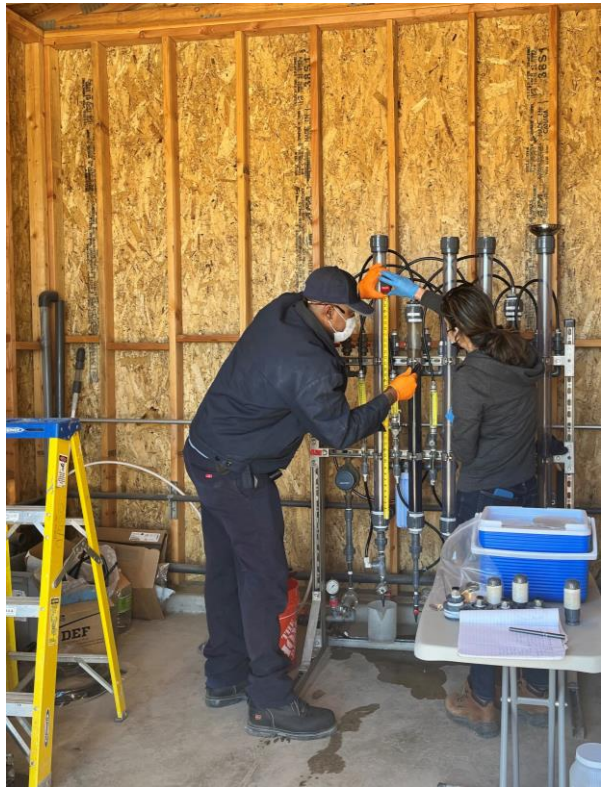
- All adsorbents tested can **successfully remove PFAS** to meet California water quality guidelines
- **Bench- and pilot-scale testing useful** to select adsorbents: Certain products had longer life removing PFOA
- Bench-scale testing revealed strong **dependency of GAC life on DOC** concentration and character
- Comparing RSSCT results to pilot-scale **validates the use of RSSCT for GAC** (i.e., predicts PFAS breakthrough fairly well), **but not the alternative adsorbents** where RSSCT predicts significantly later breakthrough of alternative adsorbents

Conclusions (cont.)

- All 4 **IX products showed later breakthrough of sulfonates** (PFOS, PFHxS) **and short-chain PFAS** (PFBS) relative to all 8 GACs
- **Alternative adsorbents**: Encouraging results though varies by product
- While all media removed PFAS from water, performance (i.e., ***lifetime*** between media change-outs) **varied dramatically**.
- In our study, Class IV estimates (+50%/-30%) indicate total unit water cost (capital + O&M) as GAC > IX >> FS200

What Now?



