

OPTIMIZATION OF DISTRIBUTION SYSTEM CHLORINE RESIDUALS THROUGH CHLORINE DECAY TESTS AND HYDRAULIC MODELING

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Outline of Presentation

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Project Genesis

In 2017, Washington Department of Health changed the definition of detectable chlorine residual in WAC 246-290.

- Old Standard – detectable chlorine residual defined as > 0.05 mg/L free chlorine
- New Standard – detectable chlorine residual defined as > 0.2 mg/L free chlorine

Silver Lake Water & Sewer District (SLWSD) had 73 samples ≤ 0.25 mg/L in 2015-2017. SLWSD met the old standard but there was concern with the change with the new standard.

Water System Background

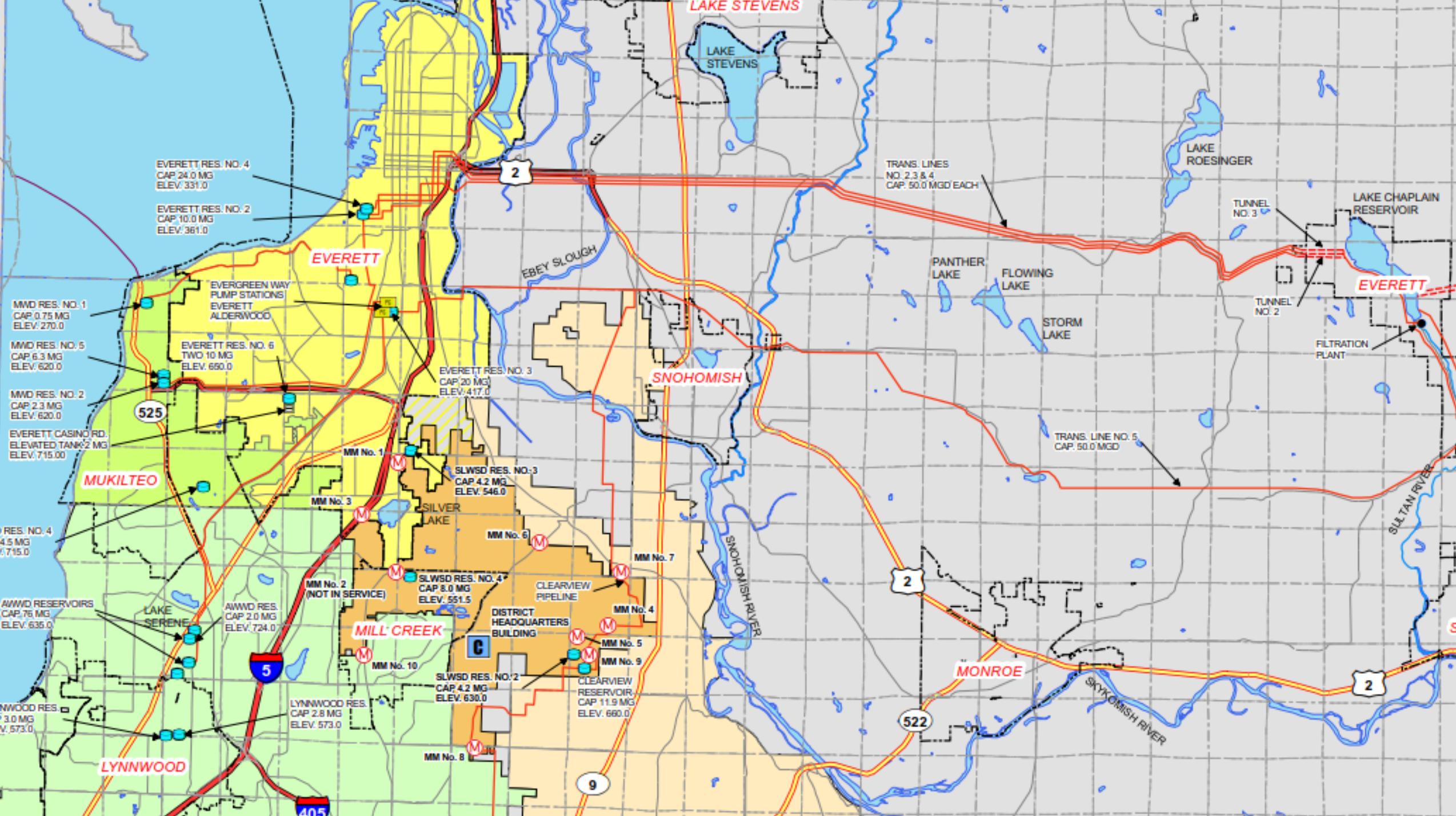
- All of the water that SLWSD is purchased and originates from the City of Everett water treatment plant.
- City of Everett treats water from Spada Reservoir.
- Treatment with coagulation, flocculation, filtration, and disinfection using hypochlorite.
- Conveyed to several water systems through multiple large pipelines.
- SLWSD is located about 20 miles from the Everett treatment plant.

