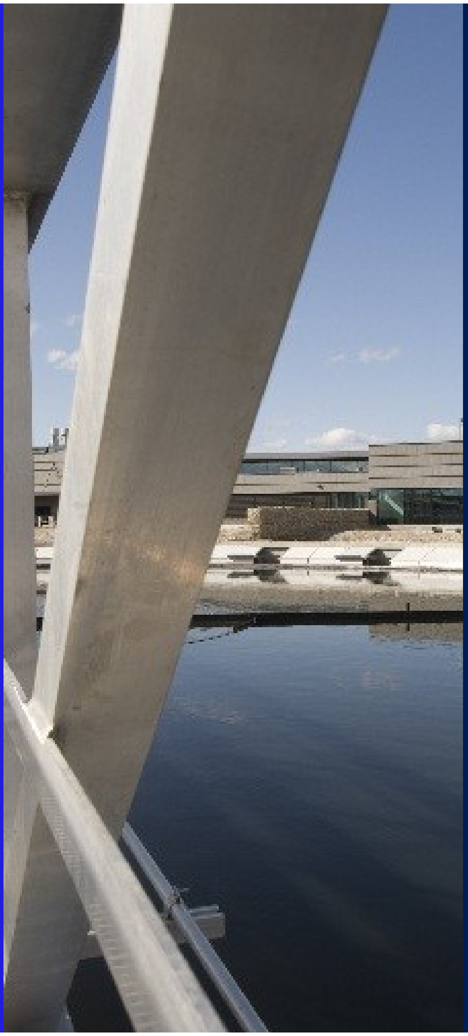
Jacobs Challenging today. Reinventing tomorrow.

In the kNOW Webinar

PFAS Considerations in the Water Sector

May 12, 2020



Welcome & Introductions

Why this issue is Important

- Peter Nicol, Jacobs Global Vice President, Global Director for Water

PFAS in Our Water Cycle

- Megan Plumlee, PhD, PE, Director of Research for the Orange County Water District
- Scott Grieco, PhD, PE, Jacobs Global Technology Leader | Drinking Water & Reuse

PFAS Impacts on Residuals Management

- Jeff Prevatt, PhD, Deputy Director of Pima County Regional Wastewater Reclamation Dept
- Todd O. Williams, PE, BCEE, Jacobs Global Technology Leader | Residuals Resource Recovery

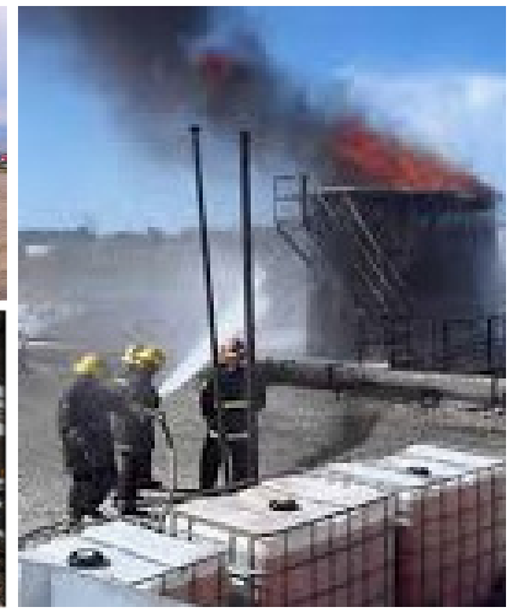
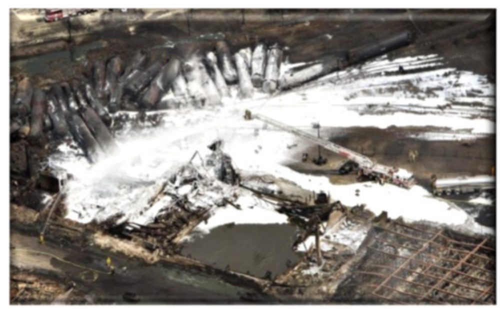
Questions & Answers

Uses

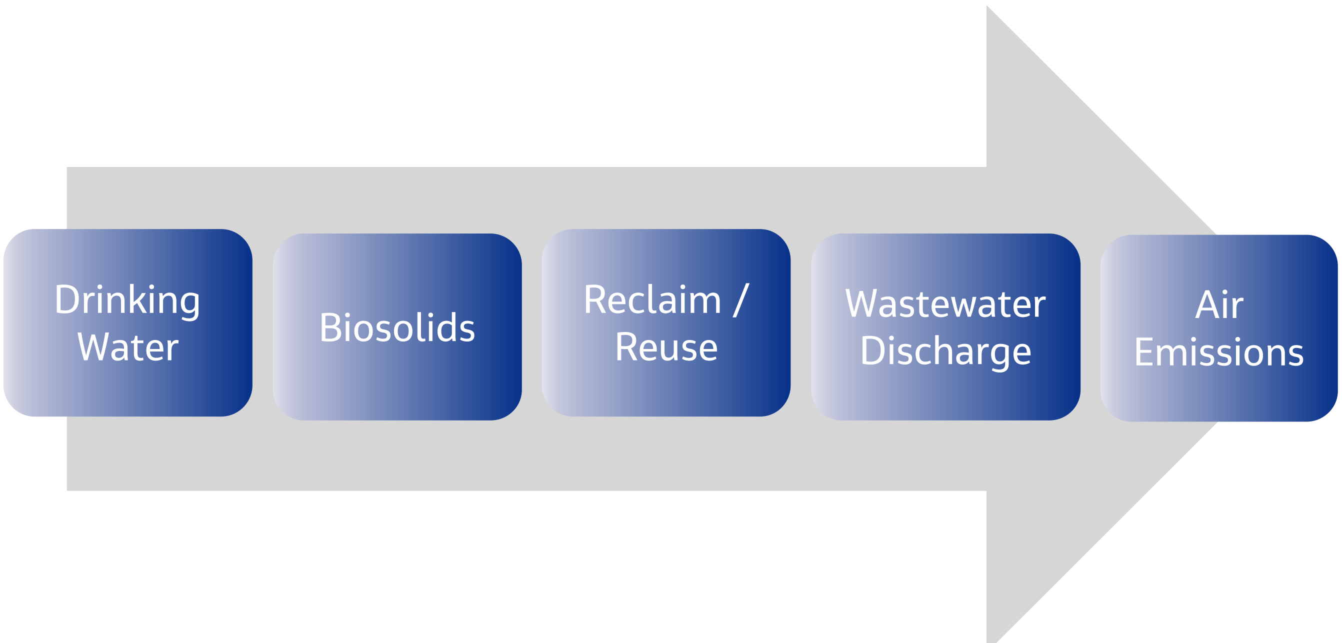
- **Aqueous Film-Forming Foam (AFFF)**
  - Airports / Airlines
  - Railroads
  - Fire Departments
  - Oil & Gas
- **Manufacturing**
  - Metals, Plating
  - Automotive
  - Chemicals
  - Pulp & Paper
- **Commercial**
  - Car Wash Waxes
  - Electronics





Where are We Now? What's Next?



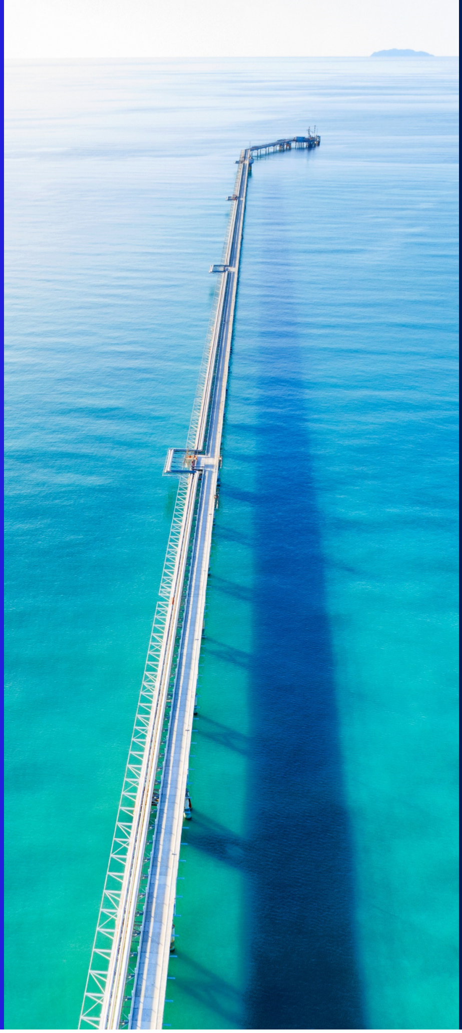
Jacobs

Challenging today.
Reinventing tomorrow.

PFAS in Our Water Cycle

Megan Plumlee, PhD, PE – Orange County Water District

Scott Grieco, PhD, PE – Jacobs

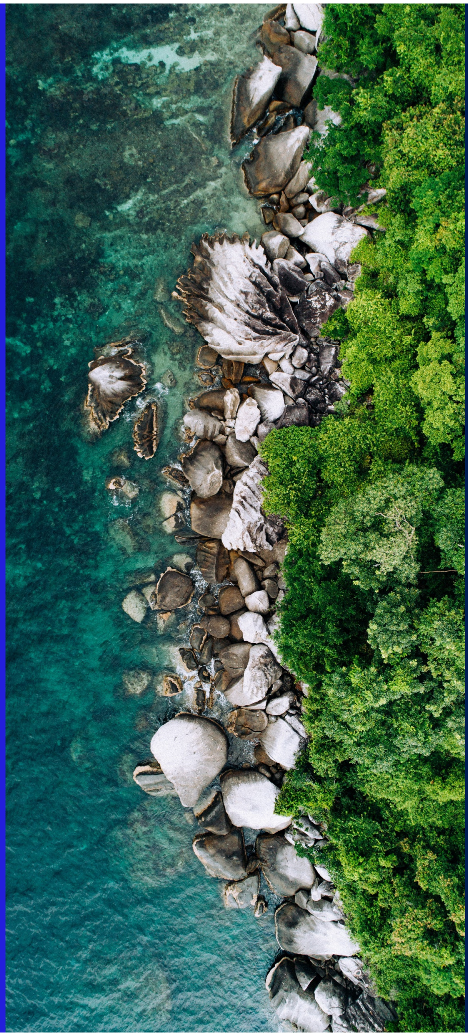


Jacobs Challenging today. Reinventing tomorrow.

