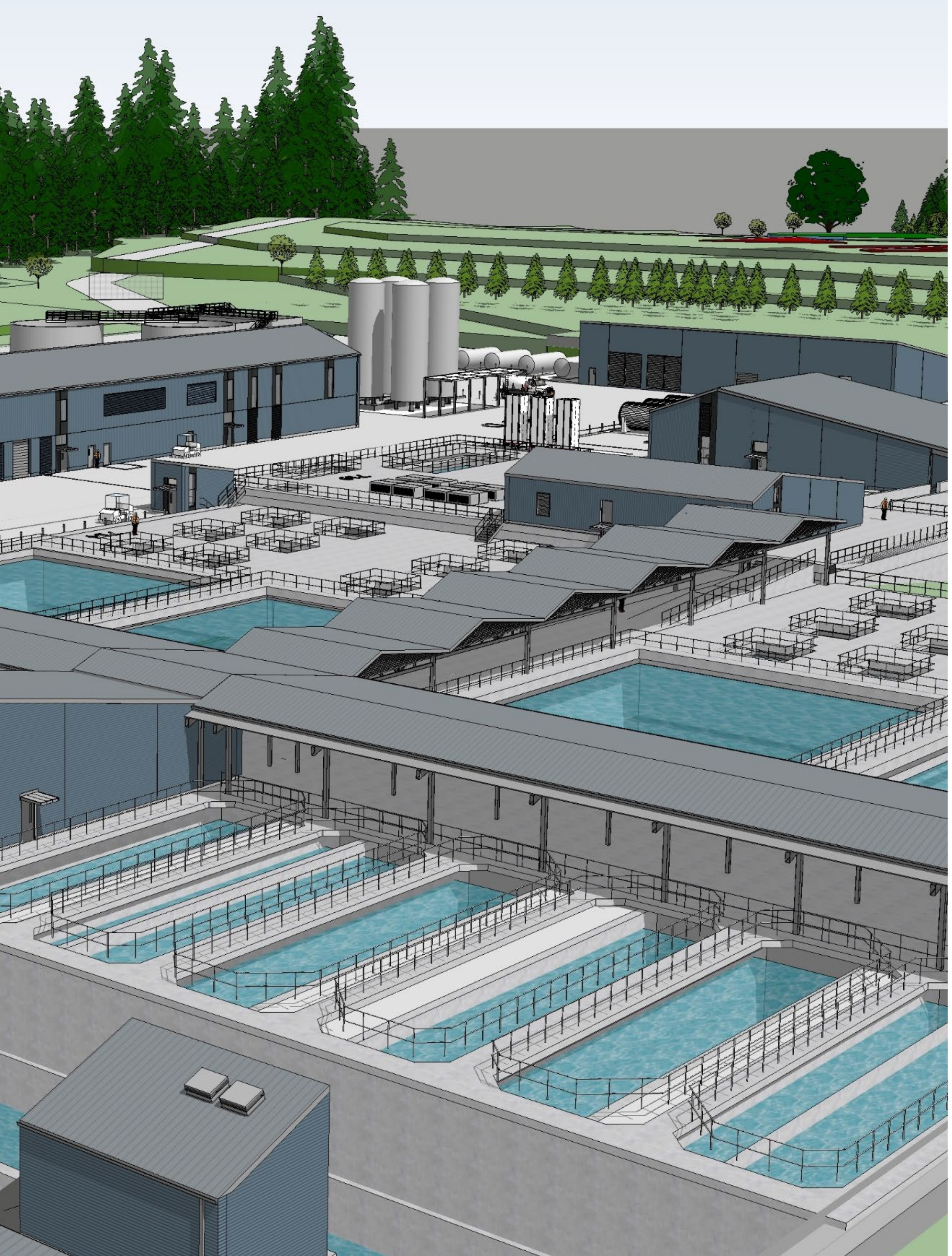


Bull Run TREATMENT PROJECTS

Our water: Safe and abundant for generations to come

PORTLAND WATER BUREAU

Bull Run Treatment Projects

Bull Run Water: Investigating Coagulation, Flocculation and Sedimentation

Mojtaba AzadiAghdam, PhD, PE

Process Engineer

PORTLAND WATER BUREAU

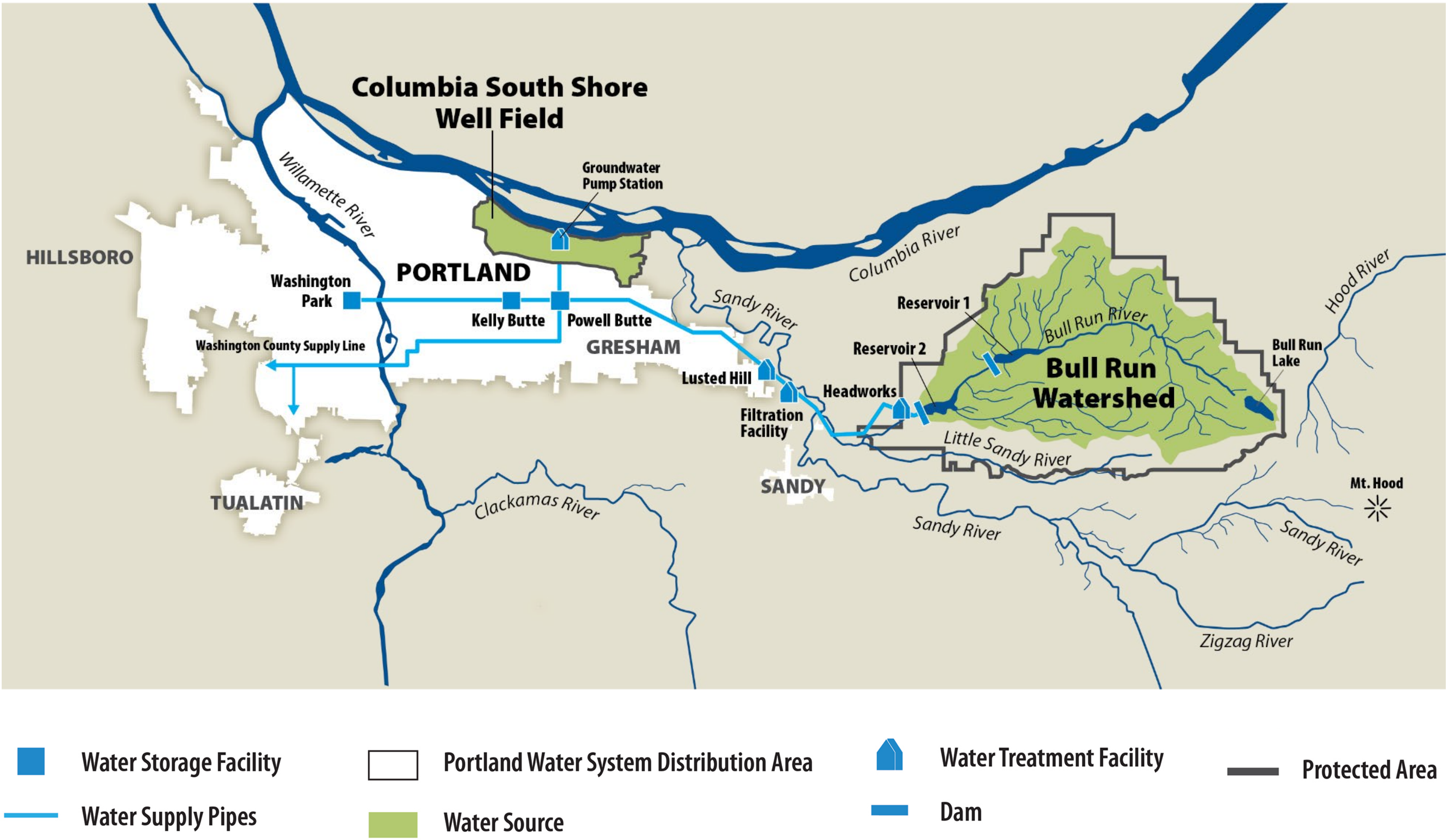
FROM FOREST TO FAUCET

CITY OF PORTLAND, OREGON 1851

PNWS-AWWA Water 2022

Tacoma, WA • April 27-29

Thanks to thoughtful planning, Bull Run has been a source of **excellent water since 1895**

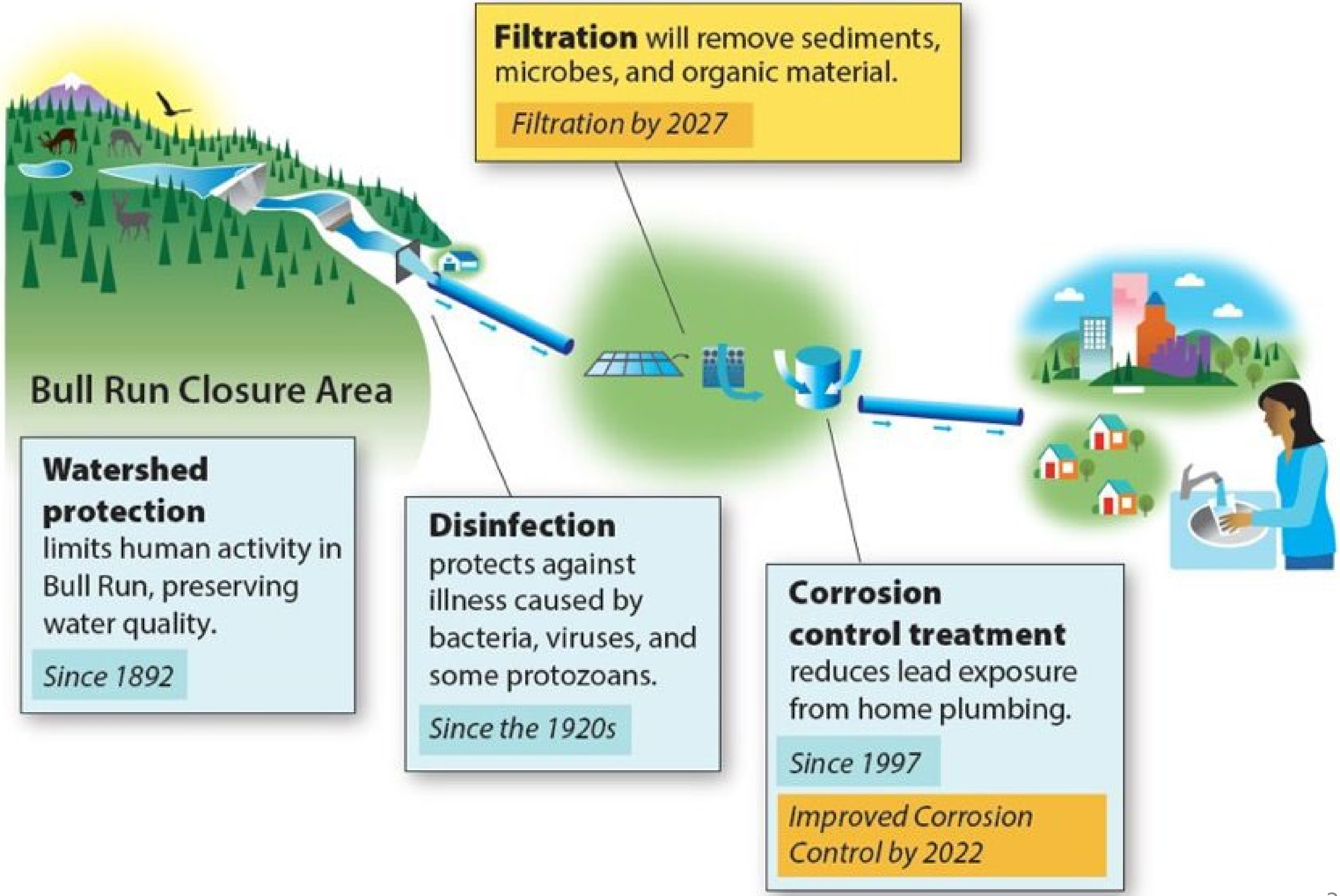


- Serves almost 1 million people
- Serves the City of Portland and 19 wholesale customers
- Uses 100 million gallons of water on an average day

Bull Run TREATMENT PROJECTS

Our water: Safe and abundant for generations to come

Improvements to our system are needed to meet national drinking water standards



Agenda

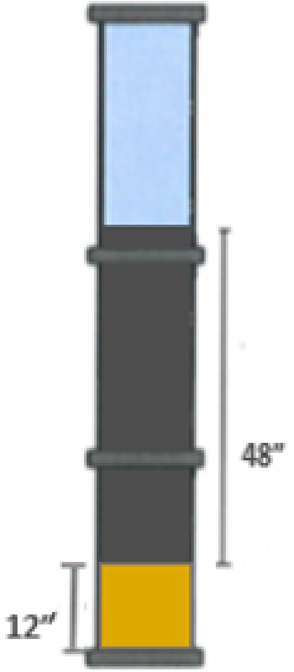
1. Alum coagulation at the pilot
2. Results of Alum Jar Tests
3. Summary

