NOTE: The following preliminary draft PFAS Piloting and Design Standards are intended to be incorporated into DEP's *Public Water Supply Manual – Part II, Community System Design Standards* (383-2125-108). The preliminary draft PFAS Piloting and Design Standards are being provided separately from the rest of the manual now for preliminary review by DEP's Public Water System Technical Assistance Center Board (Board) at the Board's February 14, 2024 meeting. Once these PFAS Piloting and Design Standards are incorporated into the broader Part II manual, the entire revised manual, which will also incorporate revisions to other sections, will be presented to the Board for review before being published as draft for public comment.

Since the following preliminary draft PFAS Piloting and Design Standards are presented here without the context of the fully revised PWS Manual – Part II, DEP wants to include the following excerpt from a more-recently revised part of the PWS Manual (the *Public Water Supply Manual – Part IV, Noncommunity System Design Standards* (394-2128-002)) as context for the preliminary draft PFAS Piloting and Design Standards:

> "The Public Water Supply Manual (PWSM) is a comprehensive publication designed to provide necessary, useful information to public water suppliers concerning Pennsylvania's Safe Drinking Water Program administered by DEP. The manual contains essentially everything the public water supplier will need to know about the Safe Drinking Water Program, including: design and construction standards; water quality standards; monitoring, reporting, and operating requirements; emergency measures; and information on government agency programs and contacts.
>
> In accordance with 25 Pa. Code § 109.602 of DEP's Safe Drinking Water regulations, a public water system (PWS) must be designed to provide an adequate and reliable quantity and quality of water to the public that complies with the primary and secondary maximum contaminant levels (MCL), maximum residual disinfectant levels (MRDL), and treatment techniques and conforms to accepted standards of engineering and design in the water supply industry. The standards outlined within this manual conform to accepted standards of engineering and design in the water supply industry and align with standards of the American Water Works Association (AWWA) and the Great Lakes - Upper Mississippi River Board Ten States Standards. An alternate design that does not meet the criteria identified in this manual may be approved by DEP if the water supplier can demonstrate the alternate design is capable of providing an adequate and reliable quantity and quality of water to the public."

For further context, 25 Pa. Code § 109.602(c) states that:

> "The Department's *Public Water Supply Manual* sets forth design standards which the Department finds to be acceptable designs. Other designs may be approved by the Department if the applicant demonstrates the alternate design is capable of providing an adequate and reliable quantity and quality of water to the public."

4.15. PFAS Piloting and Design Standards

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are human-made chemicals that are resistant to heat, water, and oil and persist in the environment and the human body. PFAS are a large group of chemicals that include perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS). As of publication of these design standards, EPA-approved laboratory methods for analyzing drinking water can detect PFOS and PFOA and several additional PFAS. The PFAS that can be detected using these methods are listed in table below along with corresponding acronyms.

Analyte	Acronym	Drinking Water Method
N-ethyl perfluorooctanesulfonamidoacetic acid	NEtFOSAA	533, 537.1
N-methyl perfluorooctanesulfonamidoacetic acid	NMeFOSAA	533, 537.1
Perfluorobutanesulfonic acid	PFBS	533, 537 v1.1, 537.1
Perfluorodecanoic acid	PFDA	533, 537.1
Perfluorododecanoic acid	PFDoA	533, 537.1
Perfluoroheptanoic acid	PFHpA	533, 537 v1.1, 537.1
Perfluorohexanesulfonic acid	PFHxS	533, 537 v1.1, 537.1
Perfluorohexanoic acid	PFHxA	533, 537.1
Perfluorononanoic acid	PFNA	533, 537 v1.1, 537.1
Perfluorooctanesulfonic acid	PFOS	533, 537 v1.1, 537.1
Perfluorooctanoic acid	PFOA	533, 537 v1.1, 537.1
Perfluorotetradecanoic acid	PFTA	533, 537.1
Perfluorotridecanoic acid	PFTrDA	533, 537.1
Perfluoroundecanoic acid	PFUnA	533, 537.1
Hexafluropropylene oxide dimer acid	HFPO-DA (aka C3 dimer acid or GenX)	533, 537.1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11Cl-PF3OUdS	533, 537.1
9-chloroeicosafluoro-3-oxanone-1-sulfonic acid	9Cl-PF3ONS	533, 537.1
4,8 dioxa-3H-perfluorononanoic acid	ADONA	533, 537.1

The following section of this guidance on PFAS is broken into two sections: Pilot Standards; and Acceptable Treatment Technologies and Design Standards for full-scale use.

