St. Cloud WTF Advanced Process Improvements

Strategic Sequencing to Maintain Treatment Objectives During Construction

Jason Kosmatka PE
Senior Project Manager
AE2S

AE2S CITY OF ST.CLOUD MINNESOTA

Outline

- Project Background & Piloting
- Planning and Sequencing
- SCWTF Advanced Process Improvements Project Construction

Project Background

Project Background

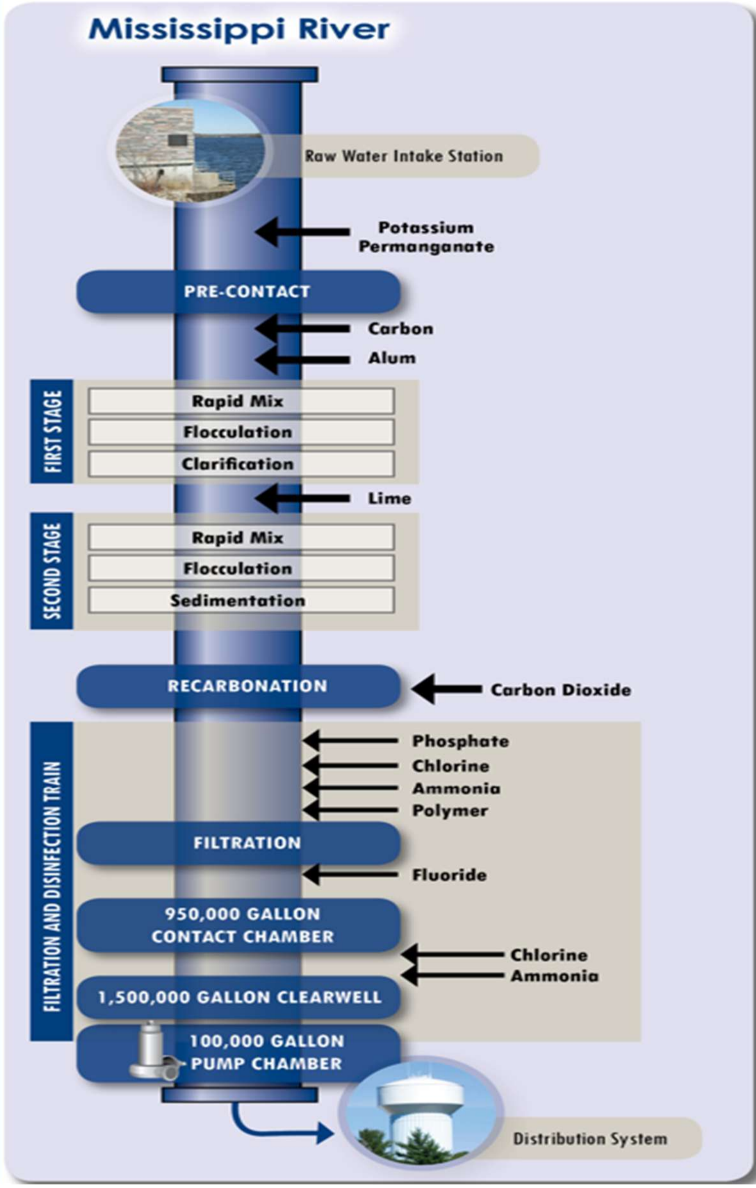
SCWTF Overview

Capacity: 24 mgd

Raw water: Mississippi River

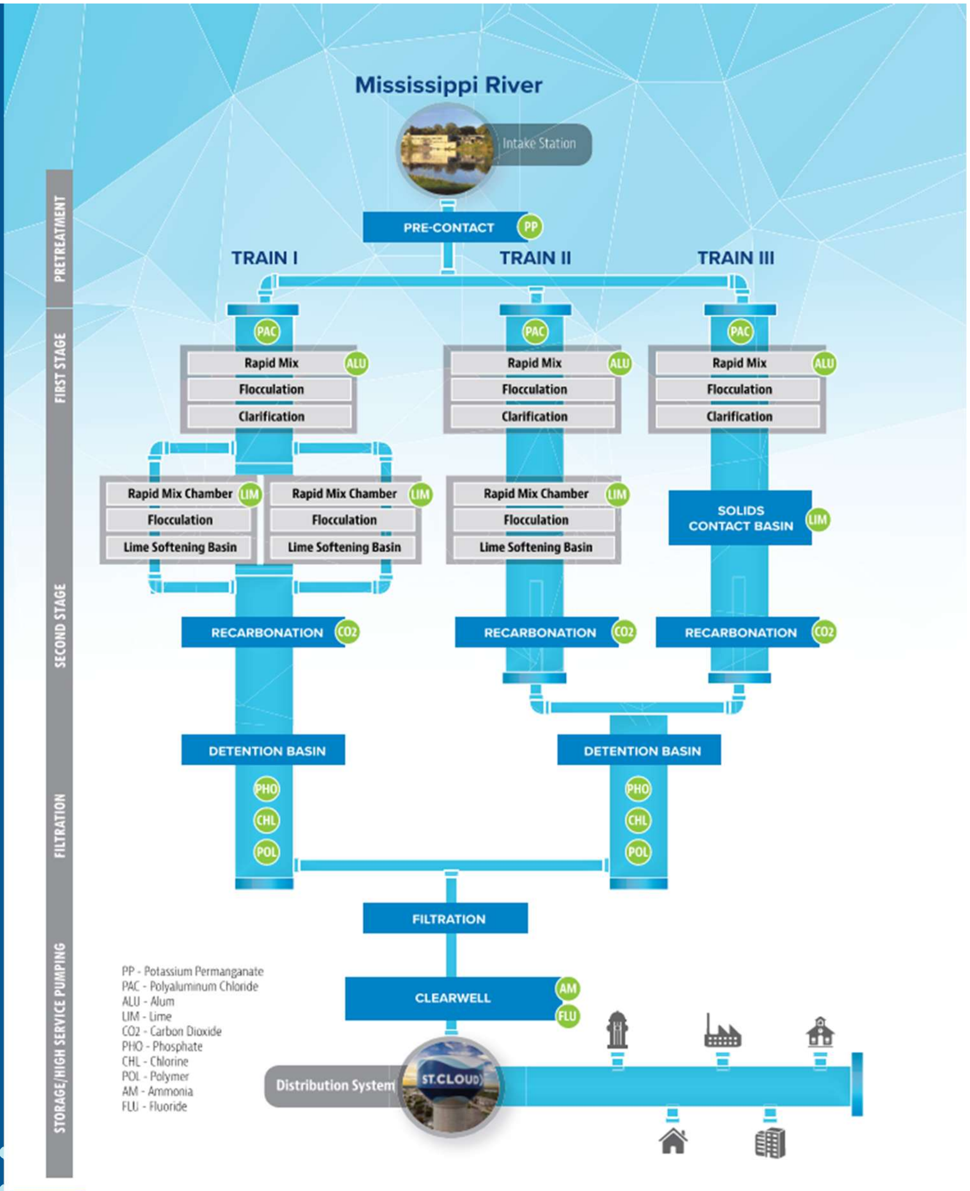
First WTP on the Mississippi River

Pre-Project: Treatment Overview



Class A Conventional Lime Softening Facility

Pre-Project Treatment Trains (3 Total)



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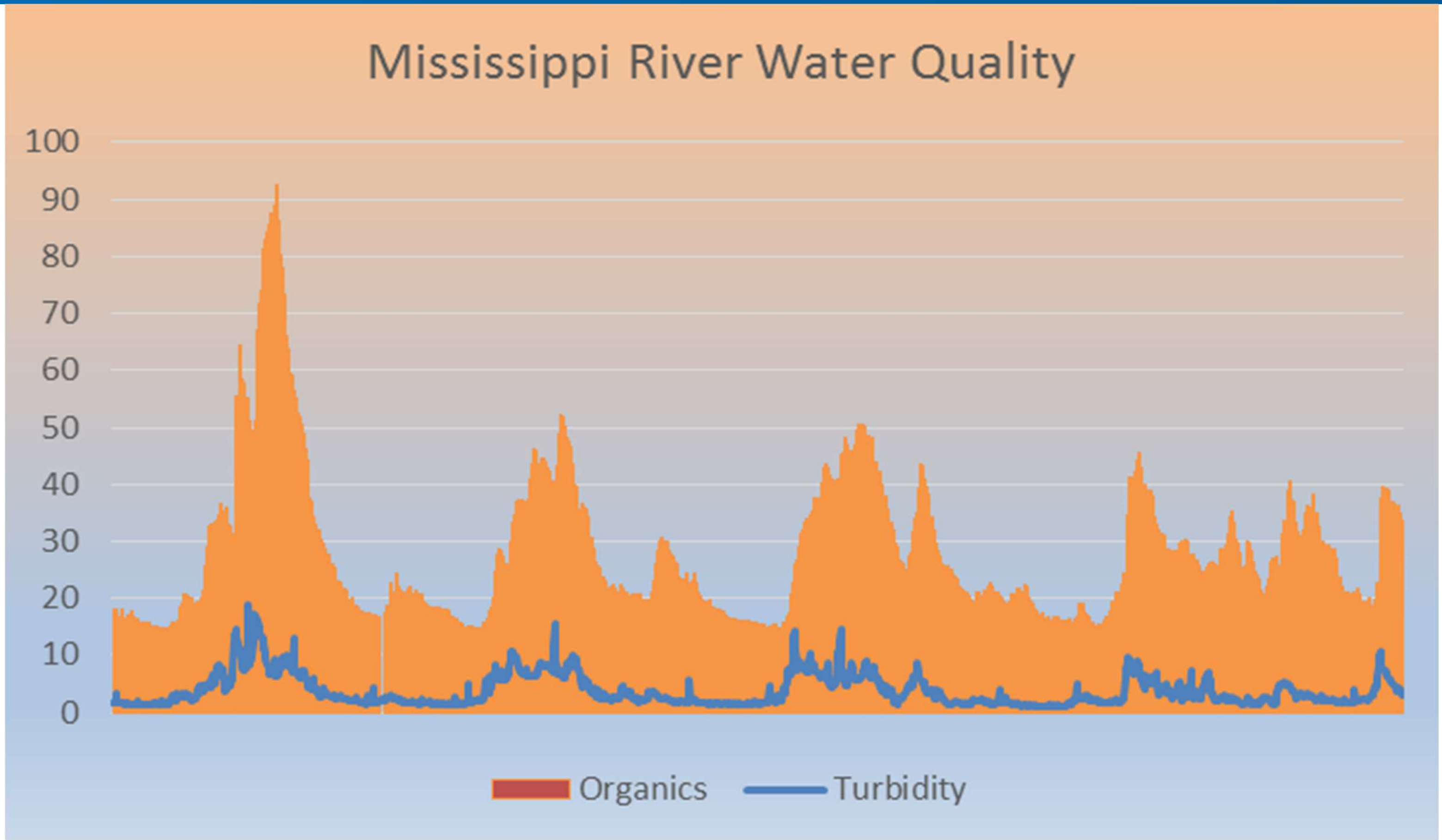
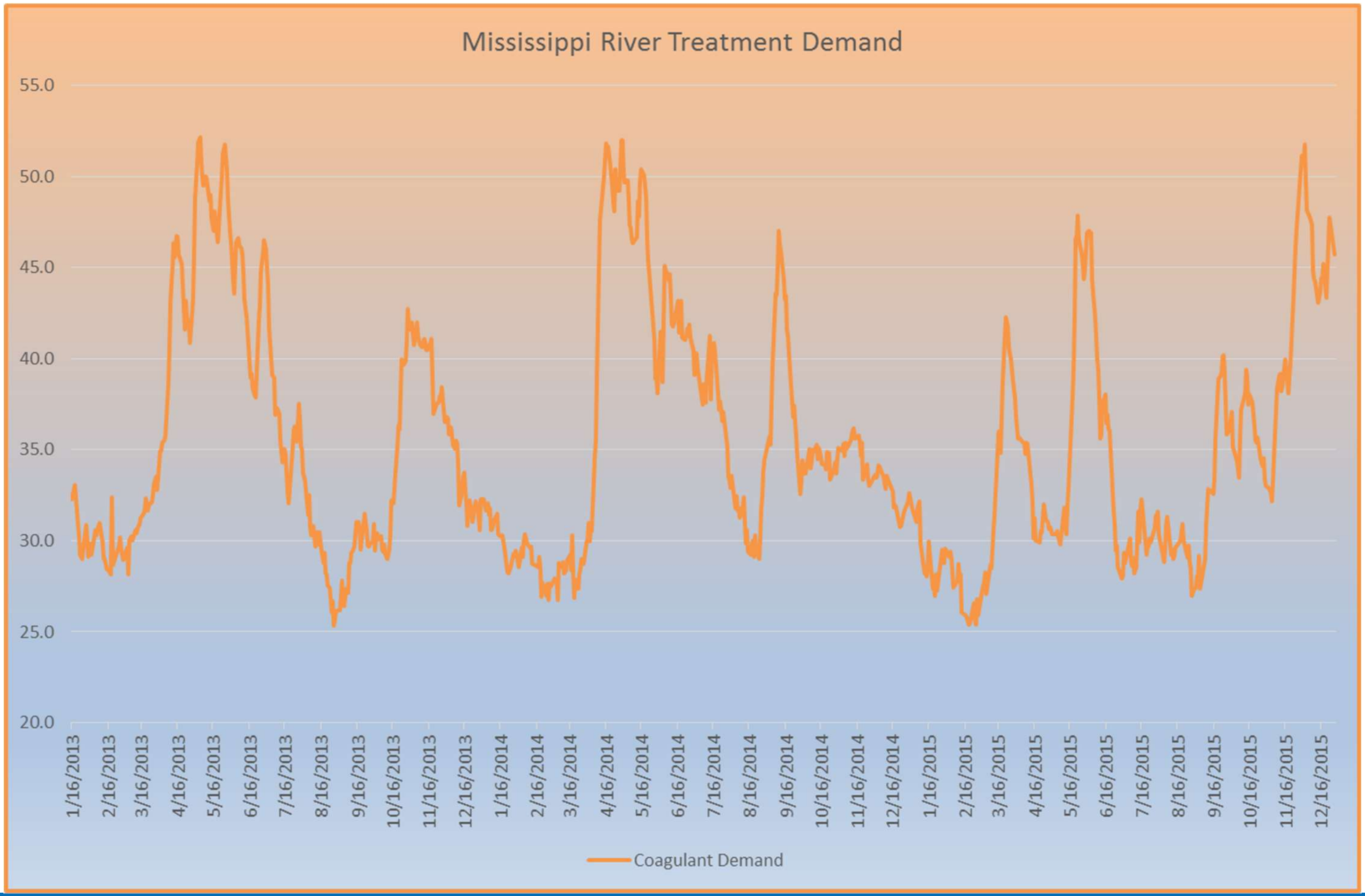
Raw Water Quality





