We work with others to protect the health of the people of Washington State by ensuring safe and reliable drinking water.

DISTRIBUTION SYSTEM OPTIMIZATION: TOOLS YOU CAN USE

Washington State Department of Health
Office of Drinking Water

PNWS-AWWA Annual Conference

Tacoma, WA

April 2018

Jolyn Leslie, P.E.

Regional Engineer

Northwest Regional Office

Presentation Outline

- What is Optimization
- Distribution System Optimization Goals
- Assessing Distribution System Performance
- Optimization Control Strategies

What is Optimization?

- An approach for water systems to improve drinking water quality, beyond compliance levels, and to increase public health protection by
  - Enhanced process monitoring and control
  - Using existing staff and facilities
  - Measuring performance relative to optimization goals
  - Using technical tools and approaches to improve distribution water quality if necessary

What is Optimization? *(Continued)*

- Program began in 1989 with turbidity optimization at surface water treatment plants
- EPA's Area Wide Optimization Program (AWOP)
- Distribution System Optimization (relatively new)
  - Focus on **maintaining disinfectant residual and reducing disinfection byproduct (DBP) formation**

Barriers to Contamination in the Distribution System

- Protecting the **physical barrier**/infrastructure from contamination (e.g., maintaining pressure, preventing backflow, protecting storage tanks, etc.) and…
- Providing a **disinfection barrier** against contamination and water quality deterioration
- The distribution system is the last "*barrier*" for protecting public health!

Why Optimize the Distribution System?

- Public health protection
  - Water distribution deficiencies were responsible for almost 25% during 1991-2000 and more than half of all water borne disease outbreaks during 2001-2002 (Craun et al., 2006)
  - On average, from 1971–2002, each distribution-related outbreak caused 152 illnesses, with the largest causing as many as 5,000 illnesses (Craun et al., 2006)
- Secondary benefits
  - Proactive approach to meeting compliance
  - Fewer complaints, happier customers!

DSO GOALS

Disinfection Goals for Free Chlorine Systems

Performance

- Maintain > 0.20 mg/L free chlorine at all locations in the DS at all times

Monitoring

- Frequency: monthly, and more frequently at critical times (i.e., summer months)
- Locations: established TCR and DBP compliance sites, the system entry point, consecutive system master meters, all tanks (draining), and identified critical sites (four minimum)

Disinfection Goals for Combined Chlorine Systems

Performance

- Maintain ≥ 1.50 mg/L monochloramine at all locations in the DS at all times
- Minimize free ammonia (NH_3-N) in plant effluent at ≤ 0.10 mg/L

Monitoring

- Monochloramine monitoring location and frequency similar to free chlorine
- Additional guidelines for nitrification parameters (i.e., nitrite, nitrate)

DBP Goals

Performance

- Individual Site Goal: Quarterly Max LRAA TTHM/HAA5 values not to exceed 70/50 ppb
  - Long-Term System Goal: Average of Max LRAA TTHM/HAA5 values not to exceed 60/40 ppb (based on 11 quarters of data)

Monitoring Goals

- Systems meeting the goals: quarterly at plant effluent and DBP compliance sites
- System not meeting the goals: monthly at system entry point, DBP sites, master meters, and minimum of four critical sites

Operational Goals for Storage Tanks

- Maintain low turnover time[1] (less than five days) at all times, or establish/maintain a tank-specific water turnover rate
- Maintain good mixing[2] (PR $\geq$1) at all times at each individual storage tank