PFAS Experience in Orange County, California

Megan Plumlee, PhD, PE – Orange County Water District

May 12, 2020



Megan Plumlee

Director of Research, Orange County Water District

Megan Plumlee is OCWD’s Director of R&D, where she oversees a team researchers that conducts applied research and technology evaluations.

Her current work includes oversight of OCWD’s PFAS treatment study, which is testing options for removing PFAS from groundwater.

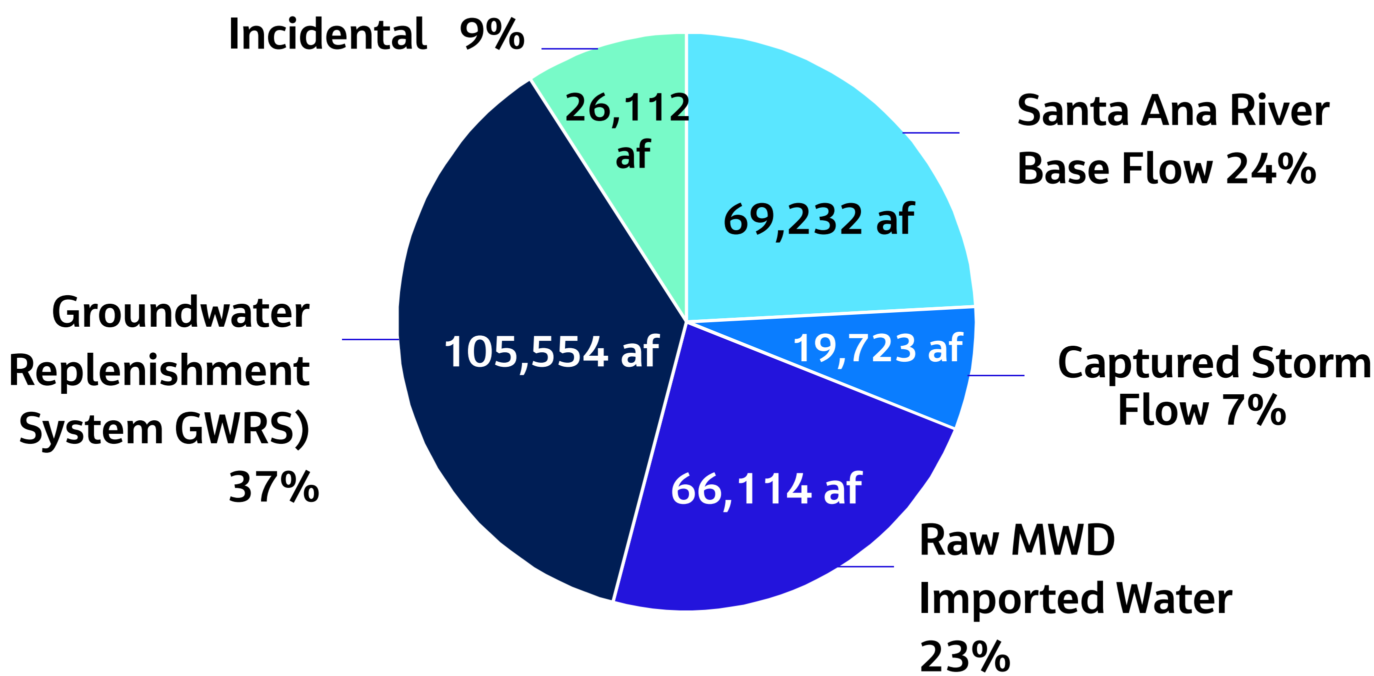
Orange County Water District

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

Santa Ana River (SAR)

- SAR baseflow is dominated by upstream tertiary wastewater discharges
- Occurrence of PFAS in conventionally treated, municipal wastewater is well-established in literature
- PFAS also detected in stormwater runoff to SAR

Managed Aquifer Recharge Portfolio WY 2017-18
Total Recharge = 286,735 af (Local dry year)



Extent of PFAS Impact in OCWD Service Area

- **11 water retailers** (i.e., groundwater "Producers") in the OCWD service area (up to 71 wells) impacted by 10 ppt PFOA Response Level
- **Up to ~ 1/3 of groundwater basin** production (100,000 afy) unable to be served
- **~ $50 million/year** additional alternative water supply cost for treated imported surface water

Current California DDW NL/RLs:

Notification Levels:

PFOA = 5.1 ng/L

PFOS = 6.5 ng/L

Previous Response Level:

PFOA + PFOS = 70 ng/L

***RL was lowered Feb 2020 !**

PFOA = 10 ng/L

PFOS = 40 ng/L

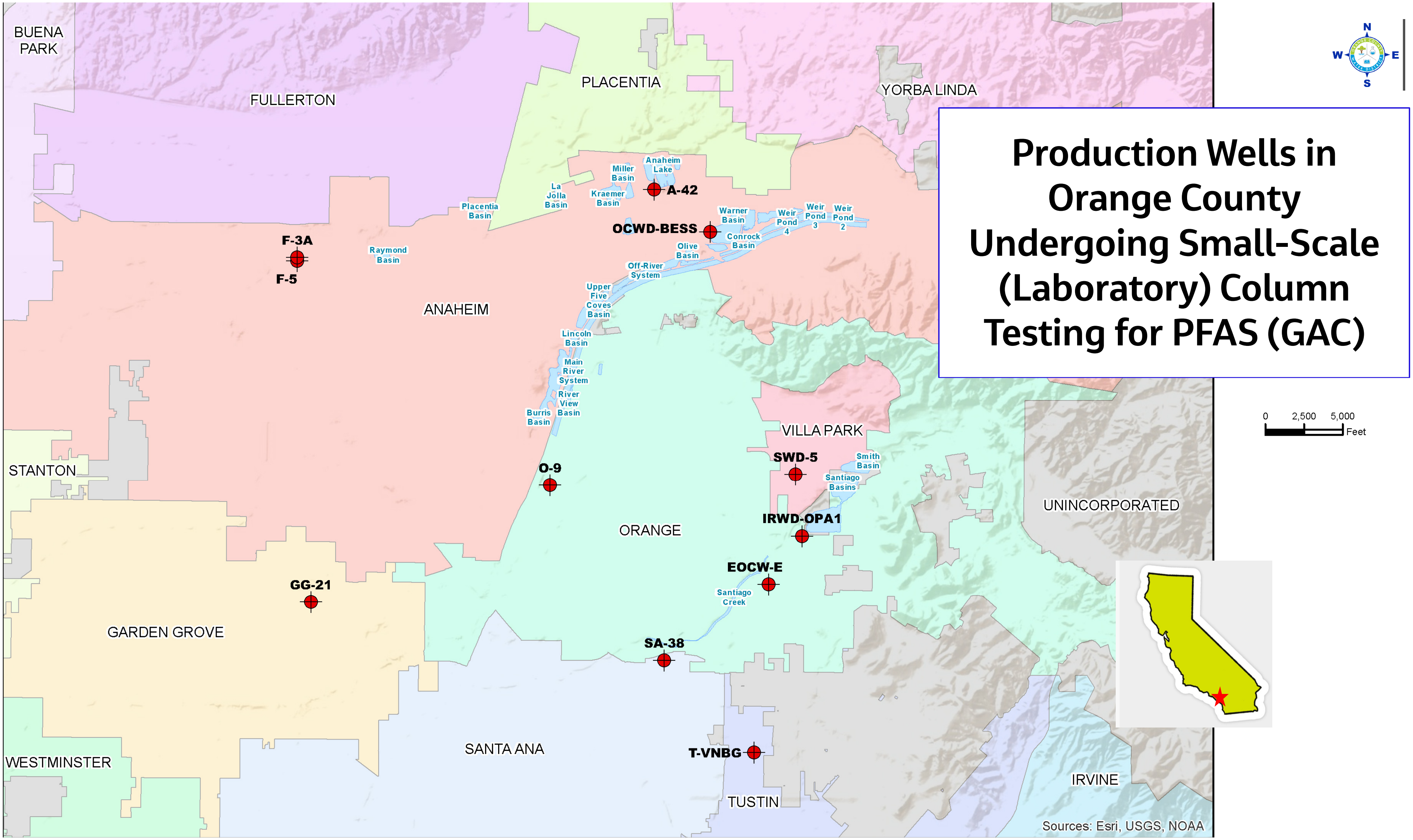
*Public Health Goal (PHG) process has begun

PFAS Treatment Study at OCWD

Objectives:

- Evaluate / demonstrate performance of various products (GAC, IX, novel adsorbents)
  - Laboratory scale testing
  - Pilot scale testing
- Use performance with unit cost to identify best value for different well water qualities (i.e., water retailers' wells)

Production Wells in Orange County Undergoing Small-Scale (Laboratory) Column Testing for PFAS (GAC)