Pilot requirements apply to all proposed PFAS treatment. The acceptable treatment technology will be project-dependent; however, each of the acceptable treatment technologies should be considered and evaluated as part of the Pilot Application process. This guidance covers Anion Exchange, Granular Activated Carbon, and Reverse Osmosis. All other technologies should be discussed with DEP prior to submitting a Pilot Study application and will be reviewed by DEP on a case-by-case basis.

I. Pilot Standards

For pilot studies, the DEP form *Pilot Study Application and Instructions* (3940-FM-BSDW0017) (Application) shall be submitted to and approved by the Department prior to the initiation of a pilot study. The Application shall include:

- Anticipated time frames
- Pilot feed water and finished water parameters to be analyzed
- Specific analysis methods and testing intervals
- Proposed methods of water treatment setup
- Empty bed contact time
- Hydraulic loading
- Pilot study review fee (see the listed fees for feasibility studies in 25 Pa. Code § 109.1407 of DEP's Safe Drinking Water regulations).

The Final Pilot Test Report (Report) shall summarize:

- The events of the pilot study
- Results
- Water quality analyses
- Recommended method of treatment
- Breakthrough curves (as defined by performance goals in Section M below)

The Report shall include a summary of the results, recommendations, and conclusions.

The Application and Report shall be completed, signed, sealed, and submitted by a Professional Engineer (P.E.) licensed in Pennsylvania.

Further details for the Application and Report can be found in the sections below; please also visit DEP's Pilot Studies webpage for more information.

A. Purpose of Pilot Testing

The purpose of pilot testing is:

1. To ensure that the proposed treatment will continuously produce water that meets State and Federal drinking water standards.
2. To ensure that the proposed treatment will not have adverse effects on other treatment processes or cause simultaneous compliance problems.
3. To determine the specific operational and performance characteristics of the selected processes throughout the anticipated range of raw water quality and hydraulic loading rates, and to determine the breakthrough timeframe, which contaminant will govern the change-out frequency, chemical feeds, and operating conditions.

4. To enable full-scale design to be implemented with the approved pilot-scale model.

B. The Application

The Application shall be developed and submitted to the appropriate DEP Regional Office for approval prior to initiating the pilot study. It is recommended that the public water supplier and the consultant meet with Regional Office staff to discuss the standards for the pilot study prior to submitting the Application.

The Application shall include the following:

1. Pilot Feed Water Quality Data

At least one year of quarterly water quality testing of the pilot feed water should have been conducted prior to submittal of the Application. Pilot feed water data can determine the pilot study's duration, water quality analysis parameters, and sampling frequency. Additionally, pilot feed water data can identify potential problems which should be more closely evaluated during the pilot test.

Polymer and phosphates should not be fed prior to GAC or anion exchange pilot columns. Surface water systems using polymer for coagulation should discuss with DEP plans to pilot PFAS treatment prior to submitting an Application as polymer coagulant could be detrimental to the operation of the pilot.

The following pilot feed water parameters should be considered to determine the treatment method:

- PFOS
- PFOA
- PFHxA
- PFHpA
- PFNA
- PFBS
- PFHxS
- 1,4 Dioxane
- Silica
- Fluoride
- Sulfate
- Iron
- Manganese
- Total Dissolved Solids (TDS)
- Total Organic Carbon (TOC)
- Ammonia (NH_3)
- Nitrite
- Nitrate
- pH
- Temperature
- Alkalinity
- Calcium
- Chloride
- Conductivity
- Hardness
- Aluminum
- Natural Organic Matter (NOM)
- Uranium
- Perchlorate
- Chromate
- Arsenic
- VOCs
- Oxidants
- Coagulant residuals
- Turbidity

C. Selection Criteria

The technologies to be tested should be selected based upon the pilot feed water sample results, design capacity, target effluent concentrations, and operational considerations.

