

Assessing a Non-Acute Total Coliform Rule Violation at Portland Water Bureau: What Happened, What Worked, What Didn't, & Why? Part 2 of 2

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Presentation Overview

- **Coliform Occurrence Pathways**
- **Conditions that May Have Contributed to TCR Event**
 - Water Quality
 - O&M
- **Effectiveness of Mitigation Strategies**
- **Recommendations**

**Independent Desk-Top
Review of Available
Information**



Coliform Occurrence Pathways

- **Source water/treatment breakthrough**
- **Direct contamination of the distribution system**
- **Regrowth in biofilms/sediments**
- **Sample tap contamination/sample collection issues**



Coliform Occurrence Pathways - Findings

■ Source water/treatment breakthrough

- No turbidity event
- No issues with CTs
- Localized

■ Direct contamination of the distribution system

- No pressure events
- No main breaks/repairs
- No fires
- No construction
- CC inspections up to date

■ Regrowth in biofilms/sediments

- Warm water ($\geq 15^{\circ}\text{C}$)
- Very low chlorine
- Nitrification event
- Lots of unlined cast iron pipe

■ Sample tap contamination/sample collection issues

- Positives at many different types of sample taps
- Different sample collectors
- Confirmed sampling protocols



What Water Quality Conditions May Have Contributed to the Biofilm/Regrowth TCR Event?

Assessment of Water Quality & System Conditions

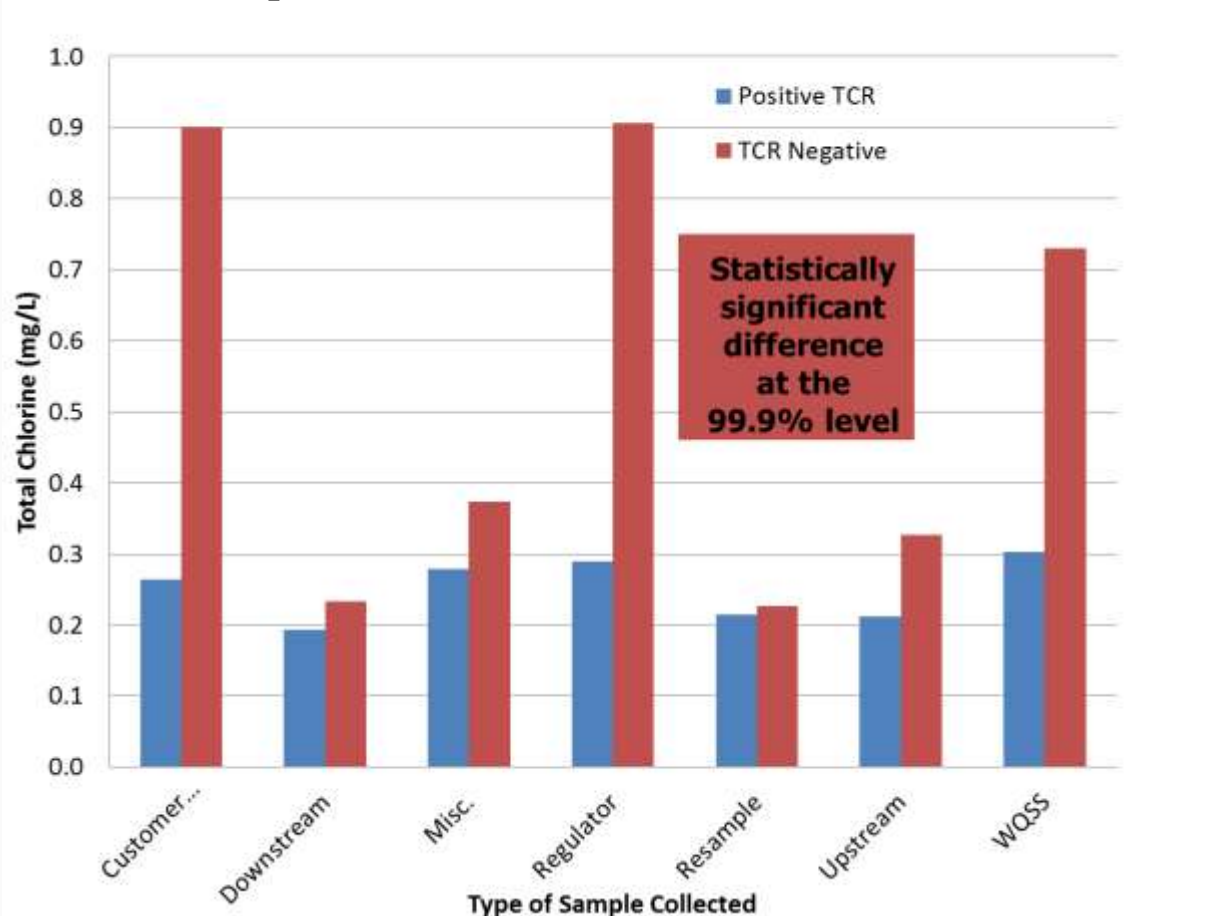
■ Key water quality issues that can contribute to regrowth/biofilms:

- Chlorine residual maintenance
- DS temperature
- Nitrification
 - Residual loss
 - pH
 - ORP
- Nutrients
 - Ammonia
 - AOC
 - Iron/Mn etc.