Phase I-✓

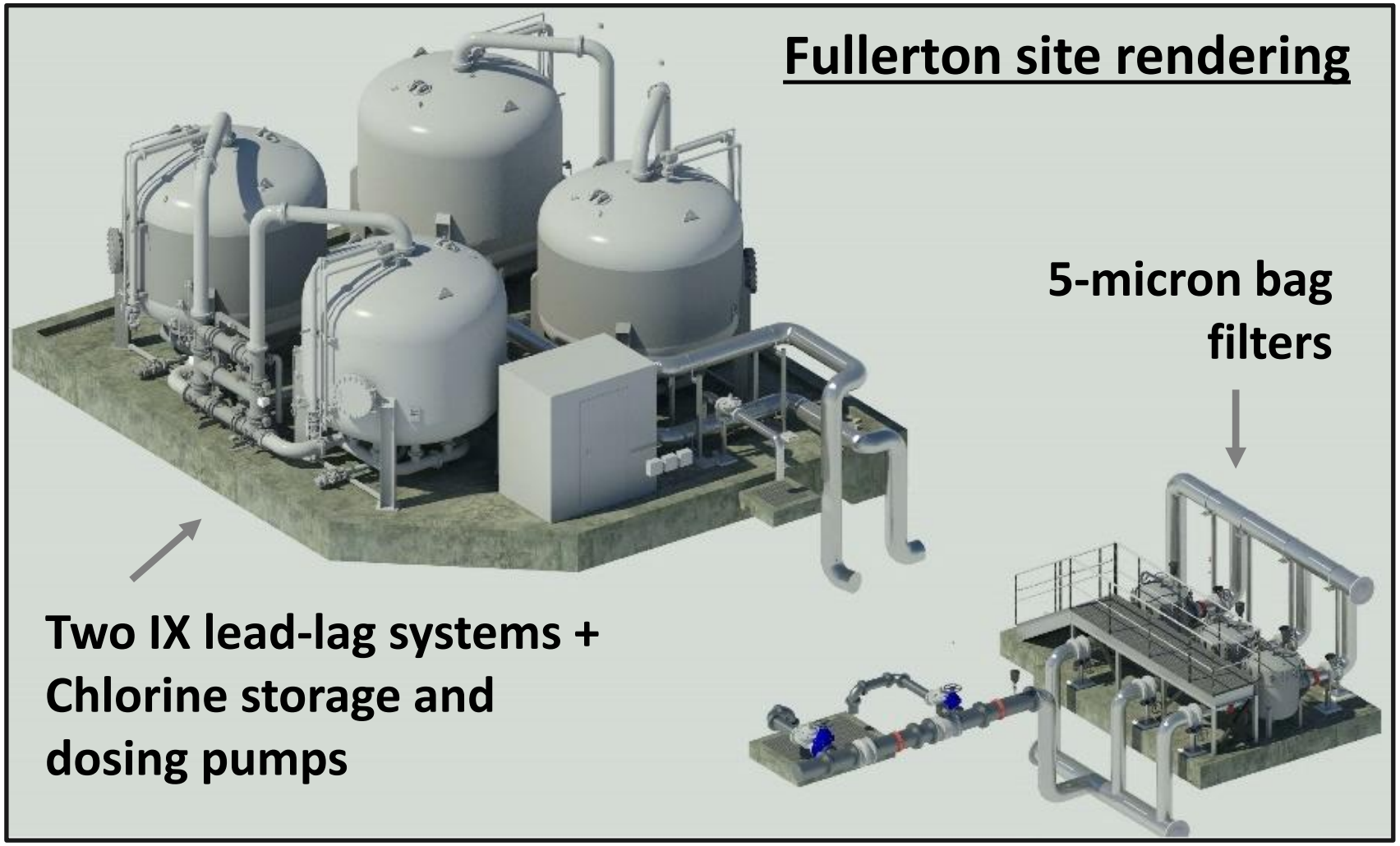
Phase II and III-Ongoing

Different Phases of Pilot

PHASE II AND III ADSORBENTS

	No.	Company	Headquarters	Product Name	Type
PHASE II ONLINE	1	Evoqua	Pittsburgh, PA	PSR2+	IX
	2			APR-2	IX
	3	LanXESS	Cologne, Germany	Lewatit® TP108DW	IX
	4	ResinTech	Camden, NJ	SIR-110-HP	IX
	5	Purolite	King of Prussia, PA	Purofine D6515	IX
	6	CETCO	Hoffman Estates, IL	FLUORO-SORB® FLEX	Alternative
PHASE III ONLINE	7	Calgon	Moon Township, PA	CalRes 2304	IX
	8	Jacobi	Kalmar, Sweden	PFCR-2	IX
	9	ECT2	Portland, ME	Sorbix LC6	IX
	10	Confidential Resin	-	Leading manufacturer	IX
Future candidate	1	ABS Materials	Wooster, OH	PQ-Osorb®	Alternative

How is Pilot Data Being Used? Supporting Initial IX Media Procurements & System Permits?



- IX selected for majority of the Orange County PFAS treatment systems thus far
- Based on bid pricing and pilot performance, Evoqua PSR2+ IX resin predominantly selected for the first 3 systems coming online
- **Thus, the pilot data was crucial in selecting treatment system media**


Serrano Water District well site
Most Producers have selected IX due to footprint constraints


Serrano Water District well site
Treatment for 2 wells (3,200 gpm max capacity)

Yorba Linda Water District

Centralized treatment for 10 wells (25 mgd max capacity)
6 pre-filters
11 trains (= 22 vessels lead/lag)

Yorba Linda Water District

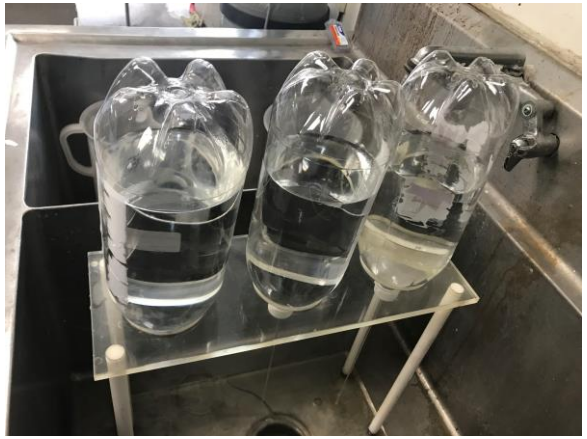
Centralized treatment for 10 wells (25 mgd max capacity)
6 pre-filters
11 trains (= 22 vessels lead/lag)

