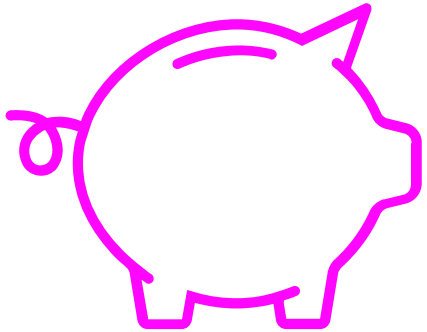
# Pushing Rapid Gravity Filtration into the 21st Century: Demonstrated Performance at 16 gpm/sf

*WRWTP 20 MGD Expansion Project, Filtration Pilot Study*

1. Project Introduction
2. Filtration Pilot Study Objectives
3. Filtration Pilot Study Conditions
4. Results & Key Takeaways

# Project Introduction

**WRWTP water demand is increasing.** The goal of the project is to increase plant capacity without constructing additional major process infrastructure.

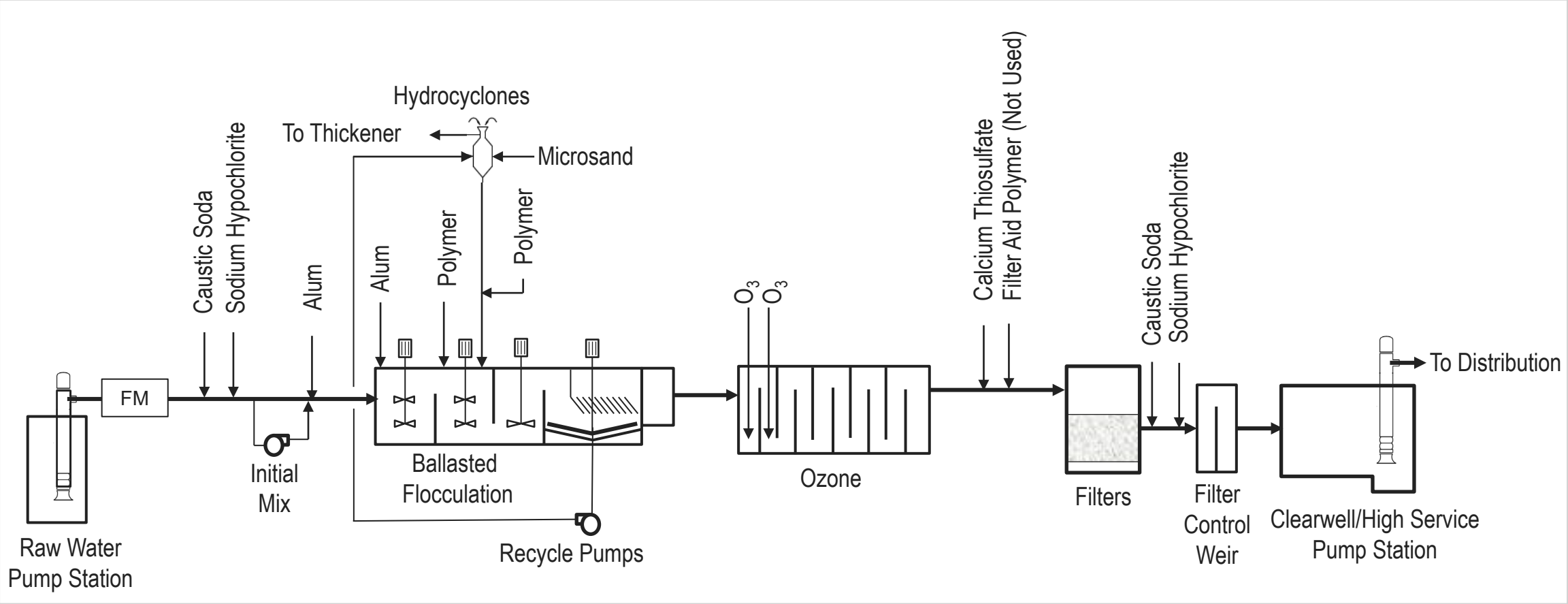


**Higher filtration rate could save the City $5-10M** by not having to build additional filters.

**OHA required a Filtration Pilot Study** to evaluate filtered water performance at higher flow rates, prior to approving the higher plant capacity.

# Project Introduction

# WRWTP Process Flow Diagram



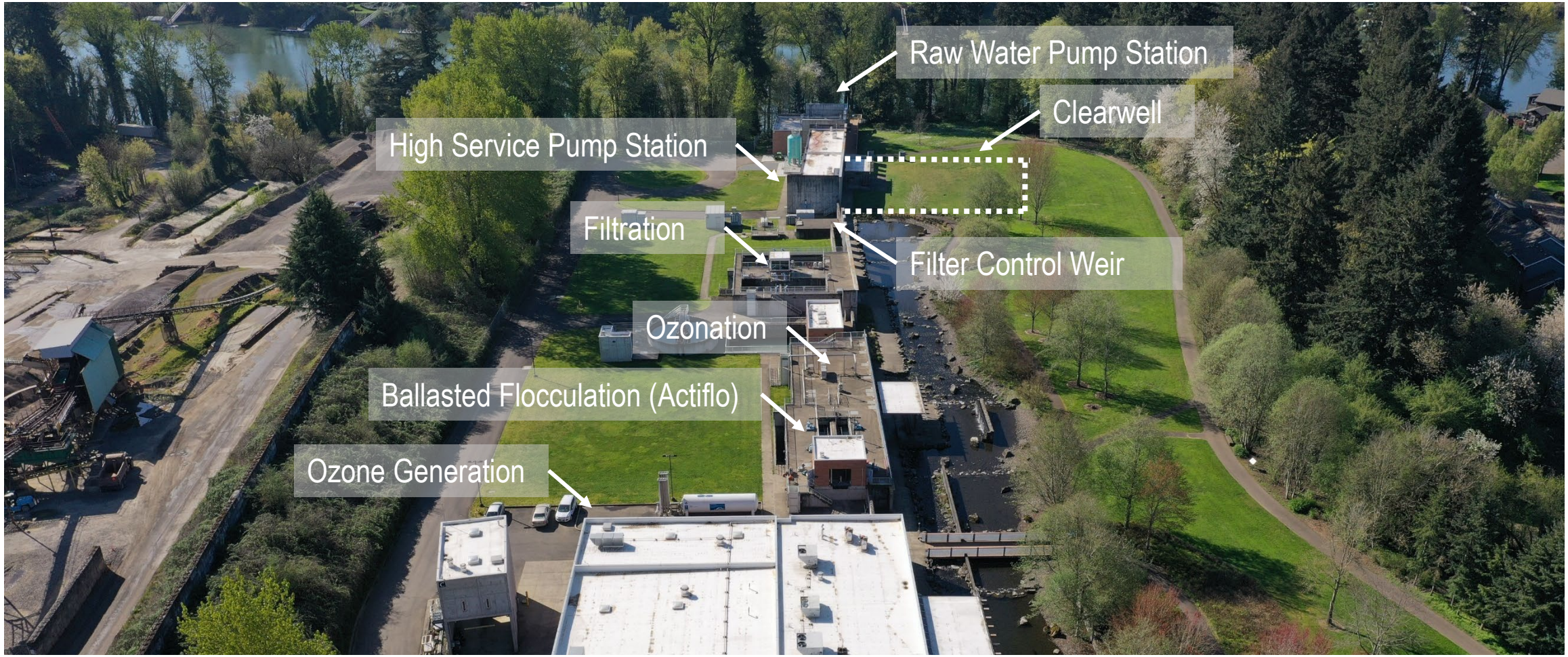

**Plant Design Flow Rate** 15 mgd

**Planned Ultimate Plant Hydraulic Capacity** 70 mgd

**Design and Built in 1999-2001**

**WRWTP was the first water treatment plant in Oregon to use deep bed filter media and ballasted flocculation**

# Project Introduction




- Expansion from 15 mgd to 20 mgd via process uprating
- Equipment replacement
- Seismic Retrofits
- Installing baffles in existing clearwell to increase disinfection capacity
- Electrical upgrades to support up to 30 mgd capacity

***Raw Water Flow***

- Ranges from **3 to 14 MGD**
- Flow is the highest in the summer, and lowest in the winter