Pilot

Alum

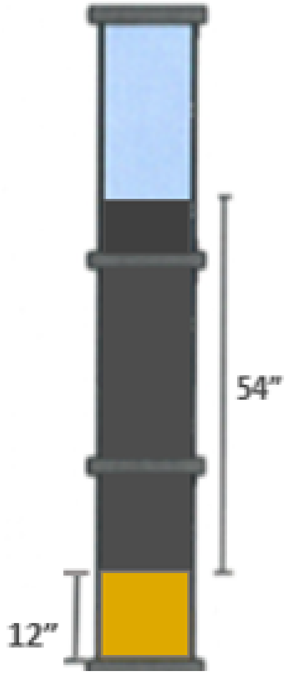
Filter Configuration

ANTH-60
Filters 1/6



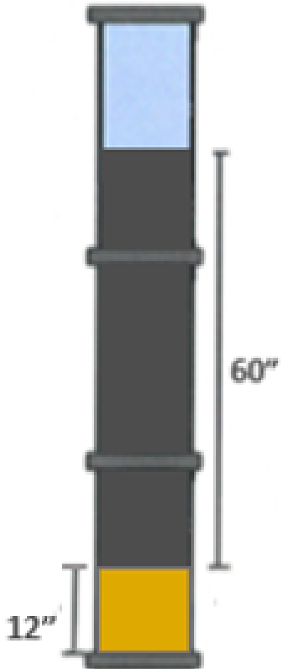
1.1 mm Anthracite
0.55 mm Sand
8 gpm/sf

ANTH-66
Filters 2/5



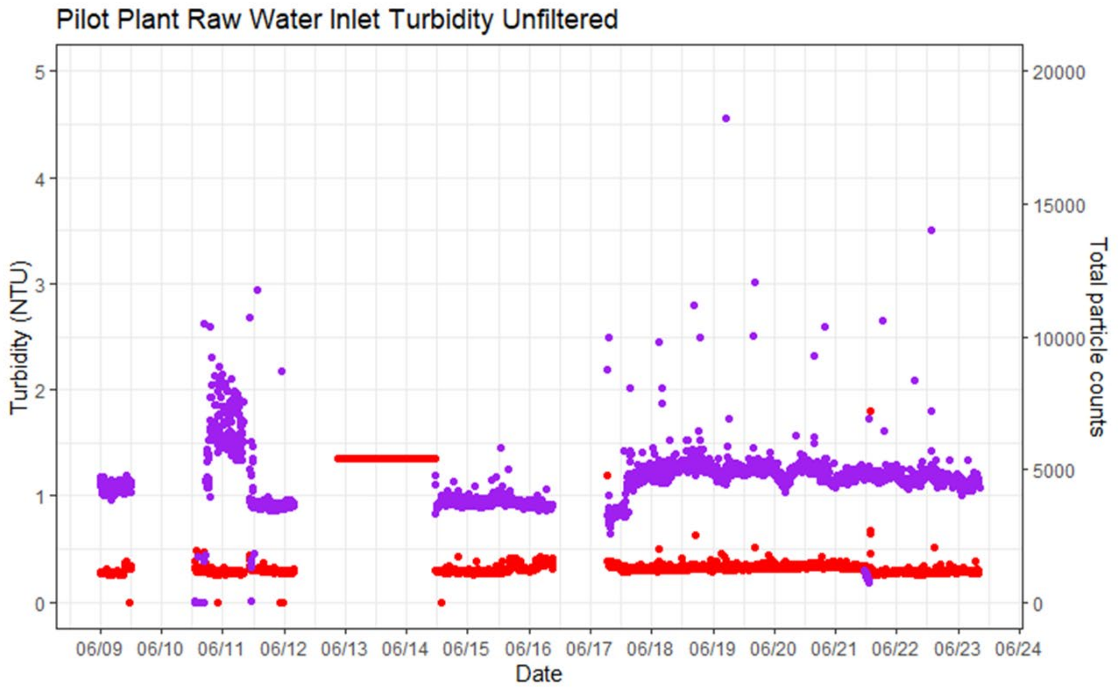
1.2 mm Anthracite
0.60 mm Sand
10 gpm/sf

