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Cost of POU vs Centralized Treatment

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Overview

Contaminants to cover

Nitrate / Perchlorate

1) Anion exchange
2) POU membranes
3) Biological treatment (anaerobic)

PFAS

1) Activated carbon
2) Anion exchange
3) Reverse osmosis

Treatment Information

Publically Available Drinking-Water Treatability Database

- Interactive literature review database that contains over 88 regulated and unregulated contaminants and covers 34 treatment processes commonly employed or known to be effective (thousands of sources assembled on one site)

Currently available:

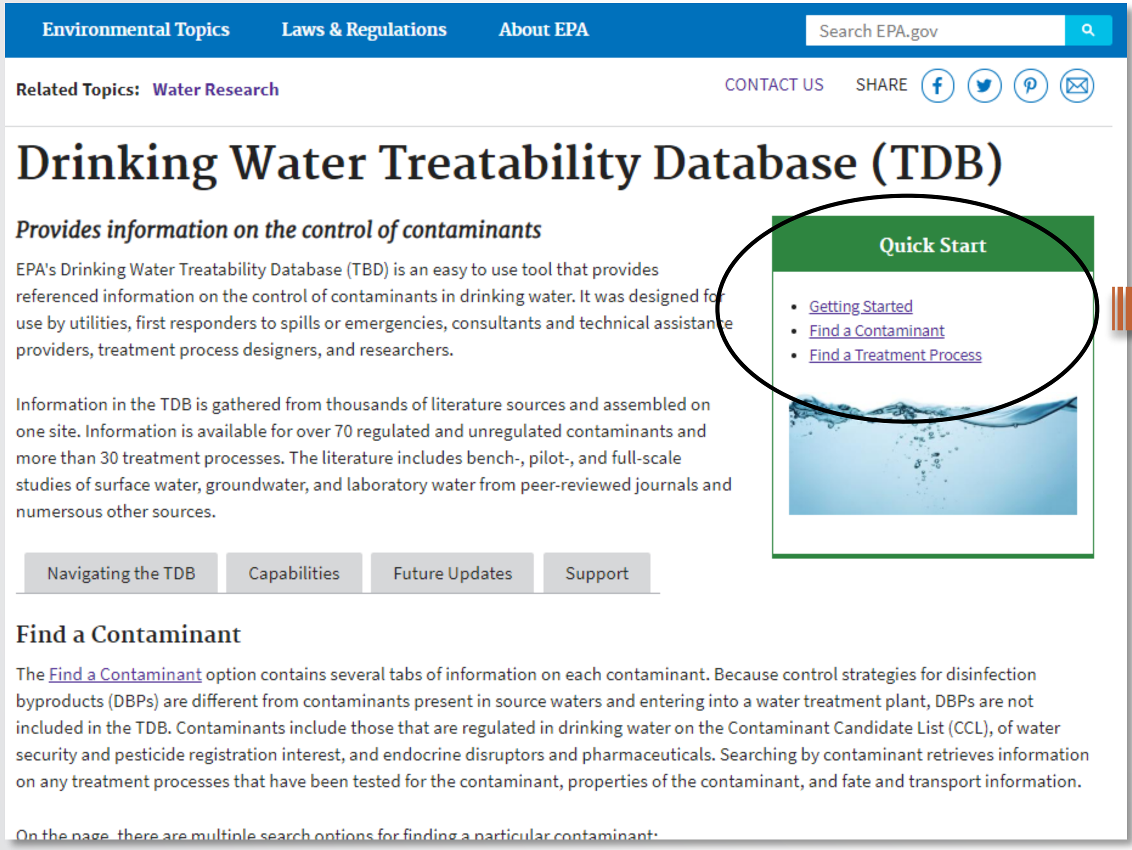
- **Nitrate**
- **Perchlorate**
- **PFOA, PFOS, PFTriA, PFDoA, PFUnA, PFDA, PFNA, PFHpA, PFHxA, PFPeA, PFBA, PFDS, PFHpS, PFHxS, PFBA, PFBS, PFOSA, FtS 8:2, FtS 6:2, N-EtFOSAA, N-MeFOSAA and GenX**

https://www.epa.gov/water-research/drinking-water-treatability-database-tdb

Search: EPA TDB

Treatability Database

Agency Landing Page



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Drinking Water Treatability Database (TDB)

Provides information on the control of contaminants

EPA's Drinking Water Treatability Database (TBD) is an easy to use tool that provides referenced information on the control of contaminants in drinking water. It was designed for use by utilities, first responders to spills or emergencies, consultants and technical assistance providers, treatment process designers, and researchers.

Information in the TDB is gathered from thousands of literature sources and assembled on one site. Information is available for over 70 regulated and unregulated contaminants and more than 30 treatment processes. The literature includes bench-, pilot-, and full-scale studies of surface water, groundwater, and laboratory water from peer-reviewed journals and numsrous other sources.

Quick Start

- Getting Started
- Find a Contaminant
- Find a Treatment Process

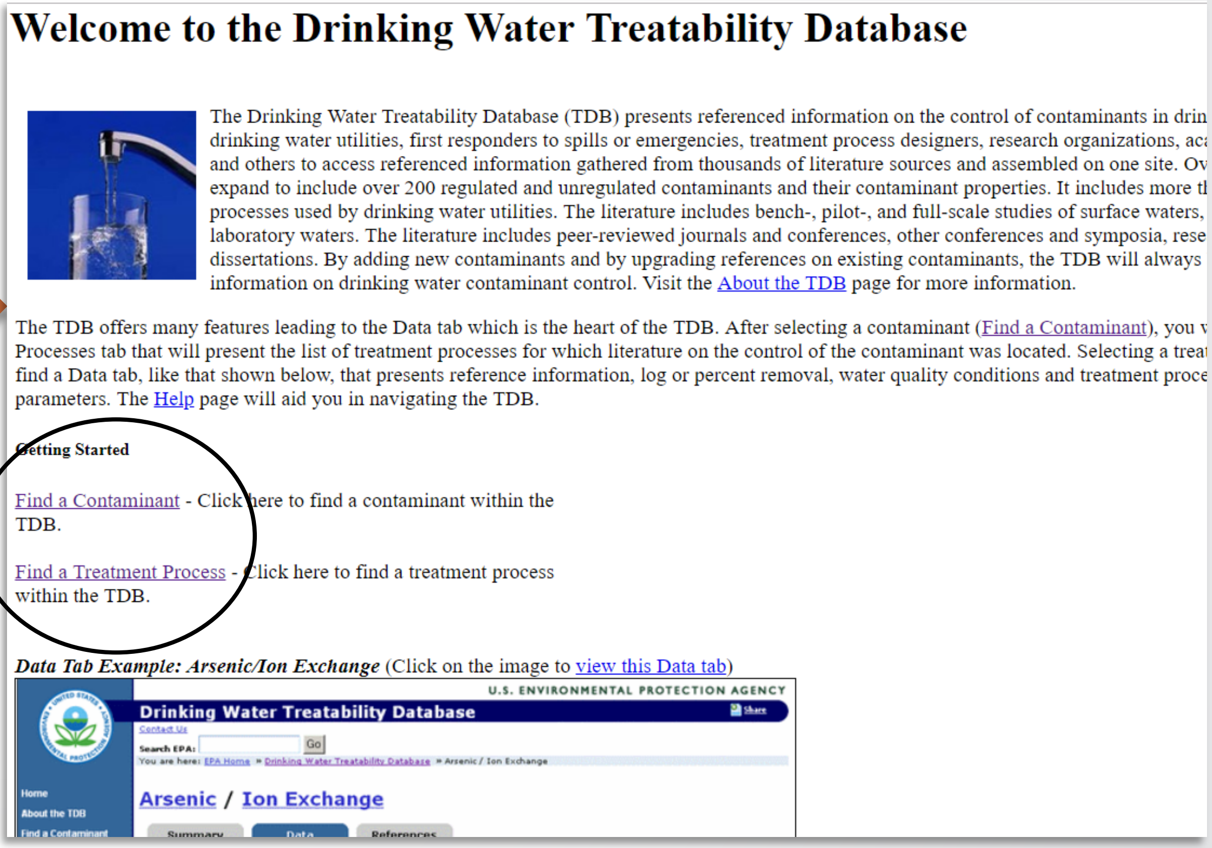
Navigating the TDB | Capabilities | Future Updates | Support

Find a Contaminant

The Find a Contaminant option contains several tabs of information on each contaminant. Because control strategies for disinfection byproducts (DBPs) are different from contaminants present in source waters and entering into a water treatment plant, DBPs are not included in the TDB. Contaminants include those that are regulated in drinking water on the Contaminant Candidate List (CCL), of water security and pesticide registration interest, and endocrine disruptors and pharmaceuticals. Searching by contaminant retrieves information on any treatment processes that have been tested for the contaminant, properties of the contaminant, and fate and transport information.

On the page, there are multiple search options for finding a particular contaminant:

Database Homepage



Welcome to the Drinking Water Treatability Database

The Drinking Water Treatability Database (TDB) presents referenced information on the control of contaminants in drin drinking water utilities, first responders to spills or emergencies, treatment process designers, research organizations, ac and others to access referenced information gathered from thousands of literature sources and assembled on one site. Ov expand to include over 200 regulated and unregulated contaminants and their contaminant properties. It includes more t processes used by drinking water utilities. The literature includes bench-, pilot-, and full-scale studies of surface waters, laboratory waters. The literature includes peer-reviewed journals and conferences, other conferences and symposia, rese dissertations. By adding new contaminants and by upgrading references on existing contaminants, the TDB will always information on drinking water contaminant control. Visit the About the TDB page for more information.

The TDB offers many features leading to the Data tab which is the heart of the TDB. After selecting a contaminant (Find a Contaminant), you v Processes tab that will present the list of treatment processes for which literature on the control of the contaminant was located. Selecting a trea find a Data tab, like that shown below, that presents reference information, log or percent removal, water quality conditions and treatment proce parameters. The Help page will aid you in navigating the TDB.

Getting Started

Find a Contaminant - Click here to find a contaminant within the TDB.

Find a Treatment Process - Click here to find a treatment process within the TDB.

Data Tab Example: Arsenic/Ion Exchange (Click on the image to view this Data tab)

EPA's Drinking Water Cost Models

- Adsorptive media
- **Anion exchange***
- **Biological treatment***
- Cation exchange
- **GAC***
- Greensand filtration
- Microfiltration / ultrafiltration
- Multi-stage bubble aeration*

- Non-treatment
- Packed tower aeration
- **POU/POE#**
- Reverse Osmosis / Nanofiltration
- UV disinfection
- UV Advanced Oxidation

Anion exchange (nitrate, perchlorate, and PFAS), Biological treatment (nitrate and perchlorate), GAC (PFAS)

*** Search: EPA WBS** http://www2.epa.gov/dwregdev/drinking-water-treatment-technology-unit-cost-models-and-overview-technologies

 # For POU/POE search: EPA small system compliance help
http://water.epa.gov/type/drink/pws/smallsystems/compliancehelp.cfm

Small System Compliance Technologies

For small systems, EPA identified several compliance technologies as affordable using the following approach:

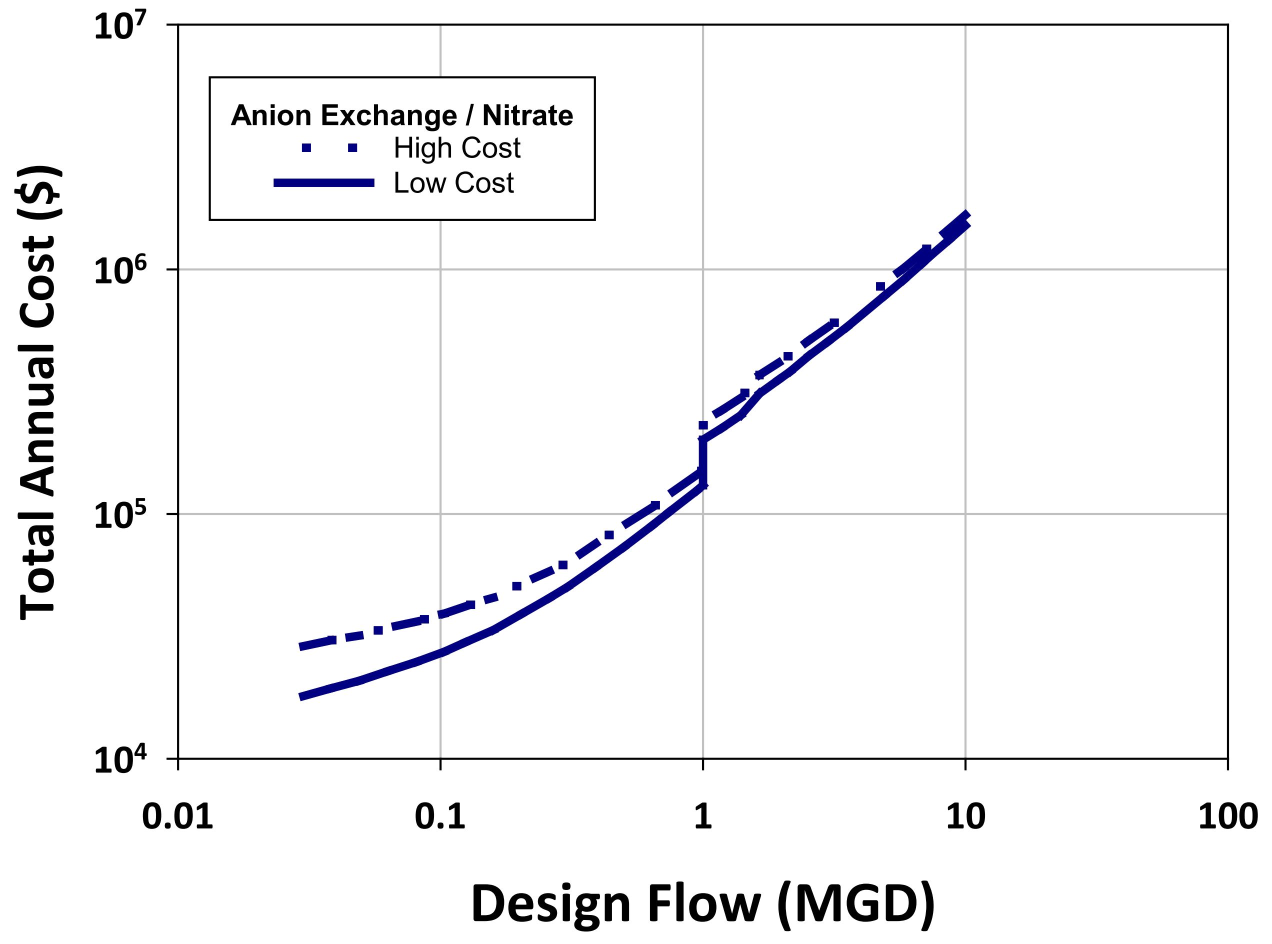
- Estimated annualized costs for three size categories (using EPA's work breakdown structure models, which estimate the capital and operating costs for model systems)
- Compared annualized costs to an expenditure margin equal to 2.5% of median household income minus average annual baseline household water utility costs
- Identified SSCTs where annualized costs < expenditure margin

Nitrate and Perchlorate

Why Nitrate and Perchlorate?

- Nitrate: A number of utilities exceed the nitrate MCL, particularly small systems
- Perchlorate: New state regulations and federal regulation consideration
- Both are fully oxidized – oxidation processes including aerobic biotreatment will not work
- The treatment processes that will work are pretty much the same
  - Anion exchange resin
  - High pressure membranes: reverse osmosis or nanofiltration
  - Anaerobic biological treatment (novel technology)

Cost: Nitrate / Anion Exchange

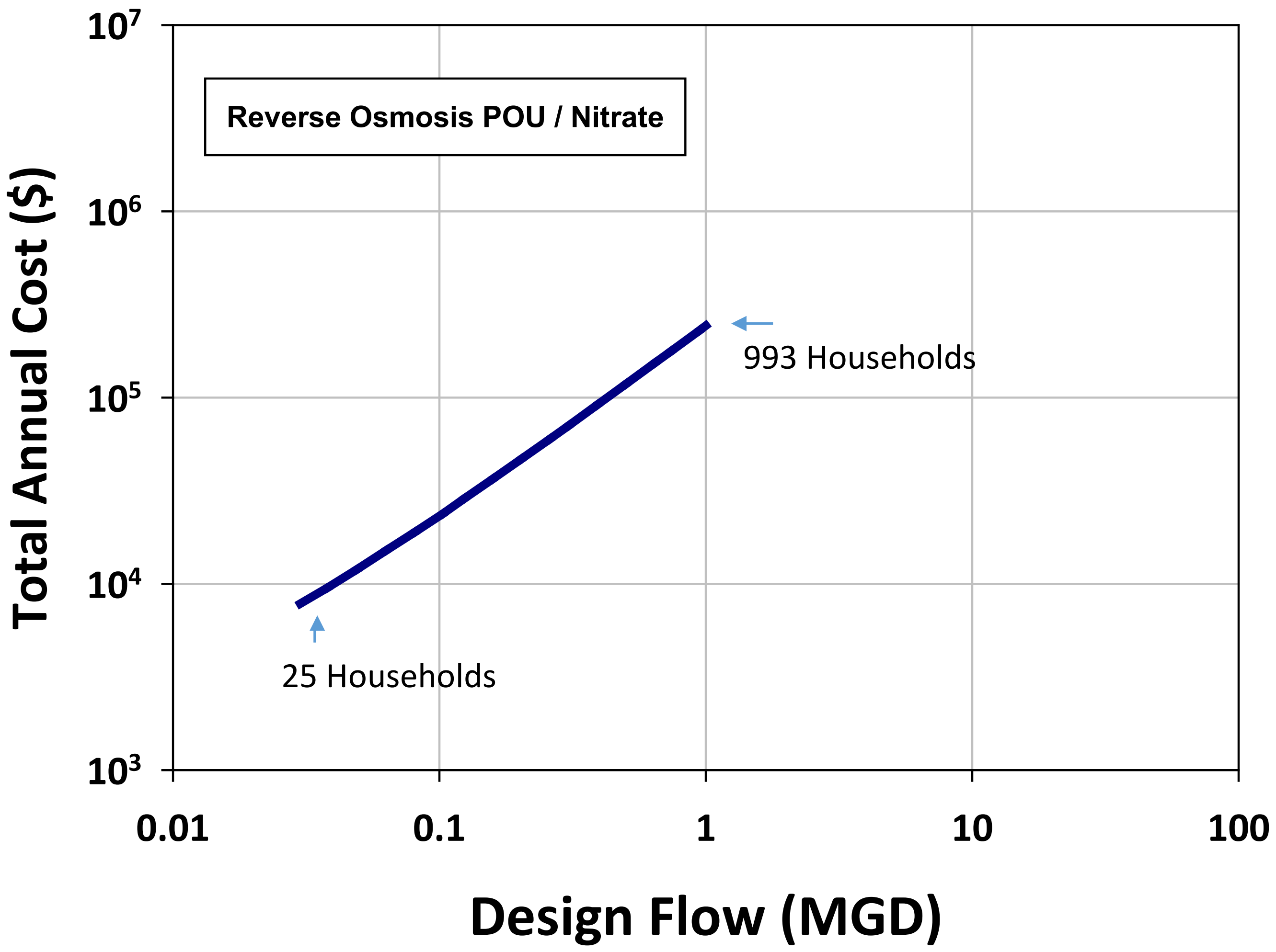


Primary Assumptions

- 20.3 mg N/L Influent
- Nitrate selective resin
- 420 Bed volumes before regeneration
- 2 minute EBCT
- Parallel contactors
- Brine discharge to POTW

Cost: Nitrate / Point of Use

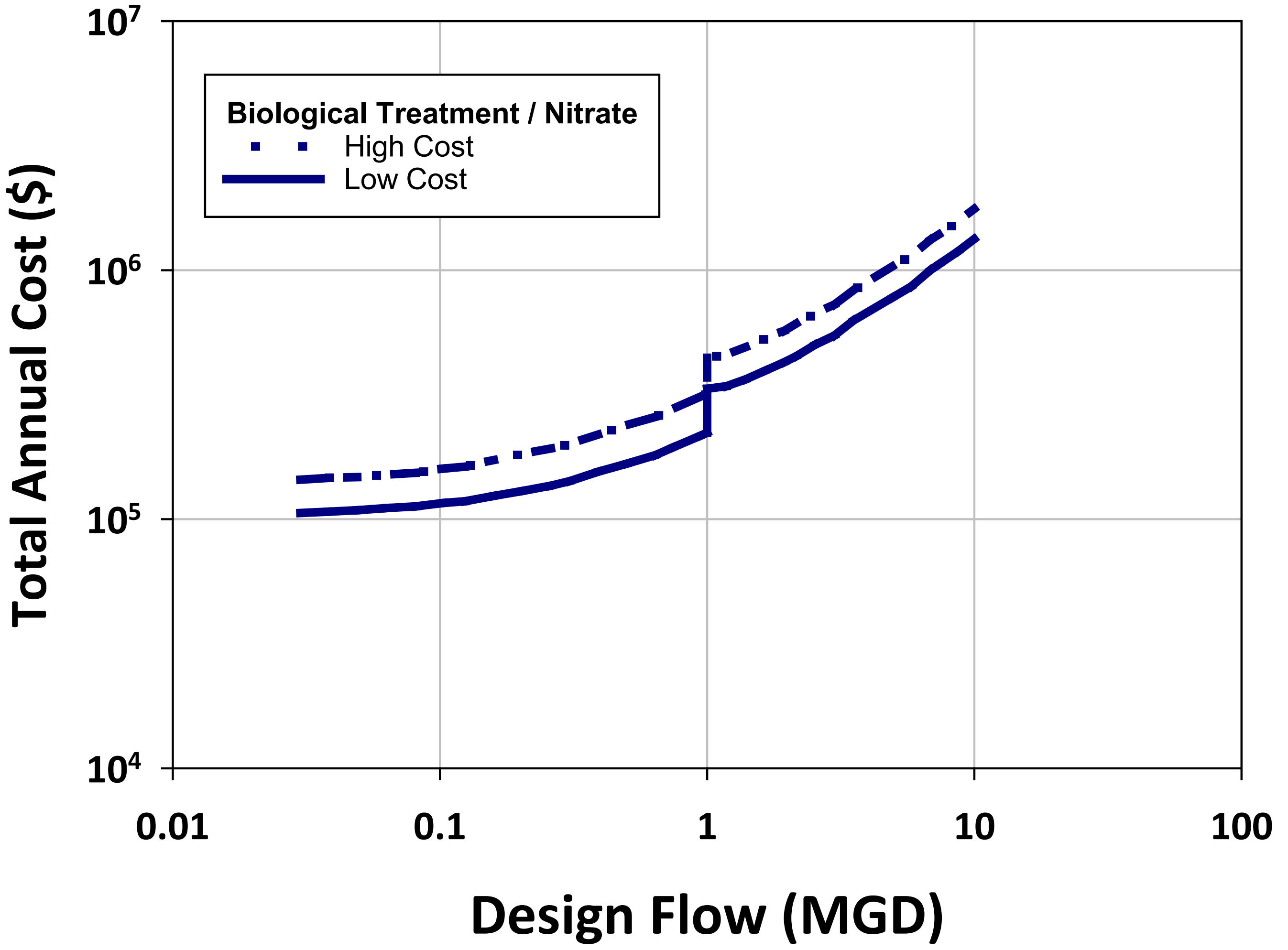
Only for 1 MGD design flow and below



Primary Assumptions

- 20.3 mg N/L Influent
- Reverse osmosis treatment
- Replacement frequency:
  - RO membrane: 3 years
  - Pre filters: 9 months
  - Post filter: 12 months
- Groundwater
- No post UV disinfection