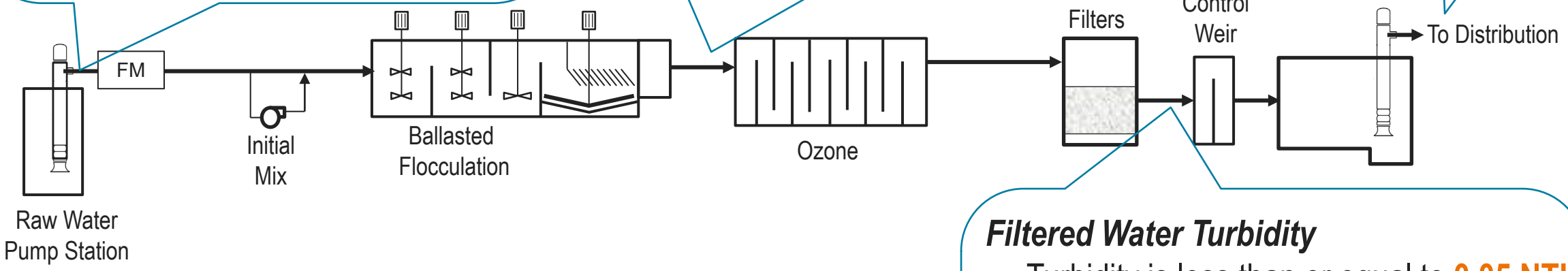
***Raw Water Turbidity***

- Ranges from **1 to >50 NTU**
- Turbidity is the lowest in the summer and the highest in the winter

***Settled Water Turbidity***

- Ranges from **0.1 to 1.5 NTU**
- Average Summer Turb **0.2 NTU**
- Average Winter Turb **0.7 NTU**

***Maximum Plant Capacity is 15 MGD***




***Filtered Water Turbidity***

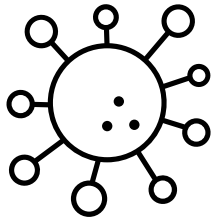
- Turbidity is less than or equal to **0.05 NTU**
- Average Filtered Water Turb **0.02 NTU**

***Filtration Rate & Run Time***

- Filtration Rate ranges from **2 to 7 gpm/sf**
- Average Filter Run time is **60 hours**
- Typical UFRV is **14,000 gal/sf**

# Filtration Pilot Study Objectives

# Filtration Pilot Requirements and Test Plan

| | Filter Uprating Requirements by OHA | Pilot Test Plan |
|---|---|---|
|  | A Pilot Study must be conducted to demonstrate filter performance at the higher loading rate and must simulate worst-case raw water quality conditions. | Testing occurred over one full year with four testing periods, each lasting 4 weeks. Most operated at 12 gpm/sf, even during the winter when demand is typically the lowest. |
|  | Filtered water turbidity optimization goals must be met.<br><br>Giardia and cryptosporidium surrogate removal rates must be monitored and evaluated in the pilot study. | Influent and individual filter effluent turbidity were monitored and evaluated.<br><br>Influent and individual filter effluent particle counts were monitored and compared against the raw water particle counts |
|  | If running at a higher filter loading rate, the pathogen reduction must not be compromised for the other major unit processes, such as the Actiflo clarifier, ozone contactor, and disinfection with chlorine in the clearwell. | Ballasted Flocculation was operated with a single train to simulate the doubling of flow through the process. |

# Testing Schedule

| | Testing Period 1 | Testing Period 2 | Testing Period 3 | Testing Period 4 |
|---|---|---|---|---|
| **Dates** | Aug – Sept 2020 | Nov – Dec 2020 | Feb – March 2021 | Apr – May 2021 |
| **Plant Production** | ↑ Highest | → | ↓ | → |
| **Raw Water Turbidity** | ↓ 1-5 NTU | → | ↑ | → |
| **Actiflo® Trains Online** | Single Train | Single Train | Single Train | Single Train |
| **Filtration Rates Tested** | 8 to 16 gpm/sf | 8 to 16 gpm/sf | 8 to 12 gpm/sf | 8 to 16 gpm/sf |

# Testing Schedule

| | Testing Period 1 | **Testing Period 2** | Testing Period 3 | Testing Period 4 |
|---|---|---|---|---|
| **Dates** | Aug – Sept 2020 | Nov – Dec 2020 | Feb – March 2021 | Apr – May 2021 |
| **Plant Production** | ↑ | → Intermediate | ↓ | → |
| **Raw Water Turbidity** | ↓ | → 3-10 & up to 50 NTU | ↑ | → |
| **Actiflo® Trains Online** | Single Train | Single Train | Single Train | Single Train |
| **Filtration Rates Tested** | 8 to 16 gpm/sf | 8 to 16 gpm/sf | 8 to 12 gpm/sf | 8 to 16 gpm/sf |

# Testing Schedule

| | Testing Period 1 | Testing Period 2 | Testing Period 3 | Testing Period 4 |
|---|---|---|---|---|
| **Dates** | Aug – Sept 2020 | Nov – Dec 2020 | Feb – March 2021 | Apr – May 2021 |
| **Plant Production** | ↑ | → | ↓ Lowest | → |
| **Raw Water Turbidity** | ↓ | → | ↑ >10 NTU | → |
| **Actiflo® Trains Online** | Single Train | Single Train | Single Train | Single Train |
| **Filtration Rates Tested** | 8 to 16 gpm/sf | 8 to 16 gpm/sf | 8 to 12 gpm/sf | 8 to 16 gpm/sf |

# Testing Schedule

***Total Number of Filter Runs: 150***

| | Testing Period 1 | Testing Period 2 | Testing Period 3 | **Testing Period 4** |
|---|---|---|---|---|
| **Dates** | Aug – Sept 2020 | Nov – Dec 2020 | Feb – March 2021 | Apr – May 2021 |
| **Plant Production** | ↑ | → | ↓ | → Intermediate |
| **Raw Water Turbidity** | ↓ | → | ↑ | → 3-10 NTU |
| **Actiflo® Trains Online** | Single Train | Single Train | Single Train | Single Train |
| **Filtration Rates Tested** | 8 to 16 gpm/sf | 8 to 16 gpm/sf | 8 to 12 gpm/sf | 8 to 16 gpm/sf |

# Filtration Pilot Testing, Success Criteria

| Parameter | Success Criteria |
|---|---|
| Individual Filter Effluent (IFE) Turbidity* | **Turbidity ≤ 0.10 NTU**, 95% of the Time<br><br>Maximum **Turbidity ≤ 0.30 NTU** |
| Individual Filter Effluent Turbidity after Backwashing* | **Turbidity returns to ≤ 0.10 NTU** within the filter-to-waste period after backwash (15 min).<br><br>Turbidity at return to service ≤ 0.10 NTU. |
| Headloss | **≤ Terminal Headloss (12-feet)** |

**From OHA Filter Optimization Goals*

# Filtration Pilot Testing, Additional Monitoring Parameters

| Parameter | Monitoring Description |
|---|---|
| Unit Filter Run Volume | • UFRV can be used to determine how efficiently a granular media filter performs.<br>• UFRV was calculated for each filter run to confirm filter efficiency does not decrease with increased filtration rates.<br>• **In accordance with OHA's requirement, UFRV will end when filtered effluent turbidity or headloss stops meeting the approval criteria.** |
| Particle Counts | • Collected data for monitoring and reporting<br>• **Log removal of particle counts** was calculated for each bin size, particularly focused on particle bin sizes similar to *Giardia* and Crypto size. |