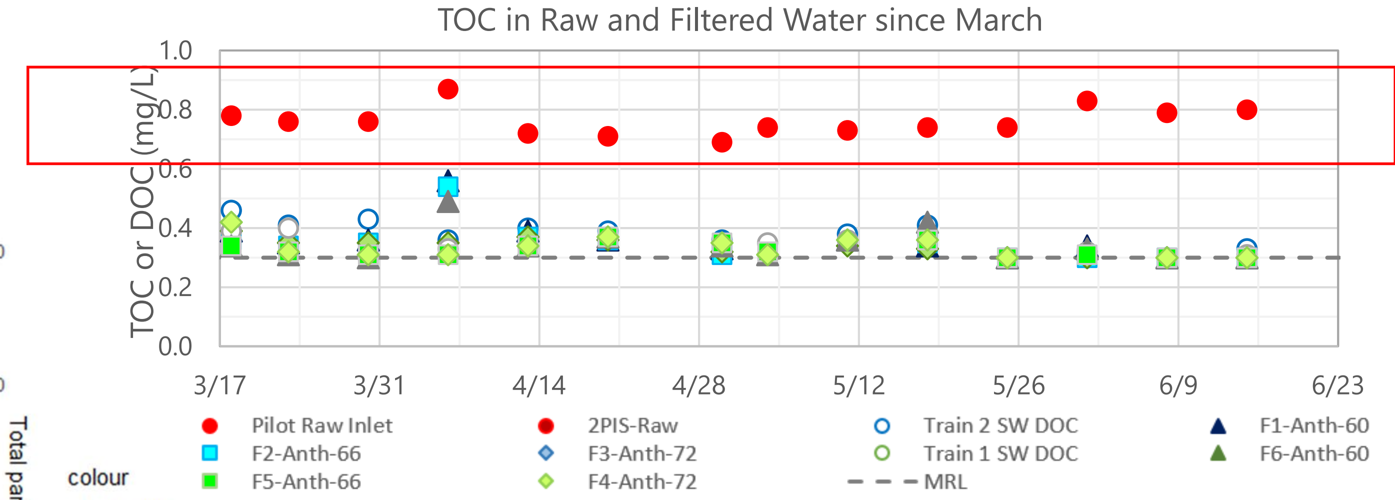
ANTH-72
Filters 3/4

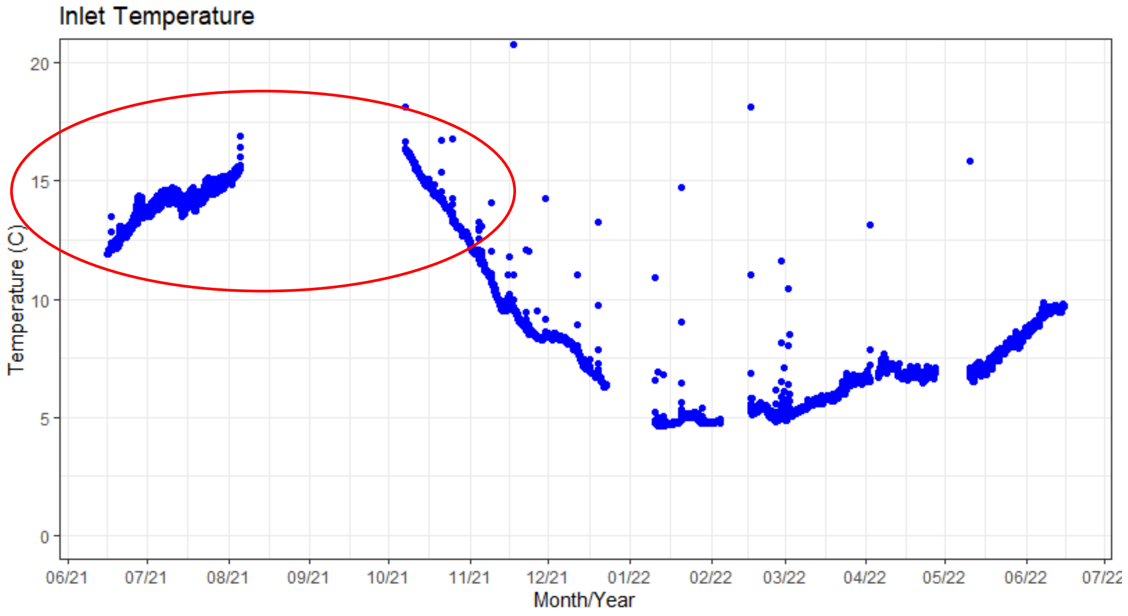


1.3 mm Anthracite
0.65 mm Sand
12 gpm/sf

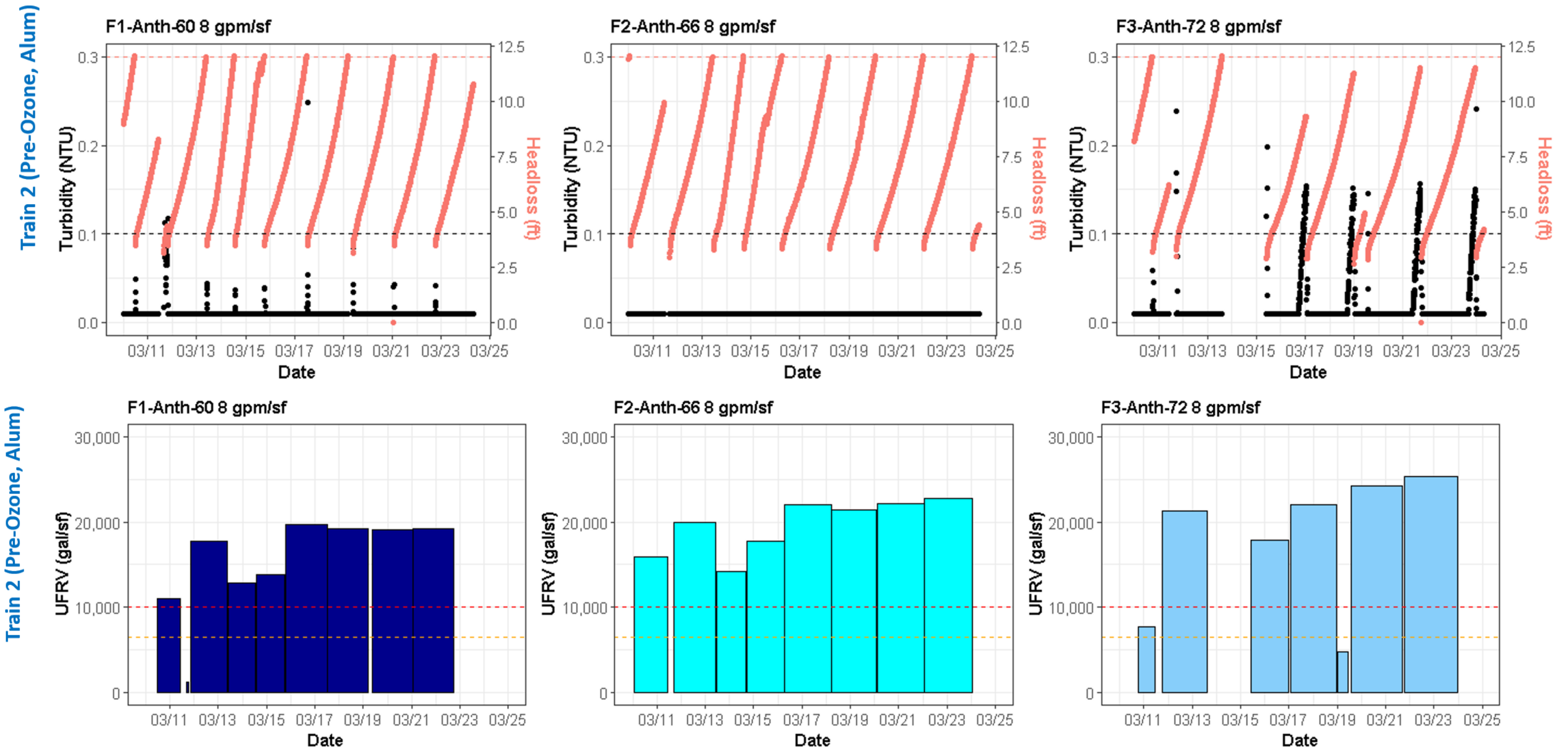
Raw Water in Spring/Summer



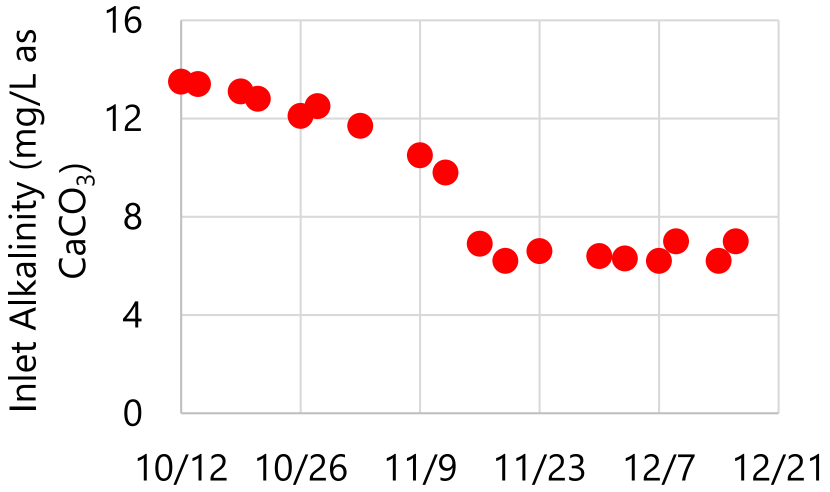


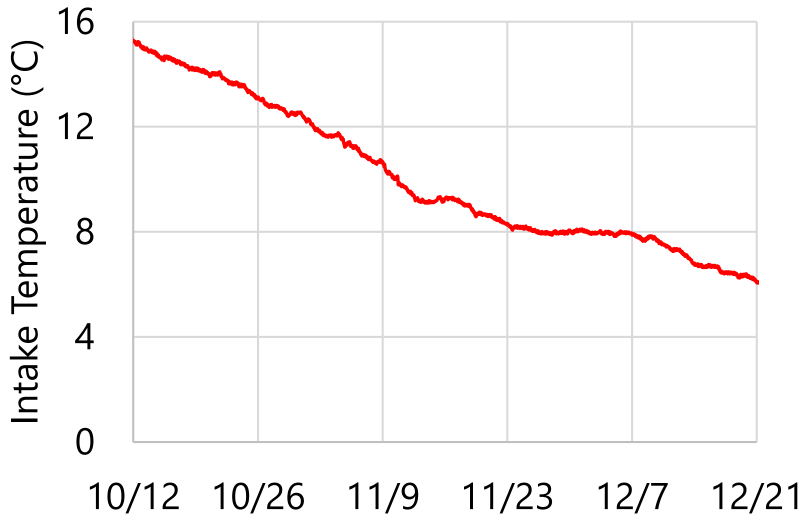


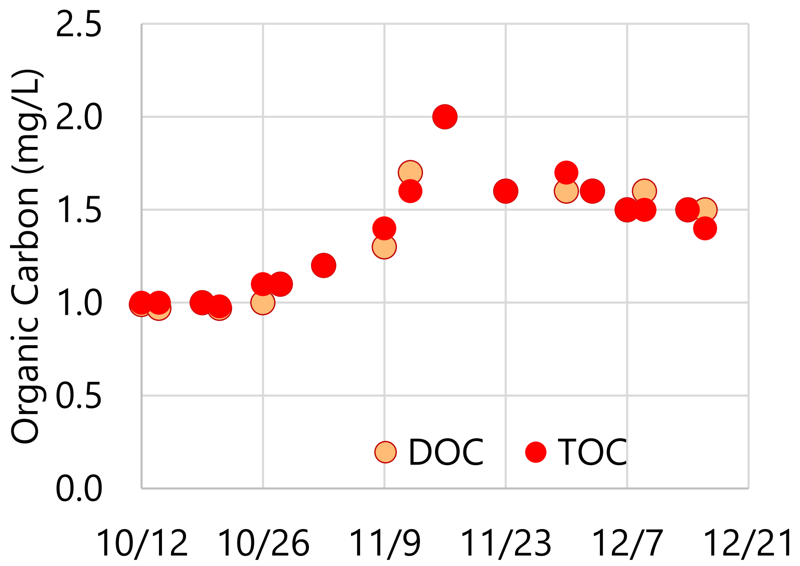
Filter Effluent and Productivity

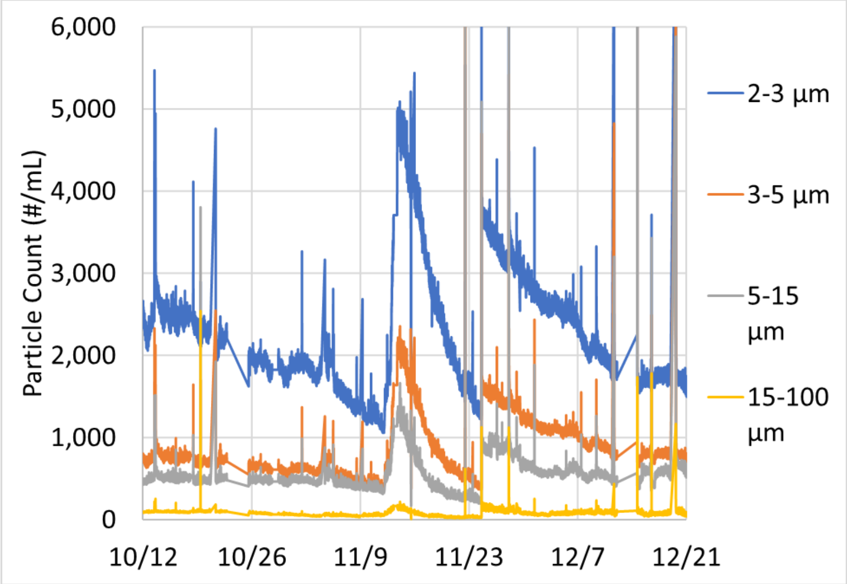


Raw Water in Fall/Winter

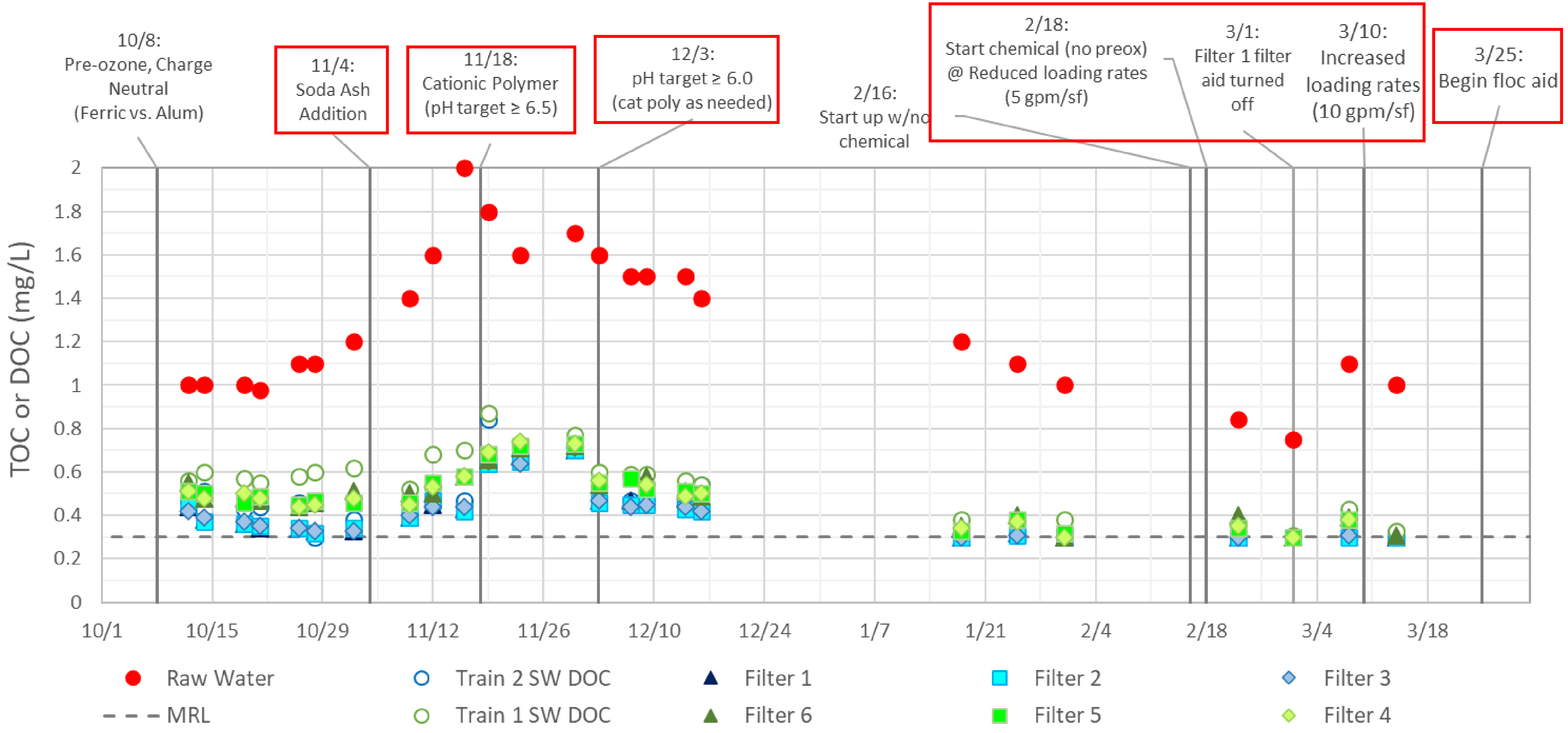






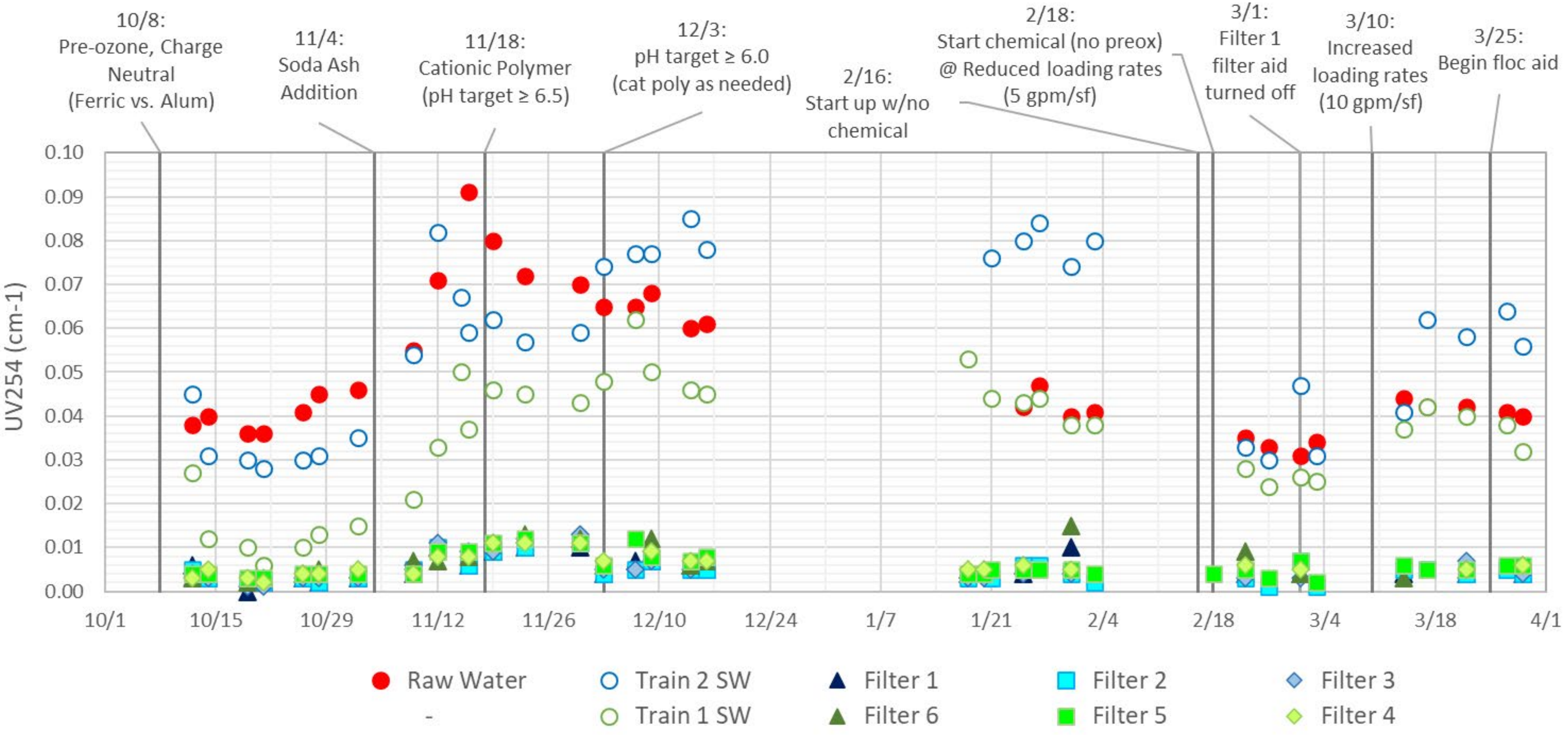


TOC and DOC



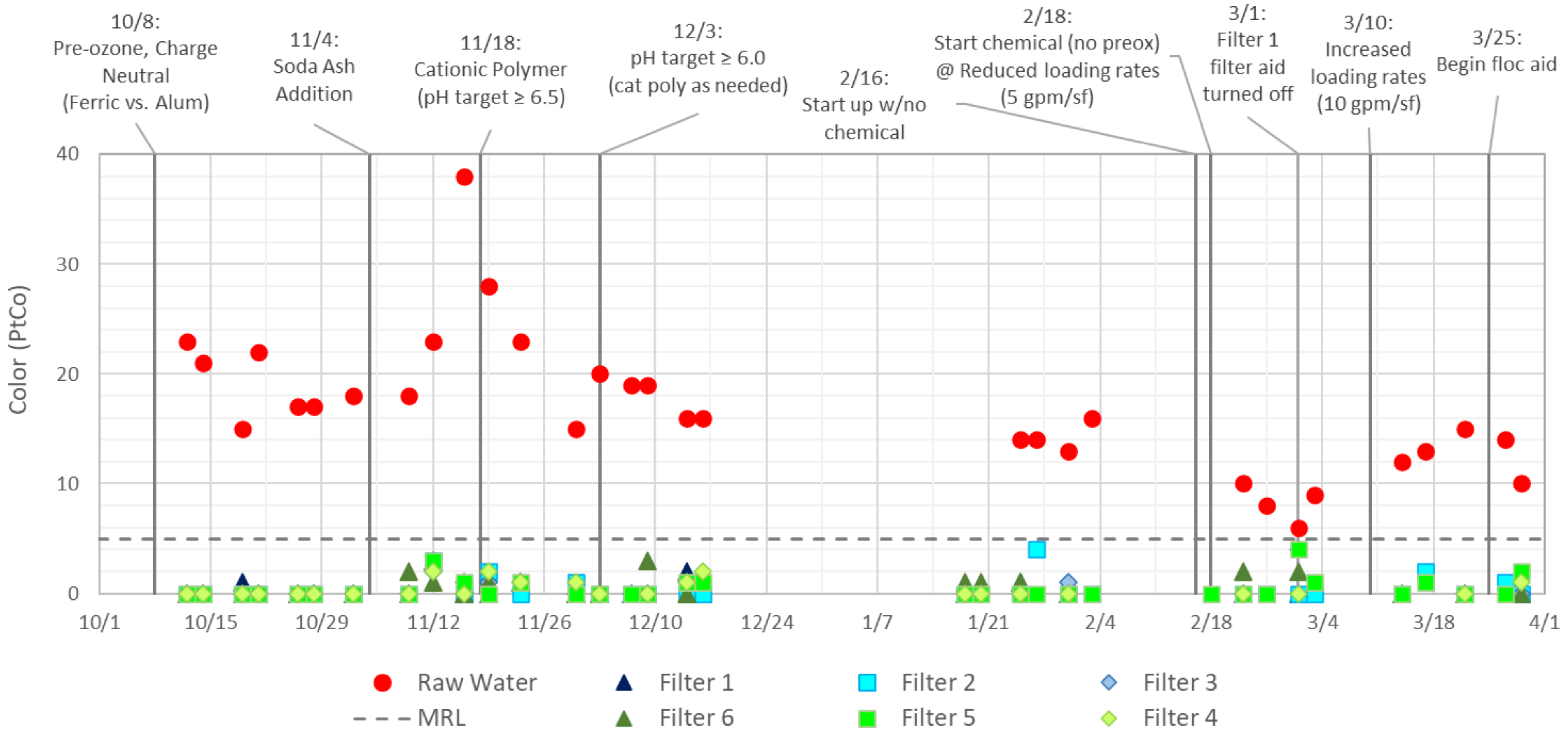
10/8:
Pre-ozone, Charge Neutral (Ferric vs. Alum)
11/4:
Soda Ash Addition
11/18:
Cationic Polymer (pH target ≥ 6.5)
12/3:
pH target ≥ 6.0 (cat poly as needed)
2/16:
Start up w/no chemical
2/18:
Start chemical (no preox) @ Reduced loading rates (5 gpm/sf)
3/1:
Filter 1 filter aid turned off
3/10:
Increased loading rates (10 gpm/sf)
3/25:
Begin floc aid
TOC or DOC (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10/1
10/15
10/29
11/12
11/26
12/10
12/24
1/7
1/21
2/4
2/18
3/4
3/18
Raw Water
MRL
Train 2 SW DOC
Train 1 SW DOC
Filter 1
Filter 6
Filter 2
Filter 5
Filter 3
Filter 4

