Welcome to our

THE ROLE OF SMART SERVICE RESERVOIRS IN DISTRIBUTION WATER QUALITY MANAGEMENT

With Special Guest Andy Seidel –
CEO and Chairman – UGSI Solutions Inc

UGSI Solutions

Distribution Network Water Quality Management

May 27th 2020

UK Webinar with Panton McLeod

UGSI Solutions, Inc. is one of the fastest growing and innovative companies in the water industry

UGSI Solutions

PAX Water Technologies
A UGSI SOLUTIONS COMPANY

PAX Tank Mixers
Tank Shark®

UGSI Chemical Feed
SOLUTIONS

Polyblend® Fluid Dynamics™
Encore® Wallace & Tiernan®

PSI Water Technologies
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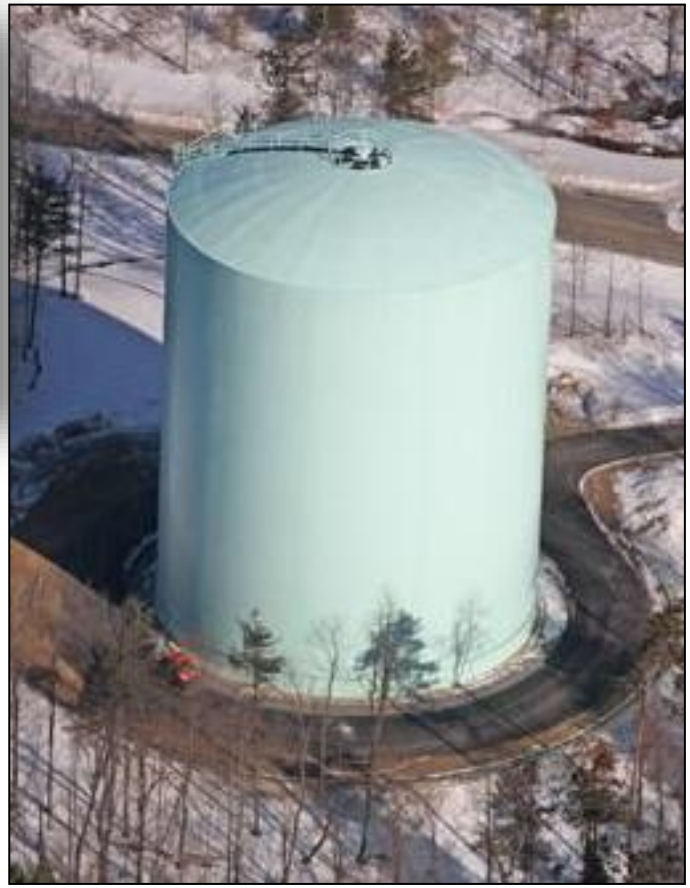
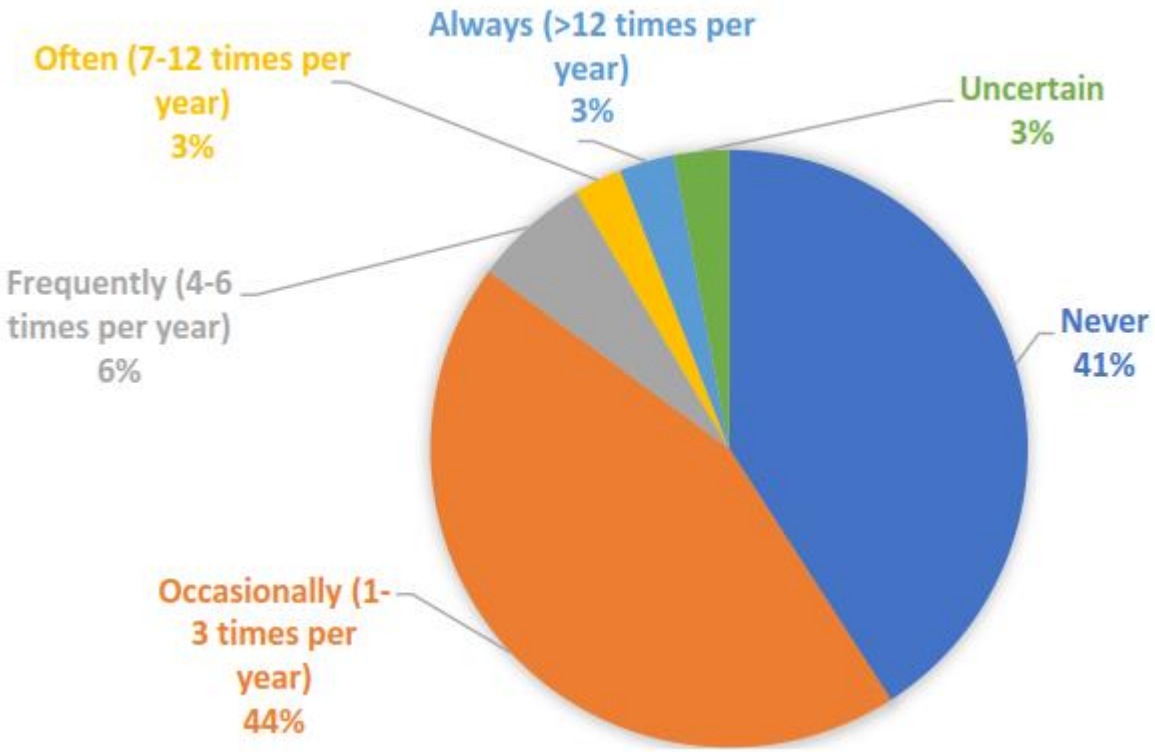
Microclor® Monoclor® RCS
PAX TRS™ ChemLocker™

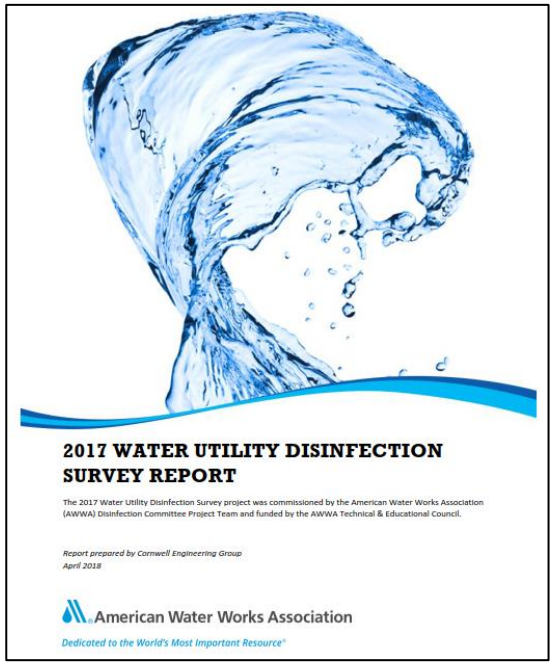
For the last several decades, water utilities have focused on bringing state-of-the-art technologies to treatment plants in an effort to improve system water quality - the next several decades will focus on the distribution network itself

- Today, control of disinfectant residual and THM production in a drinking water plant is manageable
- Tank systems are designed for storage and system hydraulics – not water quality management
- Utilization of water storage tanks and reservoirs to improve delivered water quality <u>starts with mixing</u>
  - THM reduction
  - Residual control



Approximately 60% respondents claimed having difficulty meeting **secondary disinfection** target occasionally or greater (USA)




2017 WATER UTILITY DISINFECTION SURVEY REPORT

The 2017 Water Utility Disinfection Survey project was commissioned by the American Water Works Association (AWWA) Disinfection Committee Project Team and funded by the AWWA Technical & Educational Council.

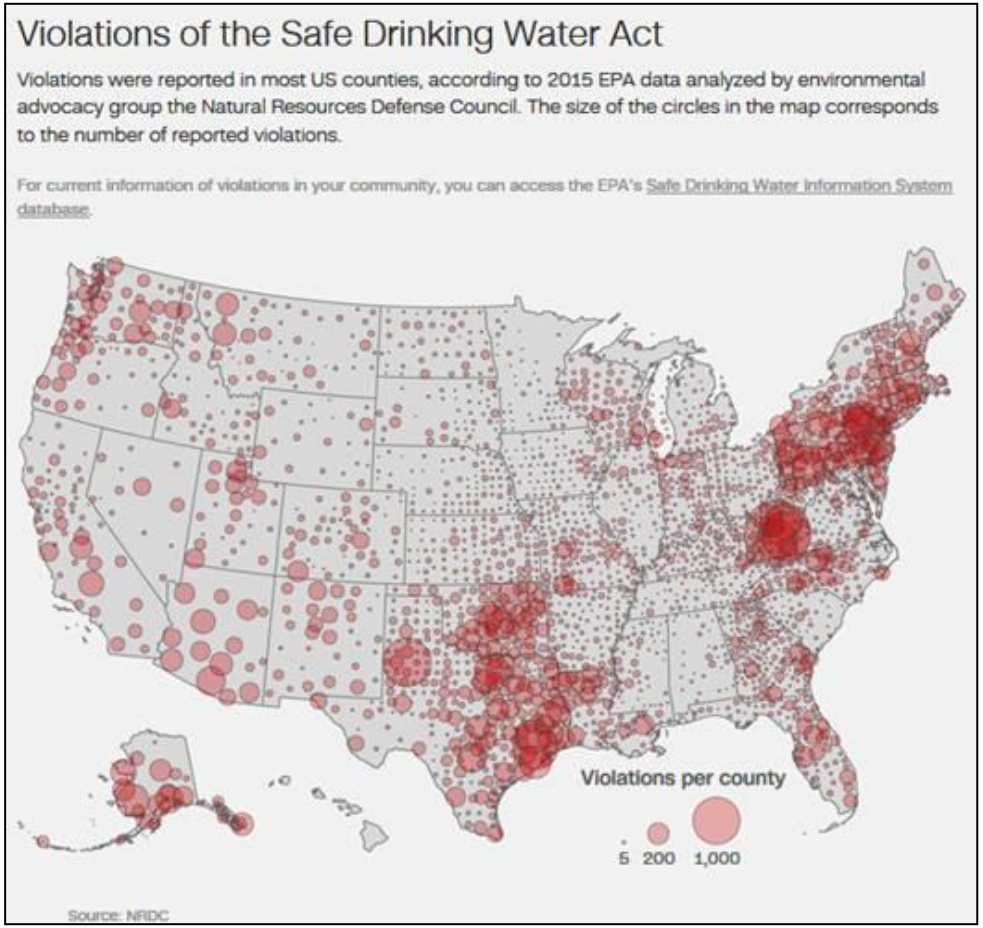
Report prepared by Cornwell Engineering Group
April 2018

American Water Works Association

Dedicated to the World's Most Important Resource®

Frequency at which respondents report difficulty in meeting target chlorine residuals for secondary disinfection (n = 269)

Increased focus in US on reducing violations in distribution networks with state-by-state levels increasingly more stringent than federal (EPA) levels



** TX and LA have 0.5mg/l mandatory residuals*

"Beginning April 29, 2019, a community water system using a chemical disinfectant or that delivers water that has been treated with a chemical disinfectant shall maintain a minimum residual disinfectant concentration throughout the distribution system sufficient to assure compliance with the microbiological MCLs and the treatment technique requirements specified in § 109.202. The minimum residual disinfectant concentration is 0.2 mg/L"

For example, for 2014-2016 total coliform violations were roughly twice that of any other category of MCL violation in CA

STATE OF CALIFORNIA

ANNUAL COMPLIANCE REPORT 2016

Water Boards

Under the TCR, results are reported on a presence/absence basis. CWSs are required to routinely sample between one sample per month and 120 samples per week, depending on the size of the system. NTNC and TNC systems are generally on a monthly or quarterly sampling frequency. A public water system is in violation of the total coliform MCL when any of the following occurs:

- For a public water system which collects at least 40 samples per month, more than 5.0 percent of the samples collected during any month are total coliform-positive; or
- For a public water system which collects fewer than 40 samples per month, more than one sample collected during any month is total coliform-positive; or
- Any repeat sample is fecal coliform-positive or *E. coli*-positive; or
- Any repeat sample following a fecal coliform-positive or E. coli-positive routine sample is total coliform-positive.

Table 5: Number and Population of PWSs with Violations of Maximum Contamininant Levels (MCLs), Maximum Residual Disinfectant Levels (MRDLs), and/or Treatment Techniques (TT)

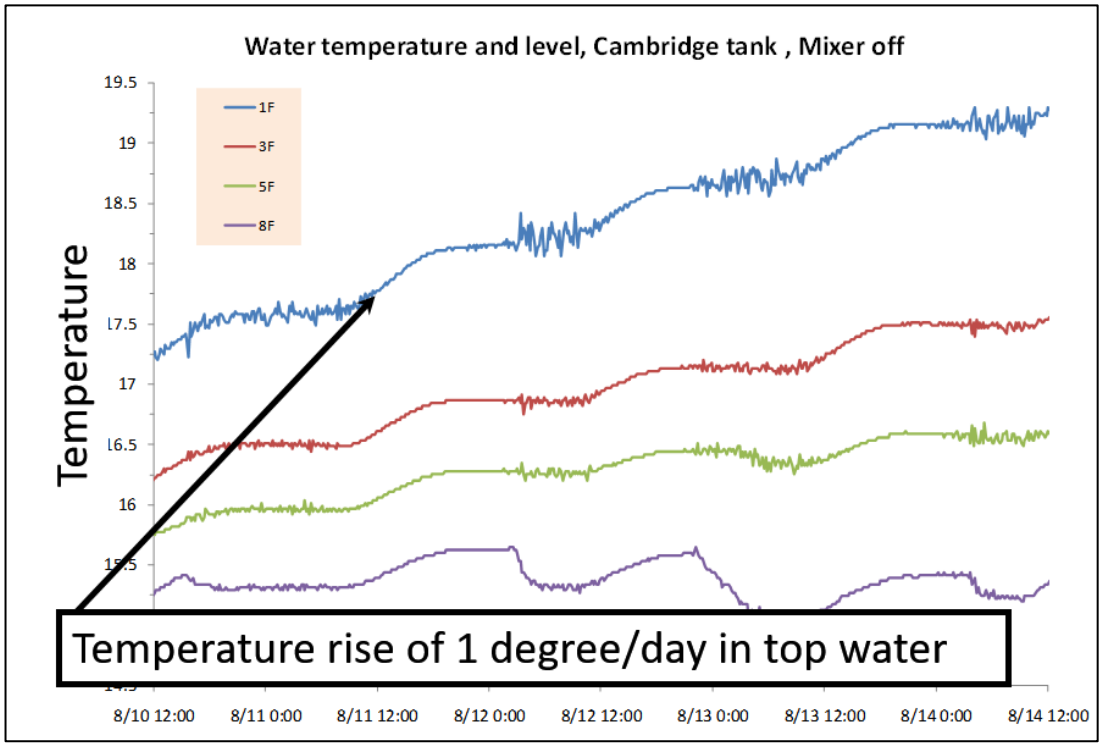
No	Category	2014		2015		2016	
		No. of PWSs	Popula-tion	No. of PWSs	Popula-tion	No. of PWSs	Popula-tion
1	Inorganic Contaminants	296	206,654	232	129,545	264	138,830
2	Synthetic Organic Contaminants (SOCs)	6	15,602	4	14,163	2	120
3	Volatile Organic Contaminants (VOCs)	2	250	0	0	1	200
4	Radionuclide Rule	28	23,865	26	52,411	28	11,418
5	Total Coliform Rule (TCR)	442	620,245	419	443,064	433	425,554
6	Disinfectants And Disinfection Byproducts Rule (DBPR)	62	214,665	74	381,063	59	221,309
7	Surface Water Treatment Rules (SWTR, IESWTR, LT2SWTR)	31	20,766	42	558,159	49	197,374
8	Groundwater Rule	2	27,360	1	420	1*	3,987,622*
9	Lead And Copper Rule (LCR)	1	3,441	11	10,494	18	12,250

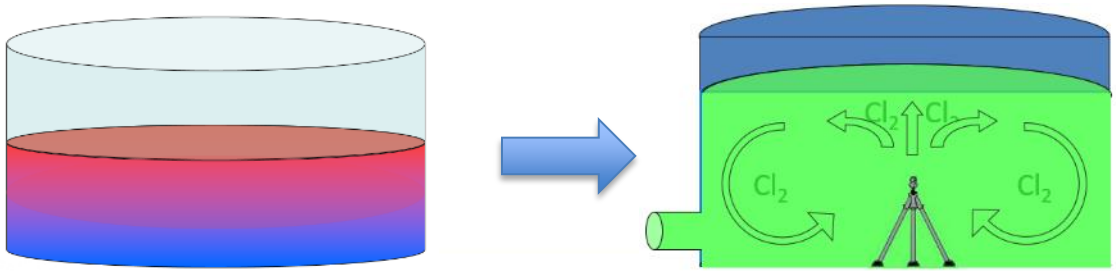
Water storage assets are the increasingly preferred as intervention points for water quality improvement in a distribution network

Reservoir water quality management requires:

- Energetic mixing to de-stratify aging water and ensure tank homogeneity
- Effective monitoring to ensure real-time water quality understanding
- Accurate dosing of chemicals at the right time in the right amount
- Strong process control with feedback for optimization of consumable use

Un-mixed tanks suffer from temperature and chemical stratification which creates a cascade of issues



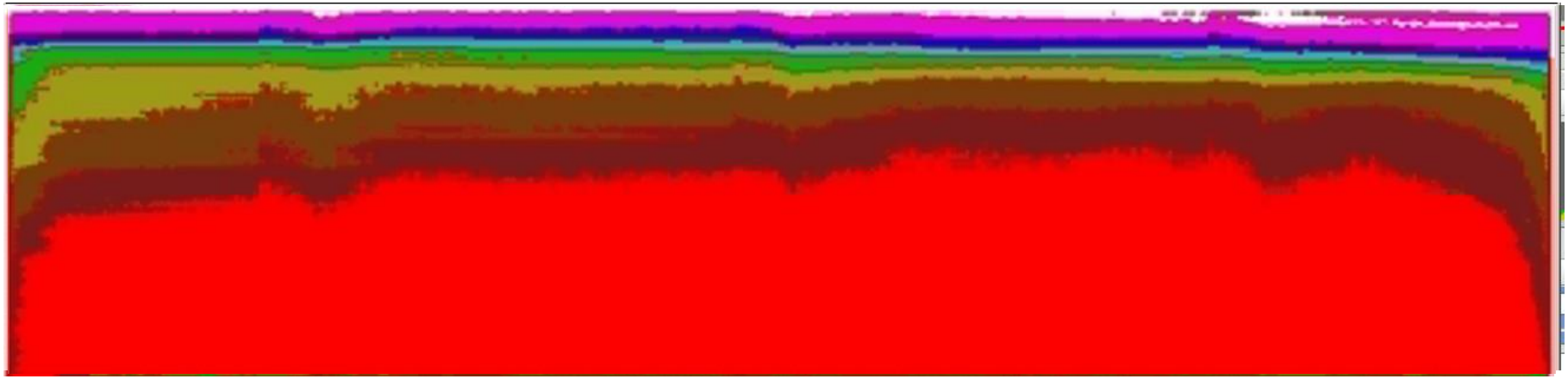


Effective tank mixing:

- Better distribution of disinfectant throughout the tank that can reduce biofilm risk and ensure consistent effluent residual
- Lower overall water temperature that is favorable for residual longevity
- Decreased sediment accumulation in tank
- Prevention of destructive ice formation

Passive mixing systems are not effective - field research and modeling demonstrates very short-lived mixing results – density differences are powerful

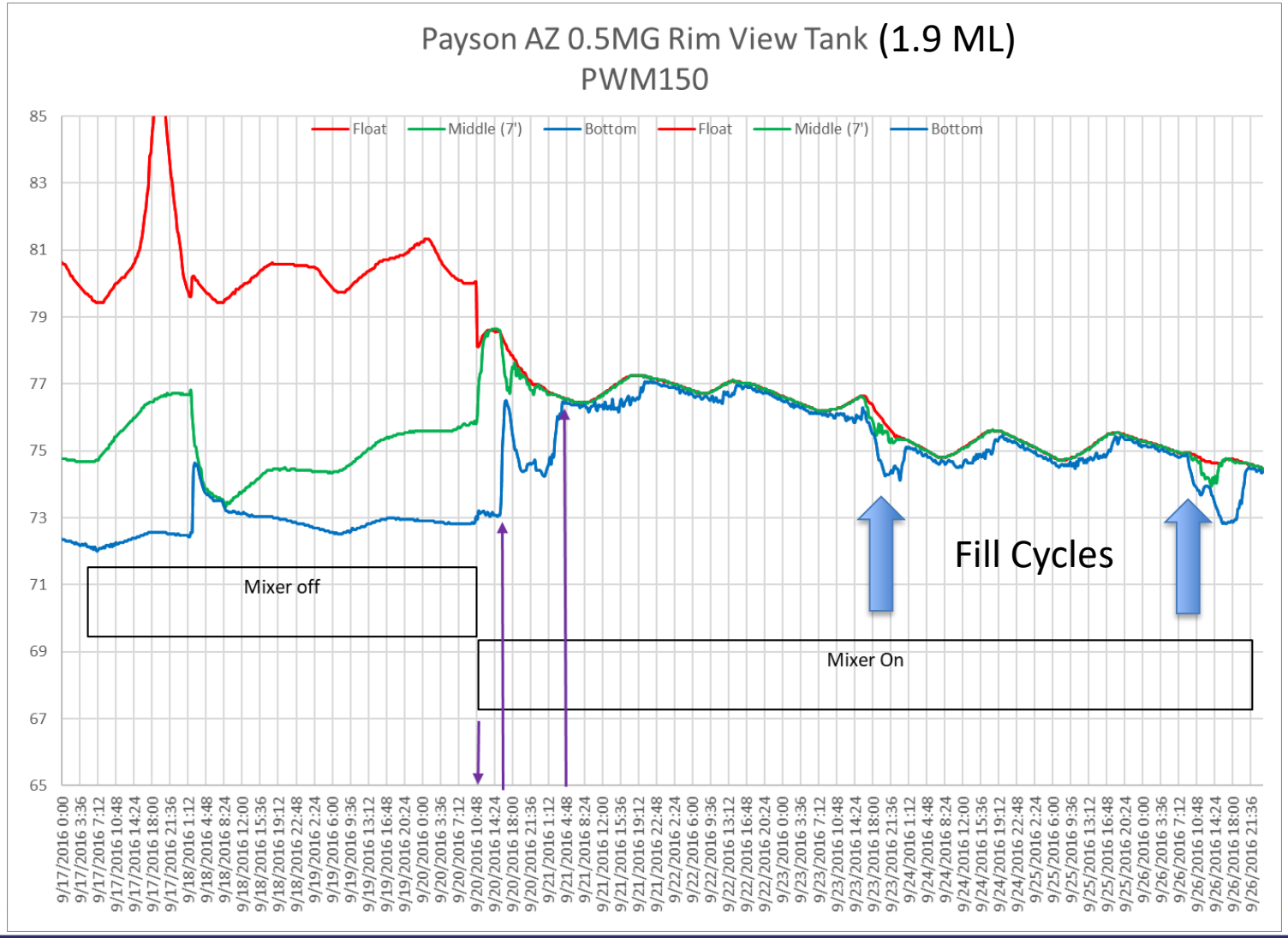
Scaled model of passive mixing
Georgia Institute of Technology