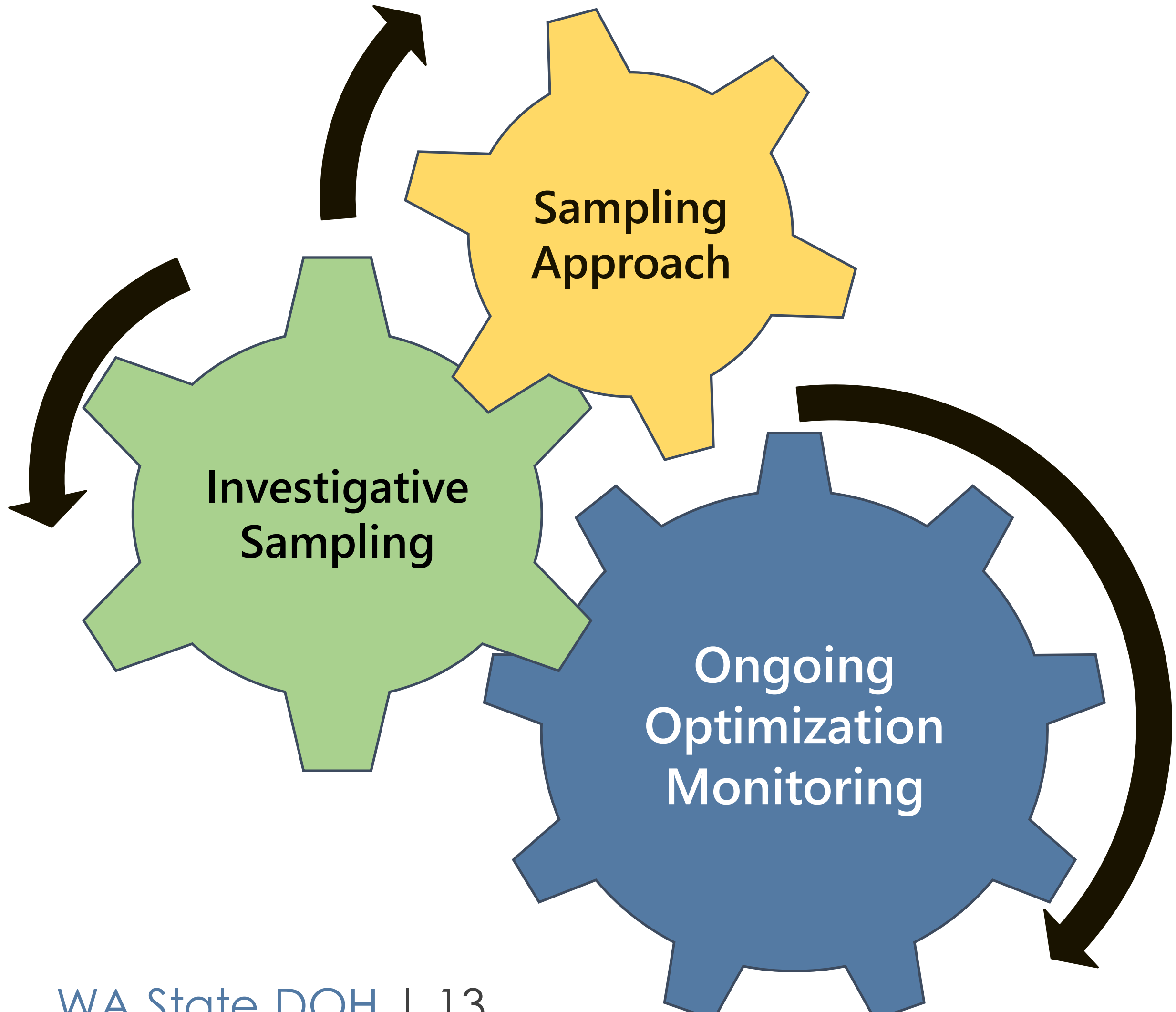
[1] Time required for one tank volume to be completely replaced