1. Briefly discuss why other available technologies were not considered or are not appropriate.

Treatment effectiveness may be influenced by:

- water temperature
- pH
- flow rates
- contact time
- types and concentrations of competing organic and inorganic substances
- residual chlorine or other oxidants

Specifically, for removal of PFOS and PFOA using anion exchange resins, water with high concentrations of the following substances may hinder the effective removal of PFAS (through physical or ion exchange site blocking), while oxidants can degrade the resin:

- TOC
- TDS
- manganese
- iron
- other dissolved organics
- sulfates
- chlorides
- competing anions
- potential foulants
- scalants
- oxidants

For GAC, effective removal of PFAS may be hindered by the following:

- TOC
- manganese
- iron
- other dissolved organics
- potential foulants and scalants
- oxidants

D. Pilot Study Design

The general approach is to provide as many different treatment options within a pilot as economically possible so the designer and water supplier can test multiple concepts and make the best decision when choosing and proposing full-scale treatment. A minimum of three different treatment products (such as different types of ion exchange resins, GAC, or other selective media) should be piloted.

In general, Pilot Study Applications should propose the use of at least two pilot-scale columns for each treatment technique or treatment product to be tested, and those columns should be installed in series (that is with a lead column and a lag column) and operated in a downflow mode. In some cases, pretreatment requirements, optimal loading rates, removal capacities, and estimated runtimes can be determined via testing using one pilot-scale column. Applicants proposing to utilize single-column testing should consult with the DEP Regional Office prior to submitting their Pilot Study Application.

Full-scale design of any technology or combination of technologies shall include provisions to protect the consumer from contaminant breakthrough. This is typically

ensured by use of two treatment vessels (a lead vessel and a lag vessel) in full-scale operation.

E. Schematic flow diagrams

Schematic diagrams for the pilot plants to be tested shall be provided showing, at a minimum, source water for the pilot (for example, raw water, settled water), source water for any backwash, location of discharge (for example, sanitary sewer, wastewater holding tank, injection well), physical dimensions, and locations of monitoring and other equipment (for example, chemical feed points) necessary for the pilot testing.

F. Sizing

The sizing of GAC and resin columns is primarily based on empty bed contact time (EBCT). A pilot-scale adsorption study should incorporate testing of several EBCTs so that the optimal vessel size can be selected.

- The sizing of the column is based on EBCT at the selected flow rate.
  - For anion exchange, at least 2.5 minutes of EBCT at design capacity should be provided per column.
  - For GAC, at least 10 minutes of EBCT at design capacity should be provided per column.
- The columns should have an internal diameter of at least three inches.
- Hydraulic loading:
  - for anion exchange should be 12 gallons per minute (gpm) per square foot (ft^2) or less at design capacity.
  - for GAC should be 6 gpm/ft^2 or less at design capacity.
- Pilot Study Applications proposing shorter EBCTs or higher hydraulic loading rates may require a longer pilot duration.

The Pilot Study Application shall include sizing calculations for all proposed equipment and processes. The Pilot Study Application shall also include calculations for proposed backwash rates, the source of backwash water, and its disposal.

G. Specifications

Complete, detailed technical specifications shall be supplied for the proposed project. Include all resin or GAC specifications, backwash recommendations, and specifications for any chemicals to be utilized during pilot testing.

H. Pilot Plant Operation

The effluent, backwashes, and rinses from pilot studies shall be fed to waste. GAC shall have an initial backwash before it is put into service. Sufficient freeboard shall exist to permit at least 30% bed expansion during backwash.

Then, the need and frequency of operational backwashing should be determined during the pilot study. Backwash requirements may vary depending upon factors such as headloss, turbidity, and floc carried over from any pretreatment processes. Operational headloss accumulation rates, as well as backwash time, duration, and volume, shall be recorded.

Anion exchange resins shall not be backwashed as this will disturb the mass transfer zone.