Courtesy of Prof. Phillip Roberts
Georgia Institute of Technology

Cold Water
Introduction

Properly sized active tank mixing eliminates tank stratification

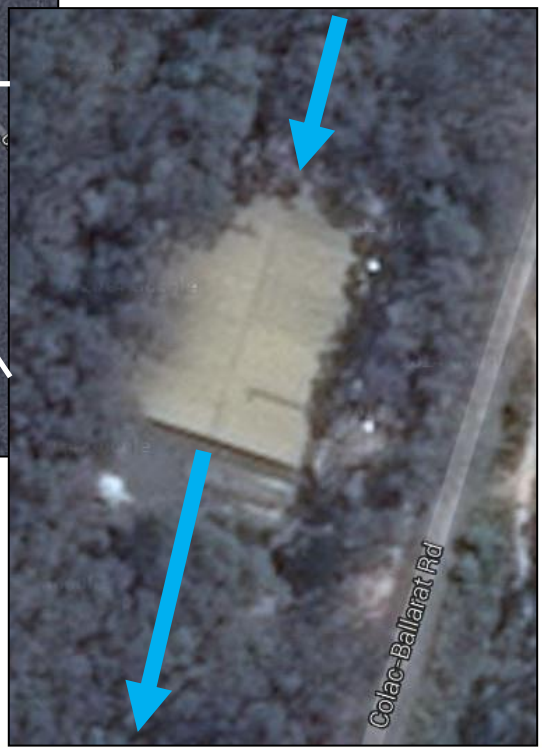


Central Highlands Water: 4 ML reservoir with low chlorine residual

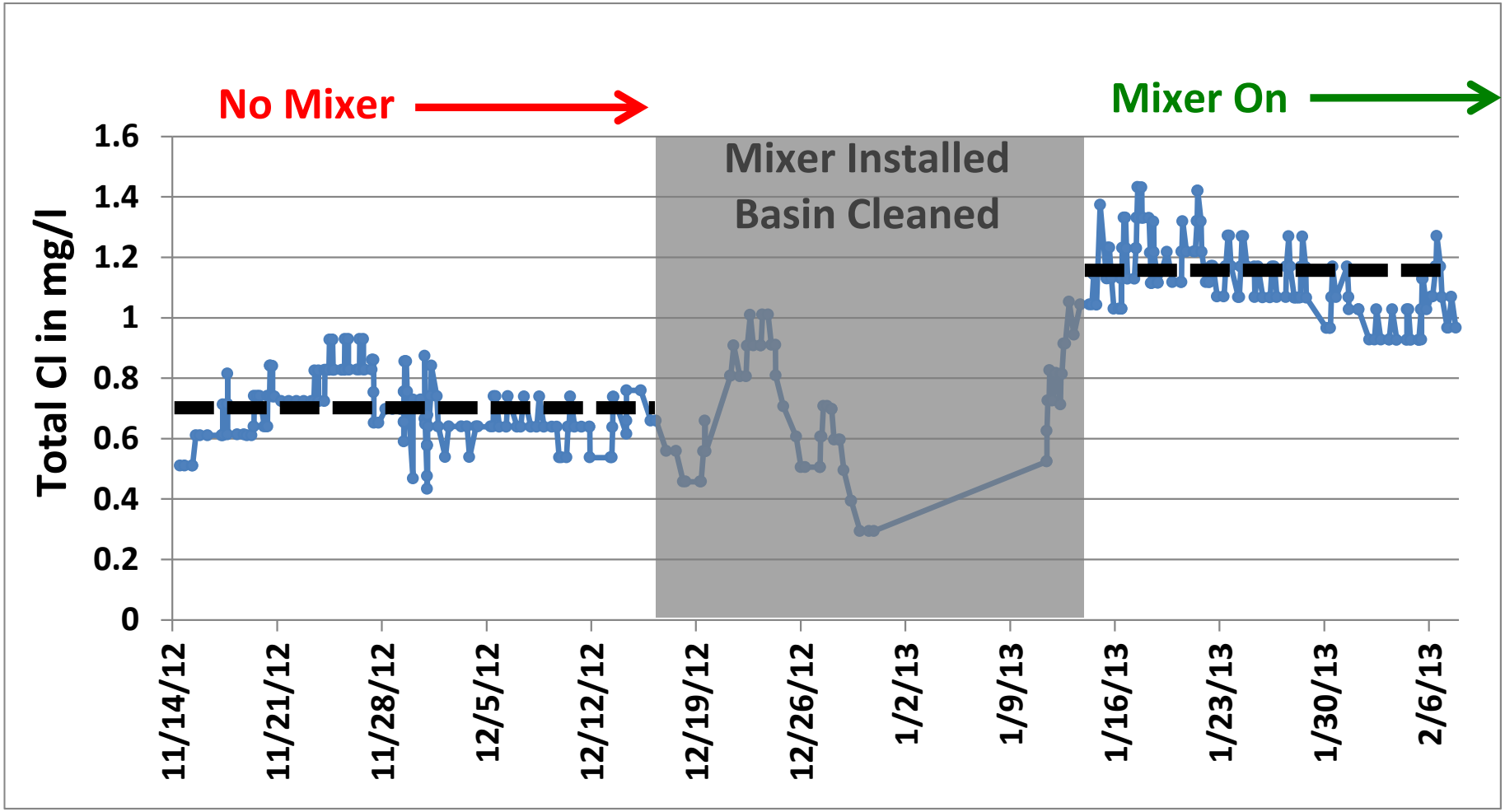
CENTRAL HIGHLANDS WATER

1 MG Enfield Reservoir

Flow



Chlorine residuals show significant improvement after mixing with no additional chemical addition



Effective mixing can come in a variety of configurations depending upon process objective and site constraints

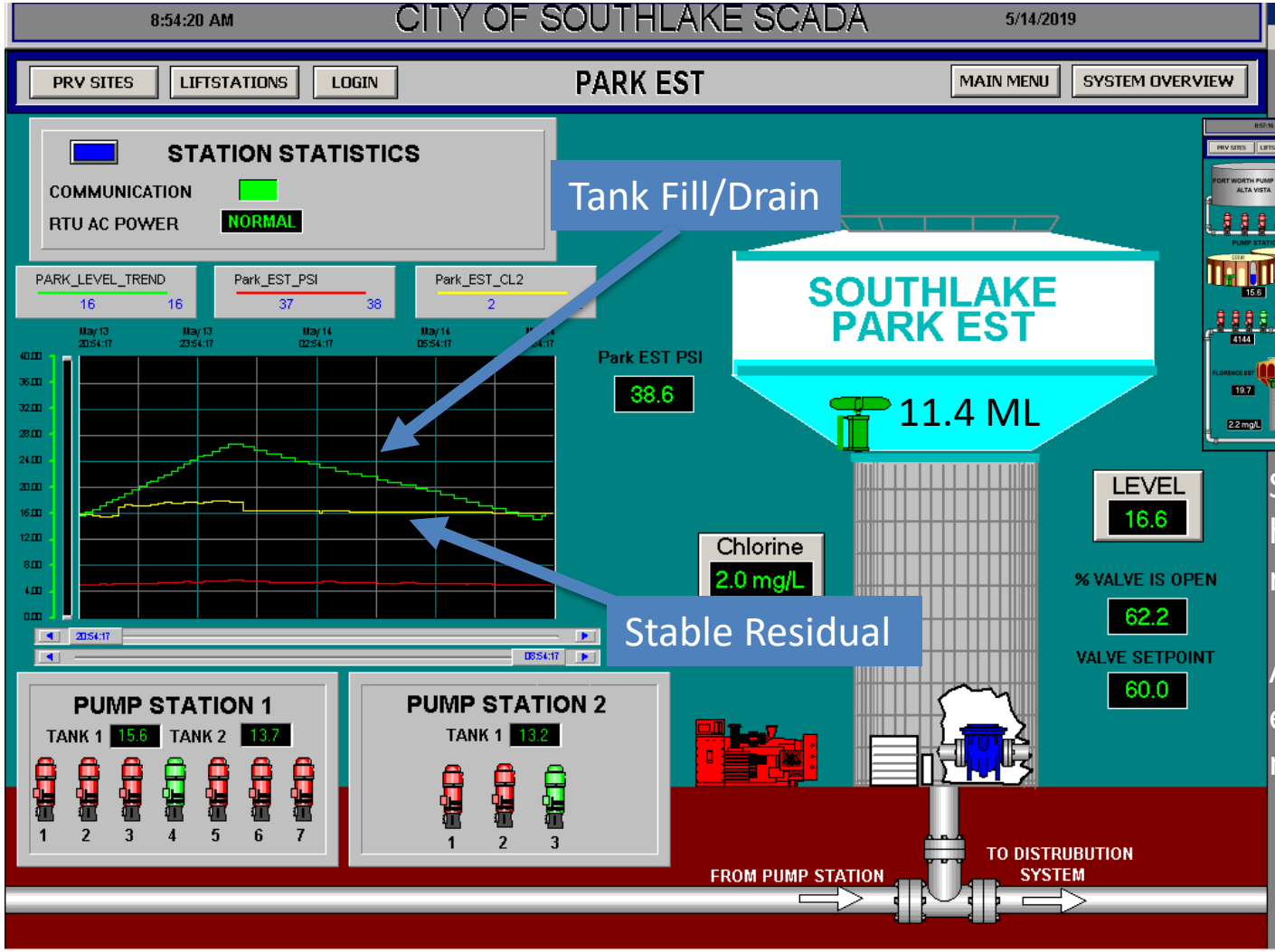
Tank Shark® Eductor Mixer

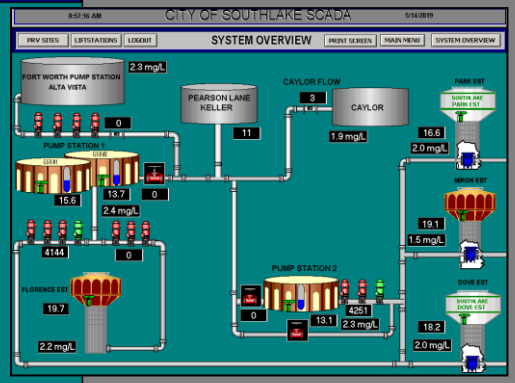
PAX Jet Mixer

PAX Impeller Mixer

Southlake, TX: Mixers add stability to disinfectant residuals system wide

Case Study



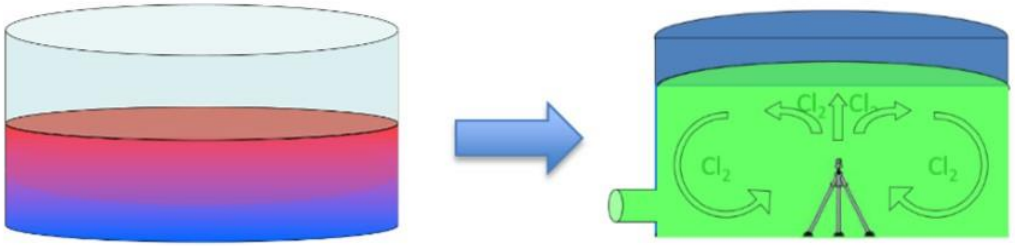


System of seven tanks had seasonal issues with residual stability

After adding mixers to each tank, residual was more uniform throughout system

Northglenn, CO: Mixers add stability to disinfectant residuals and allowed for lower plant chlorine dosing

Case Study



Adding appropriate mixing energy to tank ensure tank is de-stratified and exhibits consistent residual

- In summer months, Northglenn increased residual (free-chlorine) plant exit values to 1.4ppm to offset loss in the network
- Increased free chlorine levels resulted in higher rates of THM formation
- By adding mixers, the utility observed higher and more uniform network residuals and no longer needed to increase plant exit residuals – thereby lowering THM formation risk

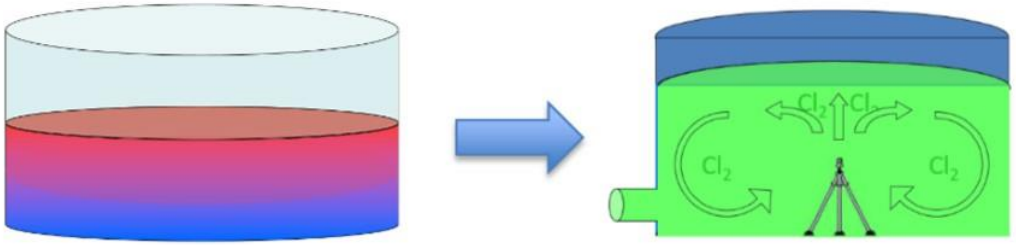
Punta Gorda, FL: Mixers add stability to disinfectant residuals and allowed for lower plant chlorine dosing

Case Study

Tank Shark®
Eductor Mixer

2MG Punta Gorda Isles Tank

- Located in a warm climate, Punta Gorda employed many operational strategies such as operating at lower tank levels, flushing and manual boosting to maintain chlorine residuals in their network
- After installing the Tank Shark® eductor style mixer, the utility experienced consistent residuals and was able to reduce flushing by 75%

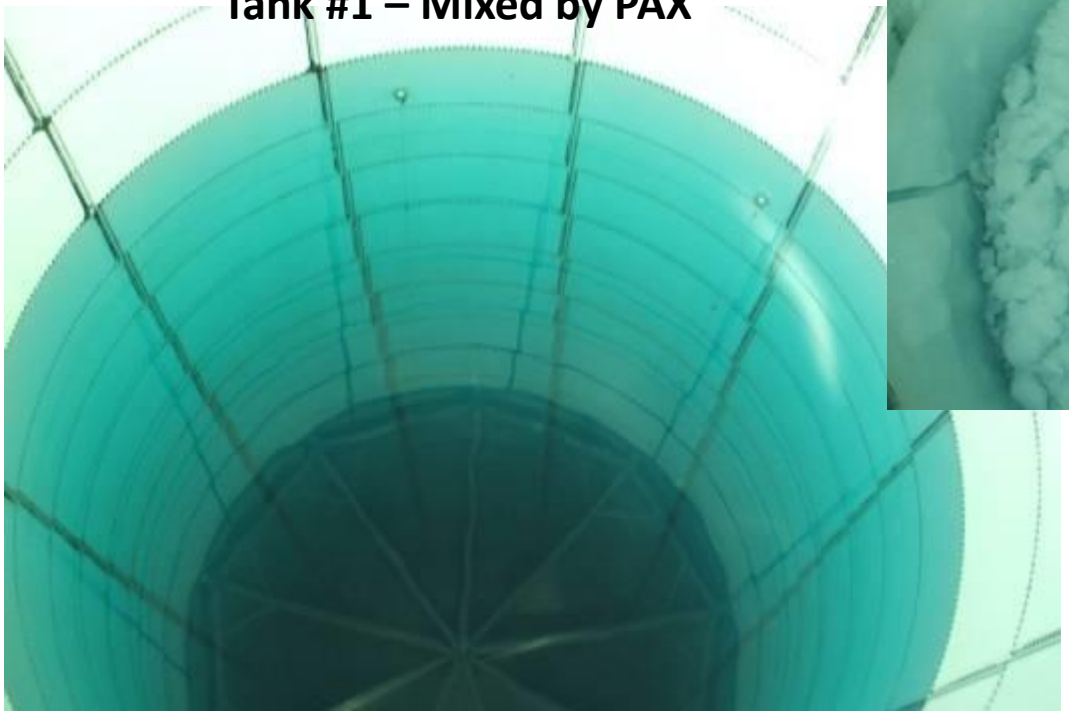


Adding appropriate mixing energy to tank ensure tank is de-stratified and exhibits consistent residual

Old Town, ME: De-icing – mixers can prevent ice formation in some tanks

Case Study

Side-by-side standpipes in winter



- De-icing application – mixer distributes warmer incoming water to top of tank to inhibit ice formation
- Prevents tank damage

Wet Installation of PAX Mixers is Common

Mixer choice depends on process objective with consideration of available power, turnover, geometry, climate and dosing needs

For Example:

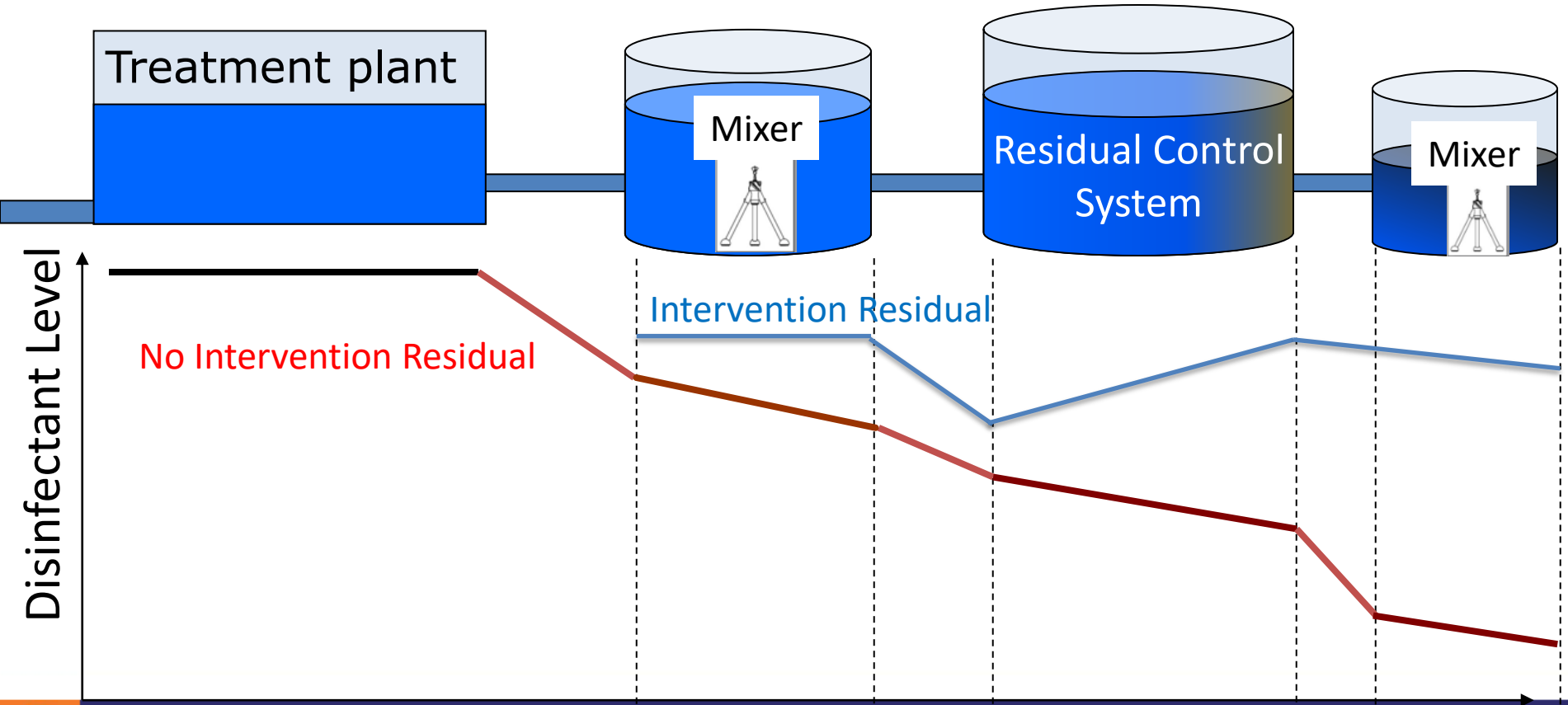
Turnover/Cycling

- Mixer must achieve mixed tank within cycle-time of tank (mixing has to be faster than rate water enters and leaves the tank)

Process Objective

- De-stratification, ice-prevention, chemical dosing, THM aeration all require different mixer capacity and power

Ultimately, powerful and effective tank mixing is the *gateway* decision for improving distribution network water quality



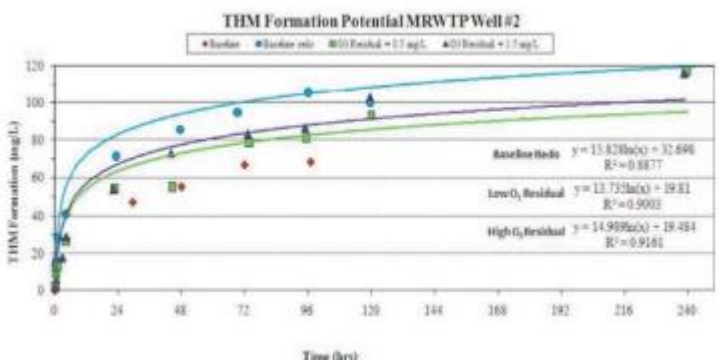
Chloramine & Free Chlorine Residual Optimization and Management in the Distribution Network

Utilities have no "free lunch" as the choice of secondary disinfectant will determine the problems they will contend with:

Secondary Disinfectant Choice

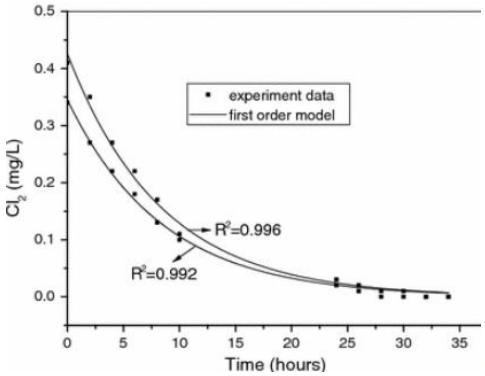
Free Chlorine

- Boosting to offset degradation
- DBP (THM and HAA5 issues) **formation**



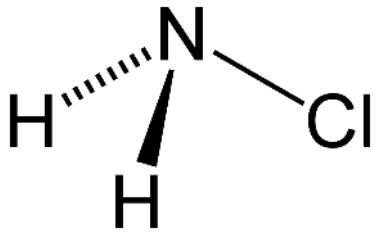
Chloramines

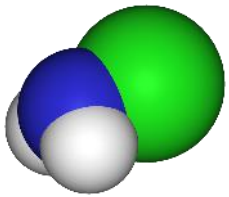
- Chloramine **degradation** (ammonia formation)
- Nitrification (nitrite and nitrate MCLs)



Chloramines, used in about a third of municipal water systems, provide longer protection in distribution systems and are less prone to encourage DBP formation

$$NH_3 + OCl^- \leftrightarrow NH_2Cl + HO^-$$

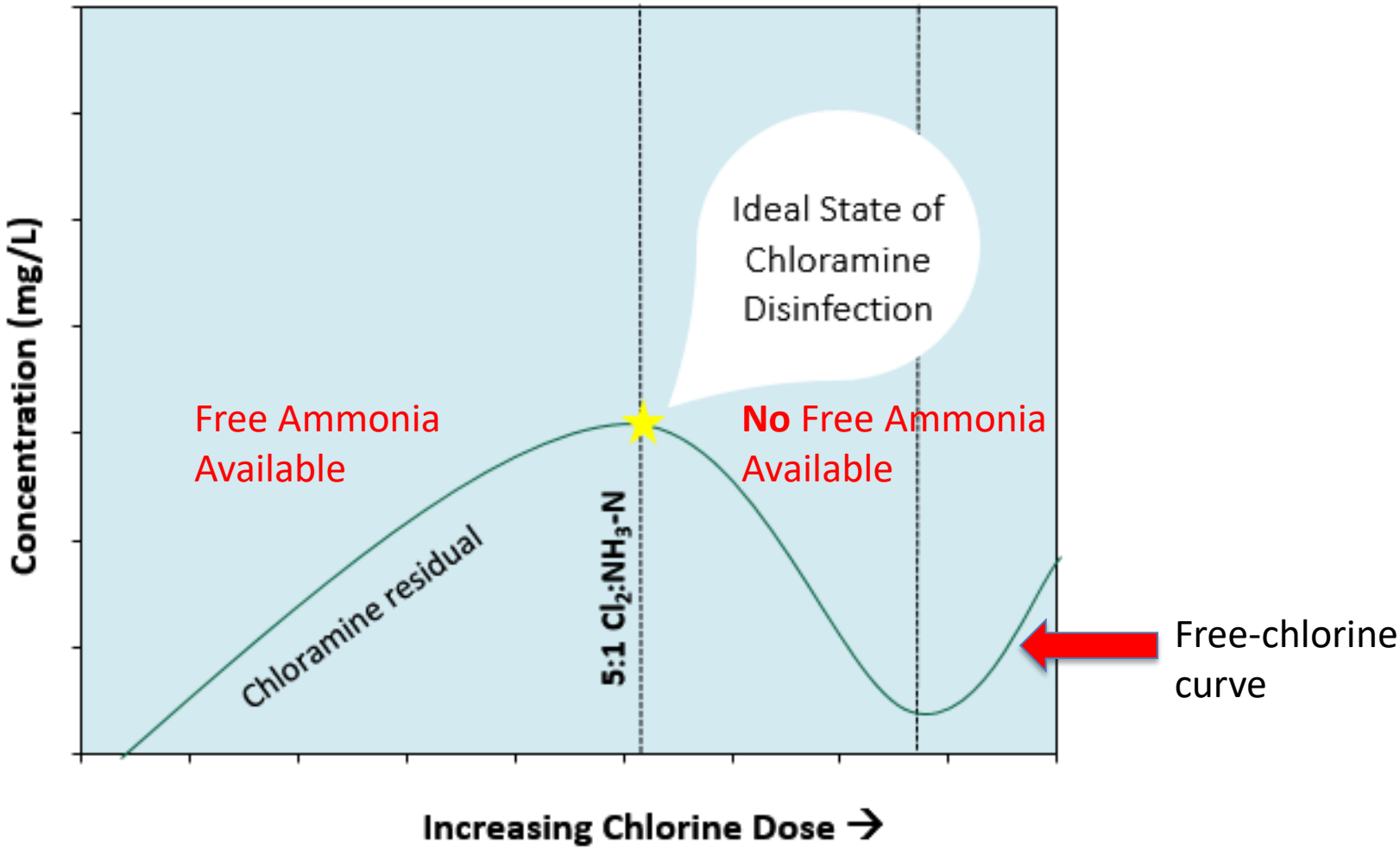




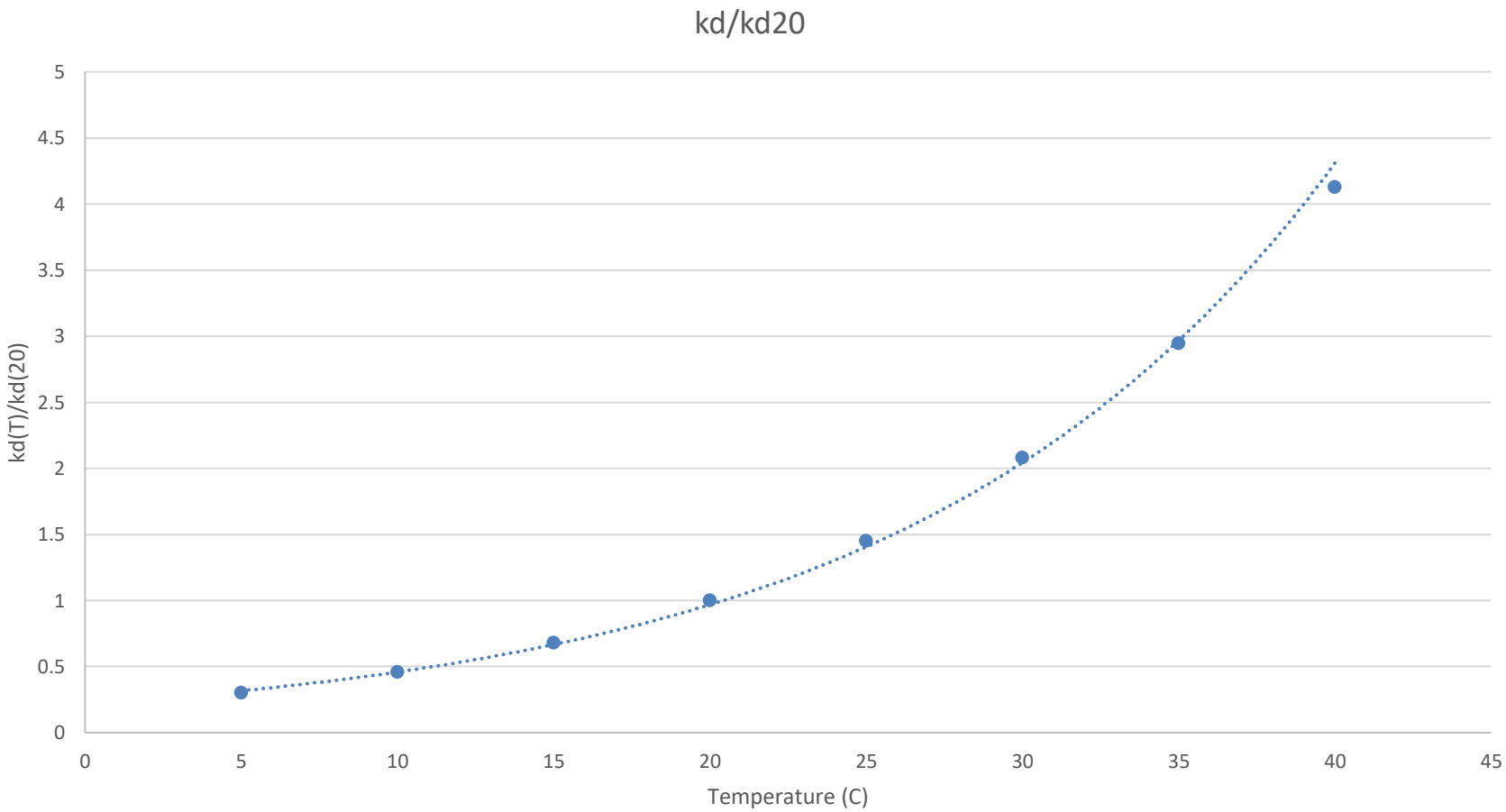
Monochloramine is formed by the reaction of chlorine and ammonia with a chlorine atom substituting for one of the three ammonia hydrogen atoms