Raw Water Quality

Treatment Challenges

Taste and Odor Issues

Disinfection Byproducts

Future Regulations

Challenges

69% of Customer Comments are Taste & Odor Related

Treatment Process Objectives

- Turbidity (NTU)
- Total Organic Carbon (TOC)
- Taste and Odor (T&O)
- Hardness Goal
- Disinfection Byproducts (DBP)
- Pathogen Removal and/or Inactivation — Cryptosporidium, Giardia and Virus
- Finished Water Quality — Corrosion Potential and Biological Stability while meeting Hardness Goals

Milestones

1. **2007** - Facility Master Plan
2. **2014** - Facility Master Plan Updates
3. **2015** - AOP and Biofiltration Pilot Study
4. **2018** - Advanced Process Improvements Design
5. **2020** - Advanced Process Improvements Construction
6. **2024** - Advanced Process Improvements Startup

St. Cloud WTP AOP Pilot Study

Principal Investigator: Qigang Chang, PE, PhD
Engineer of Record: Jason Kosmatka PE

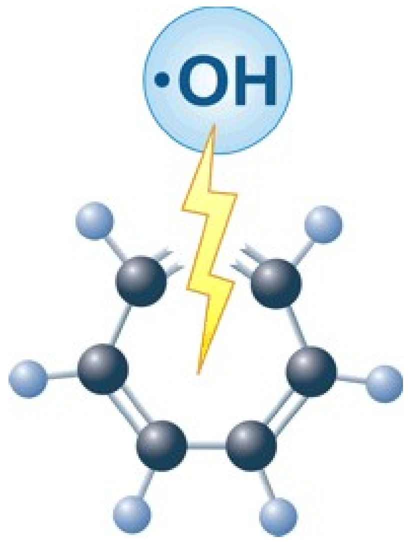
Pilot Alternatives

Alternative A	Conventional Filtration with UV/H2O2
Alternative B	Ozone with Bio-Filtration and Chlorine Disinfection
Alternative C	Ozone with Bio-Filtration and UV Disinfection

What is AOP?

Advanced oxidation processes (AOPs) refers to chemical treatment procedures designed to remove organics in water by oxidation through reactions with strong oxidizing reagent, usually hydroxyl radicals (·OH).

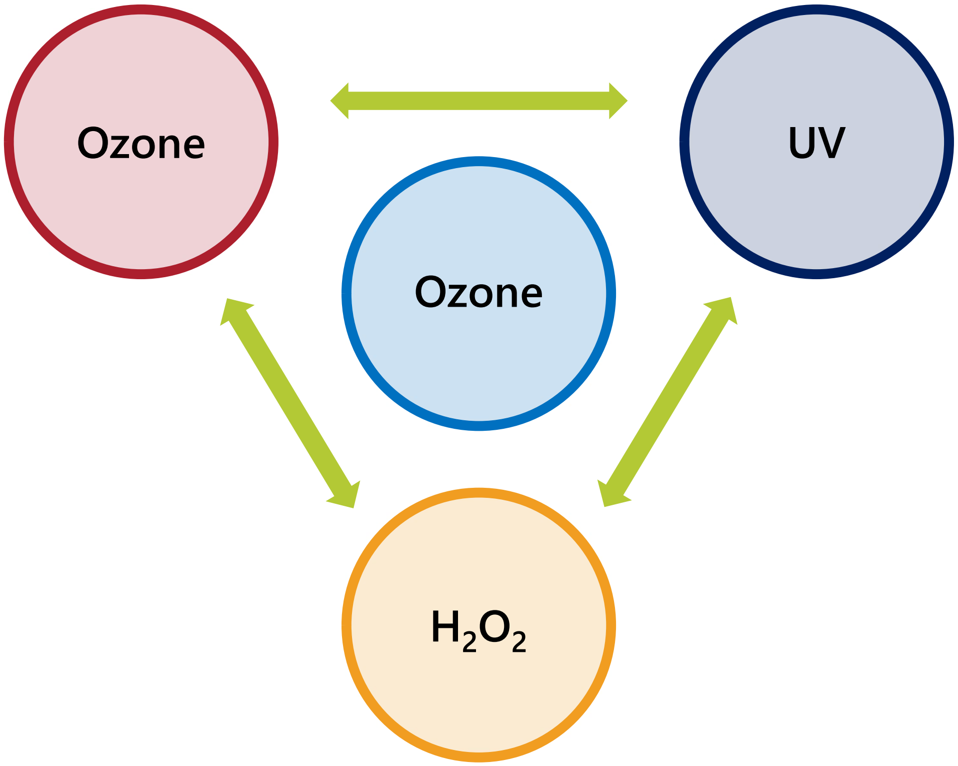
No.	Name of Oxidant	Oxidation Potential (eV)
1	Hydroxyl radical	2.8
2	Ozone	2.1
3	Hydrogen peroxide	1.8
4	Potassium permanganate	1.7
5	Chlorine dioxide	1.5
6	Chlorine	1.4



Advanced Physicochemical Treatment Processes. Edited by Lawrence K. Wang, Yung-Tse Hung, Nazih K. Shammas

How to Form AOP?

- Ozone + UV light
- Ozone + H_2O_2
- UV + H_2O_2
- High pH Ozonation



What is Bio-Filtration?

Filtration with Biodegradation

- The microbial growth attached to the filter media (biofilm) and consumes the organic matter that would otherwise flow through the treatment plant and ultimately into the distribution system.
- Remove contaminants by three main mechanisms:
  - Biodegradation
  - Adsorption
  - Filtration of suspended solids

