“Smart Tanks” - Optimizing Water Quality in Drinking Water Distribution Systems

Presented by Haley Goddard, PE

PNWS-AWWA Annual Conference

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SOLUTIONS THAT WORK

WATER STORAGE TANK DESIGN AND OPERATION



- Tanks are sized and configured for:
  - Peak demand
  - Fire flow requirements
  - Distribution system hydraulics
  - Future growth
- Limited water circulation and water flow can lead to water quality challenges.

Water storage tanks often suffer from lack of maintenance, which exacerbates water quality challenges.



Biofilm formation



Infrequent inspections and maintenance



Inferior corrosion protection

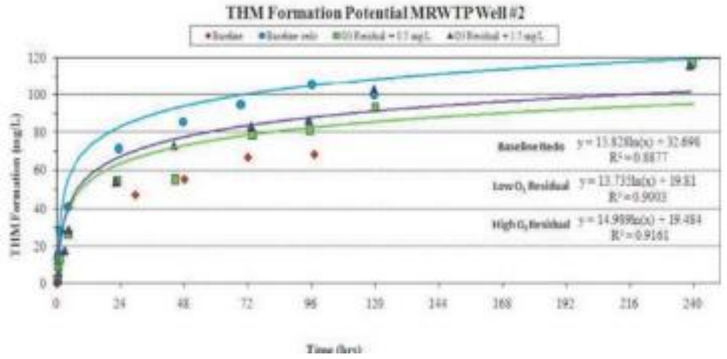


Sediment accumulation

“NO FREE LUNCH” – THE CHOICE OF SECONDARY DISINFECTANT WILL DETERMINE THE PROBLEMS UTILITIES CONTEND WITH.

Free Chlorine

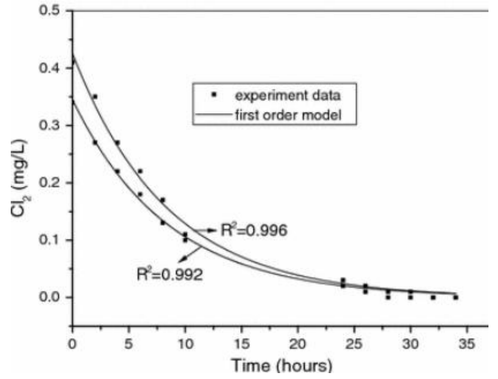
- Boosting to offset **degradation**
- DBP **formation** (THM and HAA5 issues)



DBP Formation Curve

Chloramines

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



Chloramine Degradation Curve

A “SMART TANK” IS THE RIGHT PLACE FOR WATER QUALITY MANAGEMENT IN A DISTRIBUTION NETWORK.



Storage tanks are the perfect intervention point for distribution system water quality.

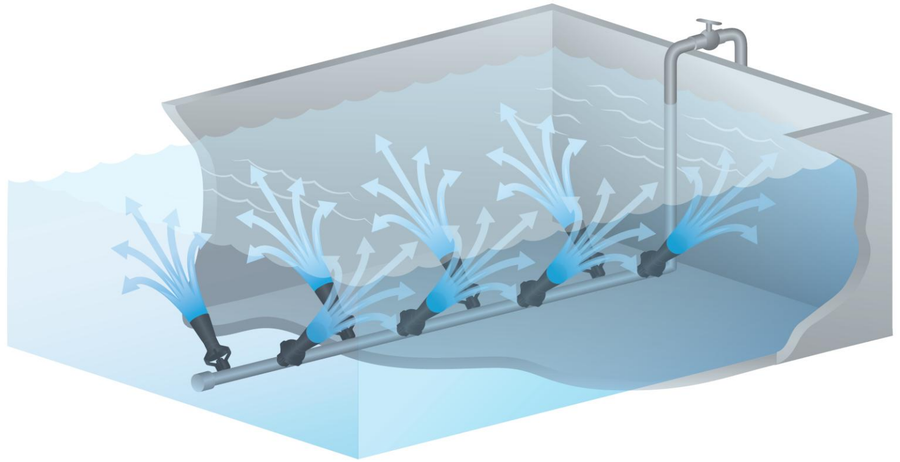
Active mixing is the starting point for water quality solutions, including:

- Ice control
- Residual control
- Nitrification and biostability
- THM removal

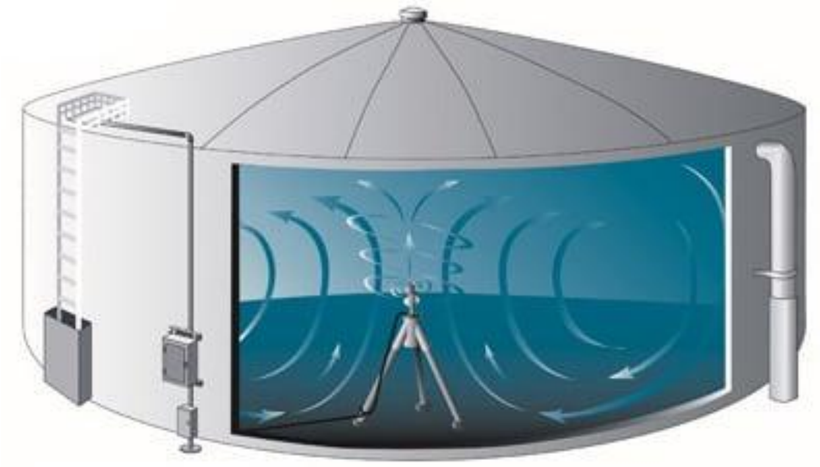
ACTIVE MIXING

Passive vs. Active Mixing

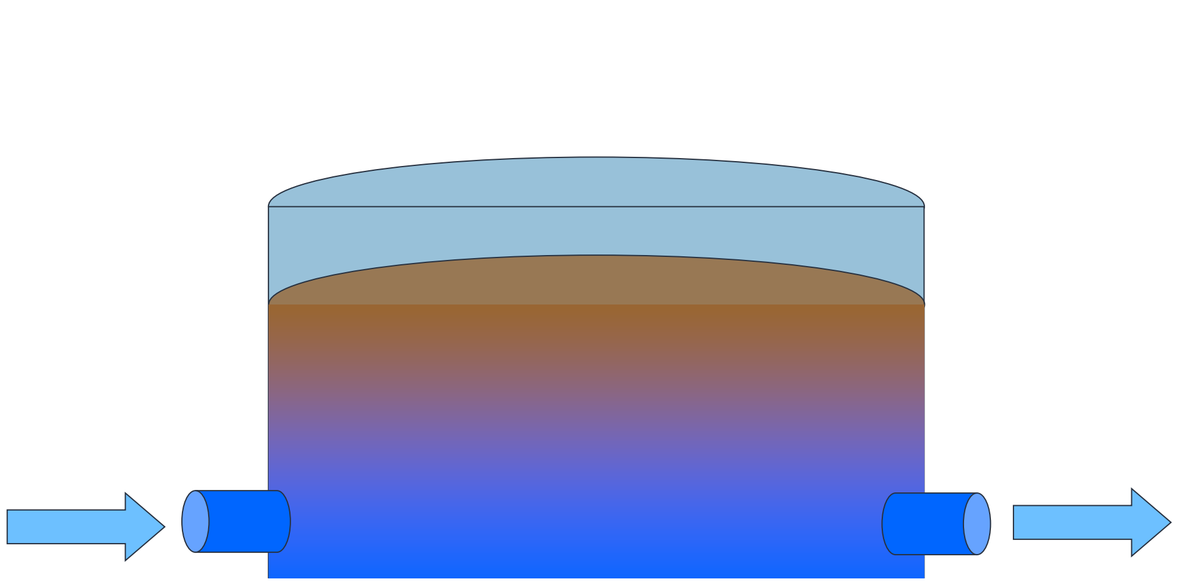
Passive mixing – application of flow energy/manipulation of flow direction to create fluid disturbance

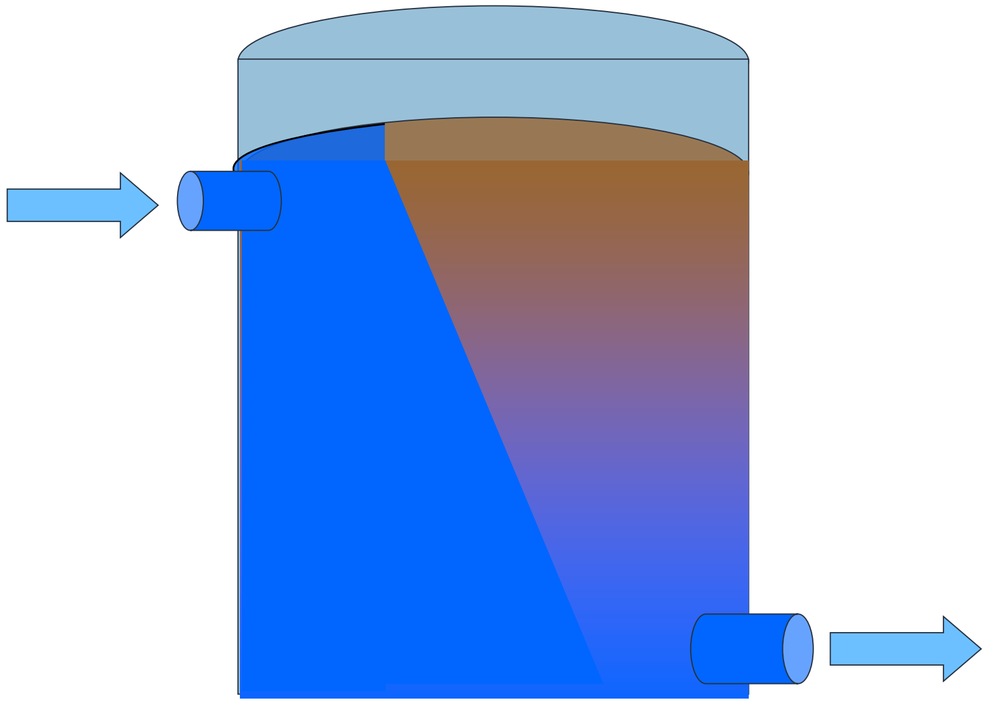


Active mixing – application of external energy to create fluid disturbance



Limitations of Passive Mixing: Short-Circuiting





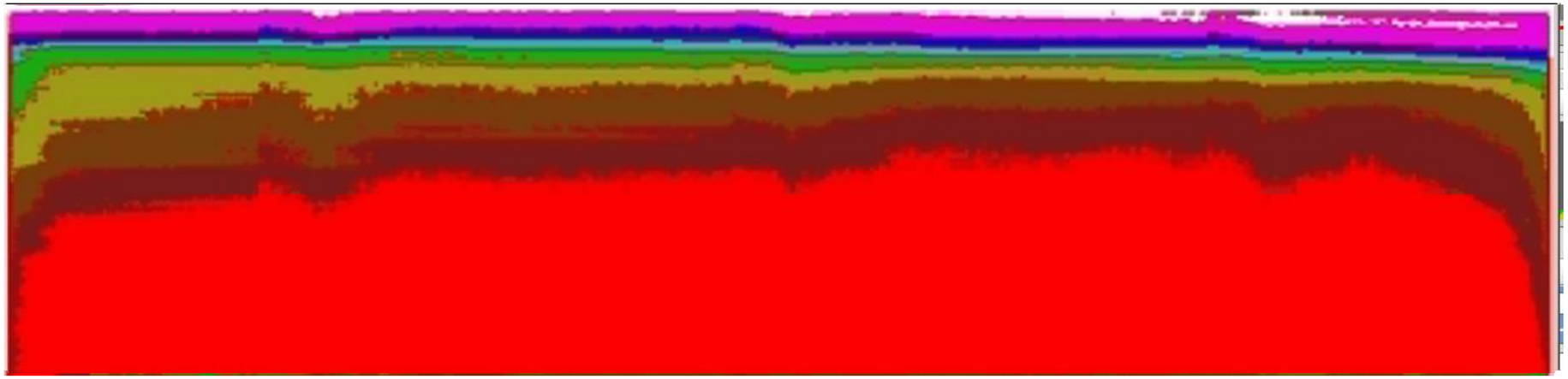
Limitations of Passive Mixing: Fill Cycles

Scaled model of passive mixing
Georgia Institute of Technology



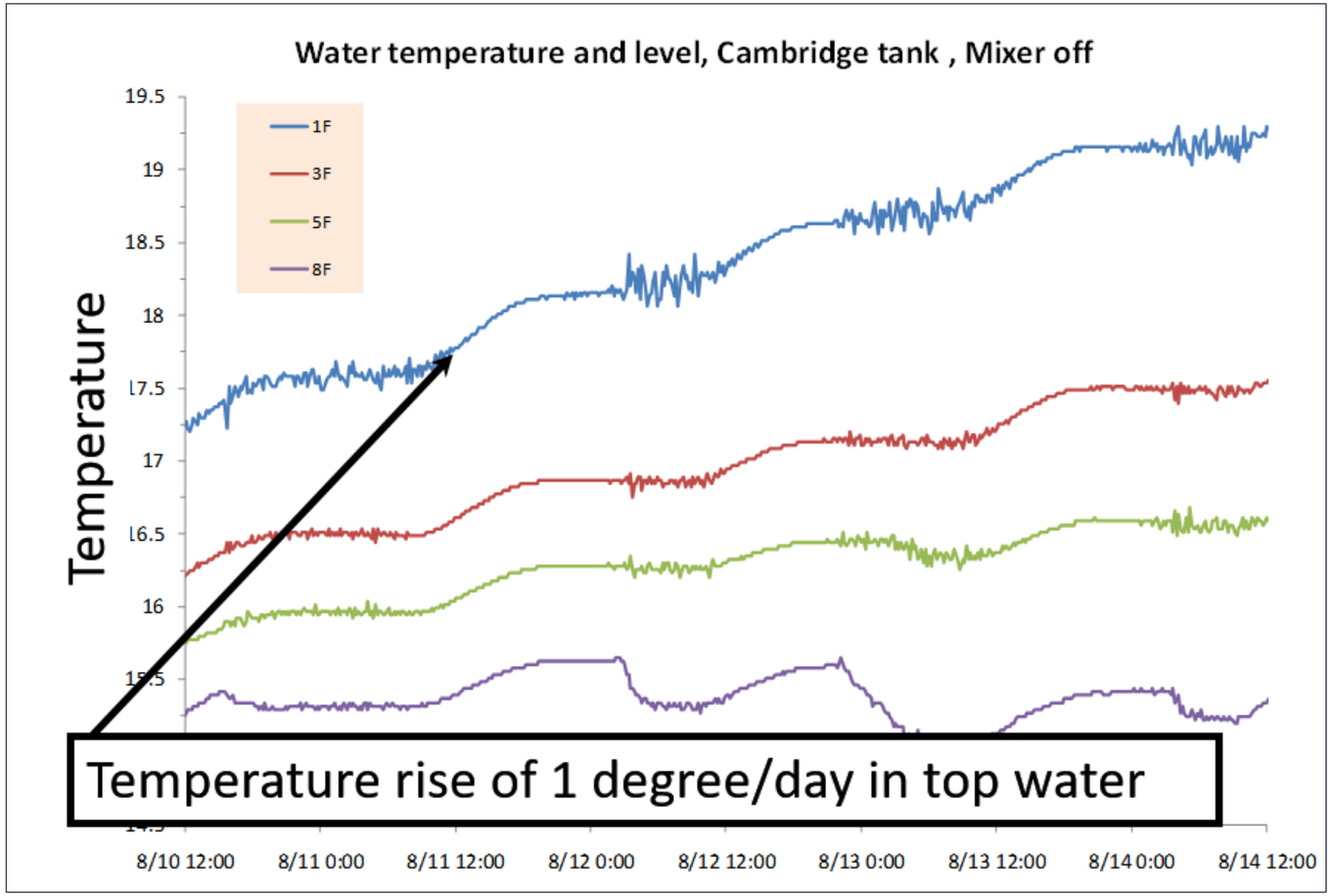
Figure 1. Mixing Device Inside Sulphur Springs I Tank.

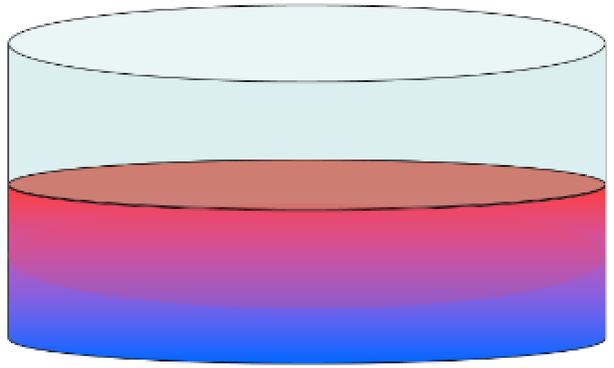
Cold Water Introduction



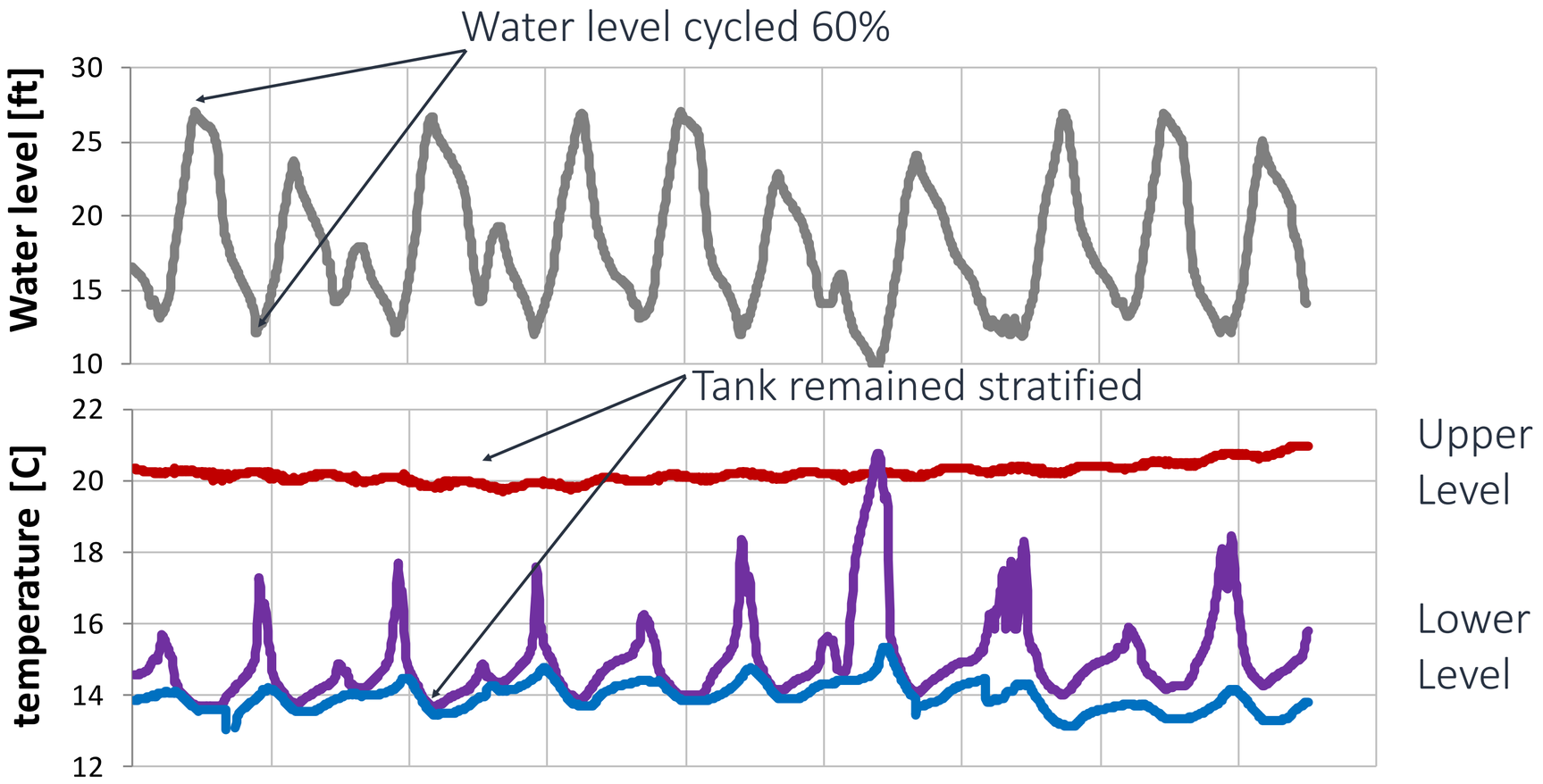
Courtesy of Prof. Phillip Roberts
Georgia Institute of Technology

Un-mixed tanks suffer from temperature and chemical stratification.

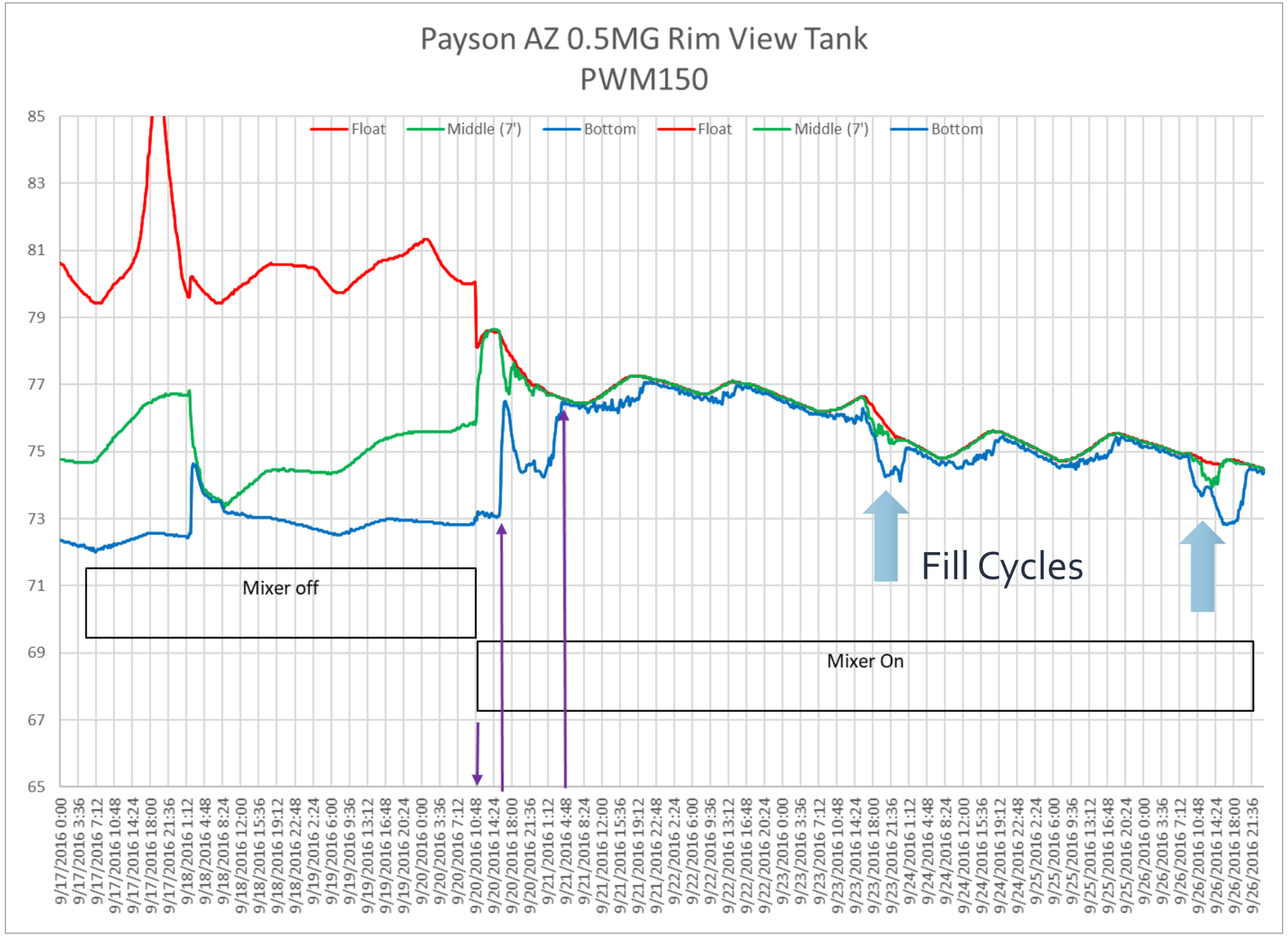




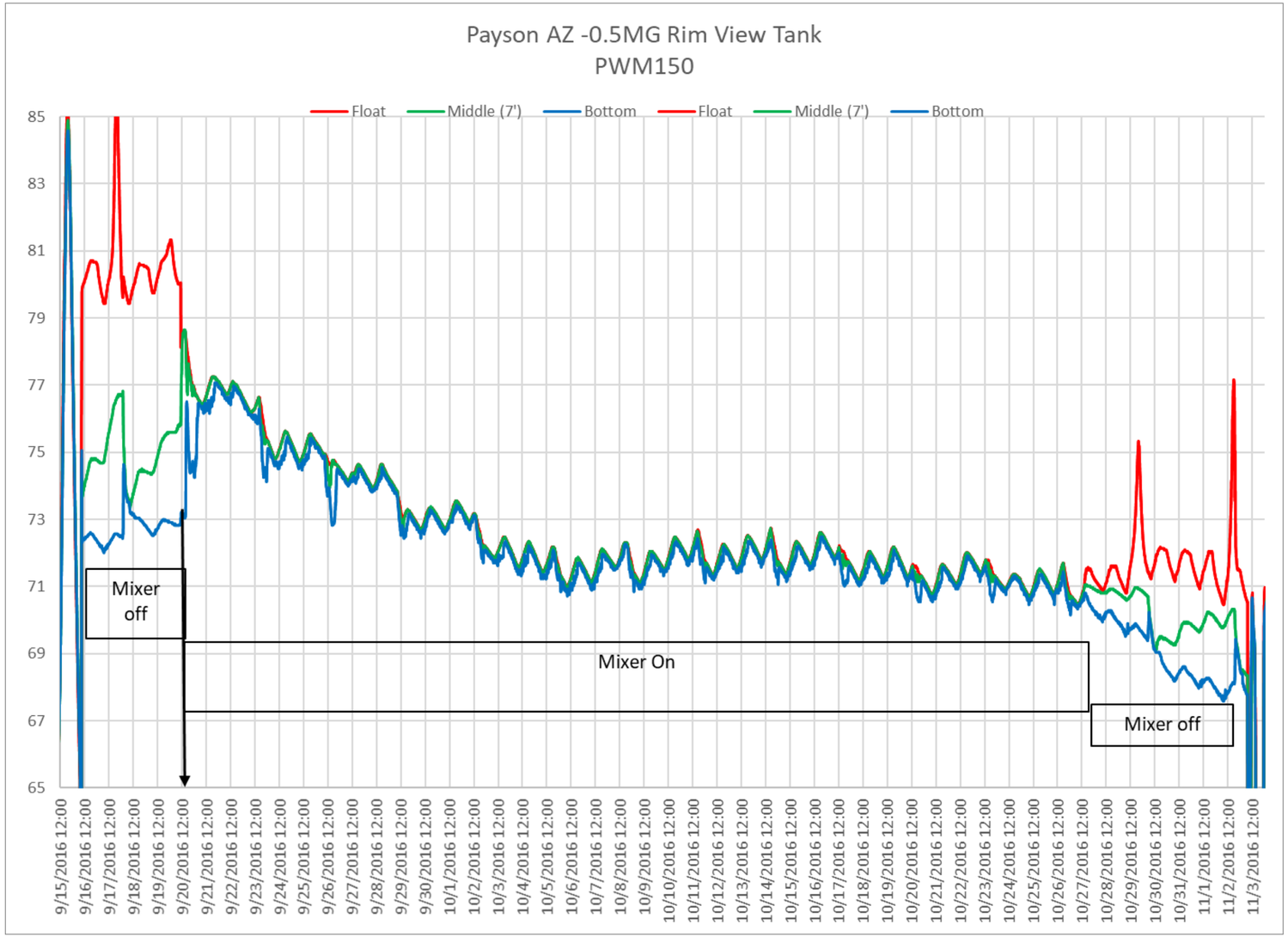
Deep cycling is not an effective mixing solution.