1:1 Molar Ratio Equates to a 5:1 Weight Ratio (Chlorine to Ammonia)

Chloramine Breakpoint Curve: Knowing where you are on the curve allows for precise dosing action

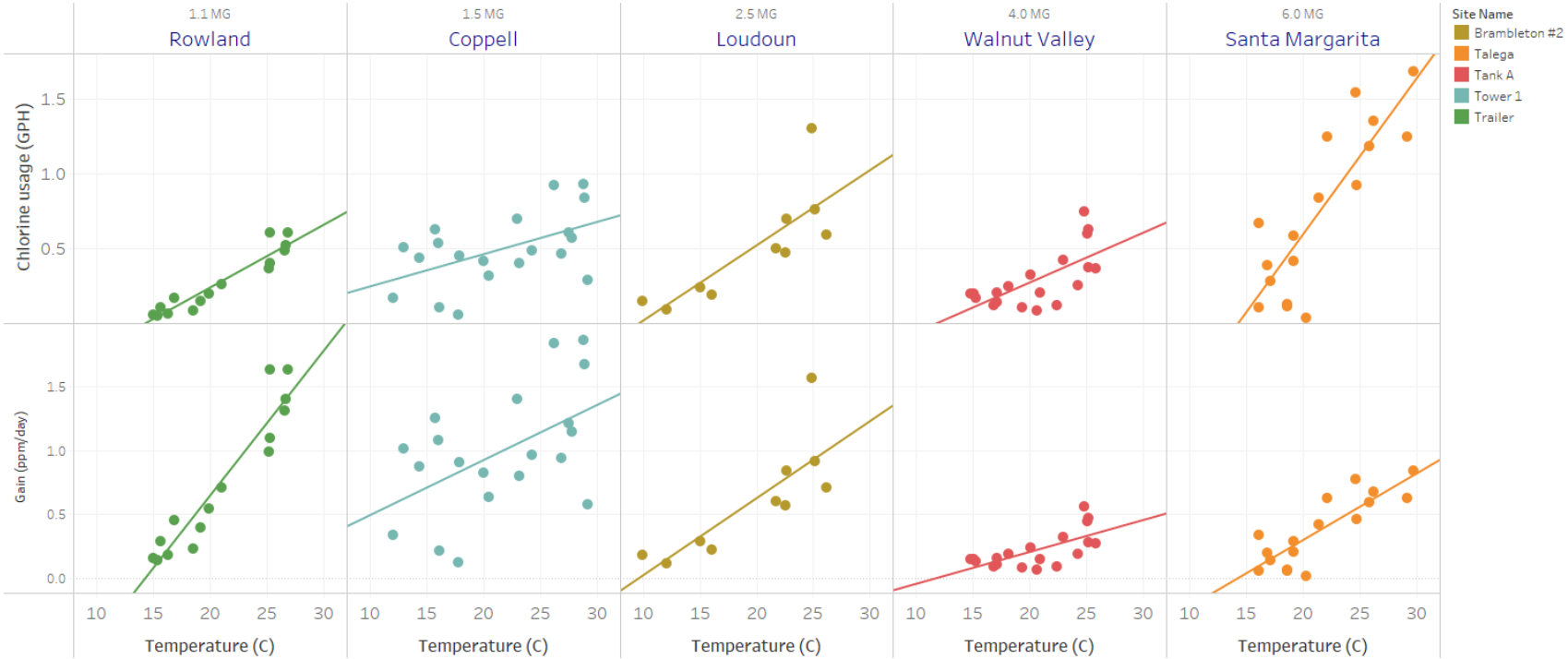


Chloramine decay rate triples from 50°F to 77°F - seasonal issues



Chemical usage increase significantly with water temperature increases: examples of six active Monoclor® RCS sites

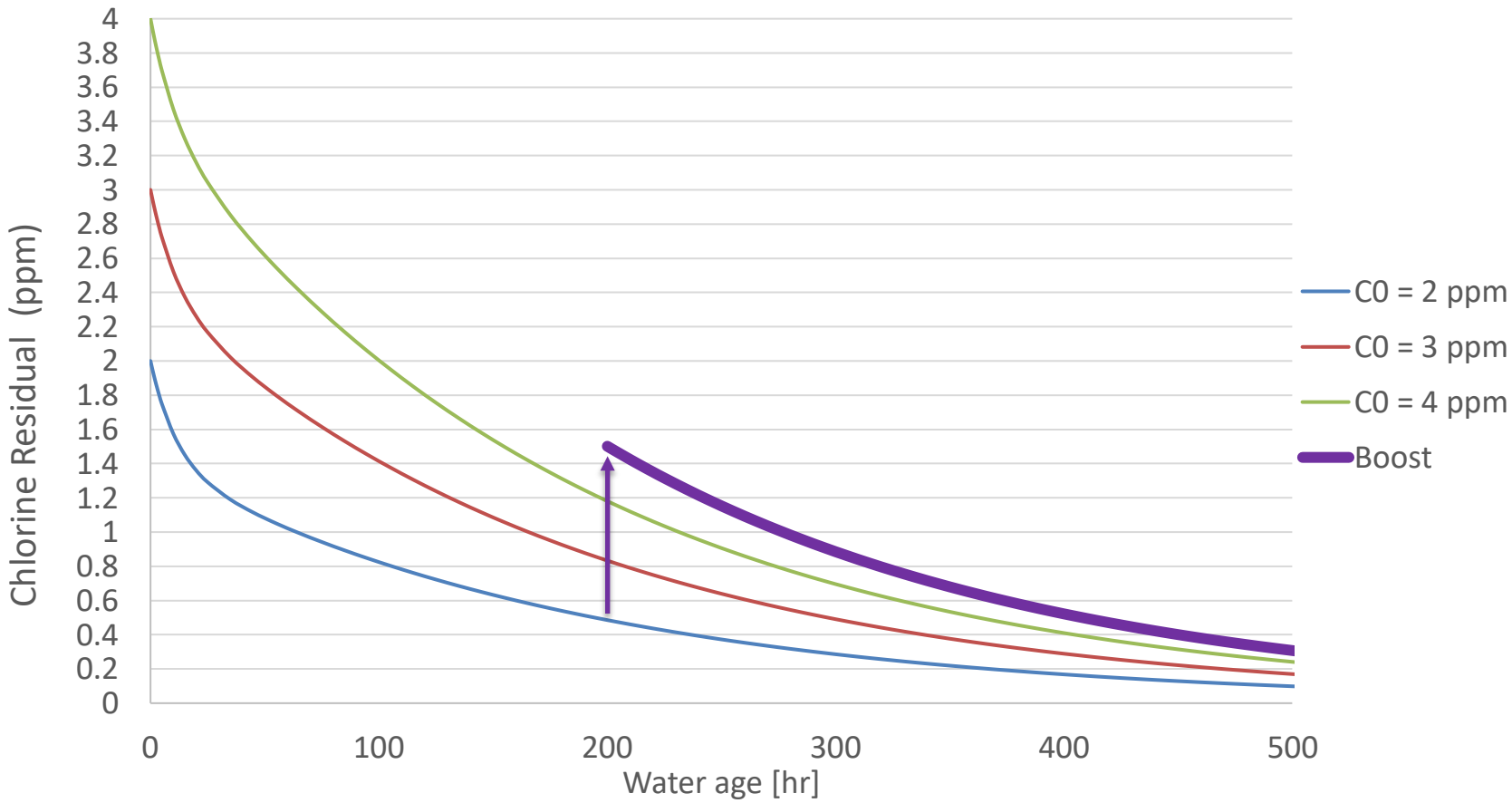
Chemical usage can quadruple during warm months



Monthly average (2017-2018)

Chemical feed rates need to be adjusted (winter/summer)
Proper sizing of chemical feed system and storage is required

Boosting in distribution allow to raise residual above the maximum dose allowed at the treatment and use also less chemical to achieve it



Four criteria must be met for proper chloramine control in reservoirs:

1. Proper mixing to ensure a homogenous water body that will not stratify
2. Accurate dosing of ammonia and chlorine to ensure proper ratio given the position on the breakpoint curve
3. High energy mixing that ensures instantaneous reaction of introduced chemicals
4. Real-time monitoring and control logic to maintain or achieve equilibrium by responding to dynamic reservoir conditions

Effective mixing can come in a variety of configurations depending upon process objective and site constraints – for example – RCS applications require higher mixing energy and must accommodate chemical injection

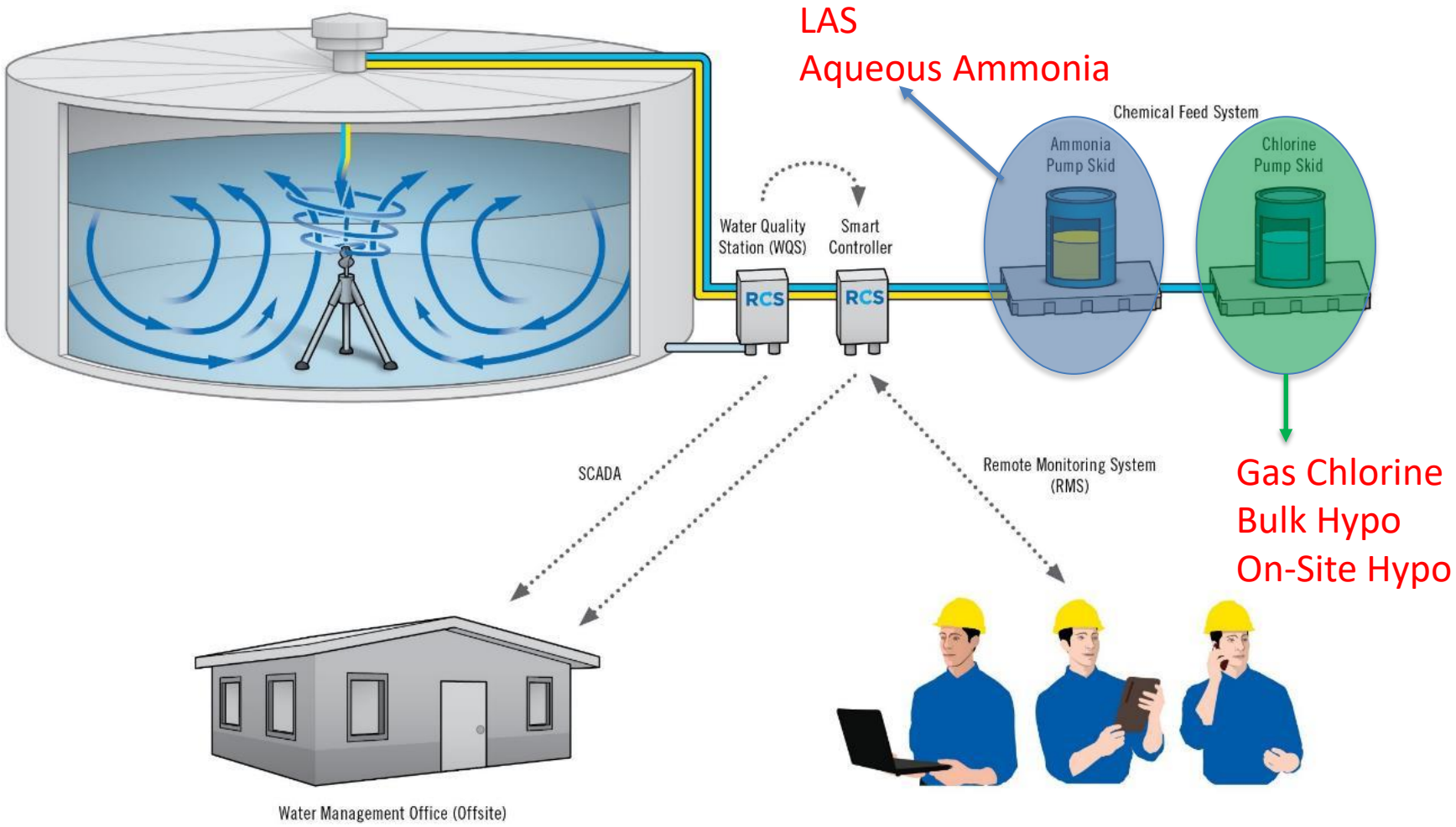
Tank Shark® Eductor Mixer

PAX Jet Mixer

PAX Impeller Mixer

Chemical Feed Version

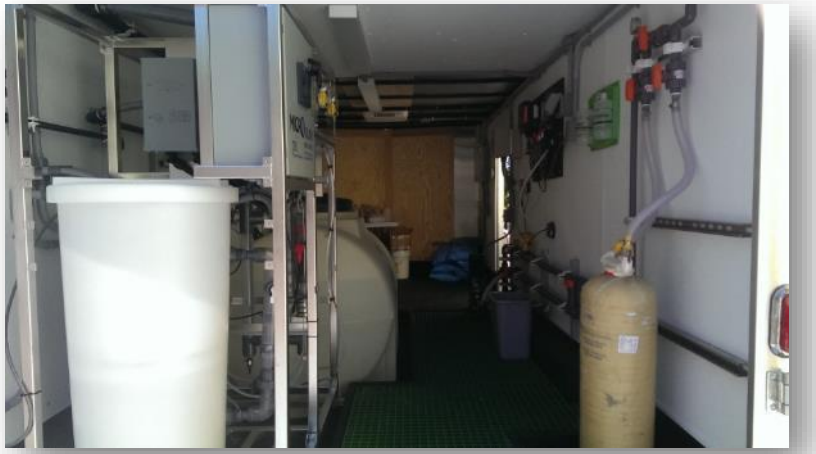
A residual control system automatically adjusts disinfectant residual to a pre-determined set-point and maintains that set-point with beneficial water quality impact to the zones it serves



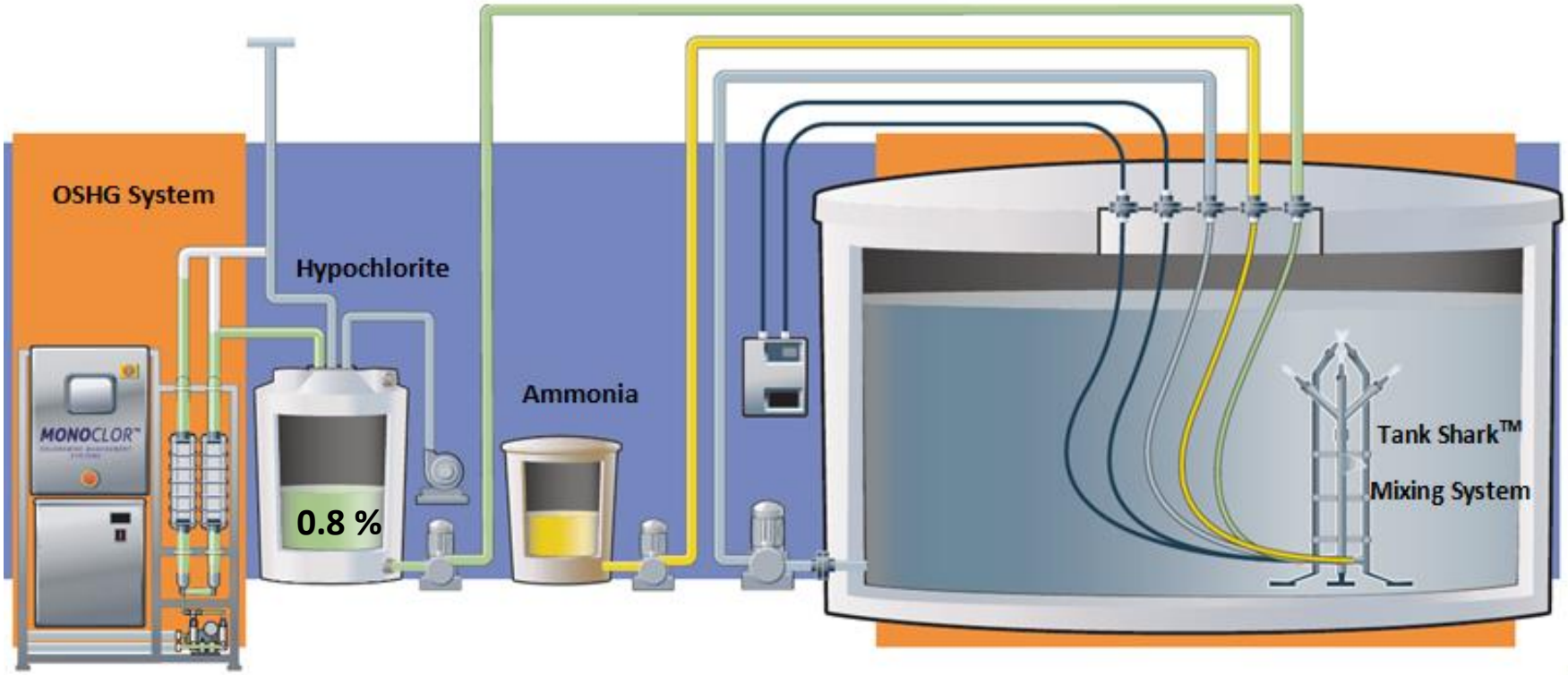
San Jose, CA – Monoclor®RCS trailer at San Jose Water Company: 1 MG reservoir

Case Study

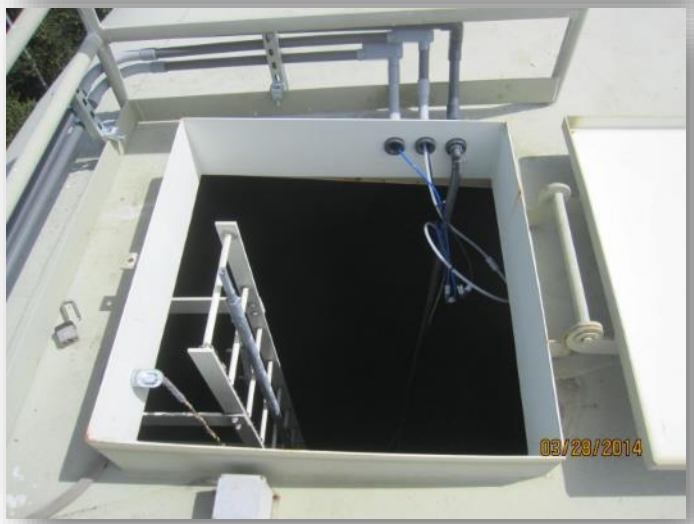
Tank Size: 1 MG (3.8 ML)
Turnover: 4 days
Problem: Chronically low residual (<0.2 mg/l)
Solution: Monoclor® RCS System



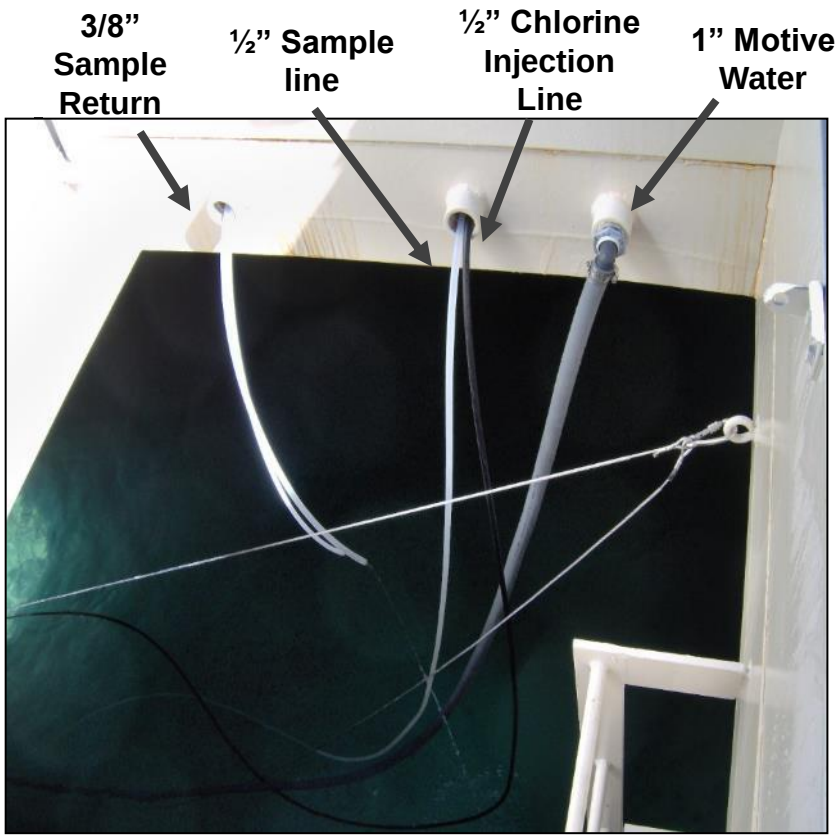
Chloramine residual control systems can take on a number of different configurations depending on tank particulars and client preferences