If media is changed during the pilot, then changeout dates, media volume, and disposal information shall be recorded. Where media changeout is performed, the media in the column shall be the same product and volume throughout the pilot, and new media shall be backwashed per the manufacturer recommendations.

All issues that interrupt operation or data collection during the pilot study shall be recorded. DEP shall be notified within one business day to discuss extended interruptions (more than 48 hours). The monthly report (See Section N below) shall include the cause, duration, and corrective actions for all unplanned pilot study downtime, regardless of duration.

I. Monitoring

Parameter	Location	Frequency
PFOS and PFOA	Pilot feed water, midpoint between pilot columns, and pilot effluent	Every 14 days#
PFHxA, PFHpA, PFNA, PFBS, and PFHxS	Pilot feed water and pilot effluent	Every 14 days#
Nitrate (if present in Pilot feed water)	Pilot feed water and pilot effluent	Daily*
TOC	Pilot feed water and pilot effluent	Daily
pH	Pilot feed water and pilot effluent	Daily*
Alkalinity	Pilot feed water and pilot effluent	Daily*
Chloride	Pilot feed water and pilot effluent	Weekly#
Sulfate	Pilot feed water and pilot effluent	Weekly#
Arsenic (if present in Pilot feed water)	Pilot feed water/feed (if present)	Weekly#
Feed water turbidity (surface water only)	Feed water	Continuous
Free chlorine or other oxidants	Pilot feed water if oxidant is added in pre-treatment	Weekly
Total Al if using Alum or PAC	Pilot feed water and effluent	Daily
Total Fe	Pilot feed water and effluent	Weekly
Total Mn	Pilot feed water and effluent	Weekly

* Parameters evaluated daily should be monitored around the same time each day.
# Parameters evaluated weekly and every 14 days should be evaluated, respectively, on the same day each week or on the same day of every other week. The date and time of initial pilot startup and all sample collection shall be recorded along with any interference with treatment process due to shutdowns, significant increase, or drop-in flow rate, etc.

J. Documentation and Records

Depending on the technology and the specifics of each pilot plant study, the daily record or log should include the following items:

1. Sample collection, methods, and analysis results
2. Operational problems and corrective measures that were taken
3. Chemicals that were used, injection locations, and their associated dosages
4. Daily measurements of flow rates, treated volumes, and headlosses
5. Time frames and daily operation hours

K. Timeframes and duration of the pilot study

The length or duration of each pilot study test shall be sufficient to demonstrate the performance of the technology. The length of each pilot study shall run through at least one complete media run determined by performance goals for each technology that will be utilized in full-scale operation.

L. Simultaneous Compliance

Alkalinity, pH, dissolved inorganic carbon (DIC), and chloride-to-sulfate mass ratio (CSMR) can have secondary impacts that limit their use. The following secondary impacts shall be evaluated:

1. Optimal pH for all other processes, particularly disinfection
2. Calcium carbonate precipitation pH
3. Oxidation of iron and manganese
4. Disinfectant byproduct control (DBP) formation
5. Lead and copper corrosion control including:
    - Alkalinity, pH, and DIC
    - Corrosion inhibitors
    - Hardness (calcium and magnesium)
    - Buffer Intensity
    - Dissolved oxygen (DO)
    - Oxidation reduction potential (ORP)
    - Ammonia, chloride, and sulfate
    - Natural organic matter (NOM)
    - Iron, aluminum, and manganese
6. Identification of possible limitations and secondary impacts for treatment options

M. Pilot Performance Goals

The Pilot Study Application shall discuss the water quality criteria used to determine if a given technology is a viable option for full-scale implementation. Technologies that do not meet these water quality criteria would not be considered viable options for full-scale operation and the Report should discuss these findings.

Additionally, wastewater production is an important consideration for operation of any PFAS treatment. The Pilot Study Application should consider the amount of wastewater produced for each media and the system’s ability to manage the amount of wastewater produced at pilot-scale and at full-scale. The Report should discuss the generation and disposal of PFAS-laden wastewater and media for full-scale operation.

