COMMONWEALTH of VIRGINIA

DEPARTMENT OF HEALTH

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State Health Commissioner

OFFICE OF DRINKING WATER

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SUBJECT: City of Richmond
PWSID No: 4760100

July 9, 2025

Mr. Scott Morris, DBA, PE, Director
City of Richmond Department of Public Utilities
Scott.Morris@rva.gov

Re: City of Richmond Water Treatment Plant Filter Optimization Plan Report

Dear Mr. Morris*:*

On June 26, 2025, you submitted the City of Richmond's Water Treatment Plant Filter Optimization Plan Report prepared by Whitman, Requardt & Associates, LLP. The report provides a summary of current coagulation and filter operations and identify opportunities for optimization. The report provided several recommendations for optimizing filter operational setpoints, filter backwash, pre-treatment, and general recommendations. Overall, the recommendations were adequate and would provide opportunities for further optimization of plant operations.

The Consent Order between the City of Richmond and the Commonwealth of Virginia signed on July 9, 2025, requires the development of a Corrective Action Plan which includes the requirement to submit a report to this Office within 120 days that outlines which recommendations contained within the Filter Optimization Plan Report will be incorporated into the operations of the water treatment plant. Please reference the Consent Order for the details on requirements of this Corrective Action Plan.

This Office appreciates the continued efforts of the City of Richmond to optimize water treatment operations at the plant.

If you have any questions or concerns regarding this matter, please contact me at james.reynolds@vdh.virginia.gov or (757)406-1252 or Sam Neth at sam.neth@vdh.virginia.gov.

Sincerely,

James Reynolds, PE
Field Director
Richmond Field Office

JR
ec: Tony Singh, Deputy Director Senior, Department of Public Utilities, tony.singh@rva.gov
Jeffrey McBride, Chief Deputy Director, Department of Public Utilities, Jeffrey.McBride@rva.gov

Water Treatment Plant Filter Optimization Plan

City of Richmond, Virginia
Department of Public Utilities

June 2025

DEPARTMENT OF
PUBLIC
UTILITIES

City of Richmond, Virginia
Department of Public Utilities

Water Treatment Plant
Filter Optimization Plan

Technical Memorandum
June 2025

Prepared By:

Whitman, Requardt & Associates, LLP
9030 Stony Point Parkway, Suite 220, Richmond, VA 23235

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1. INTRODUCTION

1.1 BACKGROUND

The City of Richmond Water Treatment Plant (WTP) located at 3920 Douglasdale Road in Richmond, Virginia is a conventional surface water treatment plant with a permitted treatment capacity of 132 MGD (Waterworks Operations Permit No. 4760100-A). The WTP is comprised of two (2) process treatment trains that operate in parallel, respectively called Plant No. 1 and Plant No. 2.

[redacted]

[redacted]

Current procedures for operating the filters during normal flow and backwash are not optimized to provide for increased filter efficiency or operational flexibility in response to adverse water quality conditions. Similarly, coagulation control at the WTP has the ability to be improved upon through raw water quality treatment and post flash mix water quality monitoring enhancements, which in turn would ultimately optimize settled water quality – increasing filter performance and runtimes.

1.2 PURPOSE & SCOPE

The purpose of this report is to provide a summary of current filter operations at the WTP and identify procedures for operation of the filters in both a “normal” and “emergency” mode. Additionally, the report reviews current pre-treatment procedures and data from previous years’ Monthly Operating Report (MOR) data, as provided by the City. The purpose for this pre-treatment evaluation is to assess the WTP’s raw water and settled water quality monitoring and treatment performance in order to outline current processes and to identify areas where improvements can be implemented to allow for optimized monitoring and control, ultimately leading to process optimization for the filters.

2.1 FILTER EFFLUENT TURBIDITY MONITORING

Individual filter effluent (IFE) turbidity samples are pumped from each filter [redacted] pump attached to the wall in the pipe gallery. Each pump is designed to pump [redacted] Turbidity samples are collected via a connection on the common backwash supply header/effluent/rewash piping and are continuously pumped via flexible hose coupled to [redacted] pipe upwards to the respective filter's turbidimeter located adjacent to each filter control console. Each filter's turbidimeter is wired to a controller that is located within each filter console; however, the WTP is currently in the process of replacing all filter effluent turbidimeters with new Hach analyzers and transmitters.