Properly-sized active tank mixing eliminates stratification.



Properly-sized active tank mixing eliminates stratification.



Mixer Selection

Depends on Process Goal

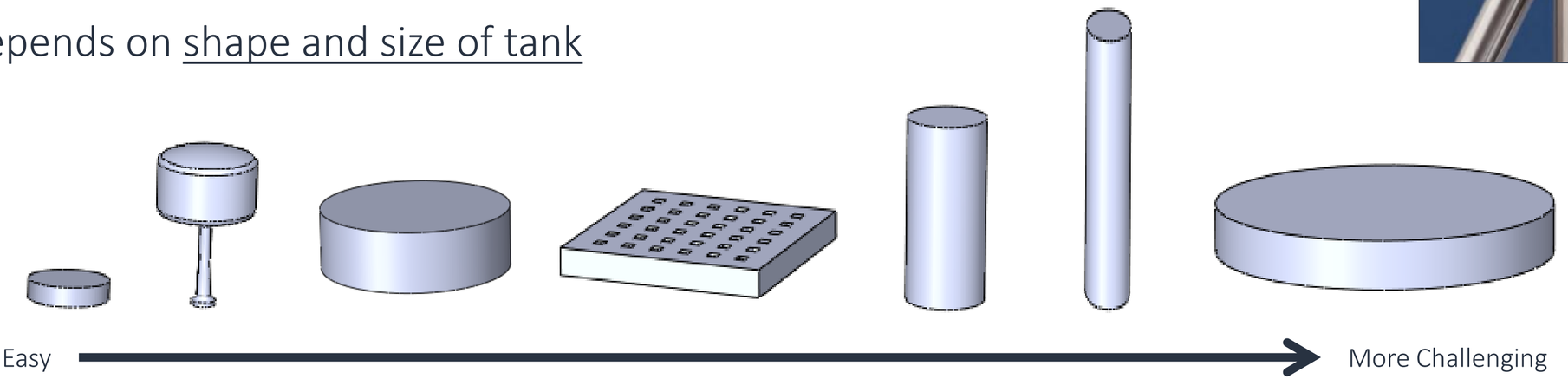
- Maintaining well-mixed conditions
- De-stratification (thermal load)
- Ice prevention (may need additional heat)
- Blending chemical dose (chlorine/ammonia)
- Aeration for THM reduction

Less Power

More Power



Depends on shape and size of tank



Easy

More Challenging

Active mixing comes in a variety of configurations depending on process objectives and site constraints.



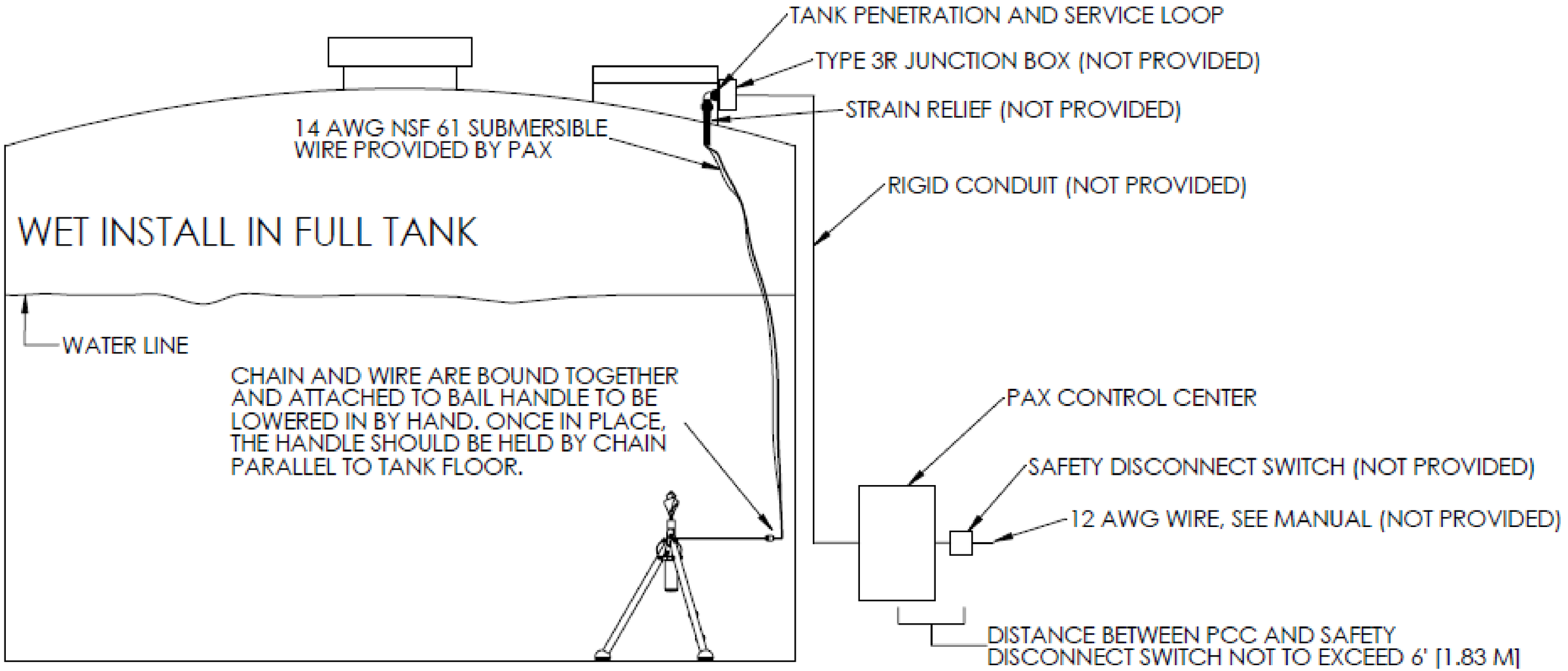
Eductor Mixer



Jet Mixer



Impeller Mixer


TANK PENETRATION AND SERVICE LOOP
TYPE 3R JUNCTION BOX (NOT PROVIDED)
STRAIN RELIEF (NOT PROVIDED)
14 AWG NSF 61 SUBMERSIBLE WIRE PROVIDED BY PAX
RIGID CONDUIT (NOT PROVIDED)
WET INSTALL IN FULL TANK
WATER LINE
CHAIN AND WIRE ARE BOUND TOGETHER AND ATTACHED TO BAIL HANDLE TO BE LOWERED IN BY HAND. ONCE IN PLACE, THE HANDLE SHOULD BE HELD BY CHAIN PARALLEL TO TANK FLOOR.
PAX CONTROL CENTER
SAFETY DISCONNECT SWITCH (NOT PROVIDED)
12 AWG WIRE, SEE MANUAL (NOT PROVIDED)
DISTANCE BETWEEN PCC AND SAFETY DISCONNECT SWITCH NOT TO EXCEED 6' [1.83 M]

CFD modeling demonstrates that a properly selected mixer will produce similar average velocities no matter where it is placed in the tank.

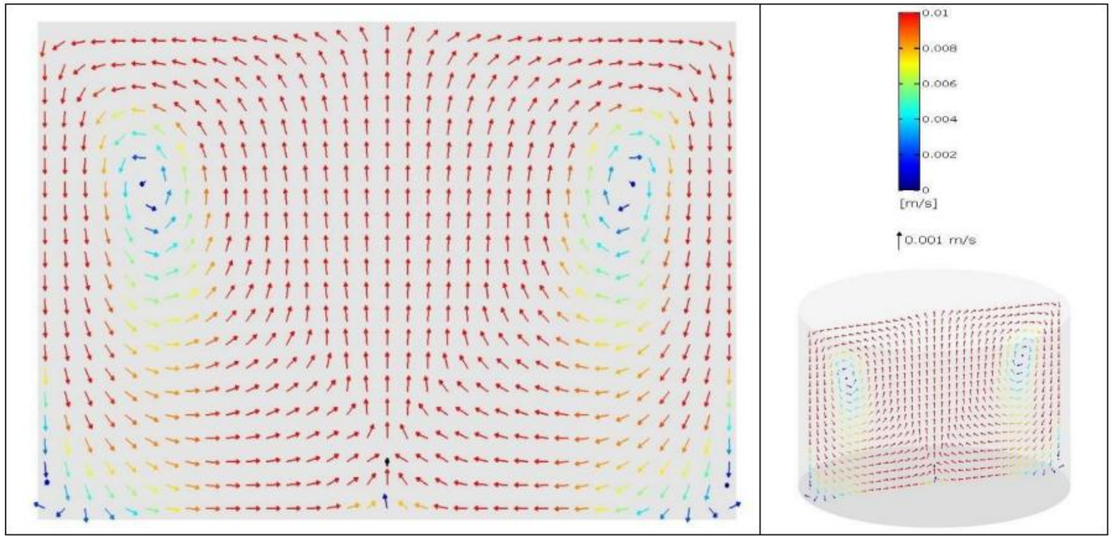


Figure 1. CFD model of a centrally positioned PAX Water Mixer in 0.5-MG tank (52'x32').

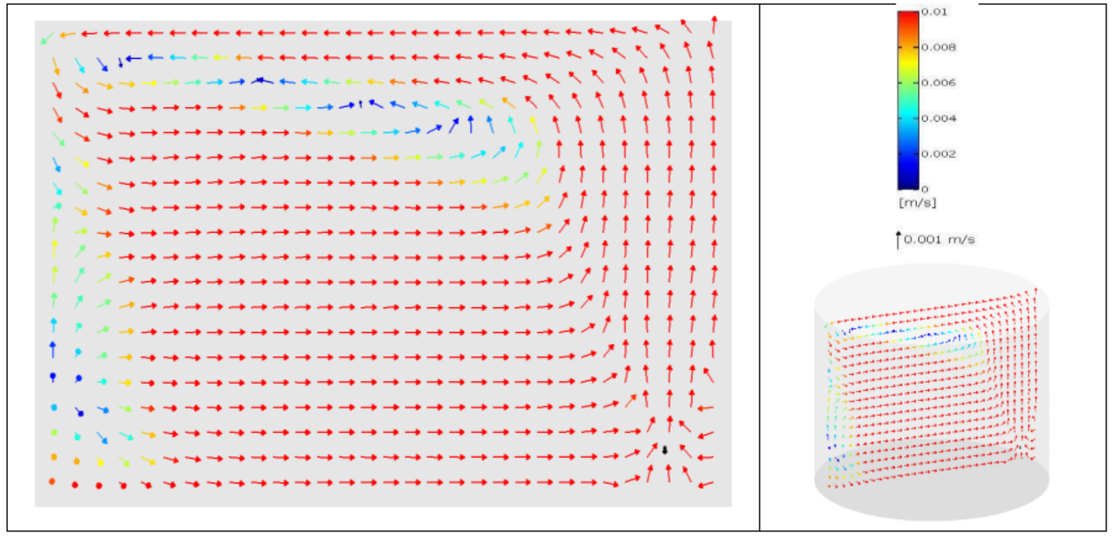
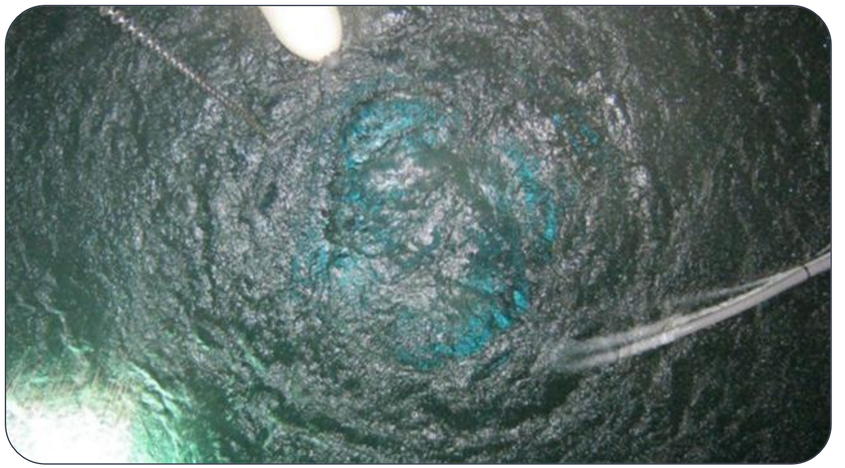


Figure 2. CFD model of the off-center PAX Water Mixer in 0.5-MG tank (52'x32').

In other words: A mixer can be installed beneath the tank hatch, even if the hatch is not at the center of the tank.

Powerful mixing is important; and once applied, it is easy to observe.

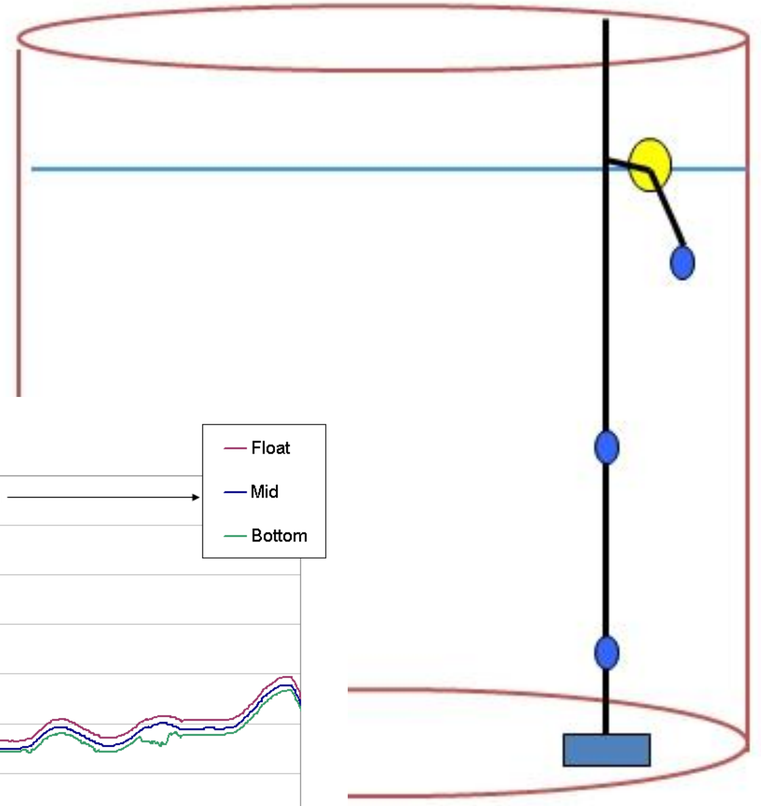


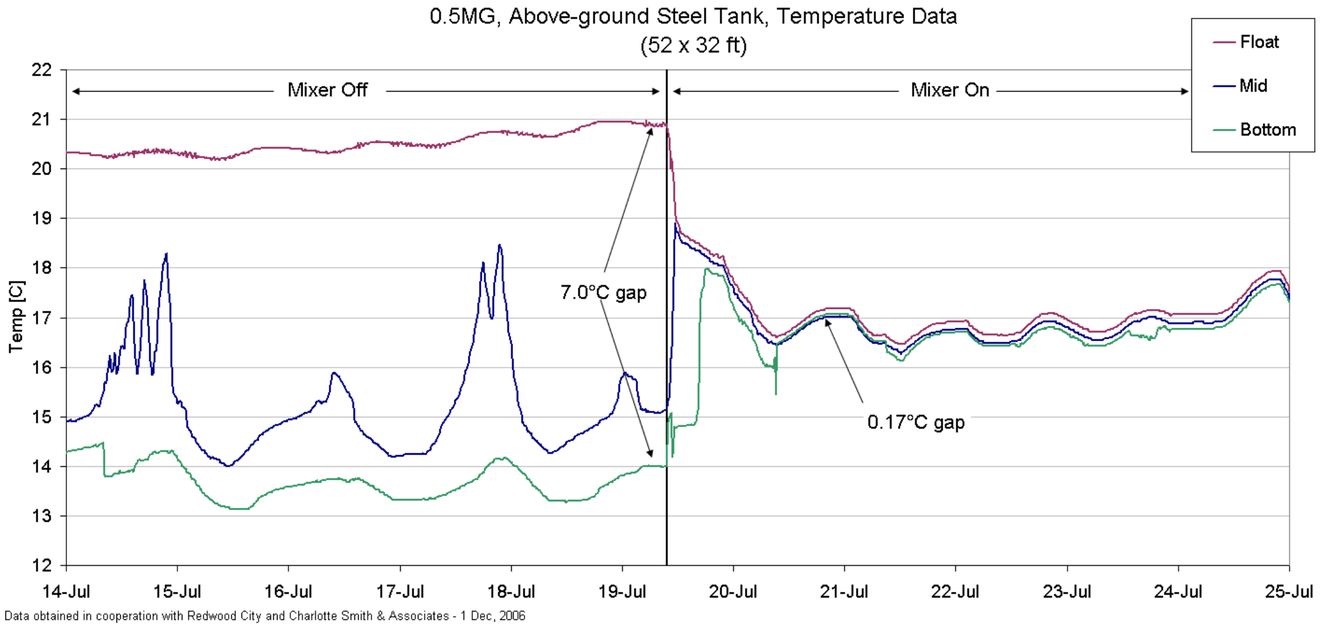


Effective Mixing – Tank Surface
San Jose, CA

Temperature profiles are the easiest way to demonstrate complete mixing.







Performance Guarantee

PART 2 – PRODUCTS

2.1 PERFORMANCE

A. Mixing system shall completely mix reservoir without any filling or draining of the tank or during offline operation according to the following minimum performance requirements. The Mixer is adequate to achieve the tank circulation and provide homogeneous conditions throughout the tank to prevent temperature and chemical stratification. These requirements shall be measured and validated after installation by the owner/operators or contractor with readily available tools such as temperature probes and total chlorine grab samplers.

1. Temperature Uniformity:

   All temperatures shall converge to within 0.50°C (0.9°F) within 24 hours after mixer is installed and activated.

2. Disinfectant Residual Uniformity:

   Disinfectant residual within top five feet of tank and bottom five feet of tank will converge to within 0.20 ppm within 24 hours after mixer is installed and activated. During continuous operation of the mixer, under normal disinfectant dosing parameters, disinfectant residual will converge to within 0.20 ppm at least once every 24 hours.

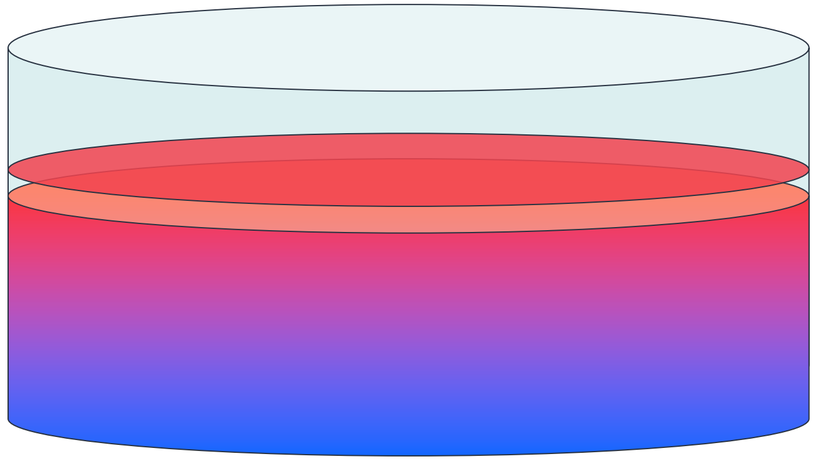
Effective mixing improves asset life and water quality.

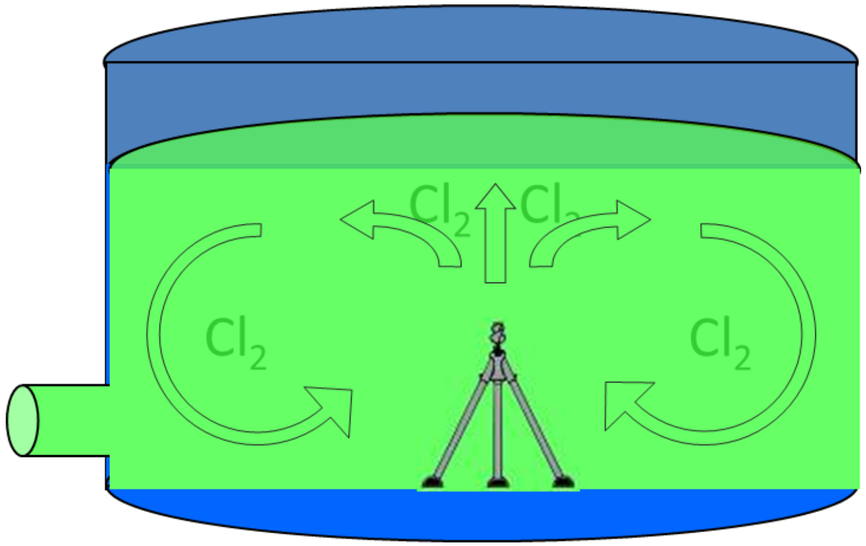
Water Quality Benefits:

- Eliminates stratification and reduces water age in storage tanks
- Reduces residual demand in tanks
- Enables safe, reliable boosting of tanks
- Reduces biofilm formation on tank walls
- Removes THMs (with active ventilation)

Asset Protection Benefits:

- Reduces sediment accumulation in tanks
- Reduces headspace temperatures (lower corrosion rates)
  - Especially with active ventilation
- Controls ice formation

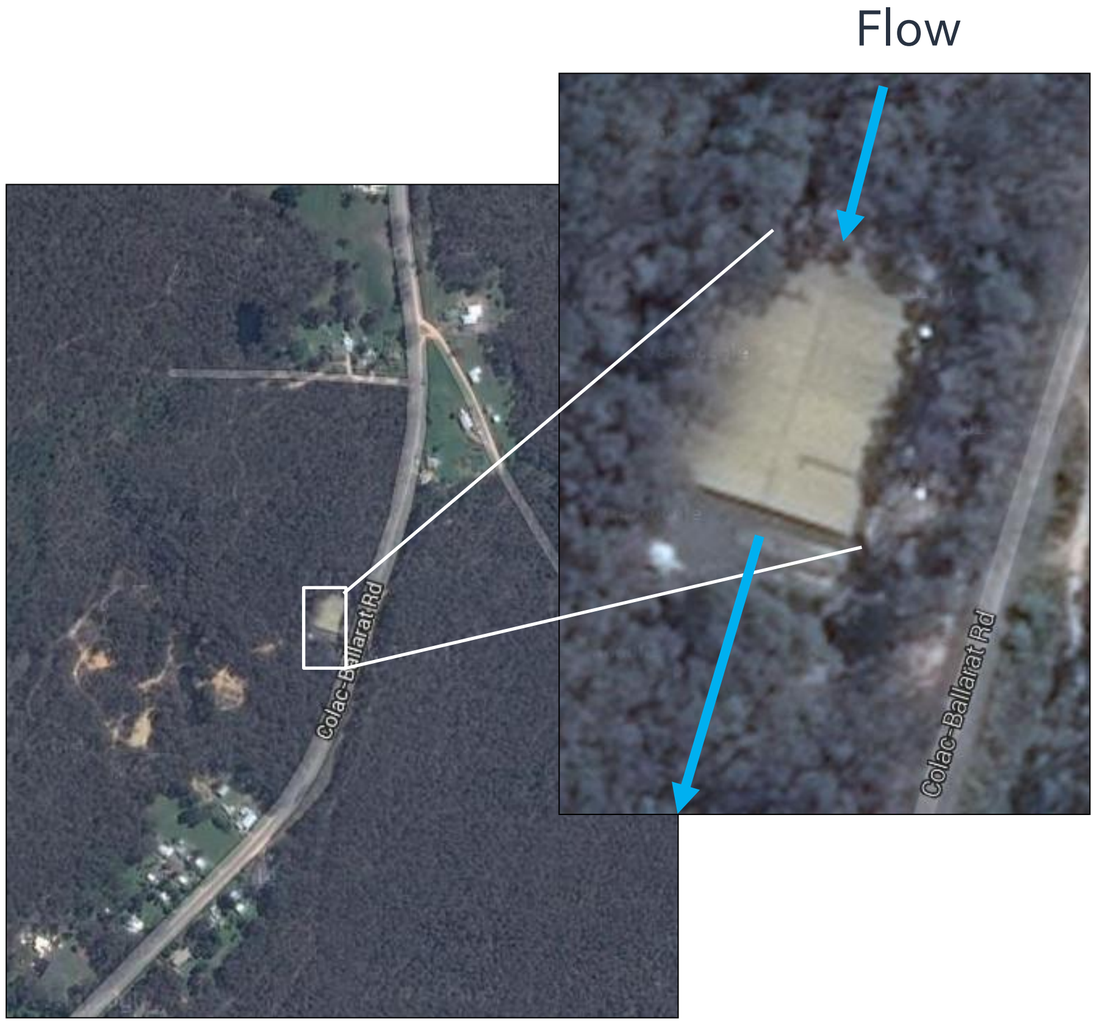




Case Study: Central Highlands Water, AUS – 1 MG Reservoir

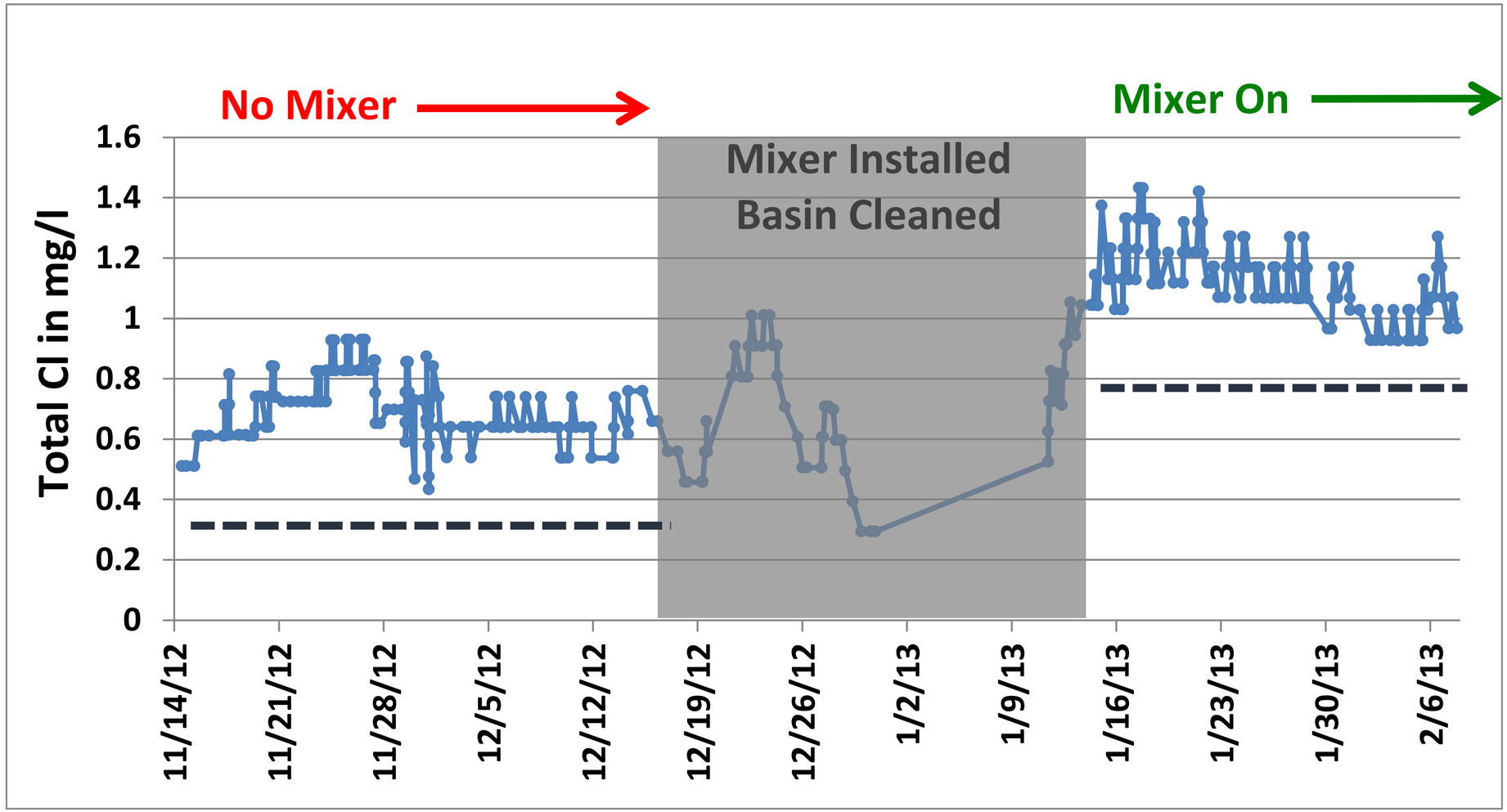


1 MG Enfield Reservoir



CENTRAL HIGHLANDS WATER

Case Study: Central Highlands Water, AUS – 1 MG Reservoir



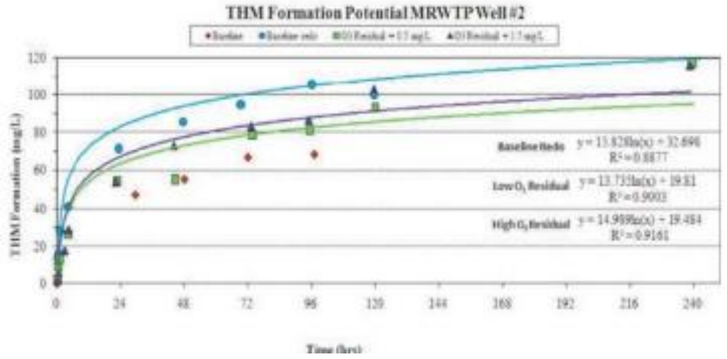
Chlorine residuals show significant improvement after mixing with no additional chemical dosing.