Site conditions in San Jose: Tank Shark® mixing and injection hardware



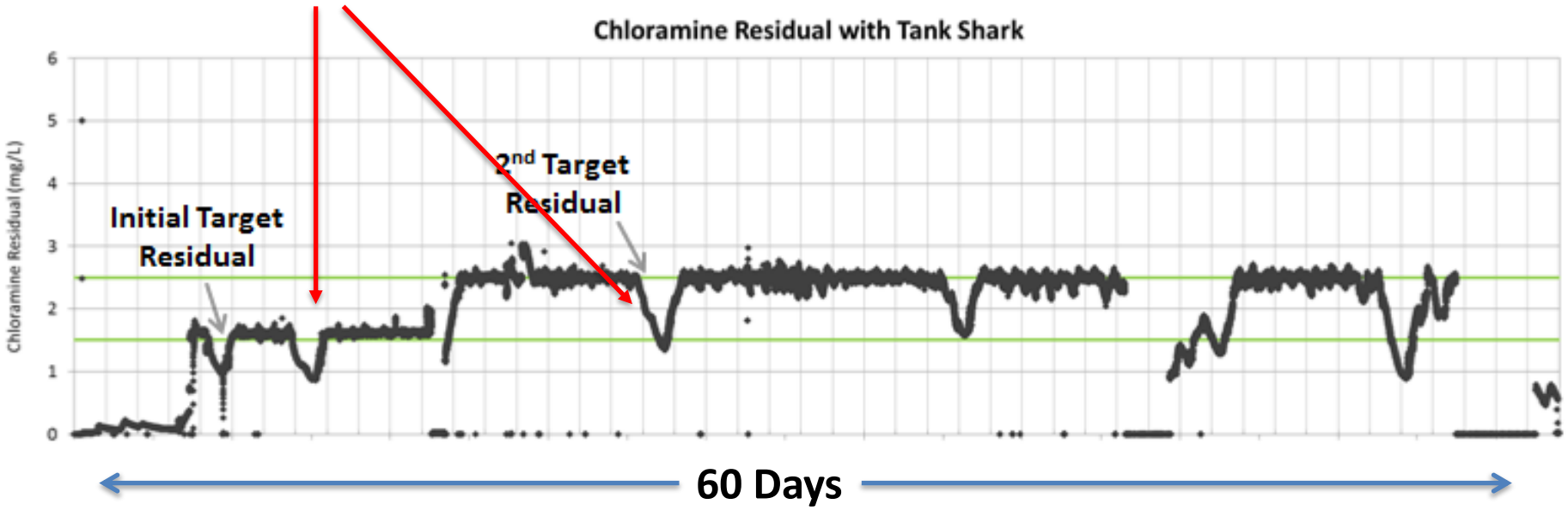
Tank Shark® mixer and injection device was installed while the tank was in service



TANK & HATCH PENETRATIONS

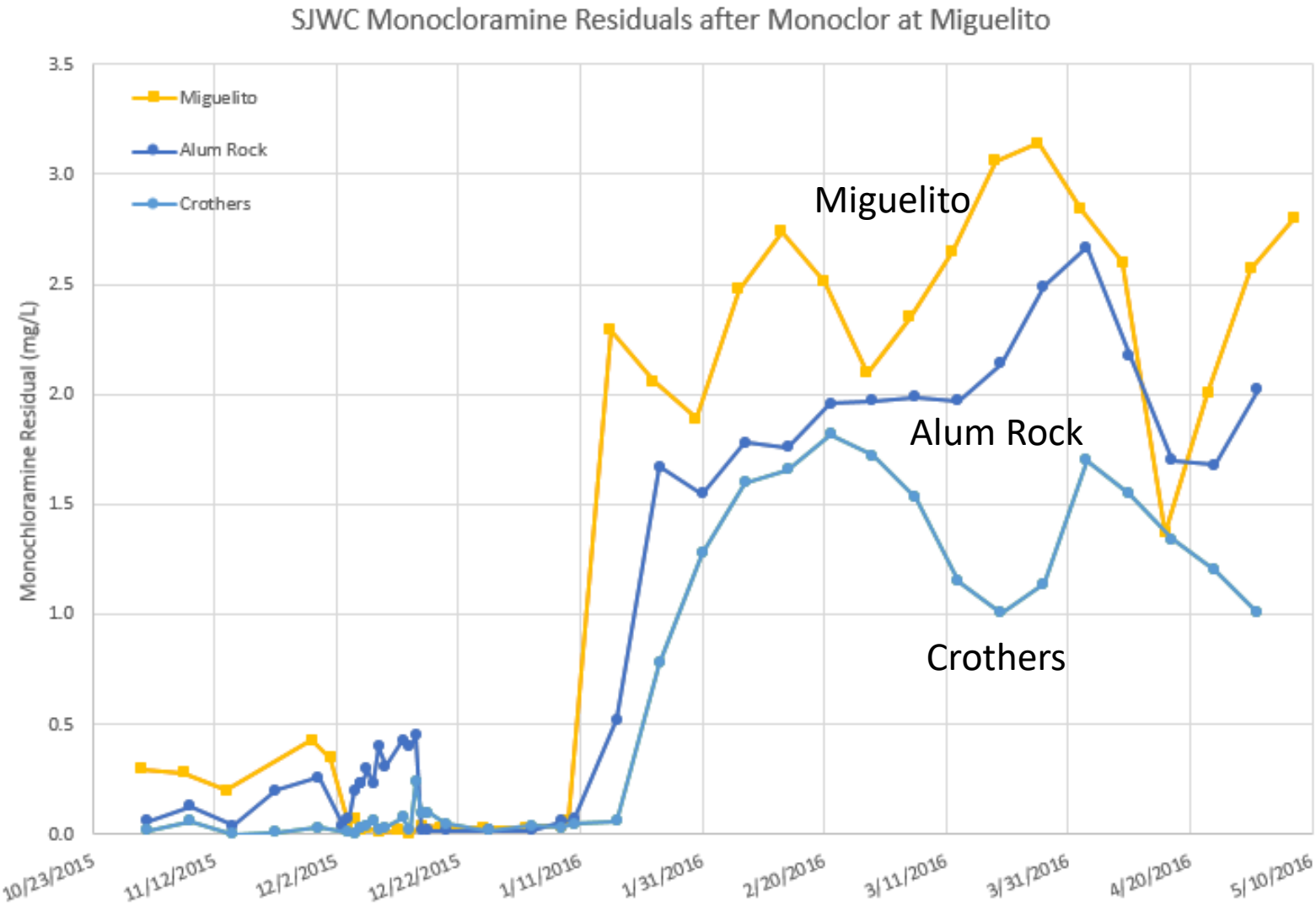
Monoclor® RCS Chloramine Management System Results

Introduction of "challenge water" volumes

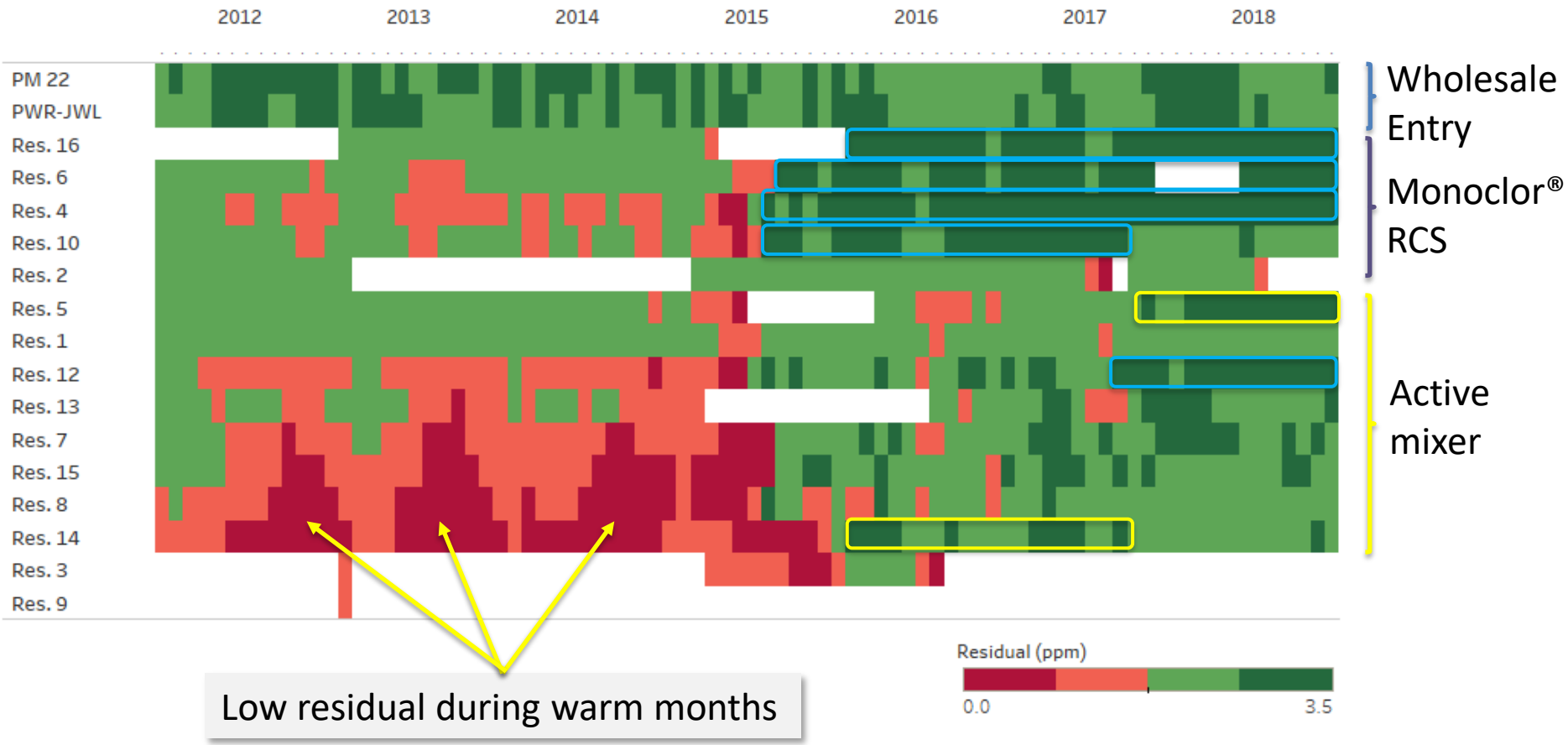


Imported water introduced in high quantities throughout the trial caused momentary and intermittent concentration changes followed by quick recovery

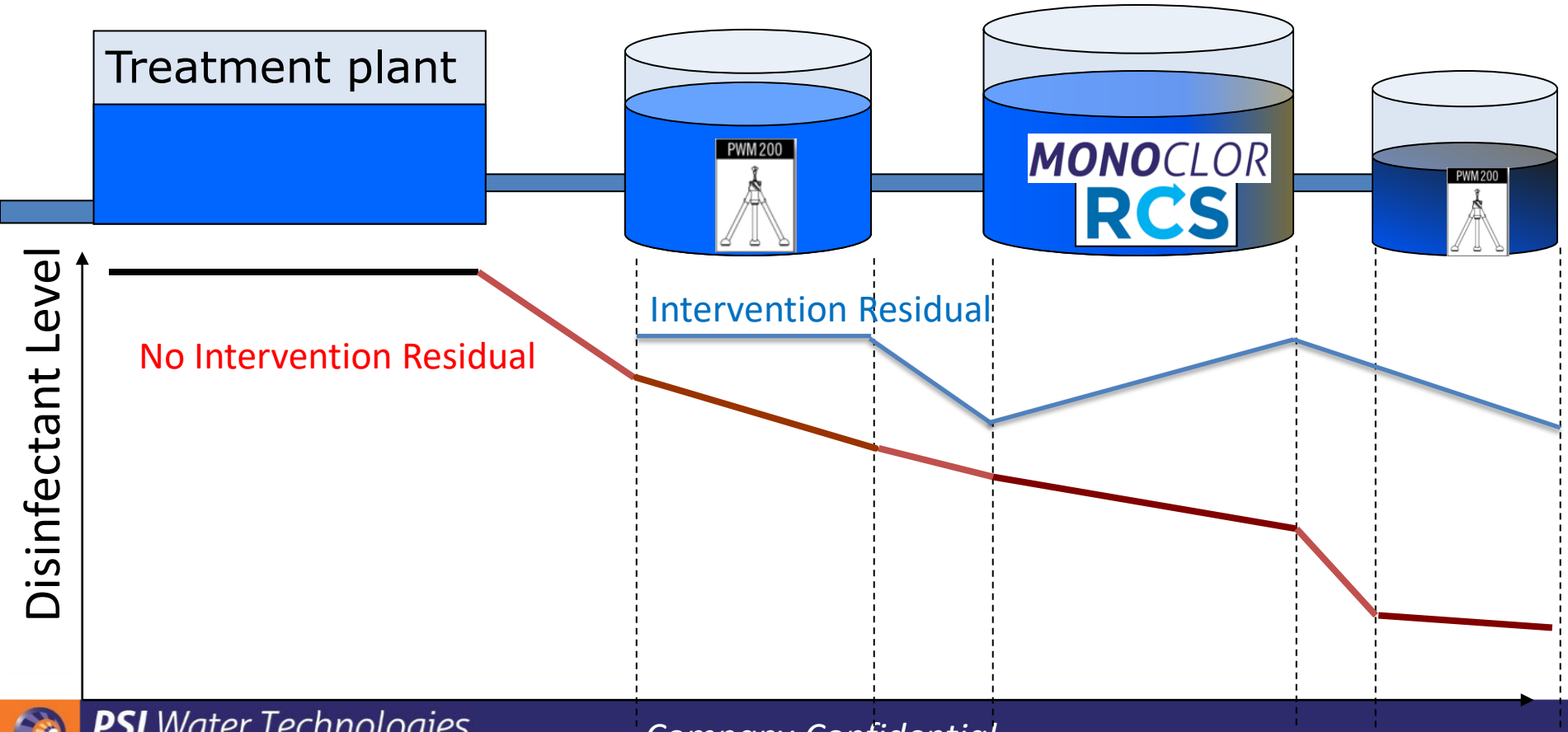
Installing a Boosting System in Miguelito Reservoirs Results in Achieving Target Residual Levels in Downstream Alum Rock and Crothers Tanks



In utility with 13 tanks, residual can be observed to improve system wide over three years (6 RCS and 13 mixers)

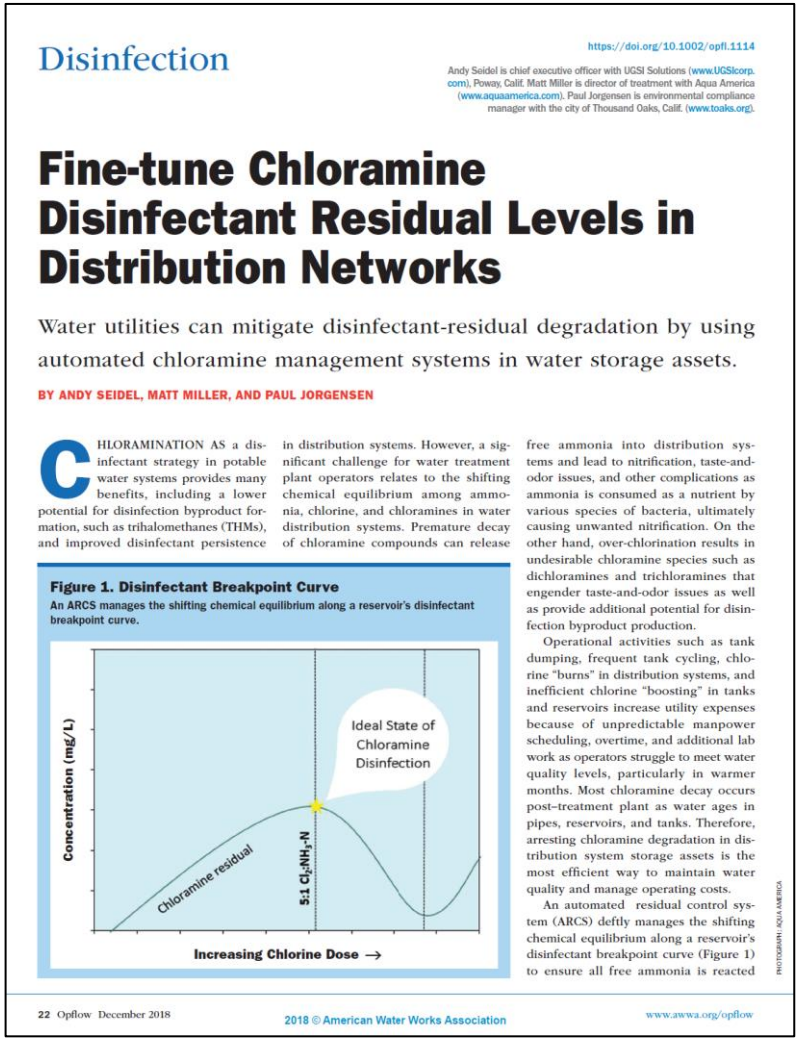


Ultimately, optimal disinfectant residual control involves a number of mitigation steps throughout a distribution network – analysis, mixing and controlled boosting



Thousand Oaks, CA – experienced chronic chloramine residual variability

Case Study



Disinfection

https://doi.org/10.1002/opfl.1114

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Fine-tune Chloramine Disinfectant Residual Levels in Distribution Networks

Water utilities can mitigate disinfectant-residual degradation by using automated chloramine management systems in water storage assets.

BY ANDY SEIDEL, MATT MILLER, AND PAUL JORGENSEN

CHLORAMINATION AS a disinfectant strategy in potable water systems provides many benefits, including a lower potential for disinfection byproduct formation, such as trihalomethanes (THMs), and improved disinfectant persistence in distribution systems. However, a significant challenge for water treatment plant operators relates to the shifting chemical equilibrium among ammonia, chlorine, and chloramines in water distribution systems. Premature decay of chloramine compounds can release free ammonia into distribution systems and lead to nitrification, taste-and-odor issues, and other complications as ammonia is consumed as a nutrient by various species of bacteria, ultimately causing unwanted nitrification. On the other hand, over-chlorination results in undesirable chloramine species such as dichloramines and trichloramines that engender taste-and-odor issues as well as provide additional potential for disinfection byproduct production.

Operational activities such as tank dumping, frequent tank cycling, chlorine "burns" in distribution systems, and inefficient chlorine "boosting" in tanks and reservoirs increase utility expenses because of unpredictable manpower scheduling, overtime, and additional lab work as operators struggle to meet water quality levels, particularly in warmer months. Most chloramine decay occurs post–treatment plant as water ages in pipes, reservoirs, and tanks. Therefore, arresting chloramine degradation in distribution system storage assets is the most efficient way to maintain water quality and manage operating costs.

An automated residual control system (ARCS) deftly manages the shifting chemical equilibrium along a reservoir's disinfectant breakpoint curve (Figure 1) to ensure all free ammonia is reacted

Figure 1. Disinfectant Breakpoint Curve
An ARCS manages the shifting chemical equilibrium along a reservoir's disinfectant breakpoint curve.

PHOTOGRAPH: AQUA AMERICA

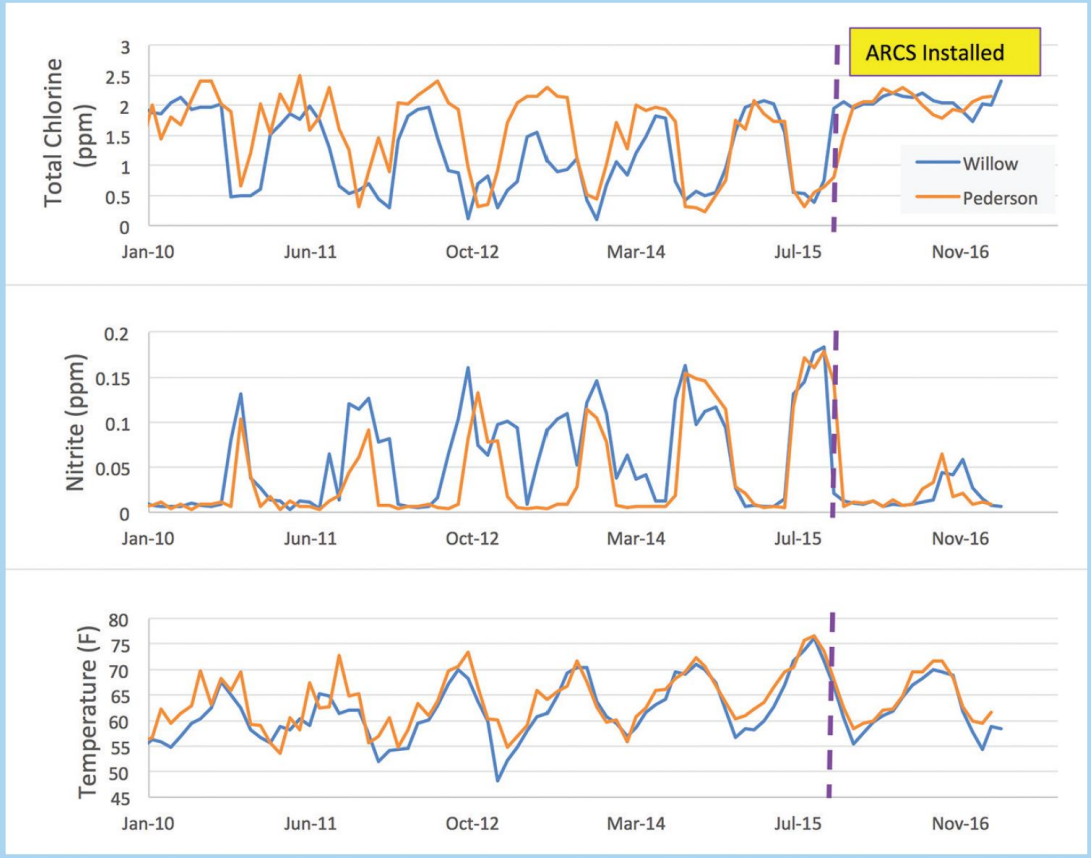
Featured in AWWA OpFlow 2018

- **Scope of Utility**
  - 51,000 Customers
  - 17,000 Service Connections
  - 230 miles of distribution lines
  - 16 Water Storage Tanks
- **Warm climate and periodic drought conditions wreak havoc on water age and water quality**
  - Nitrification risk

Despite having 10 PAX mixers, chloramine residual remained difficult to control, so the utility rented residual control trailers for two tanks for one season of residual boosting

Figure 3. Thousand Oaks' Pederson and Willow Tanks

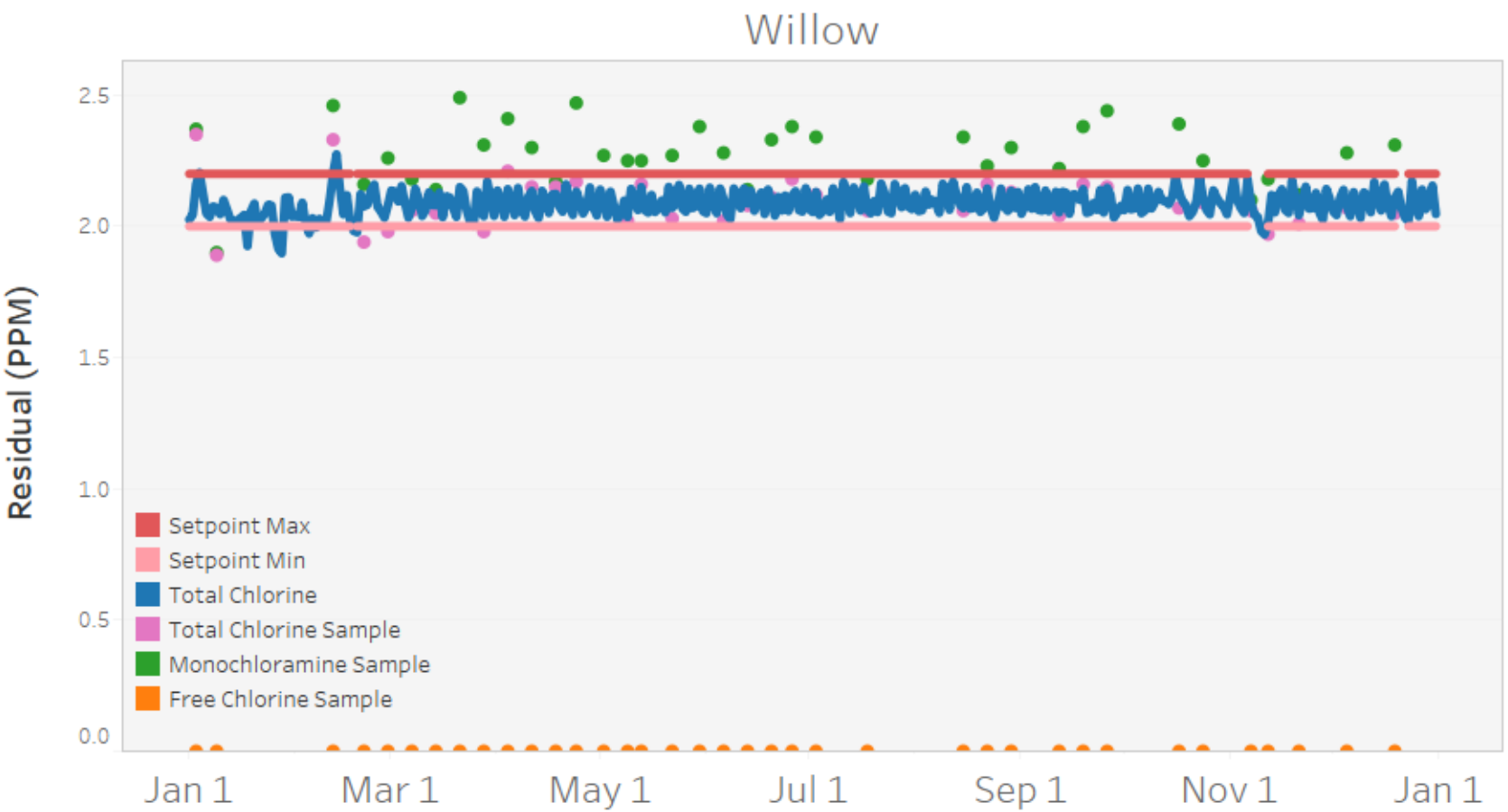
As water temperature increased, disinfectant residual decreased and nitrite formation increased as ammonia-oxidizing bacteria became more active.