OCWD Pilot Program for GAC, IX, and Novel Adsorbents

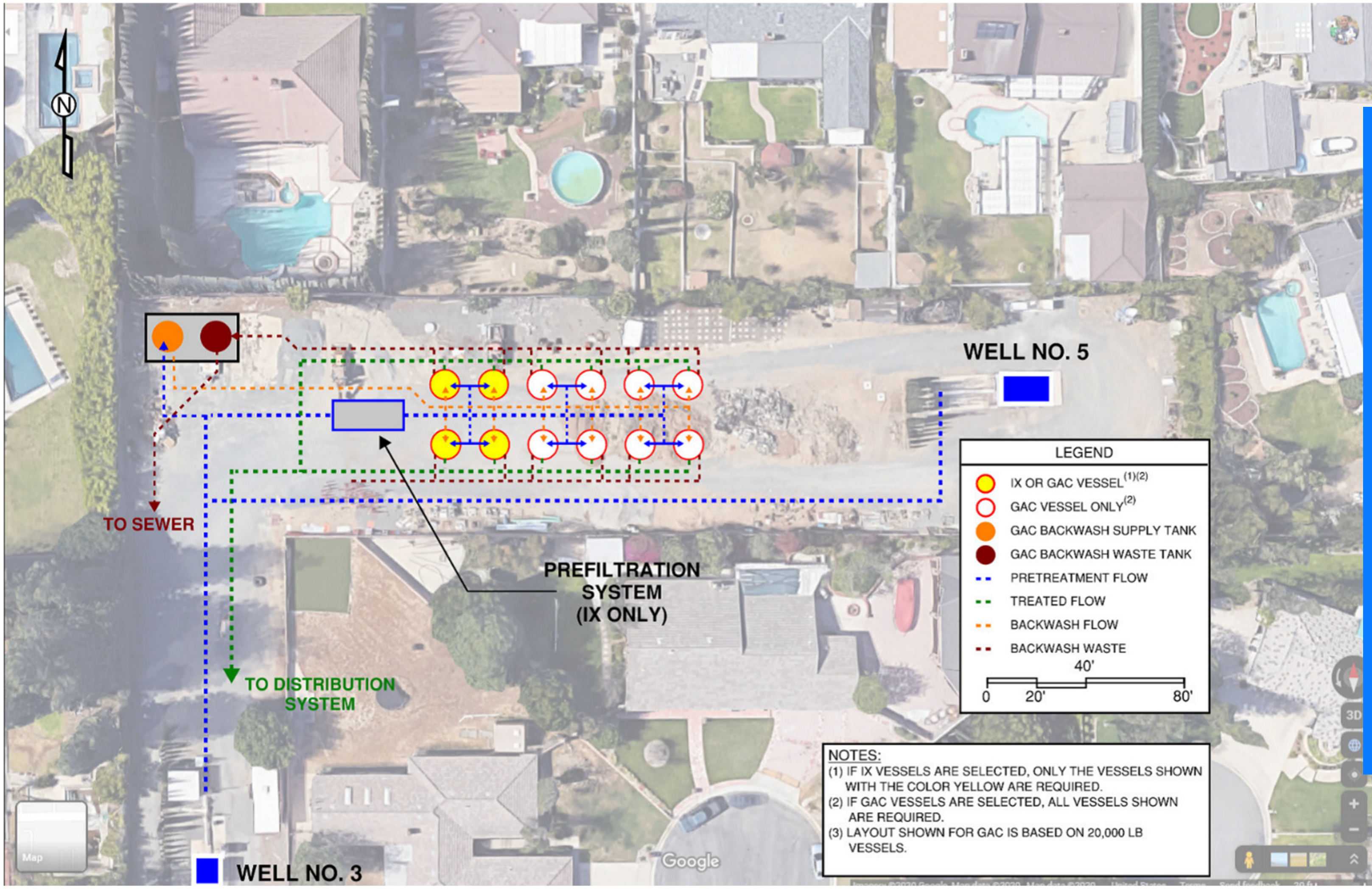
- Pilot adjacent to OCWD-owned non-potable well in Anaheim that supplies the water
- PFAS in well:
  - 14 - 23 ng/L PFOA
  - 19 - 27 ng/L PFOS

OCWD Pilot Program for GAC, IX, and Novel Adsorbents

8 GAC (10-min EBCT) + 4 IX (2-min EBCT) + 2 novel adsorbents

Also in Progress – OCWD Pre-Design Planning Study

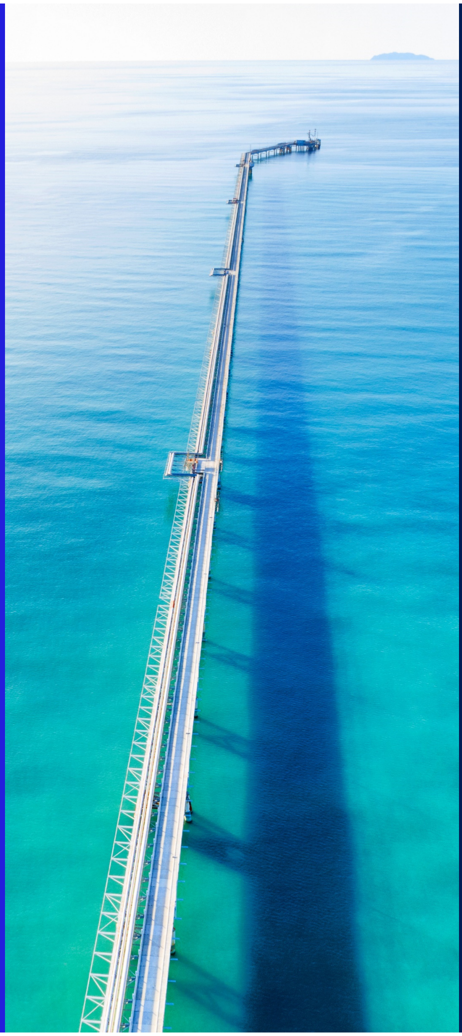
- Pre-design near complete for 10 cities / retailers
- Goal: bring treatment online within 1 to 3 years



Jacobs Challenging today. Reinventing tomorrow.

PFAS in Our Water Cycle

Scott Grieco, PhD, PE – Jacobs



Why are PFAS in Drinking Water?

Possible Sources:

- Fire training area released AFFF to the ground
- Industrial Release
- Wastewater reclamation - planned and defacto reuse
- Leaching from Biosolids or Beneficial Reuse Solids with PFAS

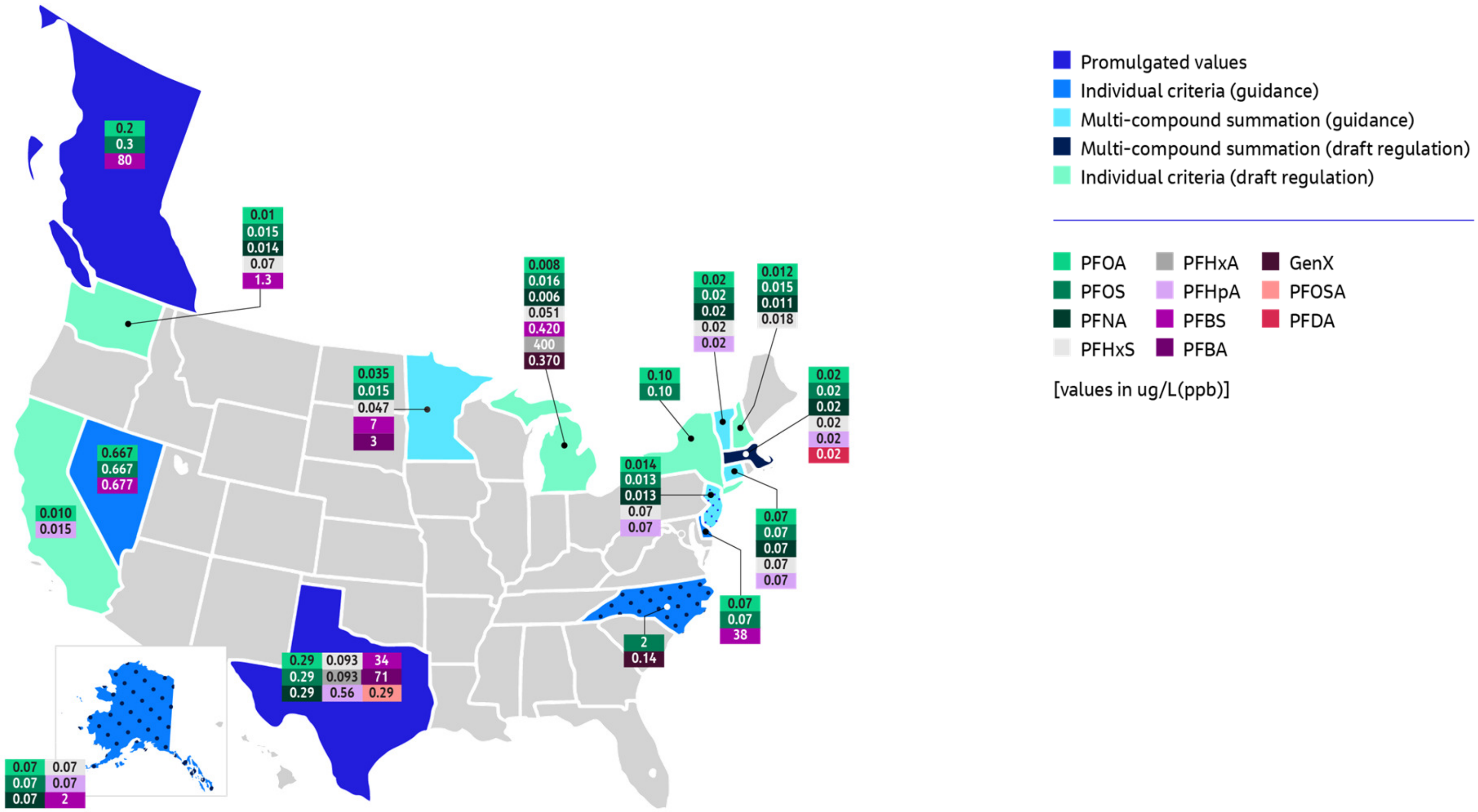
Lack of Consistent International Value for PFAS in Drinking Water