# Filter Media Design and Operational Conditions

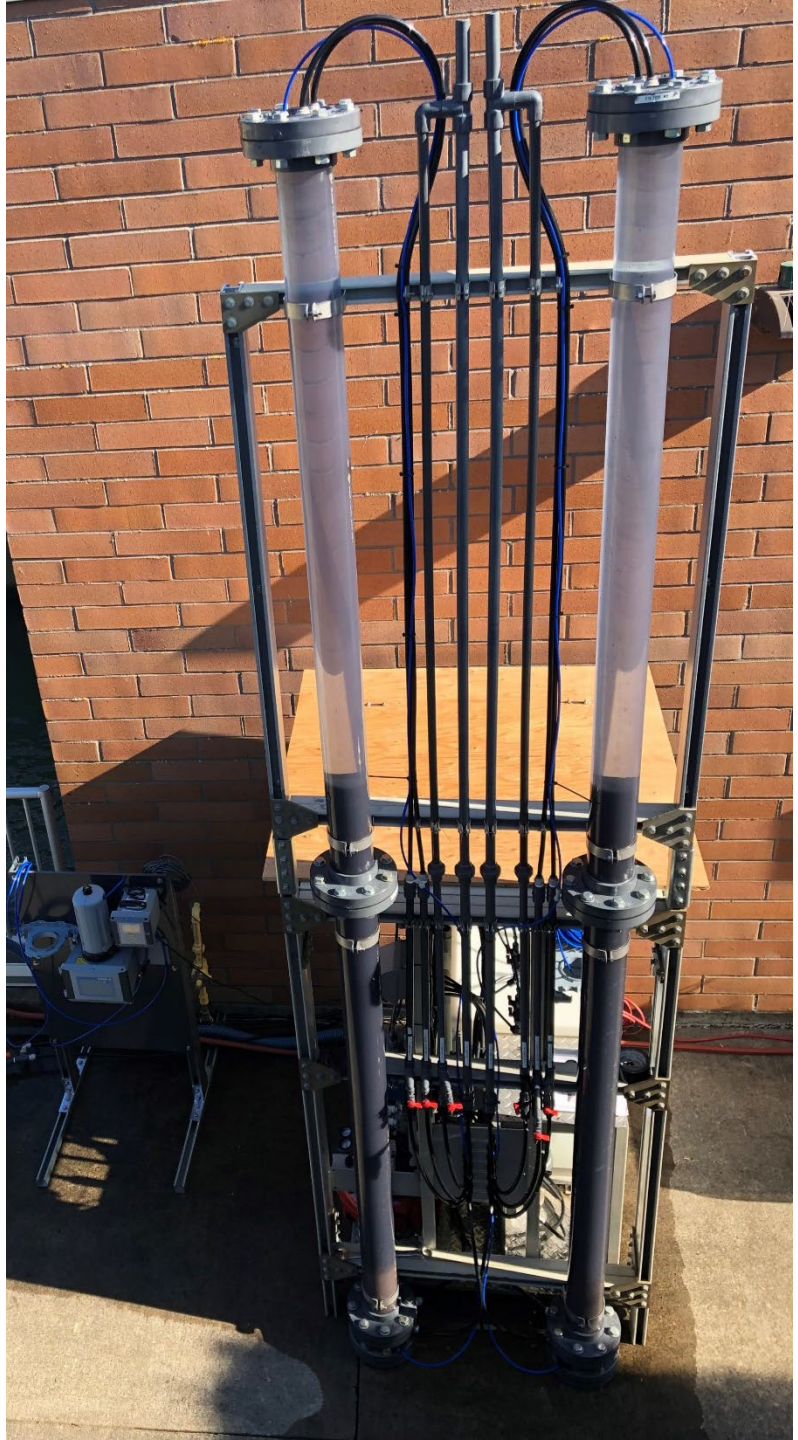
# Full-Scale and Pilot Filter Design

| | Units | Current | Proposed | Pilot |
|---|---|---|---|---|
| Firm Plant Capacity | mgd | 15.0 | 20.0 | - |
| Filtration Rate, All Filters in Service | gpm/sf | 5.7 | 7.6 | - |
| Filtration Rate, One Filter OOS | gpm/sf | 7.6 | 10.1 | 12.0 |
| Filter Hydraulic Capacity | gpm/sf | 12.0 | 12.0 | >12.0 |
| Terminal Headloss | feet | 12.0 | 12.0 | >12.0 |

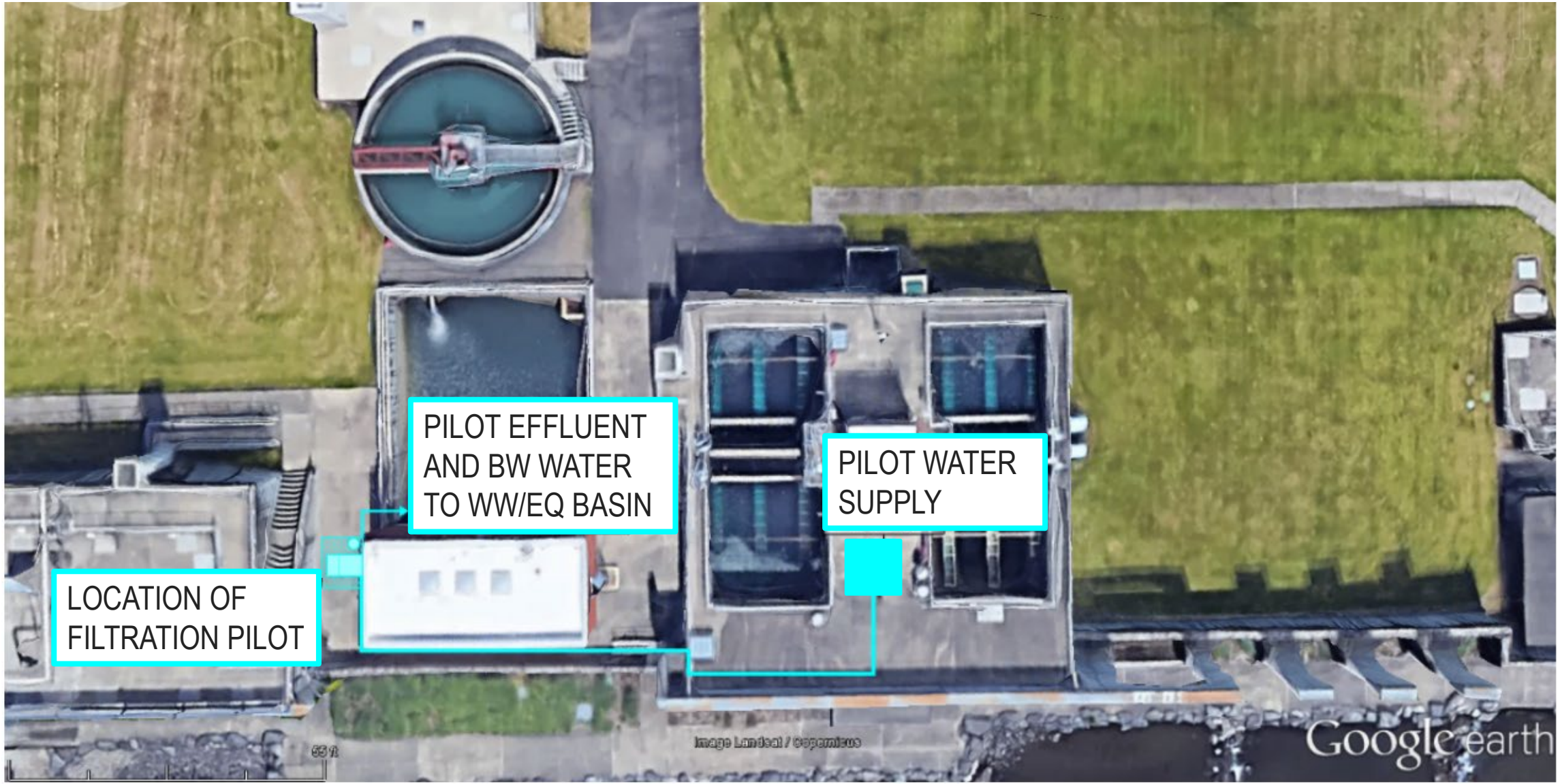
***Most filter runs were operated at 12 gpm/sf to demonstrate performance at the hydraulic capacity of the full-scale filters. However, filtration rate ranged from 8 – 16 gpm/sf due to excellent performance.***