Large swings in Total Chlorine eliminated with RCS trailers

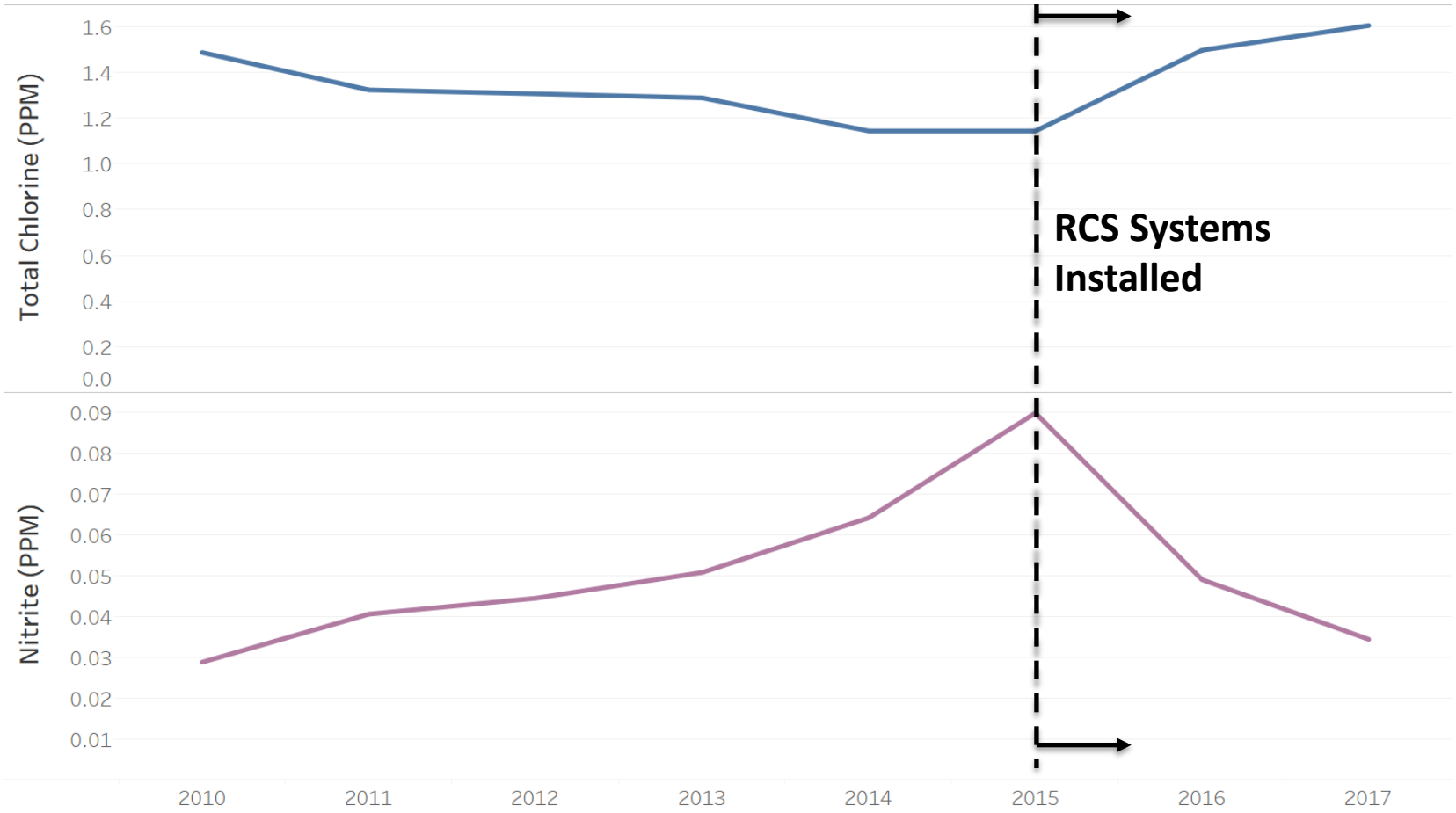
"Canary in Coalmine" nitrite levels were kept low

The rental trailers were so successful that Thousand Oaks purchased two permanent systems which control system residual today

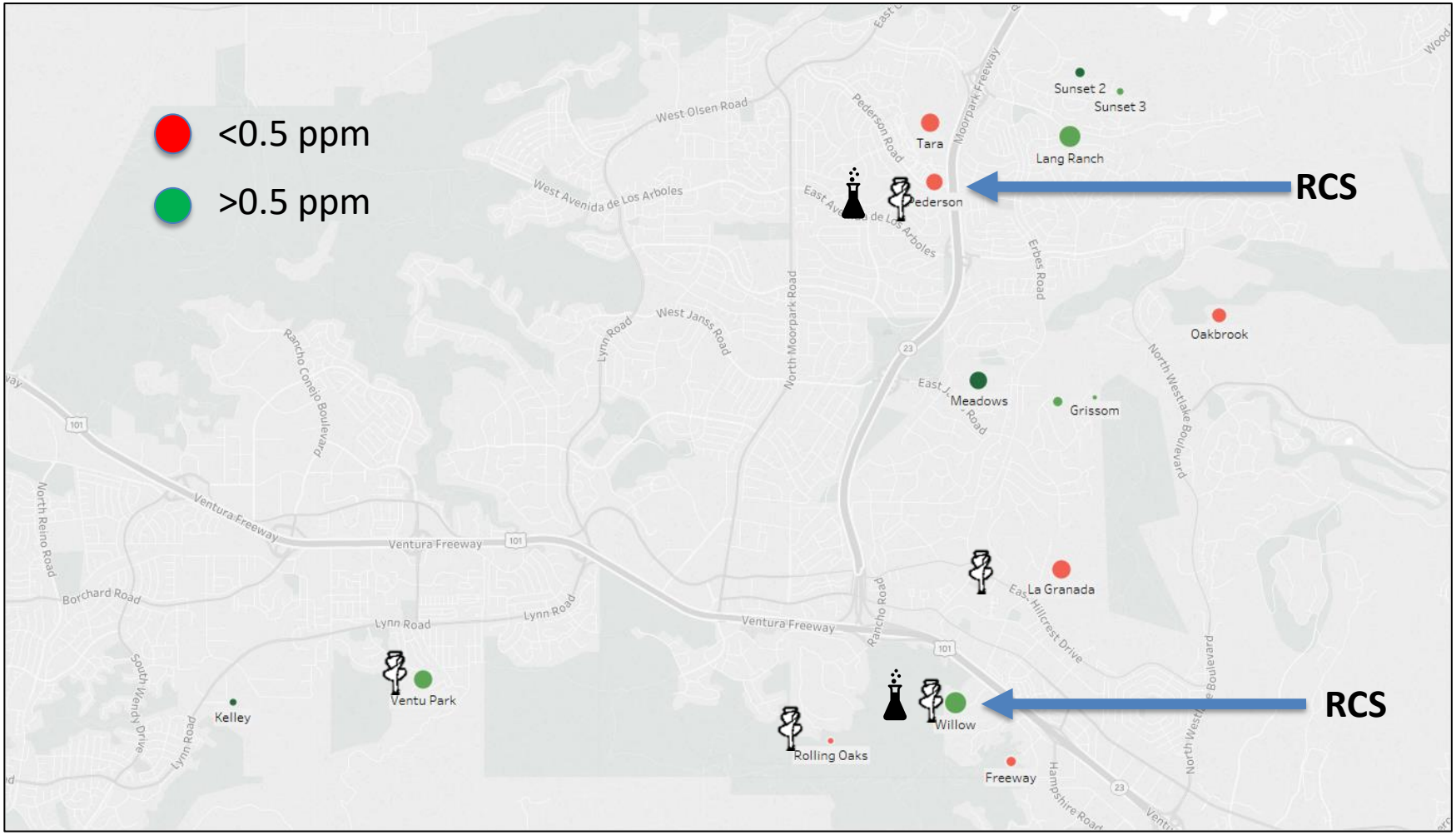


2019 Willow Tank Residual Plot Depicting 2.2 ppm Setpoint Being Maintained

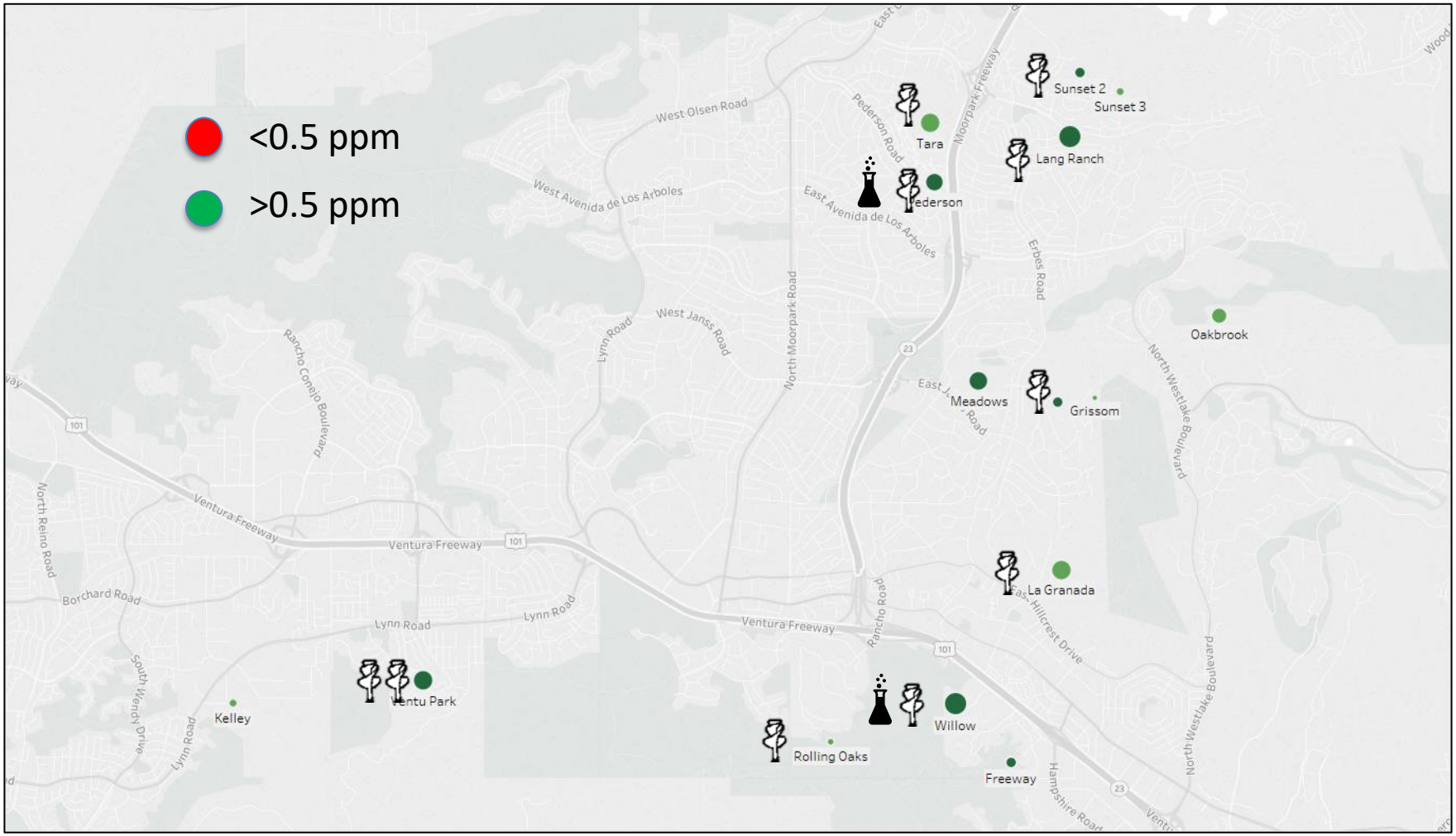
System wide annual average: water quality has improved significantly since 2015



Distribution Map (2015): Purchased 5 PAX mixers and *rented* 2 Monoclor® RCS trailers



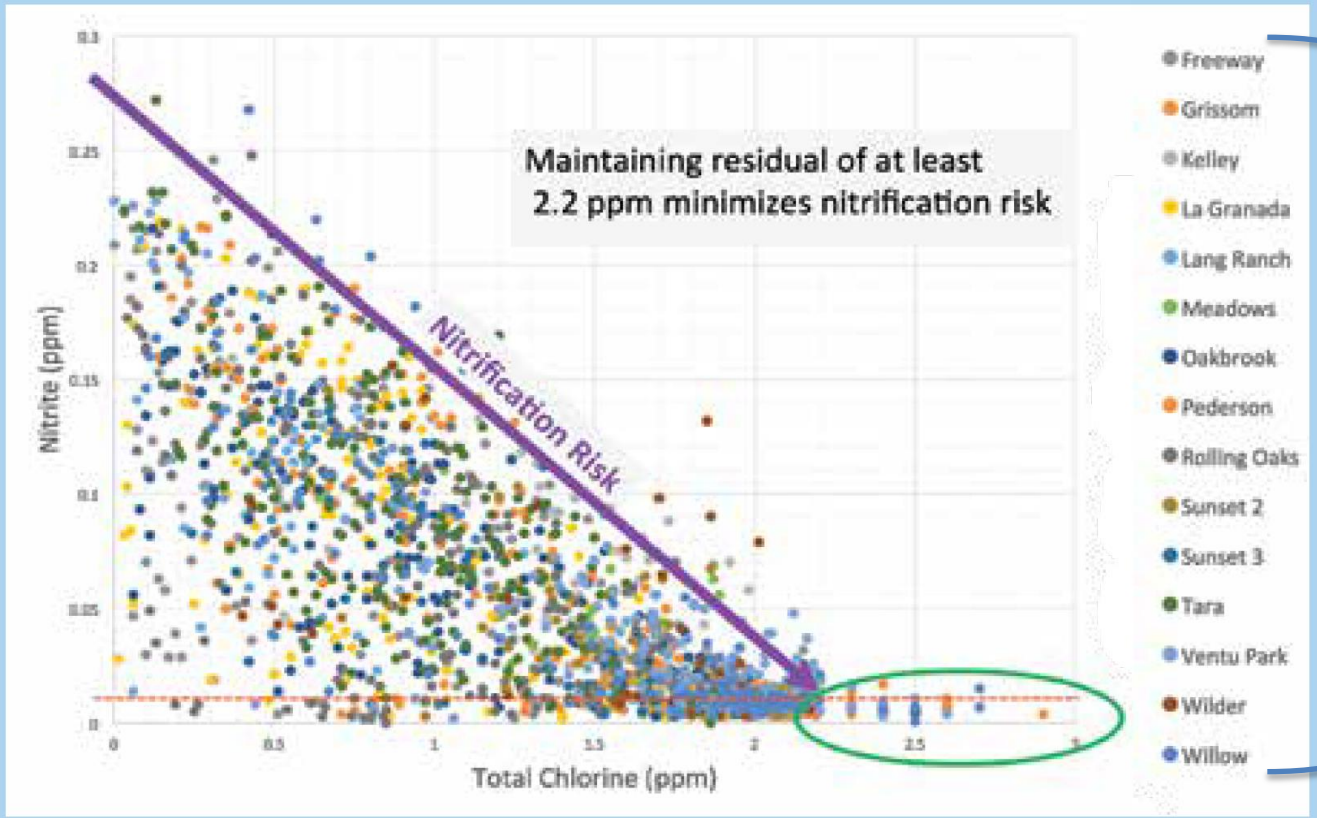
Distribution Map (2017): System wide water quality improved after purchase of additional 5 PAX mixers and 2 Monoclor® RCS systems



By examining multiple years of compliance data, we were able to observe that a 2.2 ppm residual would remove system nitrification risk

Figure 4. Chlorine vs. Nitrite

By plotting the aggregated sample data for all tanks, Thousand Oaks can forecast a system average residual that can eliminate any nitrification risk.



Data from 16 Tanks

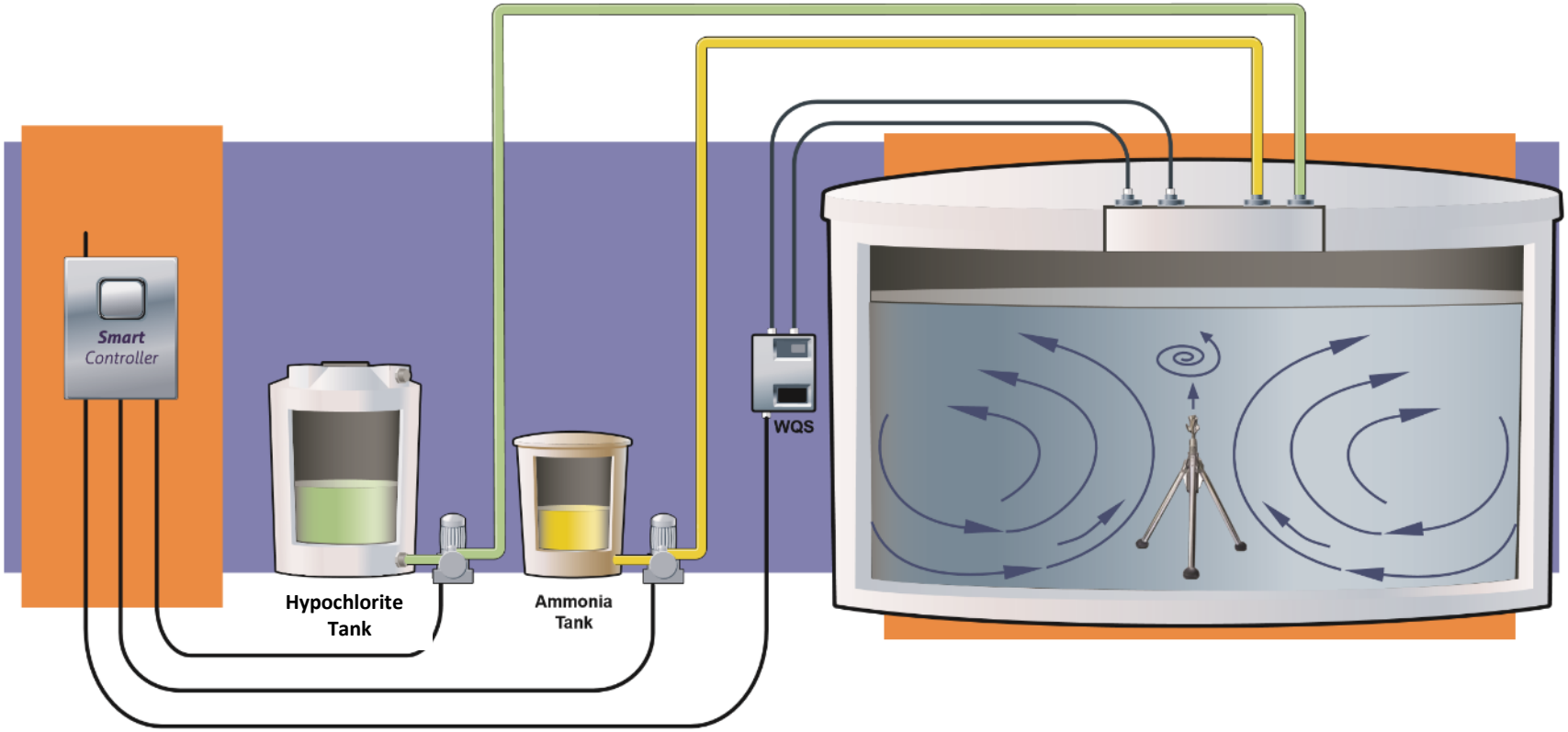
Coppell, TX: chloraminated consecutive system with chronically low residual

Case Study

1.5 MG (5.7 ML) Elevated Storage Tank

- Low residual (0.42 mg/l – regulatory minimum is 0.5 mg/l)
- Nitrification risk
- Periodic flushing; 66 MG (250 ML) in 2015
- Periodic breakpoint chlorination (creating THM risk)

Chloramine residual control systems can take on a number of different configurations depending on tank particulars and client preferences

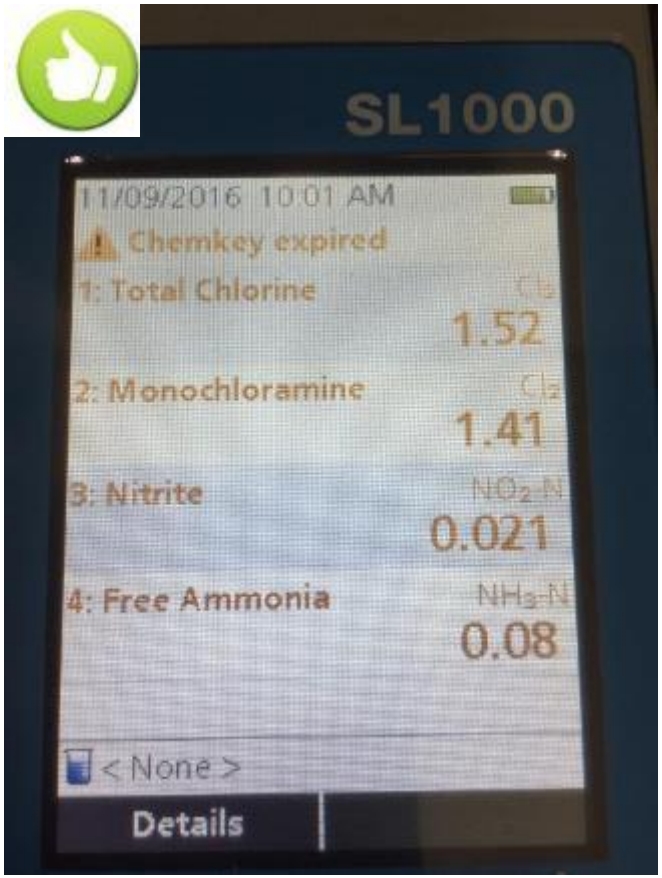


Controlling chloramine residual levels in-tank reduces nitrification risk

Before

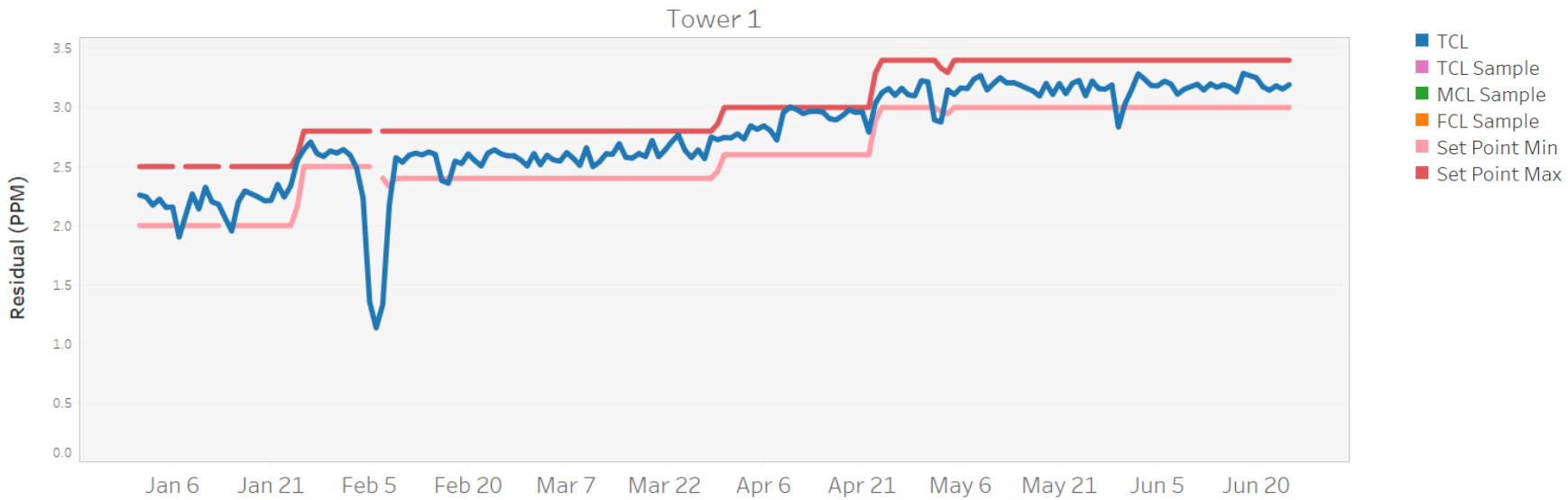
Low residual with incipient nitrification