[2] Mixing performance ratio (PR): a measurement of actual mixing/desired mixing

ASSESSING DS PERFORMANCE

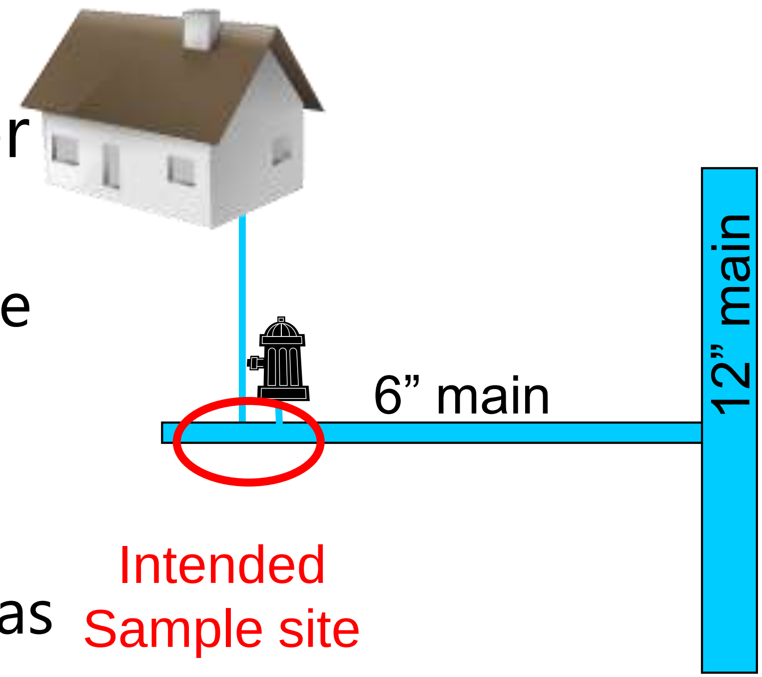
Assessing DS Performance

Objective
To develop an accurate "picture" of water quality in the distribution system



Sampling Approach: Use the Calculated Flush Time (CFT) Protocol

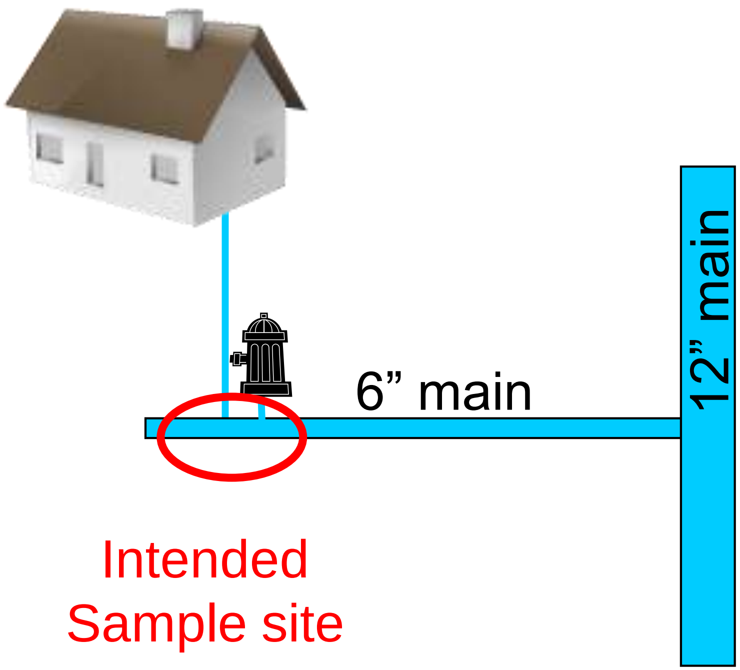
- Provides a consistent and technically sound approach for sample collection
  - Time-based approach, based on the service line length, diameter, and pre-determined flow rate.
  - Stable water quality (i.e., temperature, residual) is **not used** as an indicator of adequate flushing.
  - Flush/waste the water in the service line before collecting a sample, but avoid over-flushing.



*Based on *Draft Distribution System Guideline for Obtaining a Representative Sample for Optimization,* Opflow (January 2009).