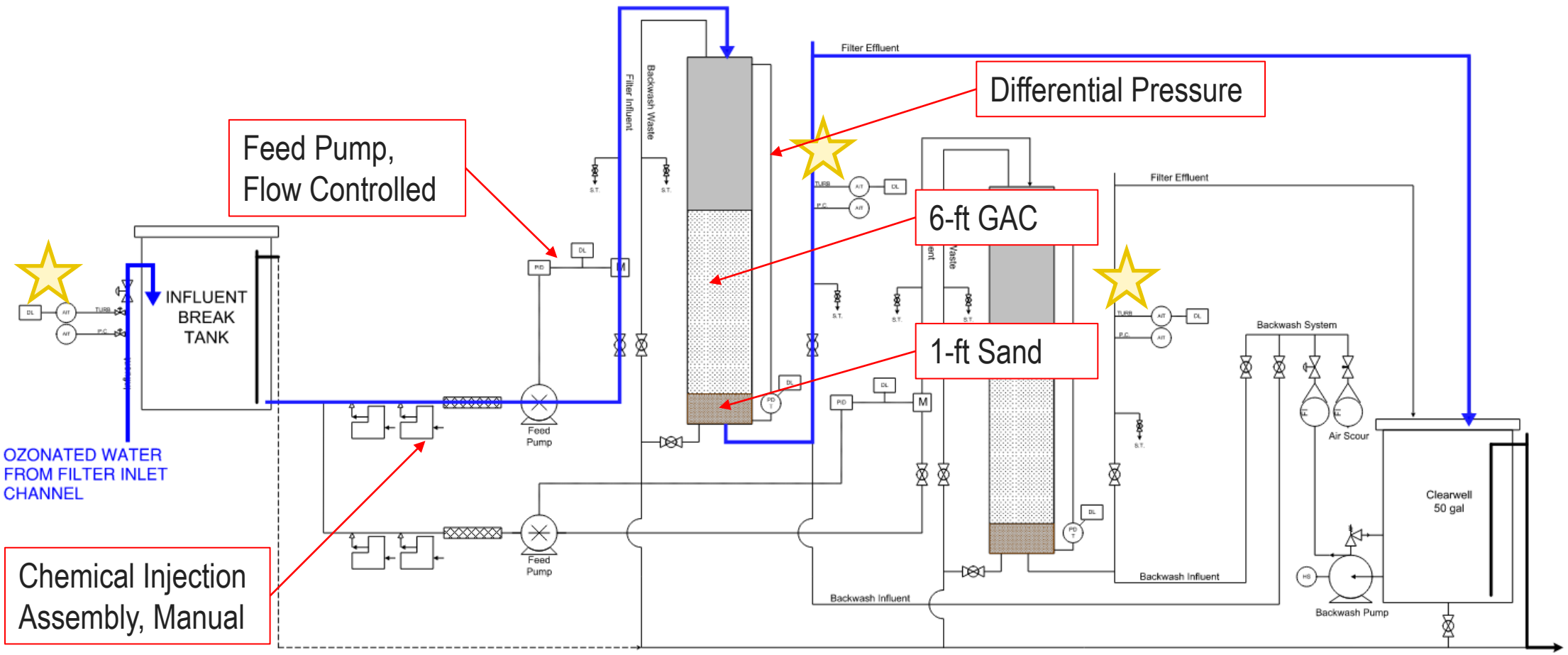
# Full-Scale and Pilot Filter Design

| | Units | Full-Scale and Pilot Filters |
|---|---|---|
| Top Media | - | GAC |
| Depth | in | 72 |
| Effective Size | mm | 1.4 |
| Specific Gravity | - | 1.4 |
| Uniformity Coefficient | - | < 1.4 |
| Bottom Media | - | Sand |
| Depth | in | 12 |
| Effective Size | mm | 0.45 |
| Specific Gravity | - | > 2.63 |
| Uniformity Coefficient | - | < 1.4 |
| Overall L/D Ratio | - | 1,984 |



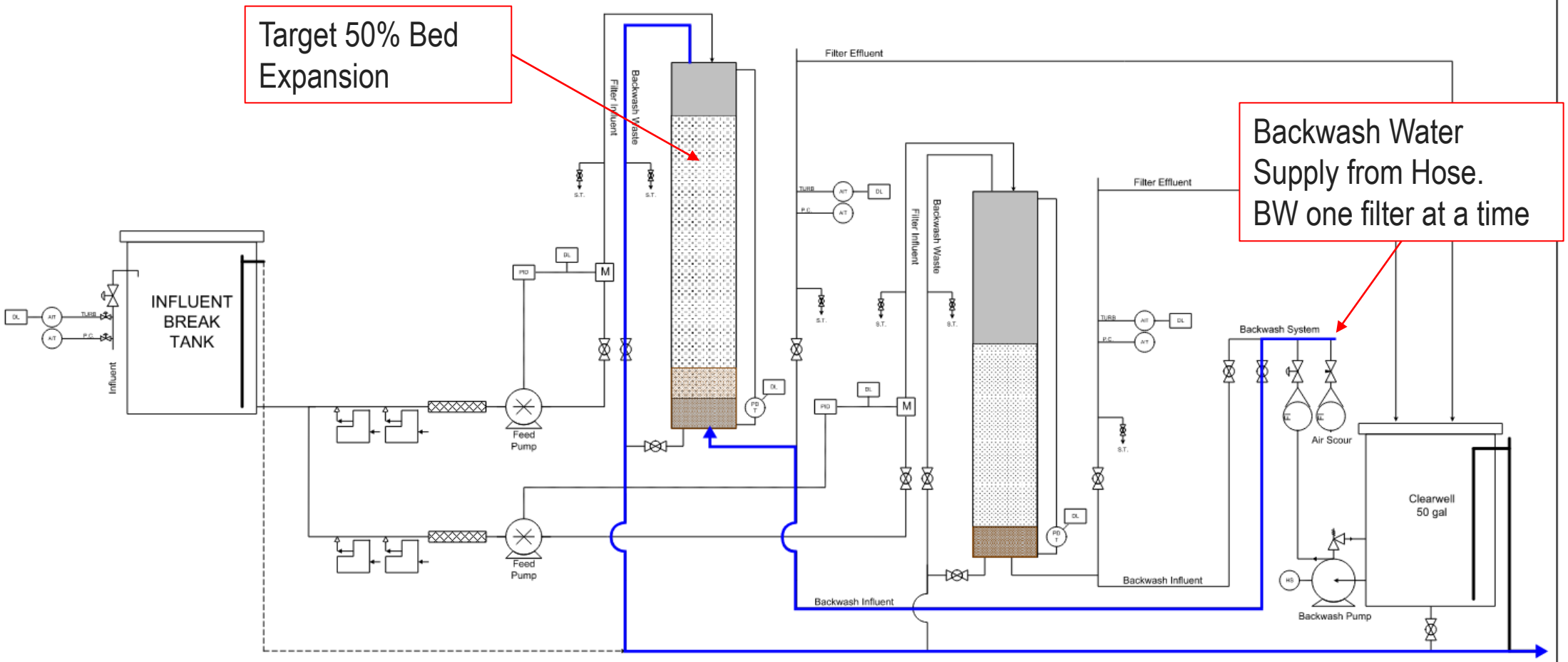
# Pilot Location and Influent Supply






Sample Location – Online Turbidimeter and Particle Counter

| WRWTP FILTRATION PILOT | DUAL FILTER SKID | Stantec |
|---|---|---|




**Backwashing Procedure:**

1. Air only for 1 minute
2. Air plus water at a low-rate for 1 minute
3. Water at a high-rate only for 4 minutes
4. Water only at a low-rate for 2 minutes

| WRWTP FILTRATION PILOT | DUAL FILTER SKID | Stantec |
|---|---|---|

# Filtration Pilot Operational Conditions

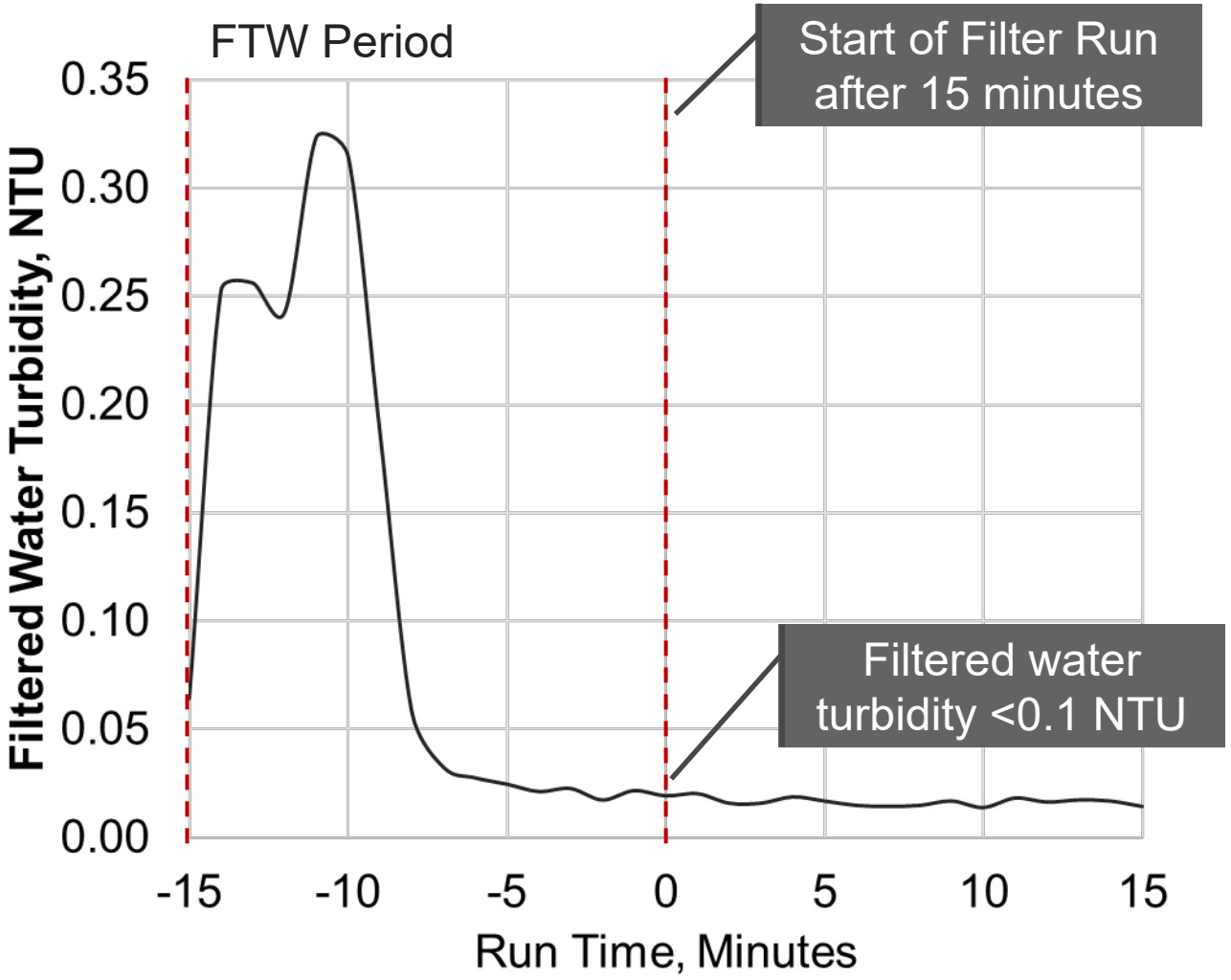
1. Backwash Pilot Filters
2. Filter to Waste (15 minutes)
3. Return Filter to Service when filtered water turbidity is ≤0.1 NTU
4. Run filters at a pre-determined filtration rate
5. Terminate filter run when:
    a) Filtered water turbidity ≥ 0.1 NTU (turbidity breakthrough)
    b) Differential pressure > 144 inch (terminal headloss)
    c) Operators can increase number of filter runs (time)