Water System Background

City of Everett water quality is good.

Parameter	Year					
	2010			2019		
	Min	Ave	Max	Min	Ave	Max
Turbidity, NTU	0.01	0.03	0.13	0.02	0.04	0.50
pH	7.3	7.6	8.8	7.0	7.6	8.5
Alk., mg/L as CaCO ₃	8.6	15.3	21.5	15.0	16.3	20.5
Hardness, mg/L as CaCO ₃	10.2	10.7	11.1	11.0	12.5	30.7
TOC, mg/L	0.49	0.53	0.59	0.57	0.65	0.76
Chlorine, mg/L	0.7	1.0	2.2	0.8	1.1	2.1

City of Everett 2014 Water System Plan indicated that average chlorine dosage was 1.9 mg/L, while the chlorine residual leaving the plant was 0.8-1.1 mg/L.



Water System Background

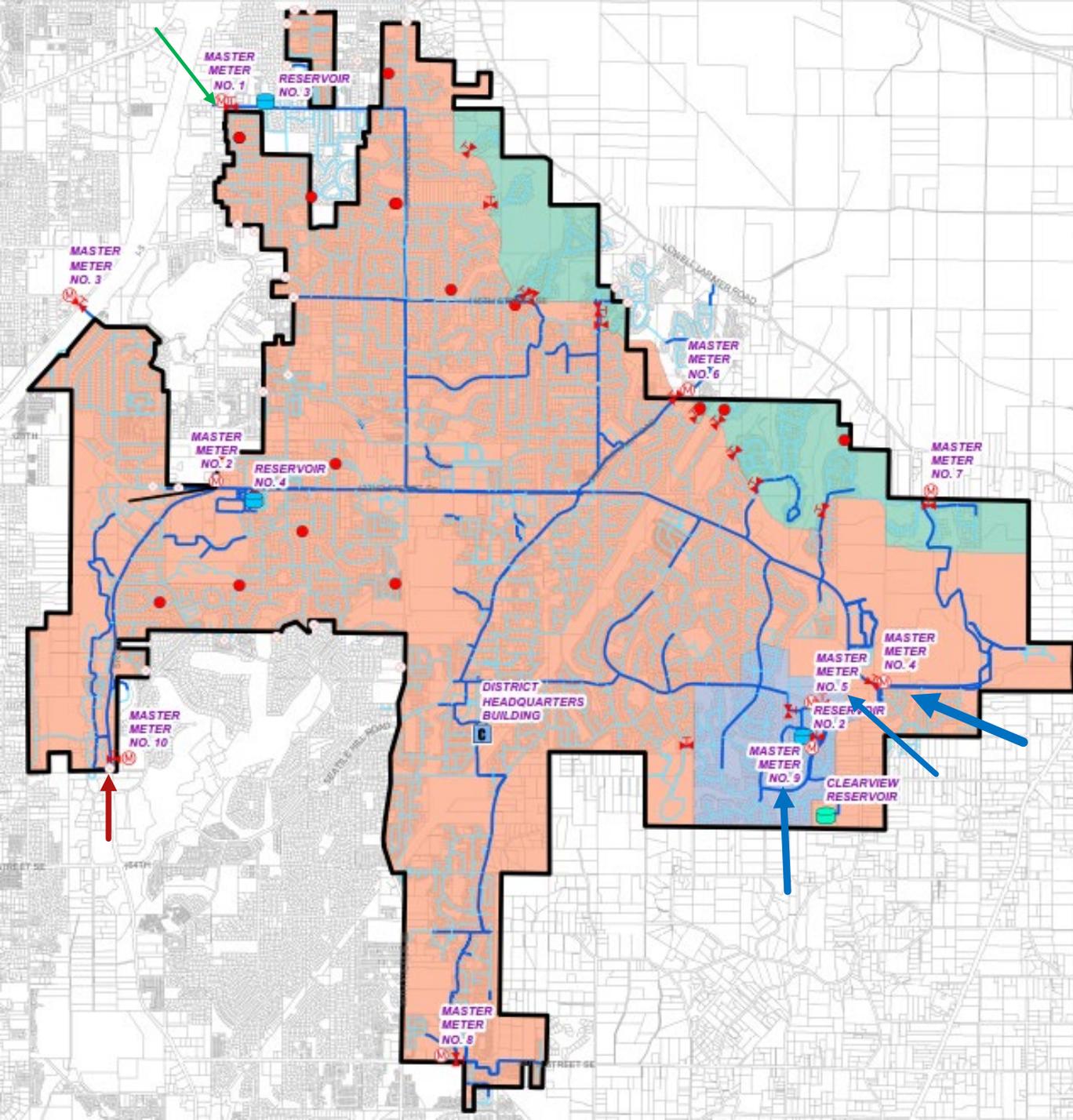
All of SLWSD is treated at the City of Everett water plant.
Five primary supply master meters from three purveyors.