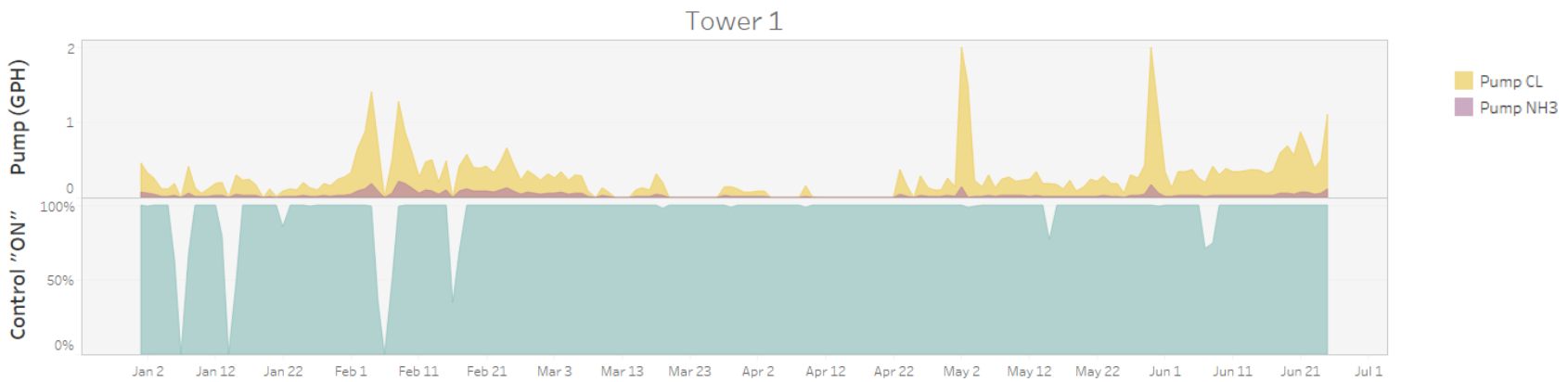
After



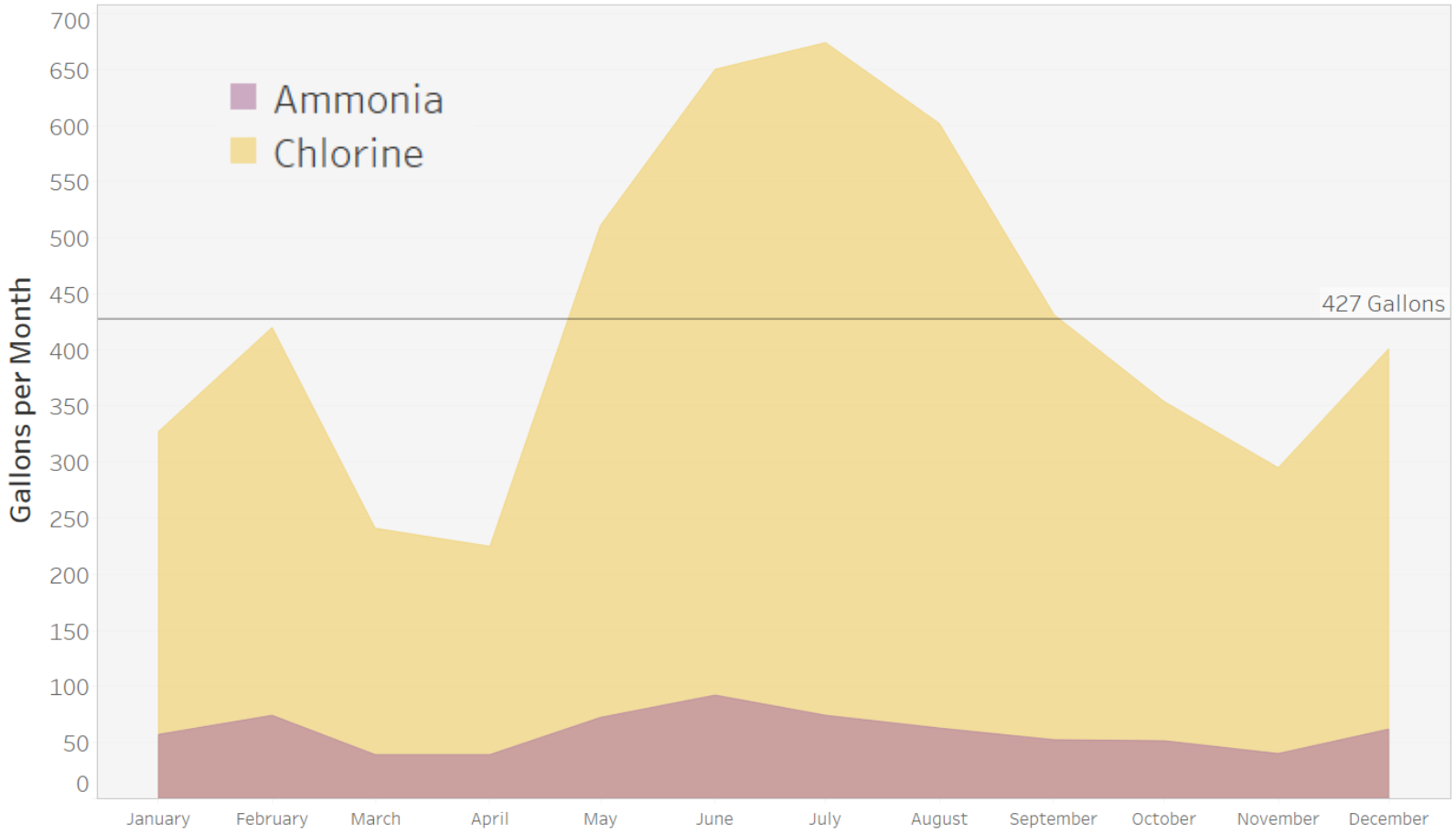
Residual in control
With no nitrification

2018 residual data at Southwestern Tank #1 illustrates ability to boost setpoint during difficult summer months





Chemical usage shows seasonality: Peak during the summer months – high chlorine use indicates more free ammonia from wholesaler in warmer months



Coppel, TX: Monoclor® RCS hardware included structures, analytics, controller, mixer and chemical feed

1.5 MG elevated tank

Water Quality Station (WQS)

Smart Controller

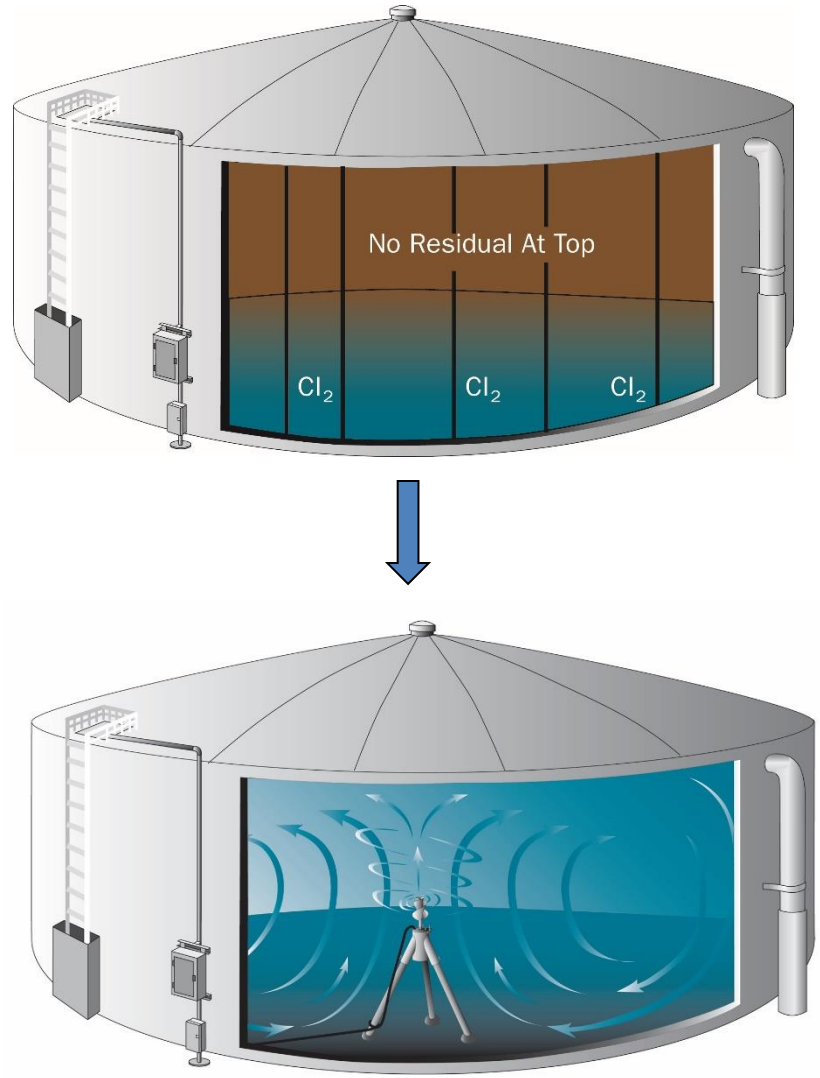
PWM 500 Mixer

CL feed skid
(Bulk Hypochlorite)

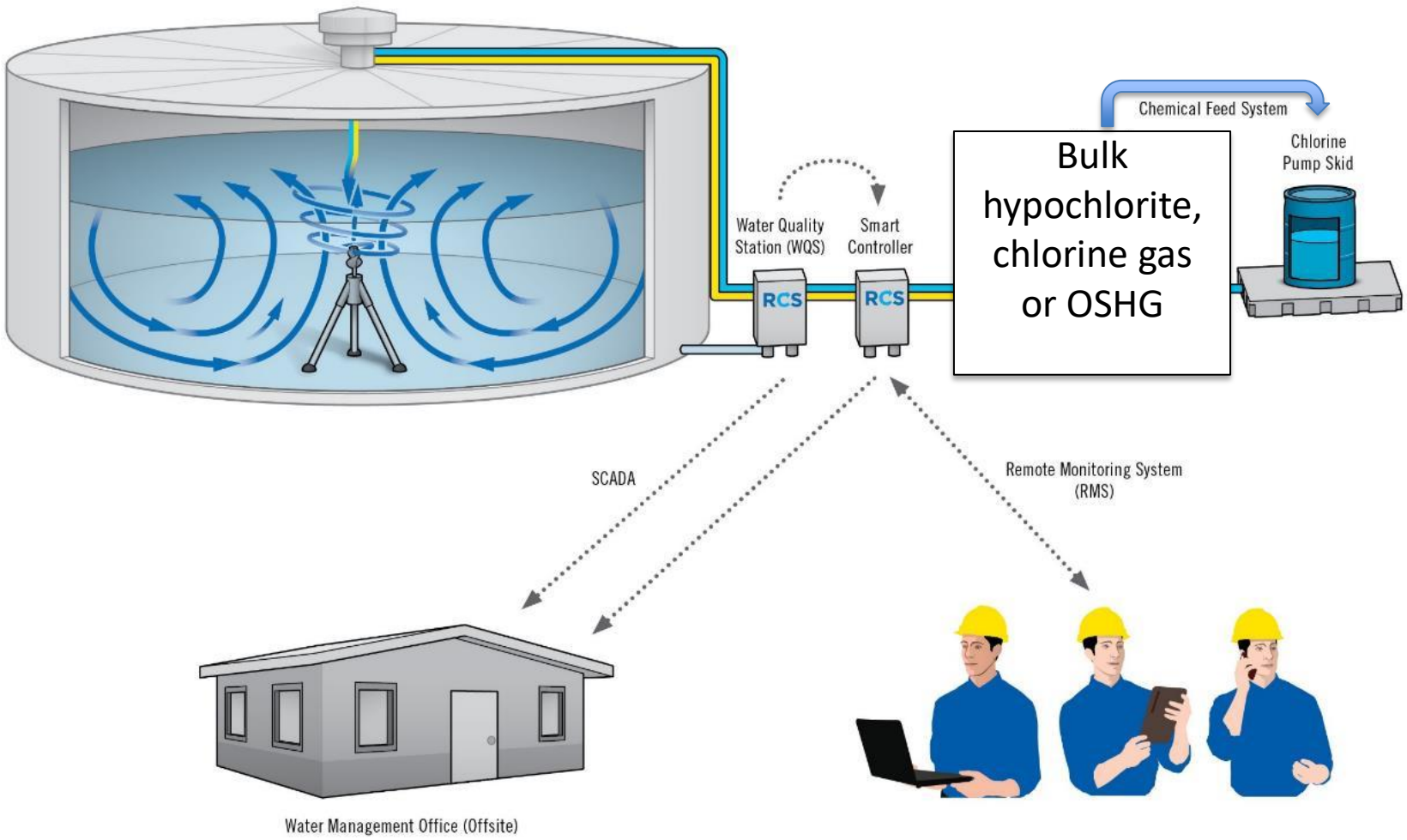
NH_3 feed skid
(LAS – liquid ammonium sulfate)

Utilizing water storage tanks as chlorine residual intervention points is a best practice; more effective than "in-line" boosting

- Tanks are a source of chlorine demand (sediment, bio-film etc.) – solve issue at source
- Tank volume provides a convenient "buffer" allowing a safe place to add chlorine and monitor before subsequent network experiences chlorine dose
  - Allows option to valve-off
  - Allows holding for adjustment
- Mixing of entire volume is ensured versus dosing into a pipe



A “Smart Tank” with residual control automatically adjusts disinfectant residual to a pre-determined set-point and maintains that set-point with beneficial water quality impact to the zones it serves

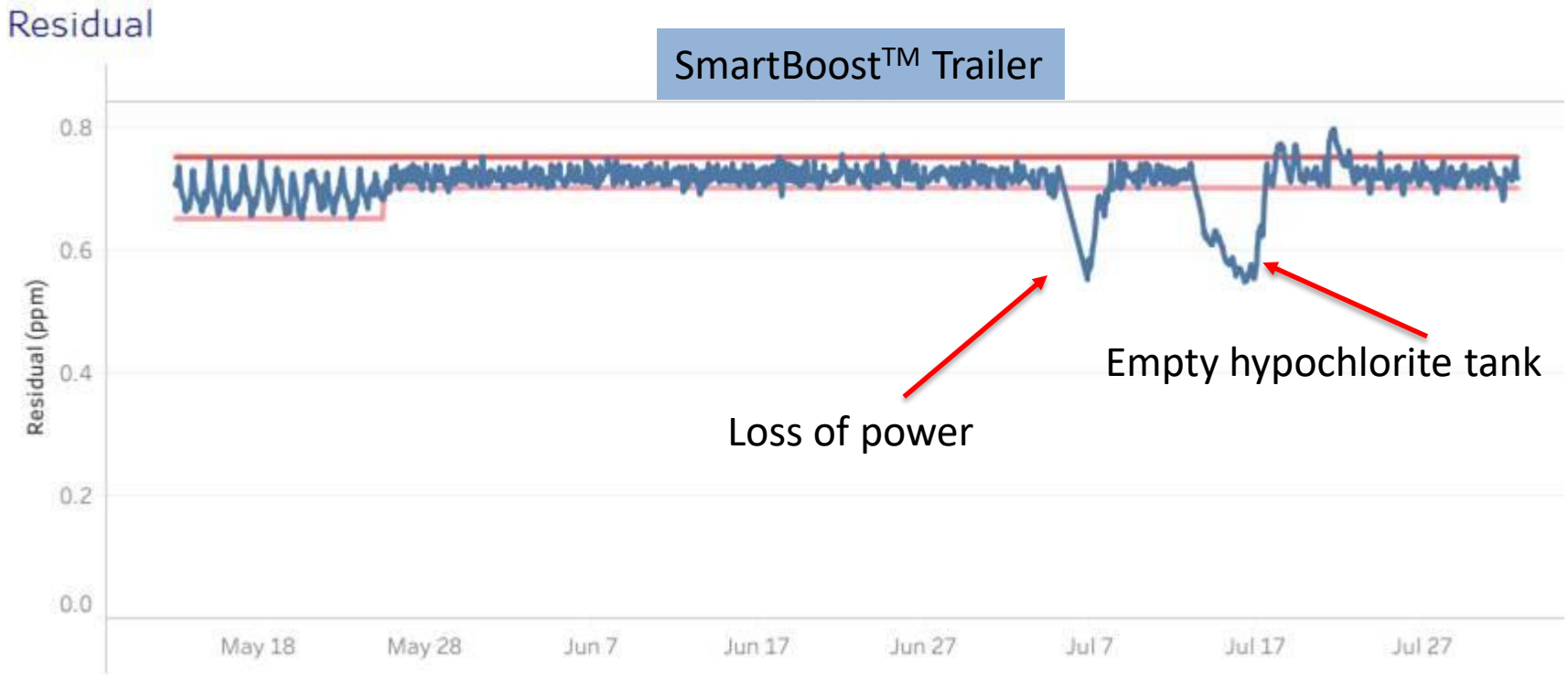


Halifax, Canada – 9 MG ground storage tank with consistent chlorine residual issues (influent was 0.7ppm with decay to 0.3ppm in warmer months)

Case Study

Demonstration **SmartBoost™** trailer in summer of 2018 managed residual to desired 0.7 ppm immediately

- 100 gpm Tank Shark® mixer
- Microclor® 60 PPD OSHG as free chlorine source



THM Removal Systems

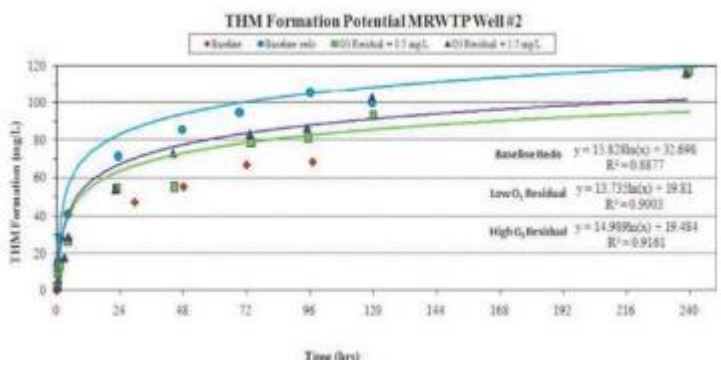
Removing THMs by Storage Tank Aeration and Mixing

Utilities have no "free lunch" as the choice of secondary disinfectant will determine the problems they will contend with:

Secondary Disinfectant Choice

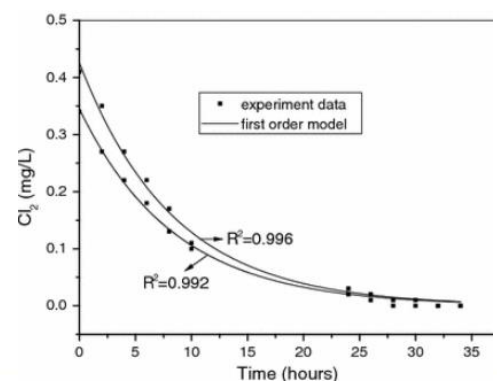
Free Chlorine

- Boosting to offset degradation
- DBP (THM and HAA5 issues) **formation**



Chloramines

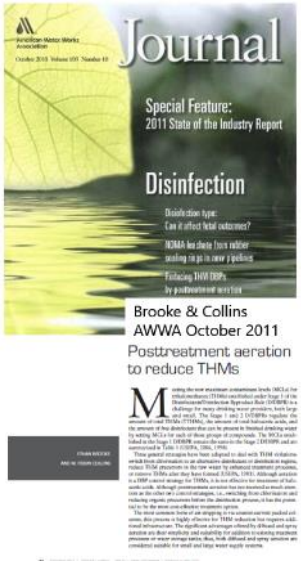
- Chloramine **degradation** (ammonia formation)
- Nitrification (nitrite and nitrate MCLs)

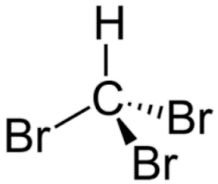


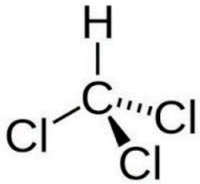
Trihalomethanes (THMs) – Long history of contaminant regulation

"The Total Trihalomethane Rule was the first modern drinking water regulation (USEPA, 1979). It established the precedent for a new regulatory methodology that is now standard procedure" ***Victor J. Kimm, USEPA Head of Drinking Water Program 1975-1985***

- 3 of 18 US Drinking Water Rules are on THMs
- US EPA Stage 2 DBP Rule mandates an ***80 ppb*** MCL based on a sample location running average (LRAA)
- THMs are second leading cause of MCL violations after BAC-T







International Agency for Research on Cancer

World Health Organization

** HAA5 – Haloacetic Acids cannot be mitigated through aeration techniques*

There are four general strategies to deal with THMs: change disinfectant (to chloramines), reduce NOM (naturally occurring organic material), reduce water age, or remove THMs after they form

PAX TRS™ removes THMs by tank aeration after they form

TIME

+

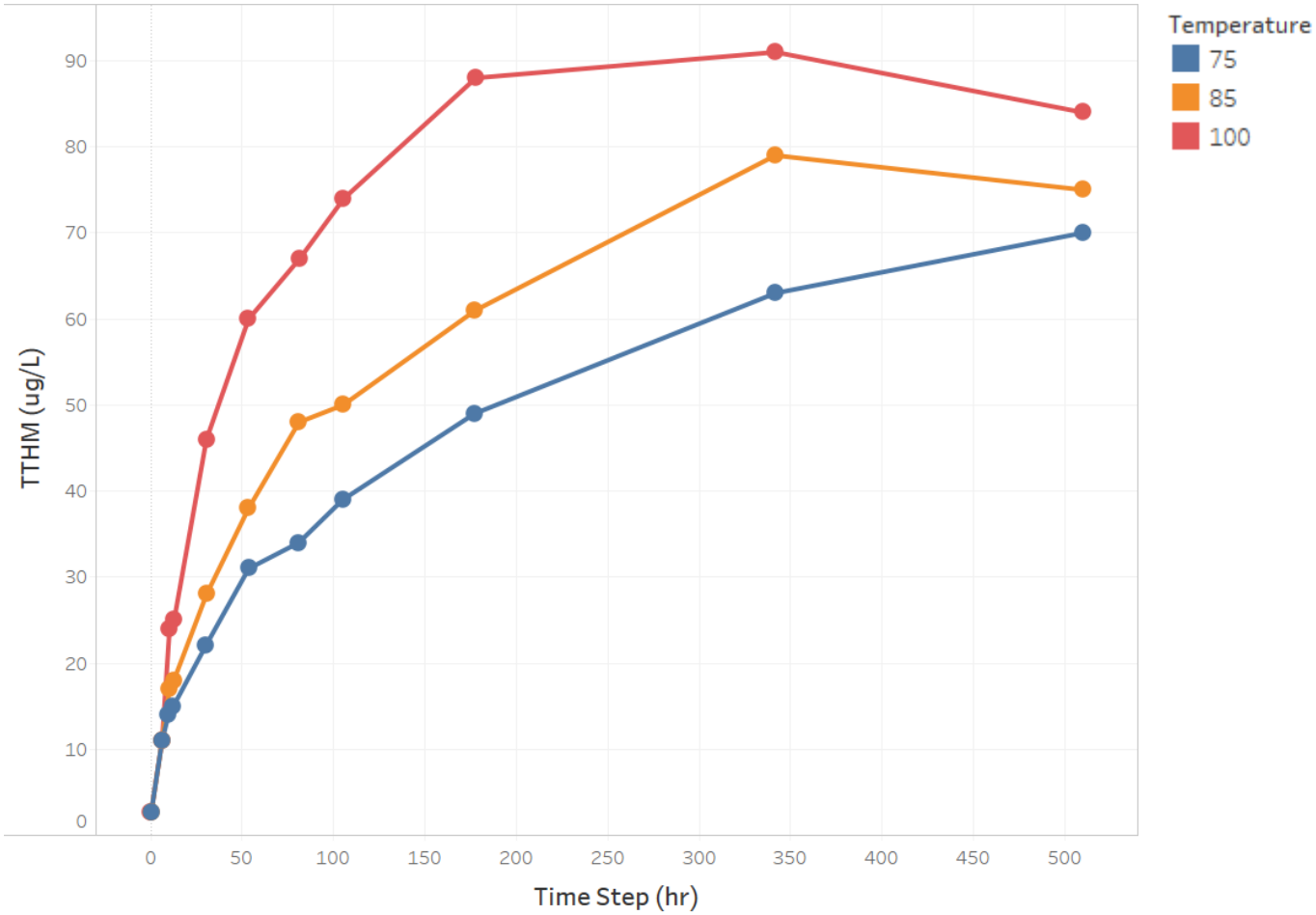
=

Free Chlorine (Cl)

Natural Organic Matter (NOM)

Disinfection Byproducts (DBP)

THMs form faster at higher temperatures



THMs are volatile … just like CO_2

- THMs would rather be in gas phase than liquid phase
- The ***driving force*** for mass transfer from liquid phase to gas phase is based on a difference in concentration between THMs in the water and THMs in the air
- THMs can build up in the headspace of a tank if its not actively ventilated, stopping THM volatilization (Henry's Law)
- Optimizing a tank to volatilize THMs can be simple or complex, depending on the tank conditions, the amount of treatment needed and energy constraints/cost