*A filter run is defined between filter returning to service and when an end condition is reached.*

# Filtration Pilot Results

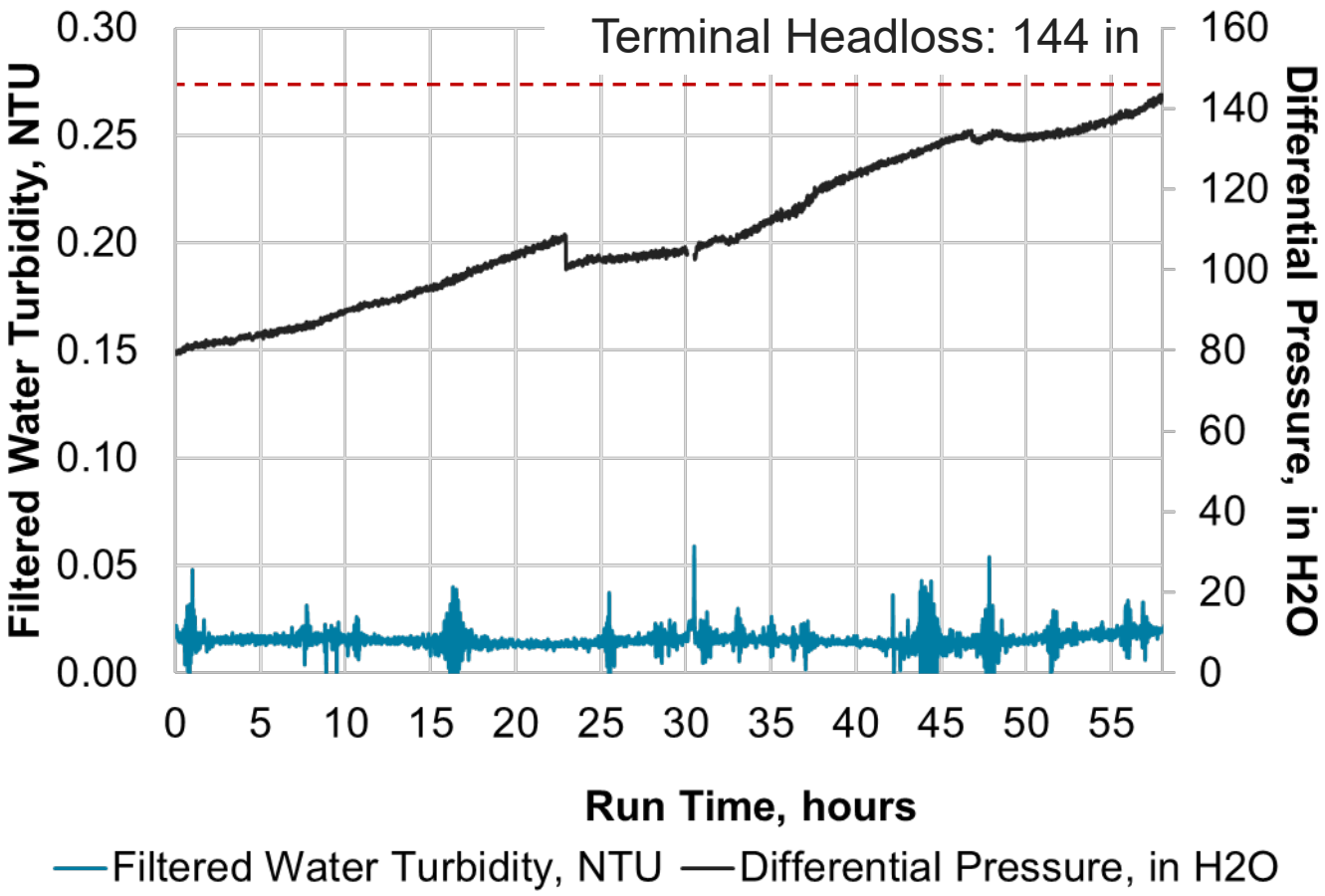
# Example Filter Run: TP1 Summer 2020

1. **Backwash Pilot Filters**
2. **Filter to Waste (15 minutes)**
3. **Return Filter to Service when filtered water turbidity is ≤0.1 NTU**
4. Run filters at a pre-determined filtration rate
5. Terminate filter run when termination criteria is met



# Example Filter Run: TP1 Summer 2020

1. Backwash Pilot Filters
2. Filter to Waste (15 minutes)
3. Return Filter to Service when filtered water turbidity is ≤0.1 NTU
4. **Run filters at a pre-determined filtration rate**
5. **Terminate filter run when termination criteria is met**

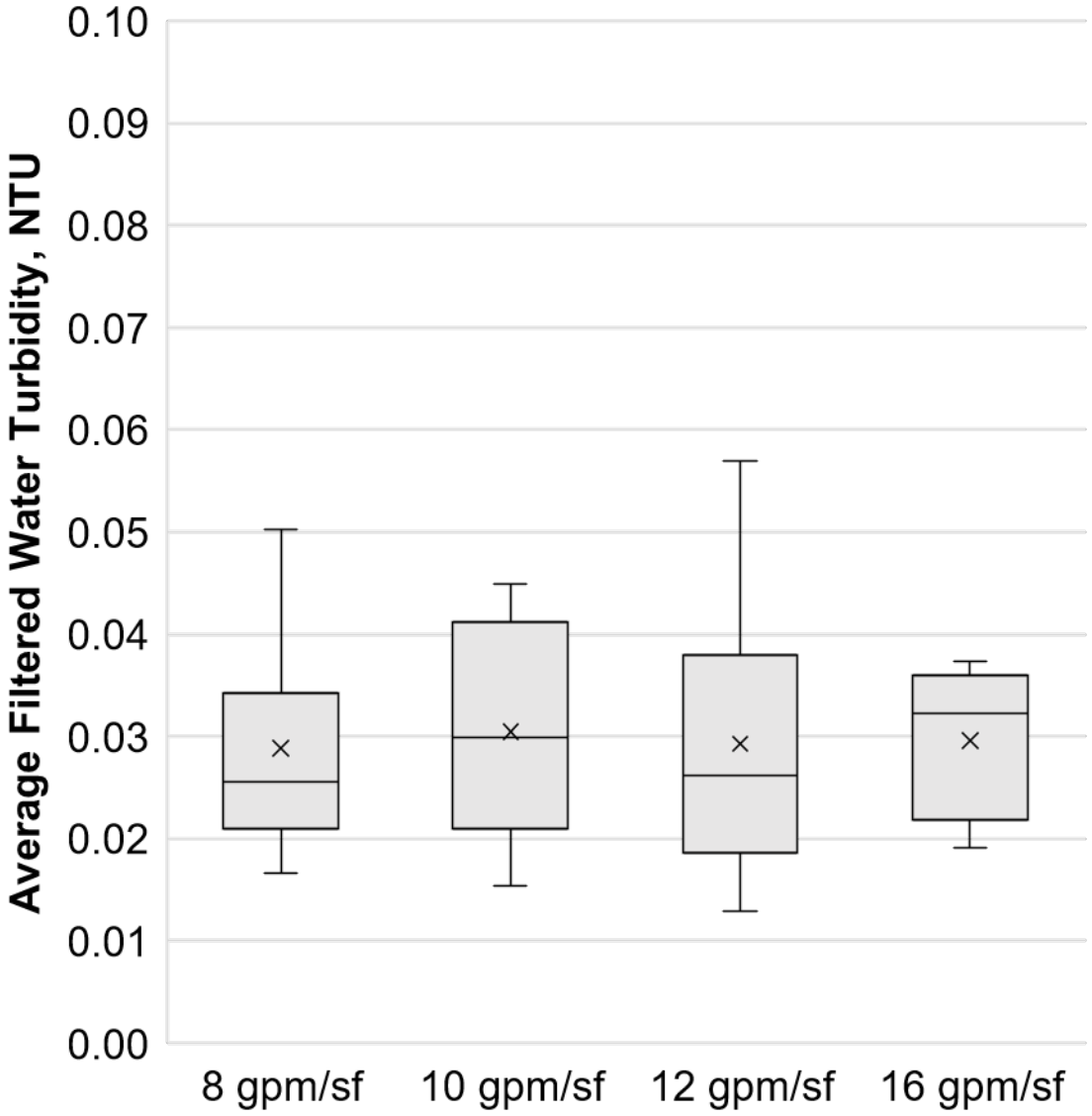



| | |
|---|---|
| ***Filtration Rate:*** | *12 gpm/sf* |
| ***Avg Filter Inf Turbidity:*** | *1.0 NTU* |
| ***Avg Filtered Water PC:*** | *<5 particles/mL* |
| ***Unit Filter Run Volume:*** | *41,400 gal/sf* |
| ***Filter Efficiency:*** | *99%* |
| ***Termination Criteria:*** | *Headloss* |