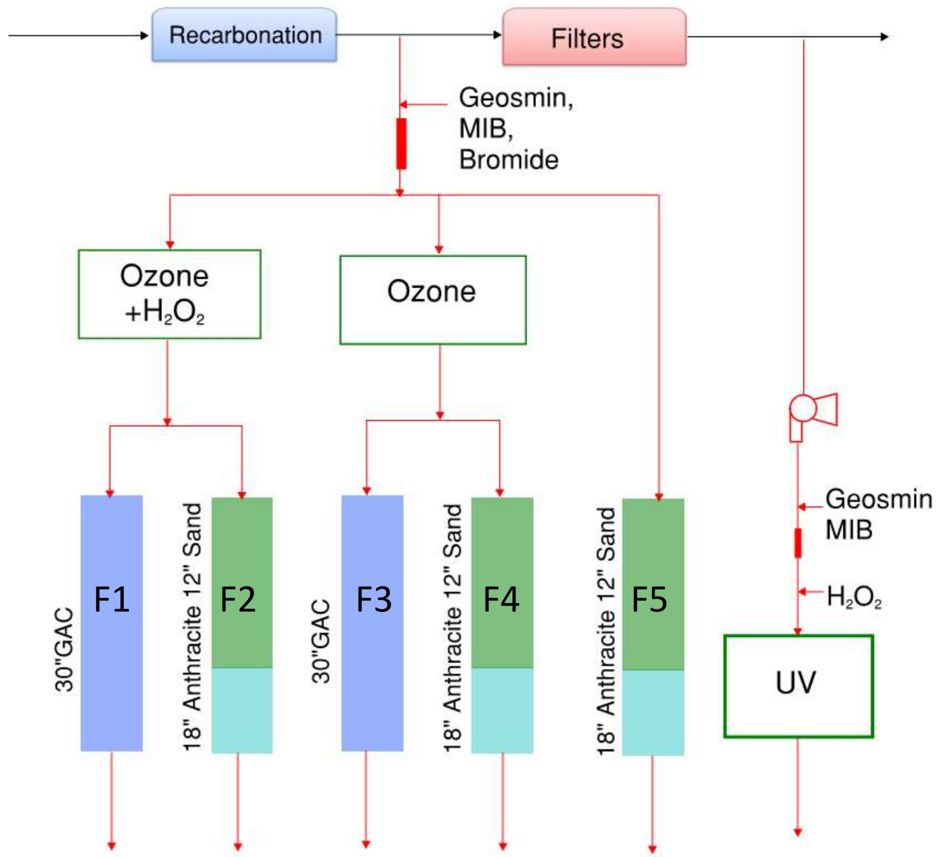
Pilot Study Process Flow Diagram

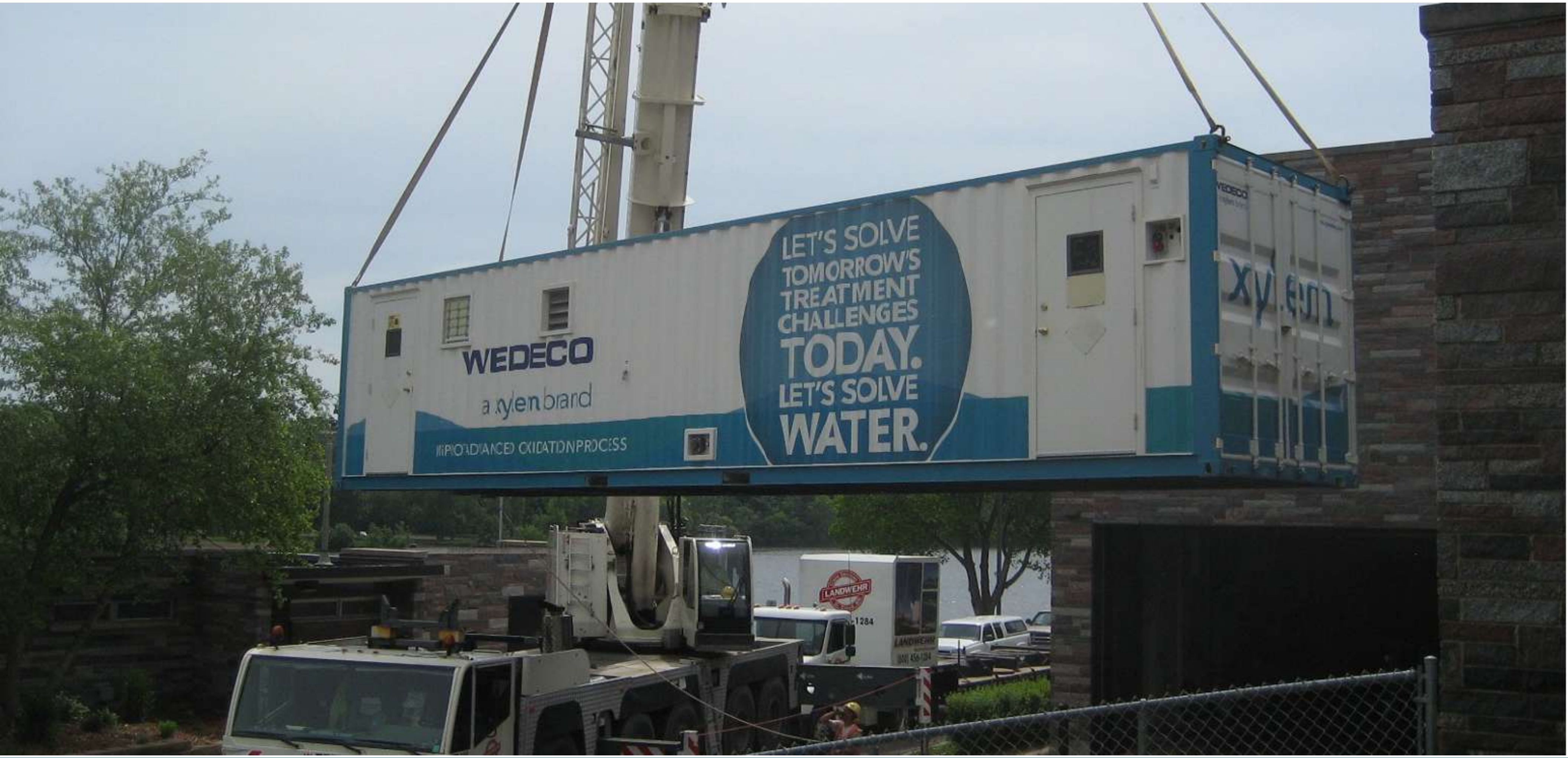
Three Alternatives

A. Conventional Filtration + UV/H_2O_2 for primary disinfection

B. AOP + Biofiltration + free chlorine primary disinfection

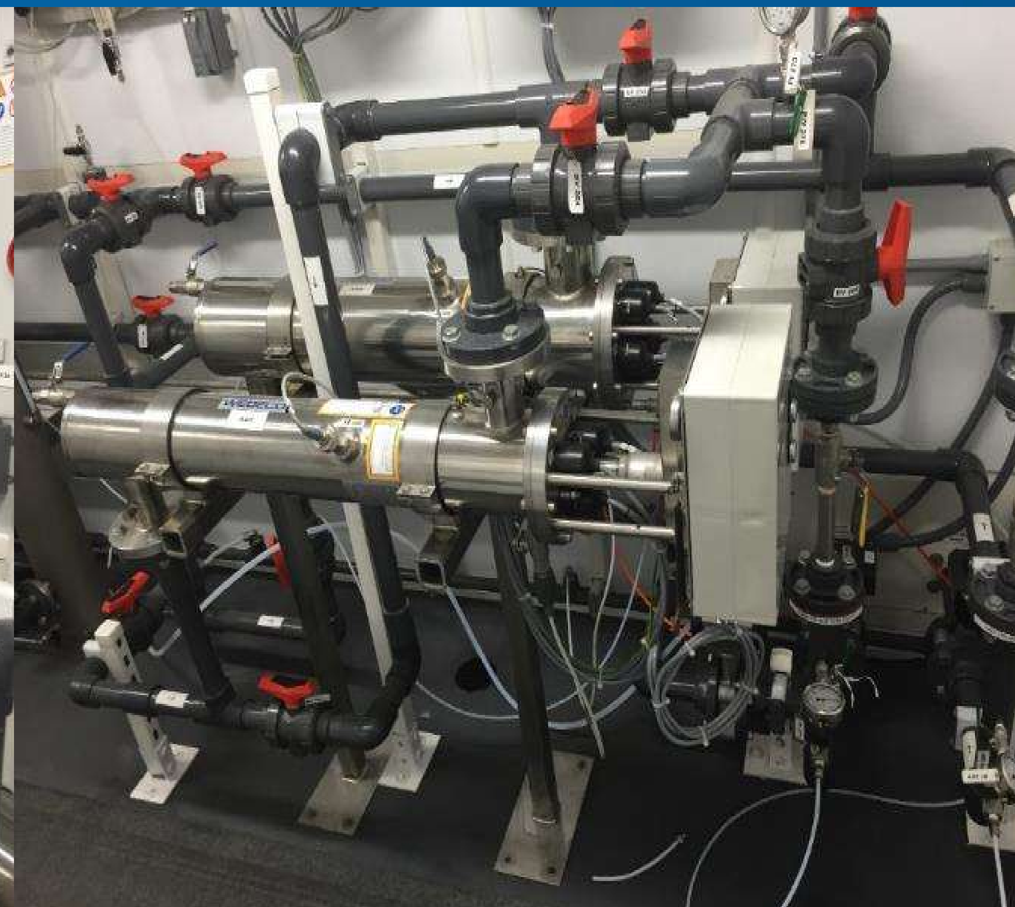
C. AOP + Biofiltration + UV primary disinfection