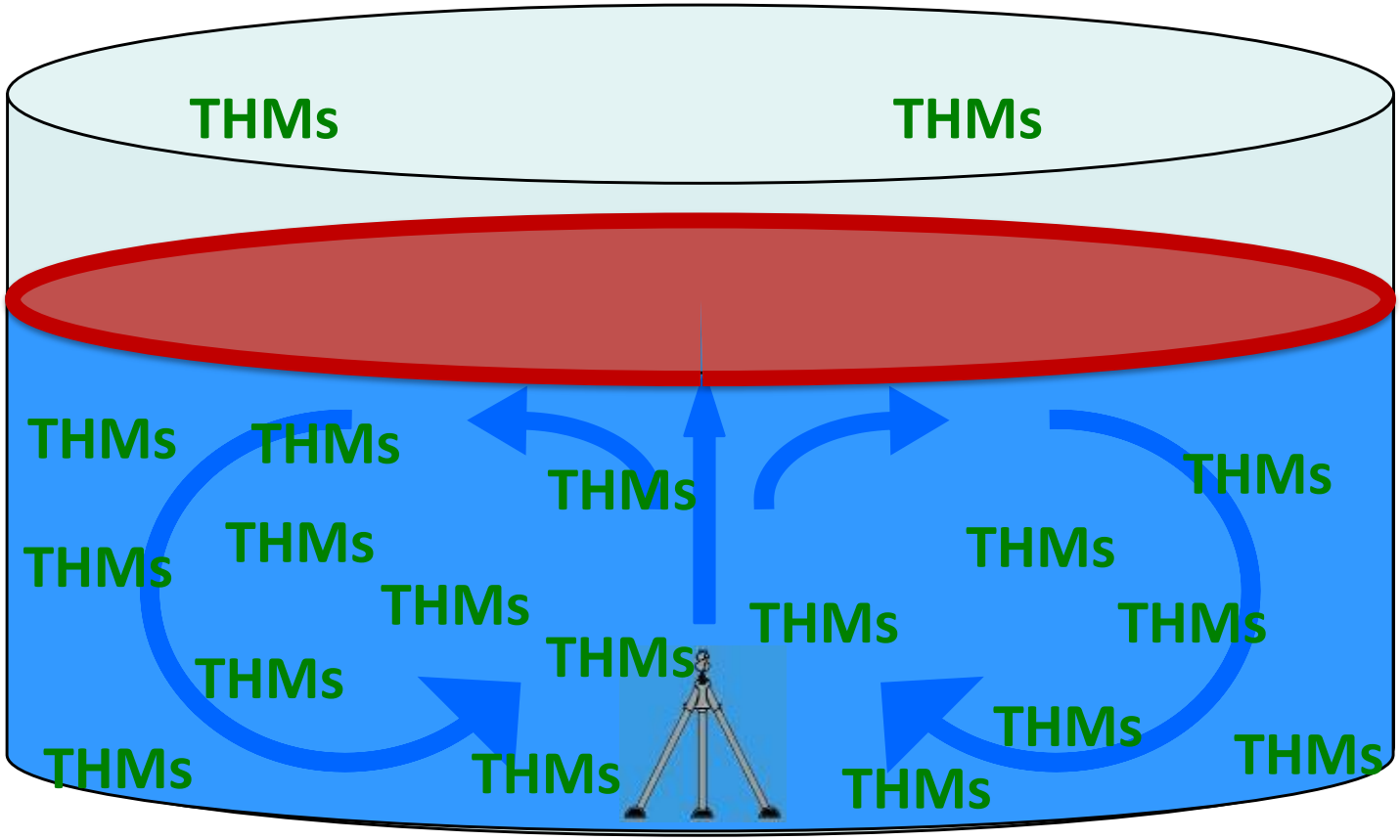
Henry's Law constants dictate the percentage of THM's that can saturate the tank head-space – ***in equilibrium***

THM species	Henry's law constant @ 20 °C
Chloroform	0.13 (87% in water)
Bromodichloromethane	0.08
Chlorodibromomethane	0.04
Bromoform	0.02 (98% in water)

Chloroform is the most "volatile" (easiest to remove)

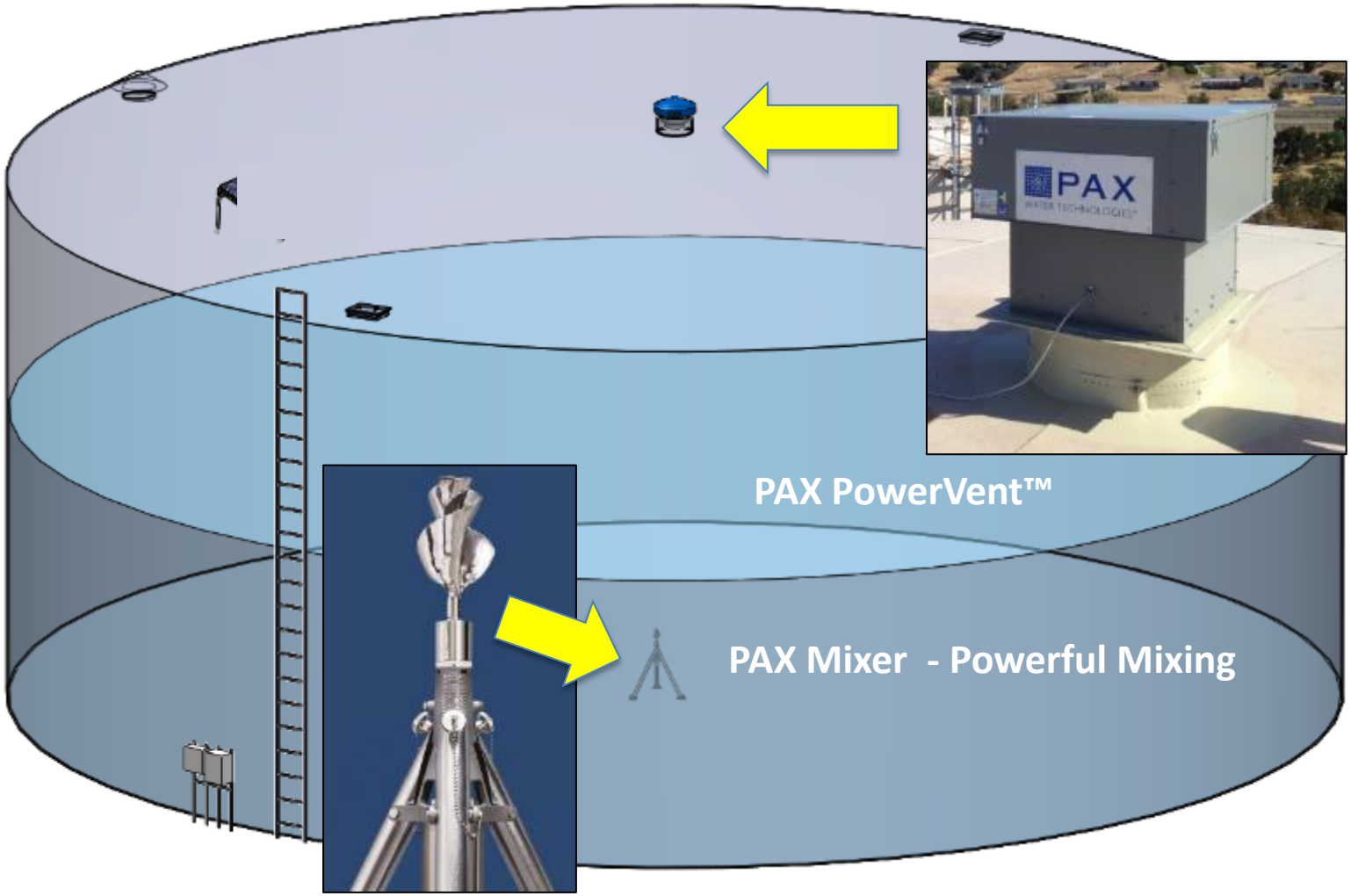
Bromoform is the least "volatile" (hardest to remove)

Henry's Law limits passive THM removal, but active mixing allows THM's to bridge the diffusional barrier

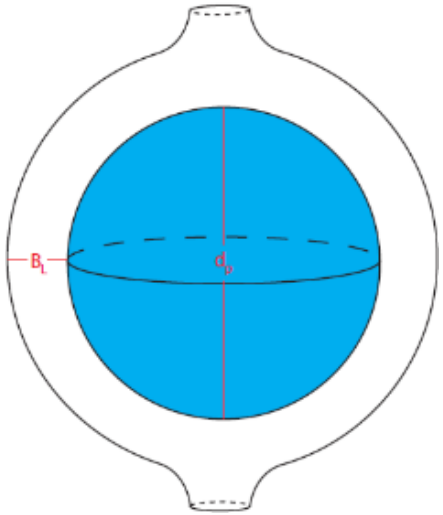


But you need <u>STRONG</u> mixing

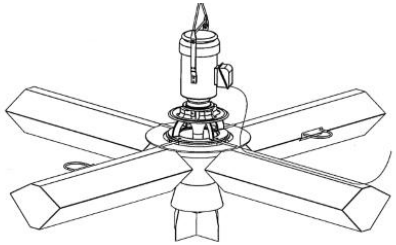
Adding active ventilation breaks Henry's Law Equilibrium in tank head-space



THM removal systems need three equipment components to effect removal:



OR



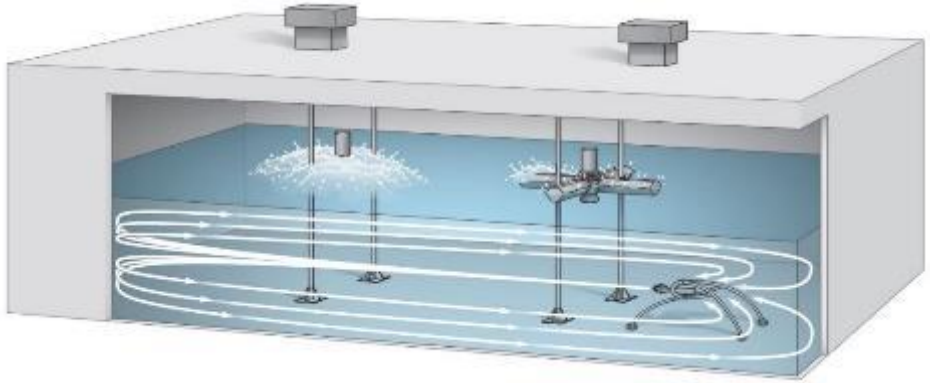
Mixer: Continually introduces THM laden water to the air-water interface

PowerVent™: Blows fresh air into the tank, exhausting THM laden air and providing the driving force for mass transfer

Air-water interface: Surface or **spray aeration** equipment increases available water surface area for additional mass transfer

There are three common in-tank aeration configurations for THM removal

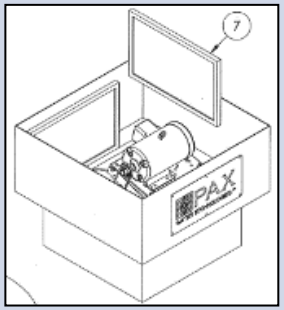
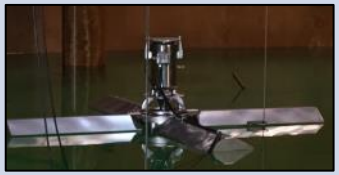
Mixer + PowerVent™



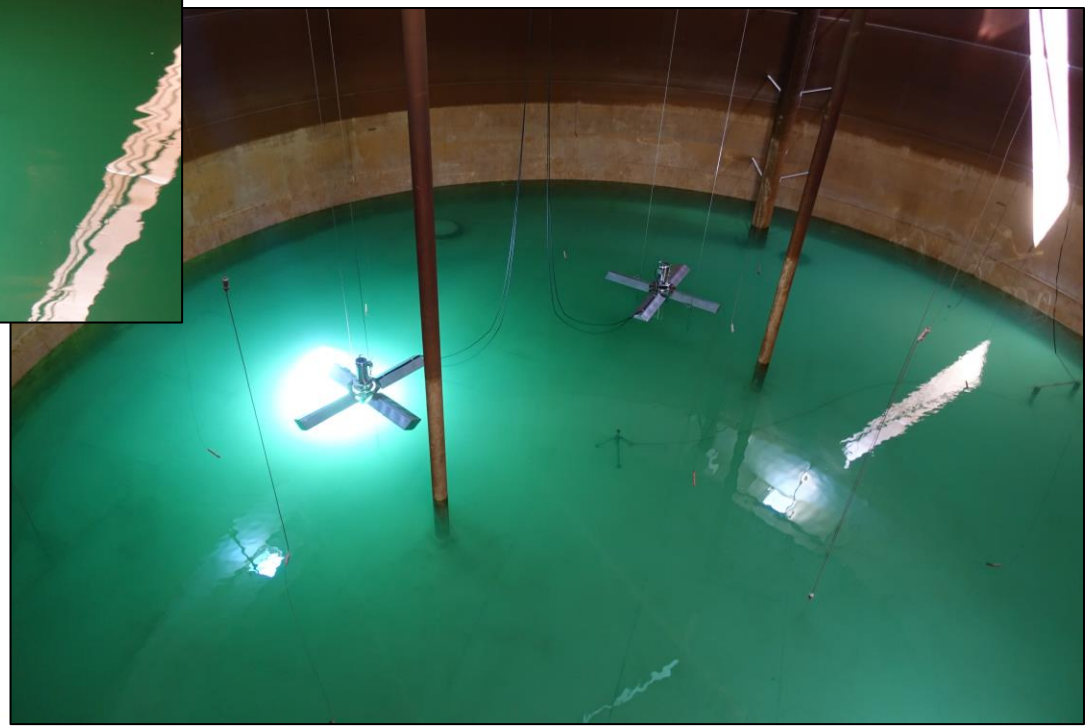
Surface Aeration

Spray Aeration

Multiple hardware options are available based on process objectives and site-specific issues

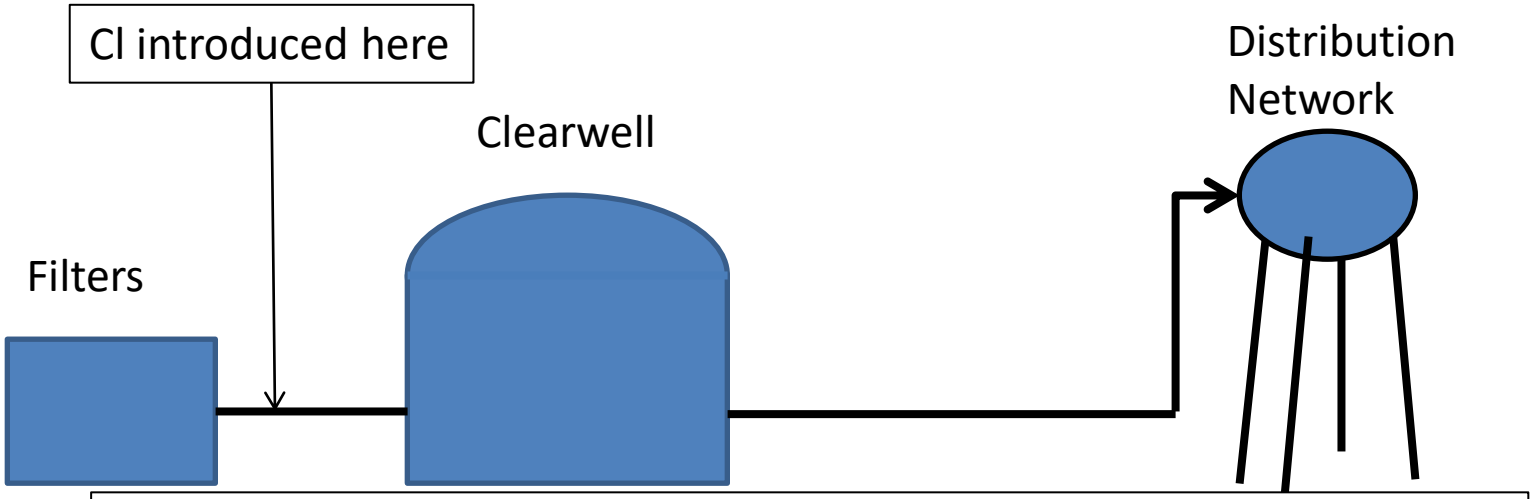
Tank Mixers	Active Tank Ventilation	Aeration Equipment	THM Analyzers	Controls
 	 	 	 	 

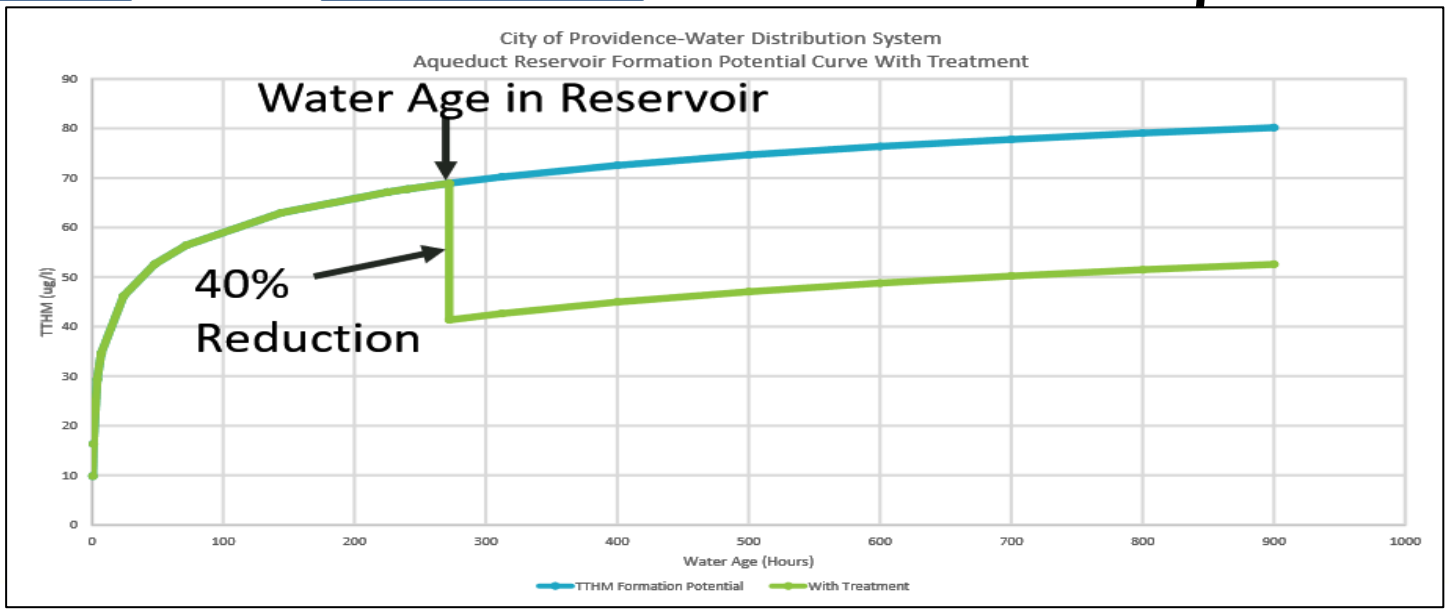
PAX TRS™ aerator installations are straightforward and do not require extensive tank modifications (crane is required)



Western Water (10 ML tank) near Melbourne, Australia ~ 35% TTHM removal (ADWG limits are 250 ppb)

Achieving THM reduction across a system requires treatment at different points with treatment at the clearwell or at tanks





Case Study

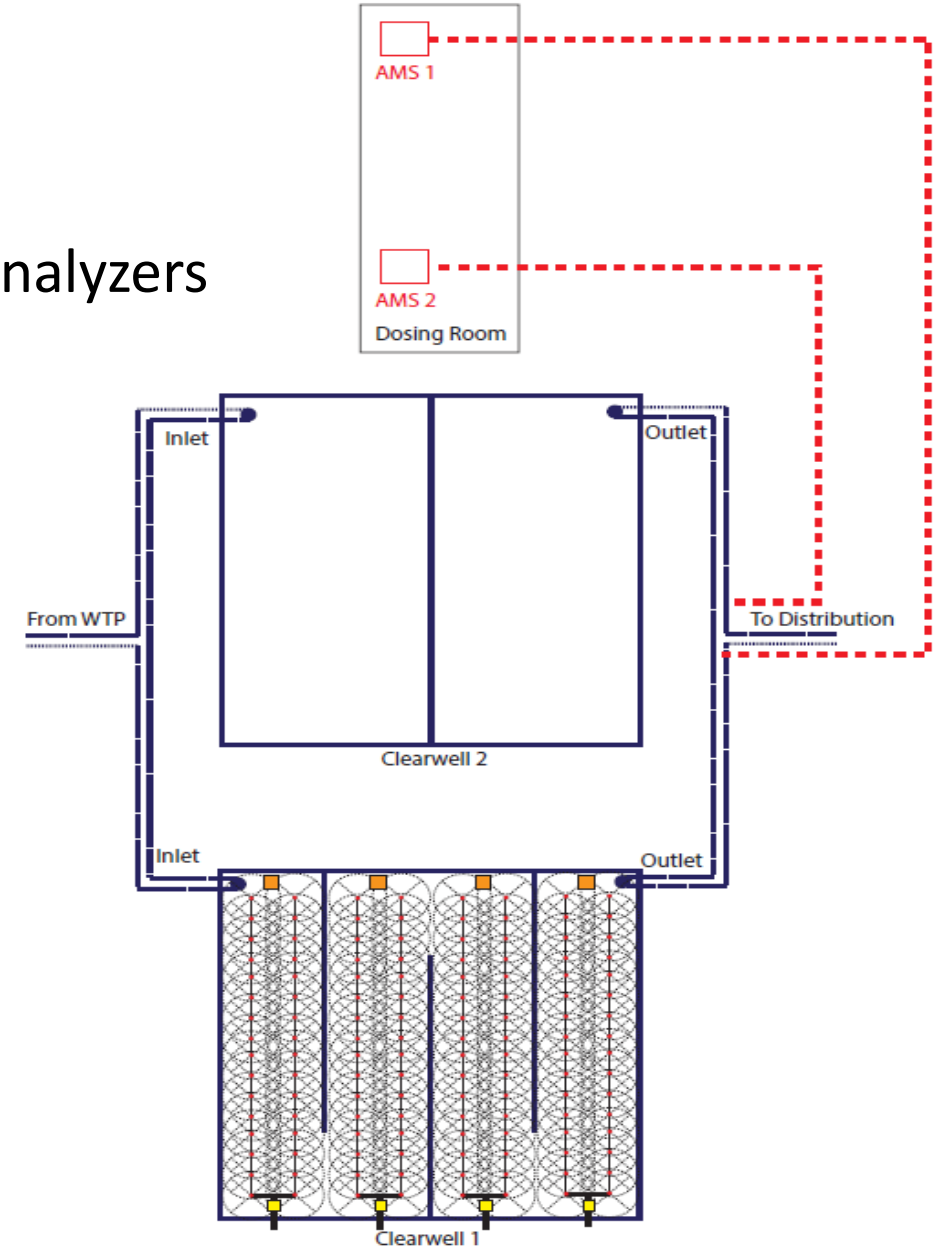
Oban, Scotland

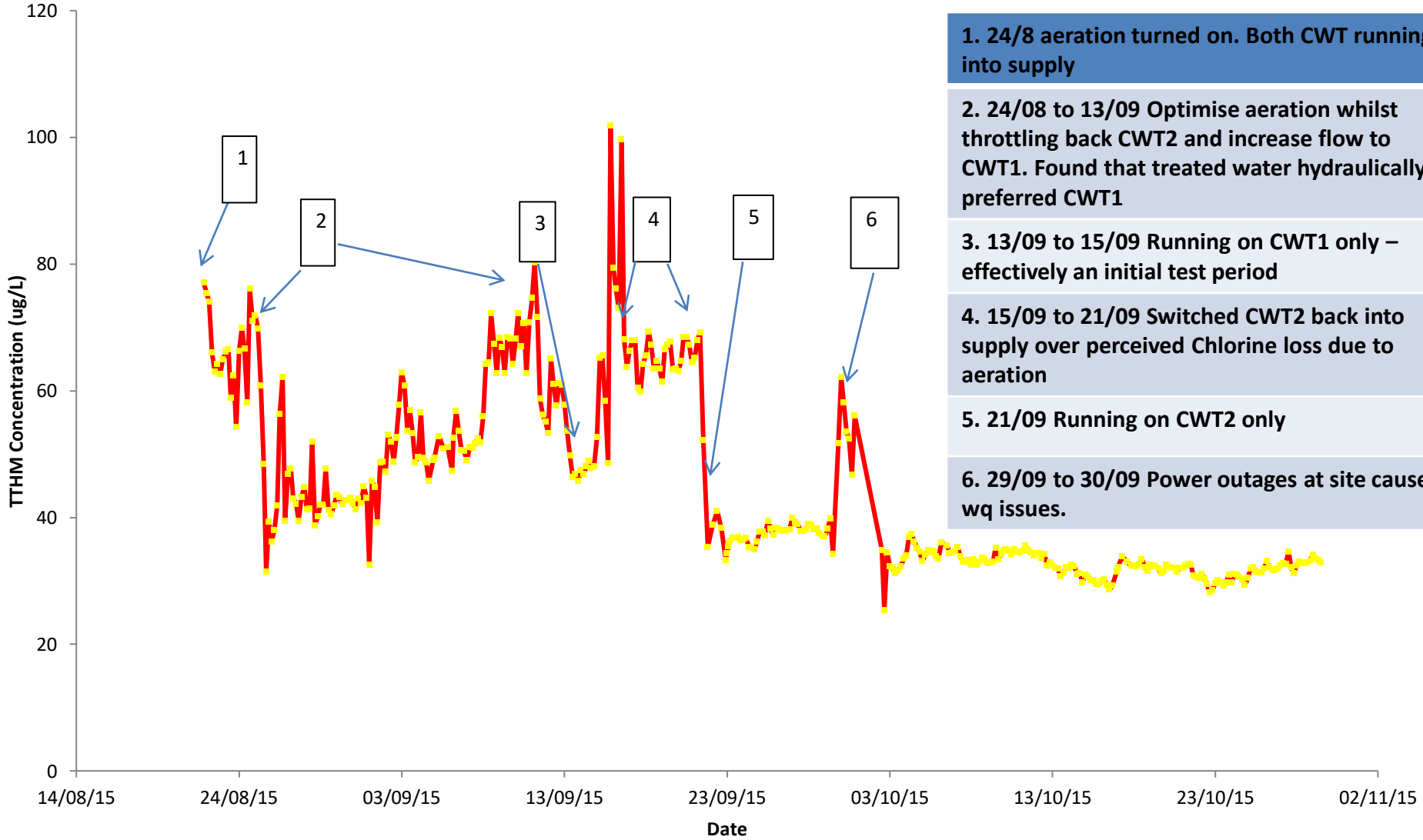
Principal Design Variables

Name	Clearwell
Tank Volume	2.25M liters
Tank Dimensions (L X W)	19 m x 24.8 m
Tank Height (TH)	14.6 m
High Water Level	14.0 m
Low Water Level	1.0 m
Turnover	9.6M liters
Target for THM removal [%]	50%