# Filtration Pilot Study Results, Impact of Filtration Rate

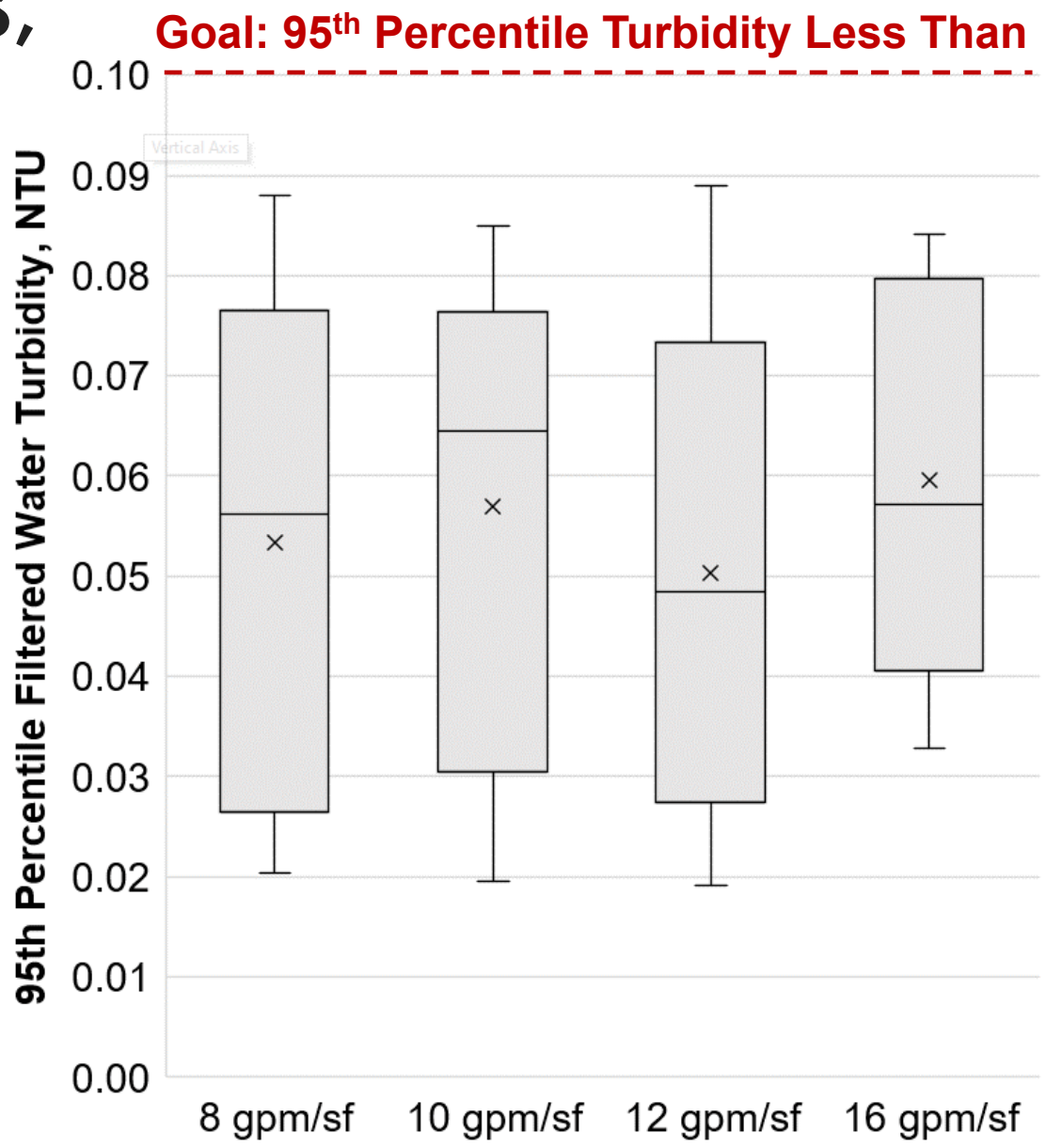
- **Filtered water turbidity is shown for filter runs at filtration rates between 8 and 16 gpm/sf based on 150 filter runs.**

- Average filtered water turbidity was **0.03 NTU regardless of filtration rate.**



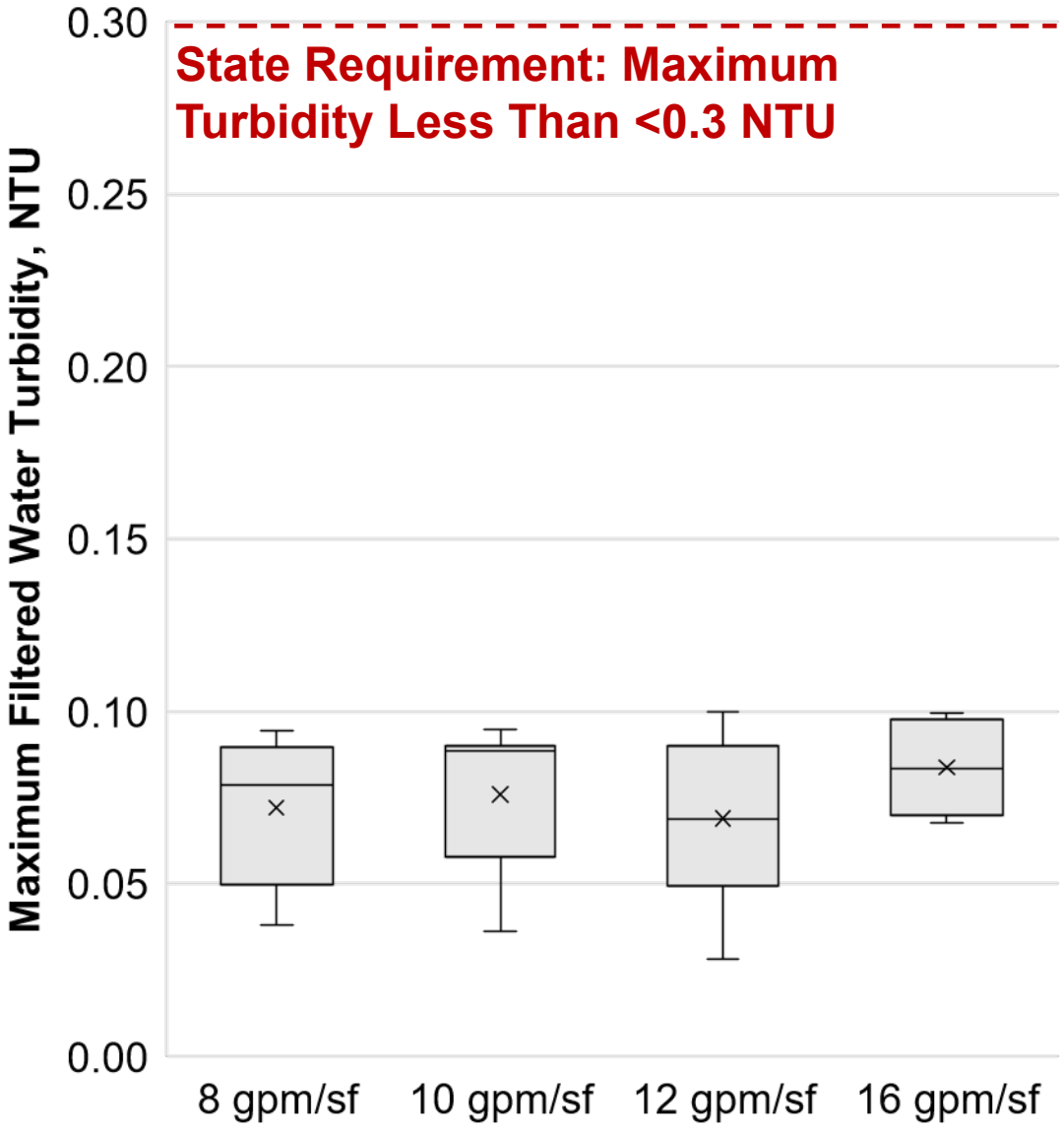
# Filtration Pilot Study Results, Impact of Filtration Rate

- **Filtered water turbidity goals were met for filtration rates between 8 and 16 gpm/sf based on 150 filter runs.**
- Average filtered water turbidity was **0.03 NTU regardless of filtration rate.**
- Filtered water turbidity was ≤ **0.1 NTU 95%** of the time regardless of filtration rate.