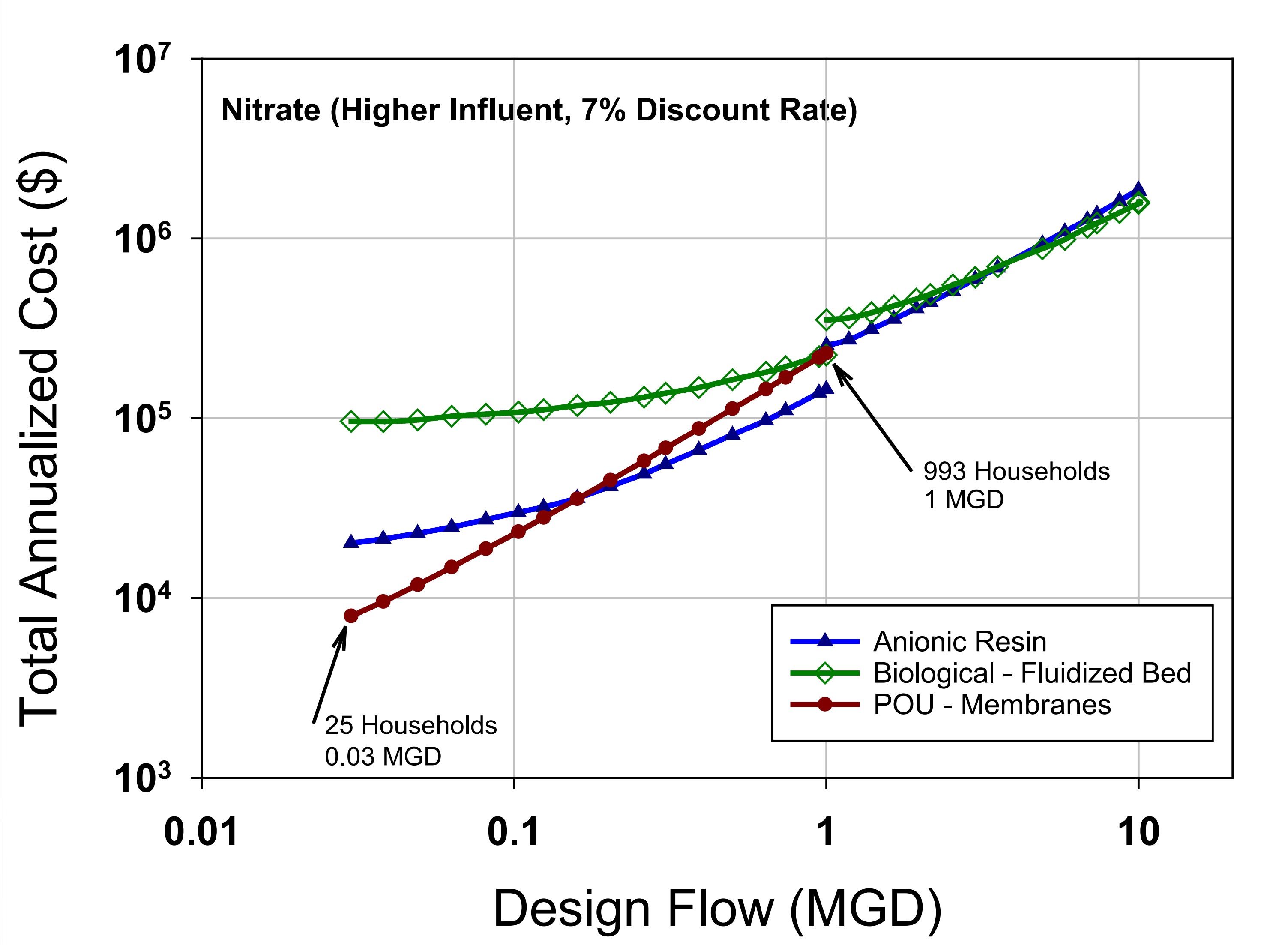
Cost: Nitrate / Anaerobic Biological Treatment



Primary Assumptions

- 20.3 mg N/L
- Fluidized bed reactor
- 28.5 mg/L acetic acid
- 2 mg P/L phosphoric acid
- 10 minute EBCT
- Post treatment aeration
- Post treatment filtration
- Recycle of spent backwash

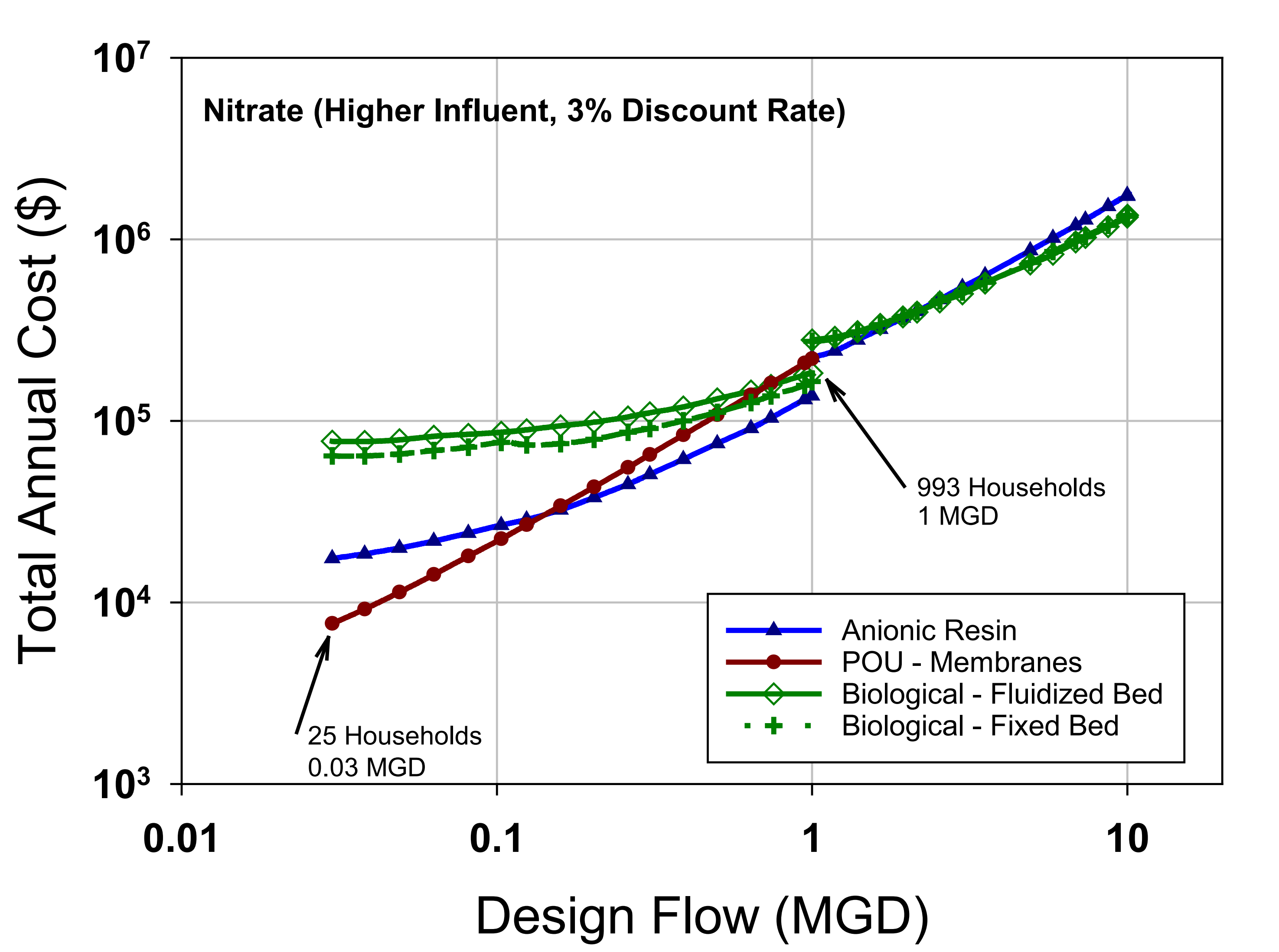
Cost: Nitrate (combined)



Primary Assumptions:

- Influent 44 mg N/L
- Groundwater
- Low cost option
- IEX: Nitrate selective
- Biological: Fluidized bed
- POU: Reverse Osmosis
- 7% Discount rate

Cost: Nitrate (combined)

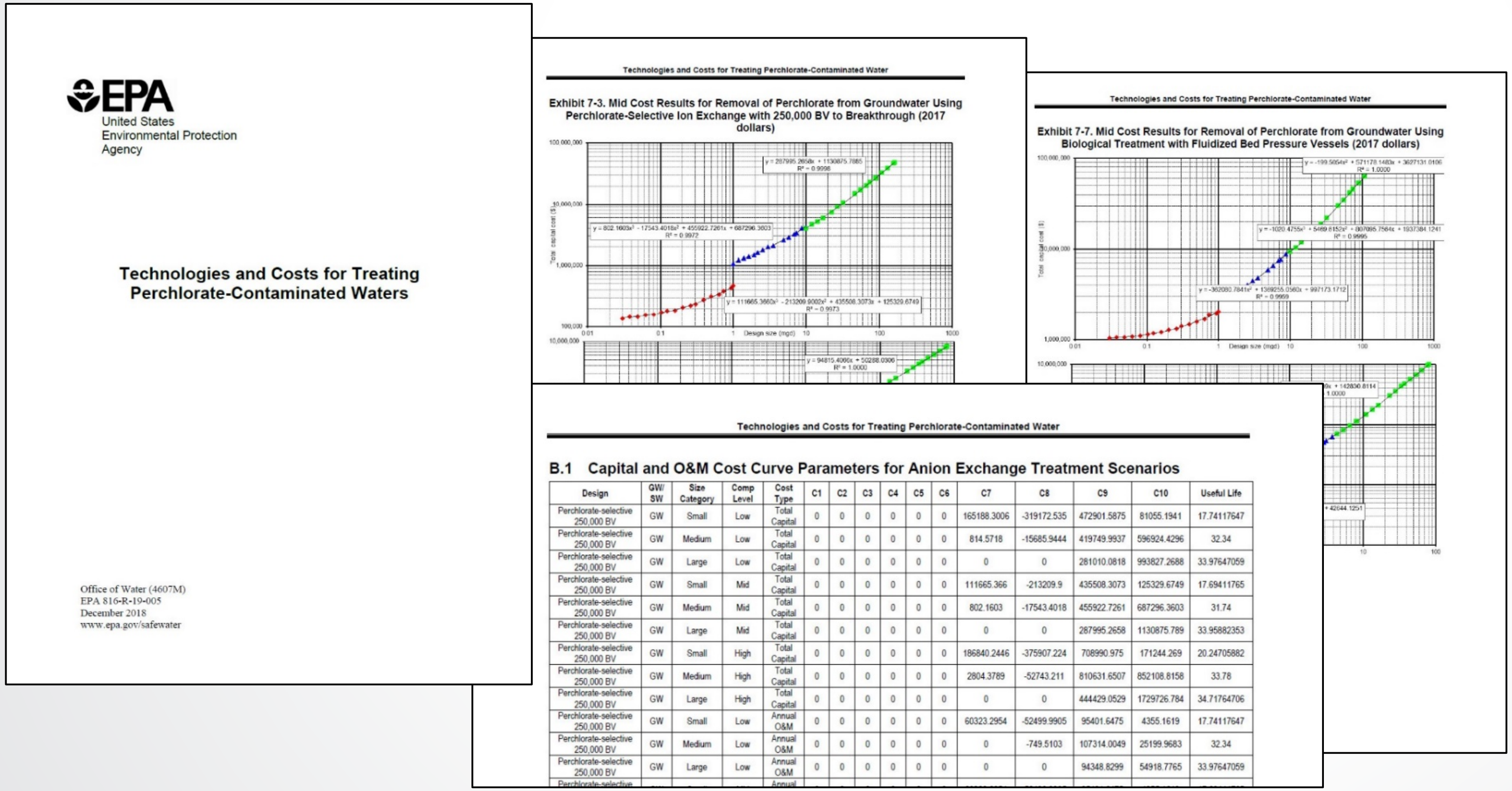


Primary Assumptions:

- Influent 44 mg N/L
- Groundwater
- Low cost option
- IEX: Nitrate selective
- Biological: Fluidized bed and Fixed bed
- POU: Reverse Osmosis
- 3 % Discount rate

Perchlorate Technologies and Cost Document

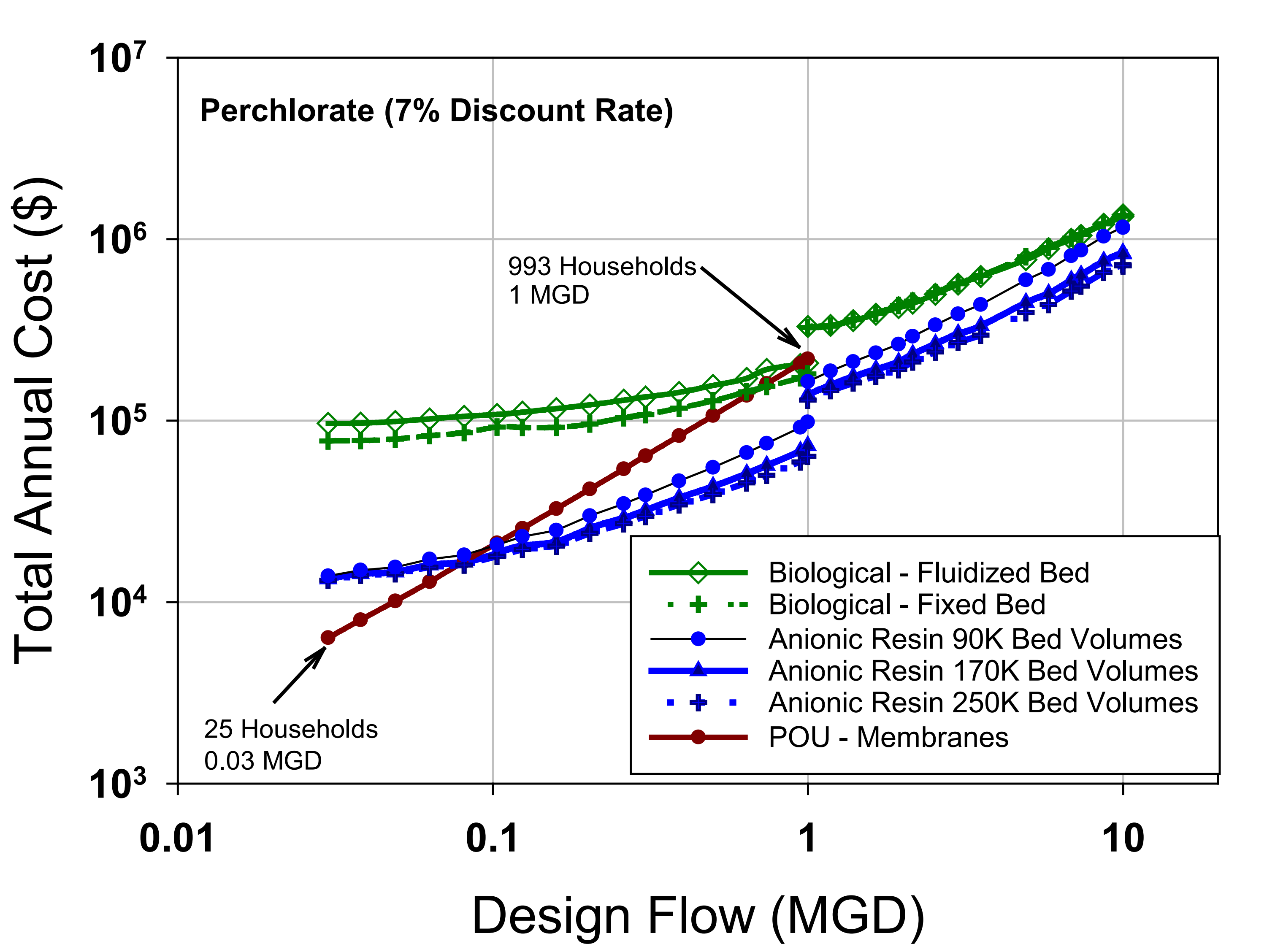
- https://www.regulations.gov/document?D=EPA-HQ-OW-2018-0780-0002