2.2 FILTER NORMAL OPERATING PROCEDURES

In normal operation under forward flow, settled water enters each filter through the filter's influent gate, gravity flows through the filter media and underdrain, and enters the clearwells (located directly beneath the filters) through each individual filter's effluent piping. In forward-flow, flow rates through each filter are controlled through the use of a modulating effluent flow rate control valve. The effluent flow rate control valves modulate in response to flow rate feedback provided by each filter's effluent flow meter and the flow rate is maintained based on an operator-assigned flow rate set point for each given filter. [redacted] An on-going project (Filter Upgrades project) at the WTP will be replacing all filter effluent flowmeters with new mag meters for increased accuracy and consistency between both Plants.

During normal filter operations, each individual filter effluent's turbidity is continuously measured and automatically logged for each filter every [redacted] in compliance with VDH requirements. Additionally, filter head loss is continuously monitored using differential pressure transmitters. Both IFE turbidity and filter head loss data is transmitted to each filter's PLC for control and monitoring of each filter via SCADA. Combined filter effluent turbidity is not monitored from combined flows leaving both Plant 1 or Plant 2. Instead, as authorized by VDH, representative CFE values are derived by averaging IFE values over the given 4-hour sample timeframe.

2.3 FILTER BACKWASHING PROCEDURES

Each filter is operated in forward flow until one of the setpoints that triggers a backwash is reached (see **Table 2-2**). A filter backwash is manually initiated by an Operator when any of the three of the backwash initiation setpoints are reached during normal filter operation. A backwash sequence can be initiated locally at the filter's control panel or via SCADA at the operator's workstation within the Plant 1 or Plant 2 control rooms. Once started, the automated backwash sequence commences.

[redacted]

3. PRE-TREATMENT CONTROL & OPTIMIZATION

The source water for the City's WTP is the James River. The James River's headwaters are located near the Virginia/West Virginia line at the confluence of the Cowpasture River and the Jackson River, and the River runs across the state and ends at the Chesapeake Bay. The James River watershed is comprised of three separate sections: the Upper James, Middle James, and Lower James. The City of Richmond WTP intake is located just a few miles upstream of the boundary between the Middle James and Lower James, and as such is impacted from any events within the Upper James and Middle James that impact the water quality within the river.

As is typical for surface water sources, during rain events it is normally observed that turbidity increases, alkalinity decreases, and temperature decreases within the River. The City's pre-sedimentation basin has a volume of [redacted] gallons, and provides a significant buffer against source water quality changes or contamination that originate upstream within the James River by providing a detention time of approximately [redacted] days at full plant capacity of 132 MGD (according to the WTP operating permit), or [redacted] days at the WTP's recent history peak day rate of 96 MGD. However, despite this buffer, the pre-sedimentation basin is still an open-air basin that is subject to direct environmental influences such as rain events. As such, the WTP still needs to actively monitor source water quality in order to appropriately and swiftly respond to variations in source water quality with appropriate adjustments to the raw water chemical treatment.

3.1 COAGULATION & FLOCCULATION

The main purpose of the coagulation, flocculation and sedimentation process is to remove turbidity and natural organic matter (NOM) from the source water. To do so, coagulants are added to the raw water during turbulent ("rapid") mixing to promote dispersion and homogenization of the coagulant. Directly following the coagulation step, flocculation occurs where the water is slowly agitated to promote the collision of microflocs, promoting the bonding and agglomeration of flocs to form macroflocs, which then settle out within the sedimentation basins. However, the mechanisms associated with the removal of NOM and turbidity are largely dependent on the source water characteristics, so without proper control of raw water chemical dosing rates, it is possible that process upsets and/or compliance issues may occur at some point as a result of inadequate turbidity or NOM removal, or chemical overdosing/underdosing.

Several key principles to recognize in coagulation control are:

1. Coagulation at the WTP occurs by dosing liquid alum followed by a coagulant aid polymer, and is completed through two main processes:
    a. *Charge neutralization*: the process in which colloids from raw water (negative charge) adsorb the positively charged ions from the coagulant on their surface, forming neutrally charged microflocs. This process is promoted by the alum.
    b. *Sweep floc*: the process in which aluminum hydroxide precipitates form (independent of colloid presence or charge) and create a sweeping blanket of precipitate that entraps colloids. This process is assisted by the polymer.
2. The polymer does not have a big impact on the charge neutralization process, after the large majority of charge neutralization has already occurred. The polymer instead promotes larger flocs to form through a process called *bridging* in which the polymer joins together the microflocs that were previously formed through the charge neutralization process. The use of a coagulation aid polymer does not typically cause a substantial

increase in residuals production, but assists in residuals settling and should allow for a reduction in the coagulant dosage.