RESIDUAL CONTROL

“NO FREE LUNCH” – THE CHOICE OF SECONDARY DISINFECTANT WILL DETERMINE THE PROBLEMS UTILITIES CONTEND WITH.

Free Chlorine

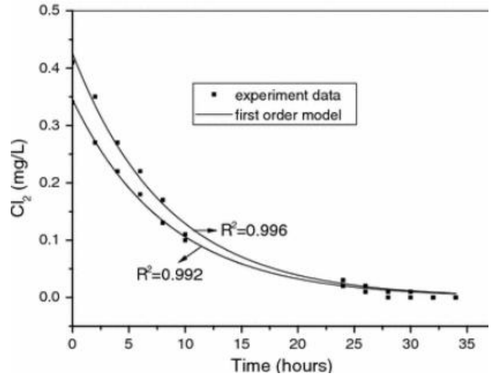
- Boosting to offset **degradation**
- DBP **formation** (THM and HAA5 issues)



DBP Formation Curve

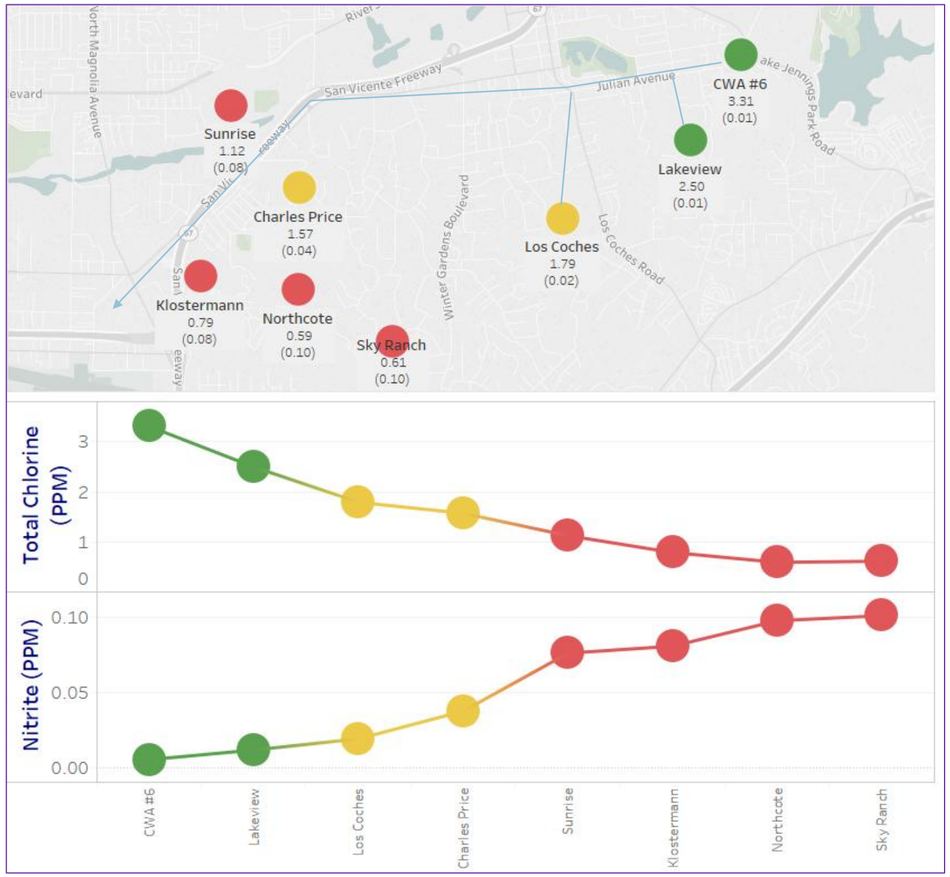
Chloramines

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



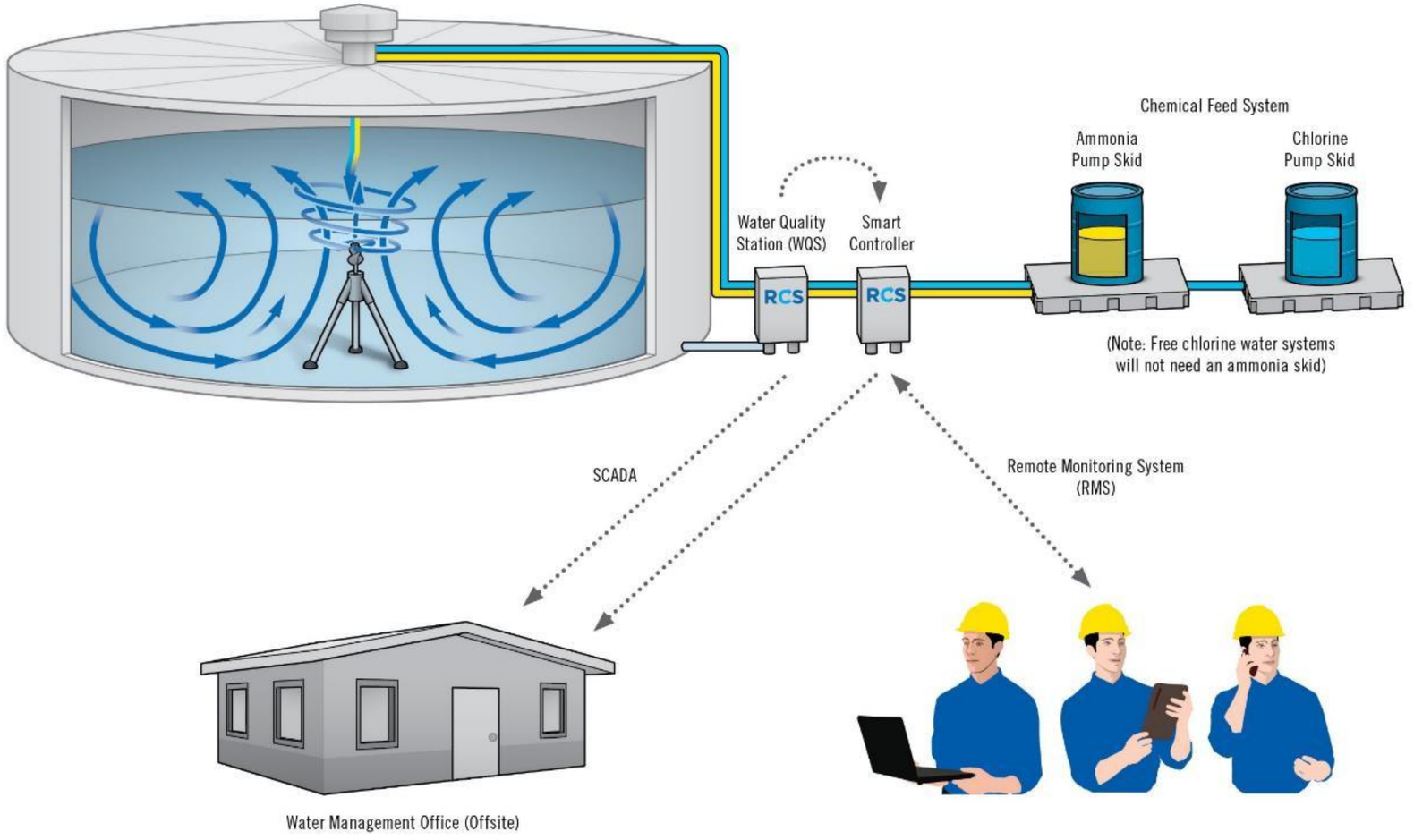
Chloramine Degradation Curve

RESIDUAL DECAY IN DISTRIBUTION SYSTEMS IS INEVITABLE.



- Natural decomposition and reactivity with organic matters (DBP) and other chlorine demand.
- Factors influencing residual:
  - Water age (time)
  - Temperature
  - System conditions
  - Chemistry (chloramination)

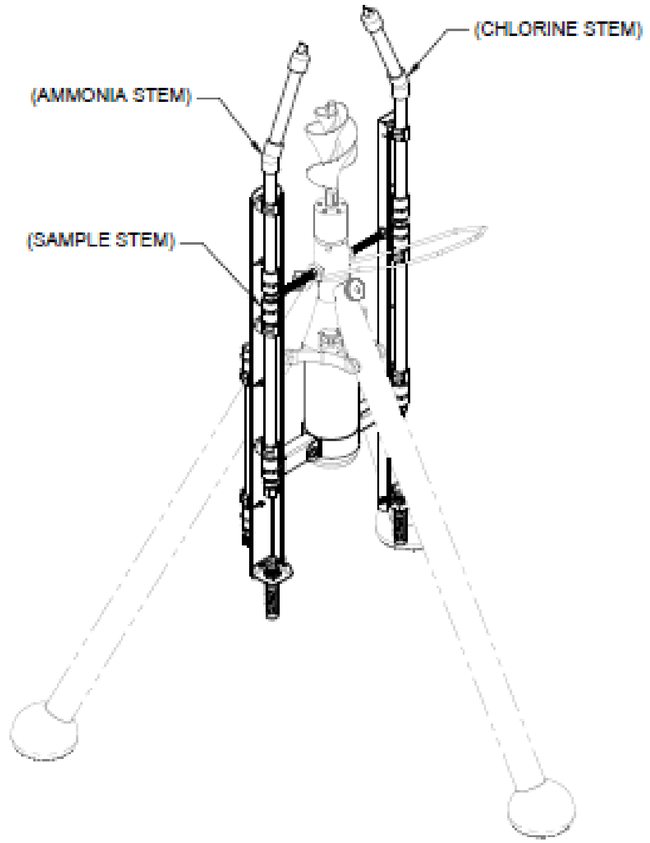
A “SMART TANK” WITH RESIDUAL CONTROL AUTOMATICALLY ADJUSTS AND MAINTAINS THE DISINFECTANT TO A PRE-DETERMINED SETPOINT WITH BENEFICIAL WATER QUALITY IMPACT TO THE ZONES IT SERVES.



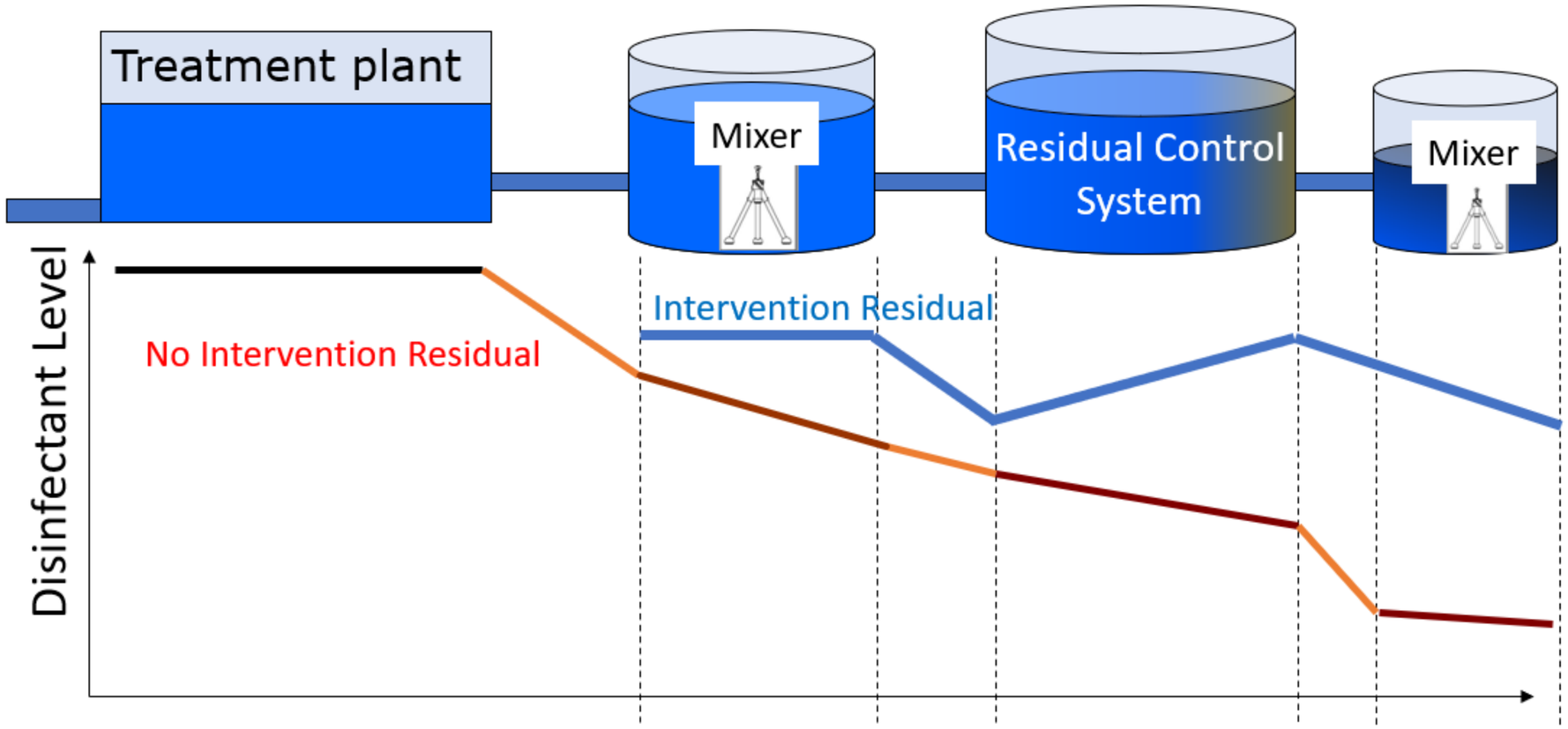
FOUR CRITERIA MUST BE MET FOR PROPER RESIDUAL CONTROL IN RESERVOIRS:

Requirements:

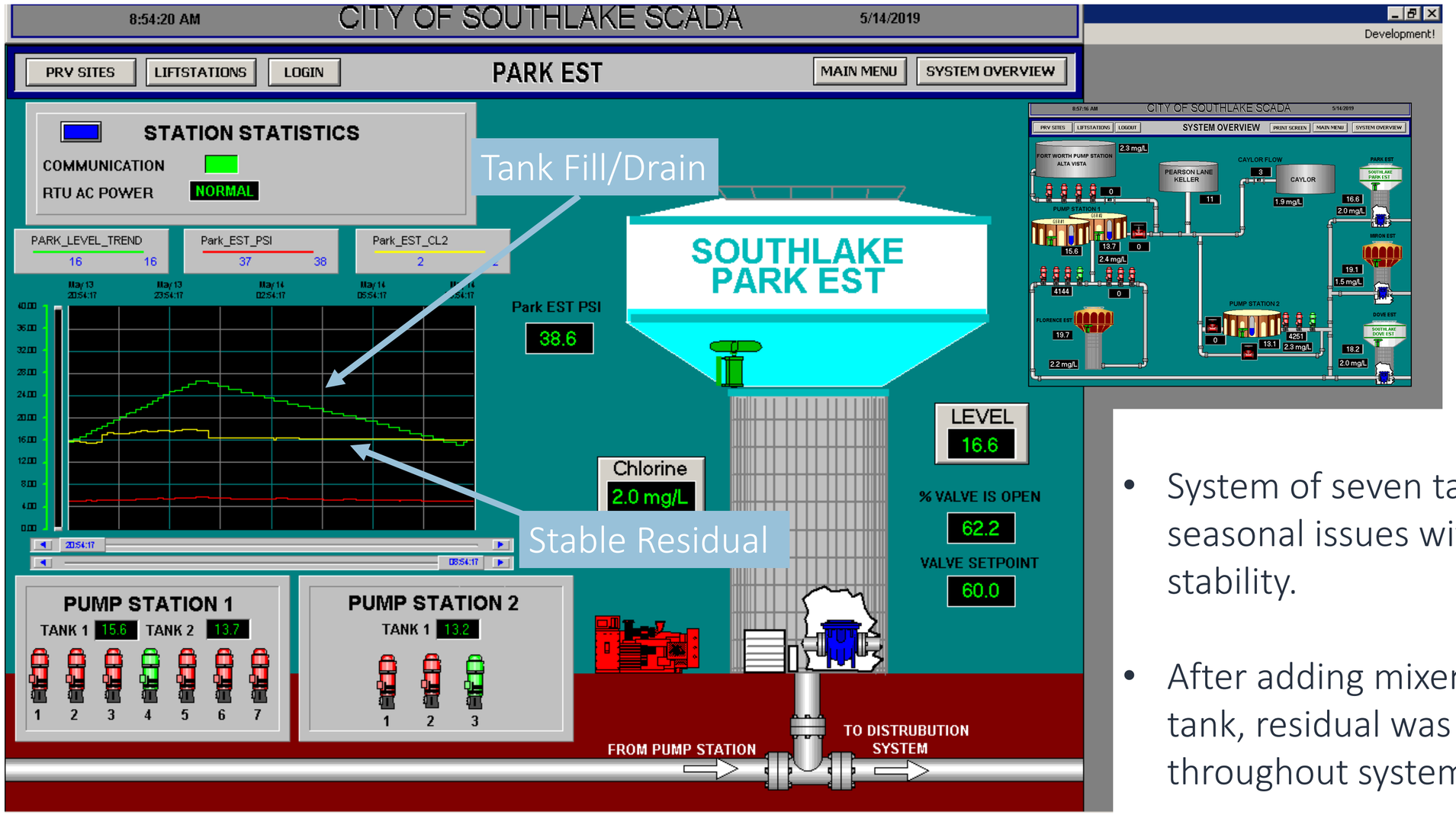
- ✓ **Energetic mixing** to de-stratify aging water and ensure homogeneity.
- ✓ **Effective monitoring** for real-time management.
- ✓ **Accurate dosing** of chemicals.
- ✓ **Strong process control** with feedback for optimization of consumable use.



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



Case Study: Southlake, TX – Distribution System Residual Management



- System of seven tanks had seasonal issues with residual stability.
- After adding mixers to each tank, residual was more uniform throughout system.

Case Study: Southlake, TX – Distribution System Residual Management



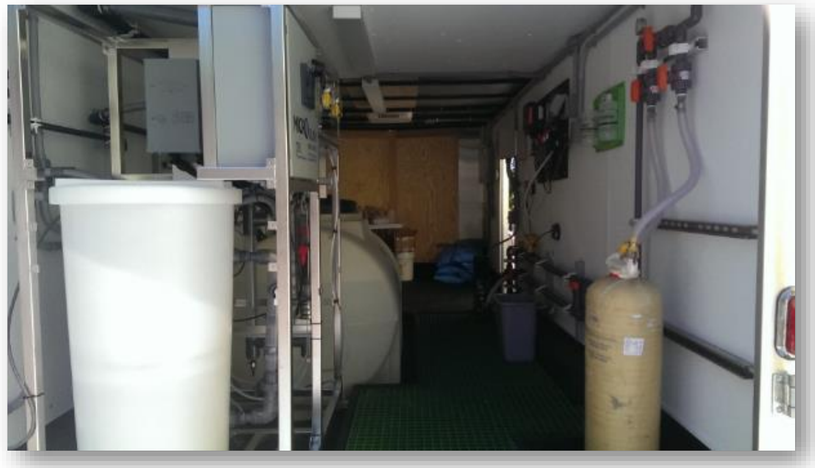


CASE STUDY: SAN JOSE WATER COMPANY, CA CHLORAMINE RESIDUAL CONTROL TRAILER

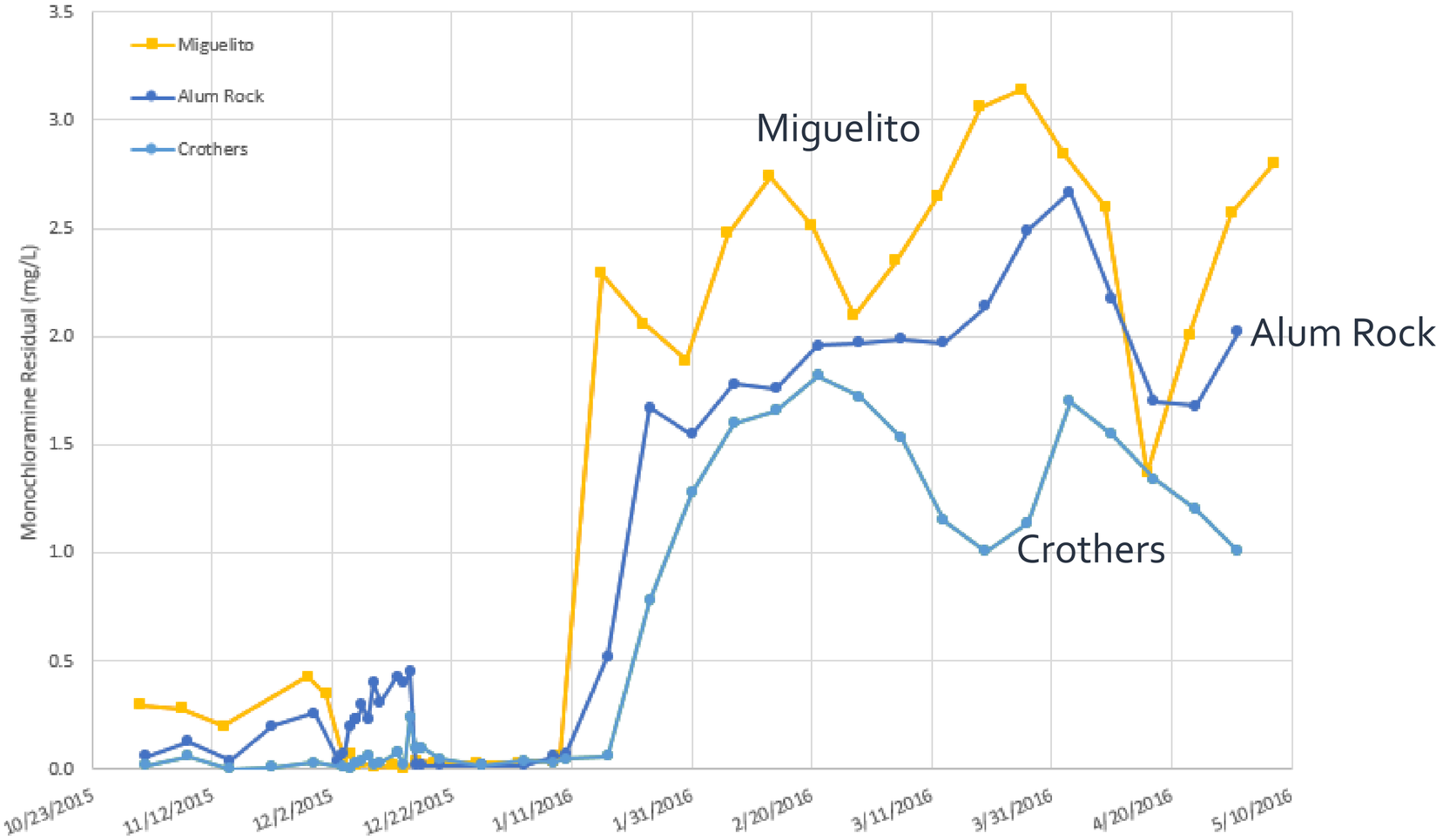


Tank Size: 1 MG
Turnover: 4 days
Problem: Chronically low residual (<0.2 mg/l)
Solution: Automated residual control





INSTALLING A BOOSTING SYSTEM IN THE MIGUELITO RESERVOIRS ACHIEVED TARGET RESIDUAL LEVELS IN DOWNSTREAM PRESSURE ZONE.

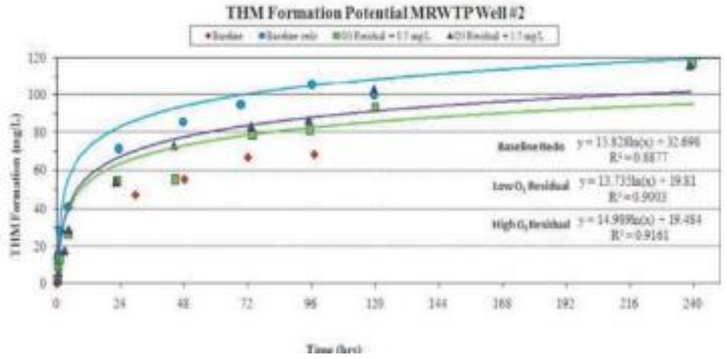


IN-TANK AERATION

“NO FREE LUNCH” – THE CHOICE OF SECONDARY DISINFECTANT WILL DETERMINE THE PROBLEMS UTILITIES CONTEND WITH.