B.1 Capital and O&M Cost Curve Parameters for Anion Exchange Treatment Scenarios

Design	GW/SW	Size Category	Comp Level	Cost Type	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Useful Life
Perchlorate-selective 250,000 BV	GW	Small	Low	Total Capital	0	0	0	0	0	0	165188.3006	-319172.535	472901.5875	81055.1941	17.74117647
Perchlorate-selective 250,000 BV	GW	Medium	Low	Total Capital	0	0	0	0	0	0	814.5718	-15685.9444	419749.9937	596924.4296	32.34
Perchlorate-selective 250,000 BV	GW	Large	Low	Total Capital	0	0	0	0	0	0	0	0	281010.0818	993827.2688	33.97647059
Perchlorate-selective 250,000 BV	GW	Small	Mid	Total Capital	0	0	0	0	0	0	111665.366	-213209.9	435508.3073	125329.6749	17.69411765
Perchlorate-selective 250,000 BV	GW	Medium	Mid	Total Capital	0	0	0	0	0	0	802.1603	-17543.4018	455922.7261	687296.3603	31.74
Perchlorate-selective 250,000 BV	GW	Large	Mid	Total Capital	0	0	0	0	0	0	0	0	287995.2658	1130875.789	33.95882353
Perchlorate-selective 250,000 BV	GW	Small	High	Total Capital	0	0	0	0	0	0	186840.2446	-375907.224	708990.975	171244.269	20.24705882
Perchlorate-selective 250,000 BV	GW	Medium	High	Total Capital	0	0	0	0	0	0	2804.3789	-52743.211	810631.6507	852108.8158	33.78
Perchlorate-selective 250,000 BV	GW	Large	High	Total Capital	0	0	0	0	0	0	0	0	444429.0529	1729726.784	34.71764706
Perchlorate-selective 250,000 BV	GW	Small	Low	Annual O&M	0	0	0	0	0	0	60323.2954	-52499.9905	95401.6475	4355.1619	17.74117647
Perchlorate-selective 250,000 BV	GW	Medium	Low	Annual O&M	0	0	0	0	0	0	0	-749.5103	107314.0049	25199.9683	32.34
Perchlorate-selective 250,000 BV	GW	Large	Low	Annual O&M	0	0	0	0	0	0	0	0	94348.8299	54918.7765	33.97647059

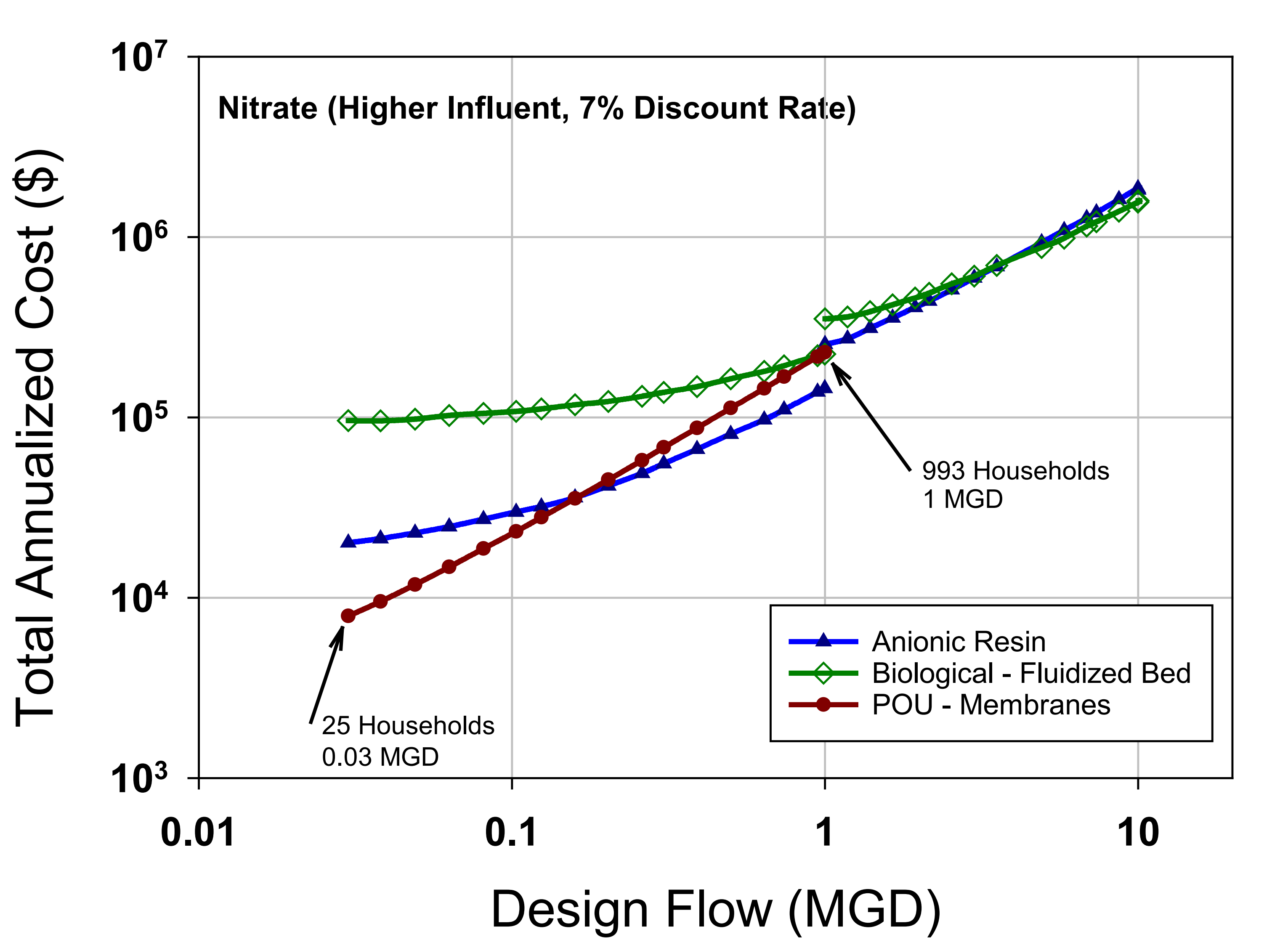
Cost: Perchlorate (combined)



Primary Assumptions:

- Influents: 24 – 270 ug/L
- Groundwater
- Low cost option
- IEX: Perchlorate selective
- Biological: Fluidized & fixed bed
- POU: Reverse Osmosis
- 7 % Discount rate

Cost: Nitrate (combined)



Primary Assumptions:

- Influent 44 mg N/L
- Groundwater
- IEX: Nitrate selective
- Biological: Fluidized & fixed bed
- POU: Reverse Osmosis
- 7% Discount rate

SSCT's for Perchlorate

Summary of results show that Small System Compliance Technologies (SSCTs) vary by system size

System Size (Population Served)	Ion Exchange	Biological Treatment	Reverse Osmosis	Point-of-Use Reverse Osmosis
25-500	**$378 to $610**	*$2,146 to $3,709*	*$2,272 to $2,671*	**$265 to $271**
501-3,300	**$98 to $148**	**$324 to $566**	**$561 to $688**	**$250 to $251**
3,301-10,000	**$104 to $153**	**$211 to $315**	**$431 to $493**	*Not applicable*

https://www.regulations.gov/document?D=EPA-HQ-OW-2018-0780-0111

Nitrate and Perchlorate Conclusions

- **Selective anion exchange resins** have the lowest costs for a wide range of systems sizes for both nitrate and perchlorate.
- For extremely small systems (below 200 homes), **point-of-use technologies (reverse osmosis)** have the lowest costs for both nitrate and perchlorate.
- For larger systems, **anoxic biological treatment systems** have the lowest costs, although for perchlorate, low concentrations and the high capacity of the selective resins favors ion exchange. Higher influent concentrations favor biological treatment.
- Other conditions such as the presence of co-contaminants or counter ions will skew these costs and potentially move the choice to another technology.
- Small systems often choose treatments based on other criteria such as operational complexity, residual stream management, facility limitations, etc..

Overview

Contaminants to cover

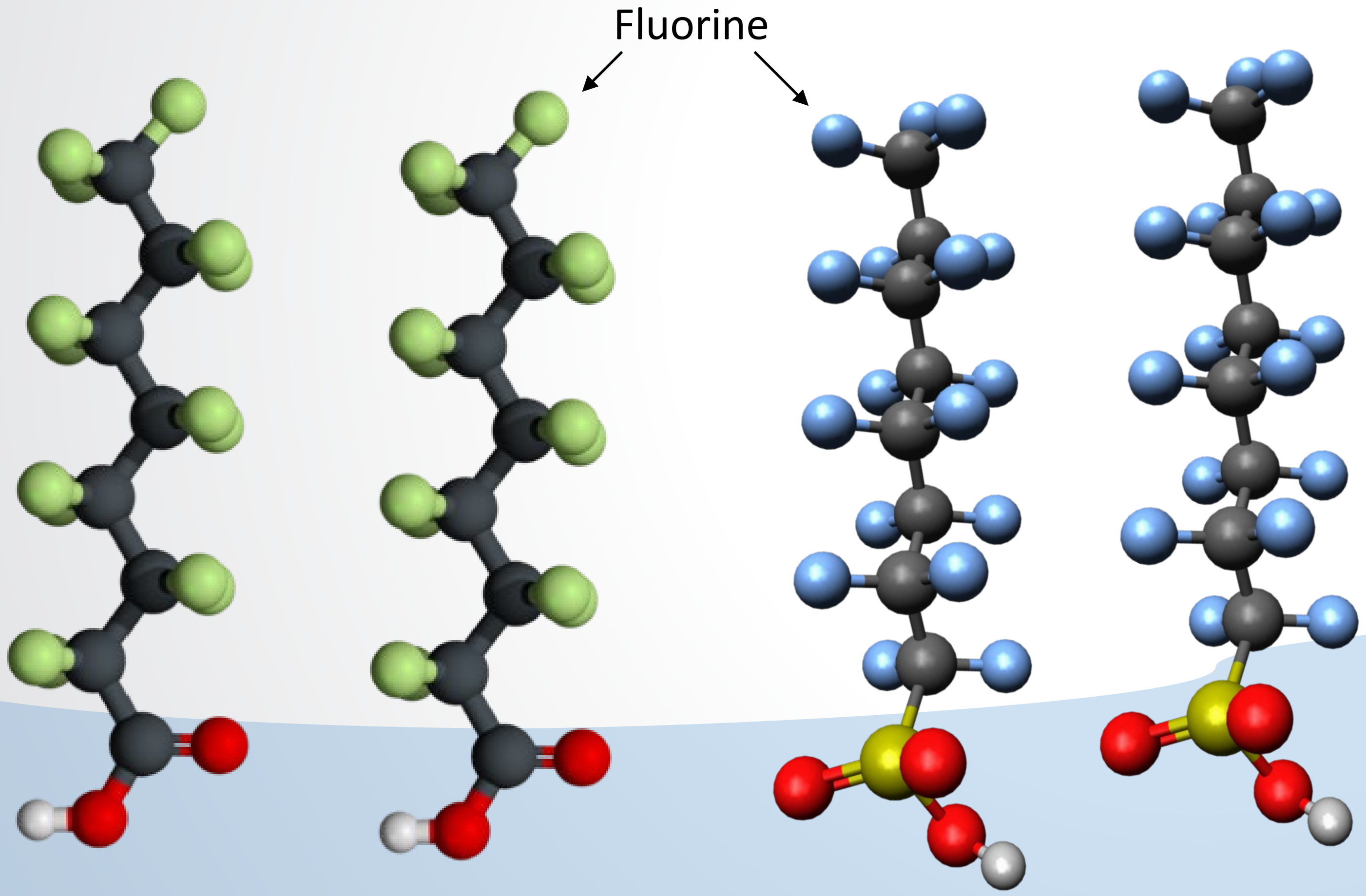
Nitrate / Perchlorate

1) Anion exchange
2) POU membranes
3) Biological treatment (anaerobic)