3.2 COAGULATION CHEMISTRY BASICS

Alum is used to form insoluble aluminum hydroxide ($Al(OH)_3$) flocs by consuming alkalinity in the water, in turn decreasing the acid neutralization capacity of the water. If insufficient or no additional alkalinity is added to the water to account for the reduction in alkalinity by the alum, the water pH will subsequently decrease.

Typical when dosing alum for coagulation, the pH of the water should generally be in the range of 6 to 8 to maximize floc formation and solids precipitation. When alum is dosed below this pH range, the settled water has a higher likelihood to contain residual soluble aluminum, and when dosed above this pH range, aluminum hydroxide floc dissolution is promoted. Both instances can lead to elevated levels of solids, discoloration, and ineffective NOM and turbidity removal in the settled water.

When optimizing alum coagulation, it is helpful to understand the pH of minimum-solubility for aluminum hydroxide. Since the pH of minimum-solubility increases with decreasing water temperature, seasonal adjustments for maintaining an optimal raw water pH are warranted to help encourage the formation and stability of aluminum hydroxide precipitates.

[redacted] This ultimately can lead to decreased treatment process efficiency downstream of sedimentation (i.e. premature increased headloss in filters) and lower finished water quality.

3.3 WTP RAW & SETTLED WATER QUALITY MONITORING AND CONTROL

The WTP doses aluminum sulfate (alum) as the primary coagulant to the raw water within each raw water channel, just upstream of the static mixer within each channel. As water enters the rapid mix basins, a coagulant aid polymer is dosed. Permanently installed alum feed lines are installed to allow dosing at the rapid mix chambers but the WTP does not currently operate the rapid mixers, and as such does not dose alum at the front of the rapid mix.

The WTP also has the ability to dose potassium permanganate, powder activated carbon, and sodium hydroxide (caustic) to the raw water, upstream of the alum dosing locations within the raw water channels. Potassium permanganate is typically dosed to the raw water seasonally to provide oxidation of iron and manganese. PAC is typically used to treat taste, odor, and color compounds and caustic is used to increase raw water alkalinity and pH; however, both PAC and caustic are not normally used at the WTP. The City previously utilized a filter aid polymer along with carbon slurry, dosed at the inlet gate to each filter's central gullet. The piping for these systems is still in-place, but the WTP no longer stores or doses either of these chemicals.

Alum dosing at the WTP is typically adjusted based on a proportional increase or decrease in plant flow and is adjusted by the WTP operators via SCADA. [redacted]

[redacted]

3.3.1 Current Water Quality Monitoring Parameters & Procedures

Between the James River and the WTP filters, the WTP currently provides continuous monitoring of the raw water turbidity (NTU) and pH within both the South Intake Basin and the North Intake Basin. Following dosing of alum and polymer to the raw water, continuous monitoring of pH is provided with samples being drawn at the back end of the flash mix for each basin (total of 8 locations). Post rapid-mix, streaming current detectors (SCDs) are installed and provide continuous monitoring of the coagulated water for increased coagulation control and optimization. [redacted] Three of these existing four SCDs were installed in 2024 to replace older units. The remaining SCD that has not yet been replaced is operational and recording data accurately but is planned for replacement in the near future for continued reliability.

Following sedimentation, the settled water turbidity is continuously monitored for each basin, with sample pumps located within the downstream section of the applied water channels pumping to the analyzers which are located in both the Plant 1 and Plant 2 headhouses. All continuously monitored water quality parameters are able to be monitored via SCADA at the operator's workstation. Similarly, individual filter effluent turbidity is monitored and available to be monitored via SCADA at the operator's workstation.

Additional water quality analysis is manually provided by WTP operators throughout each day [redacted] for post rapid-mix and settled water quality monitoring. This monitoring includes collecting samples via grab samples or at the sample taps within the operations lab adjacent to [redacted]

A summary of the parameters monitored by the WTP upstream of the filters, including the frequency and method for which they are collected are summarized in **Table 3-1**.

[redacted]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
		[redacted]
[redacted]		[redacted]
	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]

3.3.2 Ongoing Operational Improvements

As part of a plant-wide improvements initiative, the City is actively developing resources, designing upgrades, and constructing improvements at the WTP for increased resilience and optimization of the WTP facilities and processes. As it relates to pre-treatment and filtration improvements, the following projects are ongoing:

A) WTP SOP Development

The City is in the process of updating existing standard operating procedures (SOPs) and developing numerous new SOPs to provide clear protocols for WTP operators and maintenance staff to use throughout the WTP. As it pertains to pre-treatment control and filter optimization, there are multiple SOPs that have been developed under this project, as outlined below.