Sampling Approach *(Continued)*

- Samples are collected from the intended area and represent water quality in the **DS main** (not in the service line or from another part of the DS)
- Provides site-specific calculations and rule-of-thumb approaches for hydrants and sample taps



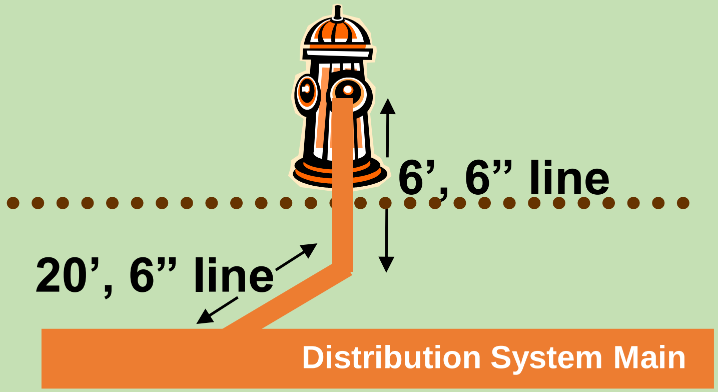
*Based on *Draft Distribution System Guideline for Obtaining a Representative Sample for Optimization*, Opflow (January 2009).

Applying the Calculated Flush Time (CFT) Approach for Sampling

- Four main steps

1. Estimate length and diameter of service line/hydrant piping
2. Determine necessary flush time (CFT) based on pipe length, diameter, and anticipated flow rate
3. Open tap, begin flushing, and confirm flow rate (adjust flow rate and/or flush time if needed)
4. After twice the calculated flush time, collect the sample

Example—CFT Calculation



Length of Pipe	Diameter of Pipe (inches)				
	2	4	6	8	12
5	0.0	0.2	0.4	0.7	1.5
10	0.1	0.3	0.7	1.3	2.9
15	0.1	0.5	1.1	2.0	4.4
20	0.2	0.7	1.5	2.6	5.9
25	0.2	0.8	1.8	3.3	7.3
30	0.2	1.0	2.2	3.9	8.8
35	0.3	1.1	2.6	4.6	10.3

Pipe Length = 26 ft
Diameter of Pipe = 6"

Flow Rate = 20 gpm

CFT = 1.8 minutes (from table)

2* CFT =
<u>3.6 minute total flush time</u>

Hydrant Sampler

Investigative Sampling

- A special study intended to
  - Identify areas of poor water quality (i.e., low chlorine residual, high DBPs) in the DS
  - Trace water quality through the system
  - Identify areas in the DS in need of process control
    - To locate and implement an autoflusher
    - Assess the impact of a storage tank in that area of the system

Investigative Sampling *(Continued)*

- Study approach includes
  - Locating sample sites
  - Collecting data
  - Assessing results

Data Analysis/Trending

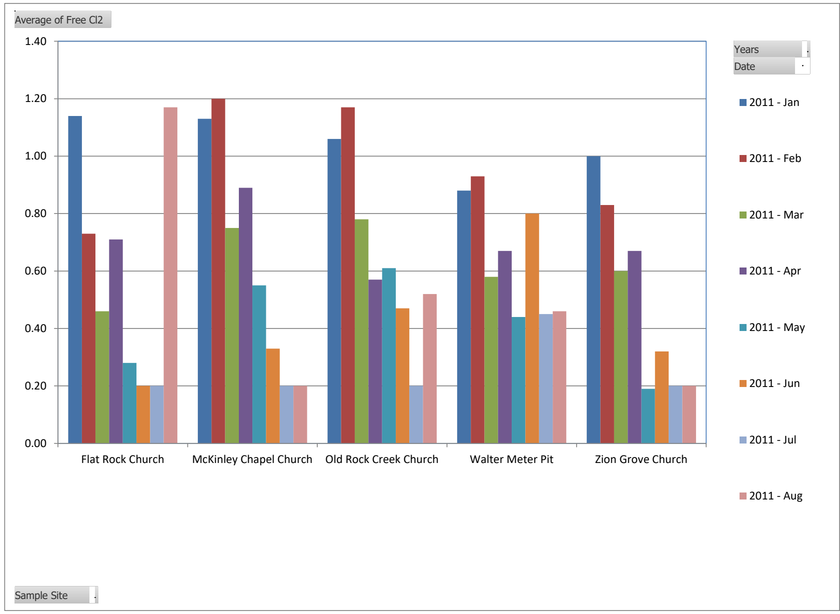
- It is critical to record the data (log sheets)—and do something with it!
- Mapping the data can show spatial trends throughout the system