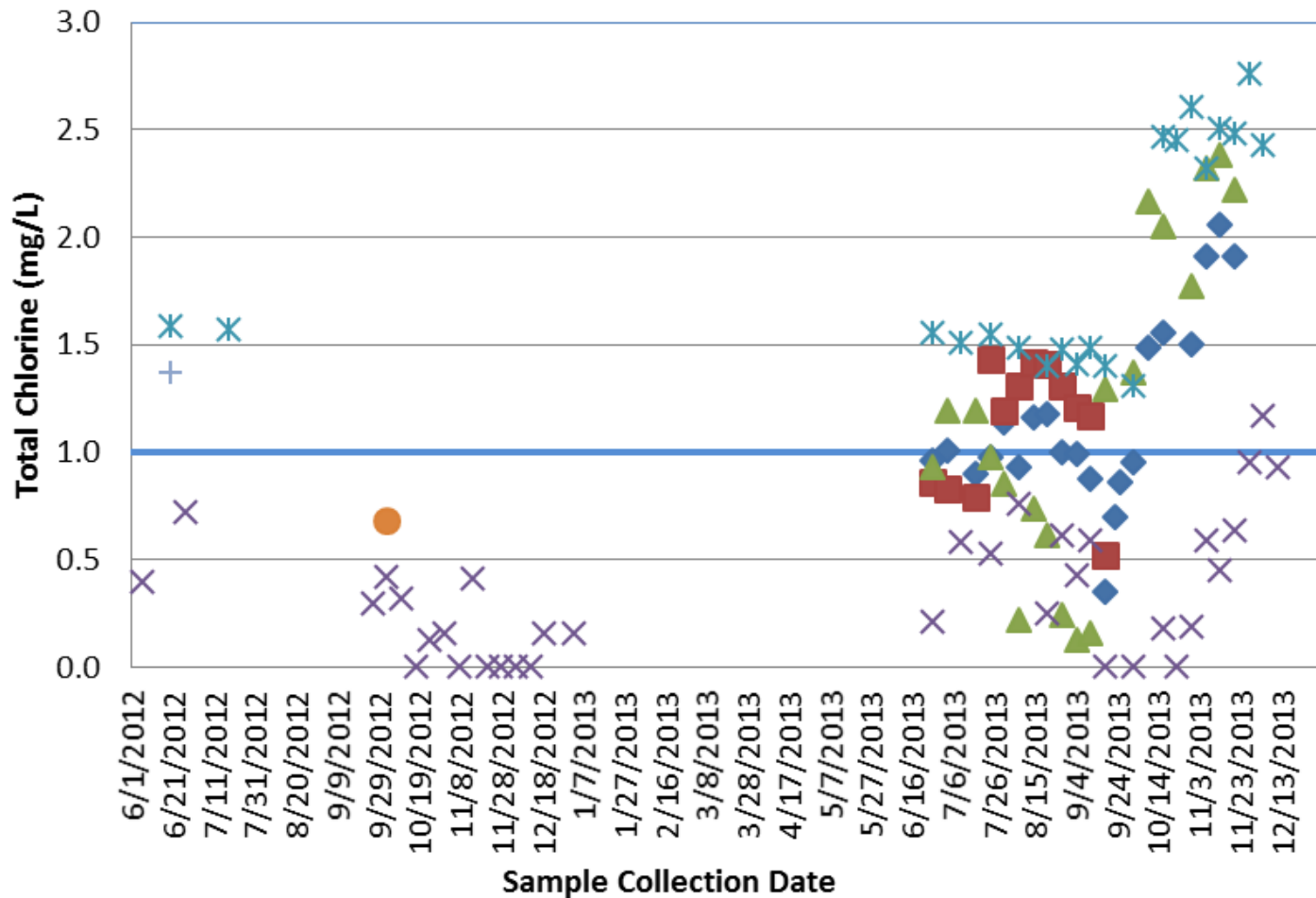
Total Chlorine - Findings

- Total Chlorine levels were significantly lower in TC + samples



Total Chlorine From 2012 and 2013 Studies

Target Level of greater than 1.0 mg/L

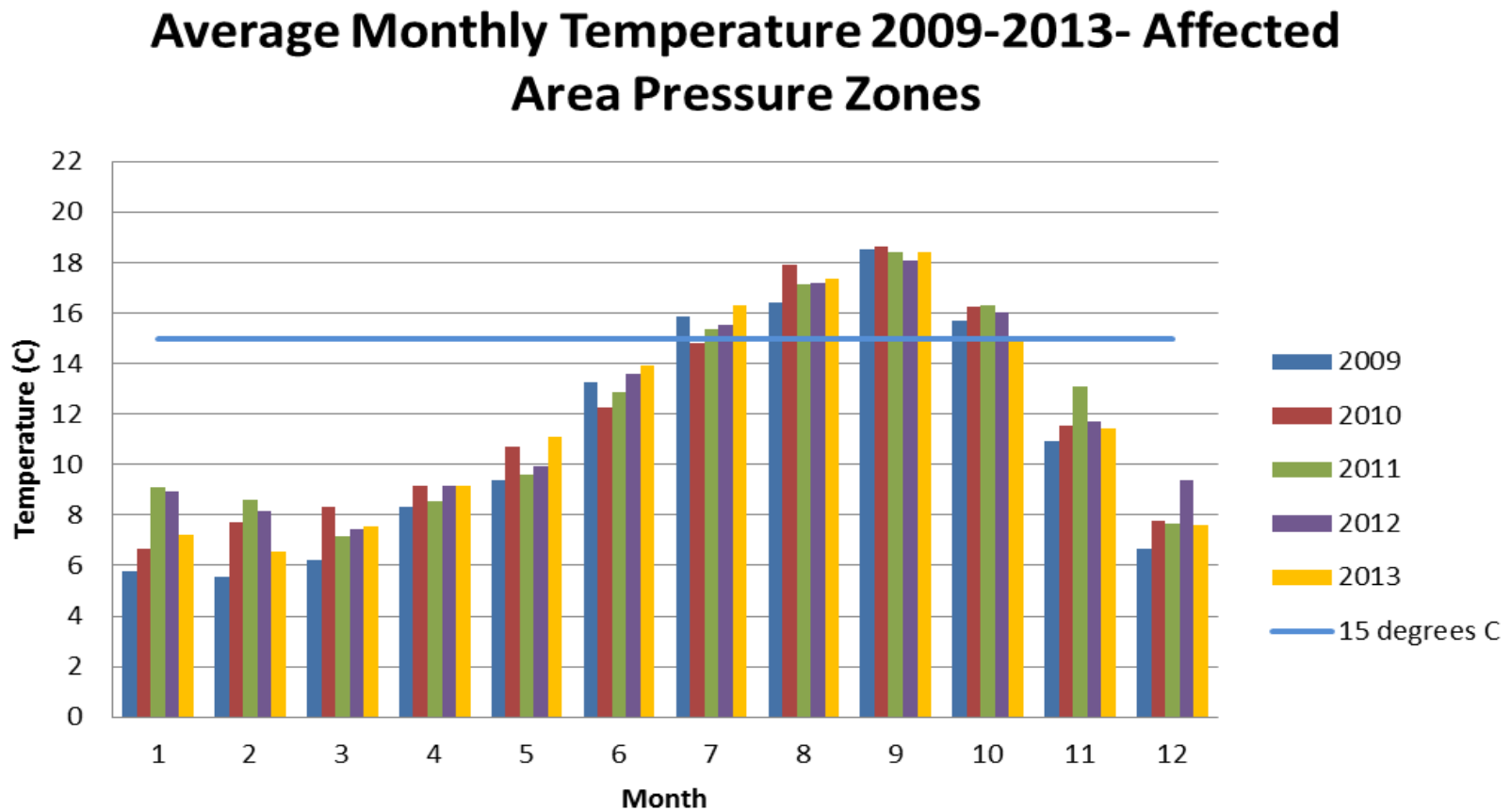


Chloramine dose increased on 10/2

- ◆ Bertha Outlet
- ▲ Marquam Hill 2
- ✱ Burlingame Pressure Zone 11
- ✱ Bertha Pressure Zone 182
- Vermont Pressure Zone
- ⊕ Arnold Pressure Zone 199
- Target/Action Level

Temperature- Findings

- Average monthly temperatures highest in Bertha and Stephenson, but not higher in 2013 compared to previous years
- Temperatures $\geq 15^{\circ}\text{C}$ July/Aug/Sept/Oct