Pre-treatment SOPs – The intent of these SOPs is to ensure the accuracy of water quality readings, the consistency in obtaining the readings, and how to interpret the readings for use in control and optimization of WTP system processes.

- pH, alkalinity, and turbidity bench scale testing and calibration SOPs
- pH meter, SCD, and turbidimeter instrument cleaning and flushing SOPs
- [redacted]
- Polymer, powder activated carbon, potassium permanganate, and caustic system operation SOPs

Filtration SOPs – The intent of these SOPs is to outline and document the procedures that WTP personnel need to follow for the safe and effective operation of the filters to ensure performance efficiency is optimized and filter downtime is minimized.

- Filter backwash procedures (both automatic and manual operation) SOPs

- Plant shutdown and startup SOP (includes filter shutdown and startup procedures)
- Filter drop test, bed expansion/rate adjustment, and maintenance/ inspection SOPs

Some additional SOPs that support both pre-treatment and filtration processes are:

- Operational parameters and goals SOP
- Storm Preparation SOP
- Sedimentation basin washout and inspection SOPs

B) [redacted]

[redacted]

C) Filter Upgrades

[redacted] the City initiated a project to provide a comprehensive upgrade to all WTP filters and filtration facilities. Key components of the project include:

- Replacement of all anthracite, silica sand, and garnet sand in all 22 filters
- Replacement of all WTP filter valves and actuators, including the conversion of existing hydraulic controls to electric control for operational consistency
- Replacement of all individual filter instrumentation including turbidimeters, flow meters, differential pressure transmitters, and level monitoring equipment
- Replacement of Plant 1 filter underdrains and washwater troughs
- Replacement and relocation of all electrical and control wiring and equipment associated with the filters to locations outside of the basement to help prevent potential water damage
- Replacement of two (2) Plant 1 filtered water pump motors and replacement of the soft starters with VFDs for increased control and resilience
- Upgrading the Plant 1 and Plant 2 UPS systems
- Replacement of the Plant 2 filter deck topping
- Structural repairs to filter shells and clearwell walls within the pipe gallery, including the replacement of the Plant 2 pipe gallery catwalk

[redacted]

The most notable relationship between the three years worth of data is the consistency in raw water quality parameters, as noted below:

1. Raw water turbidity is most normally low, below 20 NTU with seasonal spikes above 20 NTU occurring between 6-8 times each year.
    a. The majority of the turbidity spikes are most likely attributable to storm events, and as expected, they largely appear correlate with a decrease in raw water alkalinity and raw water pH.
2. Raw water pH consistently remains above a pH of 7 and below 8, although there were periods in 2022 and 2023 where raw water pH reached upwards of 8.3.
3. Raw water alkalinity consistently fluctuates in the range of [redacted] mg/L.
4. Raw water temperatures are the hottest around August and coldest at the end of January.

For alum dosage, the data appears to trend most closely to raw water temperatures, with the lowest alum dosages occurring in January, and the highest alum dosages occurring around August for each year. Since water production from the WTP is highest during the hottest months, and since alum dosing at the WTP is typically adjusted based on a proportional increase or decrease in plant flow, this correlation makes sense. However, if streaming current and zeta potential monitoring is being used for optimized coagulation control, it would be expected that alum use would increase during the storm events due to a decrease in alkalinity and increase in organic matter and turbidity within the water.

Although there appears to be room for additional optimization, data supports that the coagulation at the WTP is effective. During the high turbidity events throughout the years settled water effluent turbidity did tend to trend up, but the turbidity was largely contained within acceptable margins, with the vast majority of months remaining in compliance with the goals set forth for clarified water under Virginia's Optimization Program.

[redacted]

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

5. OPTIMIZATION RECOMMENDATIONS

5.1 FILTER OPERATION IMPROVEMENTS

5.1.1 Updating Operational Set Points

[redacted]. During filter backwash, running the high-rate backwash on a time-based setpoint is potentially leading to additional water and energy consumption beyond what is needed, increasing the rate of loss and/or degradation of the existing filter media, and leading to over washing of the filters – which increases the duration required for the filter to waste sequence. Similarly, during filter to waste, if the sequence is run based on a pre-determined time and not effluent turbidity there is the potential to run the sequence either too short or too long.