UV254



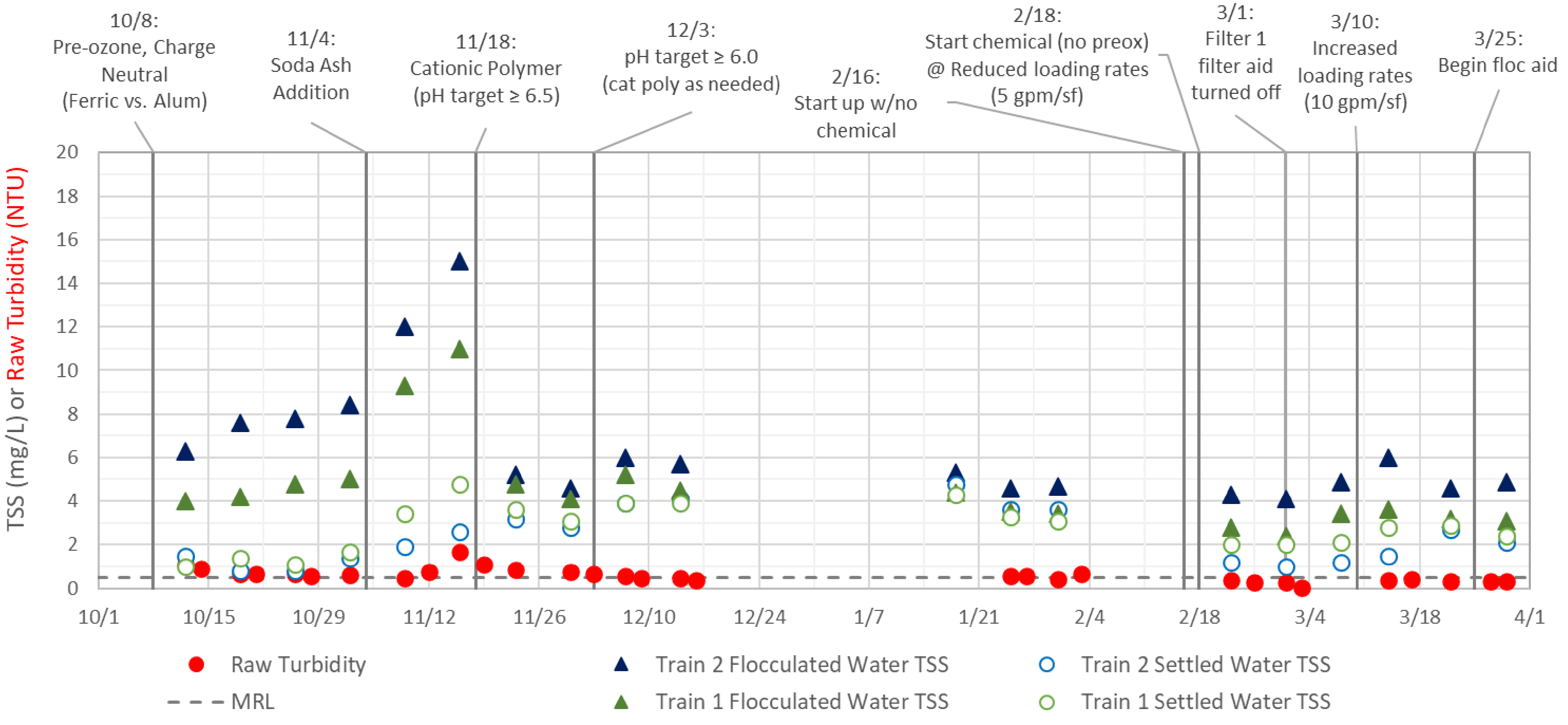
10/8: Pre-ozone, Charge Neutral (Ferric vs. Alum)
11/4: Soda Ash Addition
11/18: Cationic Polymer (pH target ≥ 6.5)
12/3: pH target ≥ 6.0 (cat poly as needed)
2/16: Start up w/no chemical
2/18: Start chemical (no preox) @ Reduced loading rates (5 gpm/sf)
3/1: Filter 1 filter aid turned off
3/10: Increased loading rates (10 gpm/sf)
3/25: Begin floc aid
UV254 (cm-1)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
10/1
10/15
10/29
11/12
11/26
12/10
12/24
1/7
1/21
2/4
2/18
3/4
3/18
4/1
Raw Water
-
Train 2 SW
Train 1 SW
Filter 1
Filter 6
Filter 2
Filter 5
Filter 3
Filter 4

Color



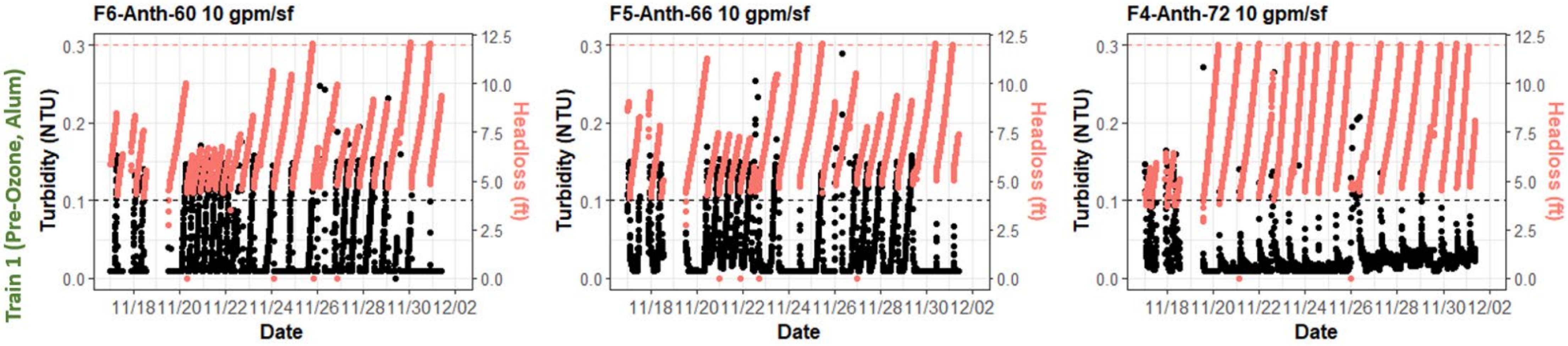
10/8:
Pre-ozone, Charge Neutral
(Ferric vs. Alum)
11/4:
Soda Ash Addition
11/18:
Cationic Polymer
(pH target ≥ 6.5)
12/3:
pH target ≥ 6.0
(cat poly as needed)
2/16:
Start up w/no chemical
2/18:
Start chemical (no preox)
@ Reduced loading rates
(5 gpm/sf)
3/1:
Filter 1 filter aid turned off
3/10:
Increased loading rates
(10 gpm/sf)
3/25:
Begin floc aid
Color (PtCo)
40
30
20
10
0
10/1
10/15
10/29
11/12
11/26
12/10
12/24
1/7
1/21
2/4
2/18
3/4
3/18
4/1
Raw Water
Filter 1
Filter 2
Filter 3
MRL
Filter 6
Filter 5
Filter 4

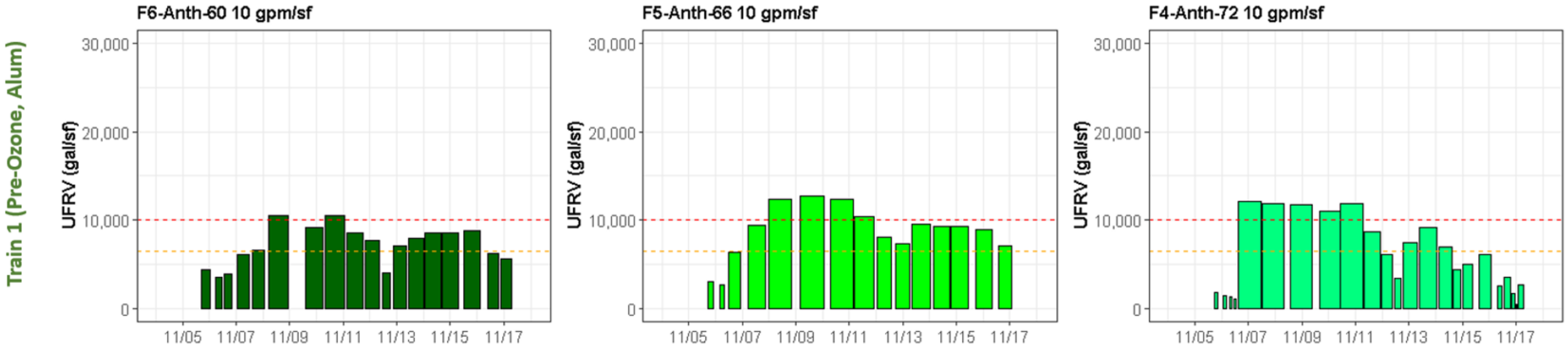
TSS



10/8:
Pre-ozone, Charge Neutral
(Ferric vs. Alum)
11/4:
Soda Ash Addition
11/18:
Cationic Polymer
(pH target ≥ 6.5)
12/3:
pH target ≥ 6.0
(cat poly as needed)
2/16:
Start up w/no chemical
2/18:
Start chemical (no preox)
@ Reduced loading rates
(5 gpm/sf)
3/1:
Filter 1 filter aid turned off
3/10:
Increased loading rates
(10 gpm/sf)
3/25:
Begin floc aid
TSS (mg/L) or Raw Turbidity (NTU)
0
2
4
6
8
10
12
14
16
18
20
10/1
10/15
10/29
11/12
11/26
12/10
12/24
1/7
1/21
2/4
2/18
3/4
3/18
4/1
Raw Turbidity
MRL
Train 2 Flocculated Water TSS
Train 1 Flocculated Water TSS
Train 2 Settled Water TSS
Train 1 Settled Water TSS

Filter Effluent and Productivity





Alum Jar Testing

Why Jar Testing?

- What chemicals are required to achieve the best coagulation, flocculation and settling performance?
  - coagulants
  - coagulant aids
  - flocculant aids
- What are the right doses for these chemicals?
- Could we use what other facilities are already using?

Coagulant Evaluation

4 coagulants will be studied in these jar testing experiments:

- poly-aluminum chloride (PACl)
- **aluminum sulfate (Alum)**
- ferric sulfate
- aluminum Chlorohydrate (ACH)

Analyses

- turbidity
- UV_{254}
- filtered UV_{254}
- color
- apparent color
- alkalinity
- pH
- zeta potential
- TOC/DOC
- Fe/Al



General Experiment Design
pH Optimization
color
Apparent Color
Settling Behavior
Coagulant Dose
UV_{254}
Filtered UV_{254}
Enhanced Coagulation
UV_{254}
Filtered UV_{254}
Turbidity
Flocculant Aid Testing
color
Apparent Color
Settling Behavior
Floc size
Alkalinity Adjustment
Settling Behavior
Floc size