Free Chlorine

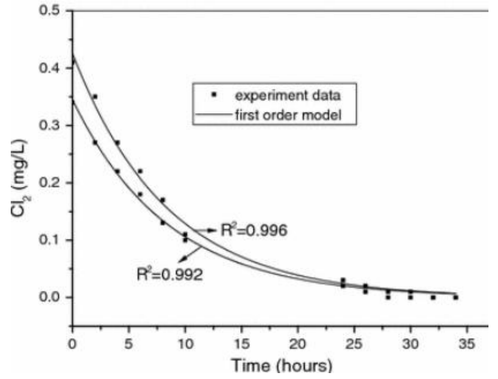
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DBP Formation Curve

Chloramines

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Chloramine Degradation Curve

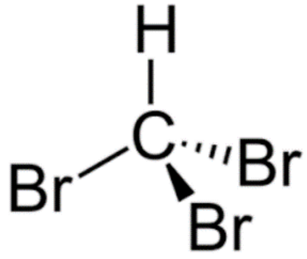
TRIHALOMETHANES (THMS) HAVE A LONG HISTORY OF REGULATION AS A DISINFECTION BYPRODUCT (DBP).

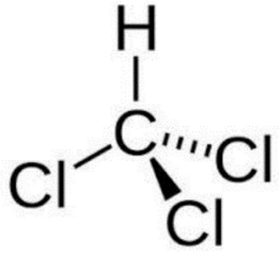
- 3 of 18 US Drinking Water Rules regulate THMs.
- US EPA Stage 2 DBP Rule mandates an 80 ppb MCL based on a sample locational running annual average (LRAA).
- THMs are second leading cause of MCL violations after BAC-T .

"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***









HOW THMS ARE FORMED?

TIME



Free Chlorine (Cl)

+



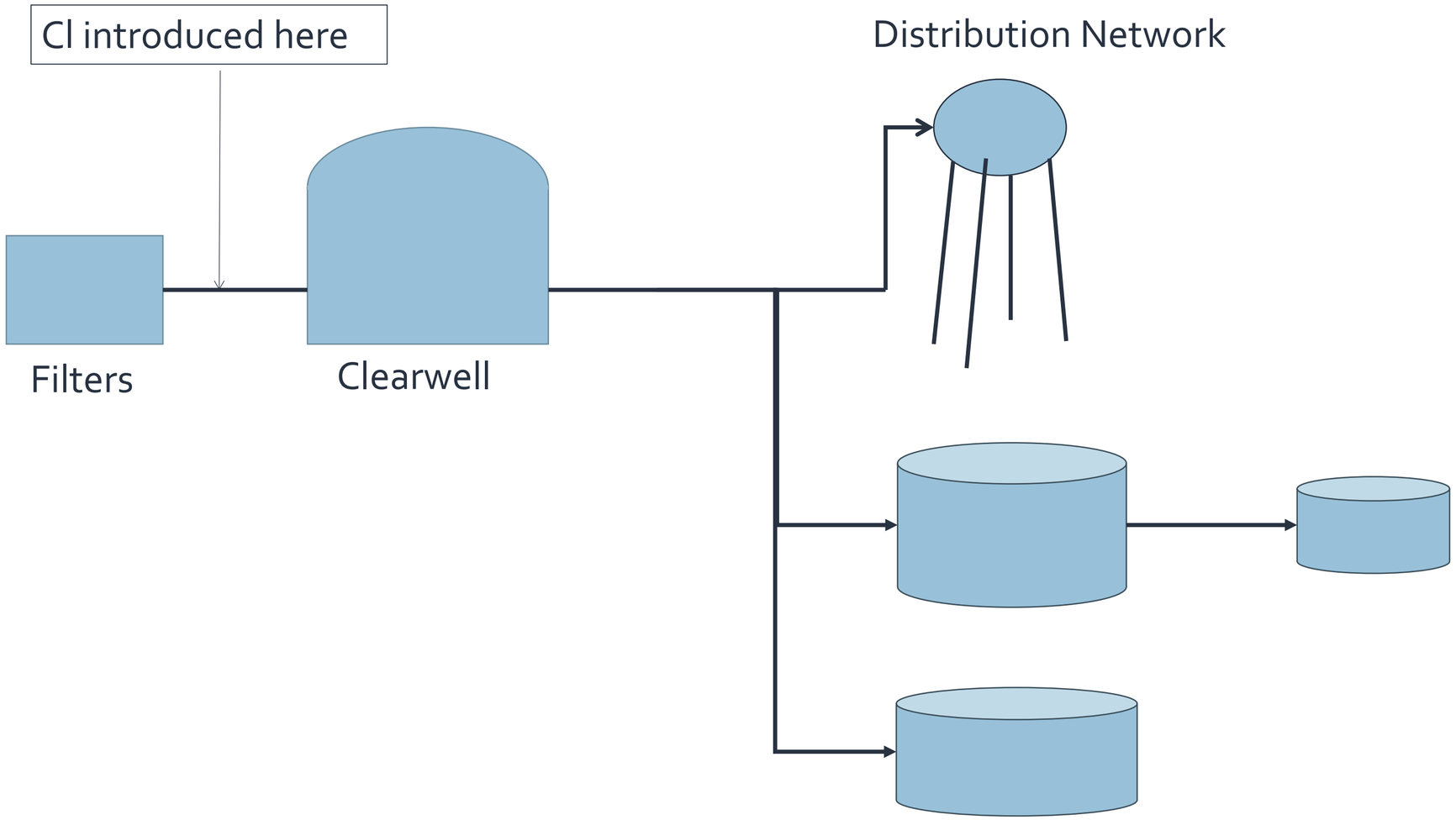
Natural Organic Matter (NOM)

=



Disinfection Byproducts (DBP)

THMS FORM IN DISTRIBUTION SYSTEMS AS WATER AGES.



SOLUTIONS FOR THM CONTROL AT A TREATMENT PLANT ARE LIMITED SINCE THM FORMATION OCCURS IN THE DISTRIBUTION SYSTEM.

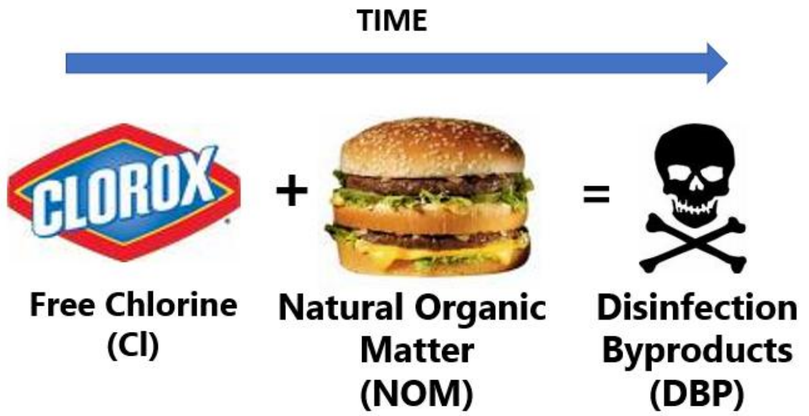
Options for THM Control:

Treatment Plant

- Remove precursors (NOM)
- Adjust chlorine dosing

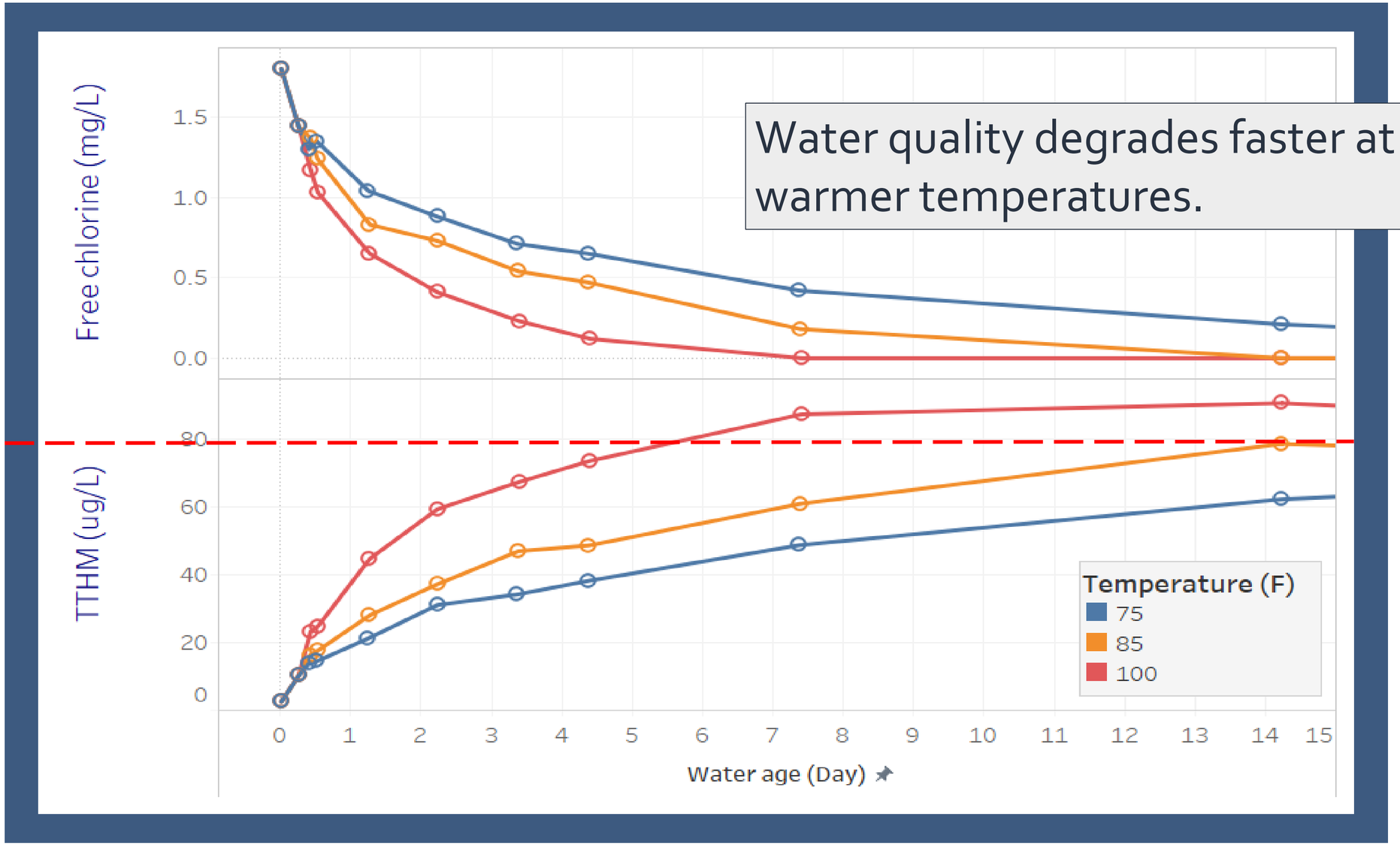
Distribution System

- Reduce water age
- Remove THMs after they are formed



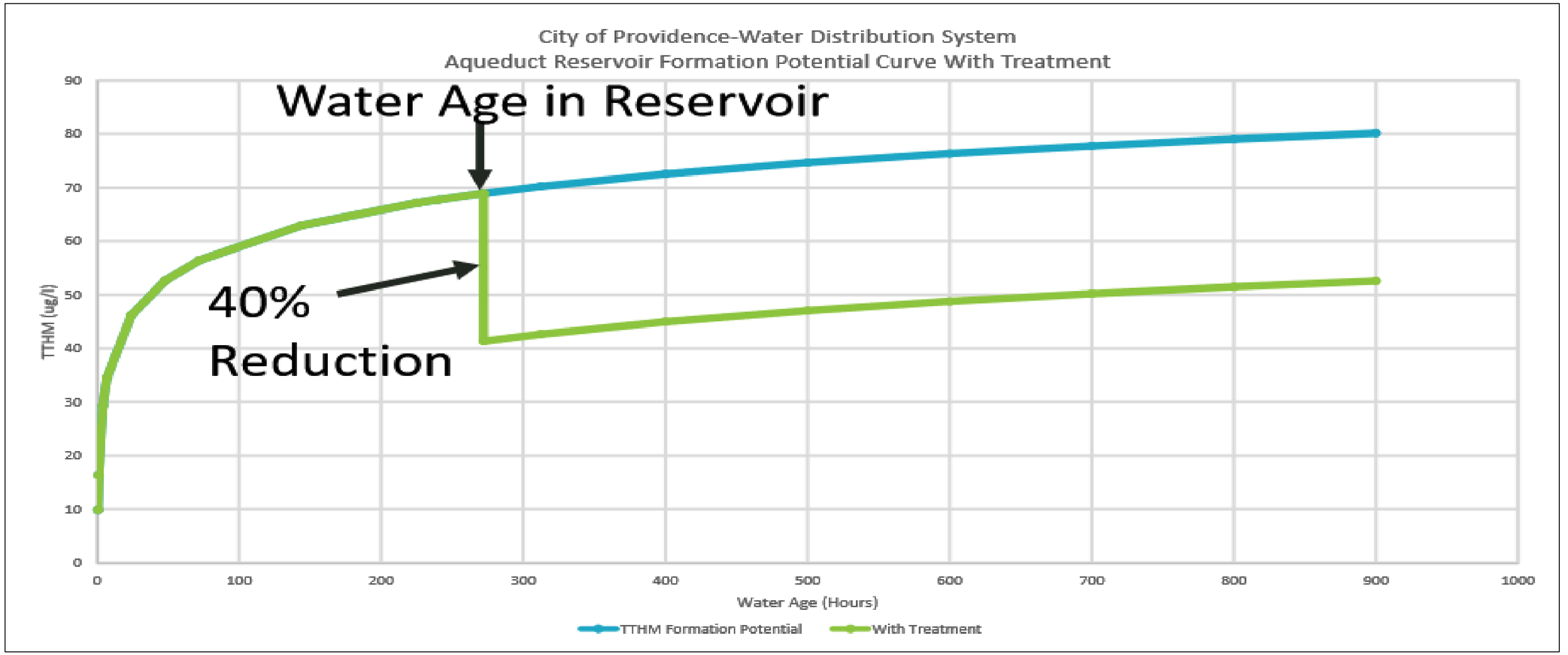
EXAMPLE THM FORMATION CURVE

MCL 80 ppb



Water quality degrades faster at warmer temperatures.

Achieving THM reduction across a distribution system requires treatment at different points in clearwell or tanks.

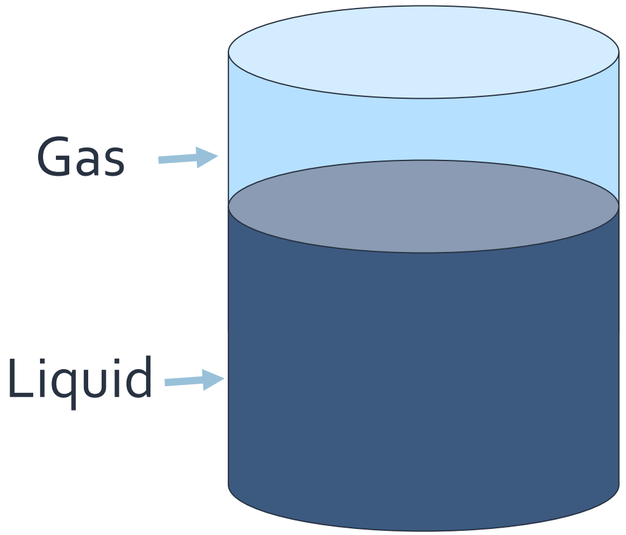


THMS ARE VOLATILE… JUST LIKE CO_2.

- THMs would rather be in gas phase than liquid phase.
- The **driving force** for mass transfer from liquid to gas is based on a difference in concentration between the water and air.
- THM concentration will build up in the headspace of a tank without ventilation, stopping THM volatilization (Henry's Law).
- Optimizing a tank to volatilize THMs can be simple or complex.



HENRY'S LAW CONSTANTS DICTATE THE PERCENTAGE OF THMS THAT WILL SATURATE THE TANK HEADSPACE ***AT EQUILIBRIUM.***

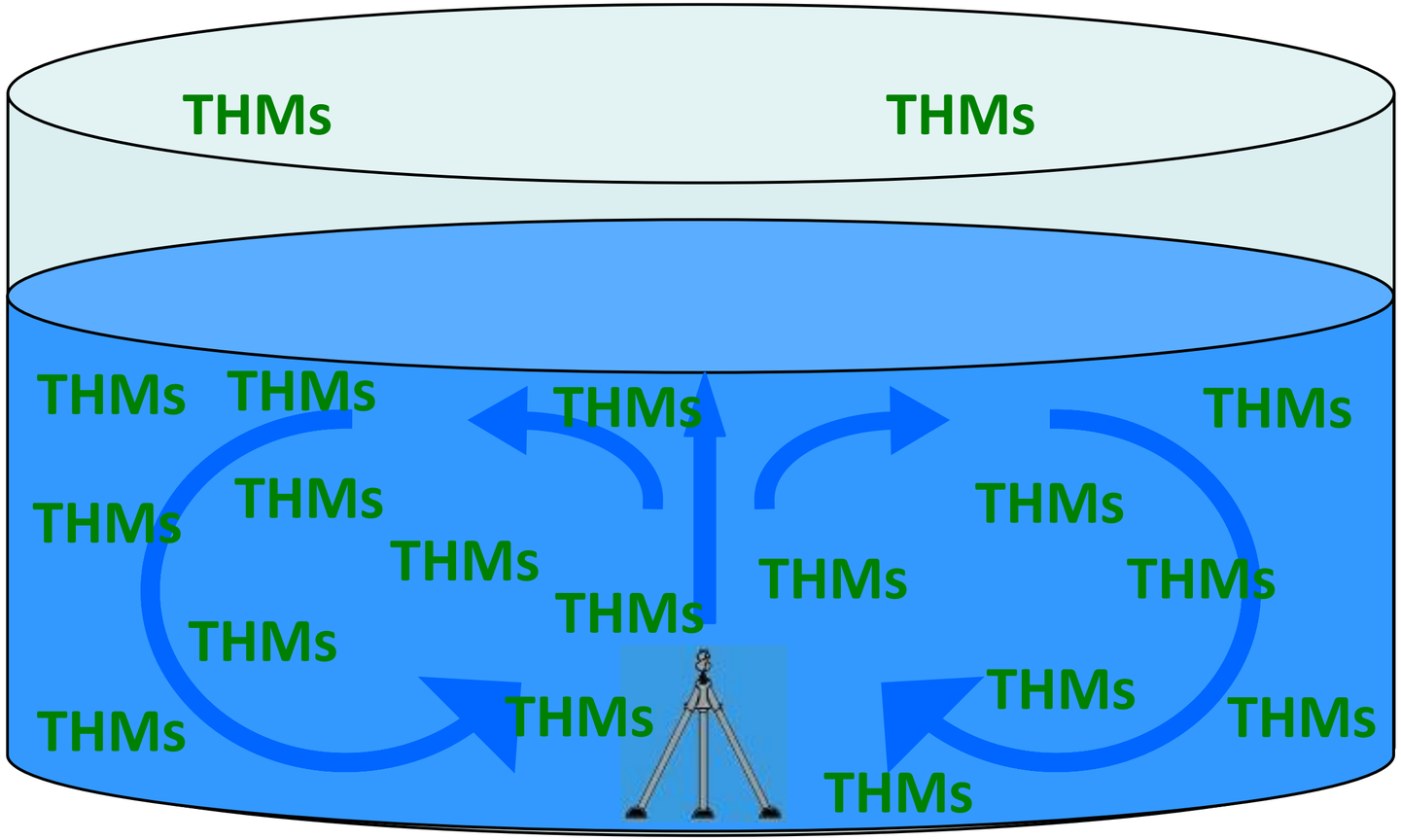


THM species	Henry's law constant @ 20 °C
Chloroform	0.13 (87% in water)
Bromodichloromethane	0.08
Chlorodibromomethane	0.04
Bromoform	0.02 (98% in water)

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

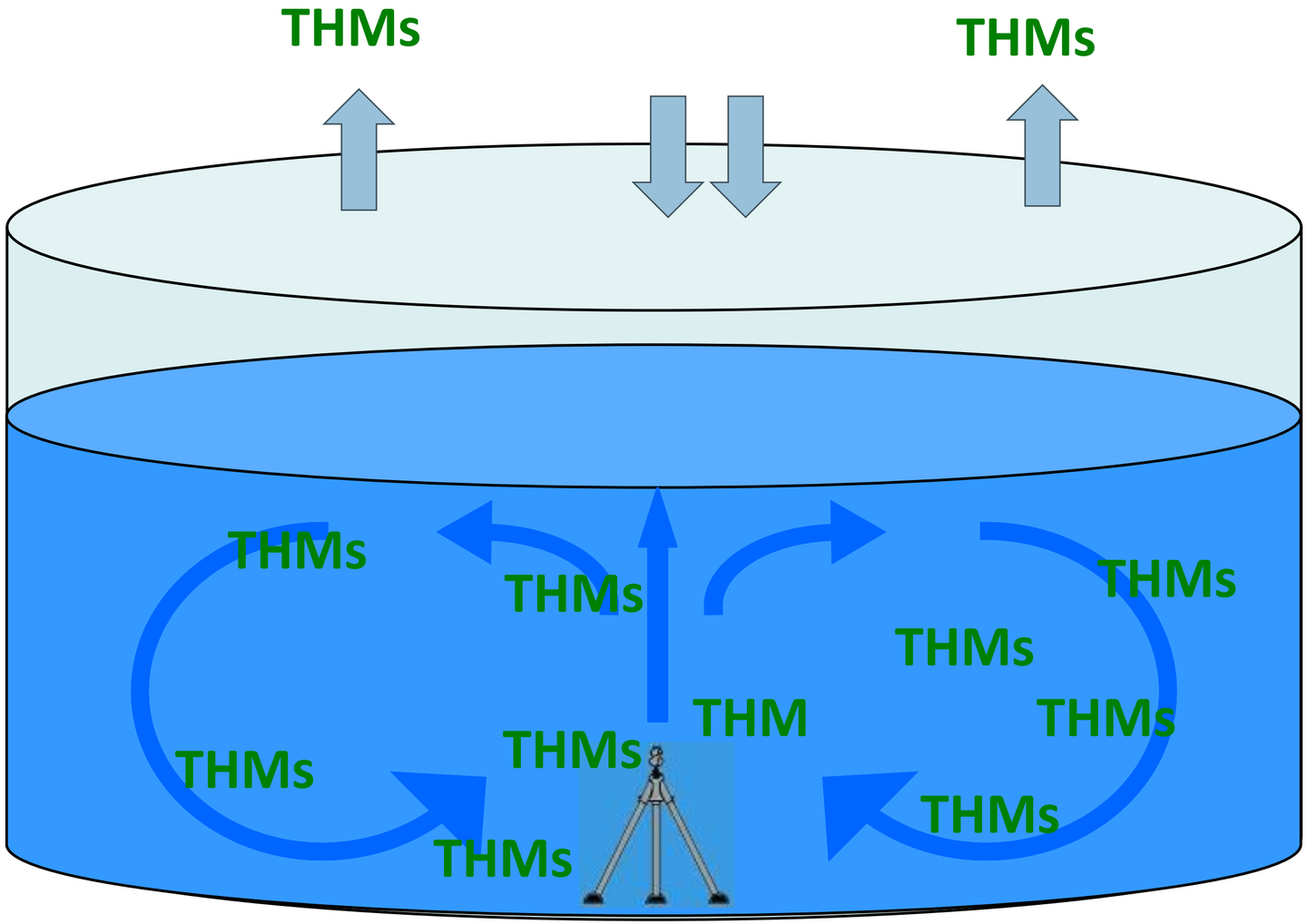
Bromoform is the least "volatile" (hardest to remove)

HENRY'S LAW LIMITS PASSIVE THM REMOVAL, BUT ACTIVE MIXING ALLOWS THM'S TO BRIDGE THE DIFFUSIONAL BARRIER.



You need <u>STRONG</u> mixing

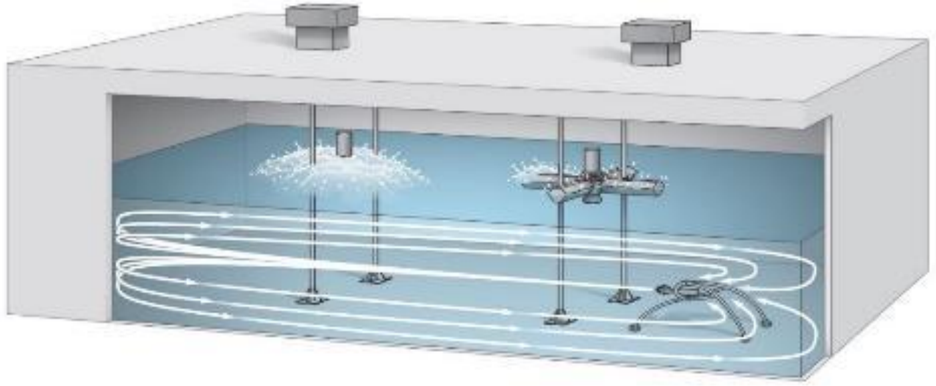
ACTIVE VENTILATION BREAKS HENRY'S LAW EQUILIBRIUM BY REMOVING THM OUT OF THE TANK HEADSPACE.



THERE ARE THREE COMMON IN-TANK AERATION CONFIGURATIONS FOR THM REMOVAL.