	PFOA	PFOS	PFHxS	PFNA	PFBA	PFBS	PFHxA	PFPeA	PFHpA	PFOSA	PFDA	6:2FTS	8:2FTS
US	70	70											
AUS	560	70	70										
CAN	200	600	600	20	30000	15000	200	200	200			200	200
DEN	100	100	100	100	100	100	100	100	100	100	100	100	100
GER	100	100	100	60	10000	6000	6000						
ITA	500	30			7000	3000	1000	3000					
UK *	300 to 90000	300 to 90000											

Values in (ng/L)

* Administrative Level 1 -3

PFAS - Regulated Inconsistently Across the US & Canada

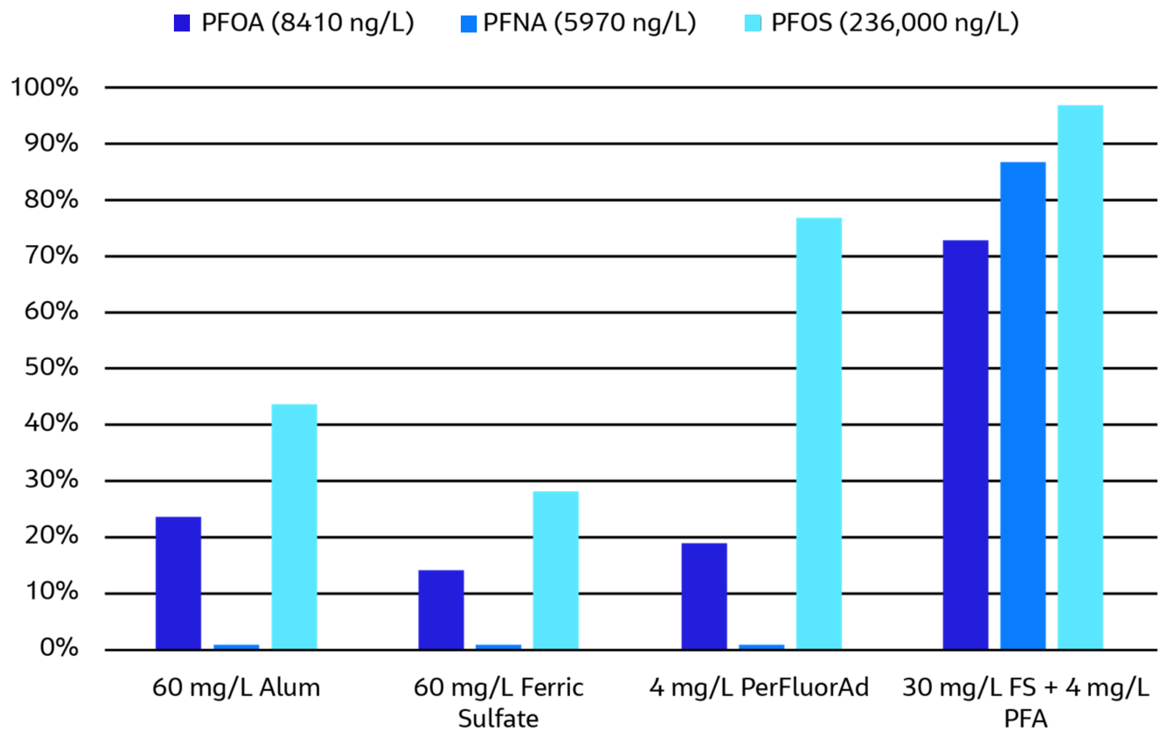


Conventional Water Treatment Processes that Reduce PFAS

- Air Stripping / Air Sparging (VOC removal)
  - Target PFAS not volatile
  - Ft-OH / other precursors show volatility
- **Chemical coagulation/precipitation**
  - Water turbidity removal
  - Softening
- Filtration/**Membranes**
  - Macro/microfiltration
  - **Reverse Osmosis (RO) / Nanofiltration (NF)**
- **Adsorption**
- Disinfection
  - Ultraviolet
  - Chemical (chlorine, chloramine)

Partial PFAS Removal with Coagulation / Flocculation

- Conventional commodity coagulants
- Specialty coagulants
  - Limited application / In development



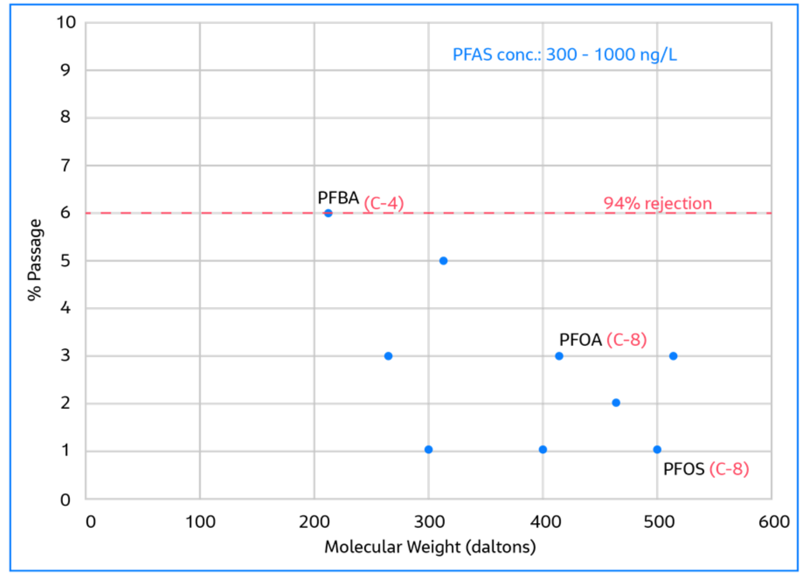
PFAS Removal with RO & NF

- RO is effective for removal
  - For long and short-chain PFAS

- Concerns
  - Expense
  - Managing liquid concentrates
  - Pretreatment (MF/UF)
  - Membrane removal function of molecular weight & chargé

- Areas of development
  - Effectiveness of precursor removal (RO & NF)
  - Lower pressure NF applications

PFAS Passage through Dow NF-270 (polypiperzazineamide) membrane (MWCO = 200 daltons)



Adapted from Appleman et al., 2013

Adsorbents Most Common for PFAS Removal

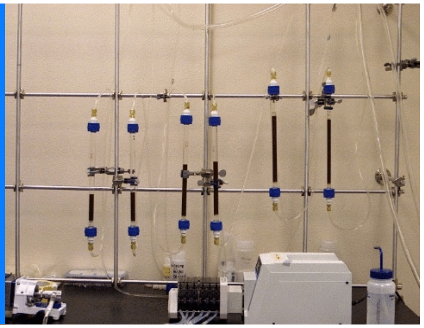
- Activated carbon
  - Granular Activated Carbon (GAC)
  - Powdered Activated Carbon (PAC)
- Ion Exchange
  - Single Use
  - Regenerable
- Surface-modified adsorbents
- Engineered adsorbents
- Biochar
- Zeolites

Not commercially applied (yet!)

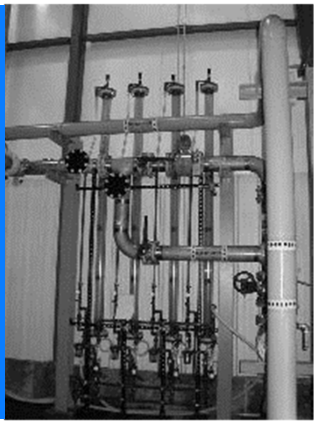
Ongoing Efforts in Adsorption Testing

- Isotherm Testing
  - Quick batch testing to assess feasibility
  - Can estimate total adsorbent usage rate

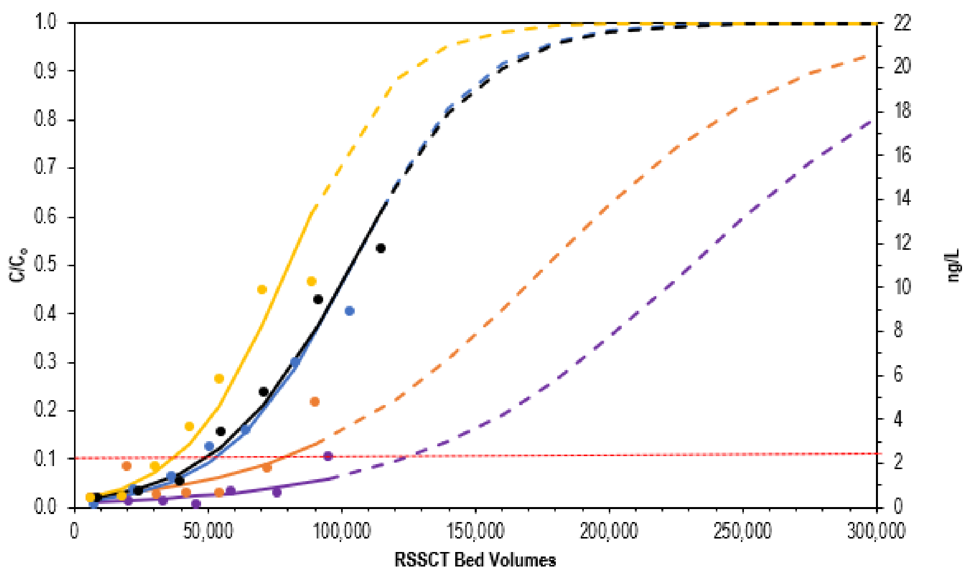
- Rapid Small-Scale Column Tests (RSSCT)
  - ONLY applicable for size-reducable media
  - Simulates full-scale performance in short period of time
  - Small diameter (less 1.0 cm ID) are typical
  - Identifies carbon type, breakthrough data, usage rates