Ongoing Optimization Monitoring

- Each system's ongoing monitoring location sites should include some combination of
  - Plant effluents and/or master meters
  - Regulatory sites (i.e., for TCR and DBP sampling)
  - Critical sites (identified through investigative sampling)
- The number and variety of sites selected will provide water quality throughout the distribution system!
- This monitoring is conducted on a routine, and long-term, basis

Data Analysis/Trending *(Continued)*

- Spreadsheet tools are available to support these efforts
  - Confirm the distribution system barrier is in-place (are the goals being met?)
  - Develop water quality data and trends over time
  - Have data needed **before** process control is implemented



Assessing DS Water Quality and Problem Area(s)

- Sometimes these are already known—or suspected; often they need to be confirmed—or further refined

Assessing DS Water Quality and Problem Area(s) *(Continued)*

- Approach includes
  - Identify general area—and then more specific location
  - Use a sampling approach (Calculated Flush Time) to ensure water quality in that area of the system is being measured
  - Due to potential variability in the system (e.g., diurnal impacts, tank influence, WTP effluent variability), repeat sampling is recommended to confirm results

Identifying Potential Problem Areas

- Areas influenced by (draining) tanks
  - With high turnover time (confirmed or suspected)
  - Operated in series
  - Standpipes (generally are poorly mixed)

Identifying Problem Areas *(Continued)*

- Hydraulic “problem areas”
  - On dead-ends ~ actual and looped (subdivisions)
  - Towards the “extremities” of the distribution system (hydraulically far from the treatment plant)
  - Near pressure zone boundaries (i.e., valve creates a “hydraulic” dead-end)
  - Areas where water from different sources is blended

Identifying Problem Areas *(Continued)*

- Areas with aging pipes (old cast iron lines)
- Low demand, low flow, stagnant areas
- Water quality problem areas
  - At TCR/DBP sites with historically low chlorine residual, high DBPs, coliform occurrences
  - Areas with persistent customer complaints

Identifying Problem Areas *(Continued)*

- It is likely that one (or more) **critical sites** will be found (at least initially)
  - Sites in the DS that have been identified as having the poorest water quality (i.e., disinfectant residual) and/or do not meet the system's established water quality goal(s)
  - Generally