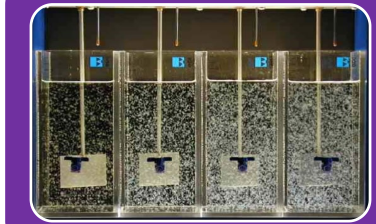
Alum Test Conditions

pH adjustments in acidic ranges

- Hydrochloric acid

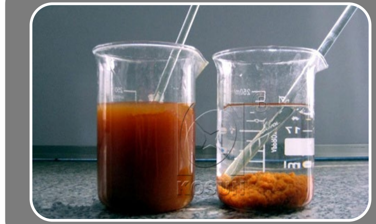
pH adjustments in alkaline ranges

- Combination of coagulant aid and soda ash



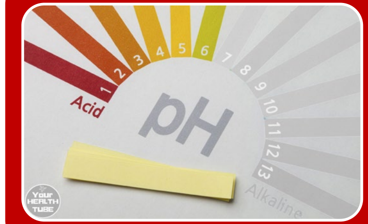
Sweep floc formation

- Sodium bicarbonate
- Sodium hydroxide
- Soda ash



Flocculant aid addition

- Anionic flocculant aid
- Nonionic flocculant aid
- Cationic flocculant aid

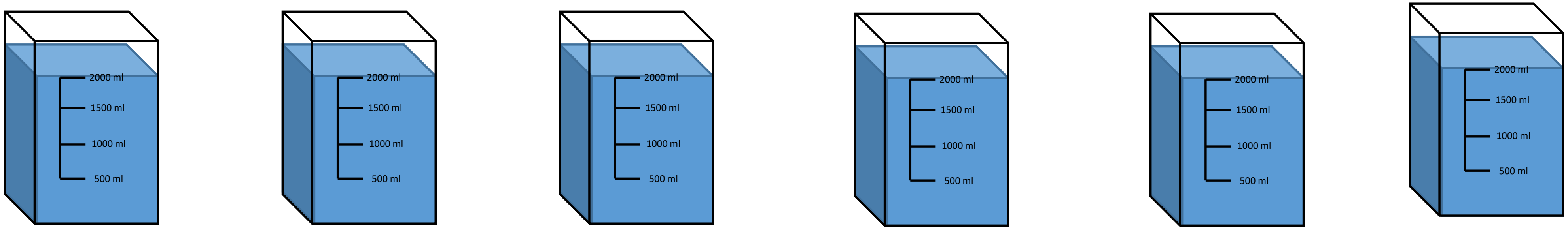


pH adjustments in acidic ranges

- Hydrochloric acid

pH adjustments in acidic ranges

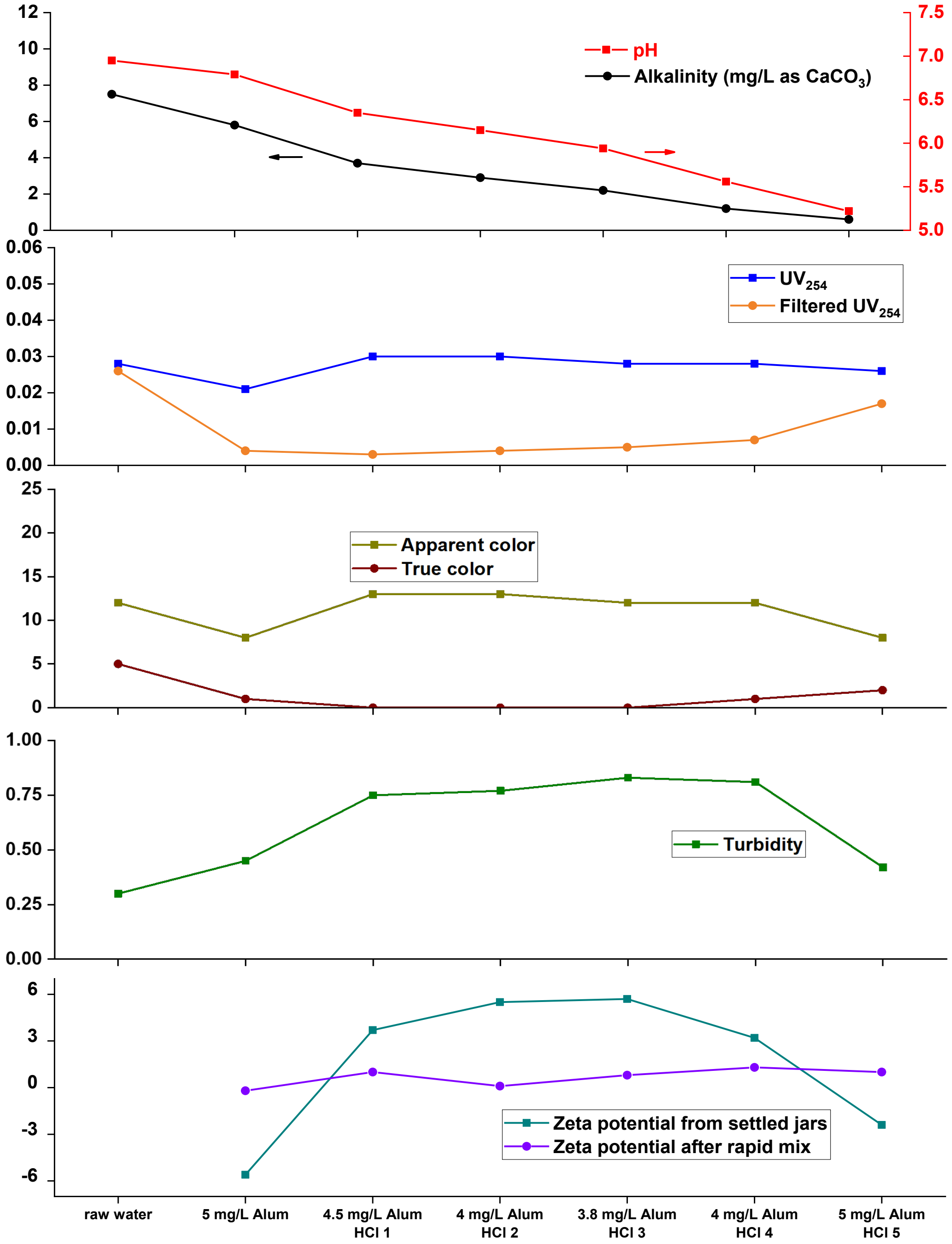
- Goal: Investigate the zeta charge reversal at acidic pH values
- Jar setup:

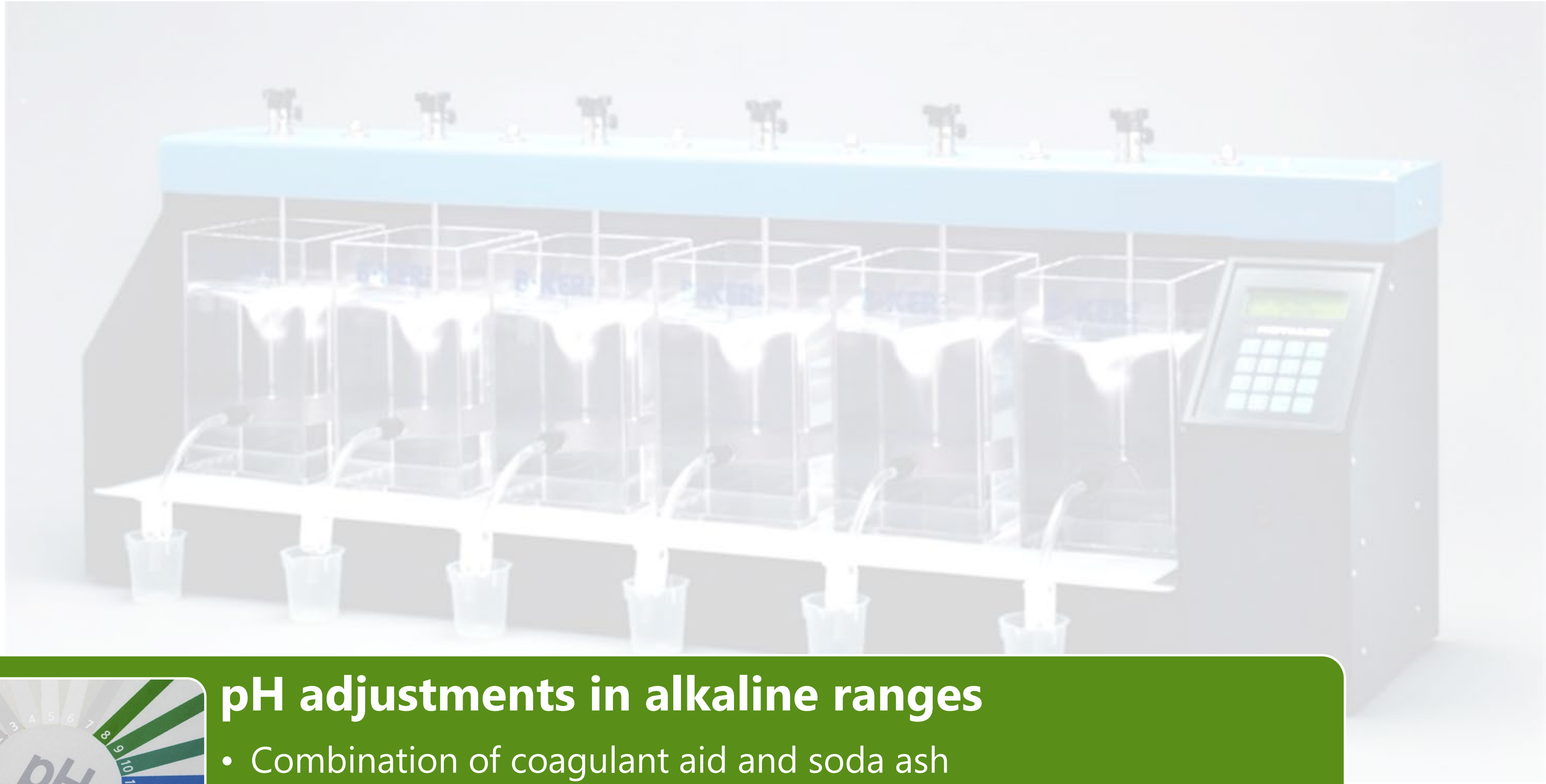


Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
5 mg/L Alum	4.5 mg/L Alum	4 mg/L Alum	3.8 mg/L Alum	4 mg/L Alum	5 mg/L Alum
(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)
	0.8 ml of 0.16 N acid	1.2 ml of 0.16 N acid	1.6 ml of 0.16 N acid	2 ml of 0.16 N acid	2.4 ml of 0.16 N acid

pH adjustments in acidic ranges

- Lowering the pH resulted in higher UV_{254} , color and turbidity.



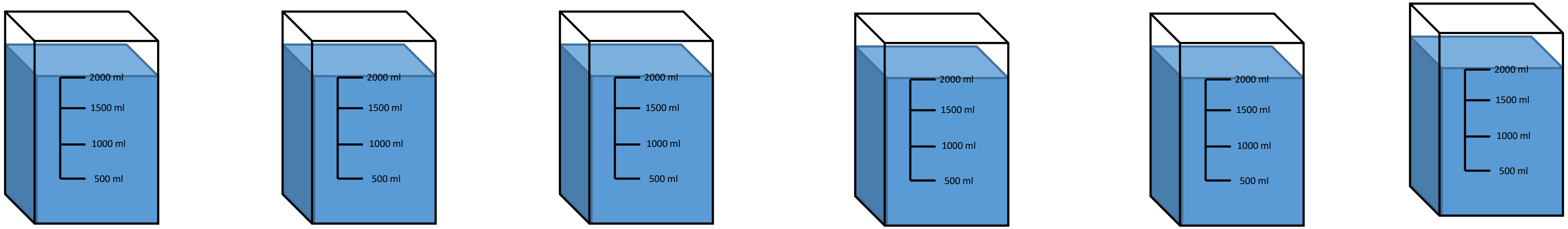


pH adjustments in alkaline ranges

- Combination of coagulant aid and soda ash

pH adjustments in alkaline ranges

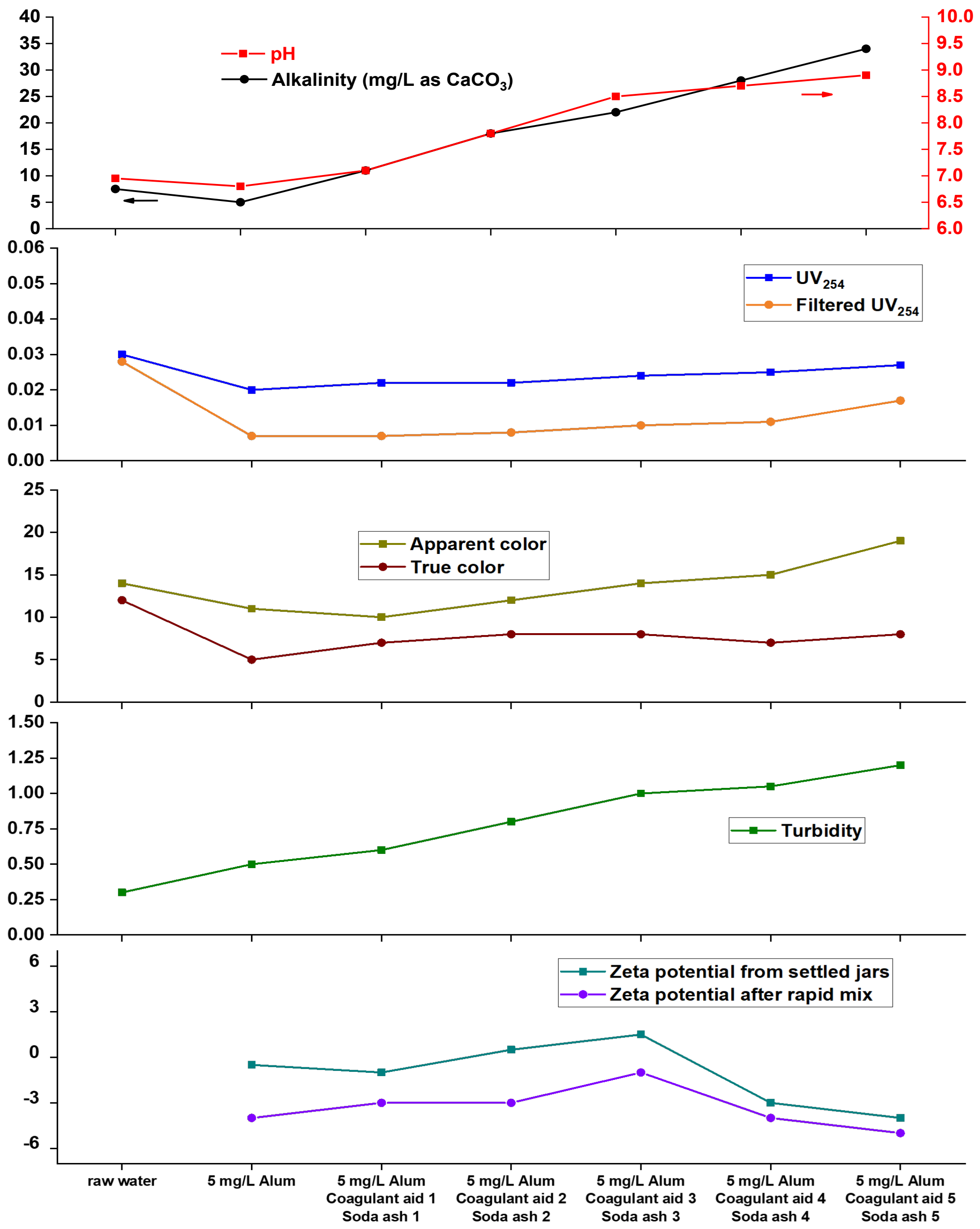
- Goal: Investigate the possibility of achieving sweep floc formation at high pH values
- Jar setup:

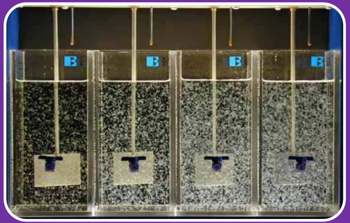


Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)
	0.8 mg/L of coag. Aid	1.4 mg/L of coag. Aid	1.7 mg/L of coag. Aid	1.9 mg/L of coag. Aid	2 mg/L of coag. Aid
	8 mg/L soda ash	20 mg/L soda ash	25 mg/L soda ash	33 mg/L soda ash	40 mg/L soda ash

pH adjustments in alkaline ranges

- Decent flocs were formed; however, the settling and water quality results are not good.