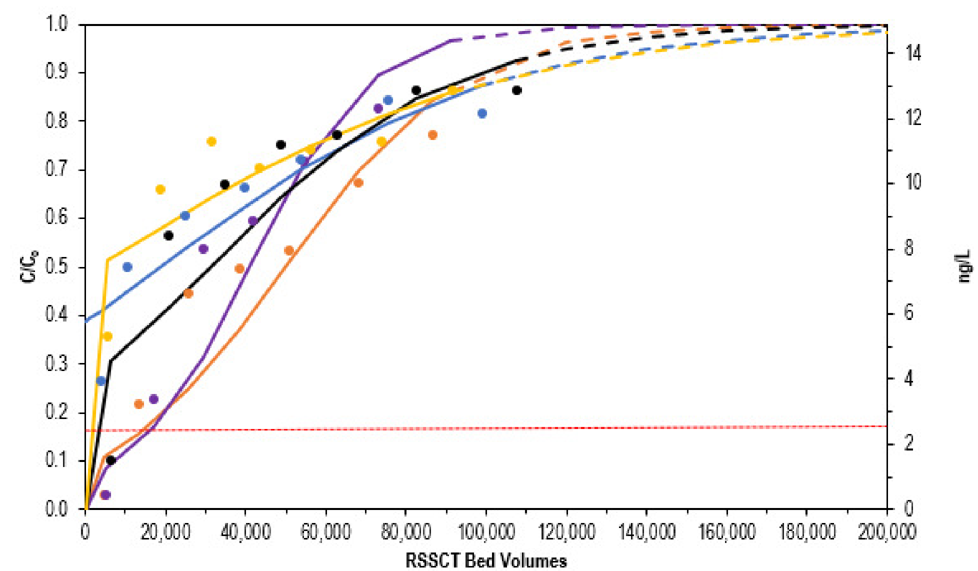
- Pilot testing
  - Applicable to all adsorbents
  - Requires the most time and resources



Application-Specific Testing for Adsorption is Required



TOC: 1.8 mg/L
DOC: 0.85 mg/L
UVA: 0.008 abs/cm

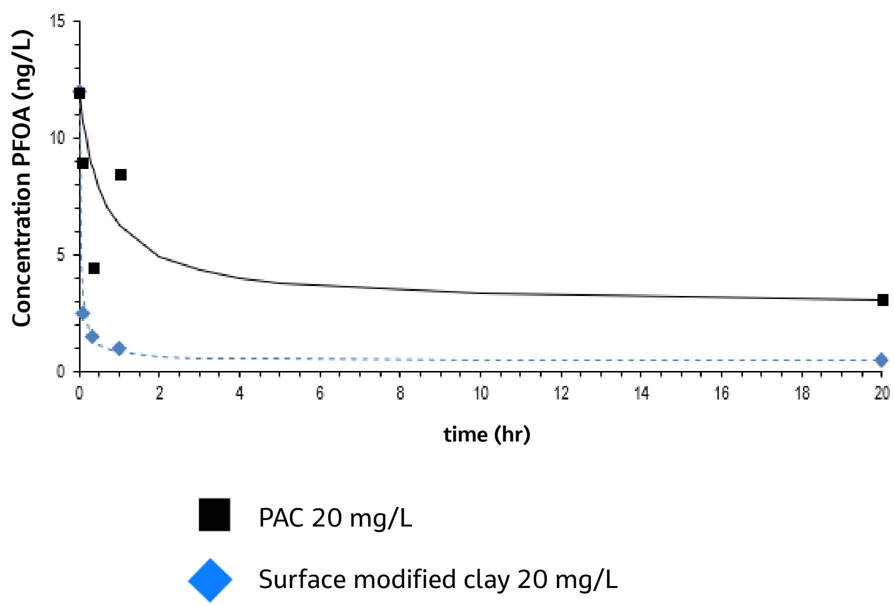


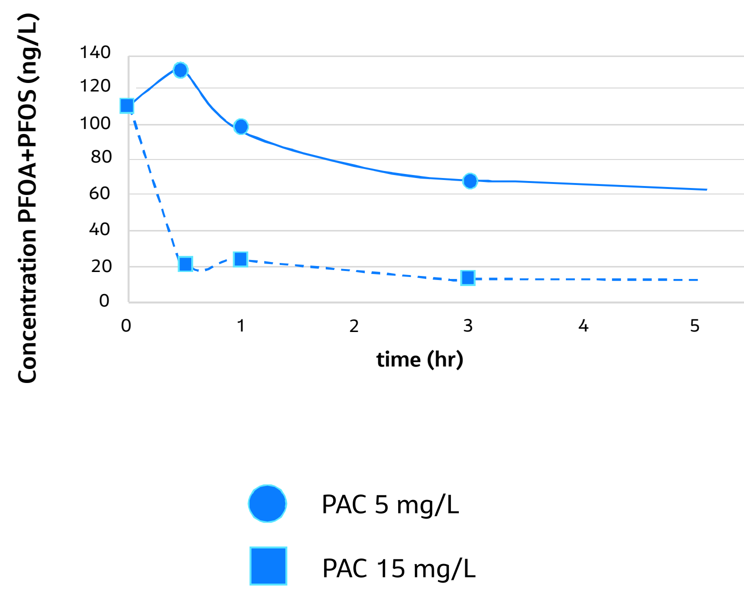
TOC: 1.6 mg/L
DOC: 1.6 mg/L
UVA: 0.03 abs/cm

Carbon A Carbon B Carbon C Carbon D Carbon E

Quick Fix: Batch Adsorbent Applications For Surface Water Plants?

- Adsorbent added to flocculation / coagulation
- Removal with Filtration or Dissolved Air Floatation (DAF)





Why are PFAS in Wastewater?

- Industry discharge
- Landfill leachate
- In potable water source (pass though household to sewer)
- Released from households

PFAS Within Wastewater Facilities is Highly Variable

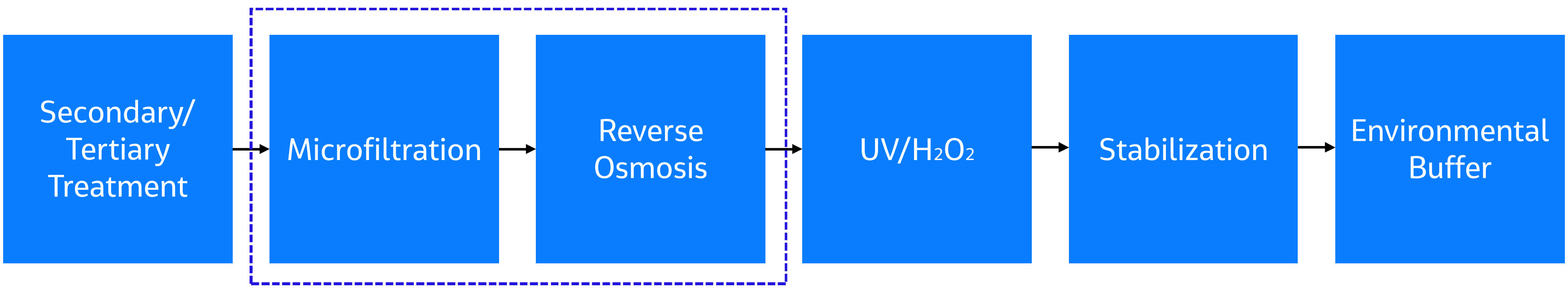
Plant	Location	PFHxA	PFHpA	PFOA	PFHxS	PFOS	Total
A	Influent	59	13	206	24	134	444
	Effluent	60	13	200	28	240	560
B	Influent	9.7	2.2	3.1	6.6	12	35
	Effluent	31	3.7	14	48	22	120

- Measured PFAS pass through WWTP with limited/no reduction
- Precursors discharged to WWTP cause PFAS increase across aeration
- PFAS also leaves plant through biosolids

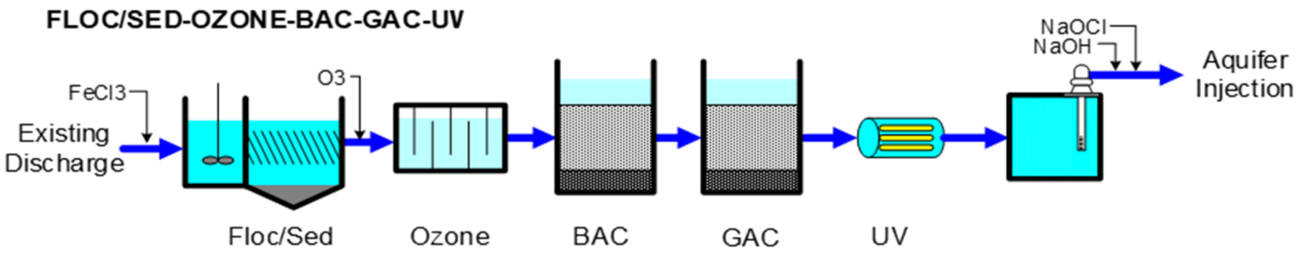
Source: Gallen et. al., 2018, *Chemosphere*

PFAS Removal in Membrane-based Reuse: PFAS in the Reject

- PFAS are soluble compounds
- No removal anticipated or provided by MF and UF
- Removal a function of:
  - Membrane characteristics
  - Molecule/compound characteristics
  - Water/solute matrix



Non-membrane Advanced Wastewater Treatment



- Indirect potable reuse program
  - 120 MGD of secondary effluent
  - Injection into the Potomac Aquifer System
- Full-scale facilities planned between 2022 and 2030
- Project drivers
- System is protective of the final adsorption step for PFAS removal
  - Opportunity to modify GAC for alterative adsorbent

Right Now vs Future: Treatment for PFAS

Category	Roughing / Pretreatment	Transfer	Destructive
Effective & Practiced	none	GAC / PAC Ion Exchange Reverse Osmosis (RO)	none
Maturing & Demonstrated	Chemical Coagulation Electrocoagulation	Specialty Adsorbents	none
Developing	none	Biochar	Electro-oxidation Low temperature plasma Chemical red-ox

Jacobs Challenging today. Reinventing tomorrow.