Overview of Nitrification Process

**Chloramine
demand/decay**

**Release of free
ammonia**

**Biological
oxidation to
nitrite and
nitrate**

Disinfectant residual loss

Decreased dissolved oxygen

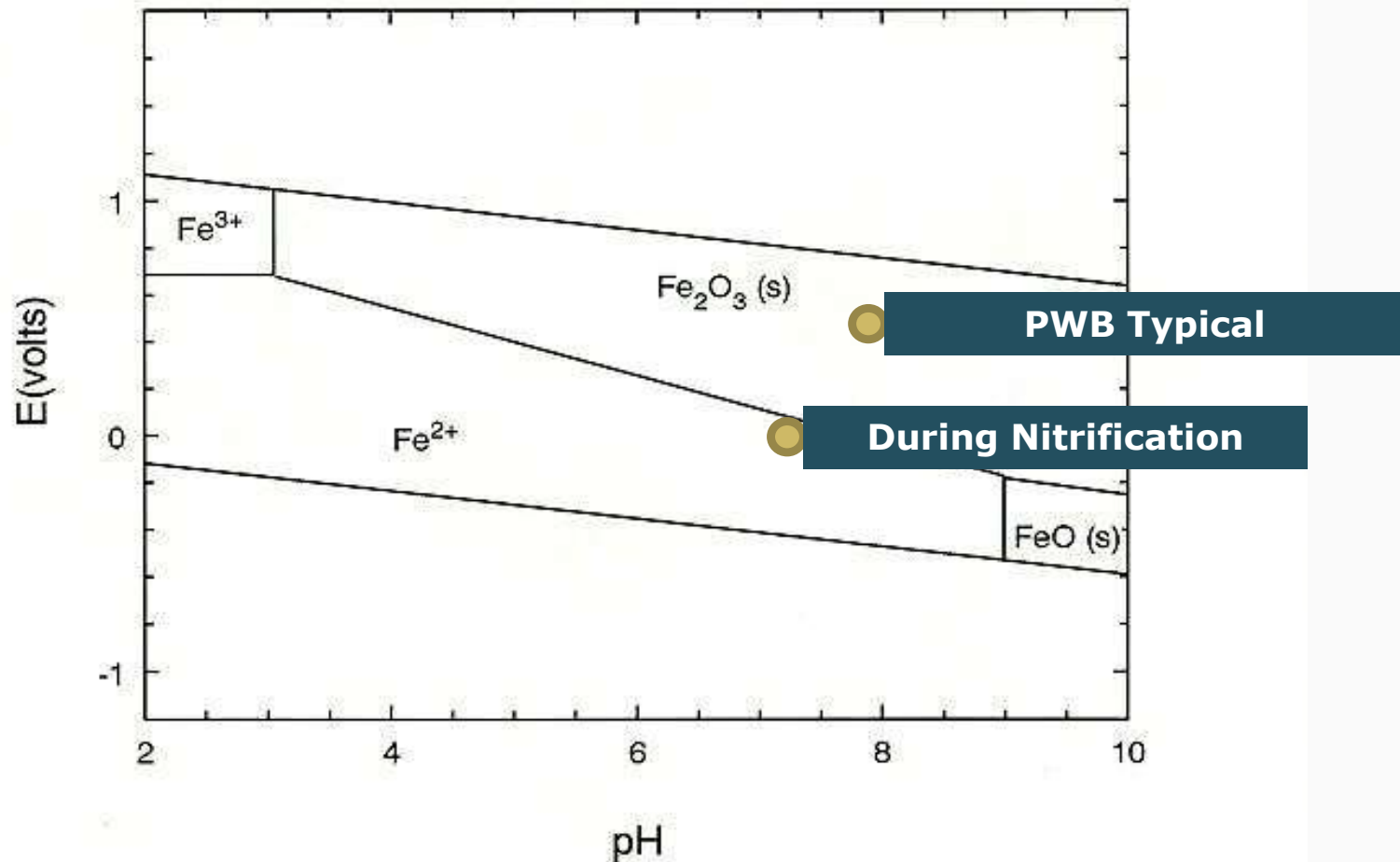
Decreased alkalinity

Decreased pH

**Lowers ORP
which impacts
stability of cast
iron scales!!!**

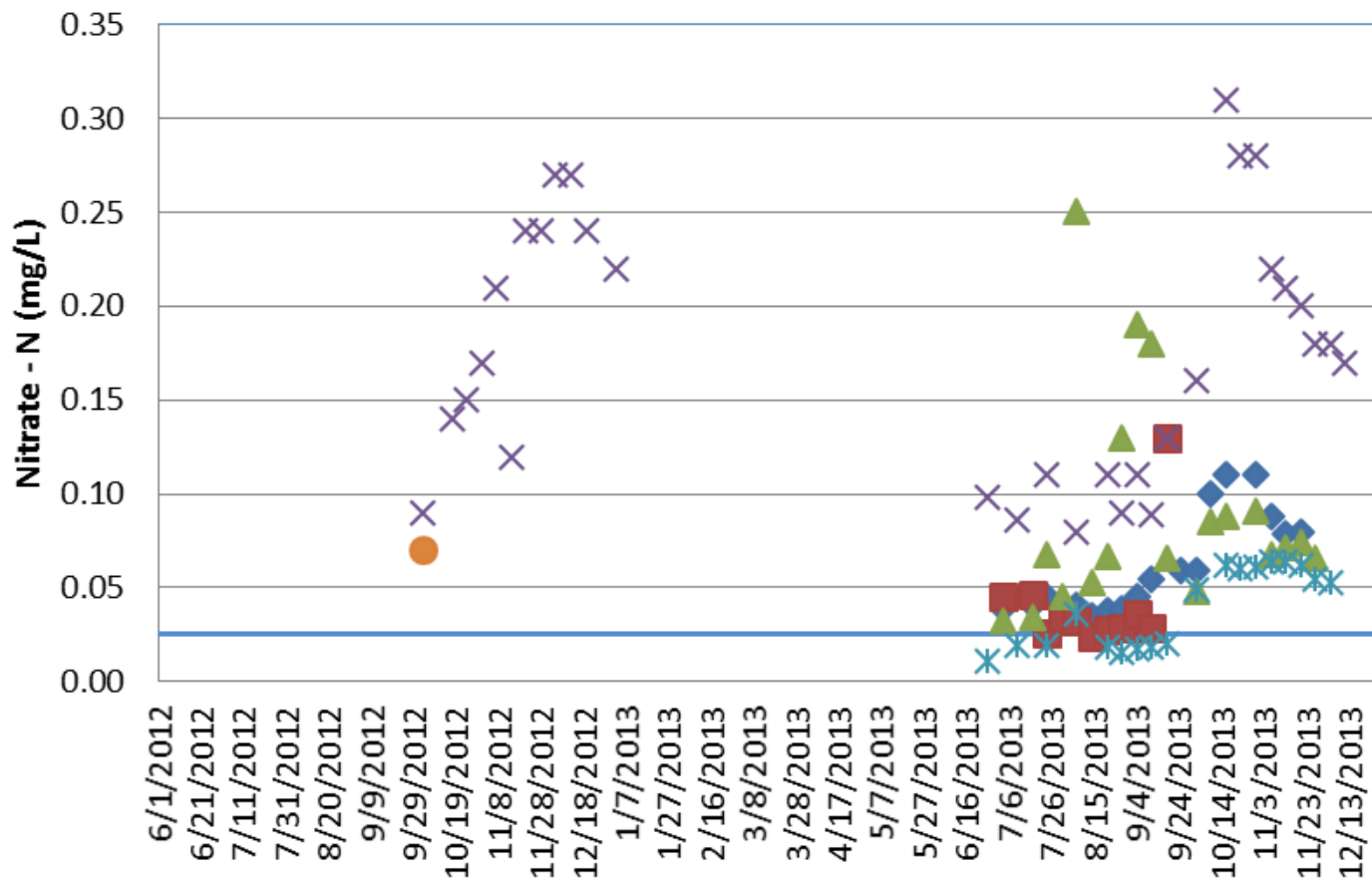
Effect of Oxidation-Reduction Potential (ORP) Plunge

Simplified Pourbaix Diagram for Some Naturally Occurring Forms of Fe



Nitrate - N From 2012 and 2013 Studies

Target Level of background, approx. 0.025 mg/L



Chloramine dose increased on 10/2

- Sample Collection Date**
- ◆ Bertha Outlet
 - ▲ Marquam Hill 2
 - ✱ Burlingame Pressure Zone 11
 - ✚ Arnold Pressure Zone 199
 - Marquam Hill 1
 - Vermont Pressure Zone
 - Target/Action Level

What Operations & Maintenance Activities May Have Contributed to a Biofilm/Regrowth TCR Event?