Peroxone (Ozone + H_2O_2) Pilot Skid

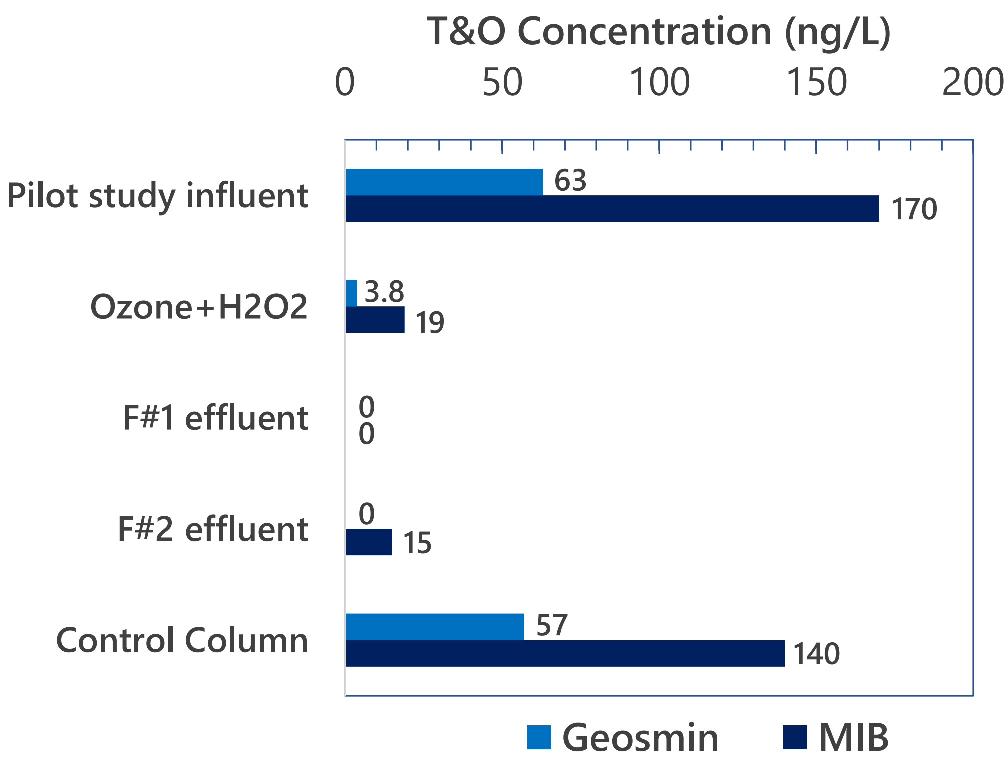
Peroxone (Ozone+H_2O_2) & UV Pilot Skid

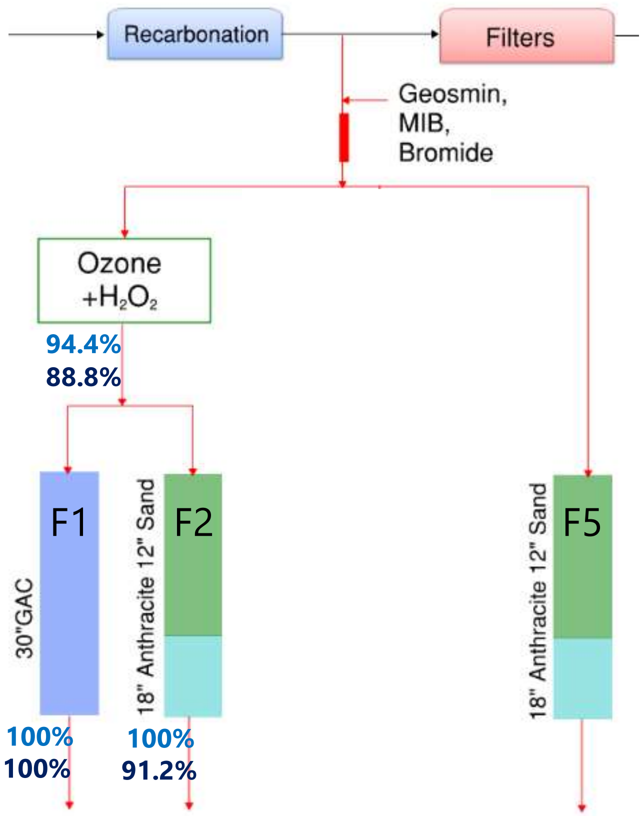


Ozone Pilot Skid

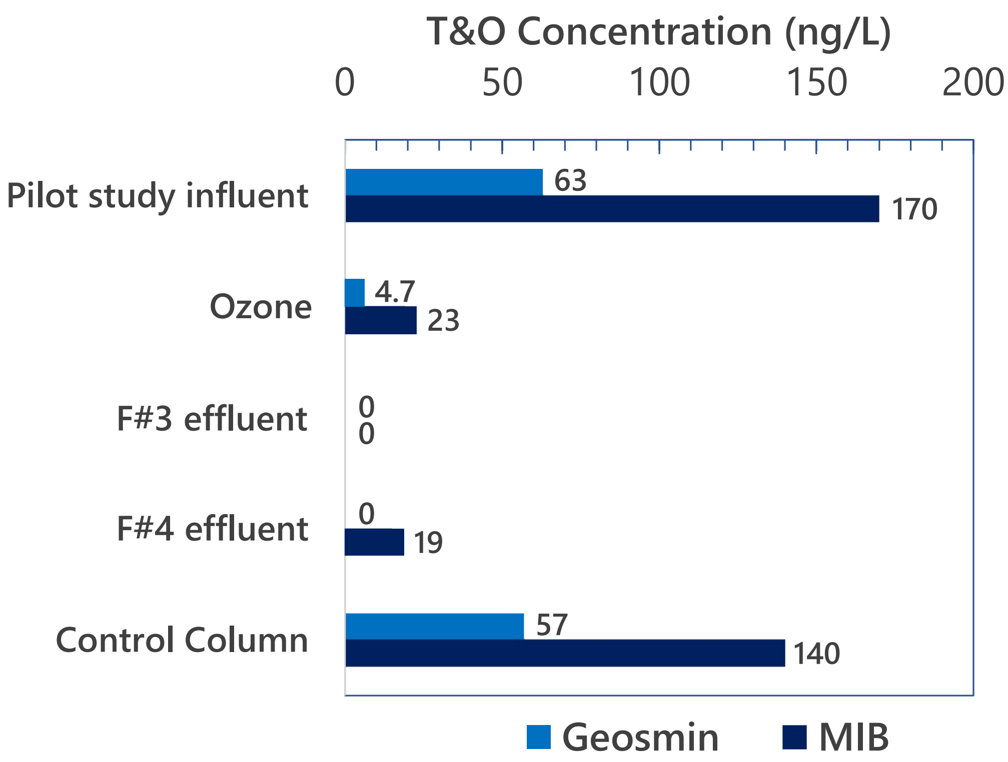
Filter Pilot Skid

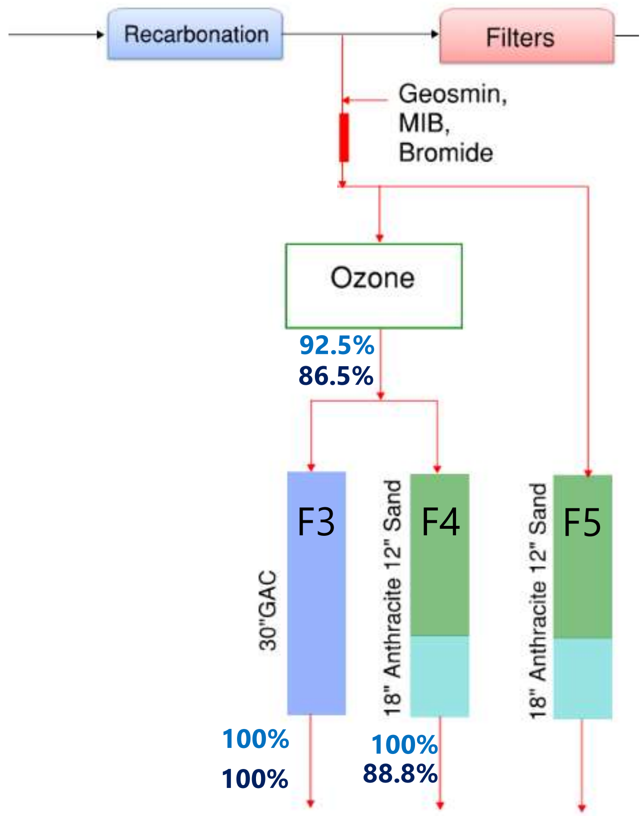
Peroxone + Biofiltration Alternative



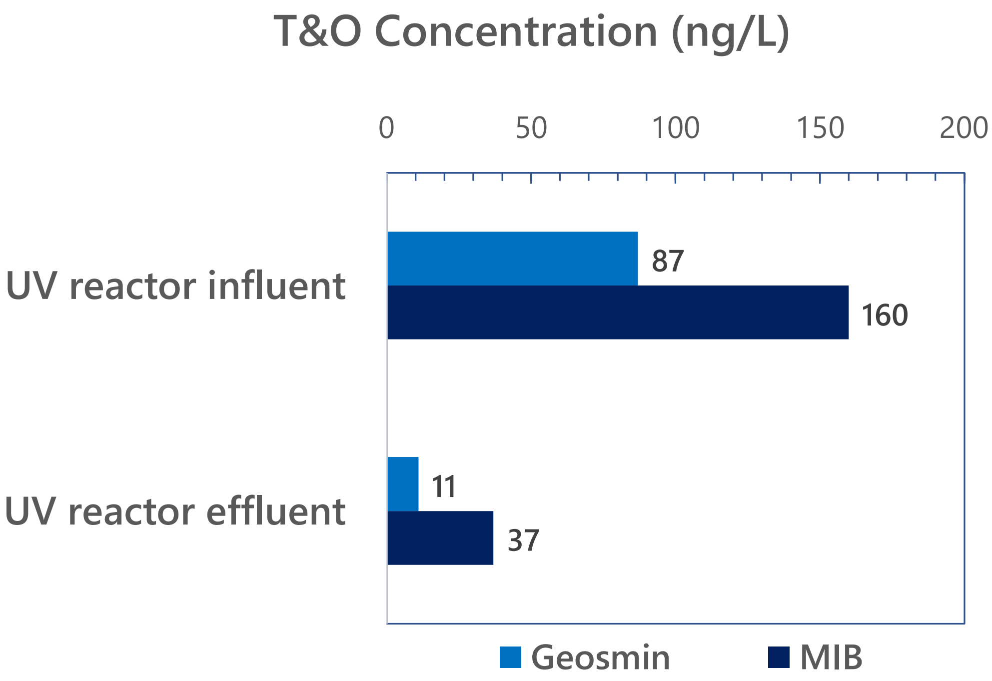


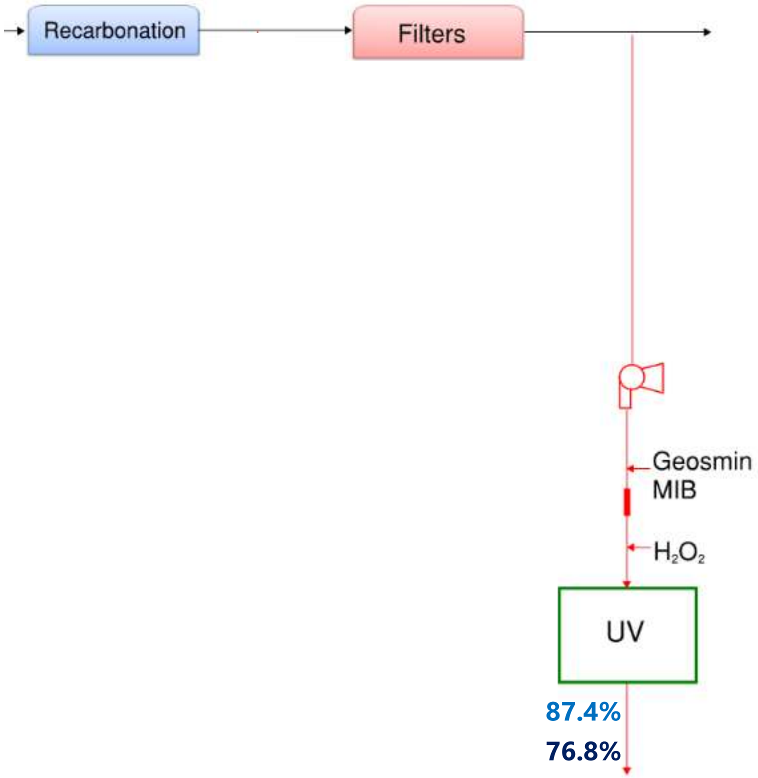
Ozone + Biofiltration Alternative



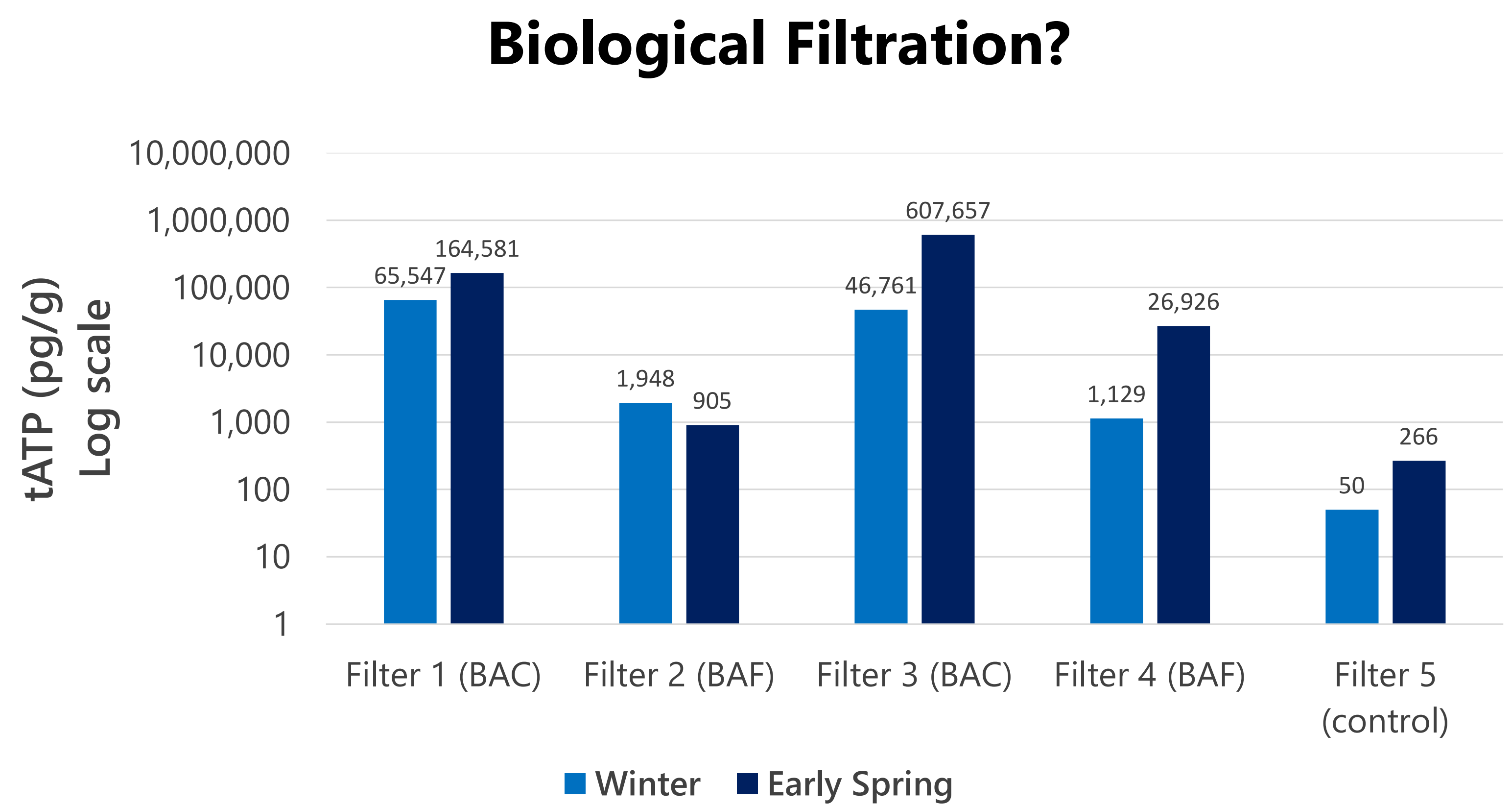


Conventional Filtration + UV/H2O2 Alternative

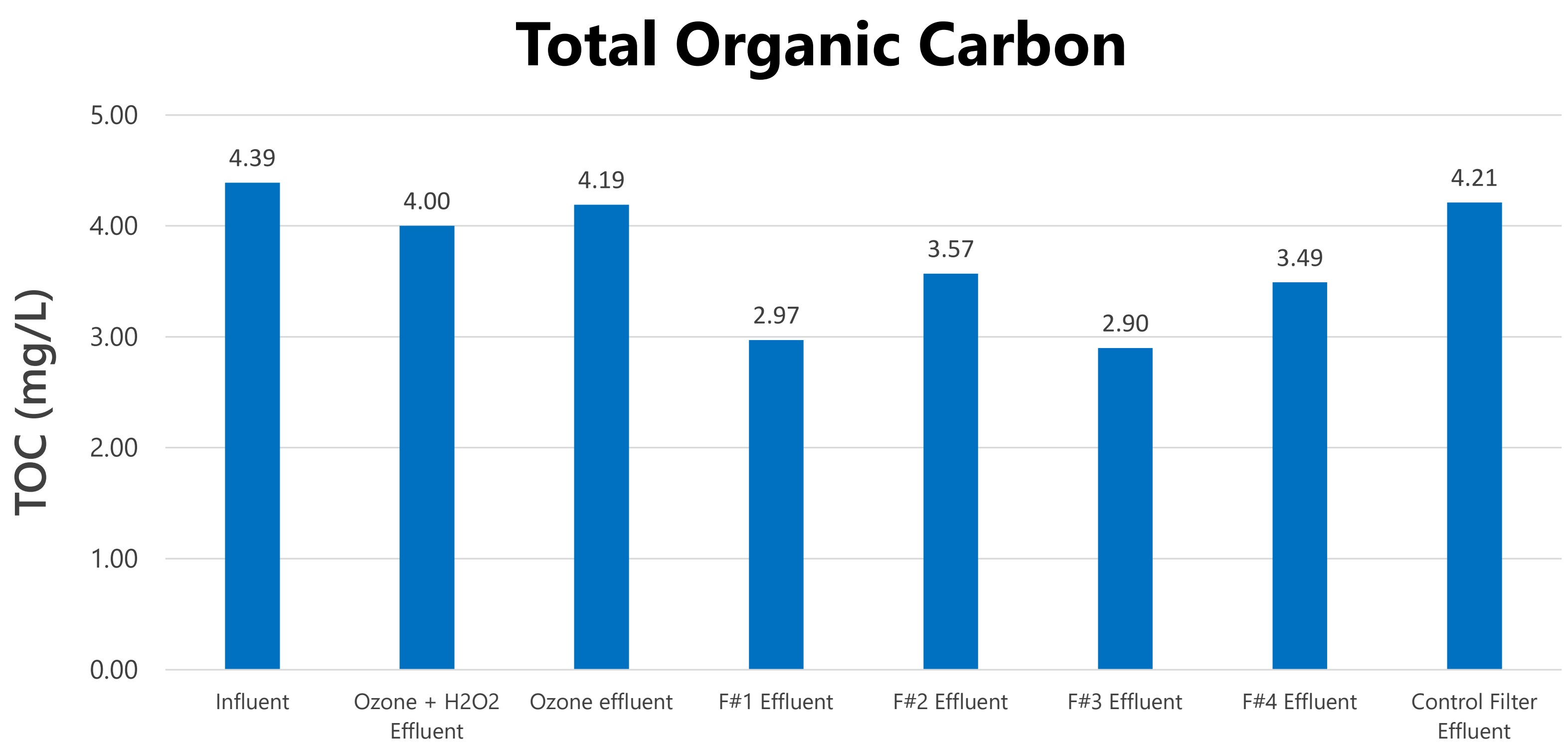




Biomass Measurement



Organic Removal



Major Takeaways

At the Pilot Study Testing Conditions

AOP

1. Ozone and peroxone can remove 80-90% Geosmin and MIB.
2. Peroxone outperforms ozone for bromate formation. Bromate is unlikely a concern for St. Cloud WTP future ozonation process.
3. UV AOP can remove 70-85% Geosmin and MIB. Increasing of UV dose and H_2O_2 dose will generally increase the removal rate of Geosmin and MIB.

Major Takeaways

At the Pilot Study Testing Conditions

Biologically Active Filtration (BAF)

1. BAC can reduce Geosmin and MIB concentrations near zero even at high background concentrations
2. Higher biomass was observed on biological BAC filters and performed better than BAF filters with regarding to organic reduction and T&O removal.
3. BAC effluent turbidities with a sand layer are comparable as the full-scale filters.
4. Ozonation increases DO and biofiltration stabilized the water.

Selection of Preferred Alternative

Alternative Ranking Summary

Alternative	Treatment Technology		Implementation		Estimated Total Present Worth		Overall Ranking *(AxBxC)*
	Score	Ranking*(A)*	Score	Ranking*(B)*	Cost ($M)	Ranking*(C)*	
ALTERNATIVE A - Conventional Filtration with UV-H_2O_2	61.1	7.85	71	8.77	$36.9	8.94	615