The Future of Biosolids and Managing PFAS

Jeff Prevatt, PhD, Deputy Director of Pima County Regional Wastewater Reclamation Dept

Todd O. Williams, PE, BCEE, Jacobs Global Technology Leader | Residuals Resource Recovery

Jeff Prevatt

Deputy Director of Treatment, Research & Innovation Pima County Regional Wastewater Reclamation

Pretreatment Concerns

- Point source control has demonstrated to be effective but locating potential sources of PFAS contamination can be challenging.

Effluent Reuse Concerns

- Water reuse, and groundwater recharge, may be limited if attributable to groundwater contamination.
- Additional regulatory limits unknown

Biosolids Disposal Concerns

- EPA contemplating hazardous waste CERCLA designation for PFAS compounds
- Land application of biosolids may be in jeopardy
- Potential liability for properties previously receiving biosolids.

Mr. Prevatt attended the University of Arizona receiving a BS in microbiology and a PhD in Chemistry.

A water professional with over 25 years of experience and creator of Pima County's Water Campus and the University of Arizona WEST Center.

Current research projects include DPR technologies, anammox, phosphorus removal, biogas purification, microplastics method development, chemicals of emerging concern and viral surveillance of sewersheds for early infection assessment.

Jacobs Challenging today. Reinventing tomorrow.

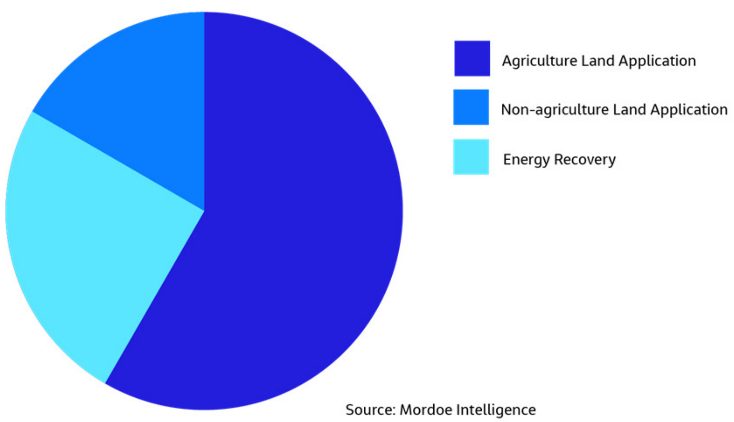
The Future of Biosolids and Managing PFAS

Todd O. Williams, PE, BCEE, Jacobs Global Technology Leader | Residuals Resource Recovery

PFAS in Biosolids – Why should we care?

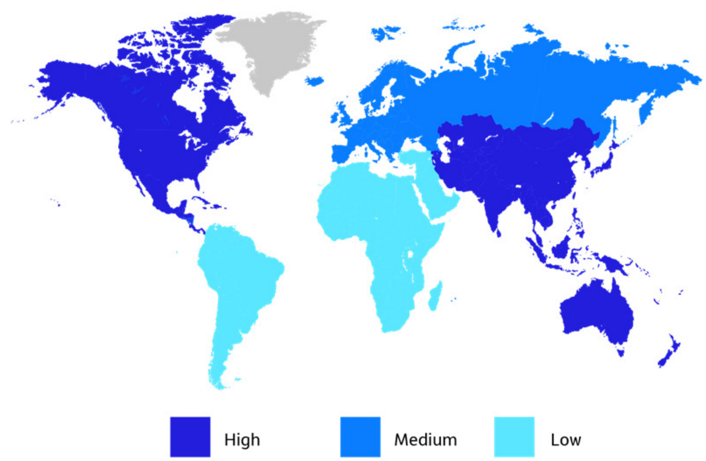
- Land application makes up 60% of the global biosolids market
- In the US, half of the 7.2 M dry tons per year of WWTP biosolids are land applied.
- The US biosolids land application market is valued at $600M/year and growing 4% per year or more
- Problems with landfills is forcing even more biosolids to land application
- What are the concerns?
  - Surface water, ground water, plant uptake
- What do farmers think?

Biosolids Market – Growth Rate by Region, 2019-2024



Source: Mordoe Intelligence

Biosolids Market, Volume (%), by Application, Global 2018



How do sources of PFAS impact WWTPs and biosolids?

PFAS Source Impacts – the big three

- Industrial
  - Platers, coatings, AFFF
- Landfill leachates
- Residential/Commercial

Impacts to treatment plants are a function of mass loading

Are there regulations related to PFAS in biosolids?

US EPA Biosolids PFAS Rule-Making Progress

- Focus is on PFOS and PFOA where there is the most data
- PFAS in Biosolids Action Plan Developed
  - Problem Formulation by 12/2020
- Screening and Risk Assessment of Emerging Chemicals of concern in 2021
  - If there are constituent limits…the 503 rule will be updated
  - Mitigation options will be included
  - Peer review and public comment period will occur

Soil / Biosolids Values are Being Developed for Protection of Groundwater

Entity	µg/Kg (ppb)		
	PFOA	PFOS	PFBS
US EPA (Soil Screening Level)	0.017	0.038	13
State values *	0.6 – 350	0.22 - 25	53 – 910
Maine (Biosolids Specific Screening)	2.5	5.2	1900

* Current states: AK, MI, NE, NC, TX. Enforceable value in AK.

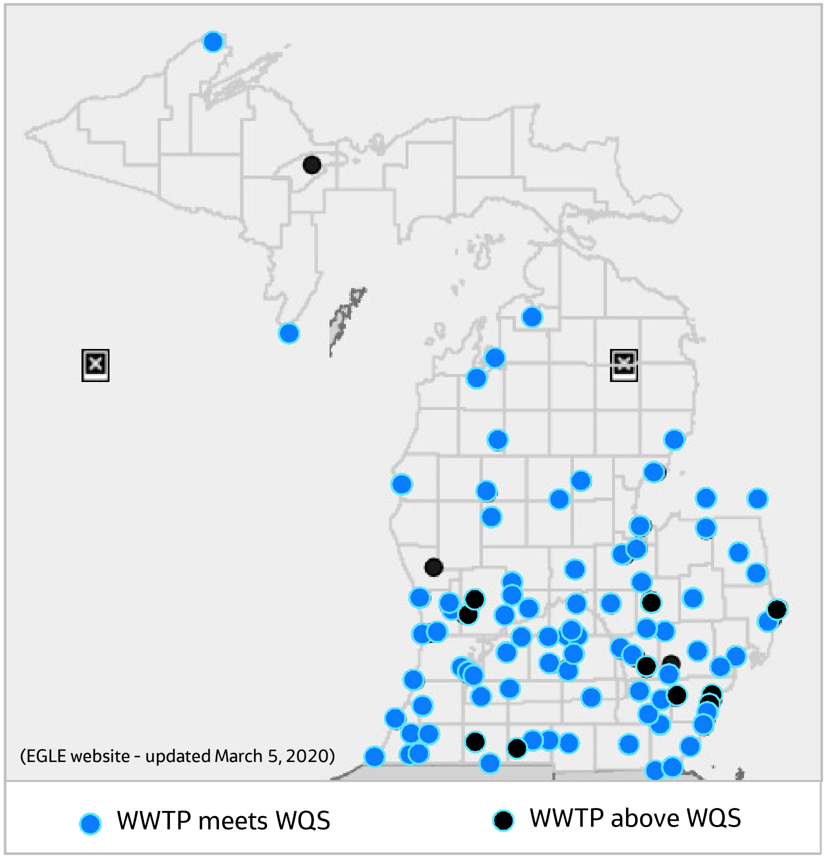
States are Approaching Standards Independently

- **California**
  - PFAS investigation plan (March 6, 2019)
  - Orders to wastewater treatment plants (by spring 2020)
  - Orders to biosolids applications (no timeline)
- **Maine**
  - WWTPs need to test for the PFAS in biosolids used as fertilizer
- **Michigan**
  - Leveraging IPP program against surface water quality standard
- **Wisconsin**
  - Sampling WW treatment plants and biosolids