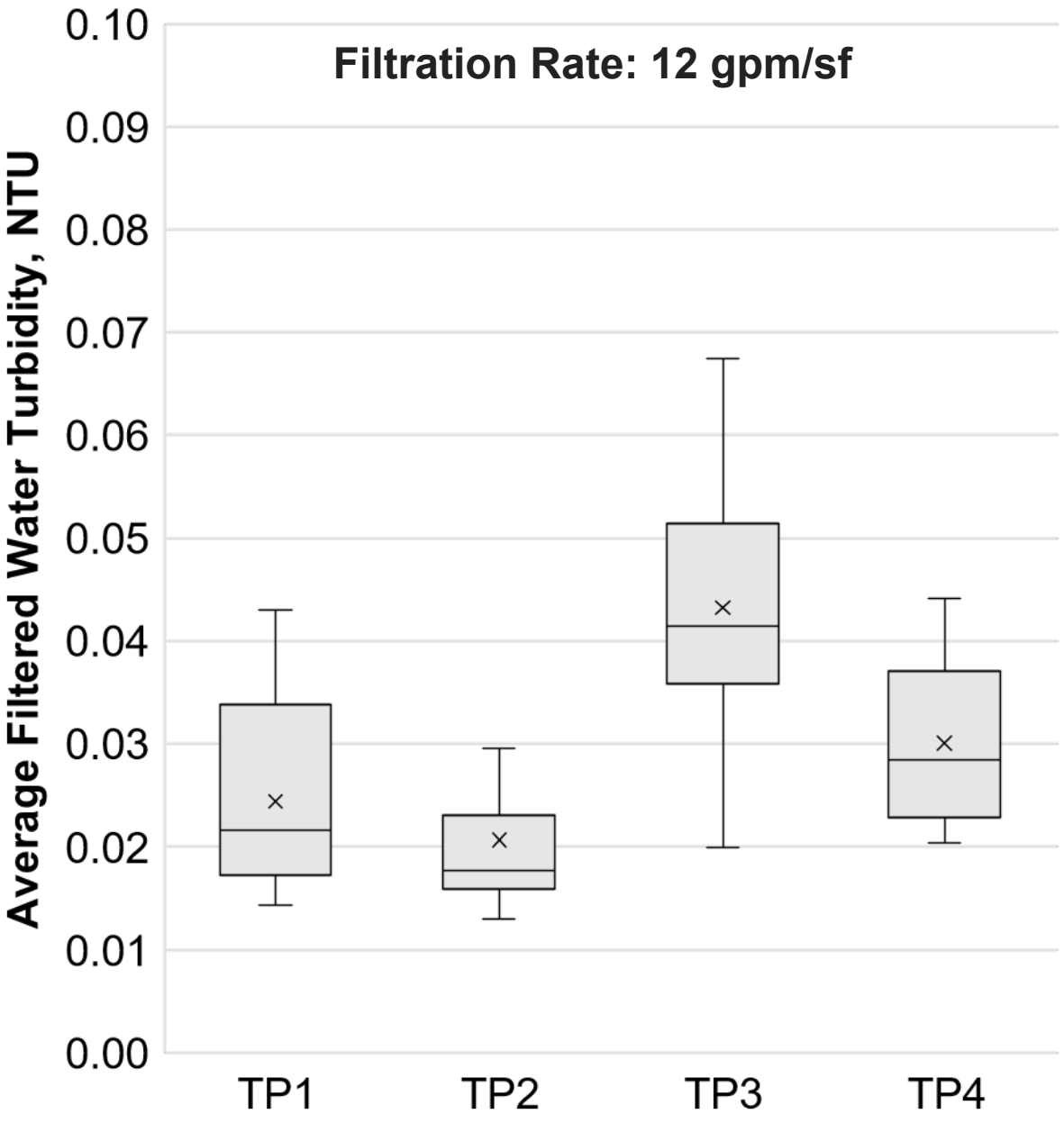
# Filtration Pilot Study Results, Impact of Filtration Rate

- **Filtered water turbidity goals were met for filtration rates between 8 and 16 gpm/sf based on 150 filter runs.**
- Average filtered water turbidity was **0.03 NTU regardless of filtration rate.**
- Filtered water turbidity was ≤ **0.1 NTU 95%** of the time regardless of filtration rate.
- Filtered water turbidity was ≤ **0.3 NTU 100%** of the time regardless of filtration rate.
- ***Pilot test results suggest filtered water turbidity was not significantly impacted by filtration rate.***



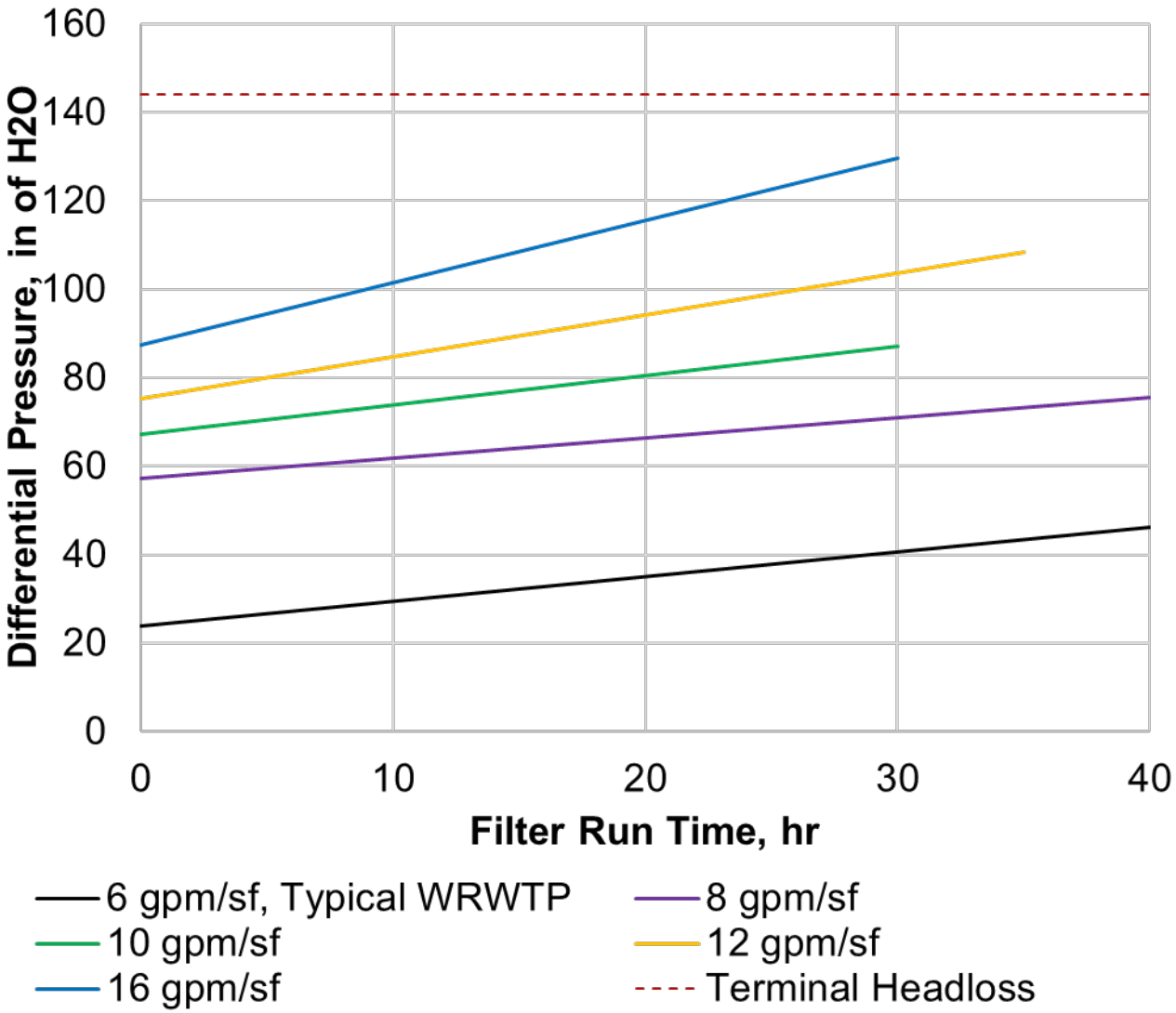
# Filtration Pilot Study Results, Impact of Seasonal RWQ

- **Filtered water turbidity goals were met during all testing periods at 12 gpm/sf based on 83 filter runs.**
- Filtered water turbidity was slightly impacted by seasonal changes in water quality.
- Filtered water turbidity was **≤ 0.1 NTU 95%** of the time regardless of seasonal RWQ.
- Filtered water turbidity was **≤ 0.3 NTU 100%** of the time regardless of seasonal RWQ.