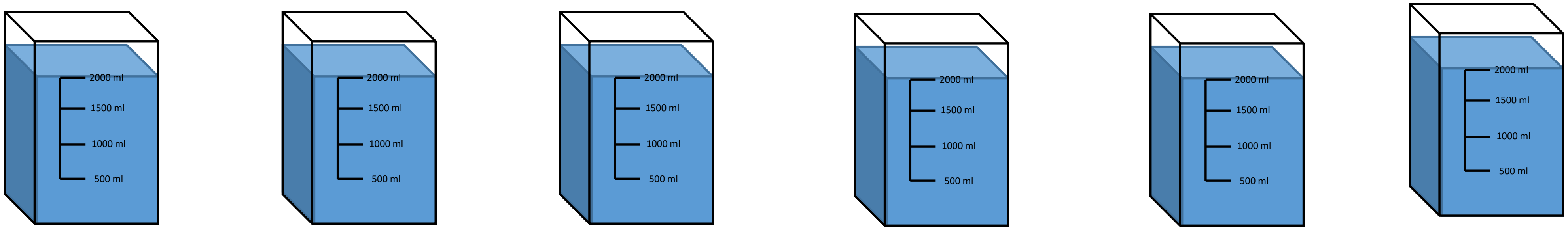


Sweep floc formation

- Sodium hydroxide
- Sodium bicarbonate
- Soda ash

Sweep floc formation by Bicarbonate addition

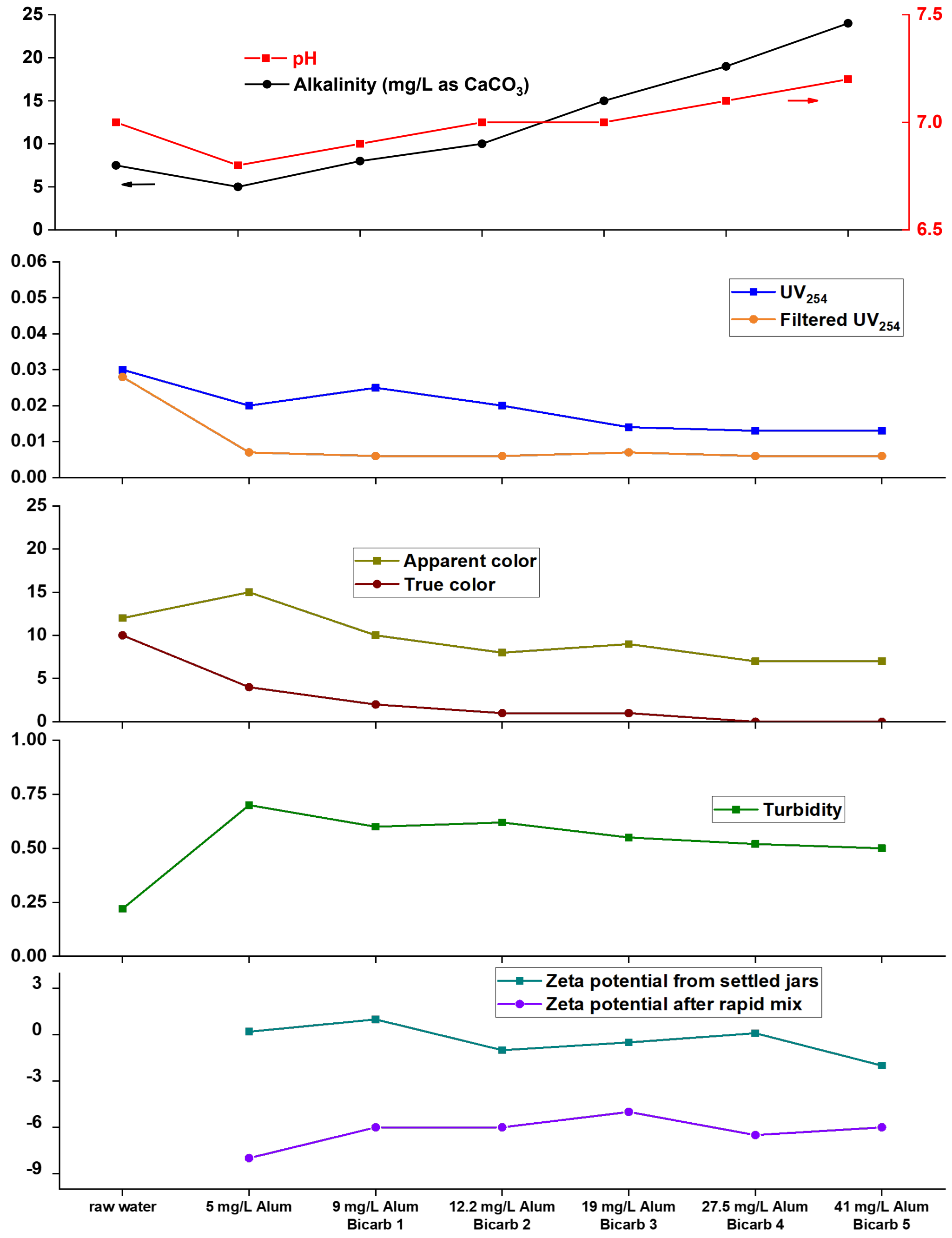
- Goal: Investigate the possibility of achieving settleable flocs.
- Jar setup:



Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
5 mg/L Alum	9 mg/L Alum	12.2 mg/L Alum	19 mg/L Alum	27.5 mg/L Alum	41 mg/L Alum
(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)
	9 mg/L of bicarb	18 mg/L of bicarb	25 mg/L of bicarb	35 mg/L of bicarb	45 mg/L of bicarb

Sweep floc formation by Bicarbonate addition

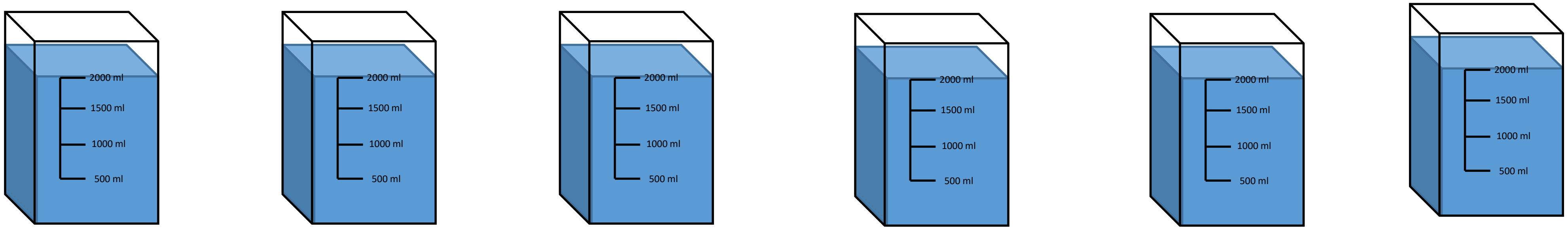
- Decent flocs were formed; however, the settling performance of the flocs were not good.
- Considering the amount of bicarbonate and coagulant needed to achieve good performance, this is not a feasible alternative.



Sweep floc formation

Sweep floc formation by NaOH

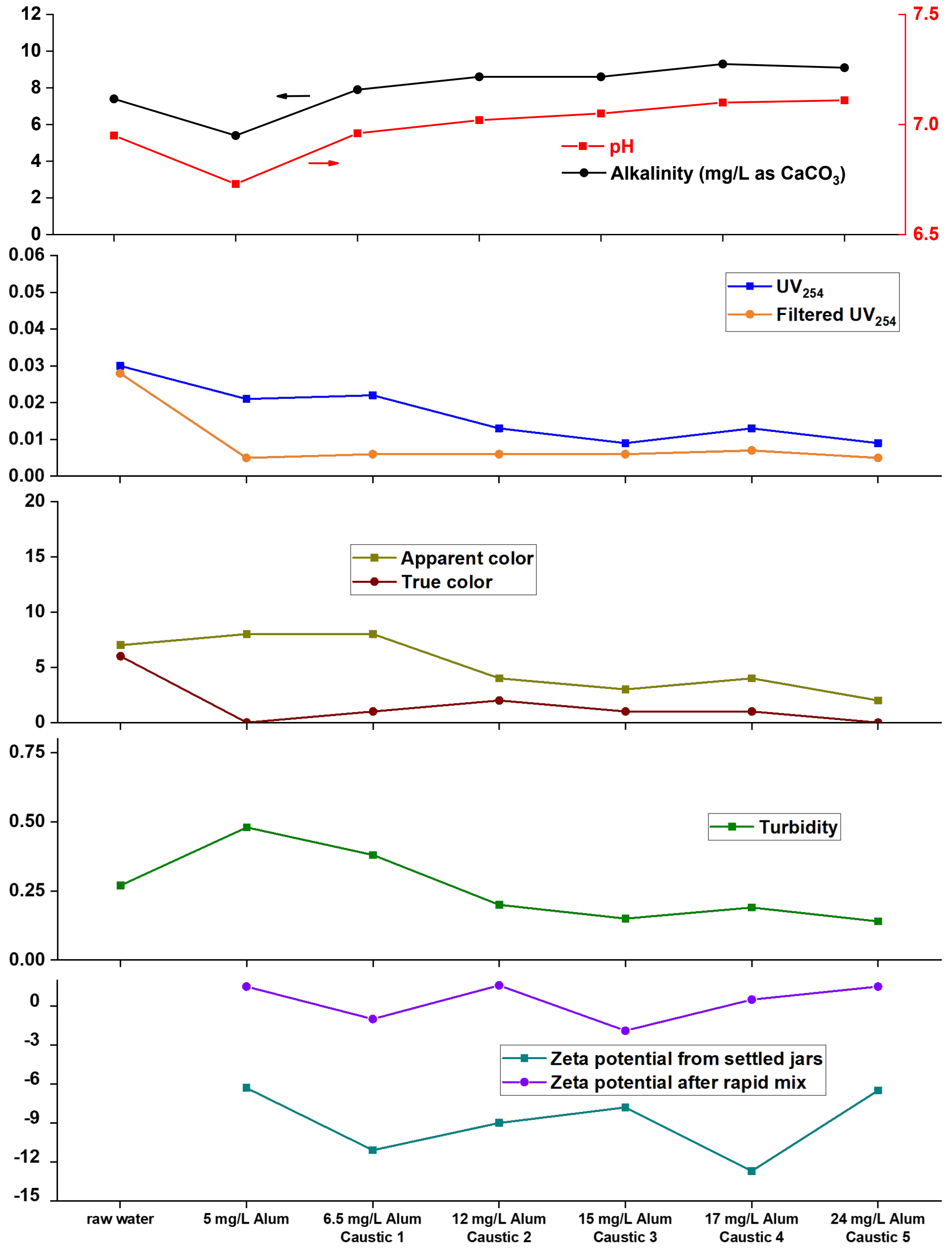
- Goal: Investigate the possibility of achieving lower turbidity and better settling.
- Jar setup:



Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
5 mg/L Alum	6.5 mg/L Alum	12 mg/L Alum	15 mg/L Alum	17 mg/L Alum	24 mg/L Alum
(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)
	0.8 ml of 0.16 N NaOH	1.6 ml of 0.16 N NaOH	2 ml of 0.16 N NaOH	2.4 ml of 0.16 N NaOH	3.2 ml of 0.16 N NaOH

Sweep floc formation by NaOH

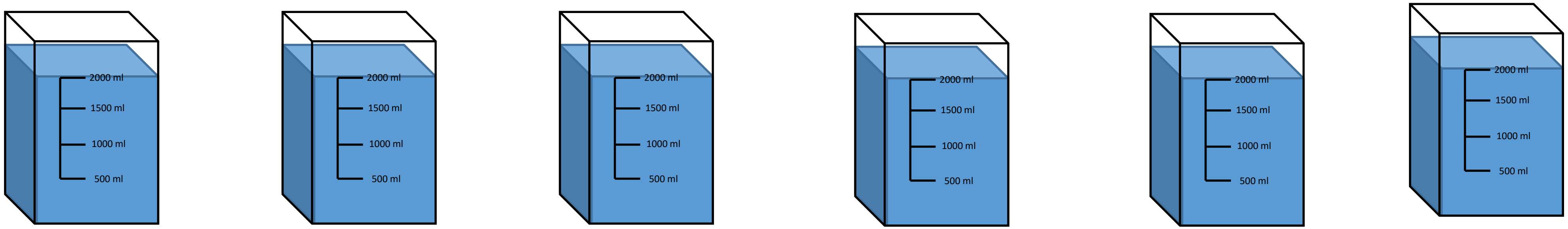
- Water quality kept improving by increasing the NaOH addition in each jar.



Sweep floc formation

Sweep floc formation by soda ash

- Goal: Investigate the possibility of achieving similar great results that were achieved by NaOH.
- Jar setup:



Jar 1
4.9 mg/L Alum
(charge neutral dose)

Jar 2
10 mg/L Alum
(charge neutral dose)
8.5 mg/L soda ash

Jar 3
13.5 mg/L Alum
(charge neutral dose)
17 mg/L soda ash

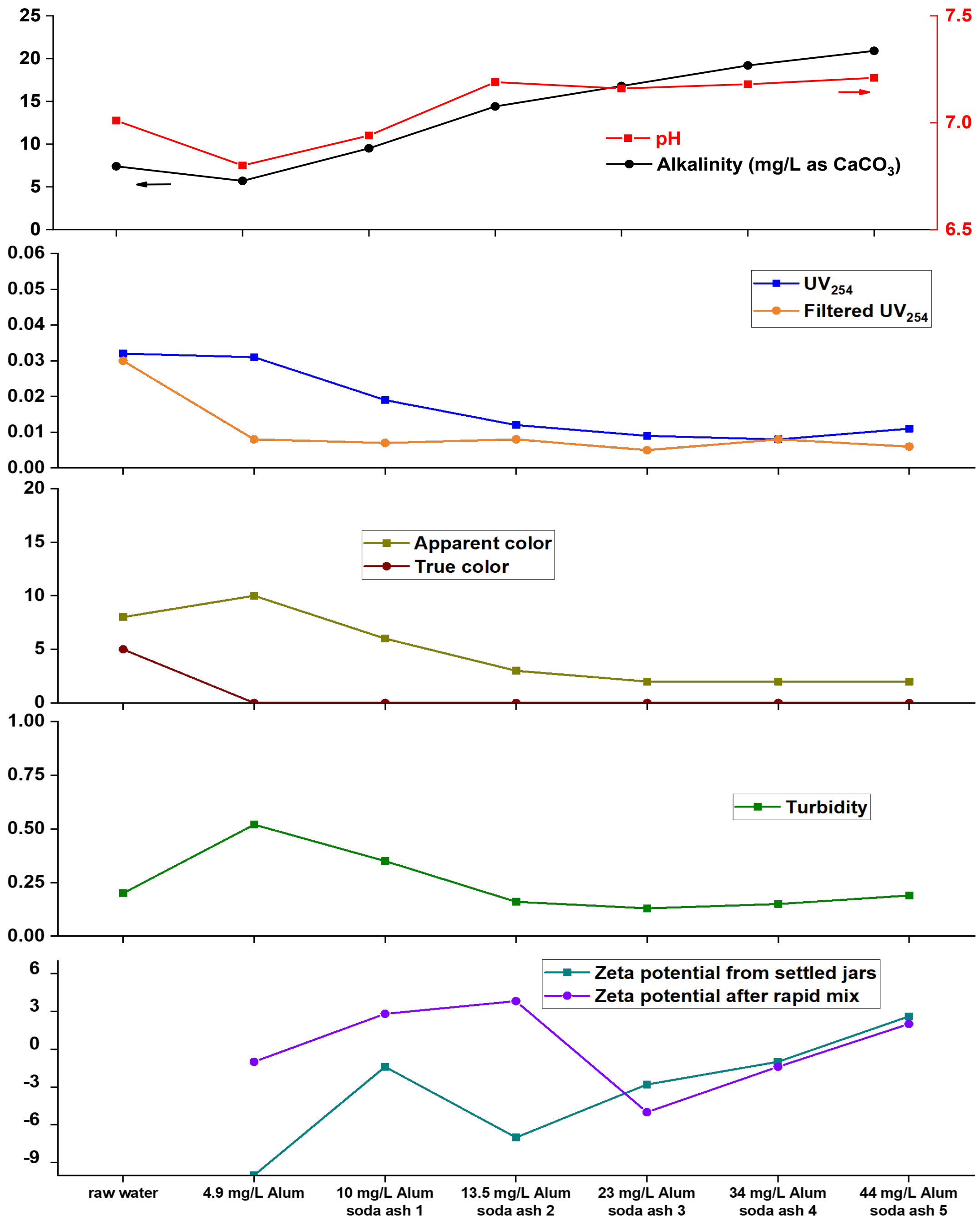
Jar 4
23 mg/L Alum
(charge neutral dose)
25.5 mg/L soda ash

Jar 5
34 mg/L Alum
(charge neutral dose)
34 mg/L soda ash

Jar 6
44 mg/L Alum
(charge neutral dose)
42 mg/L soda ash

Sweep floc formation by soda ash

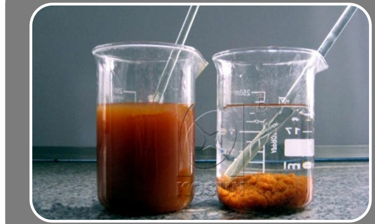
- Water quality improved by addition of soda ash in the jars.