The Pilot Study Application shall establish the following performance goals:

1. Effluent water quality standards for any regulated PFAS found in the source water.
2. Effluent water quality standards for non-PFAS parameters necessary for downstream treatment processes or distribution of the finished water.
3. The minimum number of technology-specific bed volumes per column before breakthrough.
    - The Application shall also define breakthrough (for example, detection, >10 ppt, > MCL, etc.).
4. The maximum volume of wastewater acceptable per technology tested.

N. Monthly and Final Pilot Test Reports

Results of the ongoing pilot testing shall be submitted to the appropriate DEP Regional Office in monthly progress reports. The submission of monthly reports allows DEP to monitor the progress of the pilot study and address concerns before the study is concluded.

Monthly reports shall include:

1. Breakthrough curve for PFOA for each media, based on bed volumes.
2. Breakthrough curve for PFOS for each media, based on bed volumes.
3. The cause, duration, and corrective actions for all pilot study downtime.
4. Sample collection, methods, and analysis results.
5. Chemicals that were used, where they were used, and their associated dosages.
6. Daily measurements of flow rates, treated volumes, and headlosses.

A Final Pilot Test Report containing the following should be submitted within two months of completing all pilot testing and shall include:

1. All water quality results obtained during the pilot.
2. Graphical summary data, including percentage removal, headloss, complete breakthrough curves for all PFAS, and other water quality parameters (pH, chloride, etc.) monitored with respect to bed volumes.
3. Recommended technology or media from the pilot for the full-scale treatment plant.
4. Estimated full-scale media replacement frequencies.
5. Description of disposal of exhausted media and backwash water.

Please visit DEP's Pilot Studies webpage for more information.

O. Bench-Scale Studies: Rapid Small-Scale Column Test (RSSCT)

Bench-scale studies may be useful for GAC; however, bench-scale studies cannot be used for anion exchange.

The bench-scale, rapid small-scale column test (RSSCT) uses small GAC particle sizes and requires less time and volume of water than pilot-scale tests.

A smaller-than-full-scale particle size should be selected for the RSSCT. Based on the ratio of the particle sizes and the operating parameters (such as EBCT, flow rate, and time to breakthrough), the results from an RSSCT can be scaled up to full-scale. Full-scale design variables – such as adsorbed operation (for example, bed in-series or in-parallel operation), EBCT, and usage rate – can be determined by conducting several RSSCTs that duplicate full-scale operation.

The following guidelines should be followed in setting up an RSSCT:

- The experimental apparatus should be constructed of glass or stainless steel to minimize adsorption of organics.
- The experiments should be conducted in a temperature-controlled room at temperature ranges of 10°C to 14°C.
- A minimum of three RSSCTs should be used when evaluating the effect of EBCT and absorber configuration, such as beds in series or in parallel, on GAC usage rate.
- The minimum column diameter to avoid channeling should be 50 particle diameters. However, if large sample volumes are required, then larger-diameter columns can be used.
- If the RSSCT is used in lieu of pilot-scale adsorption tests, then the user should understand that the limitations of the test have not yet been clearly defined. However, two limitations which are known include:
    - The RSSCT is performed over a short period of time compared to that required for a pilot study. If the influent adsorbate concentration is not relatively constant, then the RSSCT may not be able to produce a breakthrough profile comparable to a pilot-scale profile.
    - Selection of the appropriate equations for scaling up the RSSCT depends upon the functional relationship between surface diffusivity and GAC particle size. Therefore, it is strongly recommended that this relationship be evaluated prior to performing the RSSCT.