# Filtration Pilot Study Results, Headloss

- **Filter runs were terminated if terminal headloss was reached.**
- Cleanbed headloss increased with higher filtration rates, as expected
- Headloss accumulation increased with higher filtration rates, as expected
- Filter run time varied based on end condition (terminal headloss, turbidity breakthrough, time). Run time goal was 24 hours



# Filtration Pilot Conclusions

# Summary of Pilot Results

| Filtration Rate | Filtered Water Turbidity | Filter Run Time | UFRV, gal/sf | Success Criteria Met? |
|---|---|---|---|---|
| WRWTP Full-Scale Filters, 4-6 gpm/sf | 0.02 NTU | 60 hrs | 18,000 gal/sf | - |
| 8 gpm/sf | 0.02 NTU | 40 hrs<br>35-55 hrs | 19,200 gal/sf | YES |
| 10 gpm/sf | 0.03 NTU | 30 hrs<br>25-50 hrs | 18,000 gal/sf | YES |
| 12 gpm/sf | 0.03 NTU | 35 hrs<br>25-40 hrs | 25,200 gal/sf | YES |
| 16 gpm/sf | 0.04 NTU | 30 hrs<br>20-40 hrs | 28,800 gal/sf | YES |

***Confirms that the higher loading rates did not compromise filtered water turbidity or UFRV***

# Uprated Design Criteria

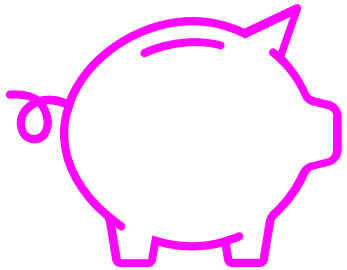
| | Approved Criteria | Potential Future Criteria |
|---|---|---|
| Condition | Baseline Expansion | Uprating Supported by Testing Data |
| Plant Flow | 20 MGD | 24 MGD |
| Ballasted Flocculation | 10 MGD per train<br>27 gpm/sf | 12 MGD per train<br>32 gpm/sf |
| **Filters** | **7.6 gpm/sf with all units in service**<br>**10.1 gpm/sf with one filter OOS** | **9.1 gpm/sf with all units in service**<br>**12.0 gpm/sf with one filter OOS** |

***Next Steps: OHA requests full-scale monitoring for ~1year to confirm the full-scale plant is operating similar to the pilot results***

# Filtration Pilot Takeaways

**Pilot Study results showed excellent filter performance up to 12 gpm/sf.** Filtration rates up to 16 gpm/sf were tested.

**Successfully testing filters at > 10 gpm/sf built operational confidence** the filters can operate at higher rates across a range of water quality conditions.



**Higher filtration rate was approved by OHA, saving the City $5-10M** by not having to build additional filters.

# Acknowledgements

WILSONVILLE OREGON

VEOLIA

City of Sherwood Oregon

Stantec RESEARCH

# Questions?

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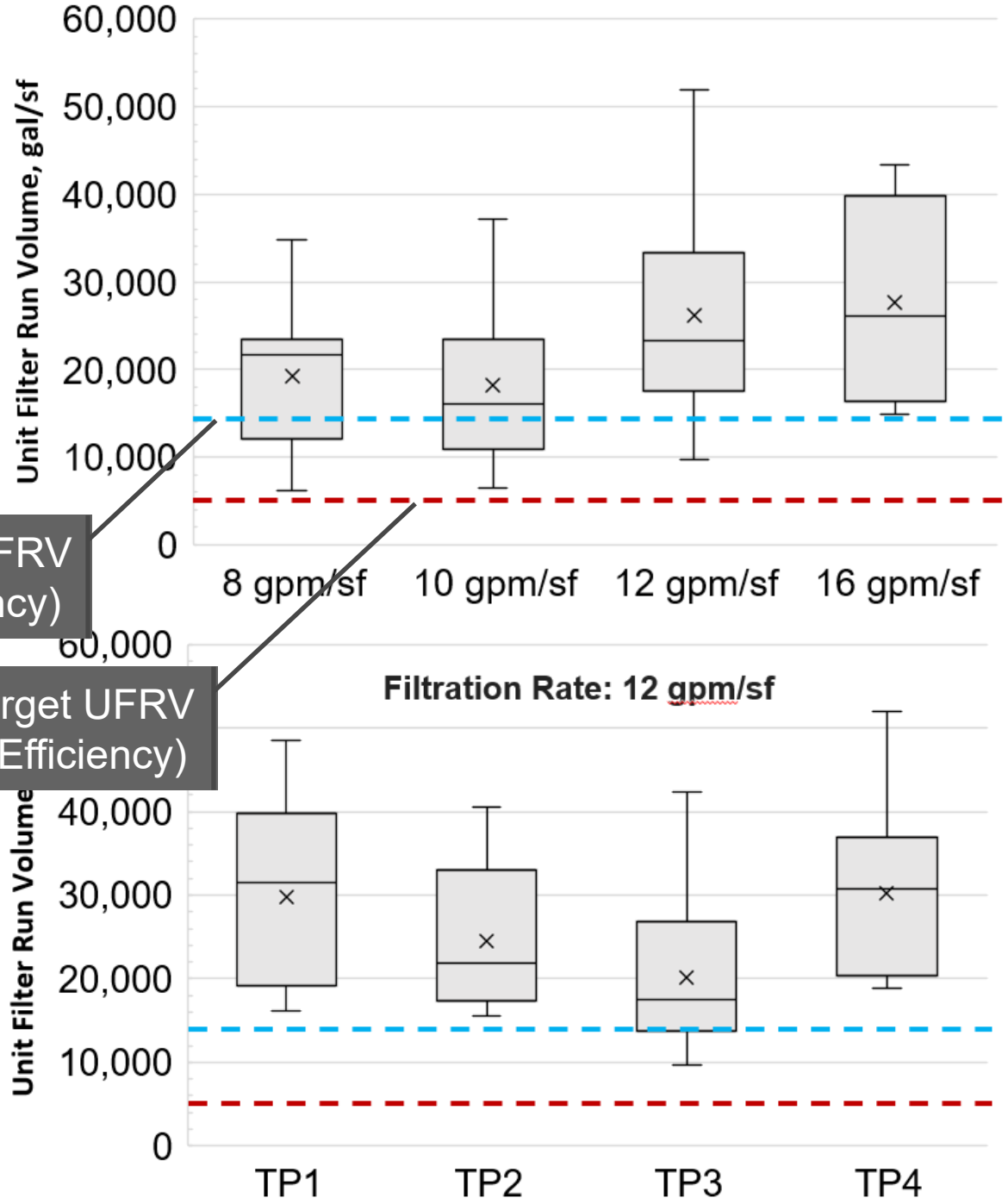
# Filtration Pilot Study Results, UFRV

- UFRV was used to calculate filter efficiency. **Filter efficiency was 99% at 12 gpm/sf** with an average UFRV of 25,000 gal/sf.
- UFRV typically met / exceeded WRWTP UFRV for pilot runs operated at 12 gpm/sf.
- Seasonal raw water quality slightly impacted UFRV during TP3, however did not fall below the 5,000 gal/sf minimum goal.
- ***Pilot test runs suggest higher filtration rates did not impact the filter run UFRV.***



# Filtration Pilot Study Results, Log Removal Values

- **≥3.0-log removal of particles sized 2 – 5 µm (surrogate for *Crypto*) was achieved.**
- **≥ 3.0-log removal of particles sized 5 – 10 µm (surrogate for *Giardia*) was achieved.**

* WRWTP is rated as a Bin 1 Supply, therefore receiving 2.0-log removal credit for *Crypto*.

* WRWTP is rated as a conventional treatment plant, therefore receiving 2.5-log removal credit for *Giardia*.

| Testing Period | Average Log Removal 2 – 5 µm (*Crypto*) | Average Log Removal 5 – 10 µm (*Giardia*) |
|---|---|---|
| TP1 | 3.6-log(1) | 3.3-log(2) |
| TP2 | 3.2-log | 3.6-log |
| TP3 | 3.5-log | 3.6-log |
| TP4 | 3.0-log | 3.0-log |

1) *Log removal of particles was calculated based on the nearest bin size in the raw water as indicated.*

2) *Raw water particle count for the 5 and 15 µm range was calculated as the sum of particles in the 5 to 10 µm and 10 to 15 µm bin sizes.*