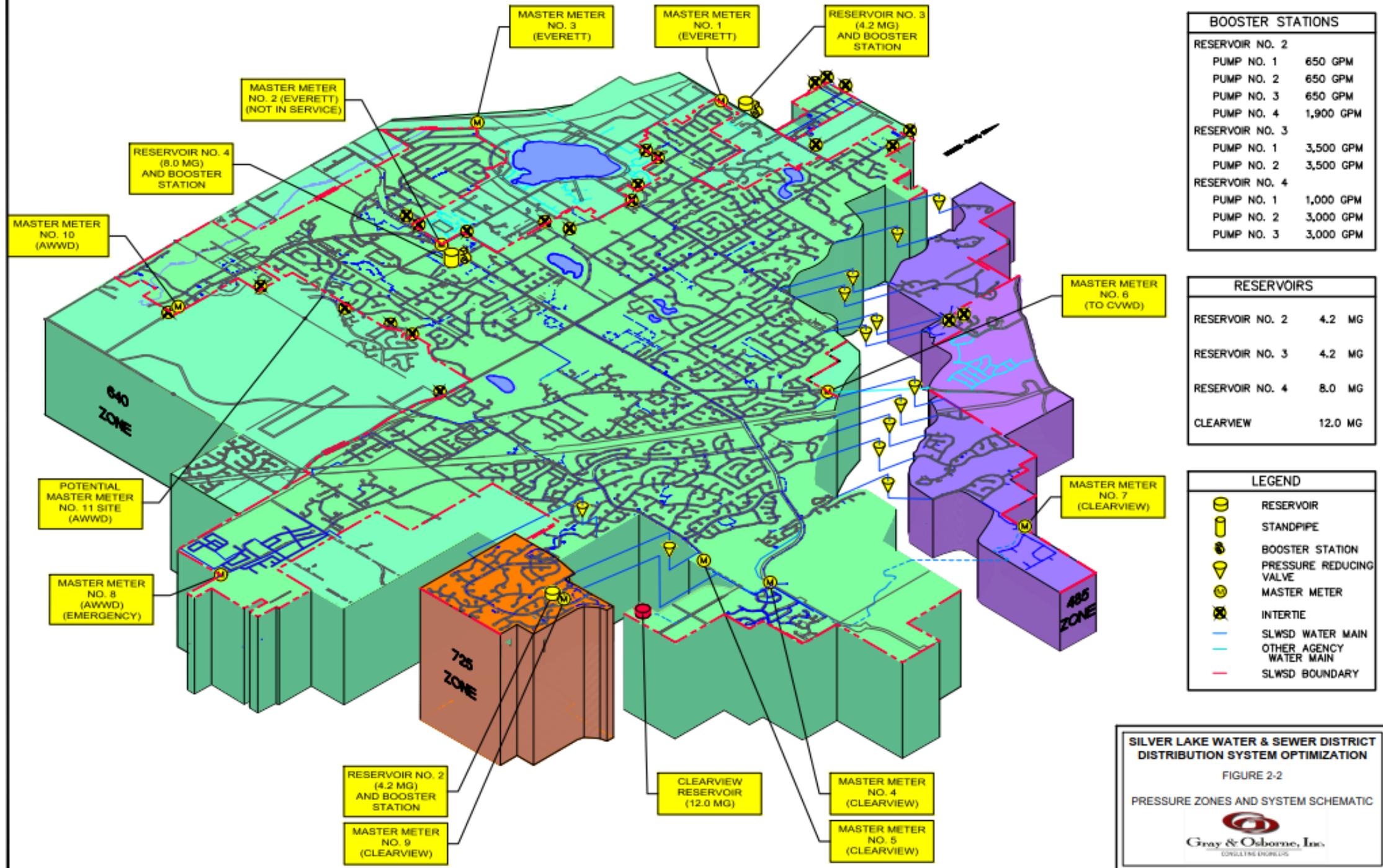
- 1 from City of Everett
- 1 from Alderwood Water and Wastewater District (AWWD)
- 3 from Clearview Water Supply Agency (CWSA)