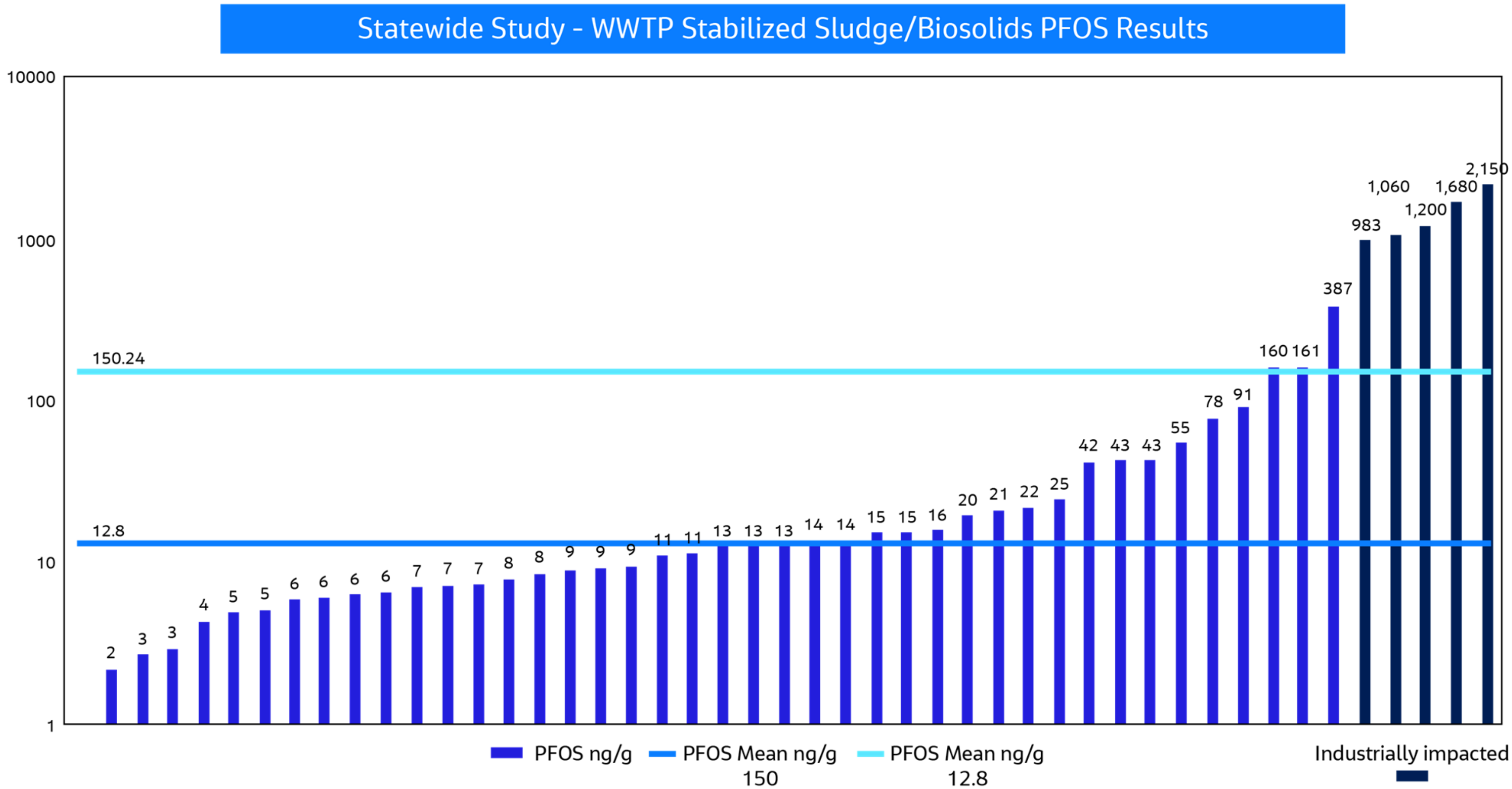
Michigan's Approach to Managing PFAS in Biosolids

- Required sampling and testing for PFOS and PFOA of effluent at WWTPs with IPP's in 2018
  - Tier 1 – WWTP effluent < 12 ppt PFOS
    - No action needed
  - Tier 2 – WWTP effluent 12-50 ppt PFOS
    - Work towards source control and monitor effluent quarterly
  - Tier 3 – WWTP effluent > 50 ppt
    - Implement source control
    - Monitor effluent quarterly
    - Monitor biosolids quality
- Land application guidelines in development

Michigan Surface Water – Rule 57		
Entity	ng/l (ppt)	
	PFOA	PFOS
Non-potable Surface water	12,000	12
Potable Surface water		11



Michigan Statewide Study of Biosolids in 2018



Source: EGLE presentation at Michigan WEA Biosolids Conference March 2019

Example of Biosolids Land Application Analyses in Michigan

WWTP Concentrations		Total dt Applied	Average dt /Acre	Weighted Use Ratio (Total dt/Site Acres)	Soil	Groundwater	Surface Water
Effluent	Biosolids						
2-5	3-90	176-400	2-10	6-23	ND-9	N/A	ND - 5
169-2,000	1,060-2,100	39-1,422	1-4	4-28	1-145	ND - 18	ND – 2,080

PFOS: Aqueous = ng/L or ppt
Solid = ug/Kg or ppb

"Typical" uncontaminated biosolids with PFOS < 90 ppb

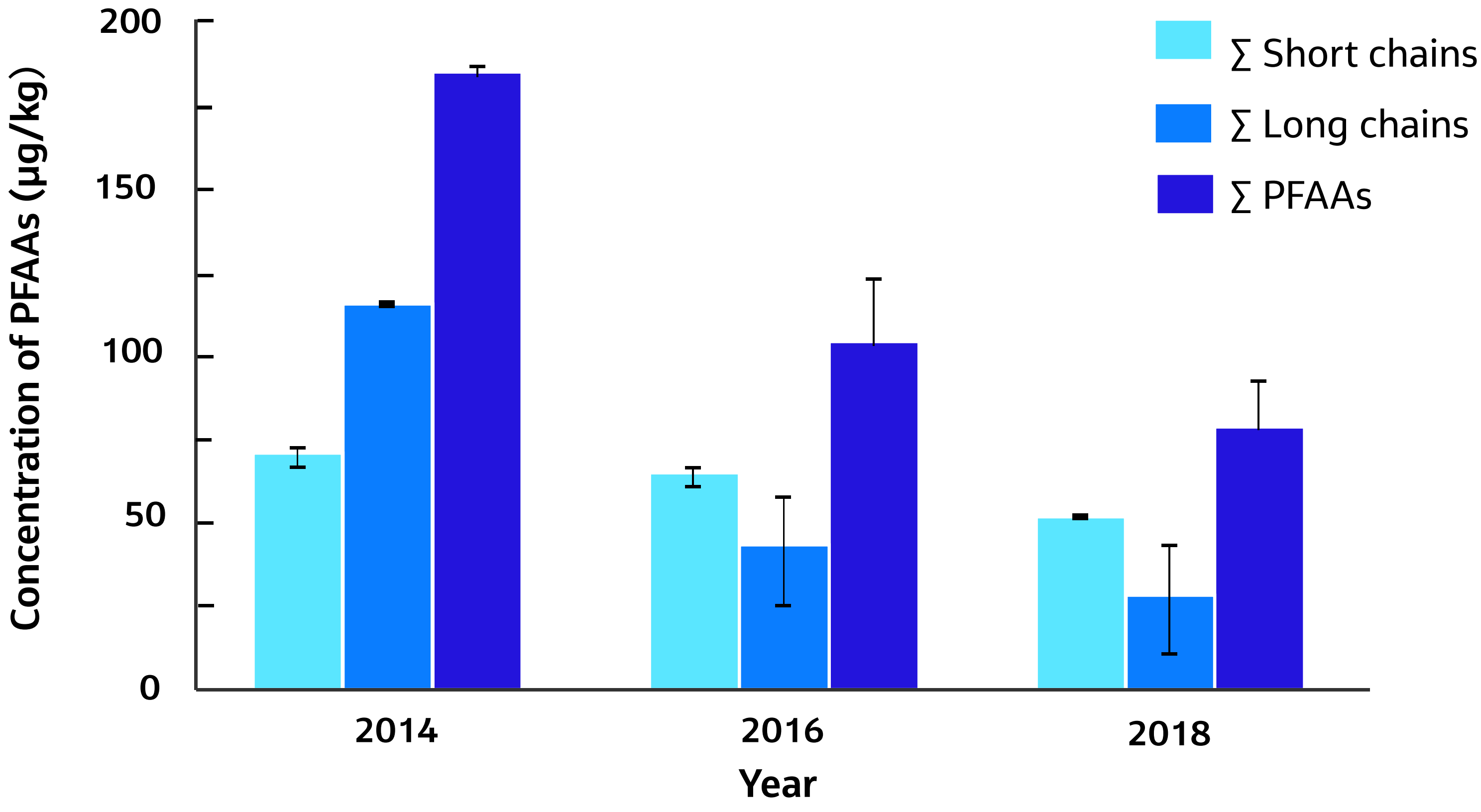
Non-typical contaminated biosolids with PFOS > 1000 ppb