ALTERNATIVE B - Ozone with BAC Filtration and Chlorine Disinfection	72.2	9.28	71	8.77	$33.0	10.00	813
ALTERNATIVE C - Ozone with BAC Filtration and UV Disinfection	77.8	10.00	81	10.00	$38.1	8.66	866

1) Rank scores are normalized versions of each individual score relative to the final three (3) alternatives.

2) Higher Scores indicate the more favorable alternative

03 + BAC Filtration + UV

Benefits

- ✓ Reduction of DBP precursors
- ✓ Eliminated Taste & Odor
- ✓ Eliminate the use of PAC
- ✓ Reduce or eliminate the use of potassium permanganate
- ✓ Reduce the use of chlorine and limit free chlorine contact time

Advanced Process Improvements Project - Strategic Sequencing

Advanced Process Improvements

Major Project Components

- Replace Traveling Water Screen
- Replace Wet Chlorine Scrubber with Dry
- Roof Waterproofing Replacement
- **Baffling of the 1990's Clearwell and adding a Chlorine Contact Chamber**
- **Conversion of the 1950's Clearwell to house Advanced Treatment Equipment**
- **UV reactors for primary disinfection (first WTF in MN with this technology)**
- **Conversion of filters to BAC filters**
- **Ozone Generation with LOX**

Treatment Challenges

1. **Continually meeting treatment goals**
2. **Continually meeting water demand**
3. **Balancing OCCT, DBPs, CT**
4. **Meeting Disinfection Credit**
   - Water temp 1-25^{0}C
   - Elevated pH >9.3
   - Varying Clearwell levels
   - Variable TOC
   - Variable ammonia/Cl2:NH3 ratio
   - Removing 1 MG of Storage/Detention

Construction Challenges

1. Only 1 Ozone Contact Basin for FTII/III
2. 1.5 MG Clearwell BF=0.3
3. Limited WTP shutdown time
4. Limited Hydraulic Grade

EXISTING WATER TREATMENT FACILITY

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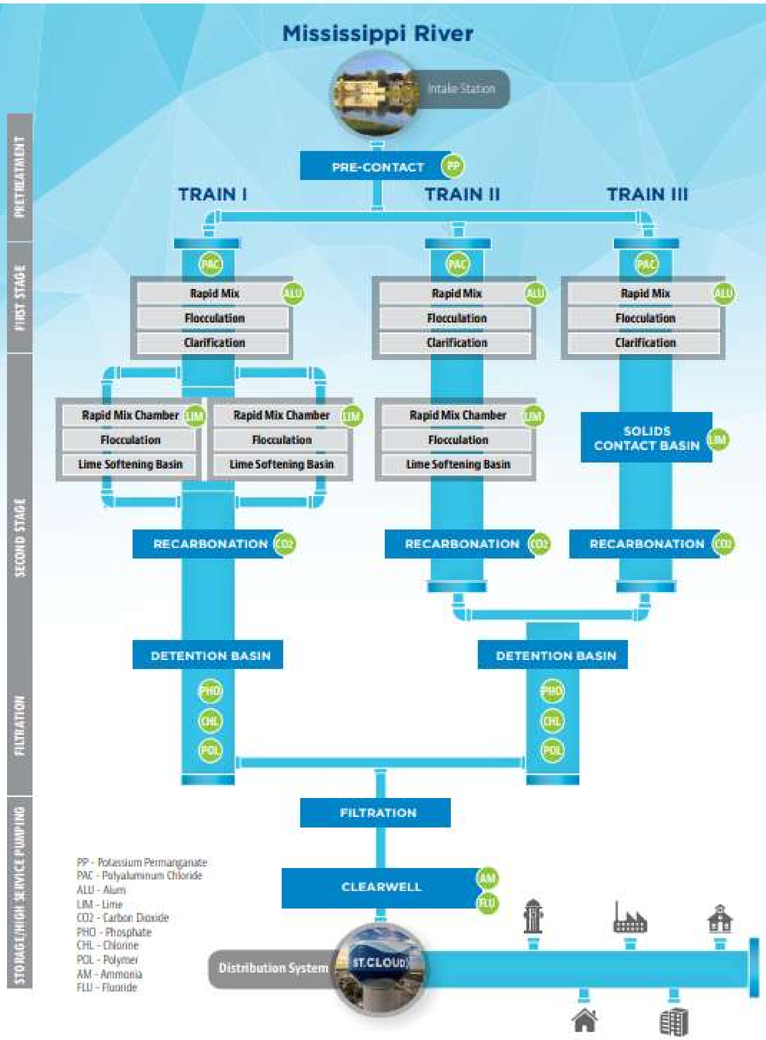
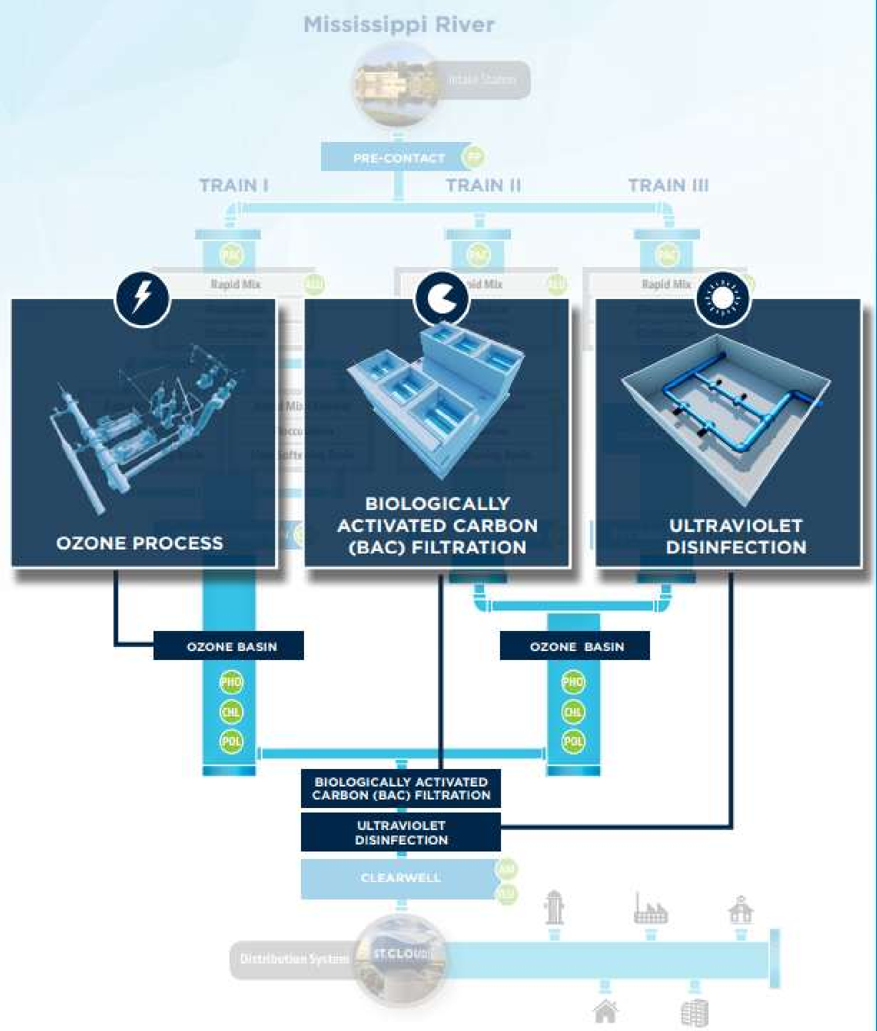
ADVANCED TREATMENT IMPROVEMENTS