O&M Activities - Flushing

■ Spot flushing

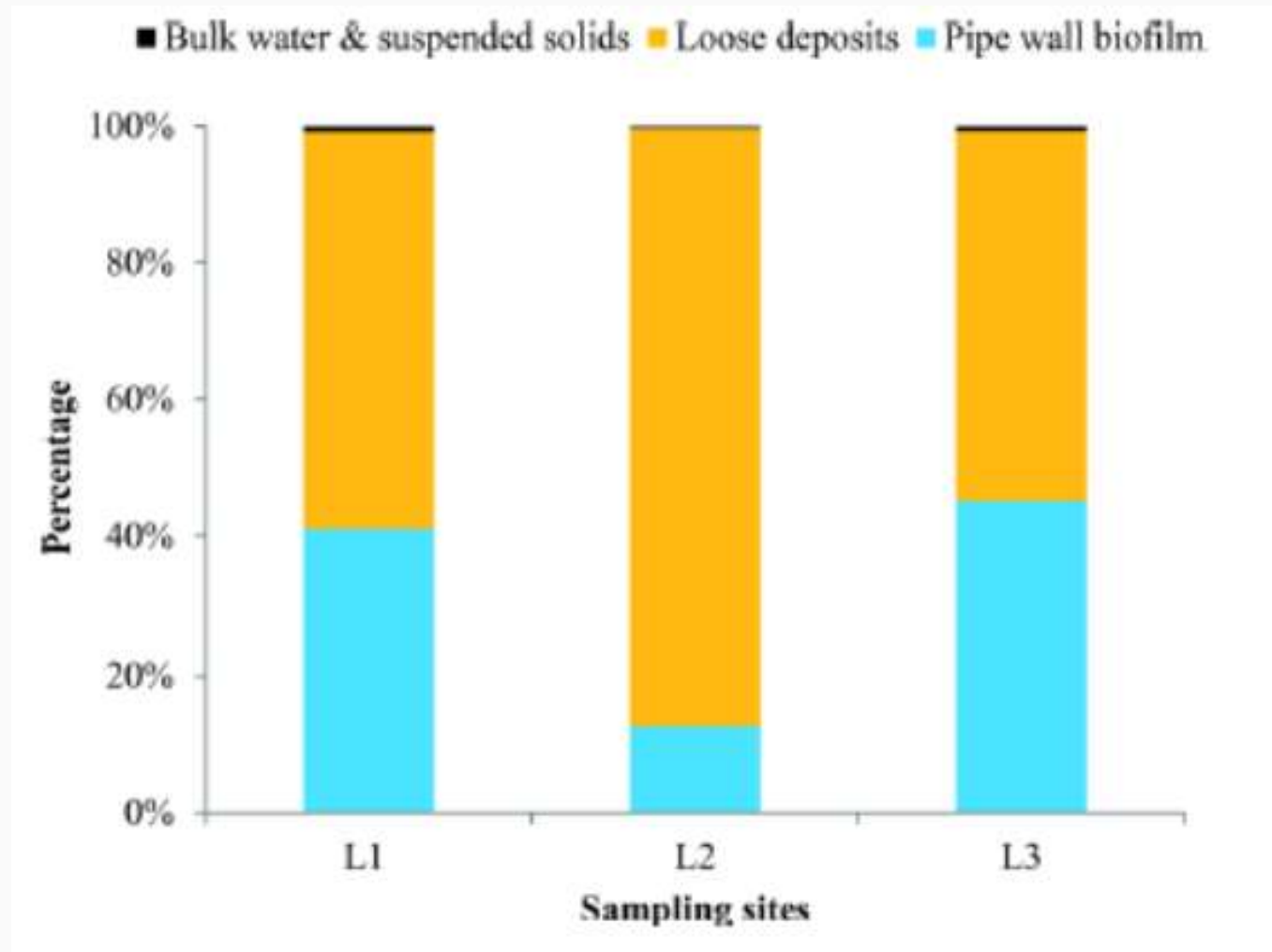
- ❑ May have stirred up and released biofilm containing coliform bacteria to bulk water
 - No valve isolation
 - Water flows to open hydrant from multiple directions
 - Can't control velocities in adjacent mains with different diameters
- ❑ If poor water quality had come from Marquam Tank, may have pulled further into distribution system

■ Lack of Aggressive UDF Program in Problem Areas

- ❑ Allowed for accumulation of biofilm and sediments
- ❑ Increases chloramine demand



Comparison of bacterial abundance in an unchlorinated distribution system in the Netherlands – 4-Inch PVC pipe



Source: Liu et al., 2014

O&M Activities - Findings

- **Does not appear that the TCR event was caused by direct contamination due to main repair/installation, pressure event, cross-connection, etc.**
- **However, O&M practices may have contributed to water quality conditions that support regrowth, biofilm sloughing, etc.**



Effectiveness of Mitigation Strategies

Mitigation Strategies Used

- **Tank O&M strategies**
- **Increased disinfection - boosting**
- **Spot flushing**
 - Proactive and reactive
- **UDF**