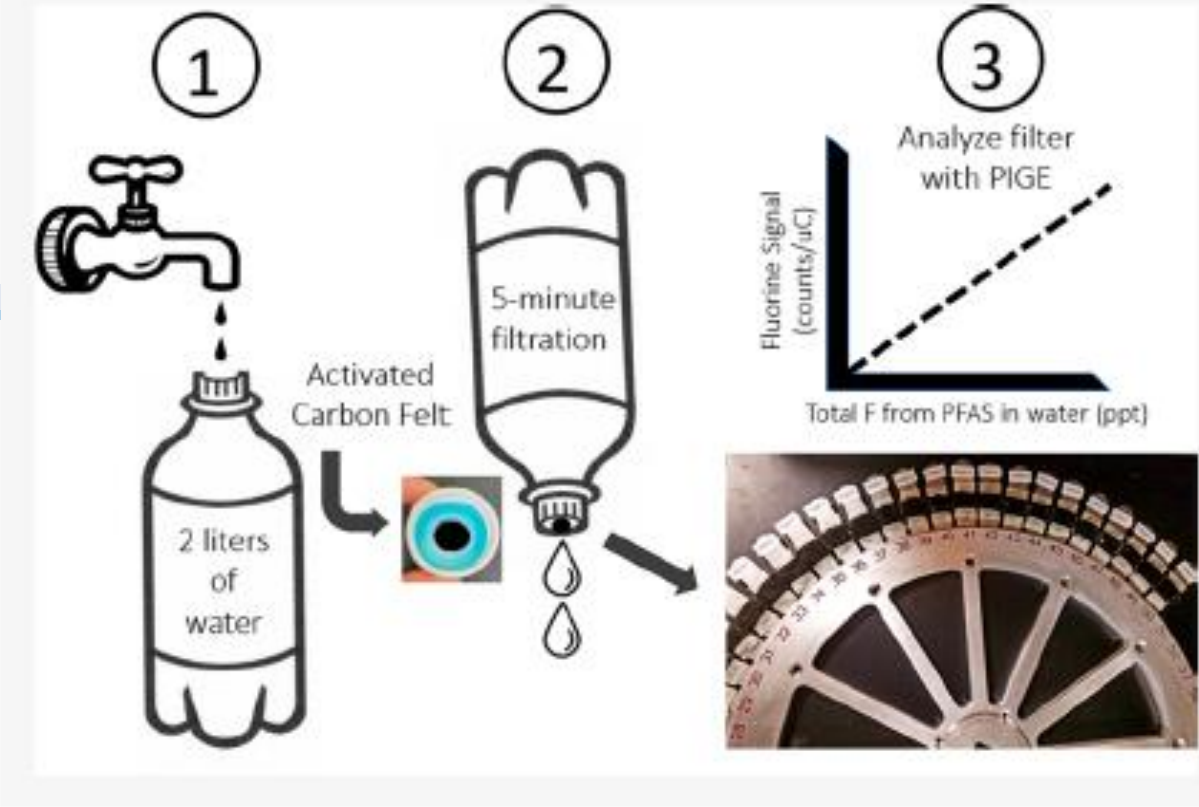
What Else?

Related Research Underway

Funding Agency	THE Water Research FOUNDATION + ORANGE COUNTY WATER DISTRICT	THE Water Research FOUNDATION + ORANGE COUNTY WATER DISTRICT	ORANGE COUNTY WATER DISTRICT
Project	Method development for screening for Total PFAS in water	Alternative methods to assess IX and AA at bench-scale	*In-situ* removal of PFAS during MAR using horizontal PRB
Hopes and Dreams	Quickly, cheaply, measure sum PFAS	Rapid lab test, avoid lengthy piloting for IX and AA	Minimize PFAS introduced to aquifer via recharge projects

Related Research Underway





Tighe et al., 2021 (ACS ES&T Water)

THE Water Research FOUNDATION

Method for Total PFAS by PIGE (Particle Induced Gamma Ray Emission)

- Project Lead:
- University of Notre Dame

WRF Project title: *Application of a Novel Method to Estimate Total PFAS Content in Water* – #5102

Thank you!!

More Information: Meeta Pannu, mpannu@ocwd.com

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https://www.ocwd.com/what-we-do/water-quality/pfas/









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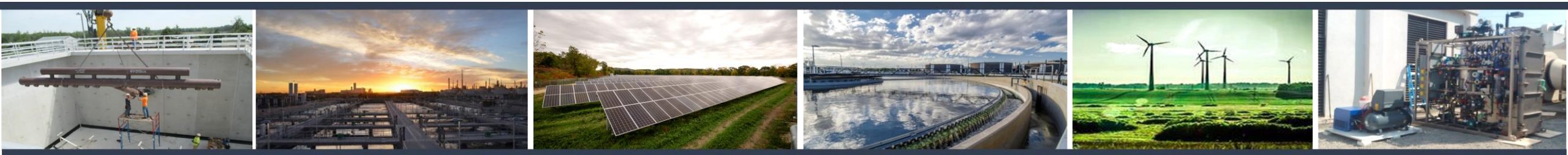
Questions?
Email Marisa Waterman at mwaterman@aaees.org with any questions you may have.



Leadership and Excellence in Environmental Engineering and Science