II. Acceptable Treatment Technologies and Design Standards (full-scale)

A. Anion Exchange

1. Pre-Treatment Standards

a. Feed water with high concentrations of TDS, iron, other dissolved organics, sulfates, chlorides, and/or competing anions, as well as potential foulants and scalants, may require pre-treatment. Anion exchange requires pre-treatment to reduce any of the following feed water quality characteristics:

- Chloride > 250 mg/L
- Nitrates > 10 mg/L
- TDS > 500 mg/L
- TOC/NOM > 1 mg/L
- Manganese > 0.05 mg/L
- Iron > 0.3 mg/L
- Sulfate > 50 mg/L

b. Chlorine or other oxidants shall not be injected or shall be quenched prior to anion exchange vessels. Oxidants will degrade the resin.

c. Phosphates, fluoride, and polymers shall not be injected prior to anion exchange vessels.

d. Cation exchange (if provided) shall be provided before the anion exchange system. Mixed beds are not permitted.

e. For surface water sources, anion exchange treatment shall be located post filtration with a lead/lag configuration.

f. Pre-filtration should be provided if the source water turbidity exceeds 0.3 NTU. Removal of TOC/NOM should also occur prior to the PFAS selective resin.

2. Design

This design uses an anion exchange resin to remove PFAS by exchanging ions in the resin for PFAS ions in the anion exchange feed water. Complex ammonium-form resins are most often used in PFAS removal. Shorter-chain PFAS molecules will break through first, as they tend to be displaced by more electronegative long-chain PFAS.

The treatment capacity shall be capable of producing the permitted capacity of the plant at a level consistently below half of the MCL within the lead vessel.

a. Vessels/Piping

1. At least two treatment pressure vessels shall be provided, piped in series (lead and lag), and operated in a downflow mode. “Lead” and “lag” labels should be provided.
2. Vessel(s) shall be capable of meeting plant permitted capacity with one vessel removed from service.
3. Piping between vessels shall be designed to prevent accidental bypass of the system. Prevention of bypass may include alarms, valve position indicators, or additional valves. Designs which allow bypass of treatment if a single valve is in the wrong position do not meet this standard.
4. Loading rates should be between 8-12 gpm/ft^2. Loading rates outside of this range shall demonstrate effectiveness with a pilot study.
5. EBCT should be at least five minutes total (2.5 minutes per vessel). Lower EBCT shall only be considered when demonstrated in a successful pilot study.
6. Anion exchange vessels shall have an access port and be located so that they are accessible for maintenance, operation, monitoring, and inspection.

7. Anion exchange vessels shall be designed to provide even flow distribution across the inlet.
8. An instantaneous flow meter shall be provided for each treatment train.
9. A totalizing flow meter shall be provided for each treatment train.
10. When multiple treatment trains are provided, a flow control shall be provided for each treatment train.
11. Sample taps shall be provided before the lead vessel, between the lead and lag vessels, and after the lag vessel. A sample tap should be provided at the middle point in the mass transfer zone within each tank.
12. Sample taps shall not use Teflon tape or be constructed of materials that may affect the validity of the sample results.
13. A pressure relief valve, vacuum breaker, and air release valve shall be provided at high points of the vessel.
14. Air release valves shall also be provided at backwash pump discharge connections.
15. Pressure differential gauges shall be provided for each vessel.
16. Anion exchange vessels shall be designed to provide pipes and fittings for resin changeout allowing for media removal and addition.

b. Media

1. The anion exchange media shall be of the highly selective PFAS type to ensure PFAS bumping by non-PFAS ions does not occur. Media may be gel (transparent) or macropourous (opaque) resin beads. Gel types are more susceptible to oxidizing agents and organic foulants.
2. The minimum bed depth of the resin shall be at least three feet (deeper bed depths are recommended).
3. Regeneration of the media using a brine and solvent (ethanol/methanol) is unacceptable.
4. A resin trap post-treatment should be provided to ensure resin does not enter the distribution system.

c. BACKWASH

1. The treatment shall be capable of initial backwash and filtering-to-waste.
2. Initial backwash shall use PFAS-treated water that does not contain oxidants. Chlorinated finished water shall not be used for backwash water.
3. Wastewater holding tanks shall have backflow prevention.
4. An initial backwash tank shall be provided. Routine backwashes are not recommended as they disrupt the classification of the resin bed, which can result in underutilized resin and allow early breakthrough of PFAS. If routine backwashes are required, any

backwash waste shall be properly disposed of in accordance with the federal Resource Conservation and Recovery Act (RCRA) and Clean Water Act (CWA).