Mixer + Ventilation



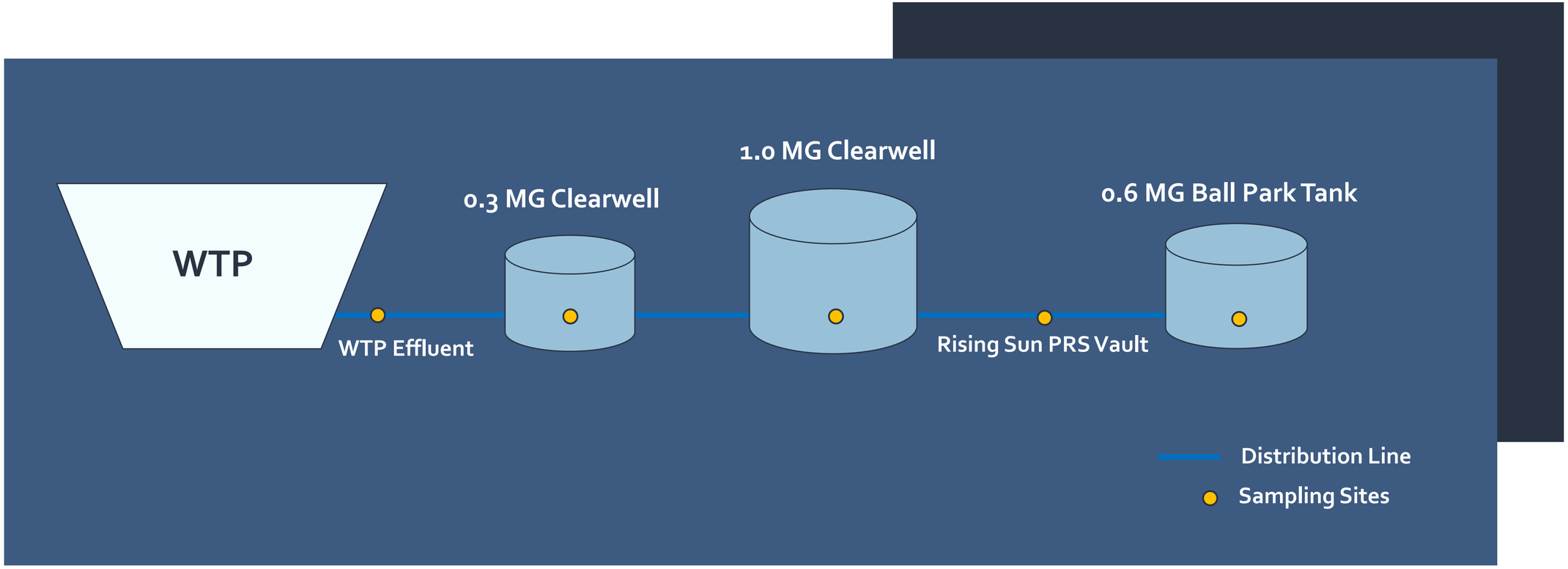
Surface Aeration



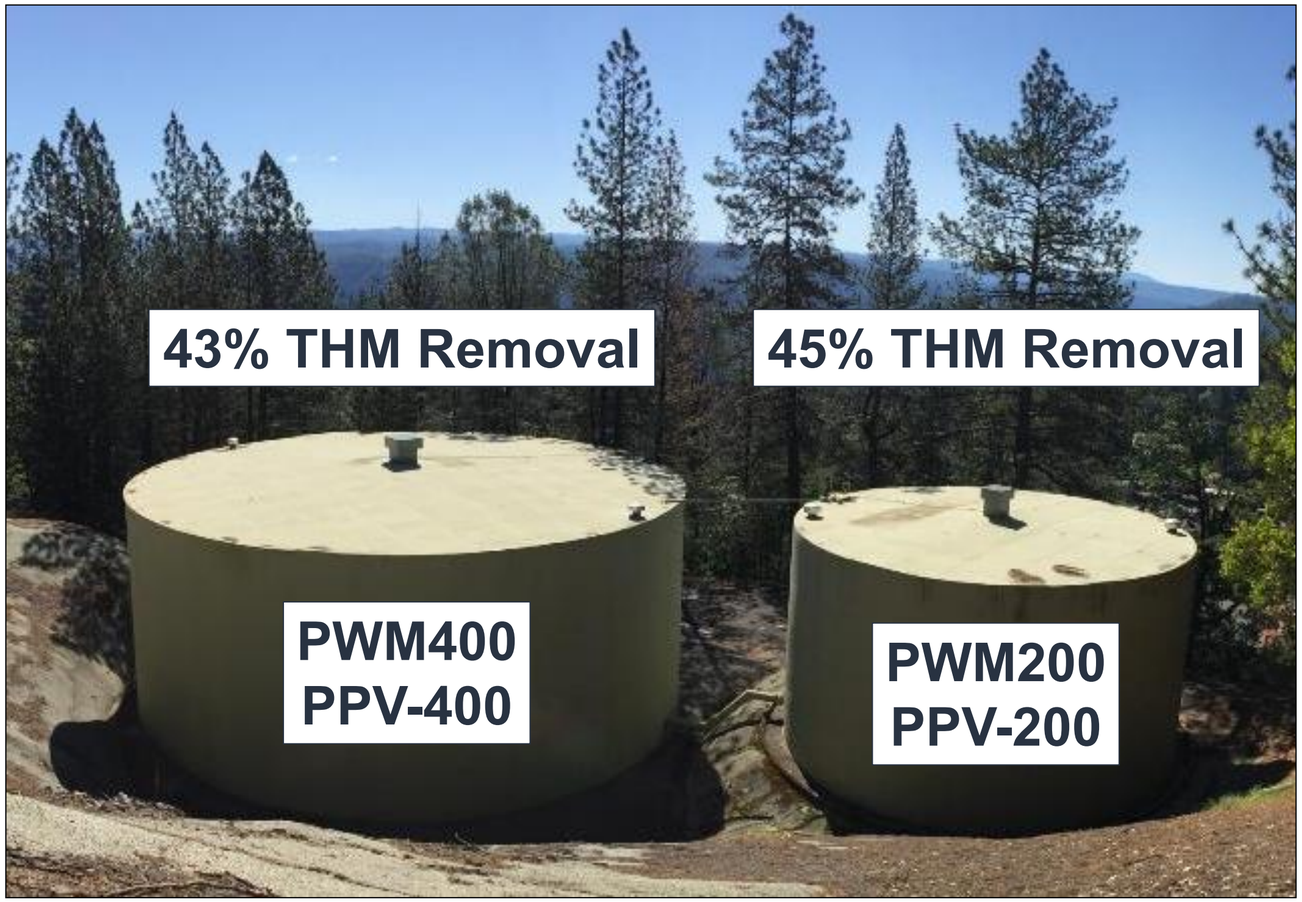
Spray Aeration

Case Study
Colfax, CA

- High water age
- Low turnover
- In-tank Aeration pilot
  Active mixing and ventilation



Case Study: Colfax, CA



0.3 MG and 1.0 MG Clearwells
(4-day detention)

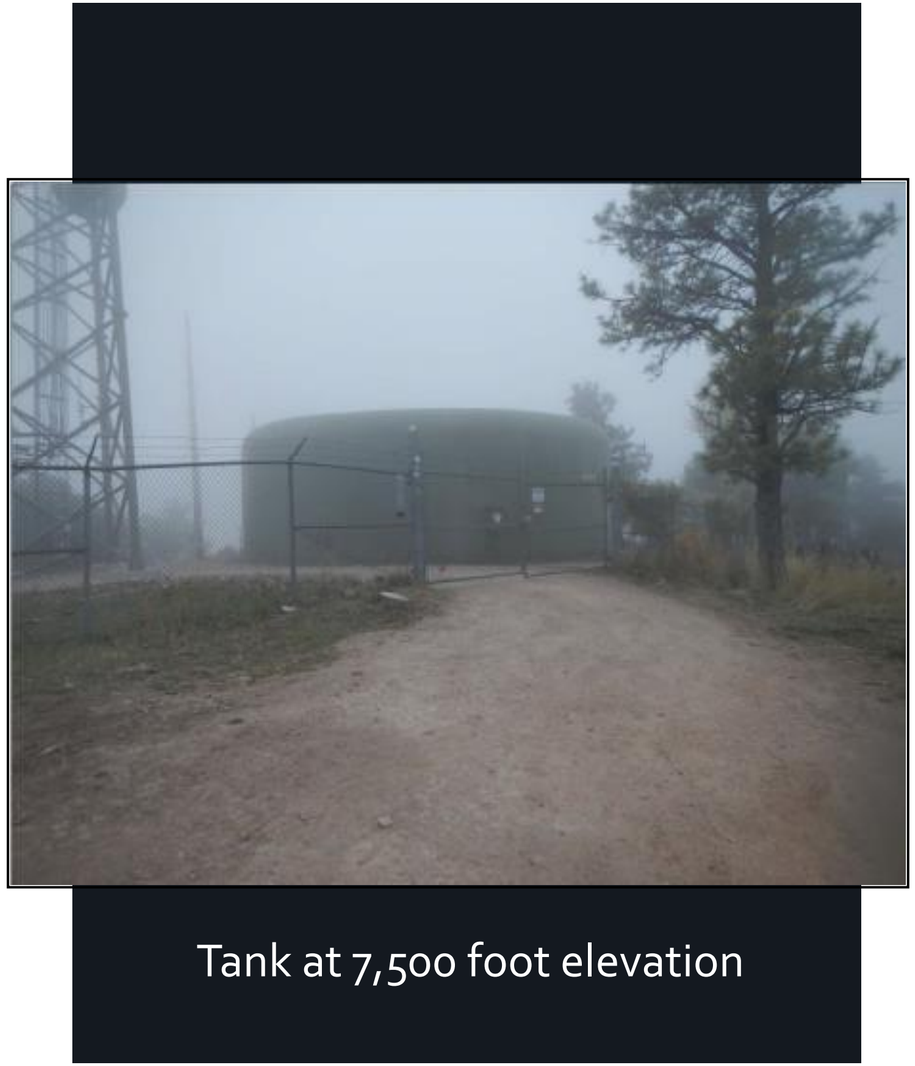


0.6 MG Ball Park Tank
(10-day detention – end of line)

CASE STUDY

Colorado Springs, CO

- High THM levels
- Prior THM mitigation efforts
- In-tank aeration
- Winter Installation



Tank at 7,500 foot elevation

Case Study: Colorado Springs, CO

DESPITE EXTREME WEATHER, THE INSTALLATION WAS COMPLETED IN THREE DAYS WITHOUT TAKING THE TANK OFFLINE.



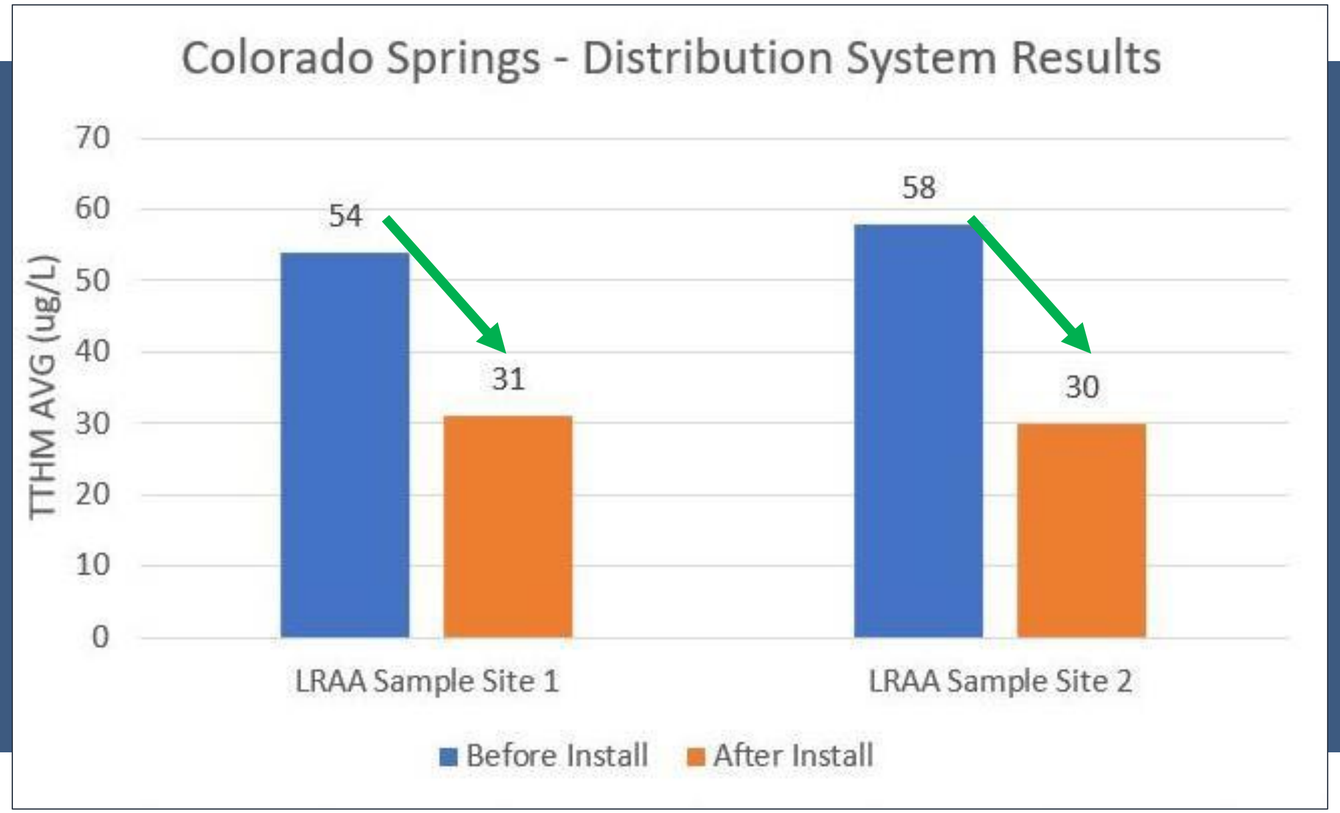
PWM 500 Mixer 0.5 HP



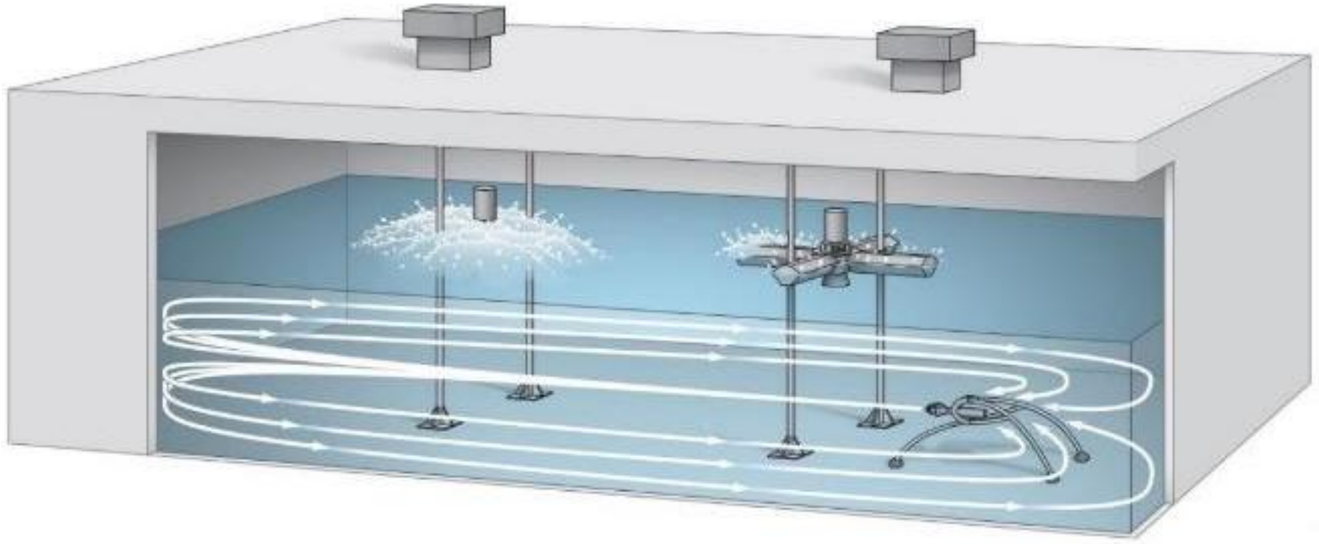
PPV 400 Powervent™ 0.5 HP

Case Study: Colorado Springs, CO

IN-TANK AERATION RESULTED IN 42% AND 48% REDUCTION IN THMS AT SAMPLE LOCATIONS DOWNSTREAM OF THE TANK.



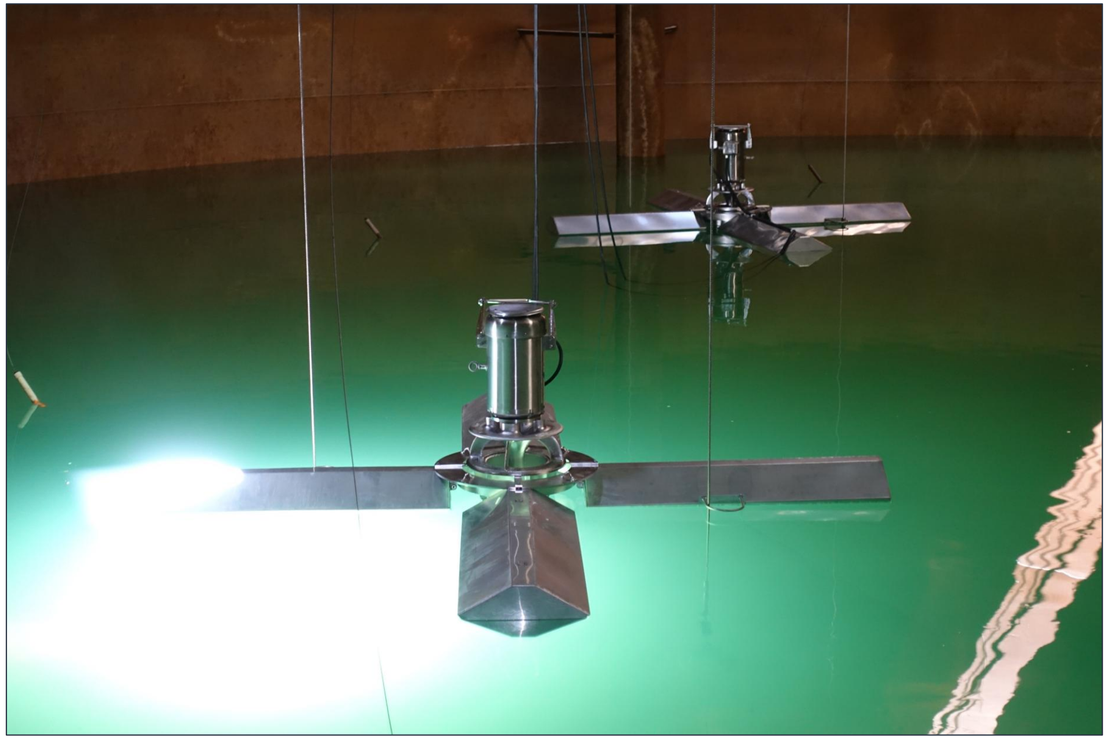
SURFACE AERATION IS A GOOD METHOD TO ENHANCE THM-REMOVAL IN TANKS, BUT PROPER EQUIPMENT SELECTION IS KEY.

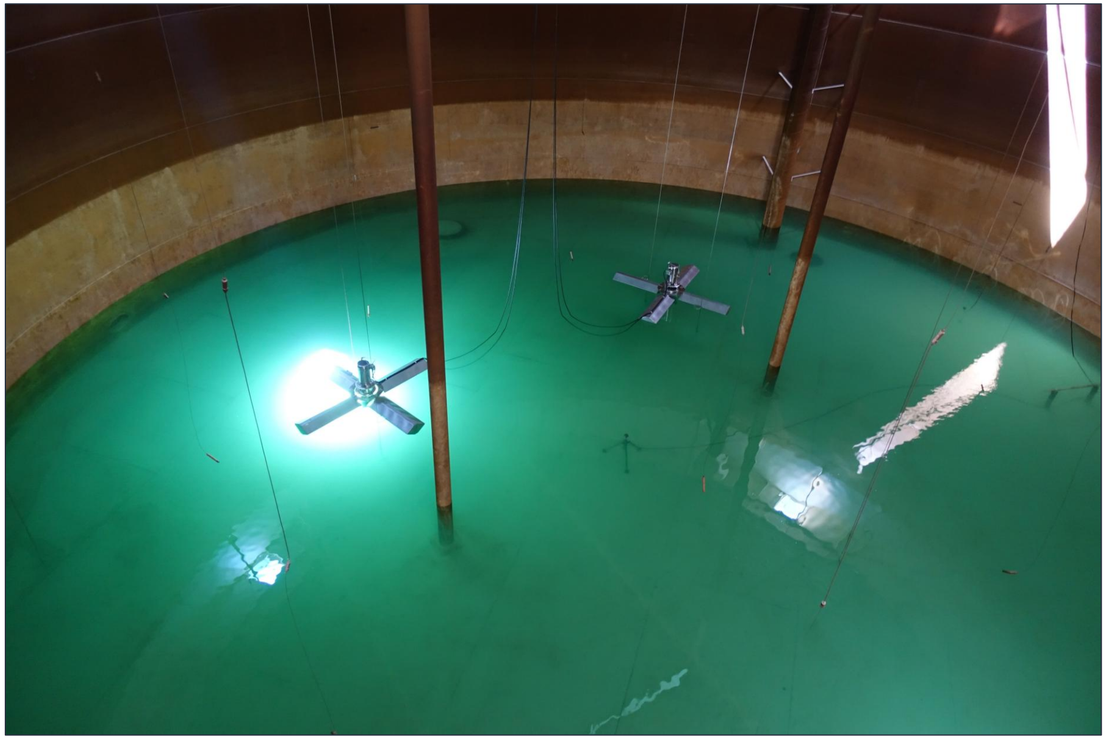


Considerations:

- Energy efficiency
- Installation
- Maintenance

SURFACE AERATOR INSTALLATIONS ARE STRAIGHTFORWARD AND DO NOT REQUIRE EXTENSIVE TANK MODIFICATIONS.







Case Study: San Luis Obispo, CA



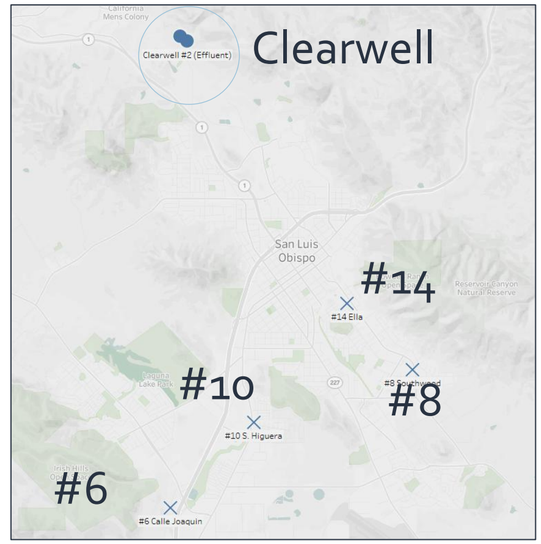


SAN LUIS OBISPO WATER TREATMENT PLANT

Case Study: San Luis Obispo, CA

SAMPLES FROM THE DISTRIBUTION SYSTEM SHOW HIGHER THM LEVELS DURING WARMER MONTHS, SOME MEASURING ABOVE THE MCL OF 80 PPB.

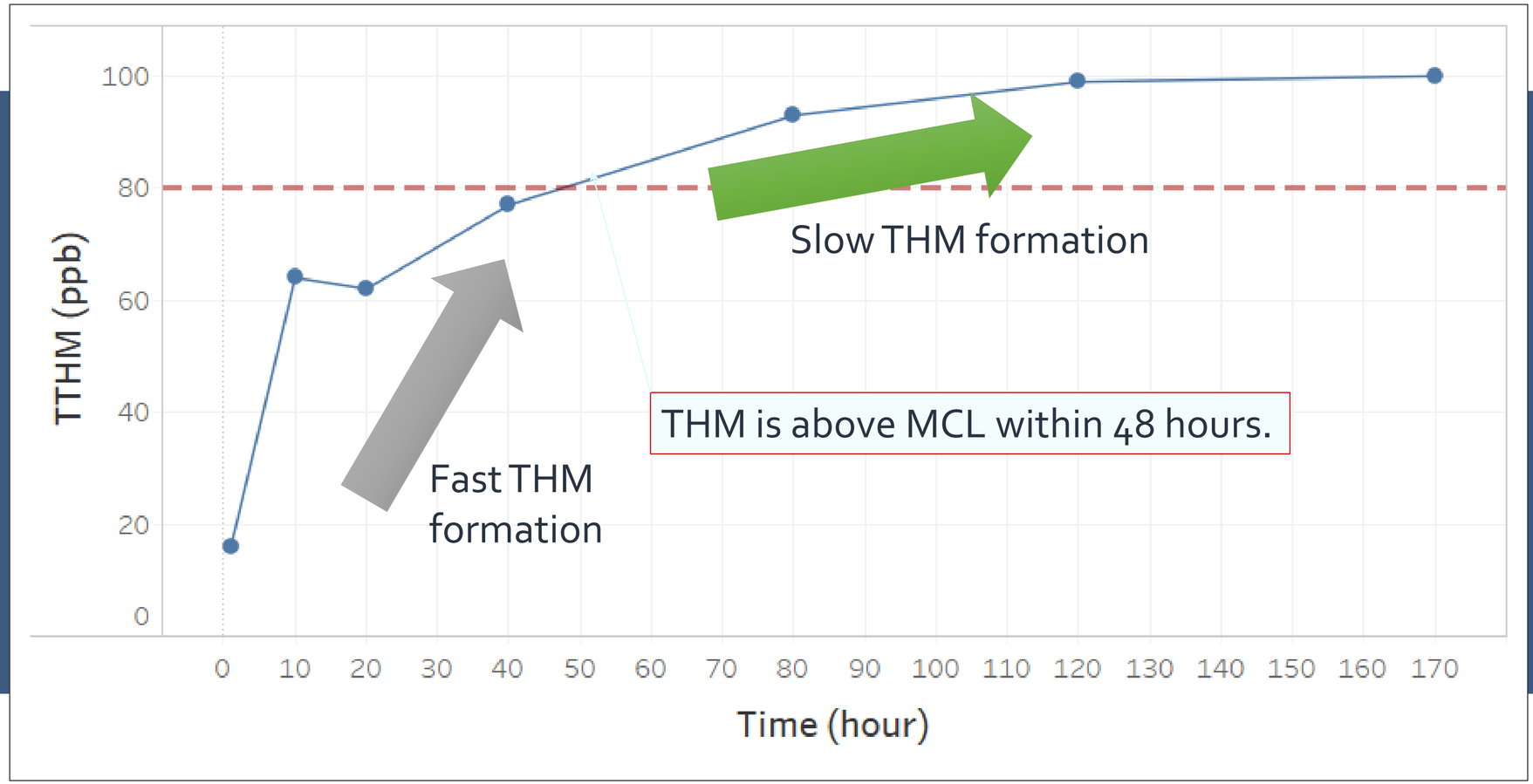
Sample Locations



	2014				2015				2016			2017				2018		
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
#6 Calle Joaquin	33	60	86	7	30	75	52	41	43	55	40	34	37	53	60	43	33	99
#8 Southwood	51	66	74	115	44	95	59	42	57	66	31	36	35	66	32	39	30	72
#10 S. Higuera	51	66	74	115	44	95	59	42	57	66	31	36	35	66	32	39	30	72
#14 Ella	57	12	75	110	40	65	57	44	62	57	35	35	39	56	39	29	31	72

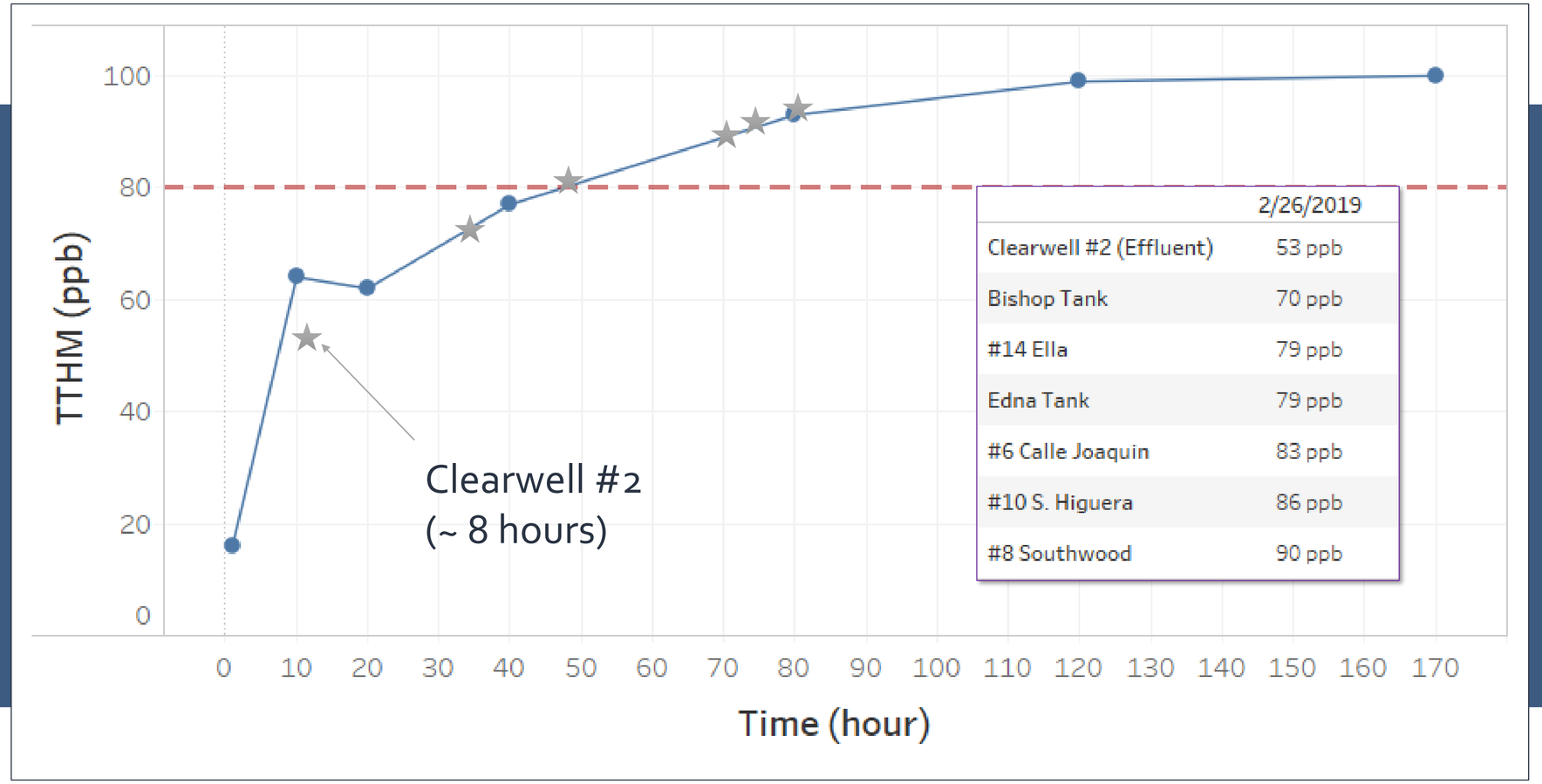
TTHM (ppb)
40 100

Case Study: San Luis Obispo, CA



Samples taken at Clearwell #1 and held in lab to generate formation curve.