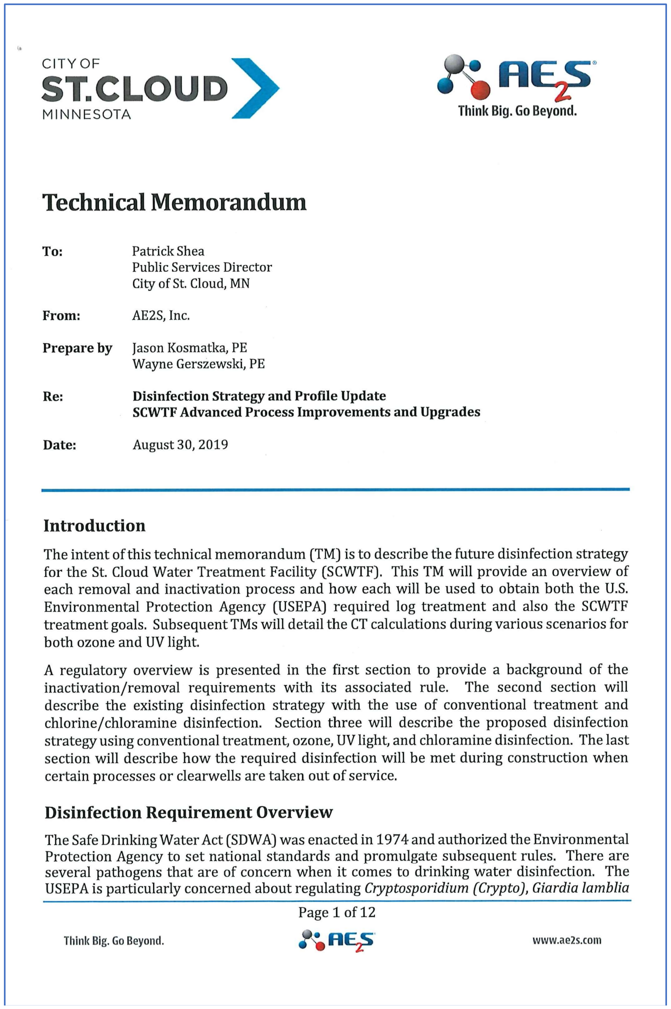
OZONE
Ozone readily oxidizes organic compounds commonly found in Mississippi River water. It is also effective for inactivation of waterborne pathogens and viruses.

BIOLOGICALLY ACTIVATED CARBON (BAC) FILTRATION
GAC has physical properties capable of adsorbing dissolved contaminants, including taste and odor causing compounds and emerging contaminants. Biological activity on GAC media can enhance treatment effectiveness, particularly when combined with ozone treatment.

ULTRAVIOLET (UV) DISINFECTION
UV disinfection can be used as the primary disinfection process. UV disinfection would compliment the other advanced treatment technologies and reduce the potential formation of regulated disinfection by-products.

Strategic Sequencing

Planning For All Scenarios



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AE2S Think Big. Go Beyond.

Technical Memorandum

To: Patrick Shea
Public Services Director
City of St. Cloud, MN

From: AE2S, Inc.

Prepare by Jason Kosmatka, PE
Wayne Gerszewski, PE

Re: **Disinfection Strategy and Profile Update**
SCWTF Advanced Process Improvements and Upgrades

Date: August 30, 2019

Introduction

The intent of this technical memorandum (TM) is to describe the future disinfection strategy for the St. Cloud Water Treatment Facility (SCWTF). This TM will provide an overview of each removal and inactivation process and how each will be used to obtain both the U.S. Environmental Protection Agency (USEPA) required log treatment and also the SCWTF treatment goals. Subsequent TMs will detail the CT calculations during various scenarios for both ozone and UV light.

A regulatory overview is presented in the first section to provide a background of the inactivation/removal requirements with its associated rule. The second section will describe the existing disinfection strategy with the use of conventional treatment and chlorine/chloramine disinfection. Section three will describe the proposed disinfection strategy using conventional treatment, ozone, UV light, and chloramine disinfection. The last section will describe how the required disinfection will be met during construction when certain processes or clearwells are taken out of service.

Disinfection Requirement Overview

The Safe Drinking Water Act (SDWA) was enacted in 1974 and authorized the Environmental Protection Agency to set national standards and promulgate subsequent rules. There are several pathogens that are of concern when it comes to drinking water disinfection. The USEPA is particularly concerned about regulating *Cryptosporidium (Crypto), Giardia lamblia*

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Strategic Sequencing

Upgrades of 1990s clearwell

- Chlorine Contact Chamber
- Baffling to get BF = 0.7

Repurposing of 1950s clearwell

- House advanced treatment equipment

UV reactors operational

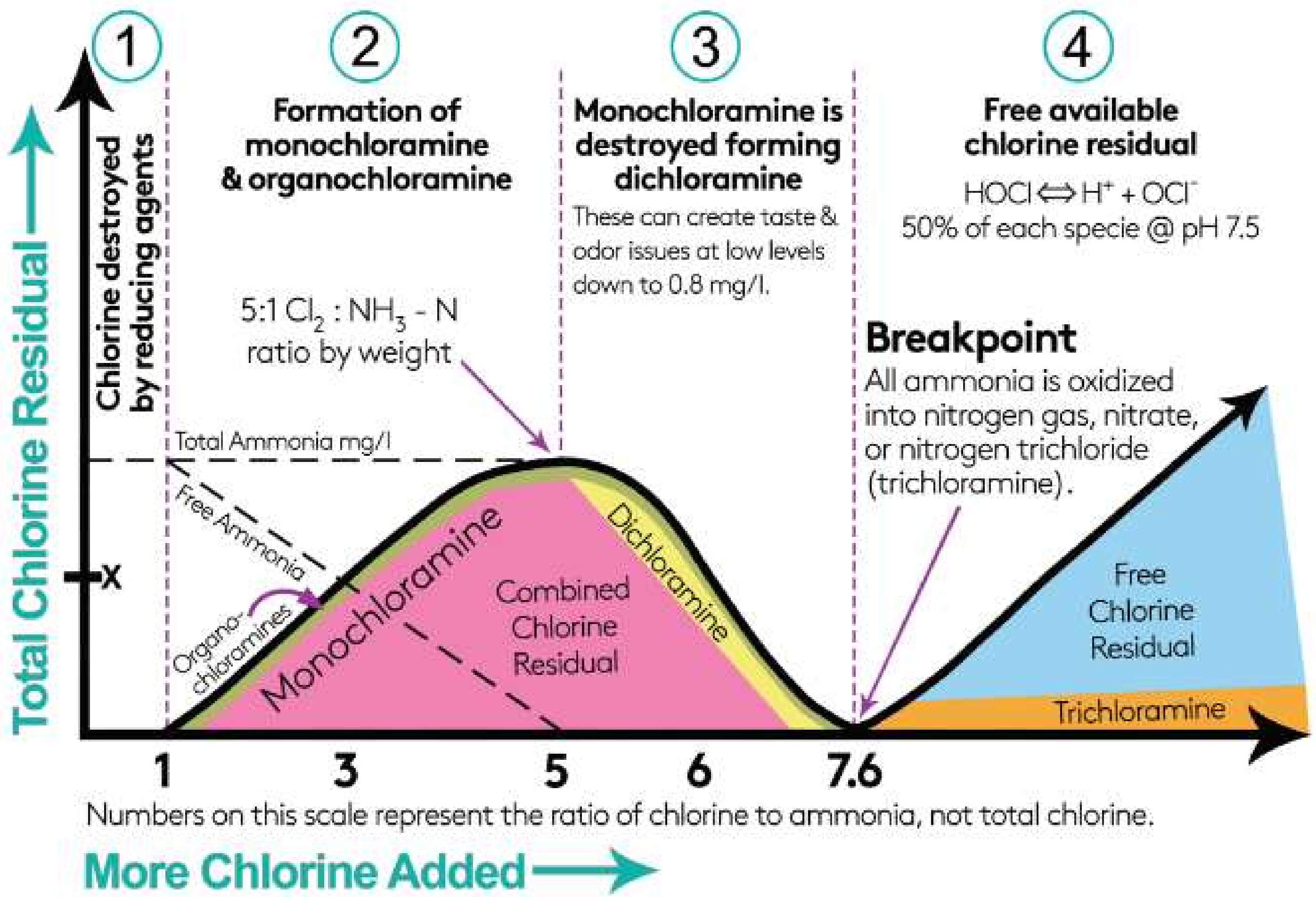
- Temperature independent
- Can turn off pre-filter chlorine

Conversion of conventional filters to BAC

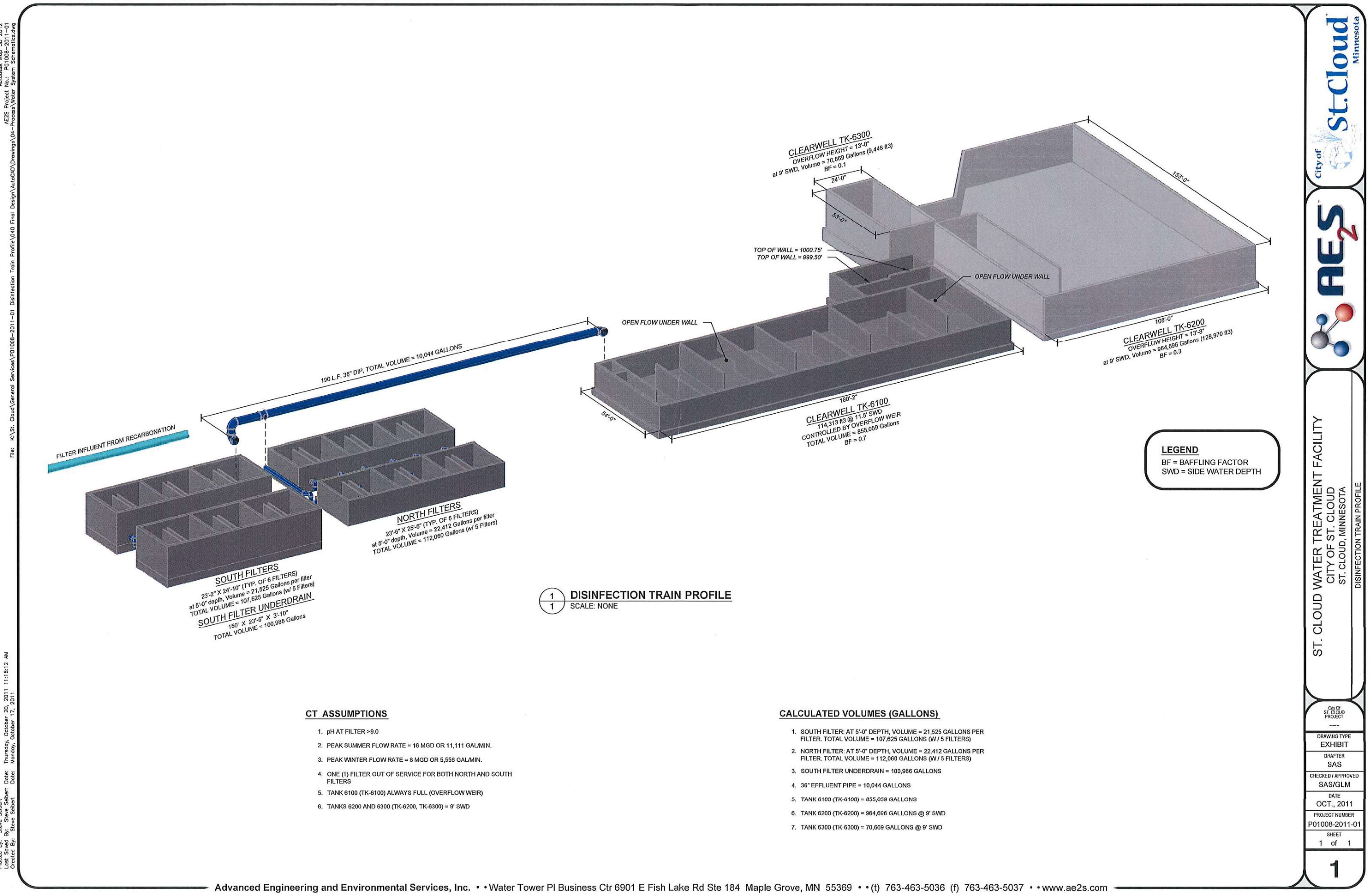
- Biological before high DO

Ozone system operational

Seasonal Disinfection Strategy



Chlorine Breakpoint Curb from IXOM Watercare.