5. Initial backwash volume and flow rates shall meet manufacturer requirements.

d. Construction Materials

1. Vessel materials shall be 316 stainless steel.
2. All equipment that may come into contact with the water or may affect the quality of the water shall be certified for conformance with ANSI/NSF Standard 61.

e. Housing

Vessels shall be housed indoors to prevent freezing.

f. Preconditioning of the Media

Prior to startup of the equipment, the media shall be backwashed to stratify and remove air from the bed. Additionally, preconditioning shall meet all other manufacturer requirements.

g. Waste Disposal

Spent media and associated wastewater shall be properly disposed of in accordance with all applicable laws and regulations.

h. Performance Monitoring

Quarterly performance monitoring of the anion exchange effluent from the lead vessel is required for PFAS. More frequent monitoring may be necessary as the concentration of the contaminants to be removed approach their respective MCLs.

i. Water Quality Test Equipment

A pH meter using an EPA-approved method should be provided.

j. Simultaneous Compliance

Any change in source or treatment techniques may adversely impact compliance with other drinking water regulations. A simultaneous compliance analysis shall be submitted with every Application.

A detailed report shall be provided that addresses how the addition of the new treatment will affect the quality and quantity of the water supplied to the system. Additionally, the report shall evaluate how any adverse effects will be addressed. Specific to anion exchange, the following shall have a detailed evaluation:

1. Lead and copper corrosion control
2. Nitrate dumping

k. Plant layout

1. Adequate head space shall be provided to allow for media changeout.

2. Additional space should be provided for additional vessel(s)/treatment train(s).

3. The building shall be designed to allow for the vessels to be removed and replaced.

B. GRANULAR ACTIVATED CARBON (GAC)

1. Pre-Treatment Standards

1. Feed water quality shall be thoroughly evaluated as there is the possibility of competition for adsorption from other contaminants which may reduce the effectiveness of PFAS treatment. GAC requires pre-treatment to reduce any of the following feed water quality characteristics:
   - TOC/NOM > 1 mg/L
   - Manganese > 0.05 mg/L
   - Iron > 0.3 mg/L
2. Chlorine or other oxidants shall not be injected or shall be quenched prior to GAC vessels. Oxidants will reduce the GAC lifespan.
3. Phosphates, fluoride, pH adjustment, and polymers shall not be injected prior to GAC vessels.
4. For surface water sources, GAC treatment shall be located post-filtration with a lead/lag configuration.
5. Pre-filtration should be provided if the source water turbidity exceeds 0.3 NTU. Removal of TOC/NOM should also occur prior to the GAC.

2. Design

This design uses GAC to remove PFAS via adsorption. GAC works well on longer-chain PFAS, like PFOA and PFOS, but shorter-chain PFAS like PFBS and perfluorobutyrate (PFBA) may not adsorb as well.

The treatment capacity shall be capable of producing the permitted capacity of the plant at a level consistently below half of the MCL within the lead vessel.

a. Vessels/Piping

1. At least two treatment pressure vessels shall be provided, piped in series (lead and lag), and operated in a downflow mode. “Lead” and “lag” labels should be provided.
2. Vessel(s) shall be capable of meeting plant permitted capacity with one vessel removed from service.
3. Piping between vessels shall be designed to prevent accidental bypass of the system. Prevention of bypass may include alarms, valve position indicators, or additional valves. Designs which allow bypass of treatment if a single valve is in the wrong position do not meet this standard.
4. Loading rates should be between 2-10 gpm/ft^2. Loading rates outside of this range shall demonstrate effectiveness with a pilot study.