Sweep floc formation

Summary: Sweep floc formation

- Water quality improved by addition of soda ash and NaOH in the jars.
- Addition of sodium bicarbonate also improved the water quality; however, it requires extremely high doses.
- There is a need for lower NaOH dose compared to soda ash in order to achieve a better water quality results. The coagulant demand is also lower for NaOH vs soda ash.

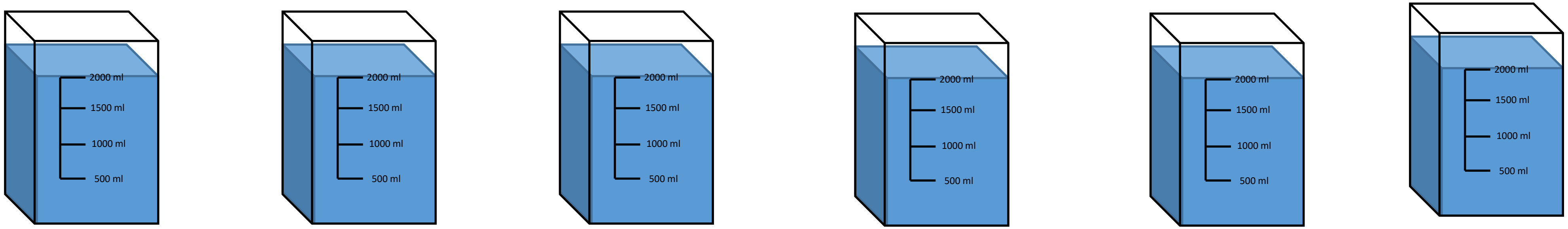


Flocculant aid addition

- Anionic flocculant aid
- Nonionic flocculant aid
- Cationic flocculant aid

Alum with anionic floc aid

- Goal: Investigate the possibility of achieving lower turbidity and better settleability
- Jar setup:



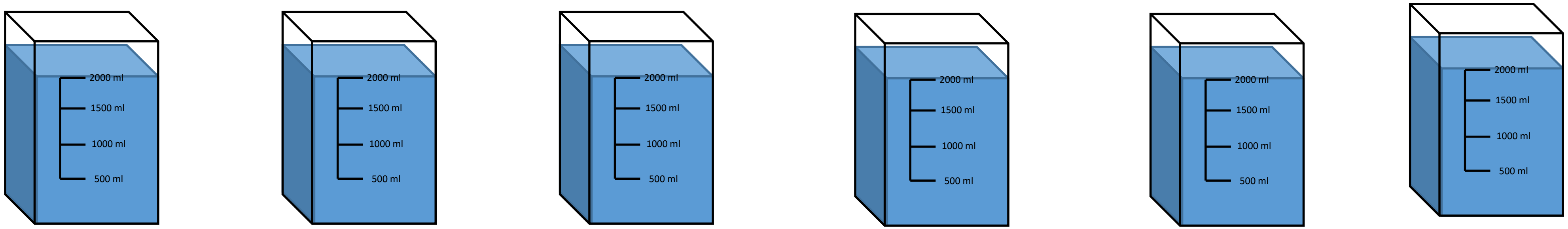
Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
5 mg/L Alum	5 mg/L Alum	5 mg/L Alum	5 mg/L Alum	5 mg/L Alum	5 mg/L Alum
(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)	(charge neutral dose)
	0.02 mg/L A-1820	0.04 mg/L A-1820	0.06 mg/L A-1820	0.08 mg/L A-1820	0.1 mg/L A-1820

Alum with anionic floc aid

- Addition of anionic floc aid into charge neutral jars resulted in stopping the floc growth in third flocculation time.
- This resulted in worse settling for all jars compared to charge neutral that had some settling.
- This is due to having a more negatively charged solution during the third flocculation.

Alum with nonionic floc aid

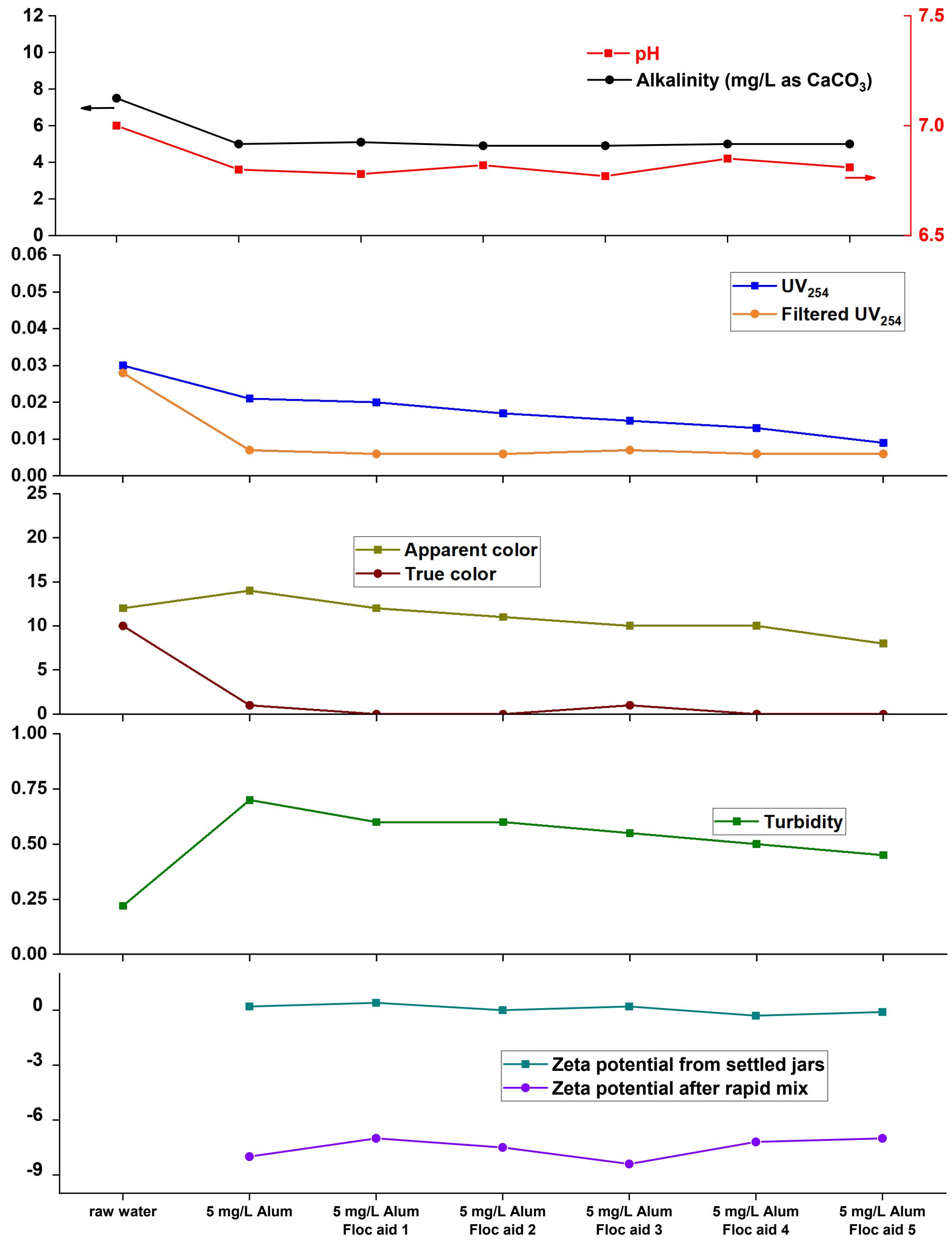
- Goal: Investigate the possibility of achieving bigger flocs, better settling and lower turbidity.
- Jar setup:



Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose) 0.02 mg/L of N-1986	5 mg/L Alum (charge neutral dose) 0.04 mg/L of N-1986	5 mg/L Alum (charge neutral dose) 0.06 mg/L of N-1986	5 mg/L Alum (charge neutral dose) 0.08 mg/L of N-1986	5 mg/L Alum (charge neutral dose) 0.1 mg/L of N-1986

Alum with nonionic floc aid

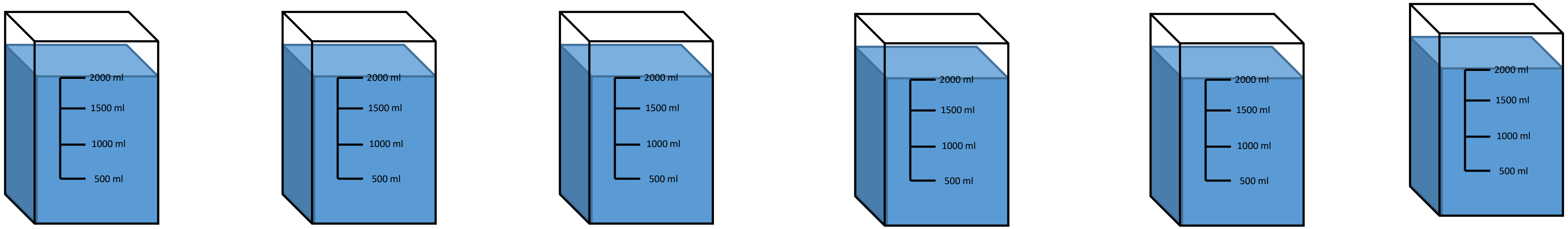
- Turbidity and color demonstrates a downward trend due to the addition of flocculant aid.



Flocculant aid addition

Alum with cationic floc aid

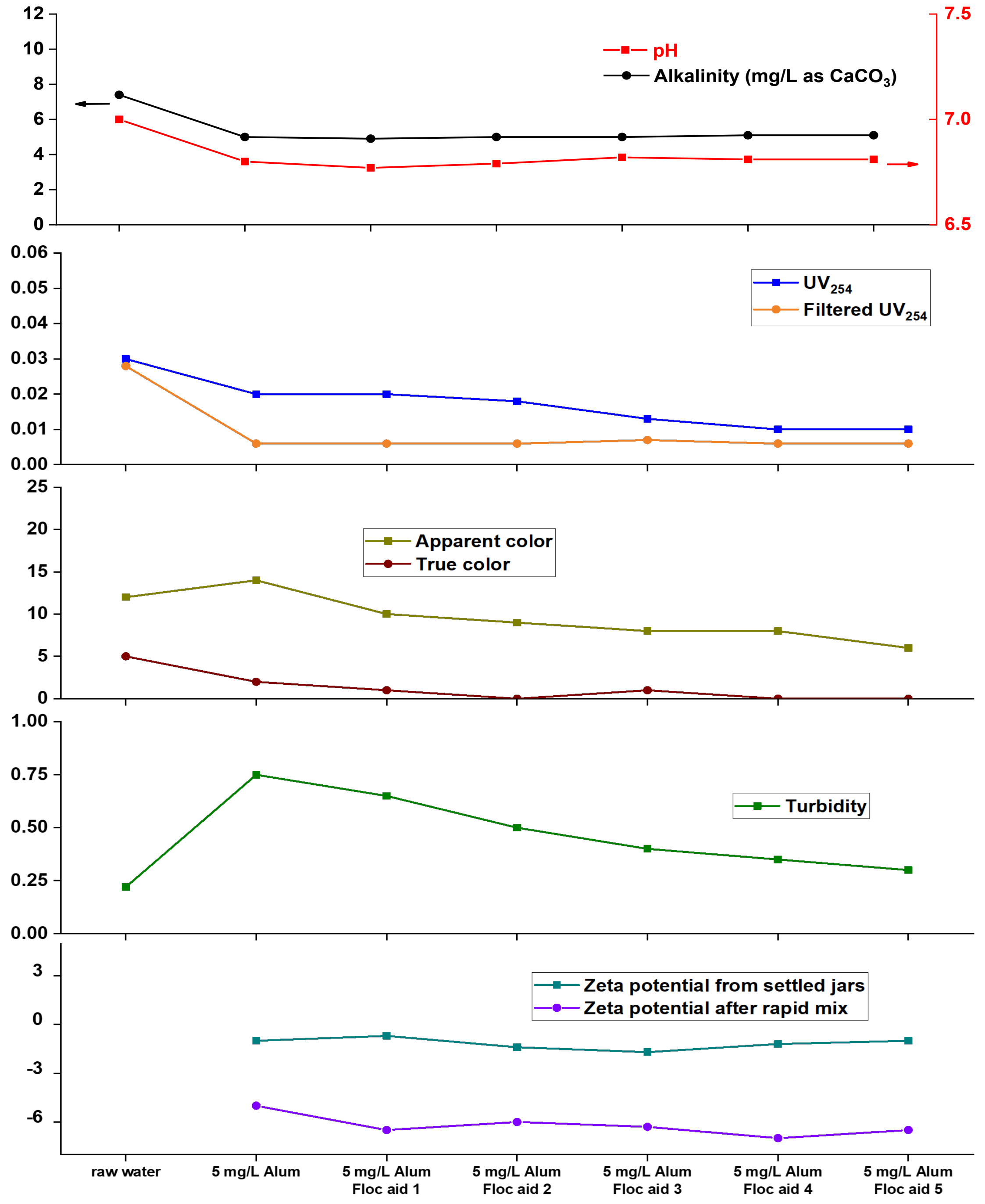
- Goal: Investigate the possibility of achieving bigger flocs, better settling and lower turbidity.
- Jar setup:



Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)	5 mg/L Alum (charge neutral dose)
	0.02 mg/L of C-1594	0.04 mg/L of C-1594	0.06 mg/L of C-1594	0.08 mg/L of C-1594	0.1 mg/L of C-1594

Alum with cationic floc aid

- Turbidity and color demonstrates a downward trend due to the addition of flocculant aid.