Tank Strategies

- **Deep cycling - Marquam Hill 2 rebounded rapidly**
 - Chlorine increased
 - Nitrate, nitrite, HPC decreased
 - However, appears to have caused negative water quality impact downstream...
- **Appropriate to take Marquam 1 and Bertha off line**
 - Reduced overall water age in the area
 - Prevented additional lower quality water from reaching area



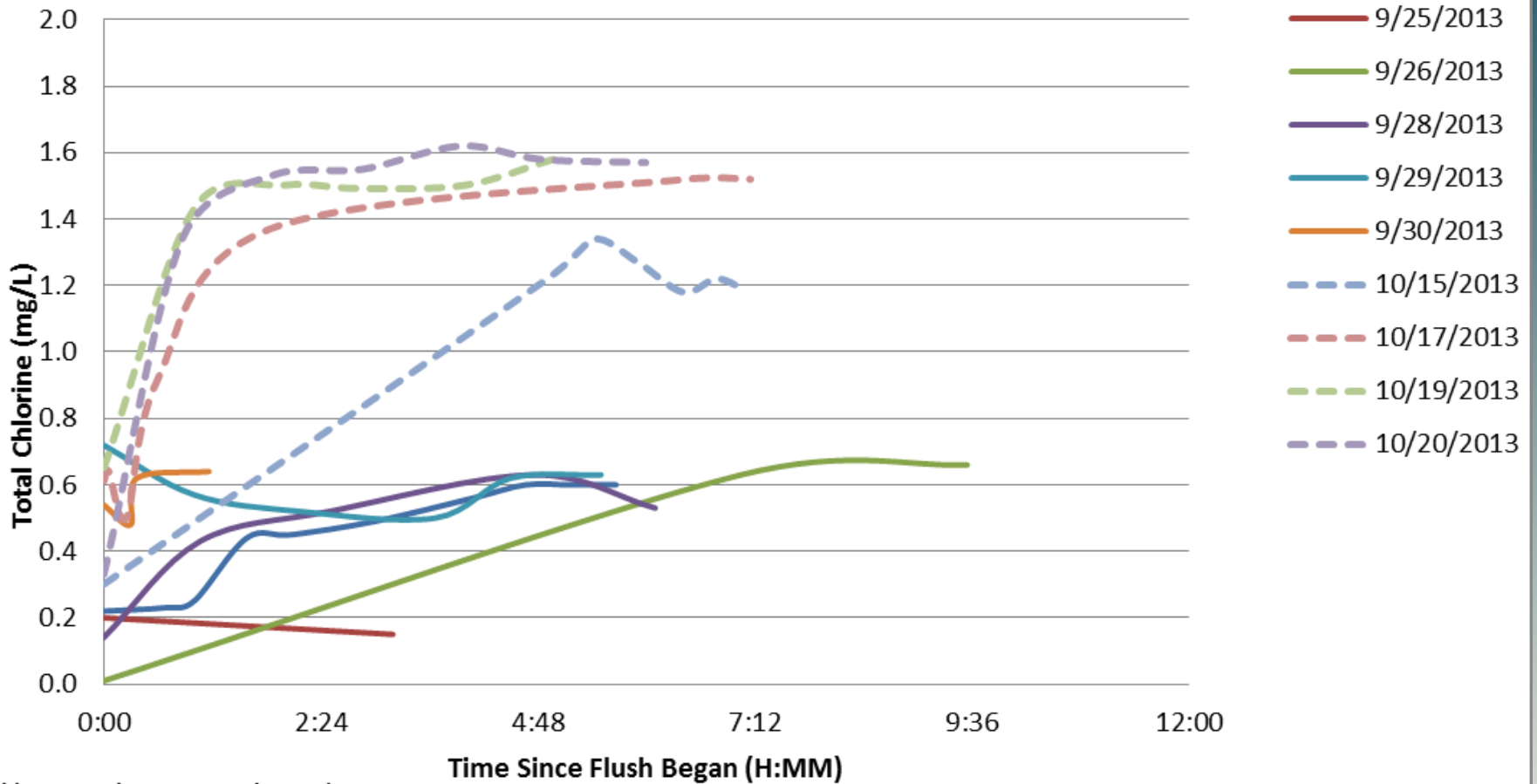
System-Wide Chloramine Boosting

- **Residual boosted from 1.8 to 3.0 mg/L at Lusted Hill on 10/2/13**
- **Increases measured at Burlingame, Arnold, and Vermont pressure zones within a week**
- **Did not reach goal of 1 mg/L at Bertha WQSS 182 for two months**
 - Consistently detectable residuals appeared within 3 weeks - 1 month
 - Difficult to overcome water age and existing chlorine demand
- **Can't necessarily rely on system-wide boosting to be timely, effective site-specific strategy given current water age and pipe conditions**