↓Chlorine residual

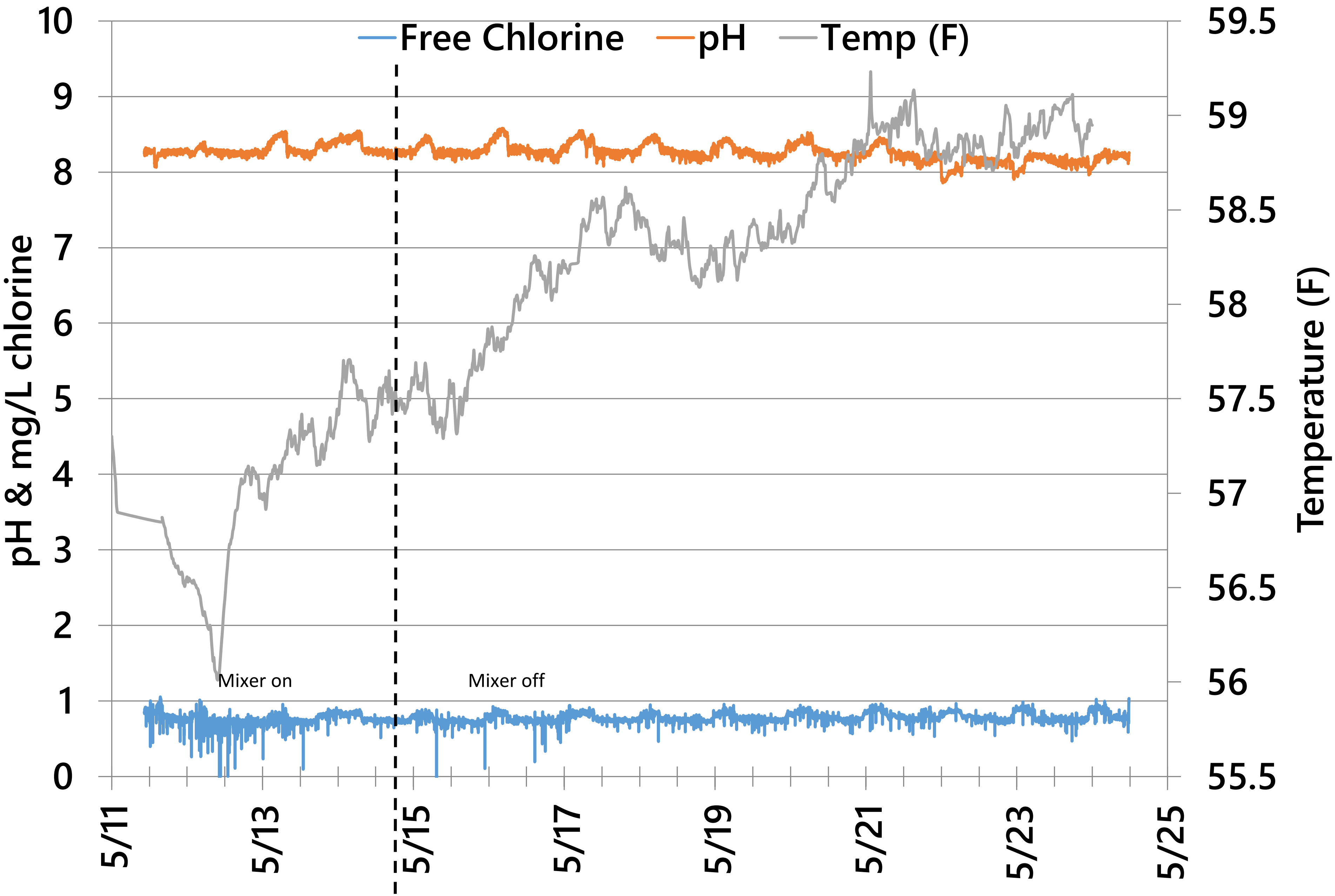
↑DBPs, water age, and microbial risk!

Repeat and Evaluate to Fully Characterize Water Quality

- Remember—DO NOT make big changes with the system until adequate data is collected
  - Repeat sampling several times to confirm results
  - Consider hydraulic influences (tanks filling/drawing) and impact of finished water quality on results
  - One-time sampling is not sufficient for making process changes!

Storage Tank Evaluations

- Tank characteristics
- Assess water storage tank turnover time and mixing
- Determine operational strategies to improve turnover time and mixing


Free Chlorine
pH
Temp (F)
pH & mg/L chlorine
Temperature (F)
10
9
8
7
6
5
4
3
2
1
0
59.5
59
58.5
58
57.5
57
56.5
56
55.5
Mixer on
Mixer off
5/11
5/13
5/15
5/17
5/19
5/21
5/23
5/25