Flocculant aid addition

Summary: floc aid

- Turbidity and color demonstrates a downward trend due to the addition of nonionic and cationic flocculant aid.
- Addition of anionic flocculant aid disrupts the floc formation and growth during the flocculation time.
- Cationic flocculant aid is able to achieve the similar great water quality results at much lower doses compared to nonionic flocculant aid.

Summary

- Acidic or Alkaline pHs did not improve the Alum coagulation.
- Bicarbonate was not as successful as other chemicals in forming sweep flocs.
- Sweep floc was achieved with both NaOH and soda ash when the pH of the raw water was raised to above 9.
- Targeting sweep floc requires increasing Alum dose.

NaOH vs. Soda ash	NaOH	Soda ash
Cost effective		√
Less chemical usage	√	
Possible smaller chemical tank and pump sizing	√	
Safety		√
Less coagulant dose	√	
Smaller sludge handling sizing and less sludge production	√	
Alkalinity increase in the raw water (lesser chemical need in corrosion control)		√

Summary

- Flocculant aids improved the floc bridging when Alum dosed at charge neutral doses as follows:

Cationic>>nonionic>>anionic

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Bull Run TREATMENT PROJECTS

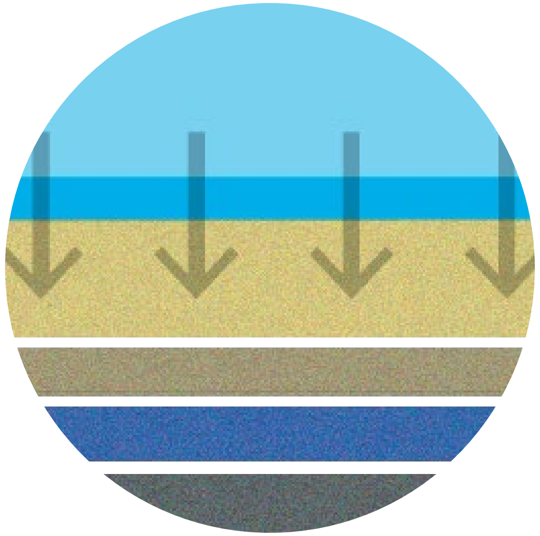
Our water: Safe and abundant for generations to come

Thank you!

Learn More portland.gov/bullrunprojects

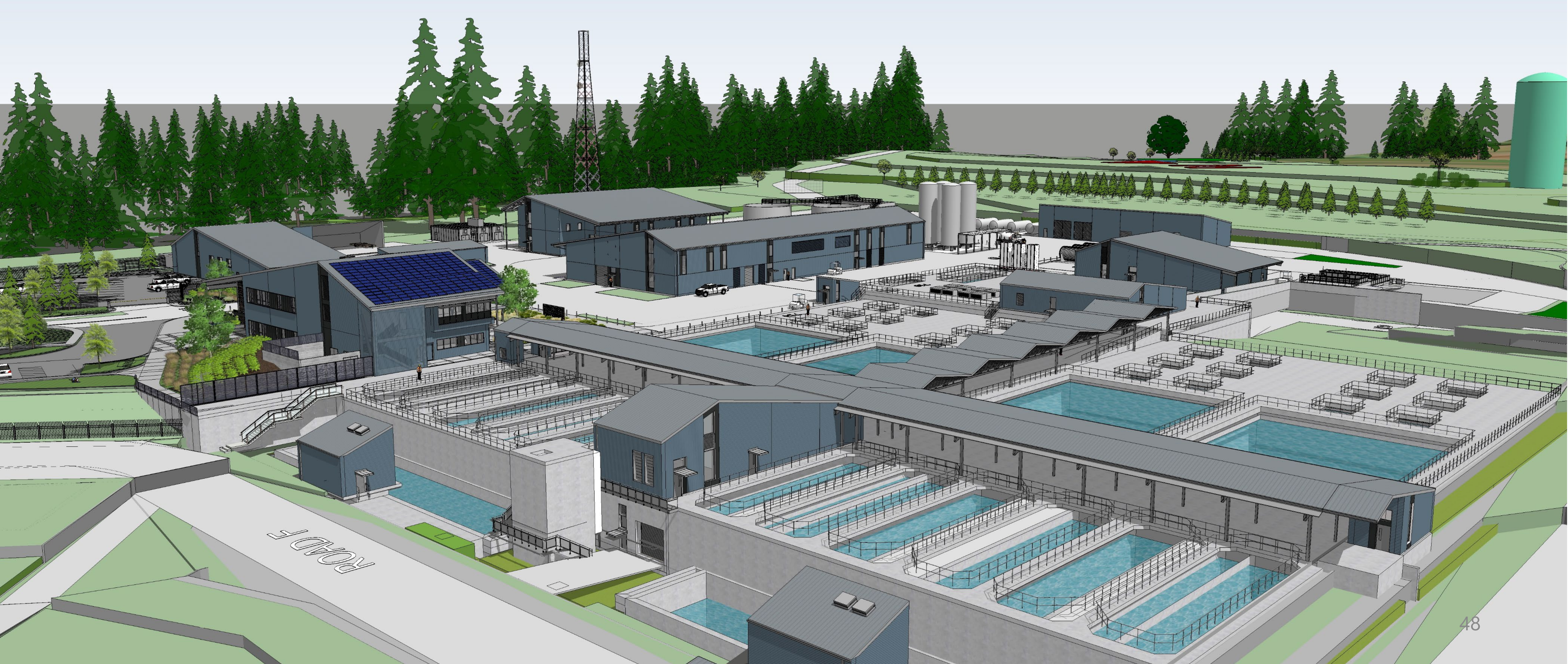
Appendix

Why filtration?

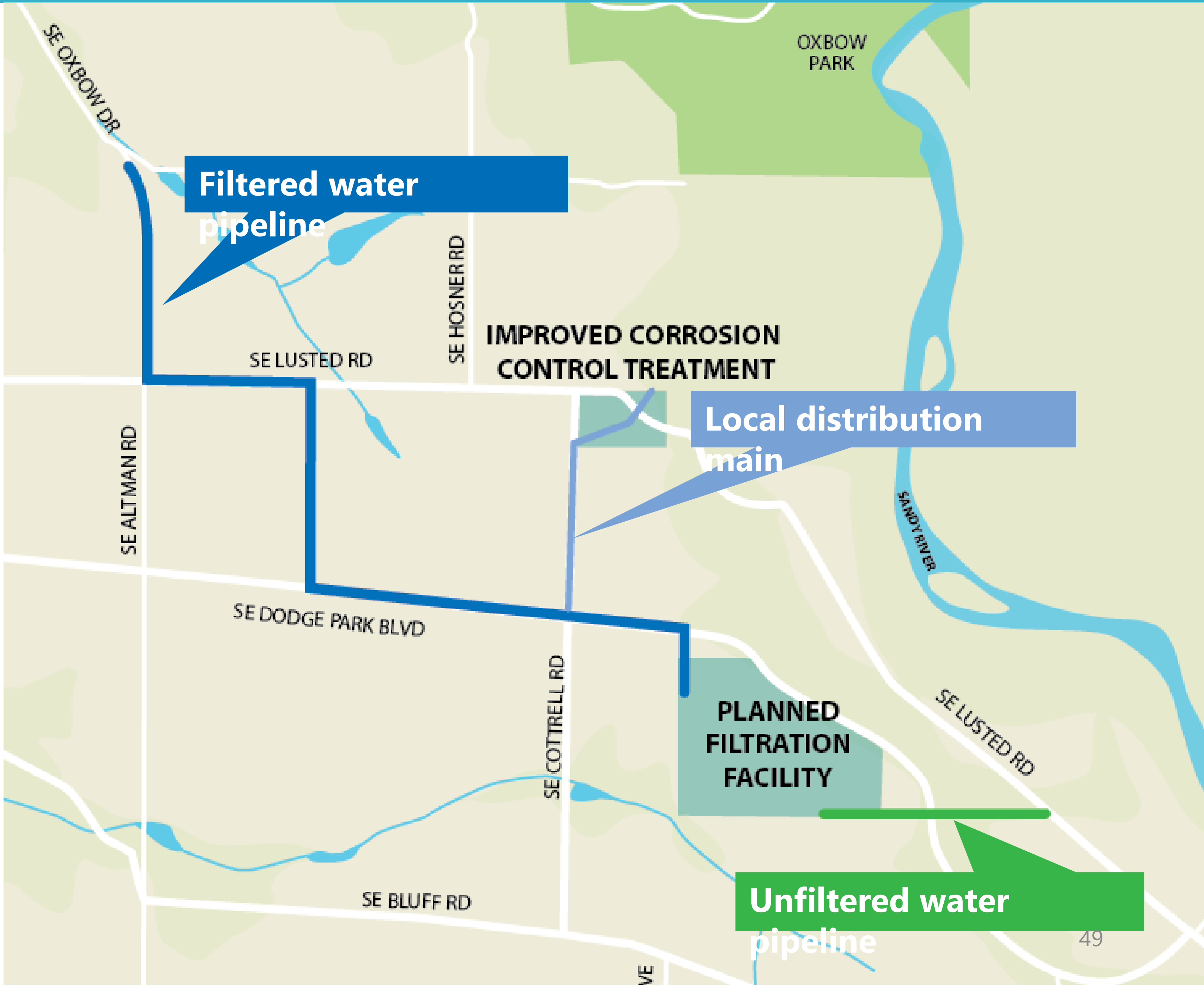


- ✓ Excellent treatment option for *Cryptosporidium*
- ✓ Reduces disinfection byproducts
- ✓ Addresses high turbidity (fire or storms)
- ✓ Addresses algae concerns
- ✓ Keeps sediment out of distribution system
- ✓ Helps prepare for future regulations and emerging contaminants

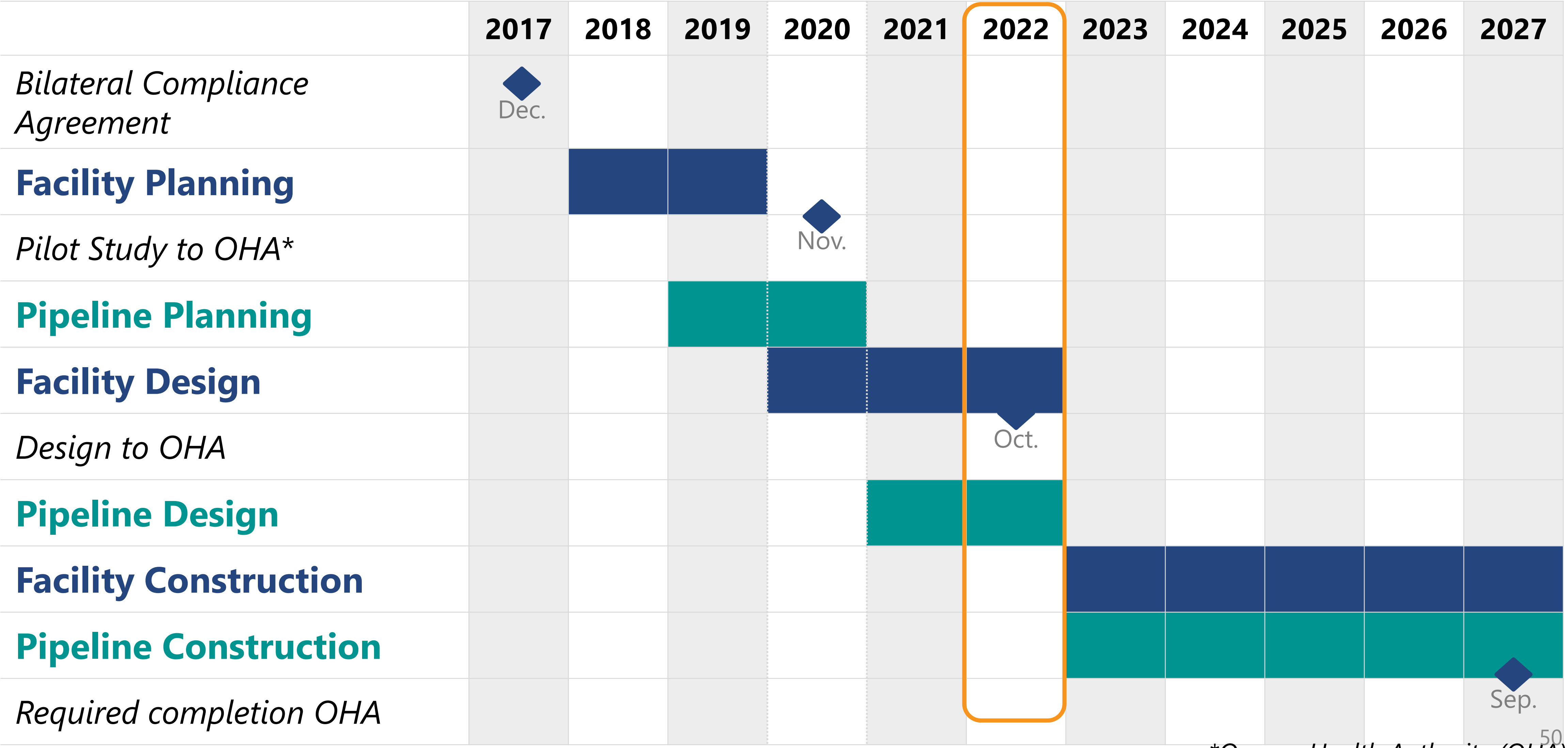
Design of the filtration facility is taking shape



New pipelines will tie the water filtration facility into the existing system



Construction anticipated to start mid-2023



*Oregon Health Authority (OHA)

The Bull Run Treatment Projects will help keep our water **safe and abundant** for generations to come

For our health

For our economy

For our future

On track to deliver filtered Bull Run water to customers beginning September 2027

Planning Completed
2018-2020

Design Underway
2020-2022

Construction Expected
2023-2027