A backwash sequence can be terminated once backwash turbidity reaches 10 NTU. [redacted]

5.1.2 Optimizing Filter Backwash

1. Continuous backwash effluent turbidity monitoring should be employed. This will provide operators more control to return a filter to service quickly if the situation warrants the

need for increased production capacity, or if the WTP wants to decrease overall backwash waste.

2. Under normal operating conditions, one filter is capable of being backwashed at any given time and subsequent filter backwashing does not commence until the previous filter concludes the filter to waste sequence. [redacted]
3. As recommended by EPA's Guidance Manual for Compliance with the Surface Water Treatment Rules: Turbidity Provisions (June 2020), filter aid polymer may be dosed during initial start-up of the filter or during the last part of backwash process to help decrease the time required for filter to waste. [redacted]
4. The VDH Waterworks Regulations allow for air scour rates to be between 3 and 5 scfm/ft^2. [redacted]
    a. [redacted]
5. [redacted] Air assisted backwash cycles can enhance media cleaning and decrease the time and water required for a backwash, but the sequence must be carefully controlled to ensure air scour is terminated prior to backwash water reaching the bottom of the washwater troughs to prevent any media damage and loss. It is recommended the WTP conduct a study through demonstration testing on one of the filters at the WTP to implement and evaluate the use of air assisted backwash.

5.2 PRE-TREATMENT IMPROVEMENTS

1. The WTP should [redacted] implement a jar testing program in order to identify optimal coagulant dosing. The jar testing should first be performed on a monthly basis on days where there is no adverse water quality event occurring. This will help develop a baseline for the WTP; however, a jar testing regiment must be maintained to account for variations in surface water quality and, at a minimum, be performed seasonally to establish and verify the optimal [redacted] range for the

WTP. [redacted]

a. [redacted]

b. During the jar testing, the zeta potential meter and the SCDs should be utilized to establish the readings that correspond to the optimal charge neutralization coagulant dose. Based on historical water quality data and trends, it is recommended that seasonal jar testing be performed (proceeding the initial 12-month jar testing) at the following times: middle January, middle April, late July, and middle October.

2. Provide additional operational oversight leading up to and during events that have the potential to lead to adverse raw water quality conditions. Currently, water quality is monitored and recorded as required to comply with the regulations; however, increasing the sampling frequency during adverse water quality events will provide for additional resilience and ensure optimal pre-treatment chemical dosing is maintained. The most drastic change in water quality often occurs near the start of storm event due to the first flush of surface runoff. Although the frequency of necessary sampling is dependent on the intensity of the weather or water quality event, it is recommended that the frequency at which an operator samples the raw water initially be increased to once every 15-30 minutes over a one-hour period at the onset of a rain or water quality event. Subsequent sampling can be performed at 1-hour intervals until water quality parameters have stabilized.

3. [redacted]

4. Monitoring raw water quality and controlling raw water chemistry is pivotal for effective coagulation when surface water is being treated. Currently, caustic feed lines are installed to allow for raw water alkalinity and pH adjustments, but caustic is not currently dosed to the raw water. Initial review indicates that the raw water alkalinity is adequate to support the quantity of alum being dosed; however, surface water can have significant variability in water quality. As such, the City should test the caustic feed to ensure they have the ability dose caustic to optimize raw water alkalinity and pH for alum coagulation during high turbidity events in the event it is needed.

   a. Raw water quality monitoring is being installed at the intake to the pre-sedimentation basin under the on-going Pre-Sedimentation Basin Dredging project (design ongoing).

   b. [redacted]

5. The existing settled water turbidity analyzers are located within the Plant 1 and Plant 2 headhouses. [redacted]

[redacted]

5.3 GENERAL RECOMMENDATIONS & INFORMATION

The WTP should monitor weather and river conditions and forecasts on a daily basis to ensure adequate time and provisions have been allocated in preparation for any adverse weather events. The following three links are resources that can be reviewed as part of an operator's normal routine at the start of each shift:

- This link provides an 8-14 day temperature and precipitation outlook for any region: National Weather Service Conus - 8 to 14 Day Outlook
- This link provides continuous and historical water quality information upstream of the City's intake in the James River at Cartersville: James River at Cartersville, VA - USGS Water Data for the Nation
- This link provides current and forecasted river level upstream of the City's intake in the James River at Richmond-Westham: James River (VA) at Richmond-Westham