5. EBCT should be at least 20 minutes total (10 minutes per vessel). Lower EBCT shall only be considered when demonstrated in a successful pilot study.
6. GAC vessels shall be sized to allow for a minimum of 30% bed expansion.
7. GAC vessels shall have an access port and be located so that they accessible for maintenance, operation, monitoring, and inspection.
8. GAC vessels shall be designed to provide even flow distribution across the inlet.
9. An instantaneous flow meter shall be provided for each treatment train.
10. A totalizing flow meter shall be provided for each treatment train.
11. When multiple treatment trains are provided, a flow control shall be provided for each treatment train.
12. Sample taps shall be provided before the lead vessel, between the lead and lag vessels, and after the lag vessel. A sample tap should be provided at the middle point in the mass transfer zone within each tank.
13. Sample taps shall not use Teflon tape or be constructed of materials that may affect the validity of the sample results.
14. A pressure relief valve, vacuum breaker, and air release valve shall be provided at high points of the vessel.
15. Air release valves shall also be provided at backwash pump discharge connections.
16. Pressure differential gauges shall be provided for each vessel.
17. GAC vessels shall be designed to provide pipes and fittings for media changeout allowing for media removal and addition.

b. Media

1. The GAC media shall be specifically selected based on the type of PFAS present.
2. The minimum bed depth of the GAC shall be at least four feet.
3. Reactivated GAC shall only be used if certified for conformance with ANSI/NSF Standard 61.
4. A GAC trap post-treatment should be provided to ensure GAC does not enter the distribution system.

c. Backwash

1. The treatment shall be capable of backwashing and filtering-to-waste.
2. Backwashing shall use PFAS-treated water.
3. Wastewater holding tanks shall have backflow prevention.
4. Adequate backwash supply shall be provided. A separate oxidant-free backwash tank should be provided.
5. Backwash shall meet manufacturer’s requirements for volume and flow rates.

d. Construction Materials

1. GAC vessels shall be constructed of 316 stainless steel.
2. All equipment that may come into contact with the water or may affect the quality of the water shall be certified for conformance with ANSI/NSF Standard 61.

e. Housing

Vessels shall be housed indoors to prevent freezing.

f. Preconditioning of the Media

Prior to startup of the equipment, the media shall be backwashed to stratify the bed, rinse fines out of the media, and remove air from the bed. Additionally, preconditioning shall meet all other manufacturer requirements. This is a critical step to ensure arsenic is removed from the bed.

g. Waste Disposal

Spent media and associated wastewater shall be properly disposed of in accordance with all applicable laws and regulations.

h. Performance Monitoring

Quarterly performance monitoring of the GAC effluent from the lead vessel is required for PFAS. More frequent monitoring may be necessary as the concentration of the contaminants to be removed approach their respective MCLs.

i. Water Quality Test Equipment

A pH meter using an EPA-approved method shall be provided.

j. Simultaneous Compliance

Any change in source or treatment techniques may adversely impact compliance with other drinking water regulations. A simultaneous compliance analysis shall be submitted with every Application.

A detailed report shall be provided that addresses how the addition of the new treatment will affect the quality and quantity of the water supplied to the system. Additionally, the report shall evaluate how any adverse effects will be addressed. Specific to GAC, the following shall have a detailed evaluation:

- Lead and copper corrosion control
- Disinfection

k. Plant layout

1. Adequate head space shall be provided to allow for media changeout.

2. Additional space should be provided for additional vessel(s)/treatment train(s).

3. The building shall be designed to allow for the vessels to be removed and replaced.

C. Reverse Osmosis (RO) and Nanofiltration (NF)

High-pressure membrane filtration can remove multiple contaminants including a variety of PFAS. There are two types of high-pressure membrane filtration: reverse osmosis (RO) and nanofiltration (NF); RO has a higher removal efficiency than NF.

A prefilter shall be provided immediately prior to each RO/NF filter vessel. Other pretreatment may be required based on the raw water quality parameters due to the high susceptibility of fouling (refer to Section 4.14.7 of this guidance).

Post-treatment mineral addition, pH adjustment, and/or corrosion control measures will almost always be necessary for stabilization.

Waste considerations are important for RO/NF, as it may be challenging to find an acceptable means of discharging or treating the PFAS concentrate reject water produced by the process. Additional permits may be required for waste discharge streams and/or disposal of waste.

DEP's Clean Water Program shall be contacted, and waste handling approval/permits shall be obtained prior to submitting a Safe Drinking Water Permit Application.

The system shall meet the design standards from this guidance's Section 4.14, Nanofiltration (NF) and Reverse Osmosis (RO) Systems Membrane Treatment Processes.