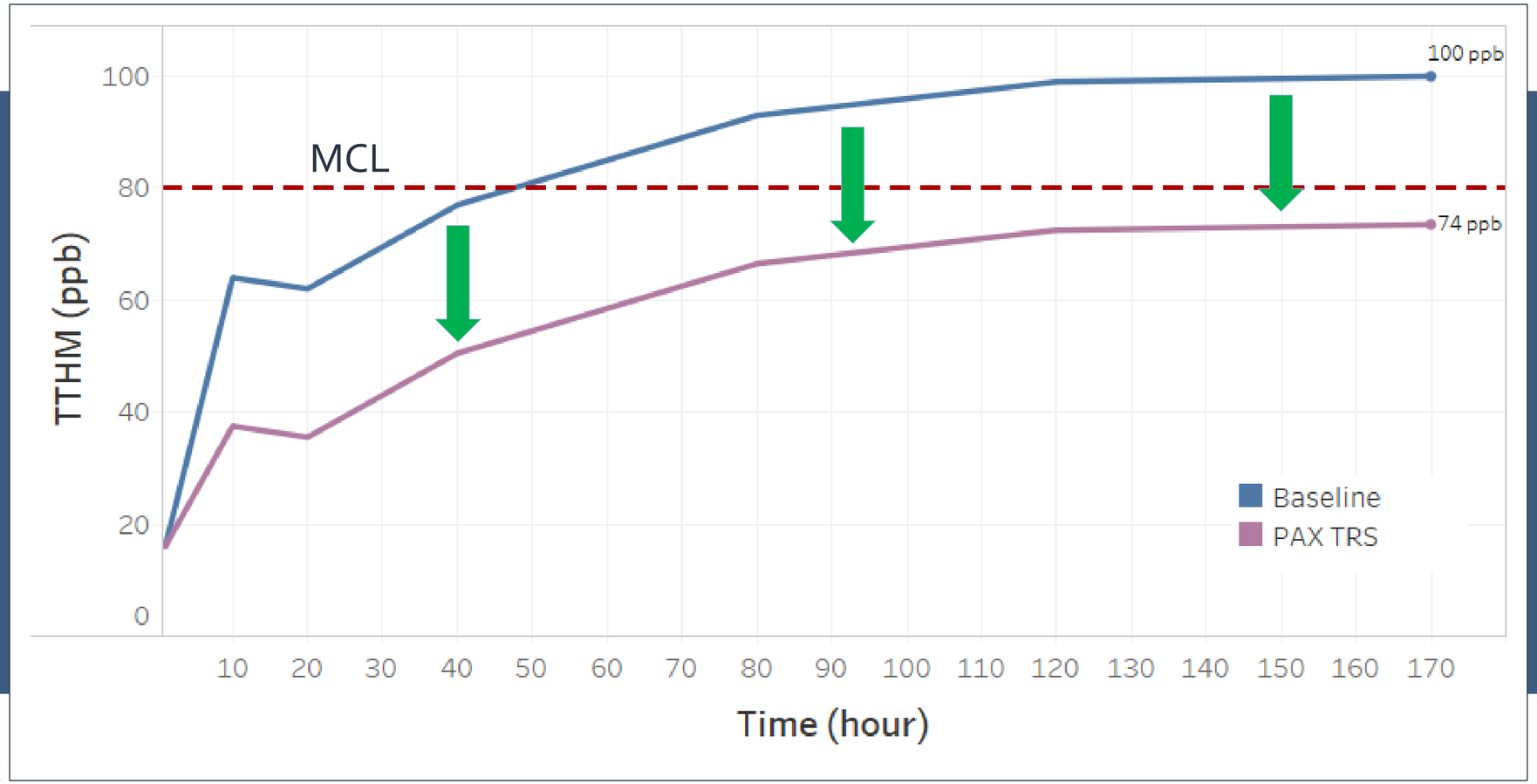
Case Study: San Luis Obispo, CA



THM formation in lab compared to actual samples from various sites in the distribution network.

Case Study: San Luis Obispo, CA

A 50% REDUCTION OF THM BY PAX TRS™ MAINTAINS THM FORMATION POTENTIAL BELOW THE MCL.



Case Study: San Luis Obispo, CA

IN-TANK AERATION DESIGN FOR CLEARWELL #2



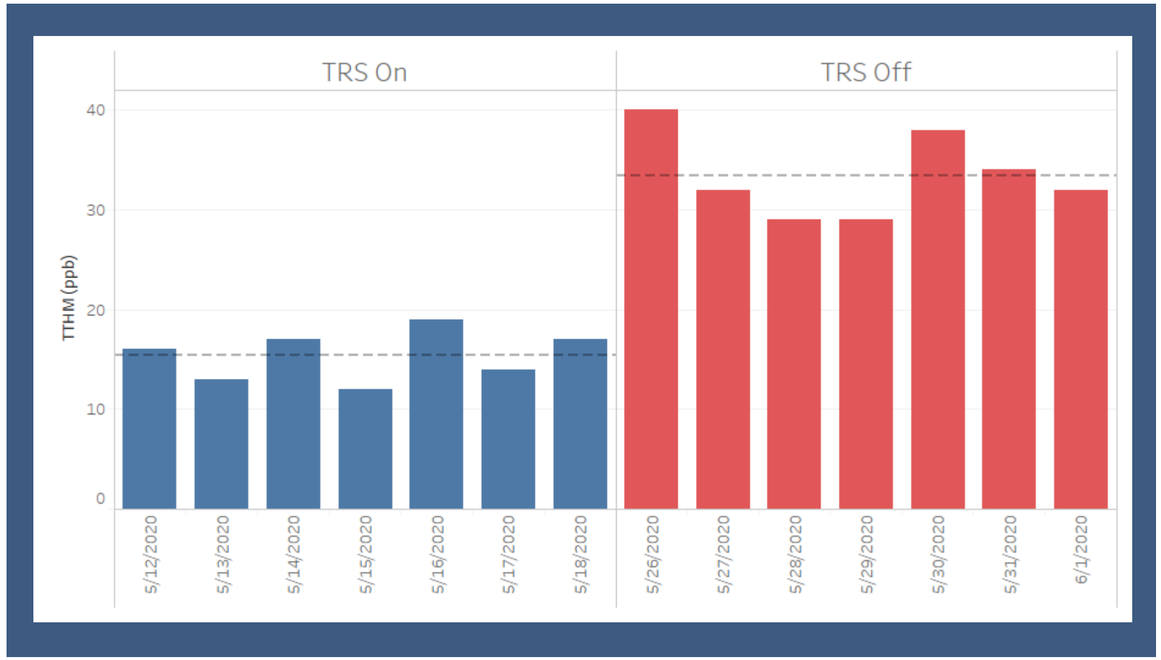


Design Criteria	
Tank Volume, gal	2,000,000
Reservoir Type	Above ground steel
Tank Diameter, ft	107
Tank Height, ft	30
High Water Level, ft	25
Low Water Level, ft	19 - 21
Turnover, gpd	5,500,000
Operating Description	Steady-state
Guaranteed THM Removal Rate	40%
On-site power required	480V, 3 Phase

Installation:

- (7) Surface Aerators : SA-150 model, 15HP each
- Active Ventilation: PPV-1000, 12,000 CFM, 7.5 HP
- Active Mixer: PWM500, 1 HP
- Integrated control panel

Case Study: San Luis Obispo, CA

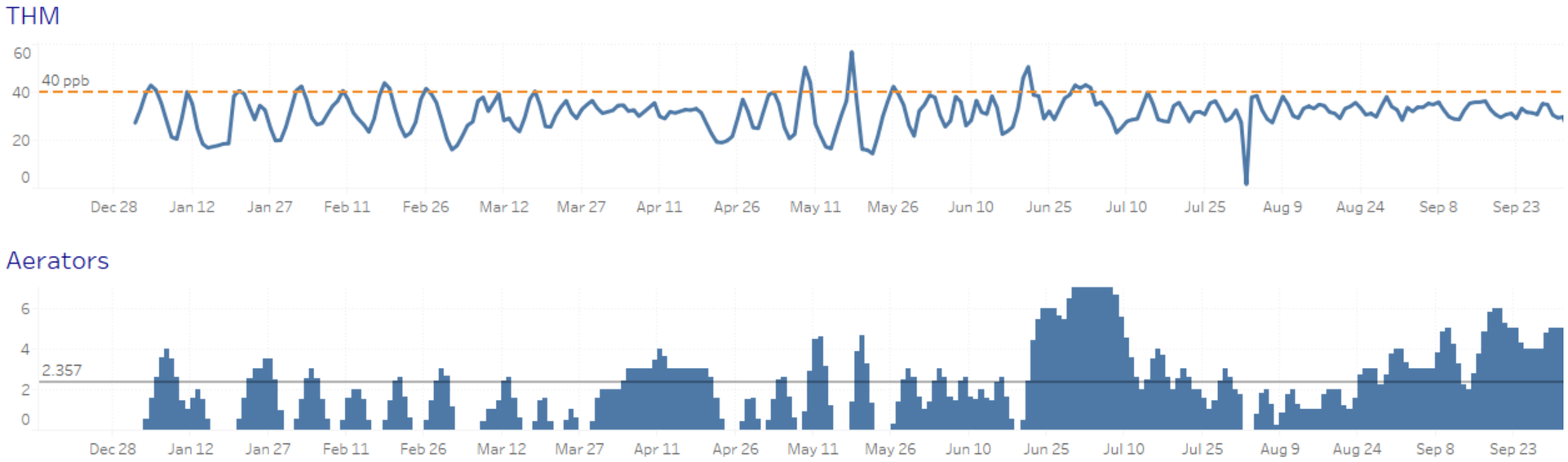


Average TTHM System On	Average TTHM System Off	% Removal	% Removal Guarantee
15.4 ppb	33.4 ppb	**53.8%**	40%

Validation protocol (“on” vs. “off”) with 7-day THM samples.

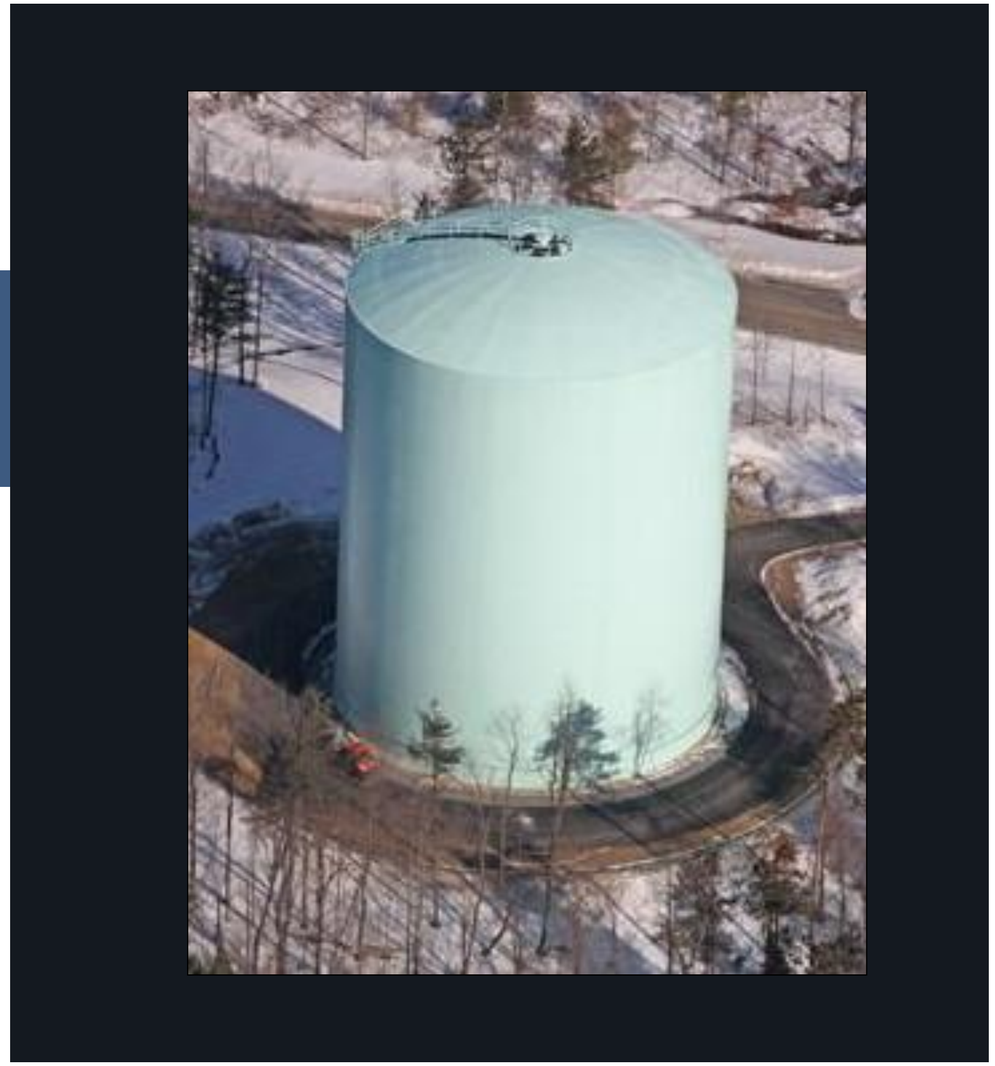
Case Study: San Jose, CA 12 MG More Avenue Reservoir

ACTIVE FEEDBACK CONTROL OF THE PAX TRS™ SYSTEM USING THM SENSORS YIELDED ~50% OPERATING COST/ENERGY SAVINGS.



KEY TAKEAWAYS

- Storage tanks are the perfect intervention point for distribution system water quality.
- **Active mixing is the starting point** for water quality solutions, including:
  - Residual control
  - Nitrification and biostability
  - THM removal



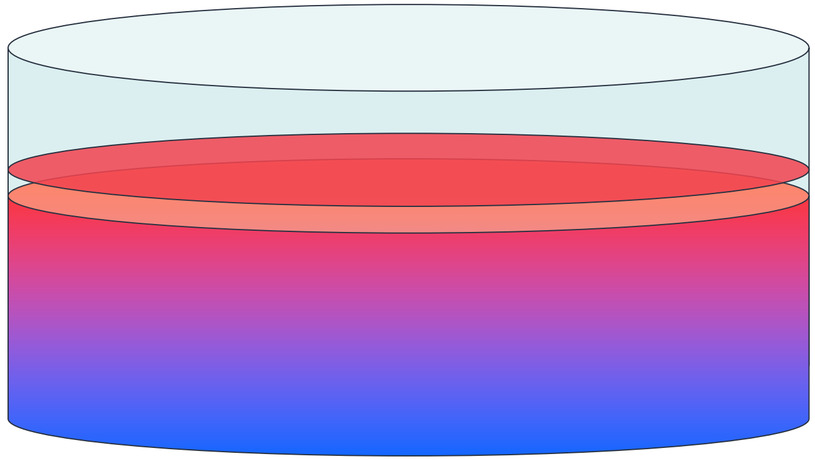
Effective mixing improves asset life and water quality.

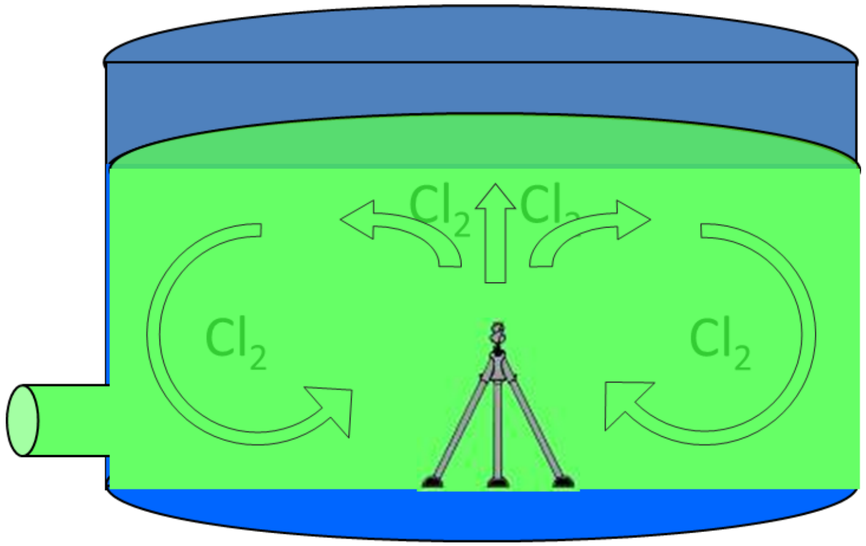
Water Quality Benefits:

- Eliminates stratification and reduces water age in storage tanks
- Reduces residual demand in tanks
- Enables safe, reliable boosting of tanks
- Reduces biofilm formation on tank walls
- Removes THMs (with active ventilation)

Asset Protection Benefits:

- Reduces sediment accumulation in tanks
- Reduces headspace temperatures (lower corrosion rates)
  - Especially with active ventilation
- Controls ice formation





THANK YOU

CONTACT INFO

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970-946-4005

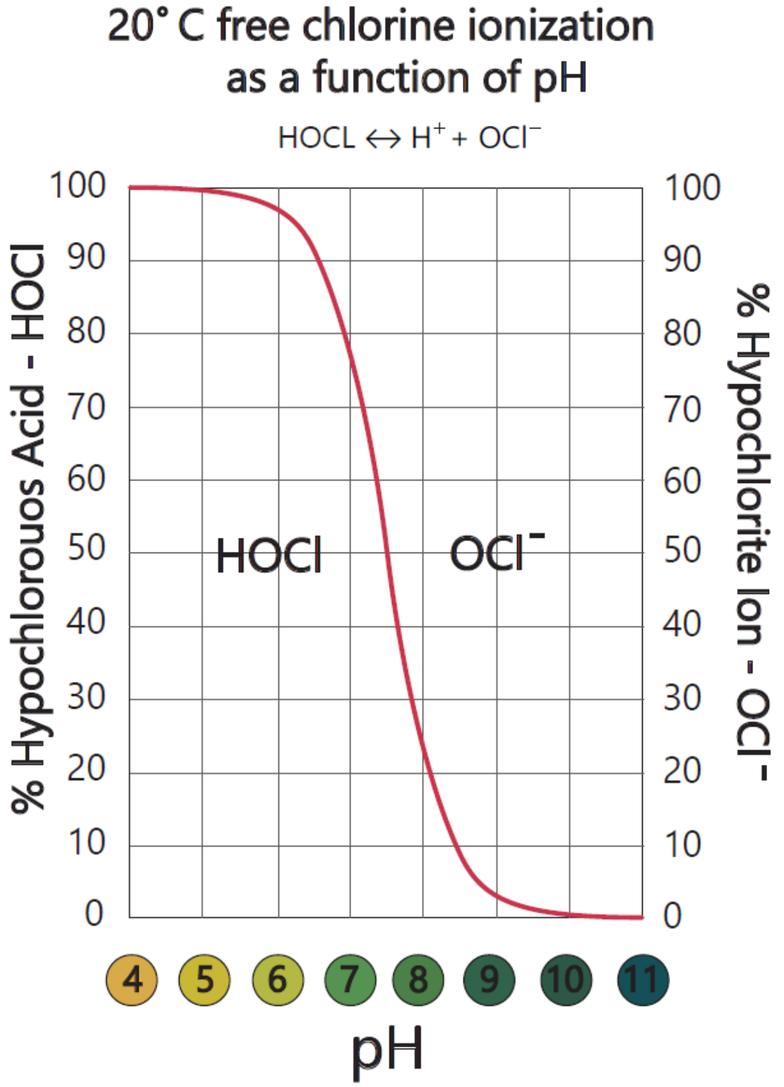


SOLUTIONS THAT WORK

CHLORINE IS NOT LOST DURING THE AERATION PROCESS

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

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

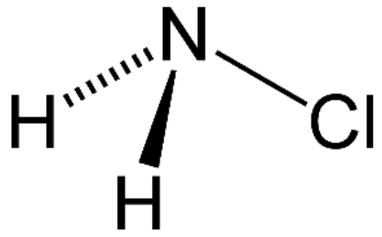


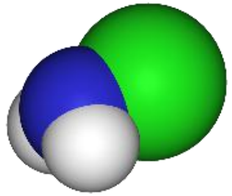
RESIDUAL CONTROL

Additional Slides

CHLORAMINES, USED IN ABOUT A THIRD OF MUNICIPAL WATER SYSTEMS, PROVIDE LONGER PROTECTION IN DISTRIBUTION SYSTEMS AND ARE LESS PRONE TO ENCOURAGE DBP FORMATION.

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

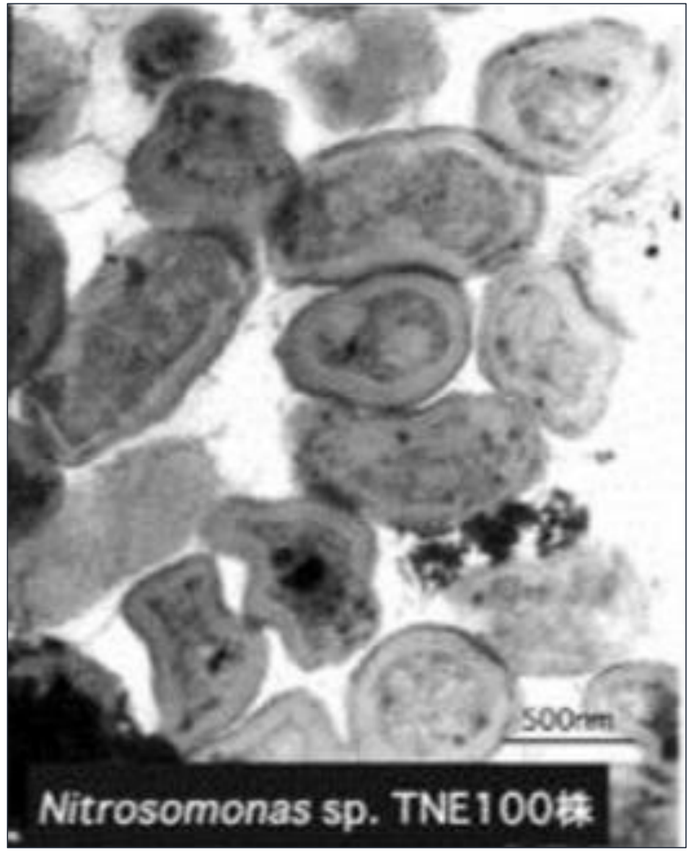




Monochloramine is formed by the reaction of chlorine and ammonia with a chlorine atom substituting for one of the three ammonia hydrogen atoms

CHLORAMINES HAVE BEEN PROBLEMATIC DUE TO THE CHALLENGE OF CONTROLLING DOSING IN A DYNAMIC DISTRIBUTION SYSTEM.