Pre-Project Disinfection Profile

Instantaneous Log Inactivation Calculator

CT Calculations

Disinfectant Type	Chloramine	Chloramine	Chloramine	Chloramine	Chloramine	Chloramine		
Area	North and South Filters (SP920/921)	South Filters Underdrain (SP920)	Filter Effluent Piping (SP916B)	TK-6100 1.0 MG Clearwell (SP917)	TK-6200 1.5 MG Clearwell (SP918)	TK-6300 HSP Sump (SP918)		
Volume (gallons)	110,286	100,986	10,044	855,059	964,695	70,669		
Peak Hourly Flow (gpm)	7,075	3,511	7,075	7,075	6,765	6,765		
Theoretical DT (min)	15.66	29.09	1.43	121.42	142.80	10.46		
Baffling Factor	0.7	0.7	0.7	0.7	0.3	0.1		
T-10 (min)	10.96	20.37	1.00	84.99	42.84	1.05		
Cl2 Residual (ppm)	2.17	2.24	2.65	2.67	2.50	2.50		
Calculated CT Value	23.81	45.60	2.64	226.93	107.23	2.62		
Required Values								
CT-Giardia (0.5 log)	125.0	125.0	125.0	125	125	125		
Log Inactivation - Giardia	0.10	0.18	0.01	0.91	0.43	0.01	1.64	Log Inactivation - Giardia
CT-Virus (2.0 log)	214.0	214.0	214.0	214	214	214		
Log Inactivation - Virus	0.22	0.43	0.02	2.12	1.00	0.02	3.82	Log Inactivation - Virus

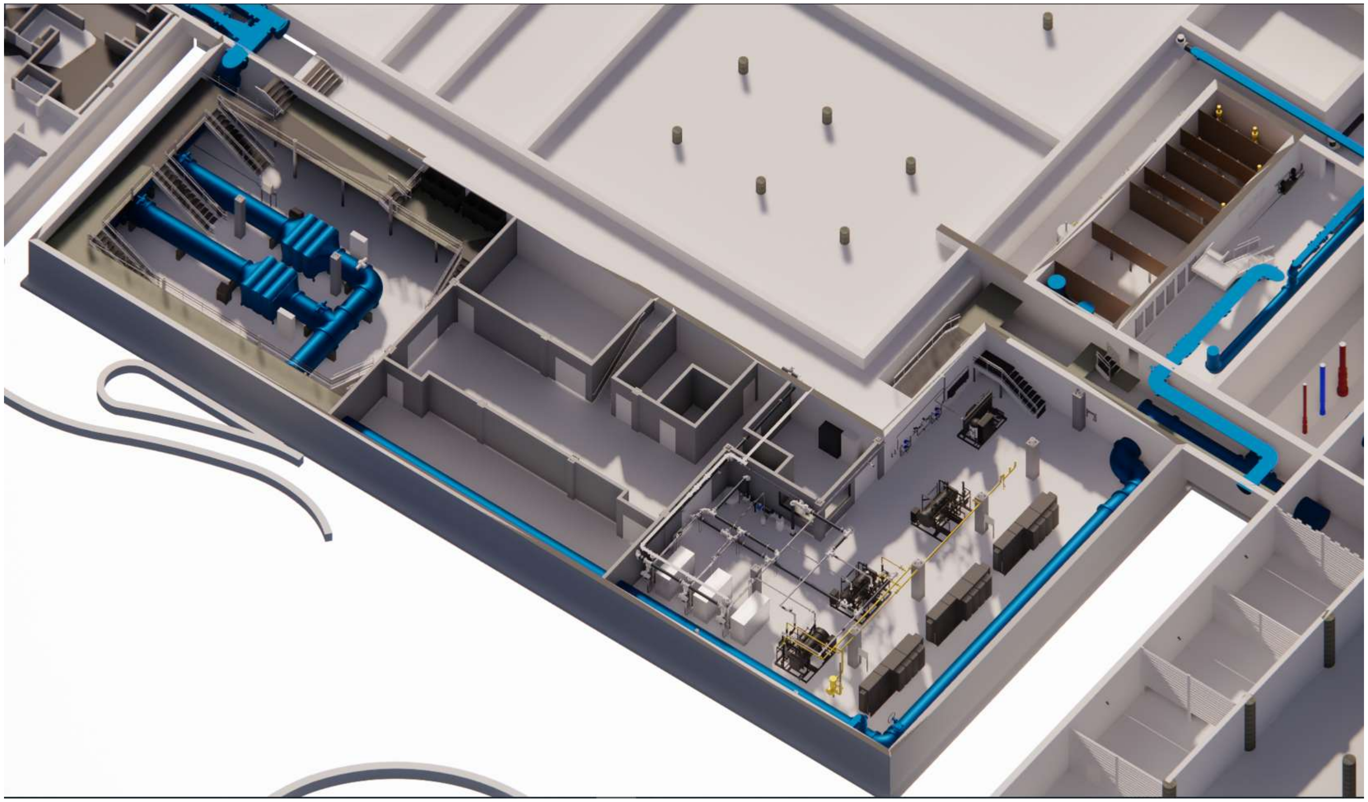
Calc Mode: Warm Temps / Cold Temps

Raw Water Temp Selector: TT1103 / TT1203

CL17 Manual Override Values (used if other than zero)	SP920 Free CL2	0.00 mg/L	SP921 Free CL2	0.00 mg/L	SP916B Free CL2	0.00 mg/L

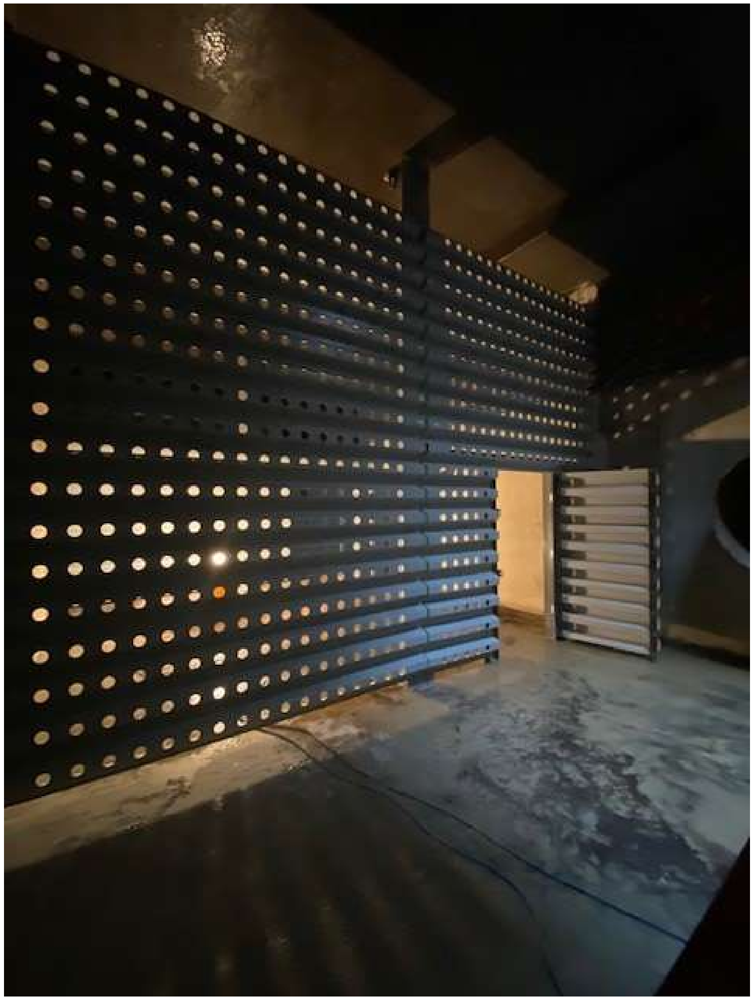
Advanced Process Improvements

1950's Clearwell Conversion



Advanced Process Improvements

Chlorine Contact Chamber



Advanced Process Improvements

1990's Clearwell Baffling

Advanced Process Improvements

Clearwell Conversion

Advanced Process Improvements

UV Reactors

Advanced Process Improvements

Ozone Generation

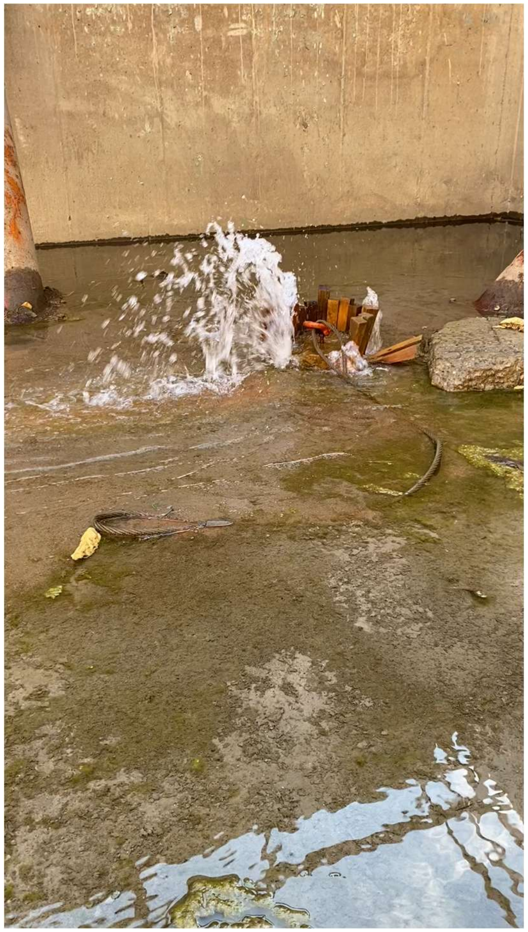
Best laid plans of mice and men…

Unanticipated Challenges

- **Bidding during COVID**
  - Zero Bids
- **Supply Chain Issues**
- **Cost Escalation**
- **Minimal Hydraulic Grade**
  - Siphoning
  - Air in Magmeters & UV reactors
- **High pH ozonation**
  - Transfer Efficiency
- **Groundwater**
- **Maintaining CT**
  - GAC Adsorption
  - UV reactor air