PFAS

1) Activated carbon
2) Anion exchange
3) Reverse osmosis

Per- and Polyfluoroalkyl Substances (PFAS)



Perfluorooctanoic acid (PFOA) *Perfluorooctanesulfonic acid (PFOS)*

- **A class of chemicals**
  - Chains of carbon (C) atoms surrounded by fluorine (F) atoms
    - Water-repellent (hydrophobic body)
    - Stable C-F bond
  - Some PFAS include oxygen, hydrogen, sulfur and/or nitrogen atoms, creating a polar end

Drinking Water Treatment for PFOS

Ineffective Treatments

Conventional Treatment
Low Pressure Membranes
Biological Treatment (including slow sand filtration)
Disinfection
Oxidation
Advanced oxidation

PAC Dose to Achieve	
50% Removal	16 mg/l
90% Removal	>50 mg/L

Dudley et al., 2015

Effective Treatments

	Percent Removal	
Anion Exchange Resin (IEX)	90 to 99	- **Effective**
High Pressure Membranes	93 to 99	- **Effective**
Powdered Activated Carbon (PAC)	10 to 97	- **Effective for only select applications**
Granular Activated Carbon (GAC)		
Extended Run Time	0 to 26	- **Ineffective**
Designed for PFAS Removal	> 89 to > 98	- **Effective**

Advantages of Select Treatments

Granular Activated Carbon (GAC)	**Most studied technology** **Will remove 100% of the contaminants, for a time** **Good capacity for some PFAS** Will remove a significant number of disinfection byproduct precursors Will help with maintaining disinfectant residuals Will remove many co-contaminants Likely positive impact on corrosion (lead, copper, iron)
Anion Exchange Resin (PFAS selective)	**Will remove 100% of the contaminants, for a time** **High capacity for some PFAS** **Smaller beds compared to GAC** Can remove select co-contaminants
High Pressure Membranes (Reverse Osmosis or Nanofiltration)	**High PFAS rejection** Will remove many co-contaminants Will remove a significant number of disinfection byproduct precursors Will help with maintaining disinfectant residuals

Issues to Consider

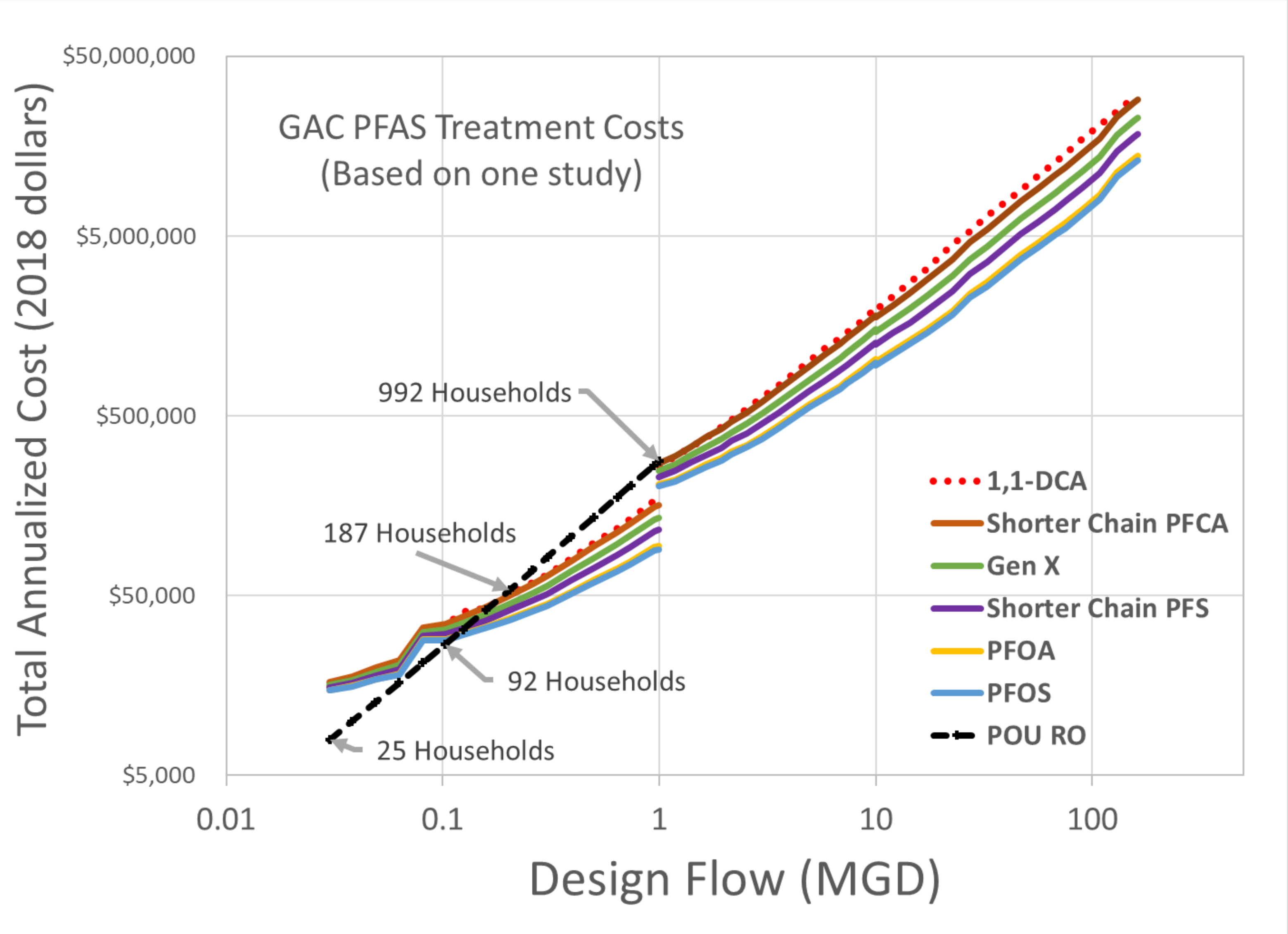
EPA is evaluating these issues to document where and when they will be an issue

Granular Activated Carbon (GAC)	**GAC run time for short-chained PFAS (shorter run times)** **Potential overshoot of poor adsorbing PFAS, if not designed correctly** **Reactivation/removal frequency** Disposal or reactivation of spent carbon
Anion Exchange Resin (PFAS selective)	**Run time for select PFAS (shorter run times)** **Overshoot of poor adsorbing PFAS, if not designed correctly** Unclear secondary benefits Disposal of resin
High Pressure Membranes (Reverse osmosis or Nanofiltration)	**Capital and operations costs** Membrane fouling Corrosion control Lack of options for concentrate stream treatment or disposal

Costs for PFAS Treatment

- The POU devices that have gone through NSF/ANSI certification for PFOA and PFOS are all RO systems
- The costs presented here use prices for devices that are certified under NSF 58, but not specifically for removal of PFOA and PFOS
- We assume these prices are representative for devices certified specifically for PFOA and PFOS under NSF 58
- The costs assume $250 per sample for laboratory analysis
- Results are limited to less than 1 MGD (~1,000 households) based on assumption that only small systems would use POU programs

Costs for PFAS Treatment: One GAC Example



Primary Assumptions:

- Two vessels in series
- 20 min EBCT Total
- Bed Volumes Fed

  1,1-DCA = 5,560 (7.5 min EBCT)

  Shorter Chain PFCA = 4,700

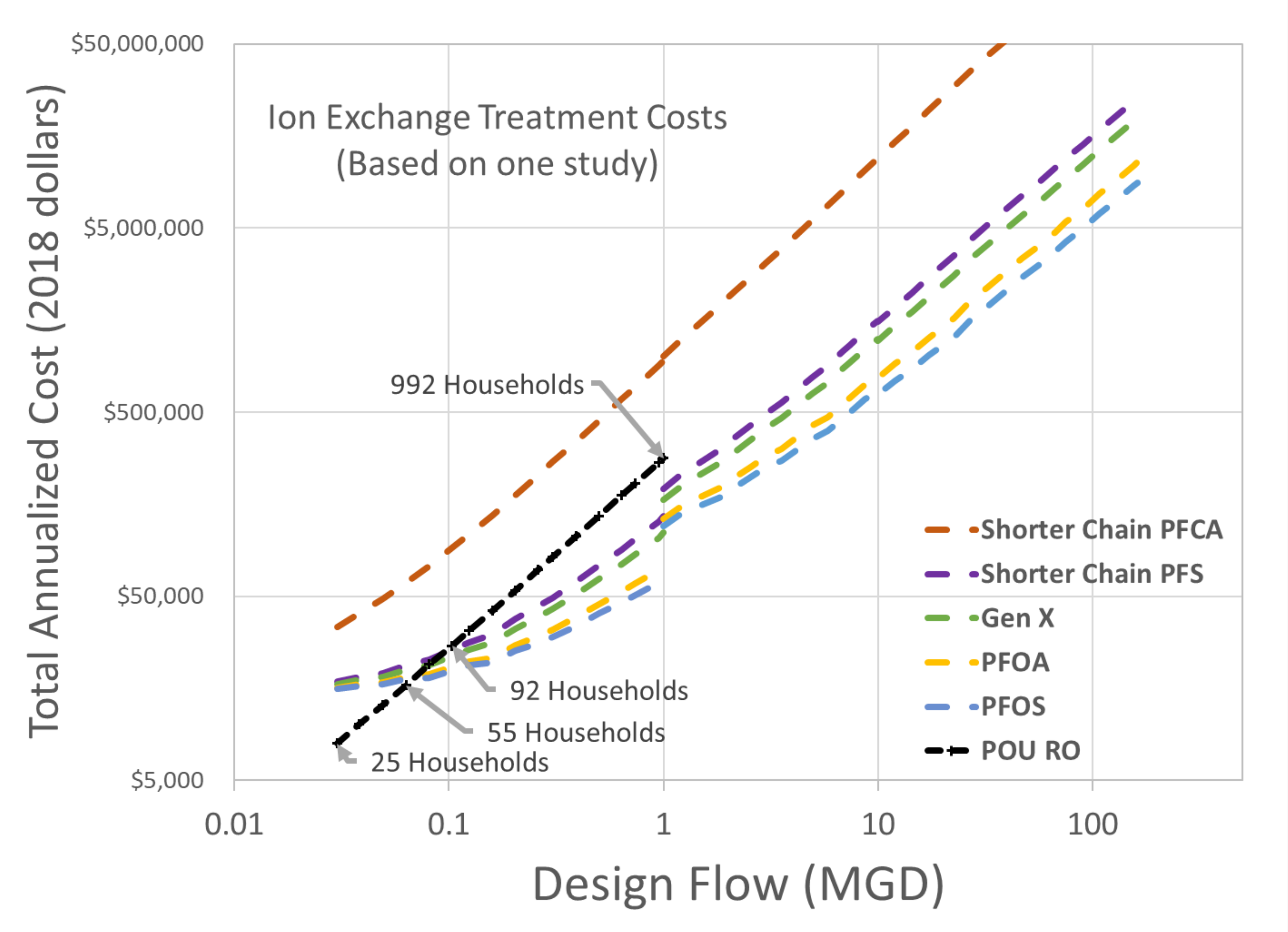
  Gen-X = 7,100

  Shorter Chain PFS = 11,400

  PFOA = 31,000

  PFOS = 45,000
- 7 % Discount rate
- Mid Level Cost

Costs for PFAS Treatment: One IEX Example



Primary Assumptions:

- Two vessels in series
- 3 min EBCT Total
- Bed Volumes Fed

  Shorter Chain PFCA = 3,300

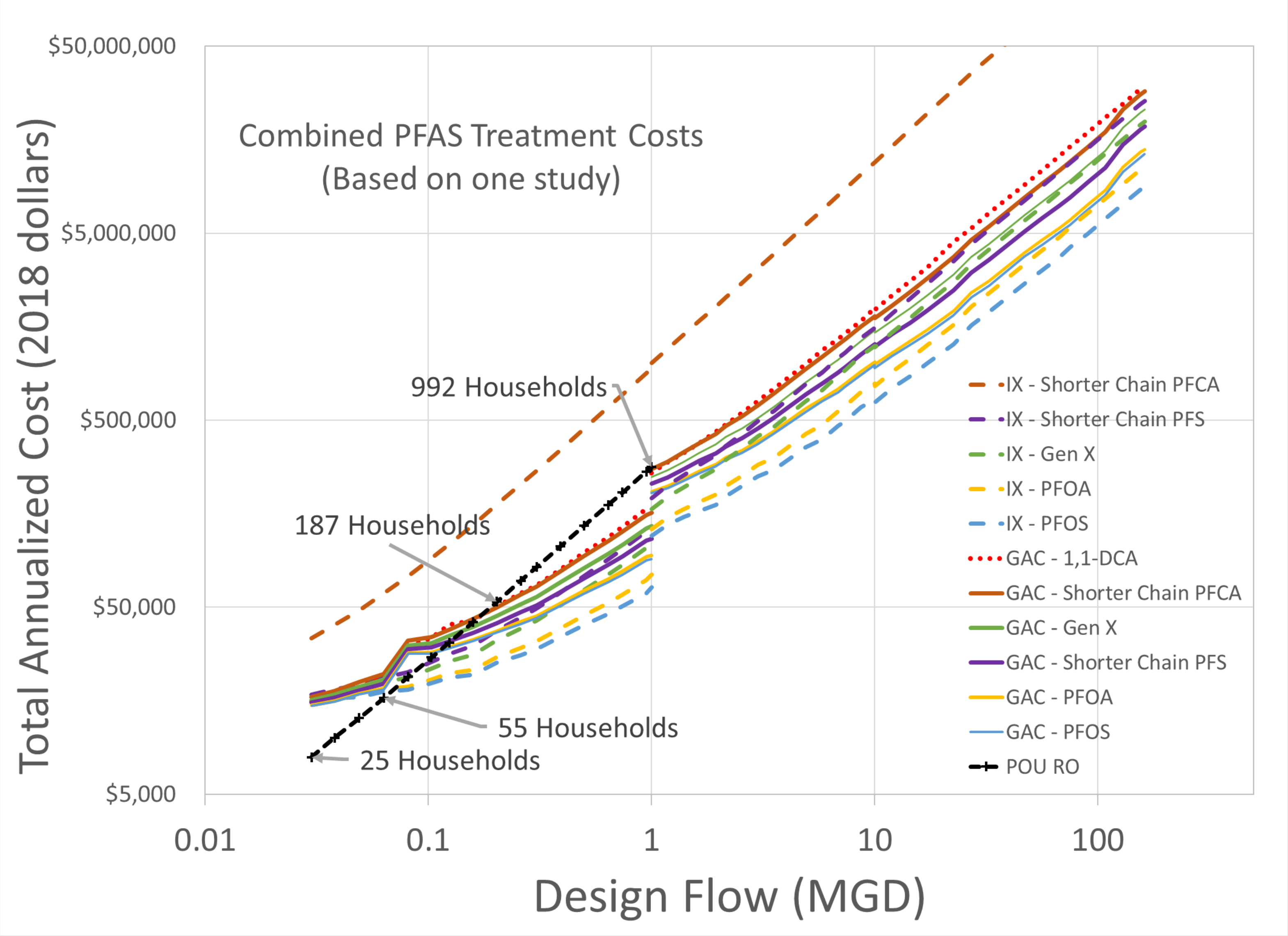
  Gen-X = 47,600

  Shorter Chain PFS = 34,125

  PFOA = 112,500

  PFOS = 191,100
- 7 % Discount rate
- Mid Level Cost

Costs for PFAS Treatment: One Example



Primary Assumptions:

- See previous two slides

PFAS Costing Conclusions

- Similar to nitrate and perchlorate, under certain conditions, POU devices can be the low cost alternative to centralized treatment although a state/utility will have to resolve other logistical/implementation concerns.
- In this instance, the cost of controlling PFAS by centralized GAC treatment is possible. Ion exchange is similar except for shorter chained PFCA – based on this one example.
- Although granular activated carbon can show fewer bed volumes fed to a certain effluent concentration as compared to ion exchange, it can still be the lower cost of treatment.
- This exercise was based on one set of pilot studies, data from additional sites will be needed for an exhaustive evaluation. Also, an evaluation at other relevant treatment goals is needed.

POU / POE Project Goal

To assess the PFAS removal effectiveness using commercially available Point-of-Use (POU) and Point-of-Entry (POE) Reverse Osmosis (RO) treatment units and Granular Activated Carbon (GAC) adsorption systems simulating water from Colorado's Widefield Aquifer.

Point-of-Use (POU)
Kitchen sink, end-of-faucet, and pour-thru devices

Point-of-Entry (POE)
Whole House; typically installed in a hot water tank room or heated garage

Contact: Craig Patterson (Patterson.Craig@epa.gov)

Project Objectives

The project also documented:

- Ease of use during installation, startup, continuous and intermittent operation based on manufacturer instructions.
- Operation and maintenance schedules for replacement of RO units and GAC media based on manufacturer instructions and the representative test water quality.

Source: H2O Distributors

Test Water Target PFAS Composition

CAS Number	PFAS Compounds	Carbon Chain Length	Target Concentration
375-95-1	Perfluorononanoic Acid (PFNA)	**C9**	200 ng/L
335-67-1	Perfluorooctanoic Acid (PFOA)	**C8**	*800 ng/L
1763-23-1	Perfluorooctane Sulfonate (PFOS)	**C8**	1,600 ng/L
375-85-9	Perfluoroheptanoic Acid (PFHpA)	**C7**	200 ng/L
3871-99-6	Perfluorohexane Sulfonate (PFHxS)	**C6**	1,000 ng/L
375-73-5	Perfluorobutane Sulfonate (PFBS)	**C4**	300 ng/L

*To align with the NSF P473 specified 2:1 PFOS:PFOA ratio, the PFOA feed concentration was increased from 200 ng/L to 800 ng/L.

Reverse Osmosis Systems

POU/POE treatment tests on three RO systems (500-1000 gal/day):

- **iSpring RCS5T (0.35 gpm)**
- **Hydrologic Evolution (0.7 gpm)**
- **Flexeon LP-700 (0.5 gpm)**