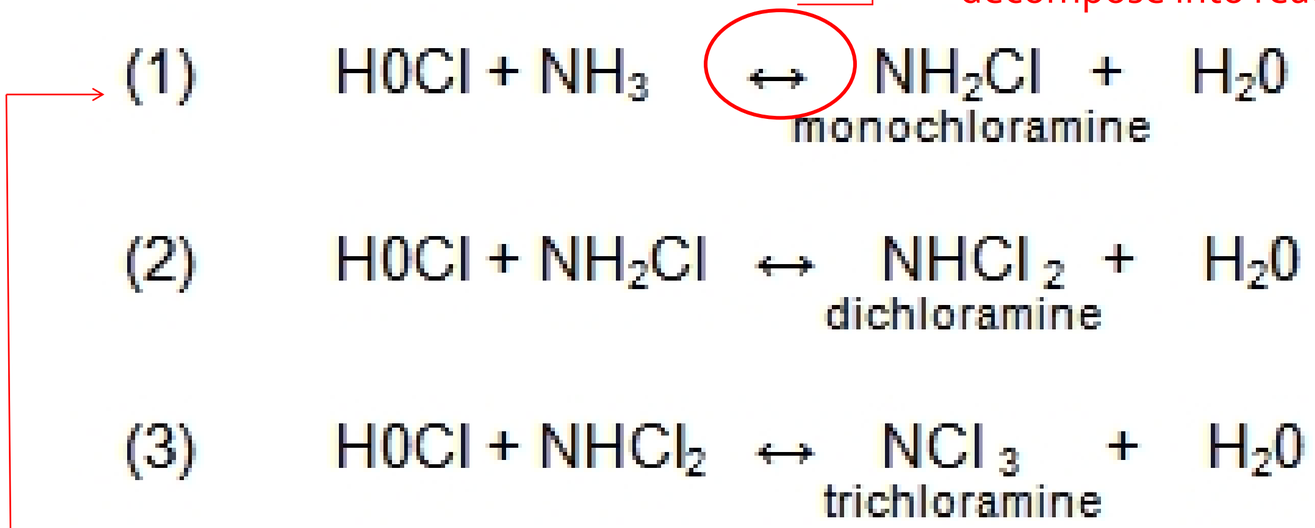
- **Taste and odor** from over-chlorination (formation of dichloramines and trichloramines)
- **Nitrification** with Ammonia Oxidizing Bacteria (AOBs) and Nitrite Oxidizing Bacteria (NOBs)
- **Low residual levels,** which can lead to costly mitigation efforts such as:
  - Chlorine burns
  - Line flushing
  - Tank cycling
  - Water wasting or tank dumping



Ammonia Oxidizing Bacteria (AOB)

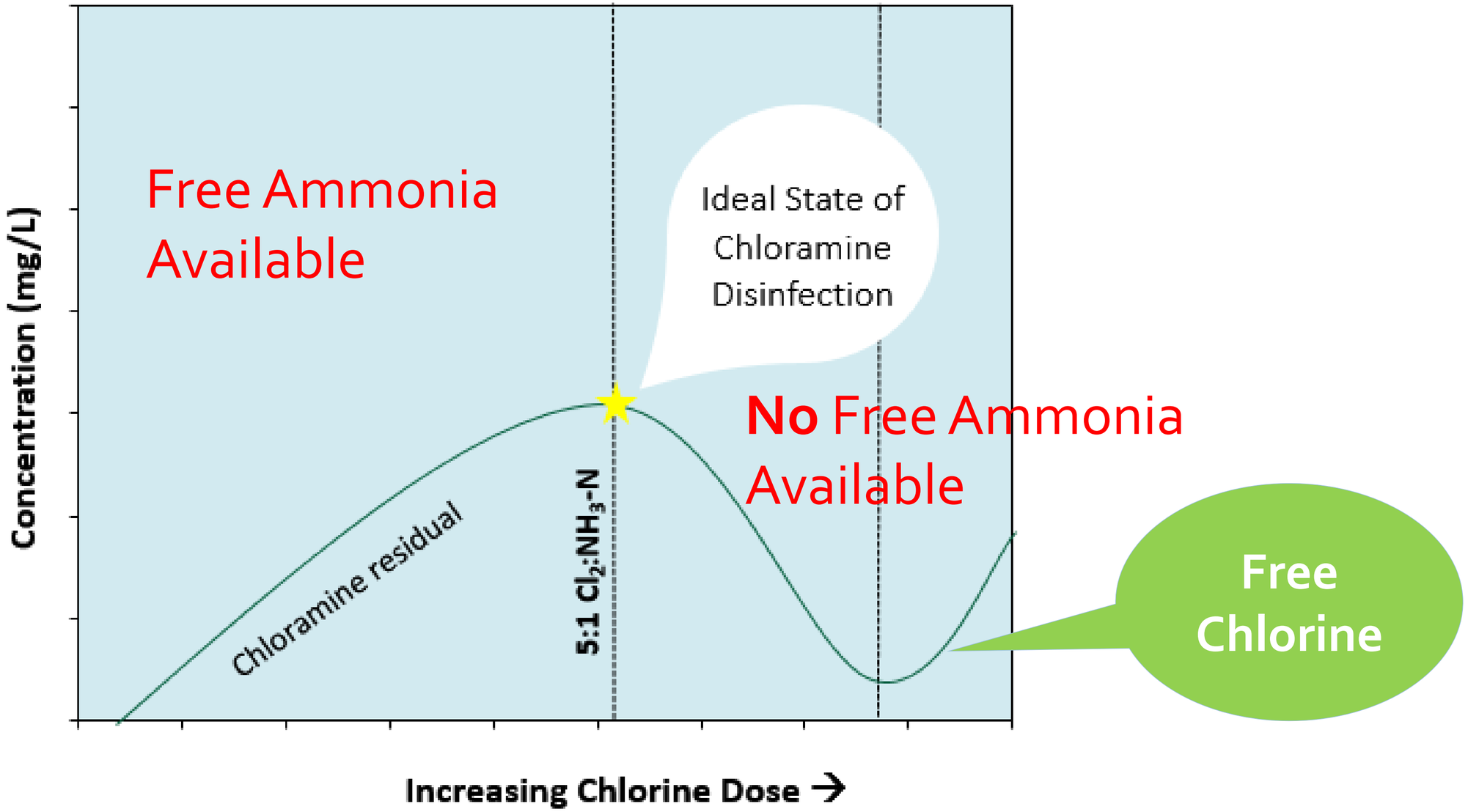
THERE ARE THREE “CHLORAMINE” VARIANTS – ONLY ONE OF WHICH IS DESIRABLE IN A WATER SYSTEM

This reaction is reversible – under certain conditions, products can decompose into reactants

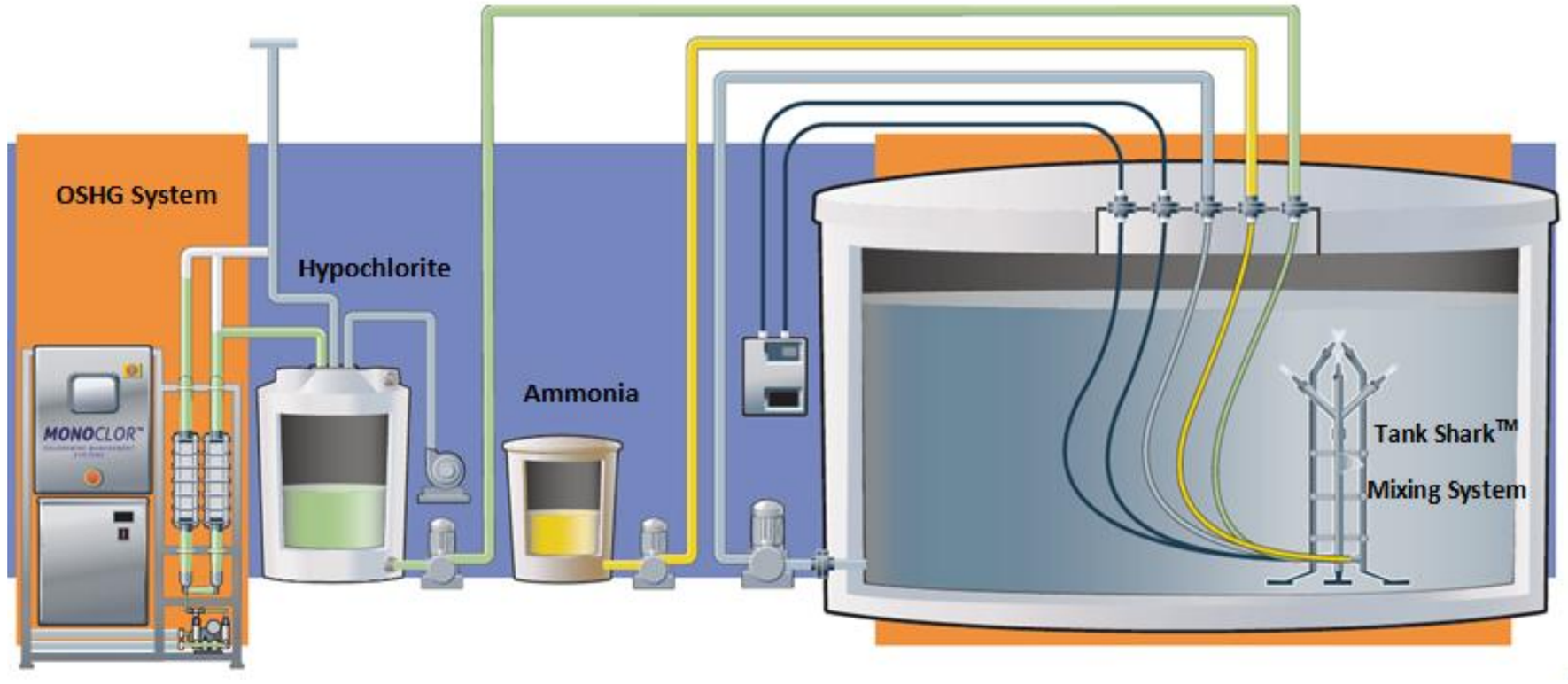


Only monochloramine is considered a suitable disinfectant

CHLORAMINE BREAKPOINT CURVE: KNOW WHERE YOU ARE ON THE CURVE.



RESIDUAL CONTROL SYSTEMS CAN BE FULLY AUTOMATED WITH DOSING OF CHLORINE AND/OR AMMONIA BASED ON REAL-TIME DETERMINATION OF WHERE THE TANK CHEMISTRY IS ON THE BREAK-POINT CURVE.



WATER QUALITY STATION



Parameters

- Total or Free chlorine
- pH & ORP
- Temperature
- Pressure

INSTALLATION EXAMPLES





INSTALLATION EXAMPLES





INSTALLATION EXAMPLES





INSTALLATION EXAMPLES





INSTALLATION EXAMPLES





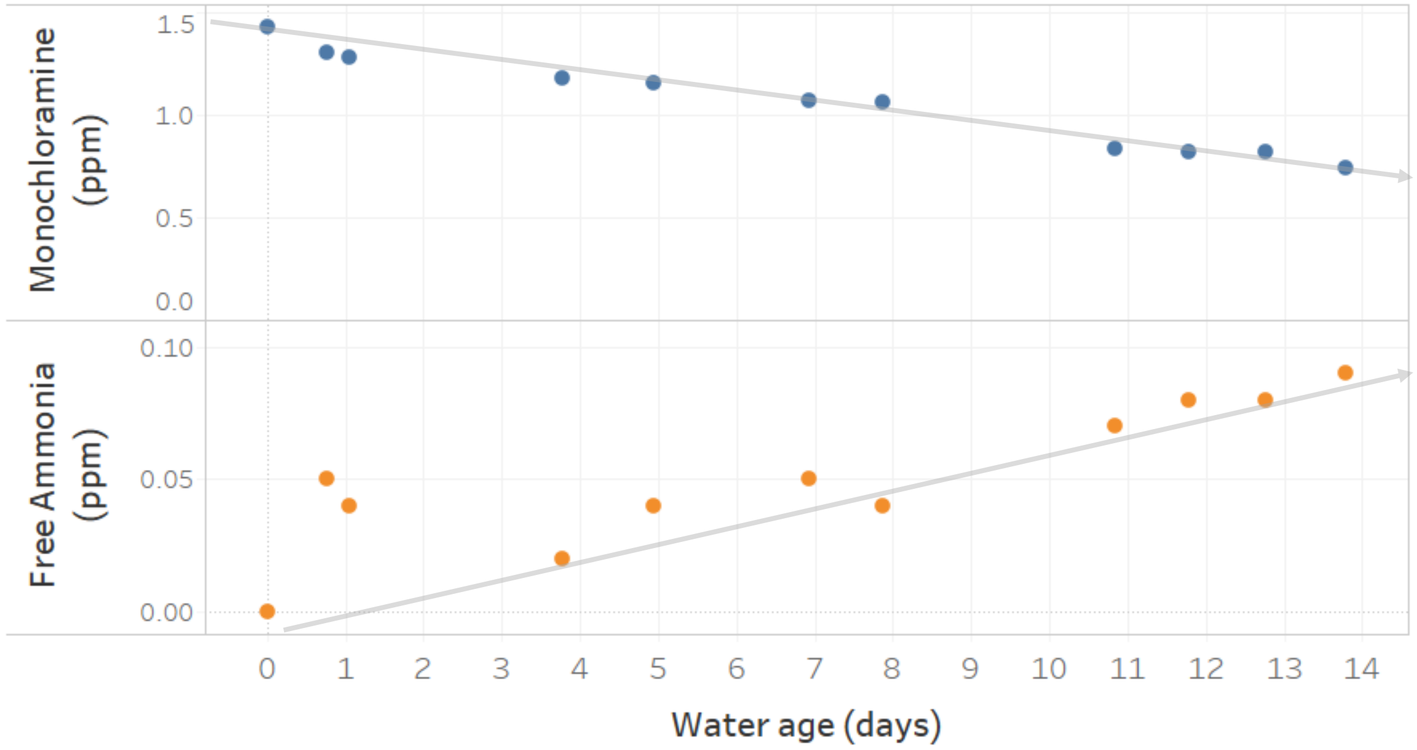




NITRIFICATION CONTROL

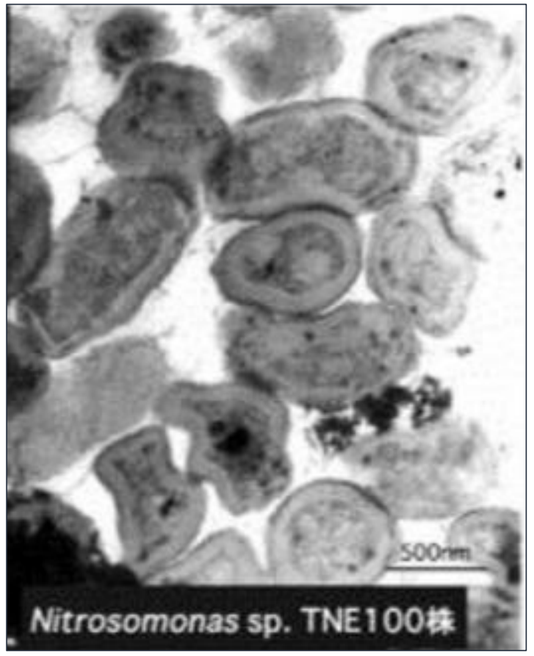
Additional Slides

HOW DOES NITRIFICATION OCCUR?



Chloramine Drops ☹

Free ammonia Builds up ☹



Ammonia Oxidizing Bacteria (AOB)

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

Holding test : Water samples taken at the same time and held for analysis over time

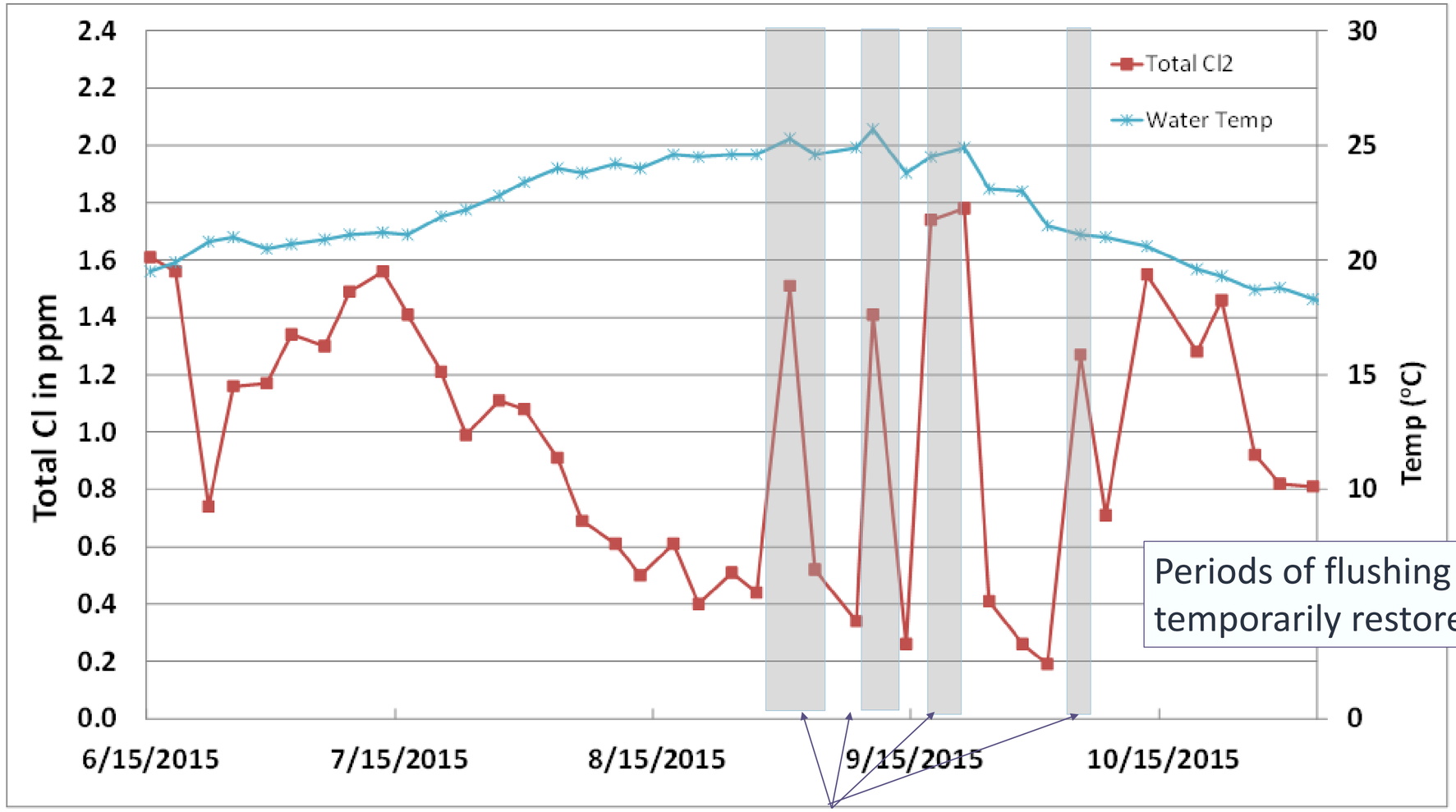
CASE STUDY
Loudoun, VA

- Low residual & nitrification
- Flushing
- Bulk hypo & LAS
- Residual Control installed in 2016



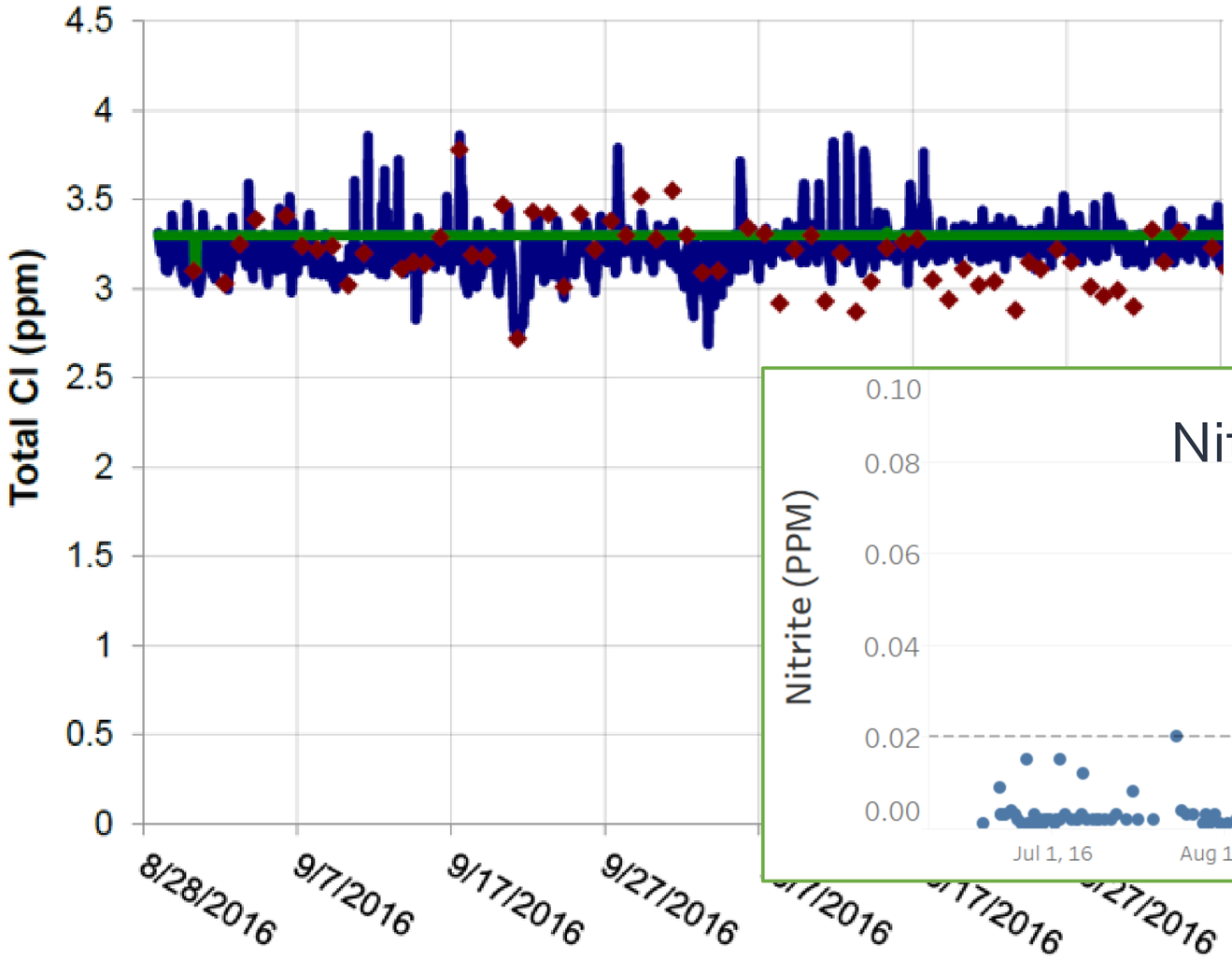
3.0 MG reservoir

THE PROBLEM: FLUSHING IS NOT EFFECTIVE!

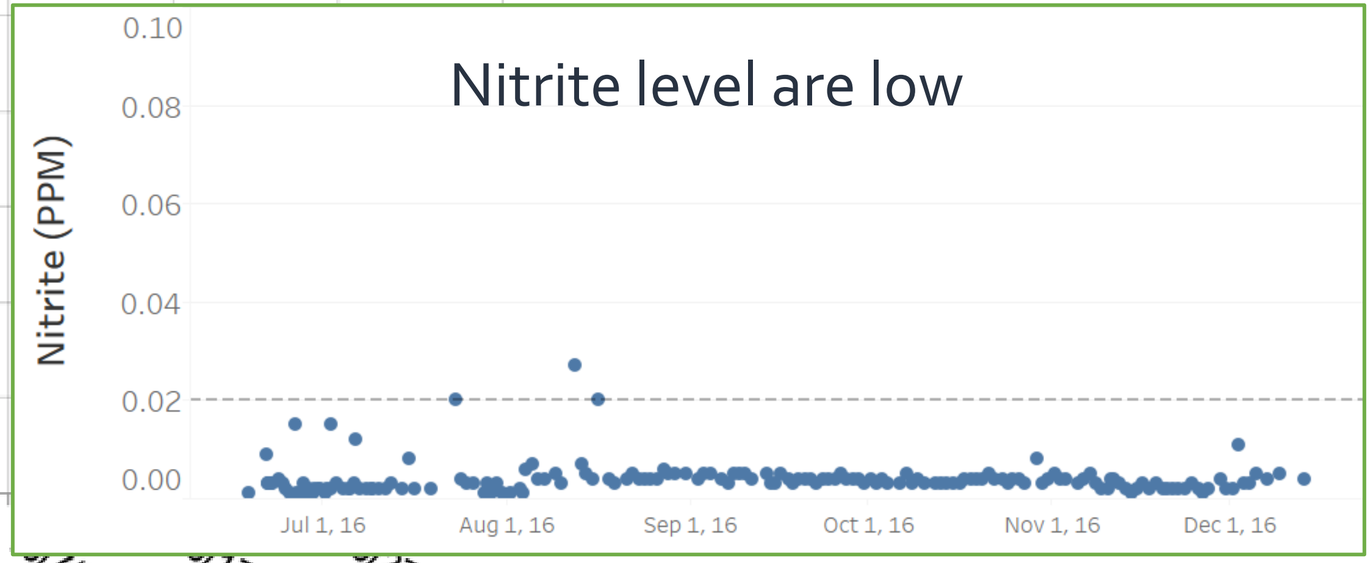


Periods of flushing (grey) would only temporarily restore residual levels.

EFFECTIVE DISINFECTANT RESIDUAL CONTROL ELIMINATED THE THREAT OF NITRIFICATION IN THE NEXT YEAR.



High residual



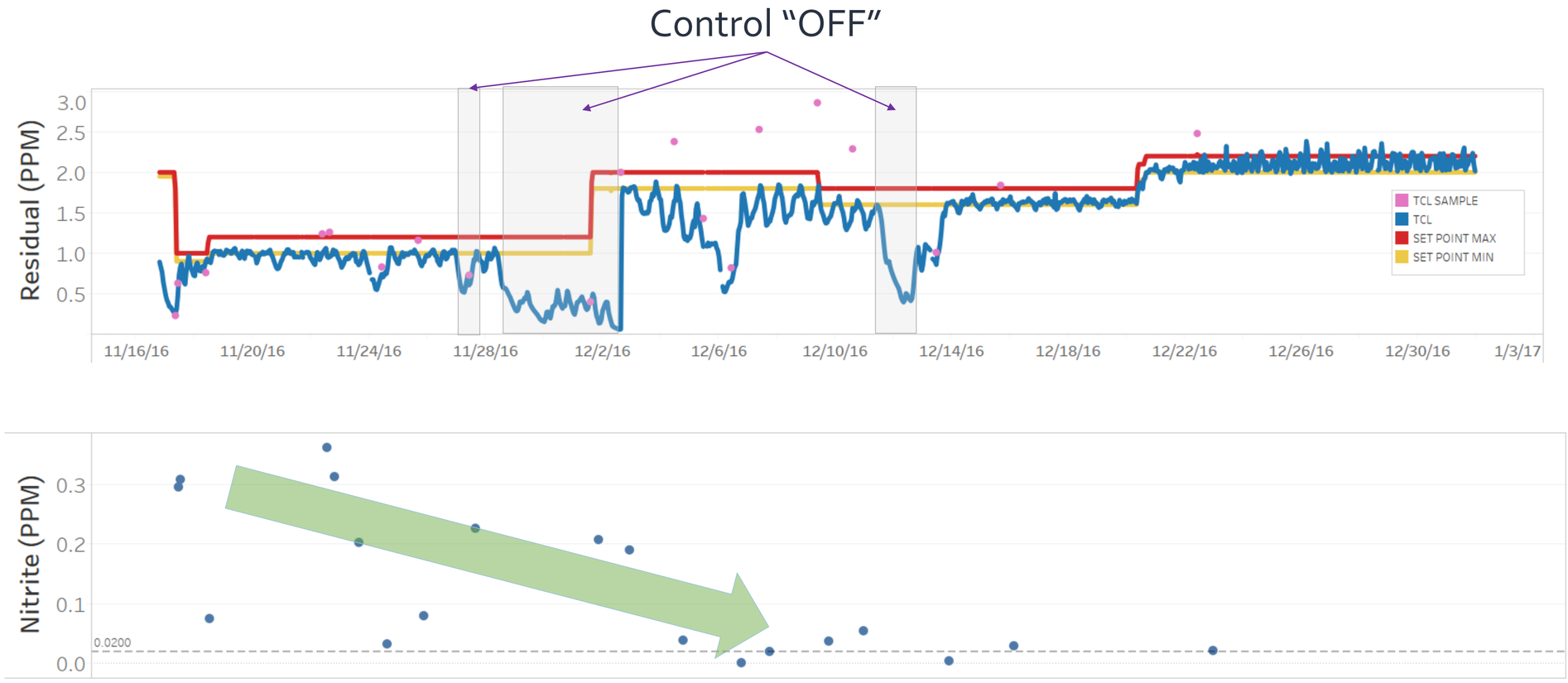
CASE STUDY
Coppell, TX



1.5 MG reservoir

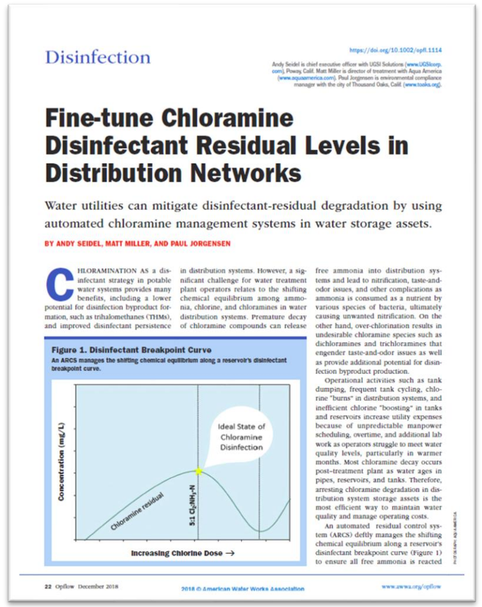


RESIDUAL CONTROL HELPS REDUCE NITRITE LEVEL TO NORMAL LEVEL.