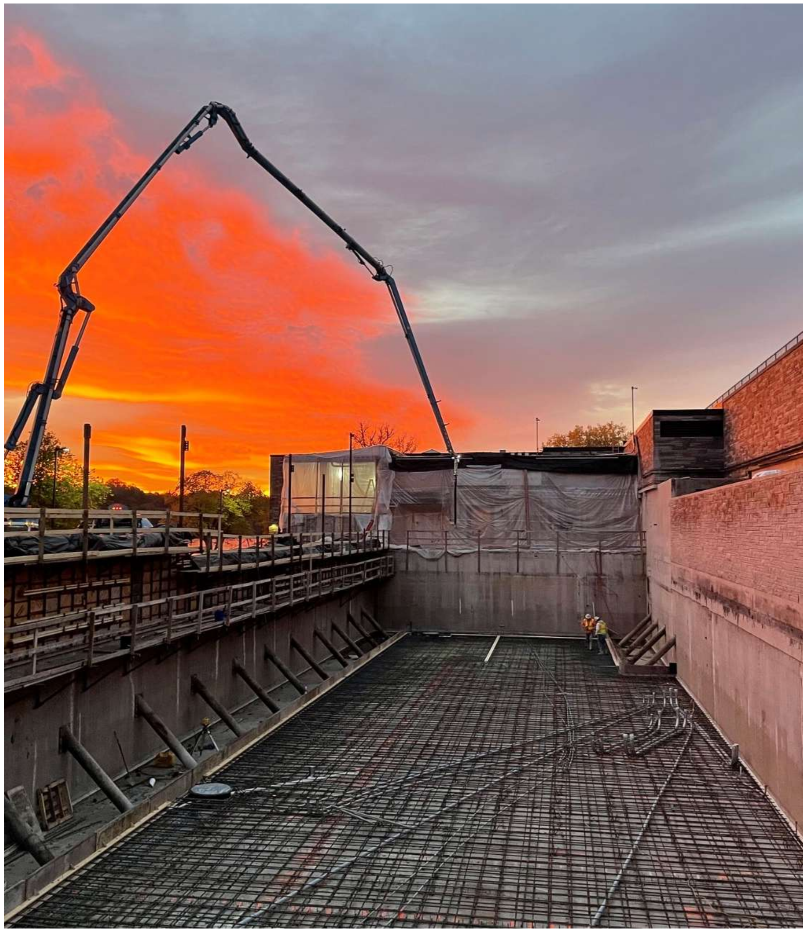
Groundwater Issue

Clearwell Conversion

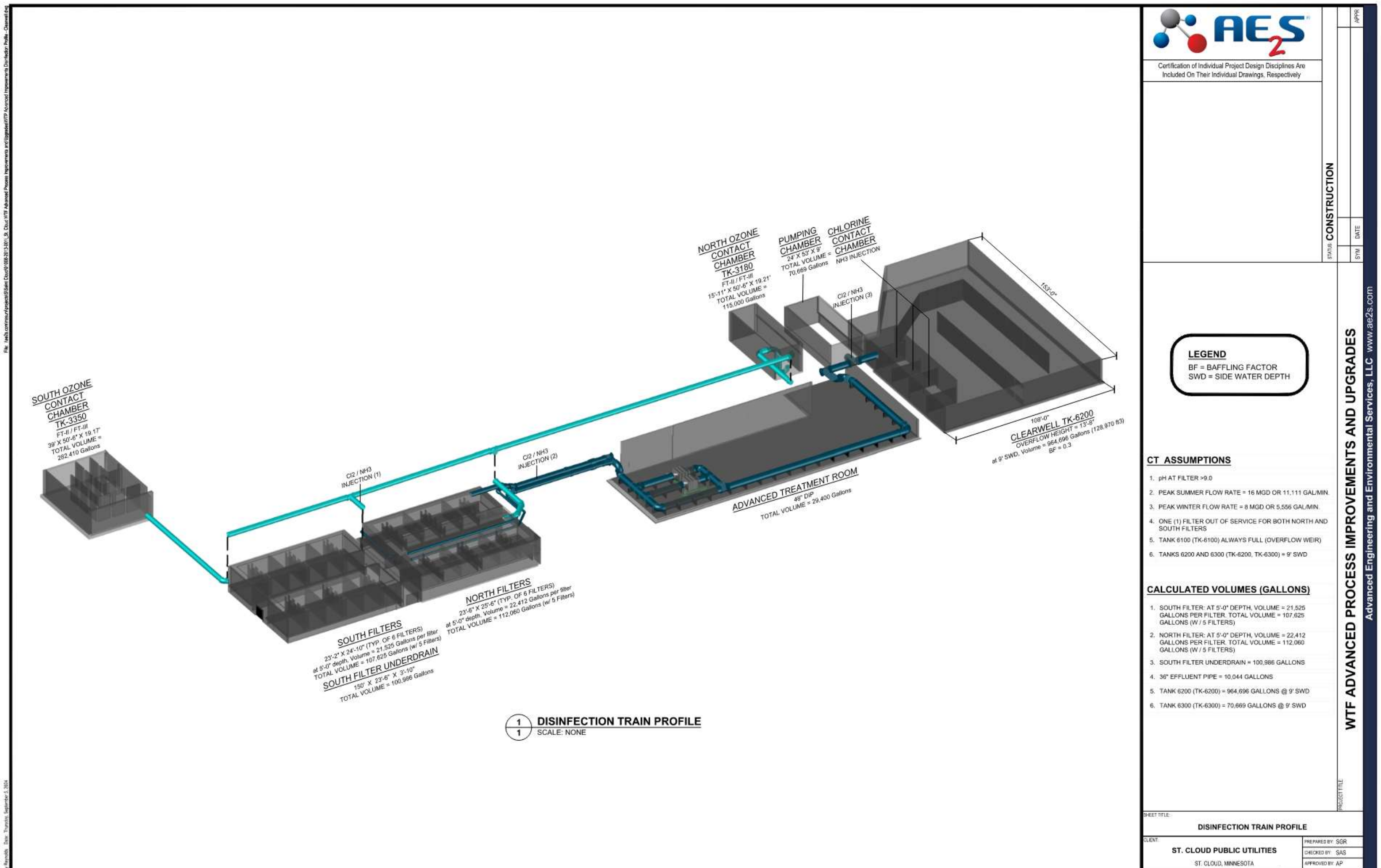


Groundwater Solution

Clearwell Conversion



Disinfection Issue



Post-Project Disinfection Profile

Disinfection Solution

Coordinate with Reviewing Authority

CT and Log Inactivation Calculations for SCWTF with Chlorine

This scenario is for replacing north filter's media (Mar. 2023)

= Required Input

6.0 MGD 4,167 gpm

Scenario A: Winter Flow =		**4167**	gpm			
Some Residual thru south filters	*Free*	*Free*	*Combined*	*Combined*	*Combined*	
	S. Filters	Underdrain+36"	48" Pipe	TK6200	TK6300	
Volume (gallons)	107,625	111,044	28,626	964,696	94,225	
Average-Peak-Hourly-Flow (gpm)	4,167	4,167	4,167	4,167	4,167	
Theoretical DT (min)	26	27	7	232	23	
Baffling Factor	0.7	0.7	0.7	0.7	0.1	
T-10 (Minutes)	18.1	18.7	4.8	162.1	2.3	
Cl2 Residual (ppm)	**2.0**	**0.6**	**2.0**	**2.0**	**2.0**	Some of the chlorine is being adsorbed by the GAC, but a 0.6 mg/l residual is carrie
Actual CT Value	36.2	11.2	9.6	324.1	4.5	
pH	9.0	9.0	9.0	9.0	9.0	
Temperature (C)	0.5	0.5	0.5	0.5	0.5	
CT-Giardia (0.5-log)	83	68	635	635	635	
Log Inactivation - Giardia	0.218	0.082	0.008	0.255	0.004	**0.57 log Giardia inactivation achieved**
CT-Viruses (2.0-log)	6	6	1,243	1,243	1,243	(Table C-7, pH 6.0 - 9.0)
Log Inactivation - Viruses	12.053	3.731	0.015	0.521	0.007	**16.328 log Virus inactivation achieved**

Inputs	
pH =	9.0
Temp (C) =	0.5

Scenario B: Winter Flow =		**4167**	gpm		**6.0**	MGD
No residual through south filters	*Free*	*None*	*Combined*	*Combined*	*Combined*	
	S. Filters	Underdrain+36"	48" Pipe	TK6200	TK6300	
Volume (gallons)	107,625	111,044	28,626	964,696	94,225	
Average-Peak-Hourly-Flow (gpm)	4,167	4,167	4,167	4,167	4,167	
Theoretical DT (min)	26	27	7	232	23	
Baffling Factor	0.7	0.7	0.7	0.7	0.1	
T-10 (Minutes)	18.1	18.7	4.8	162.1	2.3	
Cl2 Residual (ppm)	**3.0**	**0.0**	**2.0**	**2.0**	**2.0**	
Actual CT Value	54.2	0.0	9.6	324.1	4.5	
pH	9.0	9.0	9.0	9.0	9.0	
Temperature (C)	0.5	0.5	0.5	0.5	0.5	
CT-Giardia (0.5-log)	92	83	635	635	635	
Log Inactivation - Giardia	0.295	0.000	0.008	0.255	0.004	**0.56 log Giardia inactivation achieved**
CT-Viruses (2.0-log)	6	6	1,243	1,243	1,243	(Table C-7, pH 6.0 - 9.0)
Log Inactivation - Viruses	18.080	0.000	0.015	0.521	0.007	**18.62 log Virus inactivation achieved**

Inputs	
pH =	9.0
Temp (C) =	0.5

Disinfection Solution

Coordinate with Reviewing Authority

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Technical Document

DRAFT

To: Kim Larsen PE
Operation Supervisor Community Public Water Supply
Minnesota Department of Health

From: AE2S, LLC.

Prepare by Qigang Chang, PhD PE

Re: **SCWTF Primary Chemical Disinfection Credits Achieved 20230211-20230217**

Date: March 16, 2023

This document intends to provide an overview of the disinfection credits achieved at SCWTF via chlorine and chloramine disinfection between 5:00am February 11, 2023 and noon February 17, 2023. During this period, the Plant Clearwell TK6200 was out of service due to a planned construction activity.

Plant Operation Conditions Summary:

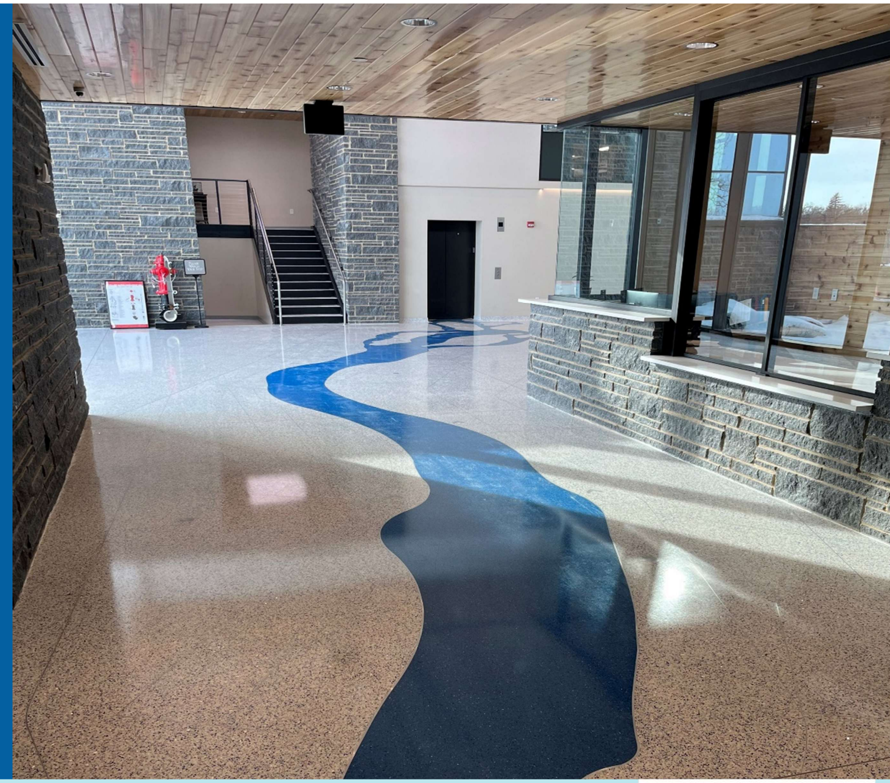
Disinfection goals: 2.0 Log virus and 0.5 Log *Giardia*
Disinfectant: chlorine and chloramine
Flow rate: 6 mgd
pH: 9.0
Temperature: 0.5 degree C
Chlorine feed point: filter split box
Ammonia feed point: 48" pipe (combined filter effluent)

Table 1. CT at pH 9 and temperature 0.5 Degrees Celsius

Disinfection Credit	Chlorine/chloramine concentration (mg/L)	CT (mg·min/L)		Notes
		Free Chlorine	Chloramine	
2.0 Log Virus	/	6	1,243	
0.5 Log *Giardia*	2.0 mg/L chlorine	83	635	
	2.2 mg/L chlorine	85		
	2.4 mg/L chlorine	87		

Thank you!

Questions?



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