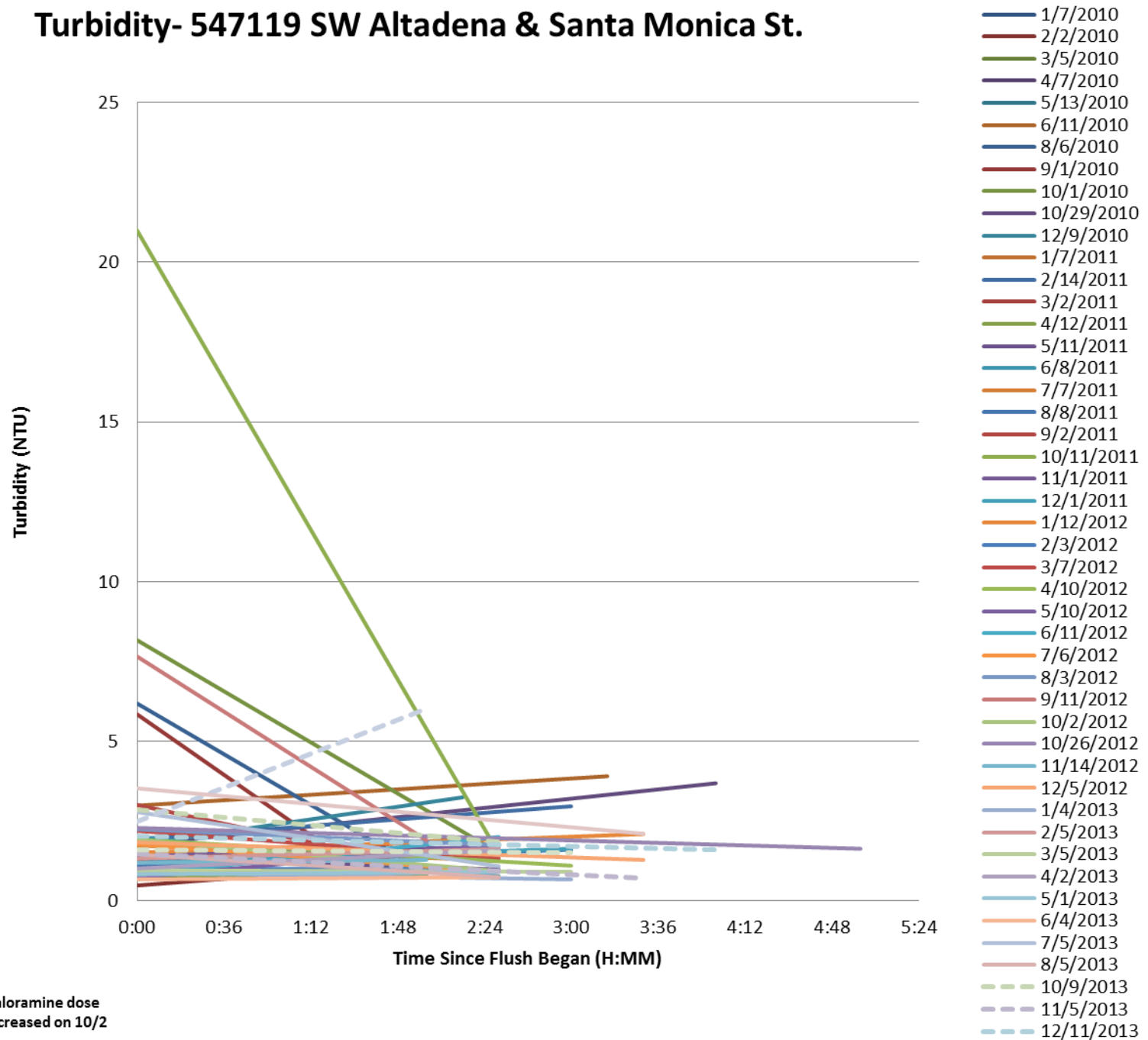
Spot Flushing

Total Chlorine - 7020 SW 10th Pocket 8 (522762)