- Residual is on target,
- Residual drop when "OFF"
- Nitrite reduction to normal level

SEASONAL PATTERNS: AUGUST TO DECEMBER CAN BE DIFFICULT MONTHS FOR NITRIFICATION.



Disinfection

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

Andy Seidel is chief executive officer with UGSI Solutions (www.UGIcorp.com), Poway, Calif. Matt Miller is director of treatment with Aqua America (www.aquaamerica.com). Paul Jorgensen is environmental compliance manager with the city of Thousand Oaks, Calif. (www.toaks.org).

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.

Figure 1. Disinfectant Breakpoint Curve

An ARCS manages the shifting chemical equilibrium along a reservoir's disinfectant breakpoint curve.

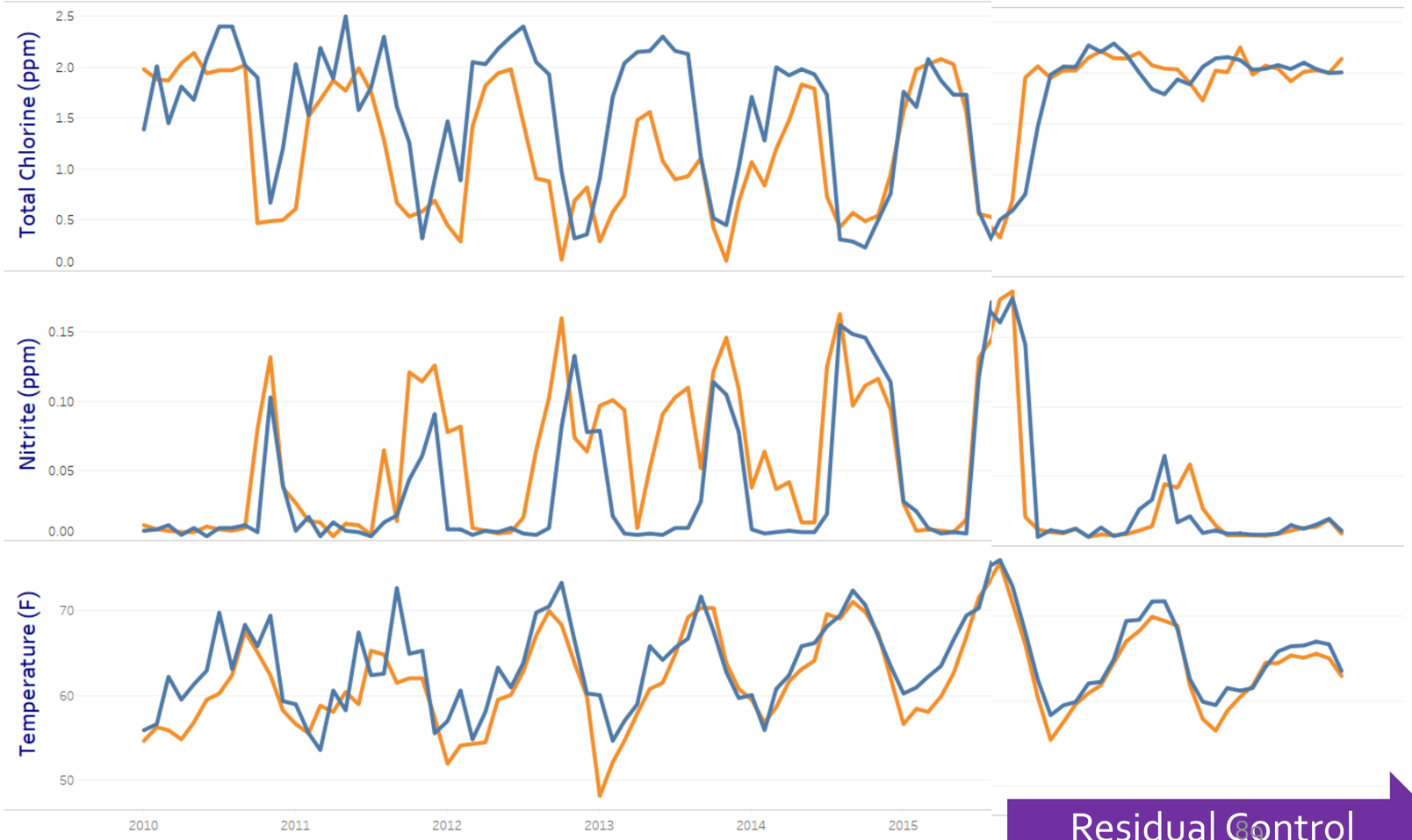
Operational activities such as tank dumping, frequent tank cycling, chlorine "burns" in distribution systems, and inefficient chlorine "boosting" in tanks and reservoirs increase utility expenses because of unpredictable manpower scheduling, overtime, and additional lab work as operators struggle to 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

2018 © American Water Works Association

Opflow (AWWA), December 2018

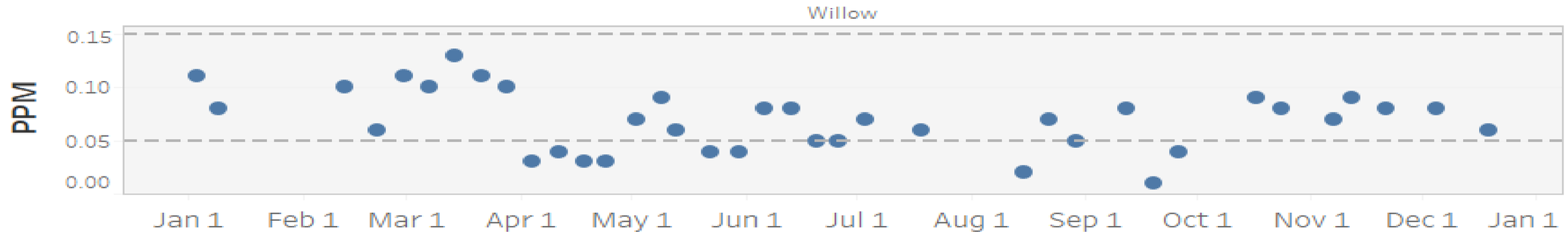
Temperature is up, residual is down and nitrite is up.



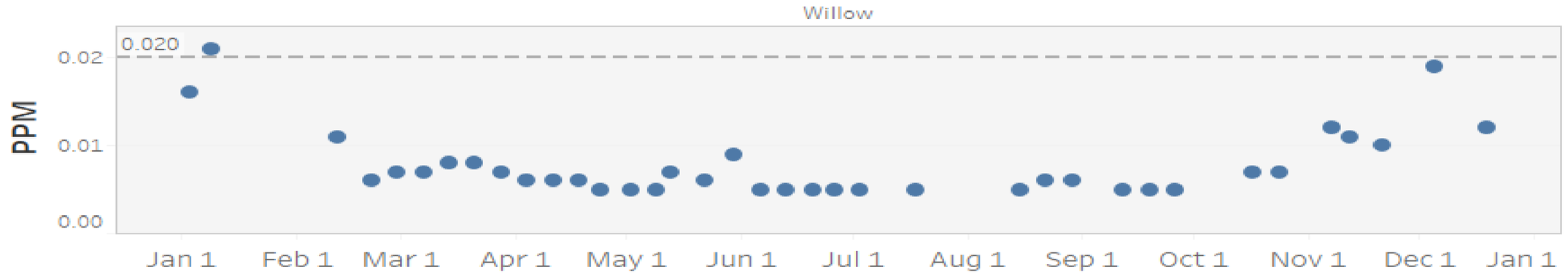
Residual Control

AS A RESULT, NITRITE AND FREE AMMONIA LEVELS ARE CONTROLLED ALL YEAR LONG WITH NO NITRIFICATION EPISODES.

Free Ammonia

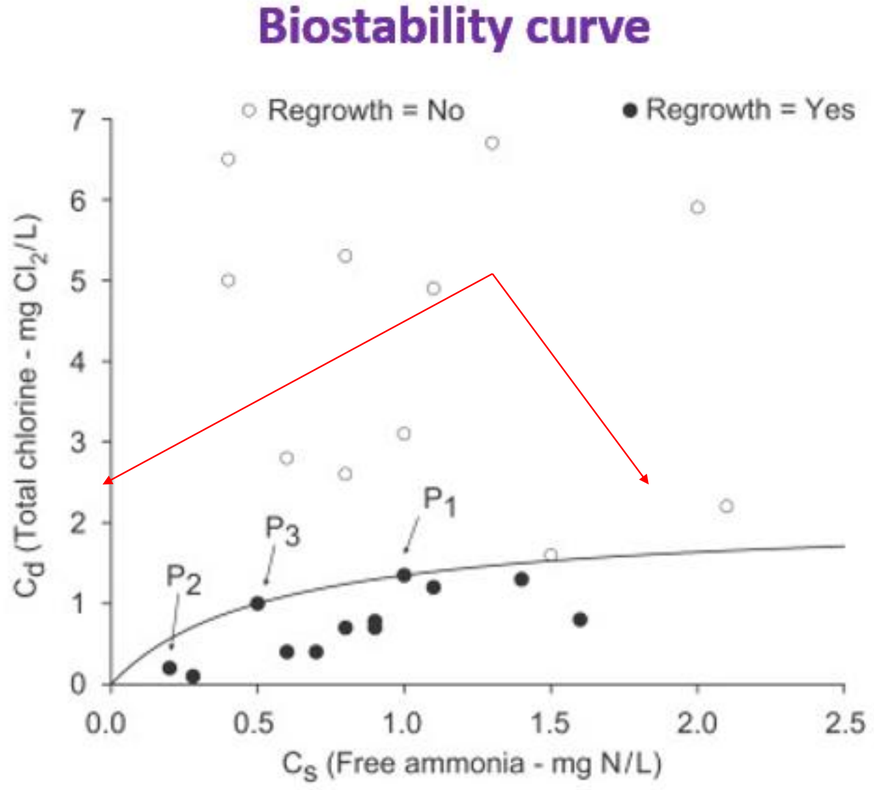


Nitrite



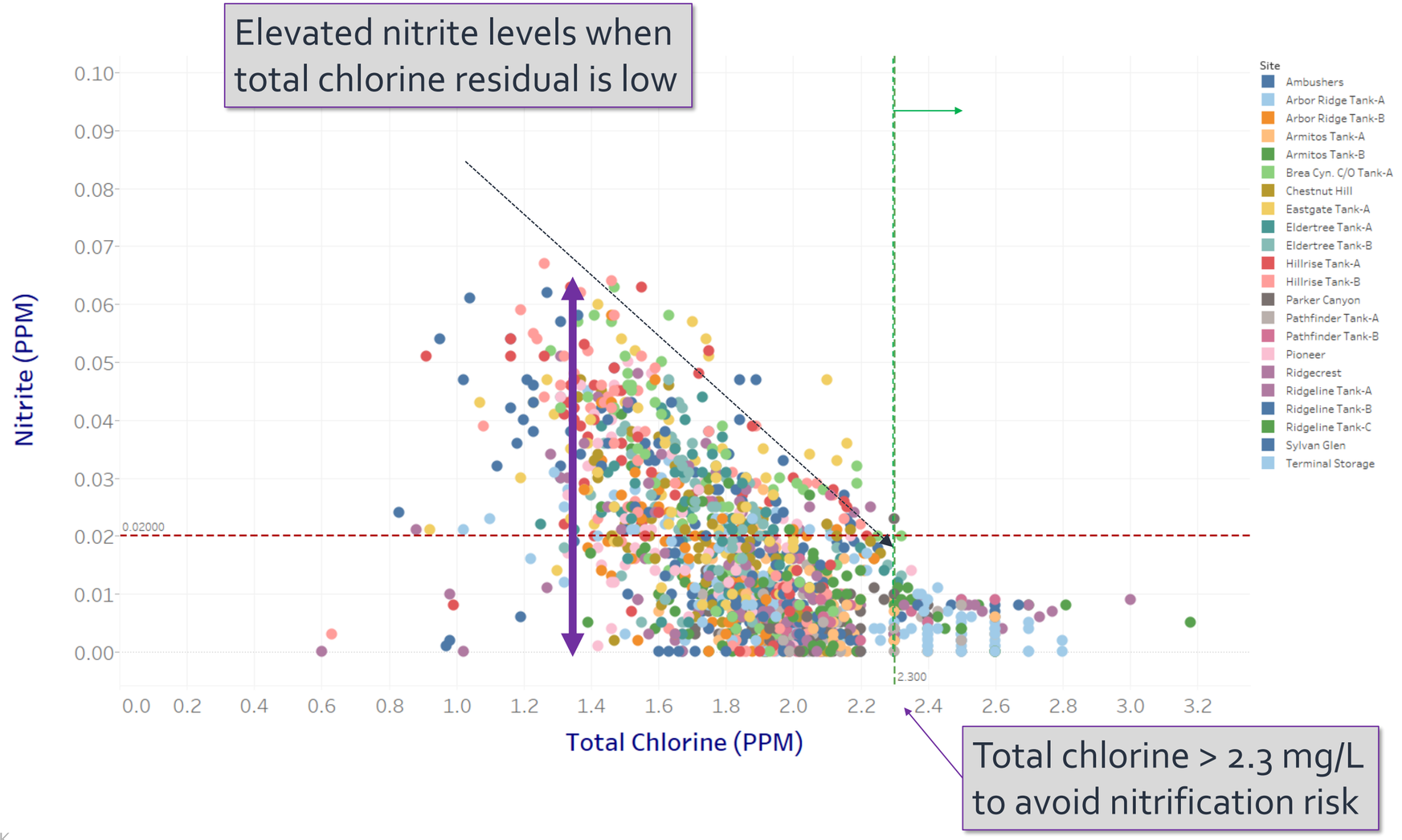
“BIOSTABILITY” IN DISTRIBUTION NETWORKS.

- Biological growth is governed by inactivation due to disinfectant levels (total chlorine) and the availability of a food source (ammonia).
- A **minimum residual** is needed to maintain biostability and avoid biological growth.



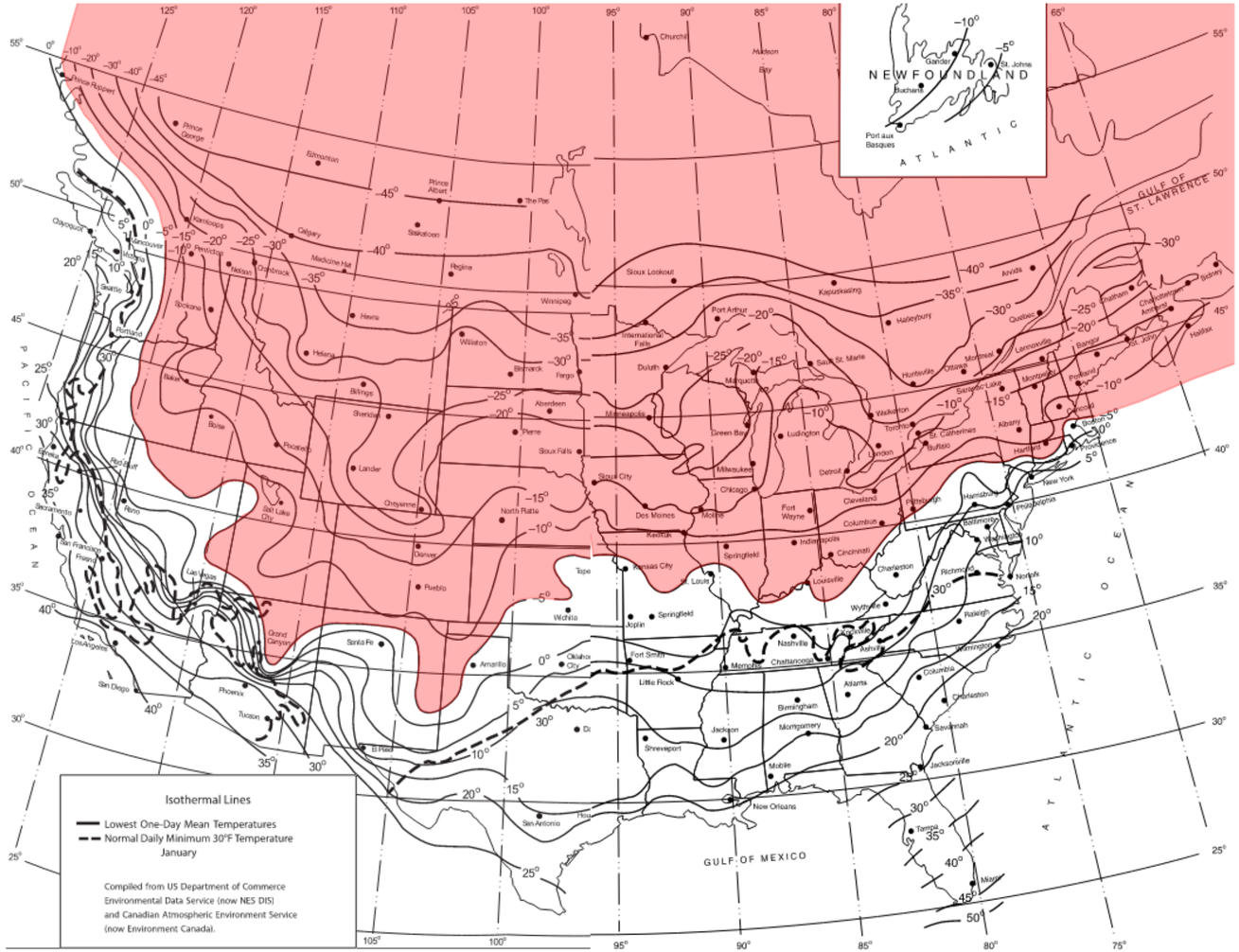
Source : Srinivasan and Harrington
Water Research Vol. 41 Issue 10 (2007)

REVIEWING DISTRIBUTION SYSTEM WATER QUALITY HIGHLIGHTED THE NEED FOR A RESIDUAL ABOVE 2.2 PPM TO AVOID NITRIFICATION RISK.

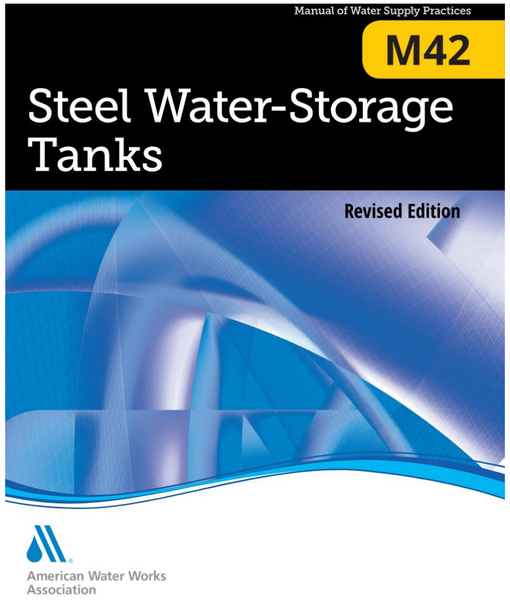


ICE FORMATION IN WATER STORAGE TANKS

RISK FACTORS: CLIMATE AND WEATHER



"Experience has shown that tanks located in areas with a lowest one-day mean temperature warmer than 5°F (–15 ° C) **normally** will not experience cold-weather operational problems."



OTHER RISK FACTORS

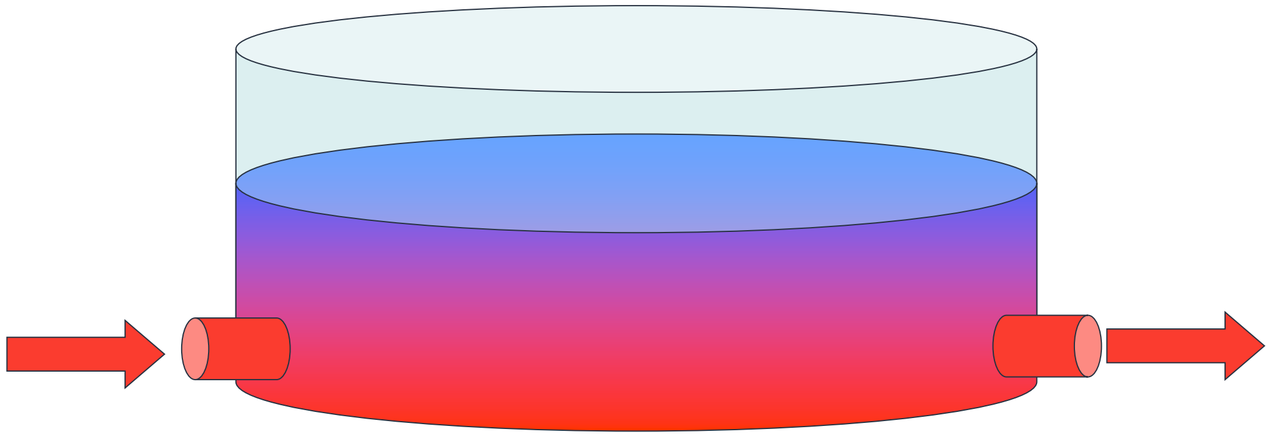
- Tank materials of construction
- Tank shape and configuration
- Influent water temperature
- Static water conditions
  - Low turnover
  - Insufficient tank circulation/mixing
- Tank overflows

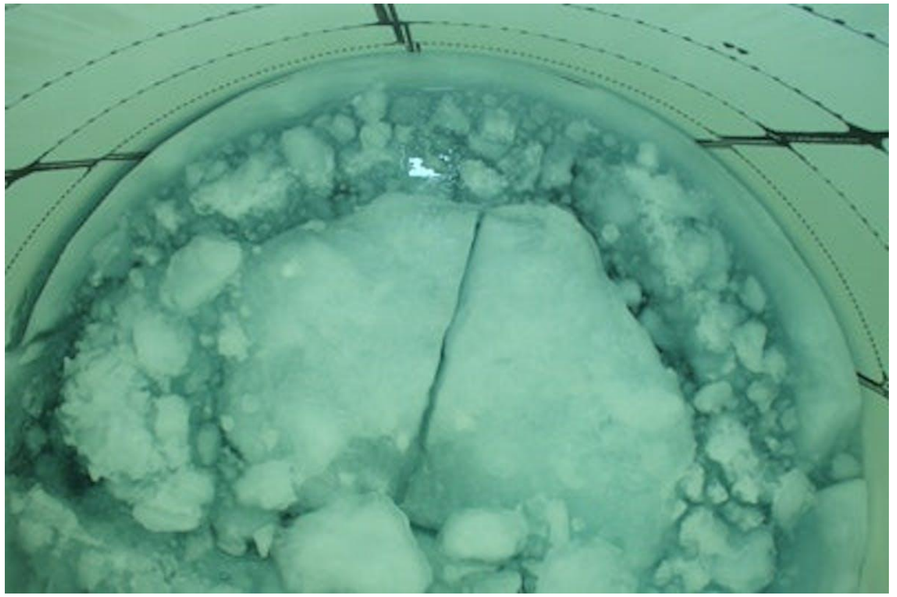


(GENERAL) RISK OF ICE FORMATION

Higher Risk of Ice Formation	Lower Risk of Ice Formation
• Steel tanks • Aboveground tanks • Elevated tanks • Standpipes • Surface source water systems • Tanks with low turnover • Unmixed tanks	• Concrete tanks • Underground tanks • Mixed tanks

ICE FORMATION IN WATER STORAGE TANKS DUE TO INSUFFICIENT MIXING/CIRCULATION





RESULTS OF FREEZING

- Reduced storage volume
- Tank damage
  - Free floating ice
  - Fixed ice buildup
- Level sensors, vents, and overflows can become blocked by ice.







METHODS FOR ICE CONTROL

- Tank design
  - Tank materials, shape, and configuration
  - Insulation
- Regular tank inspections
- Increase water turnover rates
  - Reduce tank water level
  - Increase tank cycling
- Increase water circulation/mixing
- Add heat



ACTIVE MIXING FOR ICE CONTROL

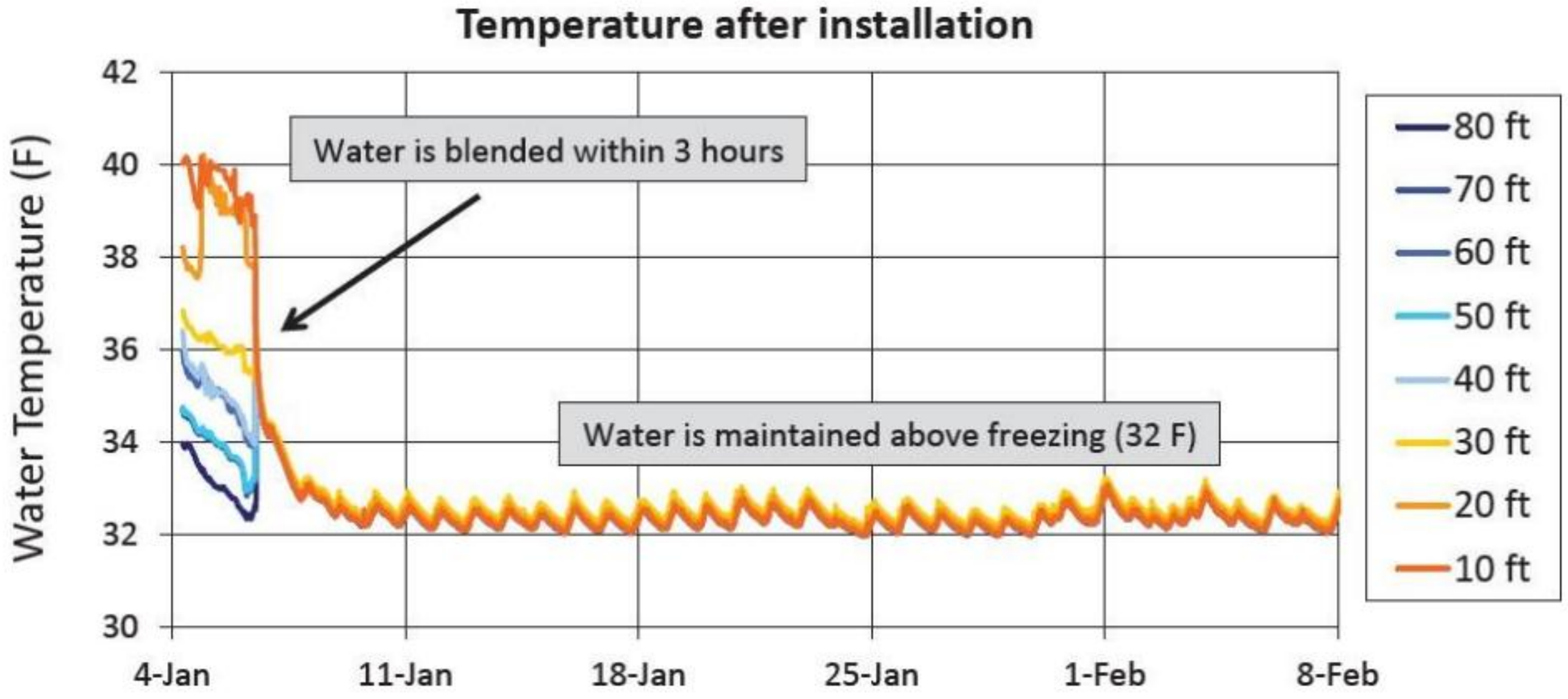


Figure 3: Temperature plot of mixed tank showing temperatures homogenized and maintained just above freezing

ACTIVE MIXING FOR ICE CONTROL



Tank #1 – Mixed

Tank #2 – Not mixed