Turnover Summary

Avg Vol Added in One Fill Period	0.24	MG
Avg Vol Drawn in One Drain Period	0.26	MG
Avg Fill Time	0.47	days
Avg Draw Time	0.52	days
Avg Fill Rate	351	gpm
Avg Draw Rate	346	gpm
Avg Duration (Fill + Draw Time)	1.0	days
Avg Flow Rate into tank	0.24	MGD
Avg Tank Vol	3.74	MG
Turnover Time	**15.5**	**days**

Mixing Summary

Avg Min Water Level	79.7	ft
Avg Actual VEF	0.07	
Avg VEF Needed for Good Mixing	0.15	
Avg Measured Water Level Change	5.2	ft
Desired Water Level Change Needed for Good Mixing	12.2	ft
Mixing Performance Ratio (Measured/Desired)	0.43	
Inlet Diameter Needed for Good Mixing	7	inches

Step 2: Turnover Time & Mixing Analysis

	No Changes	Scenario A	Scenario B	Scenario C	
Tank diameter	88	88	88	88	ft
	0	0	0	0	ft
Inlet Diameter	1.33	1.33	1.33	1.33	ft
High/Max Level	84.89	84.89	84.89	70.00	ft
Low/Min Level	79.66	30.00	72.00	58.00	ft
H/D ratio	0.96	0.96	0.96	0.80	
Actual Level Change	5.23	54.89	12.89	12.00	ft
Dimensionless Mixing Time	10.20	10.20	10.20	10.20	
Desired Level Change Needed for Good Mixing	12.18	6.35	11.38	9.85	ft
Pressure Drop After Change in Min Water Level		21.5	3.3	9.4	psi
Fill rate/ Pumping rate	351	351	351	351	gpm
Draw rate/ consumer demand	346	346	346	346	gpm
Avg fill time	0.47	4.94	1.16	1.08	days
Avg draw time	0.52	5.02	1.18	1.10	days
Avg volume added during fill	0.24	2.50	0.59	0.55	MG
Avg Duration (fill +draw)	0.99	9.96	2.34	2.18	days
Ave Flow Rate	0.24	0.25	0.25	0.25	MGD
Ave Tank Vol	3.74	2.61	3.57	2.91	MG
Mixing Performance Ratio (Measured/Desired)	**0.43**	**8.64**	**1.13**	**1.22**	
Turnover Time	**15.5**	**10.4**	**14.2**	**11.6**	days

OPTIMIZATION CONTROL STRATEGIES

Optimization Control Strategies

- Tank management/operations
- Flushing
- Re-routing water
- Optimizing booster chlorination

Optimization Control Strategies

- Tank management/operations
  - Modifying tank levels
  - Changing rate or duration of filling
  - Removing tank from service

Increase turnover in your storage tanks and minimize water age

Optimization Control Strategies

- Flushing
  - Conventional
  - Unidirectional
  - Continuous blowoff

Minimize water age and increase distribution residual

Optimization Control Strategies

- Rerouting water
  - Valve and reroute through parallel lines
  - Valve changes to reroute to areas of higher demand

Minimize water age

Be aware of potential flow reversal and water quality impacts

Optimization Control Strategies

- Optimizing disinfection
  - Changes to system influent disinfectant residual
  - Booster chlorination stations in the distribution system

Increase distribution residual

Summary

- Distribution System Optimization is important for public health protection and as a proactive approach for water systems to meet compliance and improve customer satisfaction
  - DSO goals/guidelines exist for residual, DBPs, and tanks
  - Assessing system performance includes data integrity considerations (CFT) and water quality throughout the system

Summary *(Continued)*

- Chlorine/disinfection is an integral part of the multiple barrier approach to public health protection
- Understanding chlorine residuals in your distribution system is an important tool in managing your system
- Distribution system optimization can help you better manage overall water quality and may help reduce customer complaints

Questions?

Contact Information

Jolyn.Leslie@doh.wa.gov

253-395-6762

doh.wa.gov/DrinkingWater

handle: WADeptHealth