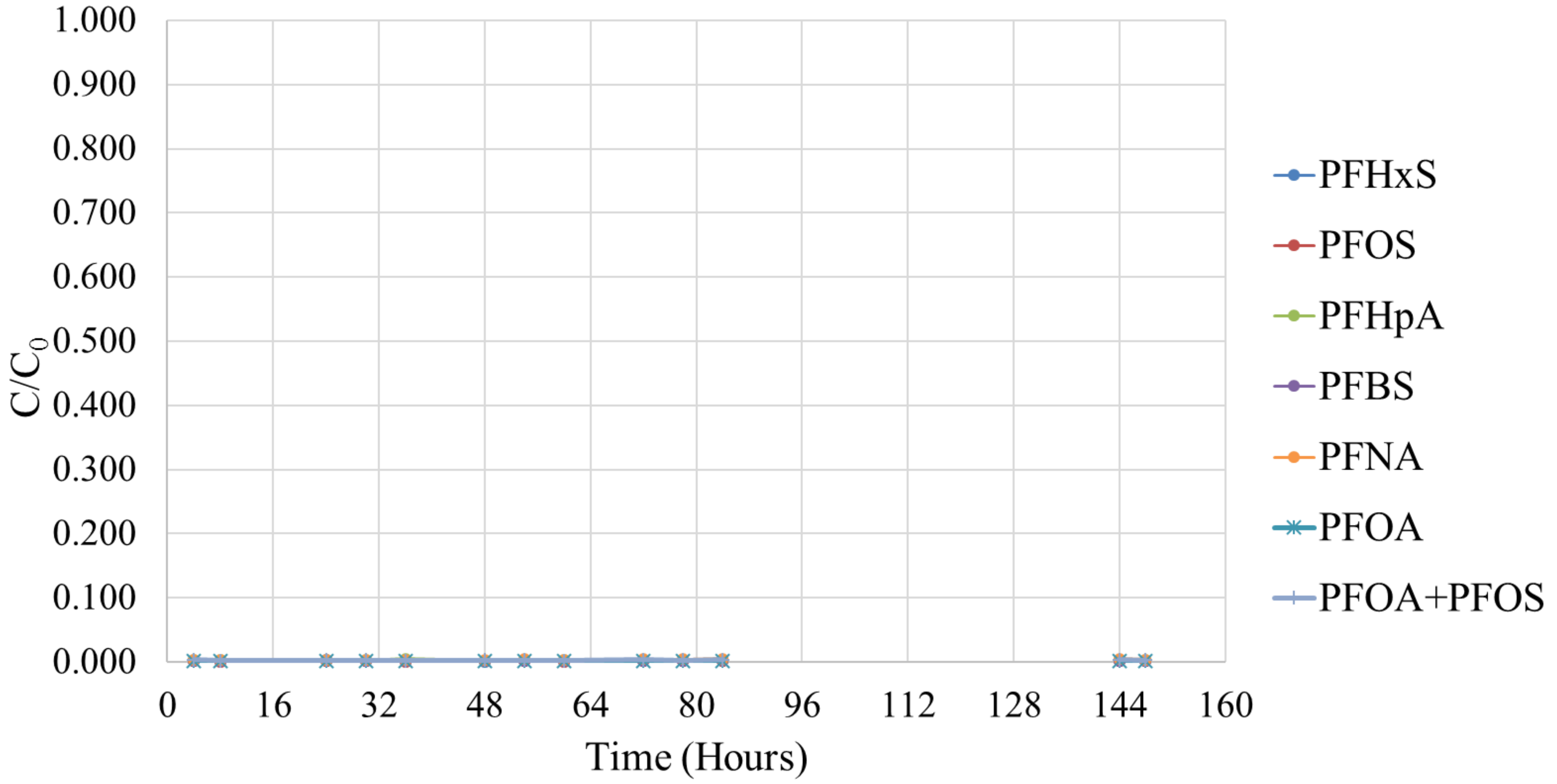
iSpring

Hydrologic

Flexeon

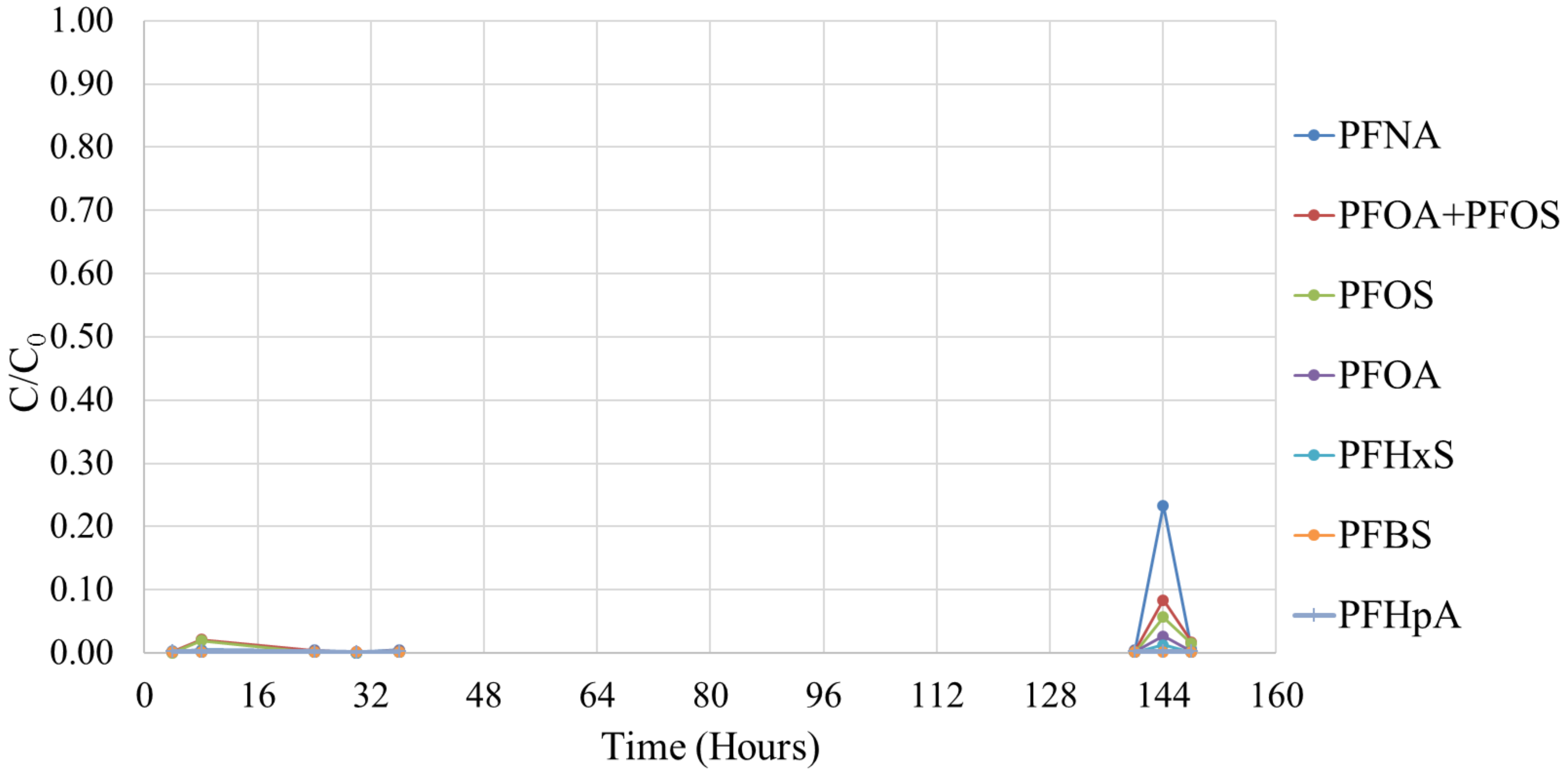
Sample Collection

PFAS Removal: iSpring RCS5T



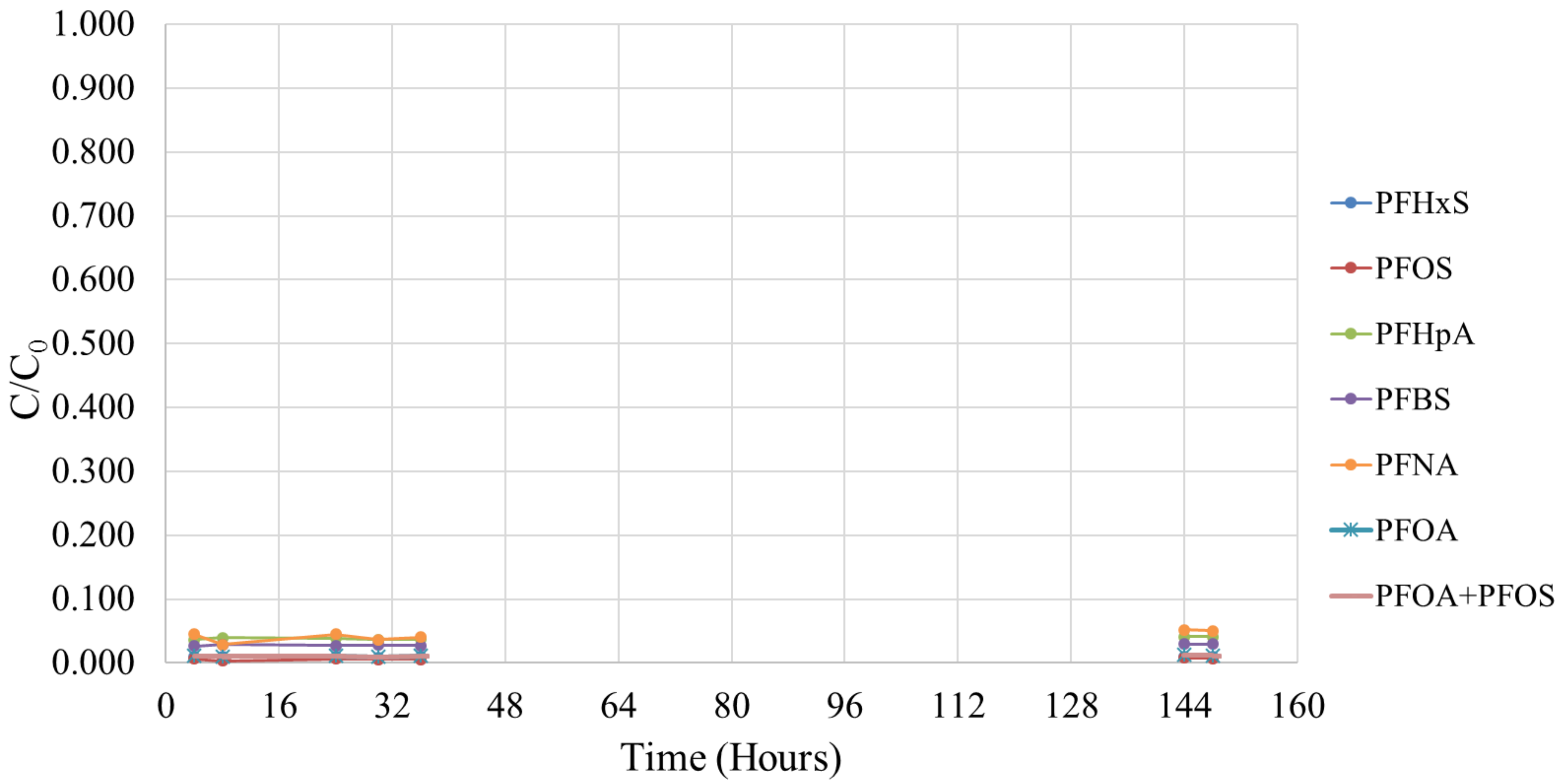
All effluent PFAS results were non-detect

PFAS Removal: Hydrologic



6 of 42 PFAS results were greater than non-detect

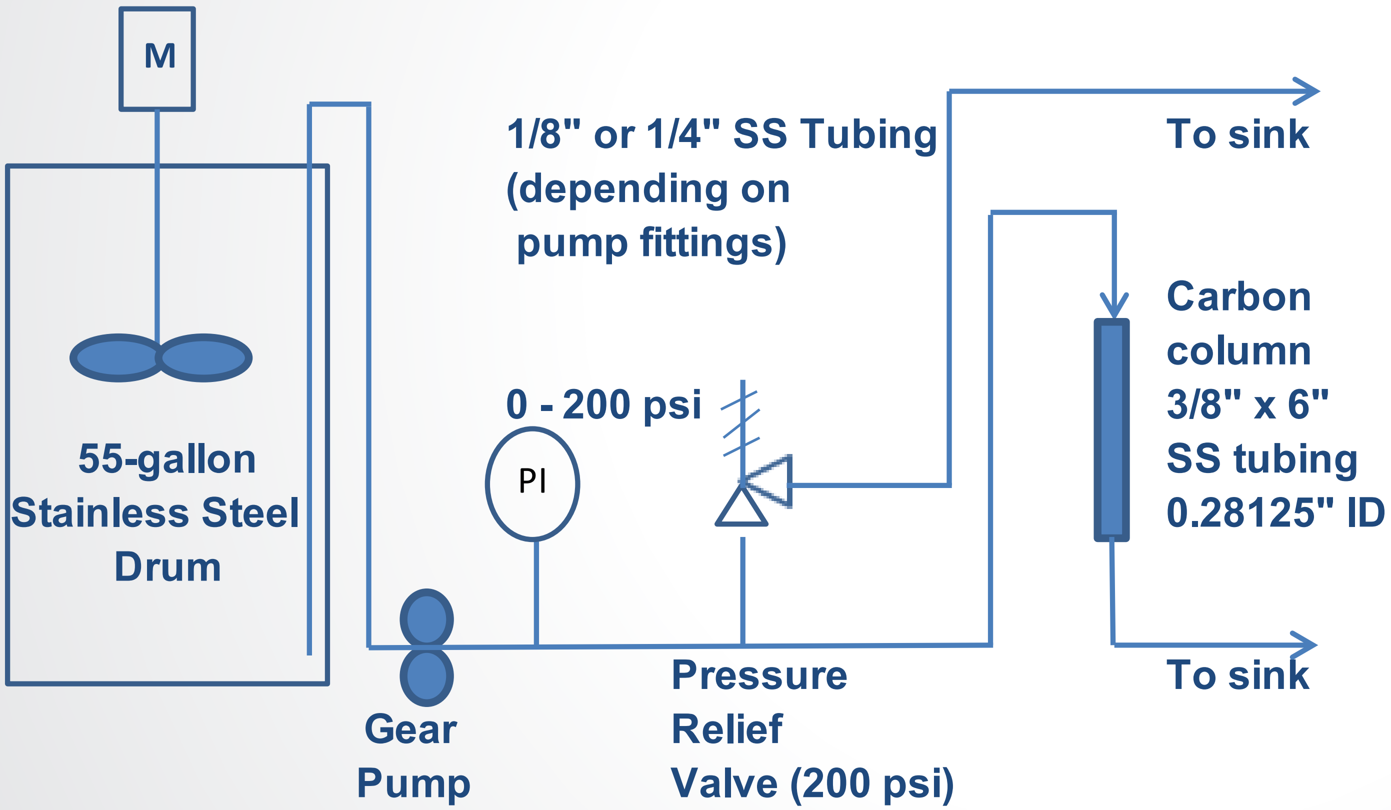
PFAS Removal: Flexeon



All effluent PFAS results were non-detect

GAC RSSCT System

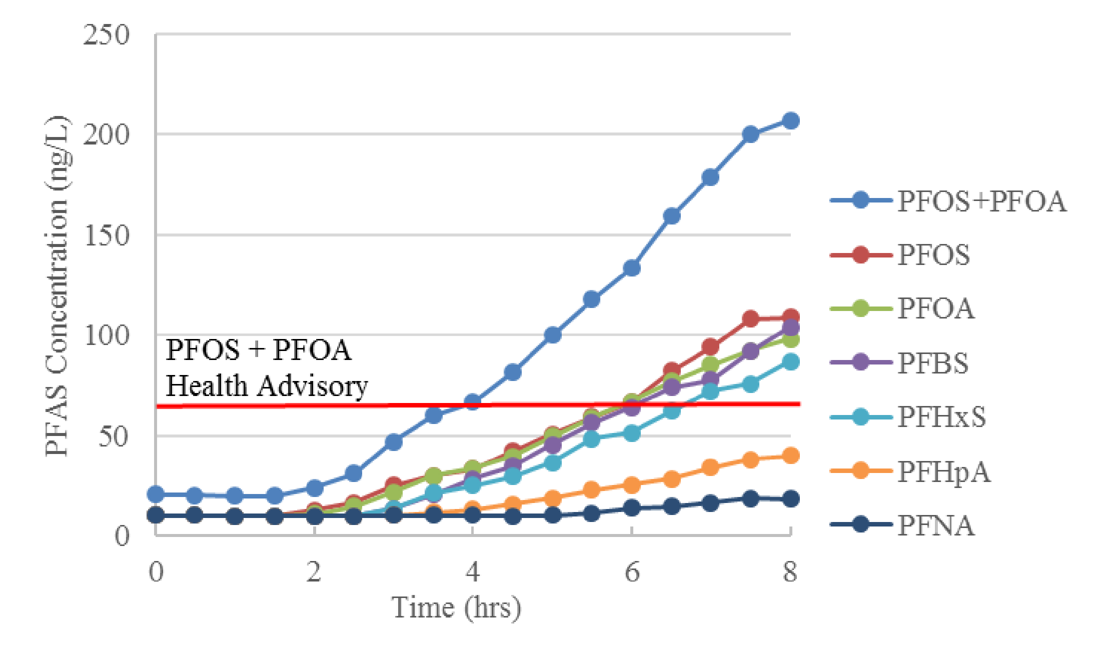
Rapid Small Scale Column Test (RSSCT)