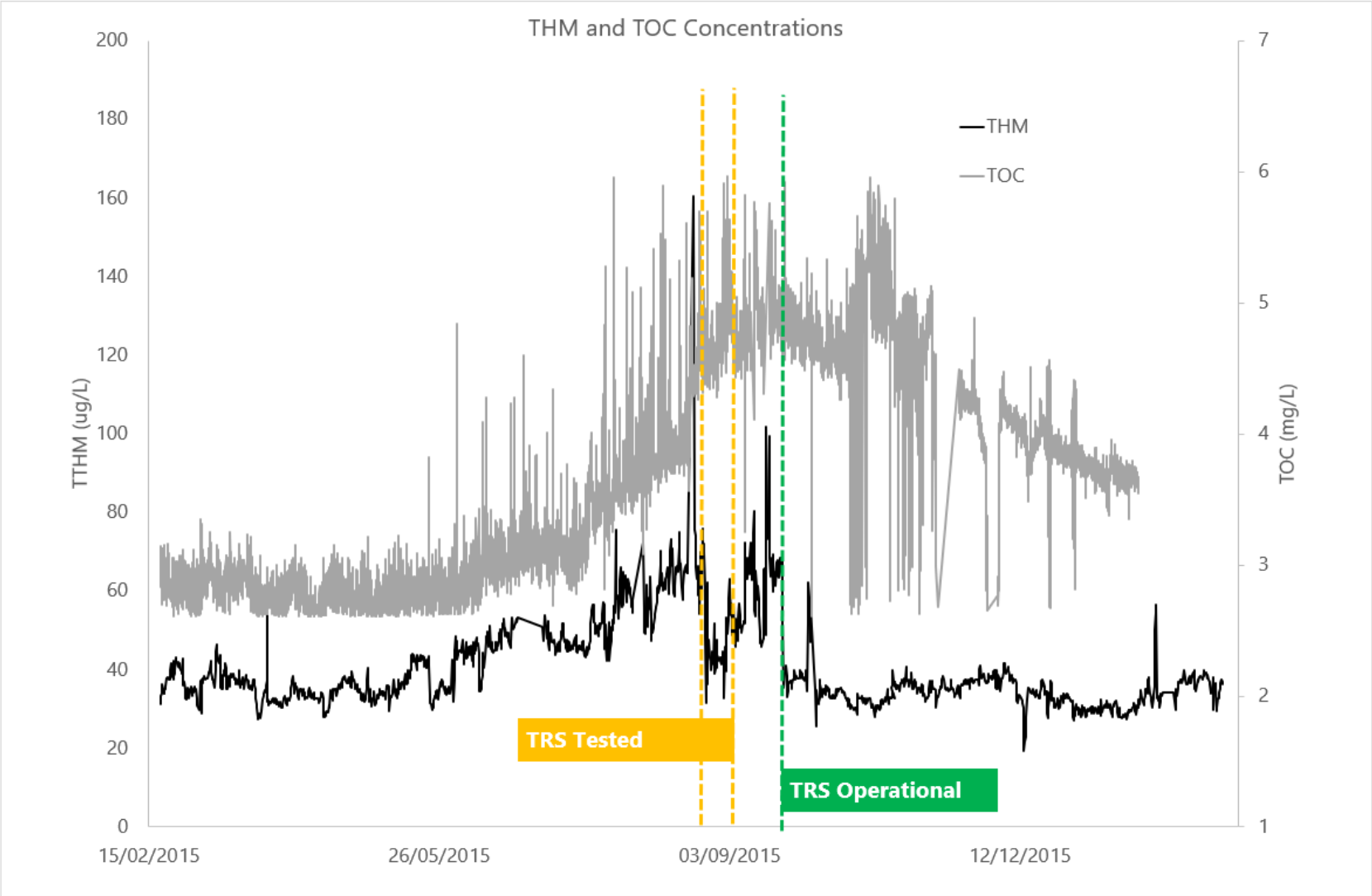
Site Layout

- Two Cells
- Two AMS THM Analyzers





1. 24/8 aeration turned on. Both CWT running into supply
2. 24/08 to 13/09 Optimise aeration whilst throttling back CWT2 and increase flow to CWT1. Found that treated water hydraulically preferred CWT1
3. 13/09 to 15/09 Running on CWT1 only – effectively an initial test period
4. 15/09 to 21/09 Switched CWT2 back into supply over perceived Chlorine loss due to aeration
5. 21/09 Running on CWT2 only
6. 29/09 to 30/09 Power outages at site caused wq issues.


THM and TOC Concentrations
TTHM (ug/L)
TOC (mg/L)
THM
TOC
TRS Tested
TRS Operational
200
180
160
140
120
100
80
60
40
20
0
7
6
5
4
3
2
1
15/02/2015
26/05/2015
03/09/2015
12/12/2015

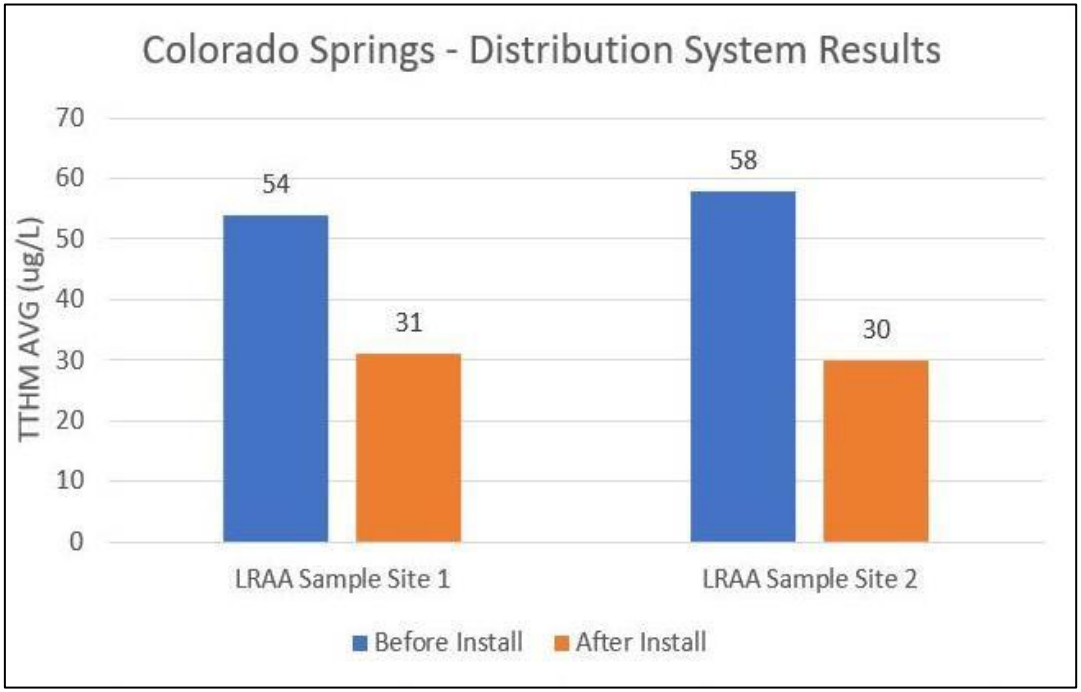
Colorado Springs Utilities

Case Study

- Despite mountain runoff, periodic problems with THM formation
- Numerous tactics employed over the years including flushing, treatment modifications, reducing water levels, on-site boosting to limit chlorine entry levels
- Decided to try network aeration to reduce THMs
- Designed to reduce THMs by 25%
- Installation without taking tank down during a 60 day window in winter

Tank at 7,500 foot elevation

Despite extreme weather, the installation was completed in three days and resulted in 42% and 48% reductions in THMs at sample locations



PPV 400 Powervent™ 1.0 HP

PWM 500 Mixer 1.0 HP

Manitoba Canada – Plumas Clearwell

Case Study

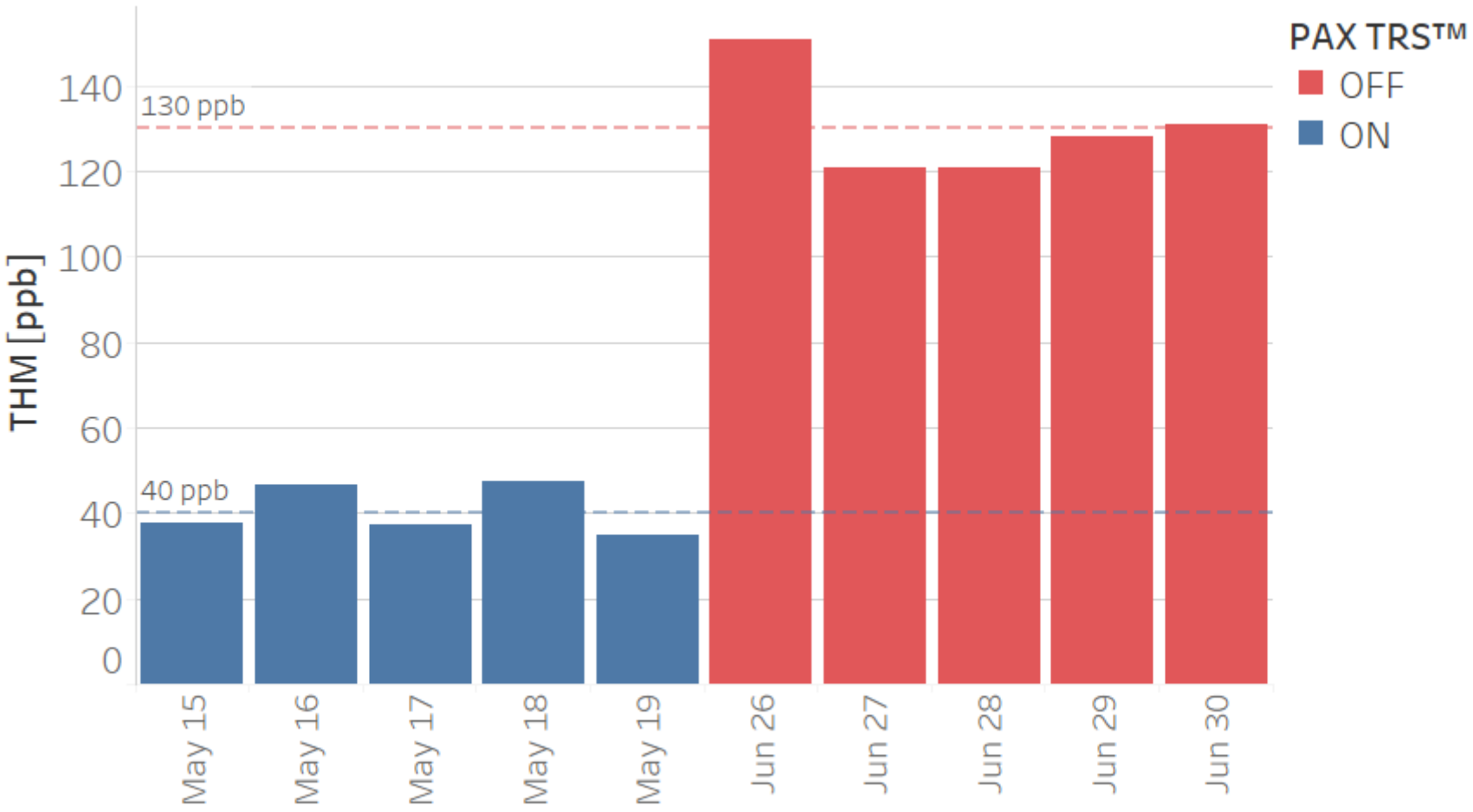
Winter temperatures of -40º C

- Canada has 100 ppb TTHM limits
- RFP issued June 2016
- 70% TTHM removal target
- Year-round treatment
- System startup November 2016
- Clearwell under building install location

Below grade clearwell – installation of one surface aerator (guides) + mixer

PAX PowerVent® with in-line duct heater

TRS on-off validation results = 70% removal

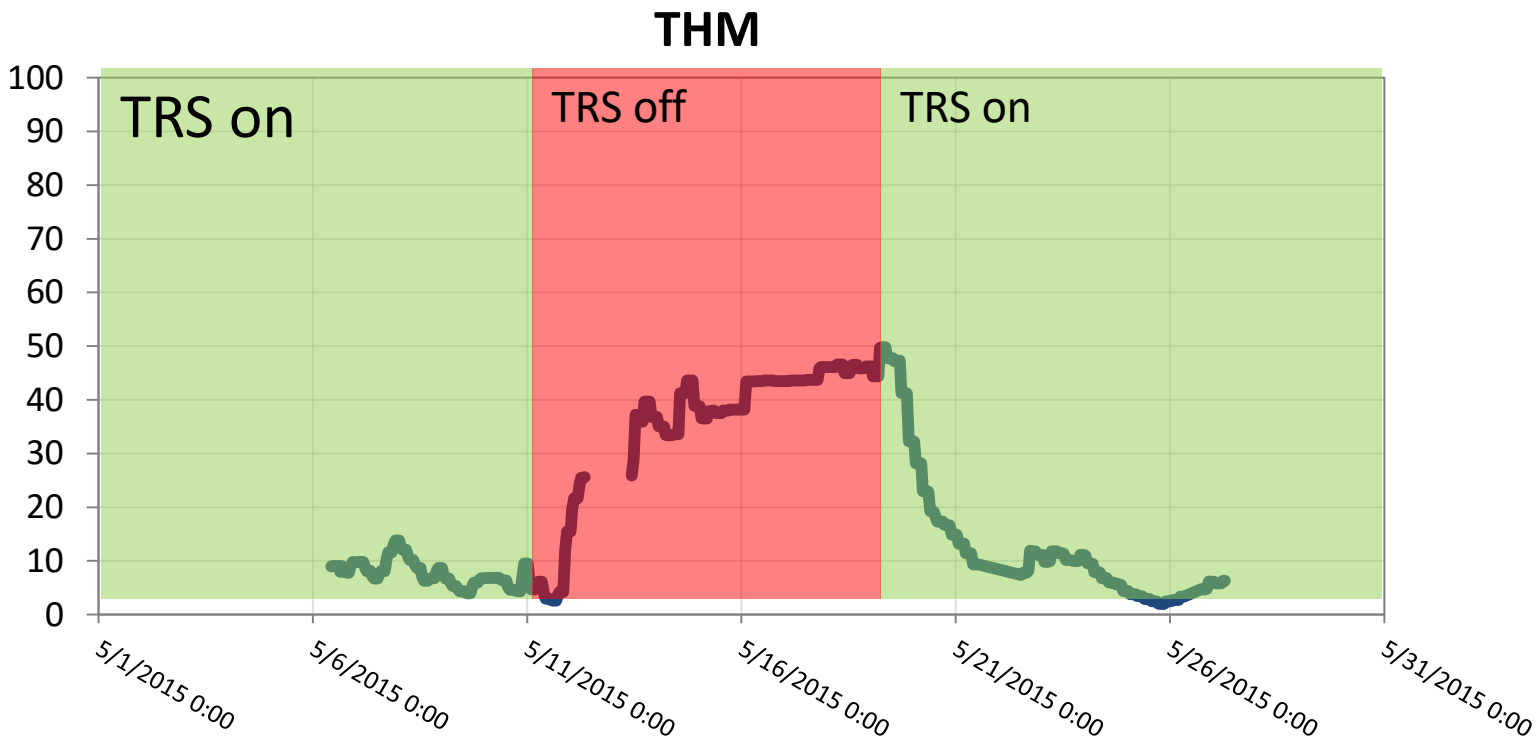


San Jose, CA: 12 MG More Avenue Reservoir

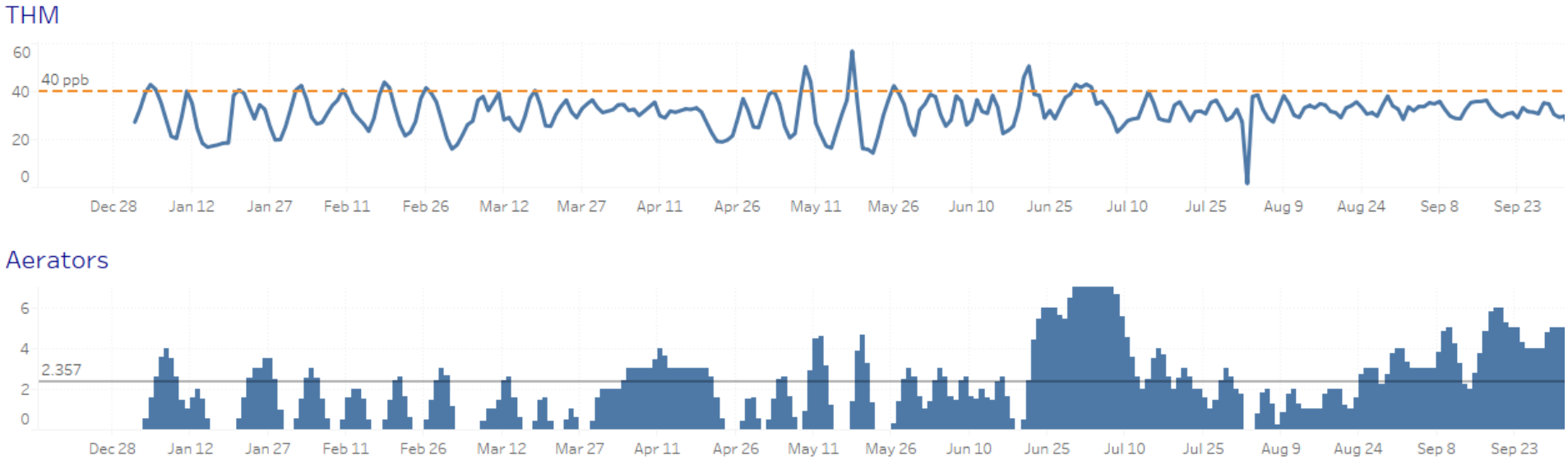
Case Study

- SJWC (investor owned utility) purchased water from Santa Clara Valley (wholesaler)
- Rising organics and bromide due to drought conditions

THM removal is influenced by tank turnover; the PAX TRS™ at More Avenue was delivering high rate of removal during periods of low demand (on/off validation)



PAX TRS™ active feedback control using THM sensors yield ~50% operating cost savings

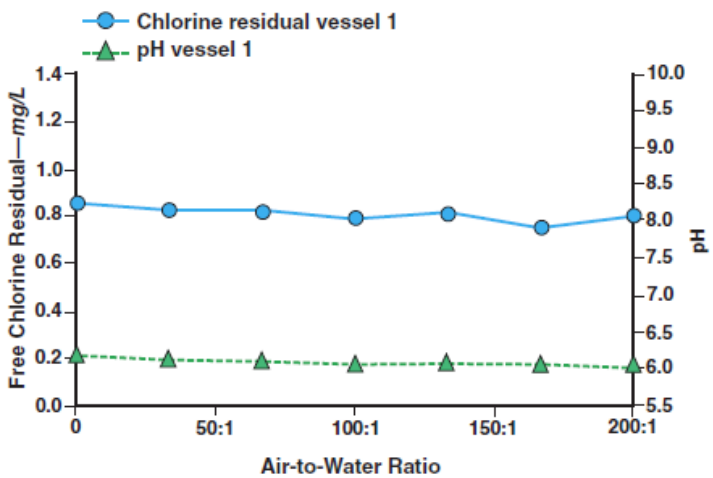


Integration of on-line THM analyzers provide an opportunity to save on energy

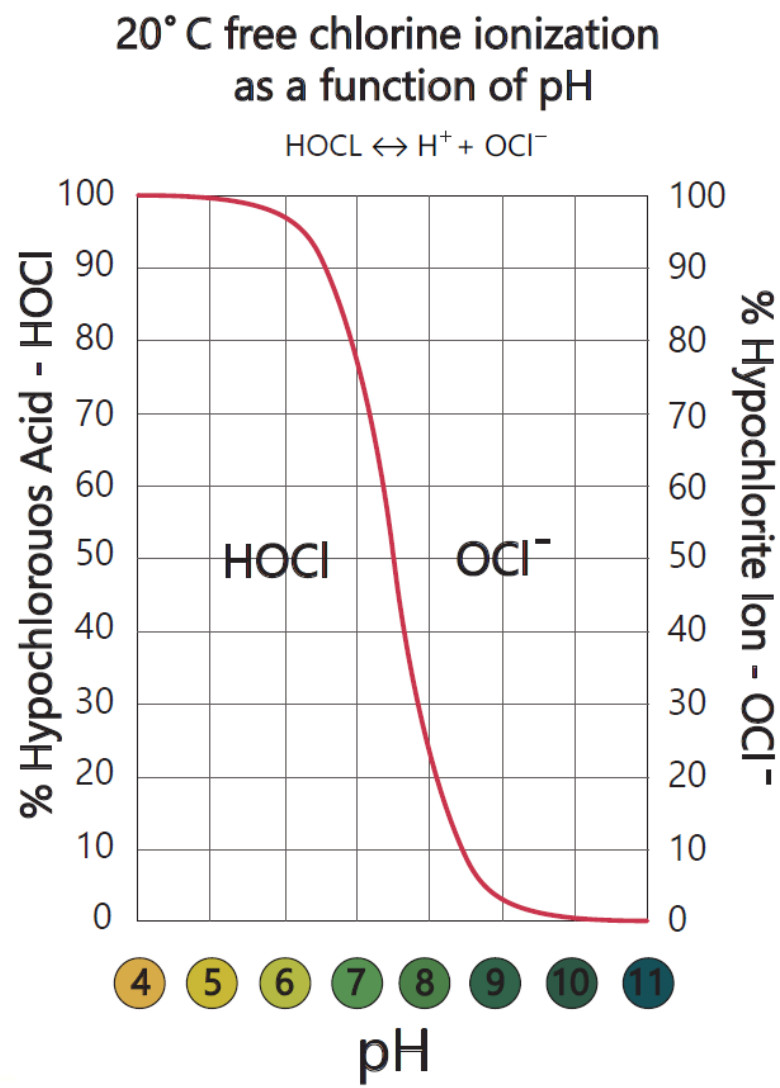
Chlorine is not lost during the aeration process

$$HOCl \leftrightarrow H^{+} + OCL^{-}$$

- Hypochlorite speciates based on pH
- Hypochlorite ion is not volatile – not a gas
- Hypochlorous acid is "thermodynamically stable" even at low pH. (See Brooke & Collins AWWA 2011)
- Drops in chlorine residual after aeration are temporary, and related to deactivation of bio-film due to mixing



A computer-aided titrator was used to maintain the pH at 6.1.



UGSI Solutions

Distribution Network Water Quality Management

May 27th 2020

UK Webinar with Panton McLeod