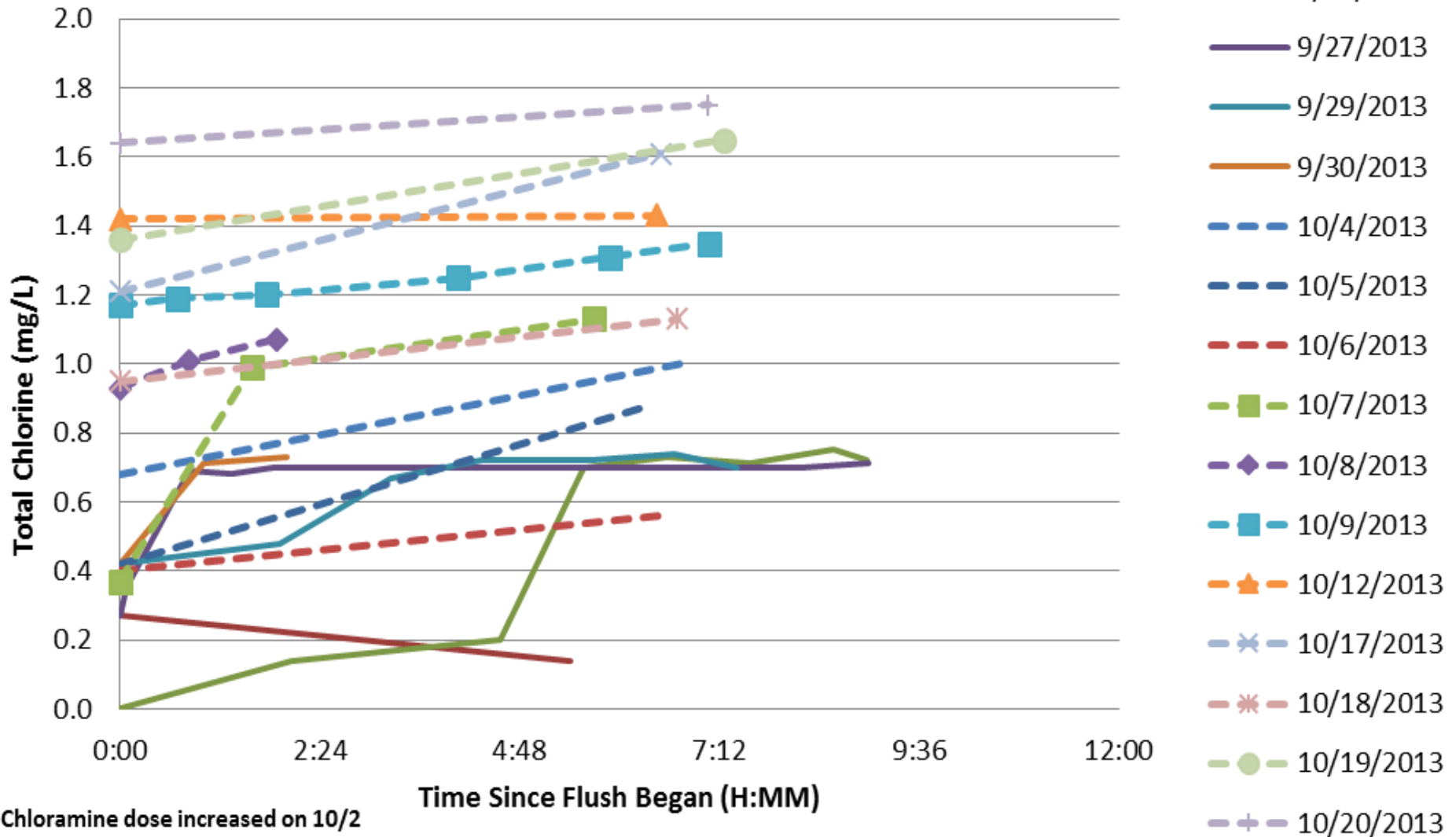
Chloramine dose increased on 10/2

Turbidity- 547119 SW Altadena & Santa Monica St.



Chloramine dose increased on 10/2

Total Chlorine - 1505 SW Dewitt (523212)



WQ and O&M Recommendations

Chloramine Residual Boosting

- **Imperative to maintain adequate residuals**
- **Immediate:**
 - Conduct seasonal boosting at Headworks during early summer and continue through nitrification season
- **Longer Term:**
 - Consider boosting at applicable tanks
 - Faster response in problem areas
 - Fewer DBPs



Unidirectional Flushing

- **Important as a proactive and reactive tool**
- **Program needs (and has since gained) ownership and management**
- **Continue with development, implementation, evaluation, and refinement of program**
- **PWB and SPU have submitted a proposal to WRF to study flushing as a corrective action under the RTCR**
- **Prioritize problem areas of distribution system**



TCR Response, Management, and Communications

- **PWB staff indicated good and positive communications during the event**
 - Teamwork
 - Timely decision making
 - No road blocks
- **Develop and add a TCR Decision Tree to current TCR Plan**
 - Suspected source water/treatment breakthrough
 - Suspected regrowth
 - Suspected contamination
 - Suspected sample tap/contamination issue



Conclusions

- **PWB data availability key to understanding trends**
- **TC+ violation appears to have been caused by a regrowth event**
- **Conditions in 2013 not unique to PWB and probably similar in portions of wholesaler systems with similar conditions!**
- **No indications of distribution system contamination**
- **Nitrification may have contributed to water quality conditions that favor regrowth**
- **Spot flushing was not an effective response strategy given water quality conditions**
- **UDF and boosting were more effective**
- **Proactive measures proven to be more effective than reactive measures**



Questions?

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Coliform Occurrence Pathways

- **Source water/treatment breakthrough**
- **Direct contamination of the distribution system**
- **Regrowth in biofilms/sediments**
- **Sample tap contamination/sample collection issues**



Source Water/Treatment Breakthrough

- **Coliform presence could occur if:**
 - Contamination of sources
 - Treatment upset allowing microbial contamination to reach the DS
 - Unusual turbidity event
- **Would expect coliform presence to be more widespread throughout the system**
 - Positive samples were extremely localized
- **No indications of CT violations or issues**
- **No unusual weather or turbidity issues**

Seems Unlikely...



Direct contamination of the distribution system - Findings

■ Pressure maintenance and associated facilities

- Pressure loss: No alarms or complaints before event
- Valves: Inspections - none identified in wrong position

■ Main breaks/repairs

- None occurred in area leading up to event

■ Cross-connections

- Always possible...
- Inspections - none identified

Seems Unlikely...

■ Storage facilities

- Inspections discovered one missing screen on Bertha overflow

■ Construction

- None occurred in area leading up to event

■ *E. coli* not present in any samples



Regrowth in Biofilm/Sediments

- **Microorganisms already present in the distribution system experience a “growth spurt” because water quality conditions are optimal**
- **Optimal water quality conditions for regrowth:**
 - Warmer temperatures (>15 degrees C)
 - Low to no disinfectant residual in DS
 - Increased nutrients
- **Unlined cast iron piping present in affected area**
 - UCI served 25 of 27 positive sample sites (92.6%)
 - 40 of 42 positive samples (95.3%)
- **No systematic UDF or routine *pipe cleaning* program in the west side of system**

Seems Likely...



Sample Tap Contamination/Sample Collection Issues - Findings

■ Sample Tap Contamination

- ❑ Initial repeat samples at WQSS 200 - negative
- ❑ Many positives appear in localized area, not only at WQSS 200
 - It is difficult to ensure integrity of repeat sampling sites

■ Sample Collection

- ❑ Multiple personnel collected samples
- ❑ PWB confirmed sampling practices

Seems Unlikely...