Example of Biosolids Land Application Analyses in Michigan

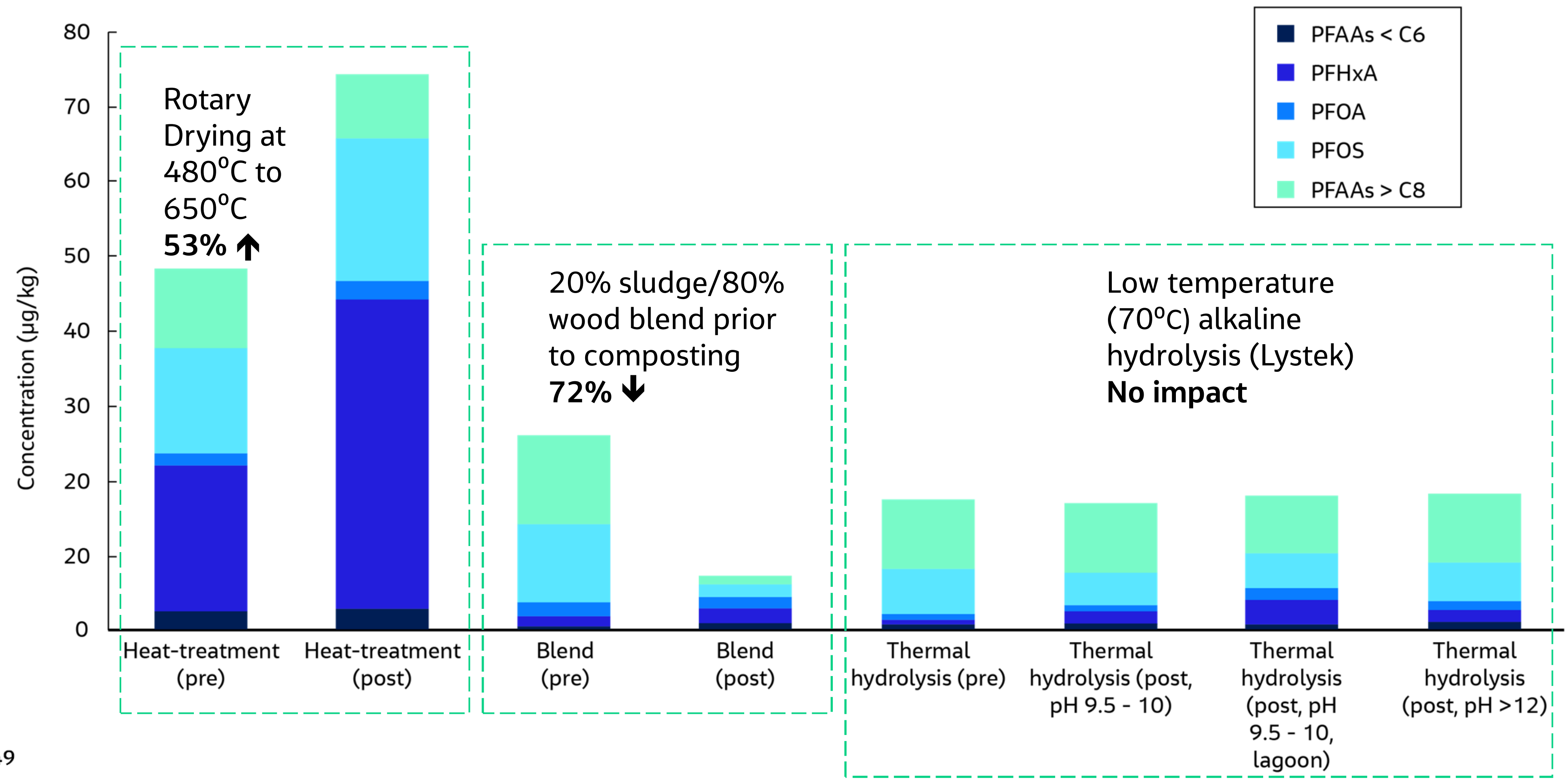
- PFAS concentrations > 1000 µg/Kg, ng/g, ppb
- PFAS concentrations > 200 and < 1000 µg/Kg, ng/g, ppb
- PFAS concentrations > 100 and < 200 µg/Kg, ng/g, ppb
- PFAS concentrations > 20 and < 100 µg/Kg, ng/g, ppb
- PFAS concentrations < 20 µg/Kg, ng/g, ppb
- PFAS concentrations < 5 µg/Kg, ng/g, ppb

How can PFAS in biosolids be treated?

PFAA concentrations in biosolids have dropped as PFOS and PFOA were phased out of production in the US (one dried biosolids case study)



Impact of thermal drying, blending with bulking agent, and chemical/thermal hydrolysis treatment (not THP)



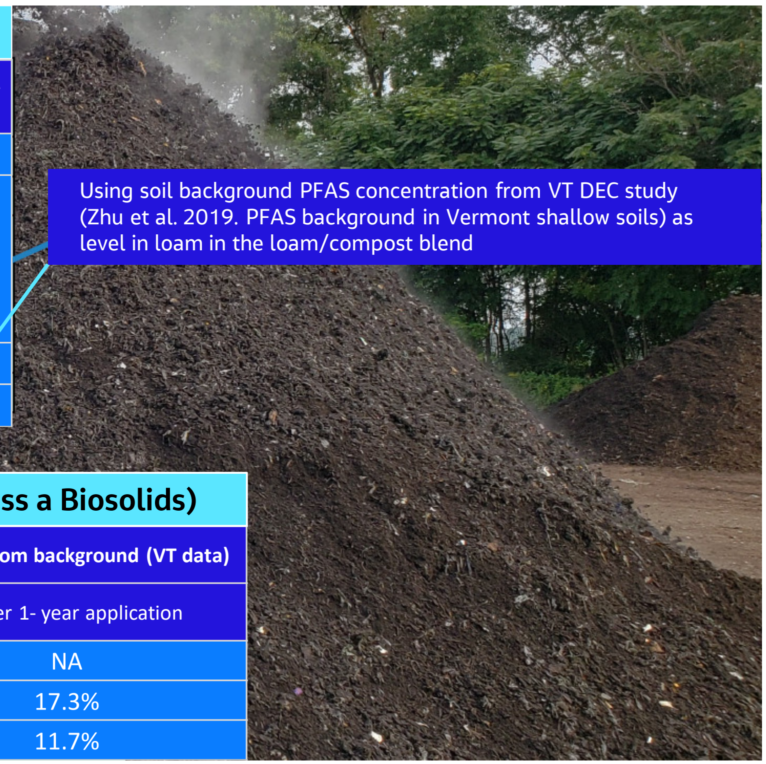
Dilution Upon Land Application Has Effect - Vermont Example (NEBRA)

Resumption of distribution/land application

Compost bendng for topsoil manufacturing

	Compost	Loam	Manufactured Topsoil
% solids	79%	85%	84.2%
denisity (per cubuc yard)	809	2400	NA
ratio by volume	1	2	
wet weight mix	14.4%	85.6%	
dry wight inn mix	13.6%	86.4%	
PFOA (µg/kg dry wt.)	7.0	0.52	1.4
PFOS (µg/kg dry wt.)	10.1	1.10	2.3

Using soil background PFAS concentration from VT DEC study (Zhu et al. 2019. PFAS background in Vermont shallow soils) as level in loam in the loam/compost blend

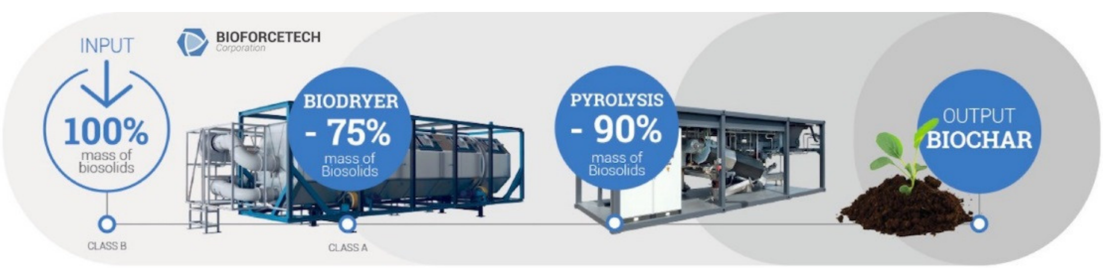


Compost Land Application (Applicable to) Other Types of Class a Biosolids)

PFAS Coumpound	Result	Screening Std.	Yars to reach std.	Increase from background (VT data)
	µg/kg dry wt.		@ 20 tons/acre	% after 1- year application
PFBS	1.74	1900	NA	NA
PFOA	7.04	2.5	27.8	17.3%
PFOS	10.1	5.2	40.3	11.7%

Biochar from Bioforcetech Corp.

- One set of samples 2019
- Pyrolysis at 1100°F (600°C)
- We know soil sampling needs to be above 1000°C for destruction of PFAS



Compound Name	Dry Biosolids (ng/g)	Biochar (ng/g)
PFBA	7.03	Not Detected
3:3 FTCA	ND	Not Detected
PFPeA	5.94	Not Detected
PFBS	2.3	Not Detected
4:2 FTS	ND	Not Detected
PFHxA	33.7	Not Detected
PFPeS	ND	Not Detected
HFPO-DA	ND	Not Detected
5:3	[illegible]	[illegible]
PF	[illegible]	[illegible]
AD	[illegible]	[illegible]
PF	[illegible]	[illegible]
6:	[illegible]	[illegible]
PFOA	89.1	Not Detected
PFHpS	ND	Not Detected
7:3 FTCA	40	Not Detected
PFNA	5.3	Not Detected
PFOSA	ND	Not Detected
PFOS	26.3	Not Detected
9Cl-PF3ONS	ND	Not Detected
PFDA	11.3	Not Detected
8:2 FTS	5.68	Not Detected
PFNS	ND	Not Detected
MeFOSAA	23.5	Not Detected
EtFOSAA	19.6	Not Detected
PFUnA	3.39	Not Detected
PFDS	ND	Not Detected
11Cl-PF3OUdS	ND	Not Detected
10:2 FTS	ND	Not Detected
PFDoA	5.85	Not Detected
MeFOSA	ND	Not Detected
PFTrDA	ND	Not Detected
PFTeDA	2.44	Not Detected
EtFOSA	ND	Not Detected
PFHxDA	ND	Not Detected
PFODA	ND	Not Detected
MeFOSE	17.1	Not Detected
EtFOSE	ND	Not Detected

PFOA =89.1 &
PFOS = 26.3

All ND
@ 2ppb

Summary Thoughts…

Implications to biosolids land application

- PFOS and PFOA are decreasing
- EPA is working through risk analysis process
- Some states may begin issuing guidance recommendations on land application of biosolids based on concentration levels
- Most data on PFAS impact in field studies has been gathered on impacted biosolids. Very little data on impact (leachability, plant uptake, etc.) in US of PFAS from non-industrially or non AFFF impacted biosolids/soils
- Very limited data available on the impact of various biosolids treatment processes on PFAS concentrations
- Studies are being initiated to evaluate various biosolids process impacts. Look for more data later this year

Biosolids PFAS Management Summary Thoughts…

- Follow studies with actual data
- Follow regulation development
- Update your biosolids management plan
- Develop flexible biosolids programs that can be modified as regulations and/or public demand require
- Consider testing your solids to understand PFAS levels
- Look upstream for industries that may use PFAS
- Be prepared for questions from the public…they will come
- Fact sheets are available from several sources
  - https://www.nacwa.org/advocacy-analysis/campaigns/pfas
  - https://pfas-1.itrcweb.org/
  - Jacobs PFAS fact sheet

Questions & Answers

Or send to: lori.irvine@Jacobs.com

Thank You!

Copyright Notice