RSSCT GAC Performance

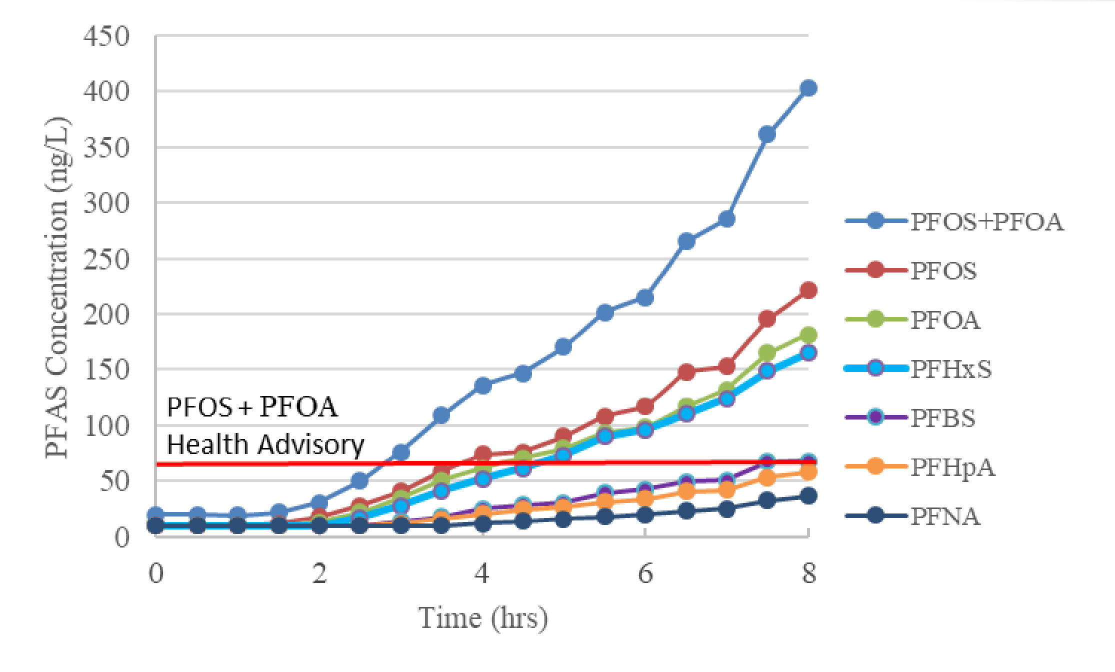
GAC #1
PFOA + FFOS > 70 ppt

- **RSSCT Data: (~ 4 days)**



GAC #2
PFOA + PFOS > 70 ppt

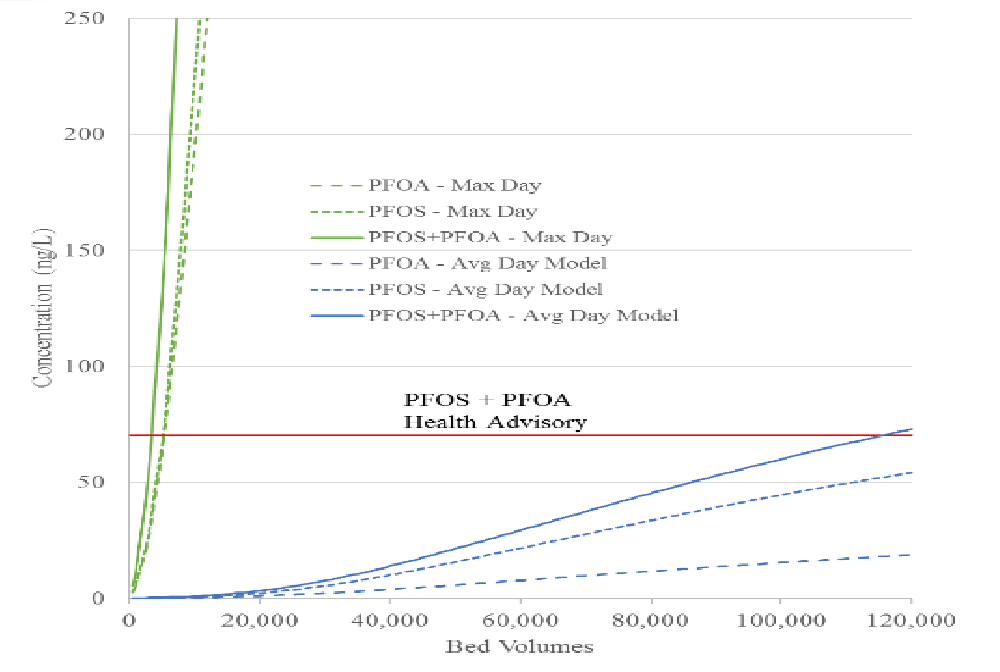
- **RSSCT Data: (~ 3 days)**



Predicted GAC Performance

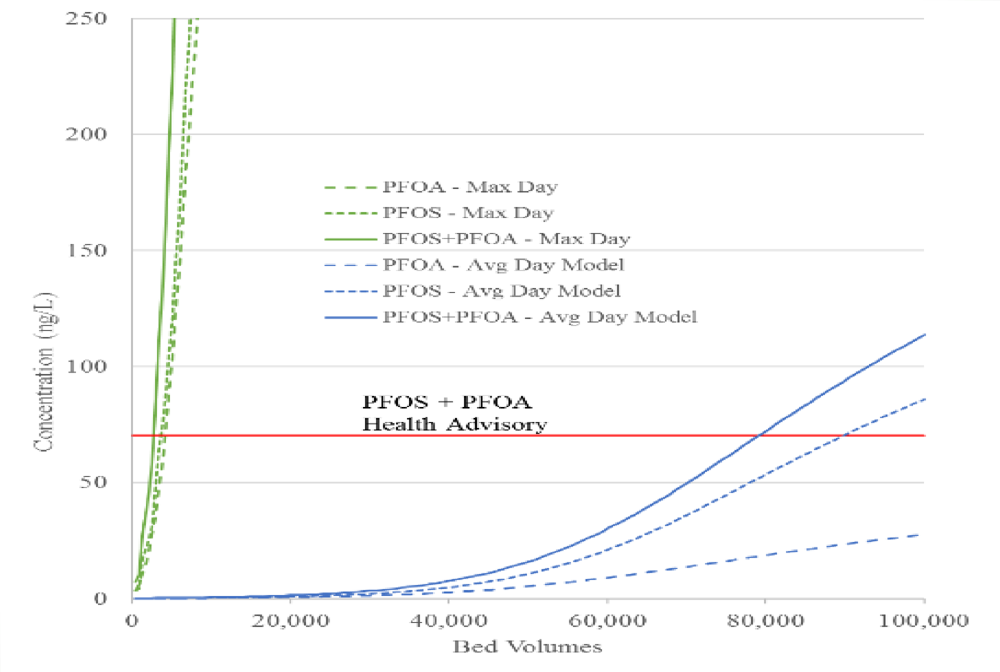
GAC #1
PFOA + FFOS > 70 ppt

- **Fit to Scaled RSSCT Data: 3,400 BVs (24 days)**
- **Predicted Average Conc: 115,000 BVs (2.2 years)**



GAC #2
PFOA + PFOS > 70 ppt

- **Fit to Scaled RSSCT Data: 2,700 BVs (19 days)**
- **Predicted Average Conc: 79,000 BVs (1.5 years)**



Large Whole House Carbon Tanks Required for PFAS Removal (10 min EBCT each)

One 4-5 GPM Non-Backwashing Whole House Carbon Water Filter ($539) 35"(H) x 9"(D) tank with 30 lbs (1 cu ft) of GAC

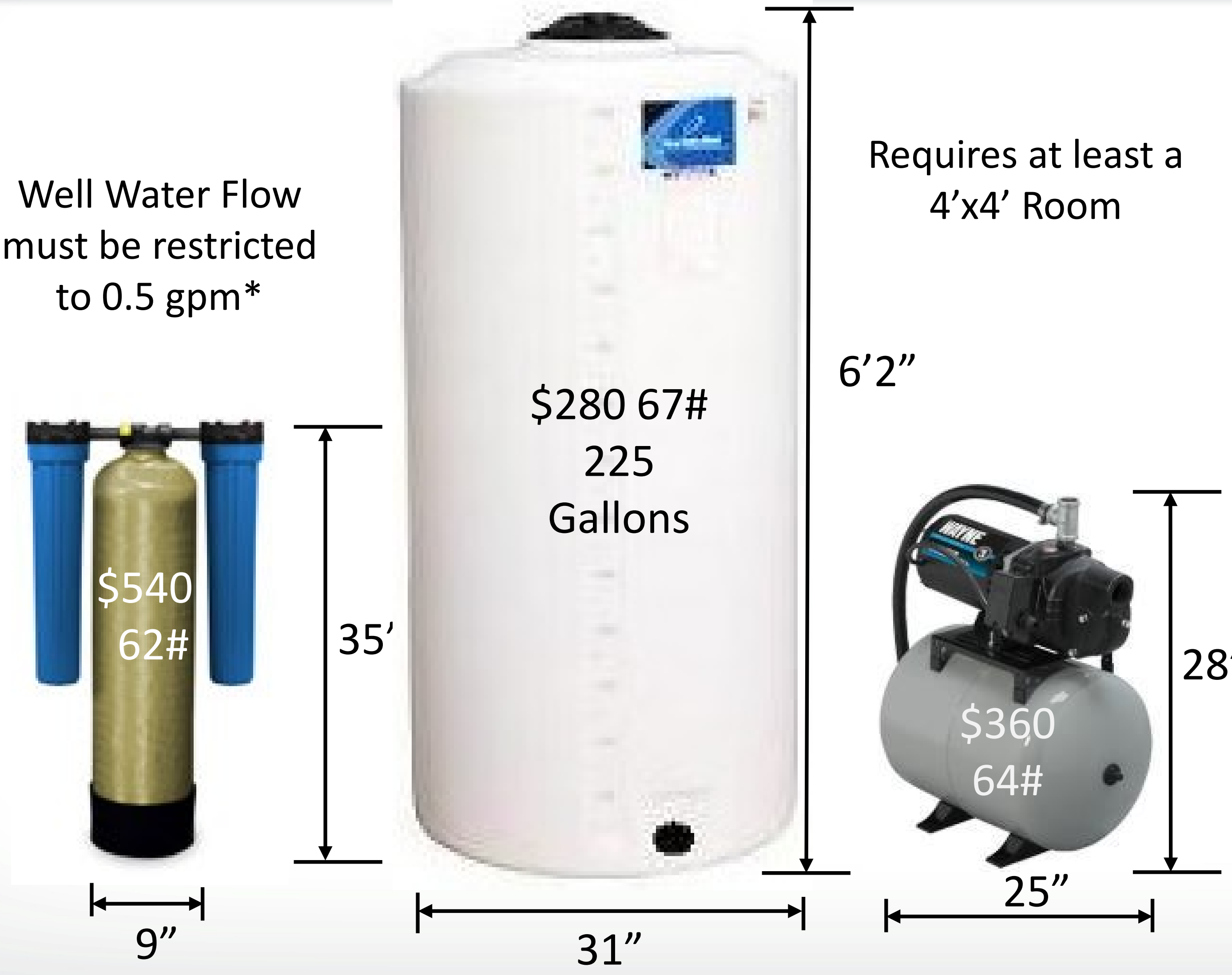
(Source: H_2O Distributors)

Two Large Whole House Backwashing Carbon Water Filter ($3990) 65"(H) x 16"(D) tank with 240 lbs (8 cu ft) of GAC (Source: H_2O Distributors)

Small GAC System for PFAS Removal

Well Water Flow
must be restricted
to 0.5 gpm*

Requires at least a
4’x4’ Room



=

$1200 before
installation, Weight:
200 lbs

*Requires more frequent GAC replacement

RO Modification for Point-of-Entry Use

RO = $500

RO Booster Pump = $880

$280 67#
225
Gallons

6’2”

31”

Requires at least a 4’x4’ Room
May require a re-mineralization cartridge

$360
64#

28”

25”

=

$2000 before installation,
Weight: 150 lbs

Requires Electricity for Well, RO Booster and Water Storage Tank Pumps

Household GAC and RO System Alternatives

Small GAC System	Large GAC System	RO System
Moderate capital and high maintenance costs	High capital and high maintenance costs	Moderate capital and maintenance costs
Large footprint and awkward components	Large footprint and heavy components	Large footprint and awkward components
Lower flow rate (0.5 gpm) requires water storage tank	Higher flow rate (4-5 gpm). No water storage tank required	Lower flow rate (0.3-0.7 gpm) requires water storage tank
Fewer connections, but requires more frequent carbon replacement	Requires backwash wastewater lines and periodic carbon replacement	Requires high system pressure, reject wastewater lines and periodic membrane replacement

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Household GAC and RO POE Systems

GAC System	RO System
Issues with logistical, cost and safety of carbon replacement	Issues with sanitizing components and replacing cartridges & tubing
Cold water temperature less affected in flow through carbon tanks	Residents may complain about room temperature “cold water”
May not be effective on short-chain PFAS	Treats both long- and short- chain PFAS
System could experience contaminant breakthrough if the carbon change-out schedule is not followed	Less likely to have contaminant breakthrough even if scheduled maintenance is not performed. Corrosion control in household plumbing may be an issue for point-of-entry water treatment
No residual stream except for spent media	Disposal of concentrate waste stream (20-50% of flow) may be an issue

POU/POE Project Conclusions

- The three RO systems tested successfully removed PFAS from the influent water to below analytical detection for a majority of the limited sampling events.
- Modeling the RSSCT results for lower concentrations (average daily concentrations) gave bed lives of 1.5 and 2.2 years for the two carbons under these conditions.
- Therefore, for these source water characteristics, POU/POE water systems can provide relatively inexpensive treatment options for PFAS.
- Proper design, operation, and maintenance and conservative replacement of POU/POE components and media may be one way to circumvent the high cost of monitoring treated household drinking water

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Questions?

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