Water System Background

Most of the water comes through 5 master meters

CWSA (81%) 
AWWD (13%) 
Everett (6%) 





BOOSTER STATIONS	
RESERVOIR NO. 2	
PUMP NO. 1	650 GPM
PUMP NO. 2	650 GPM
PUMP NO. 3	650 GPM
PUMP NO. 4	1,900 GPM
RESERVOIR NO. 3	
PUMP NO. 1	3,500 GPM
PUMP NO. 2	3,500 GPM
RESERVOIR NO. 4	
PUMP NO. 1	1,000 GPM
PUMP NO. 2	3,000 GPM
PUMP NO. 3	3,000 GPM

RESERVOIRS	
RESERVOIR NO. 2	4.2 MG
RESERVOIR NO. 3	4.2 MG
RESERVOIR NO. 4	8.0 MG
CLEARVIEW	12.0 MG

LEGEND	
	RESERVOIR
	STANDPIPE
	BOOSTER STATION
	PRESSURE REDUCING VALVE
	MASTER METER
	INTERTIE
	SLWSD WATER MAIN
	OTHER AGENCY WATER MAIN
	SLWSD BOUNDARY

**SILVER LAKE WATER & SEWER DISTRICT
DISTRIBUTION SYSTEM OPTIMIZATION**
FIGURE 2-2
PRESSURE ZONES AND SYSTEM SCHEMATIC

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Water System Background

SLWSD has three at-grade steel reservoirs.

Reservoir	Capacity, MG	Year Built	Overflow Elevation, ft	Overflow Level, ft	Diameter, ft
2	4.2	1987	630.0	45.0	126
3	4.2	1989	546.0	45.0	126
4	8.0	2008	551.5	61.5	150
Total	16.4				

SLWSD do not provide gravity storage. All water is pumped from the reservoirs to closed zones.

Water System Background

SLWSD has a booster station at each reservoir.

Master meter operation

- Master Meters are controlled by flow rate to meet a preset daily supply order.
- Operation mode is designed to curb peaks, does not operate on fill and draw of reservoirs

960,000 linear feet of pipe

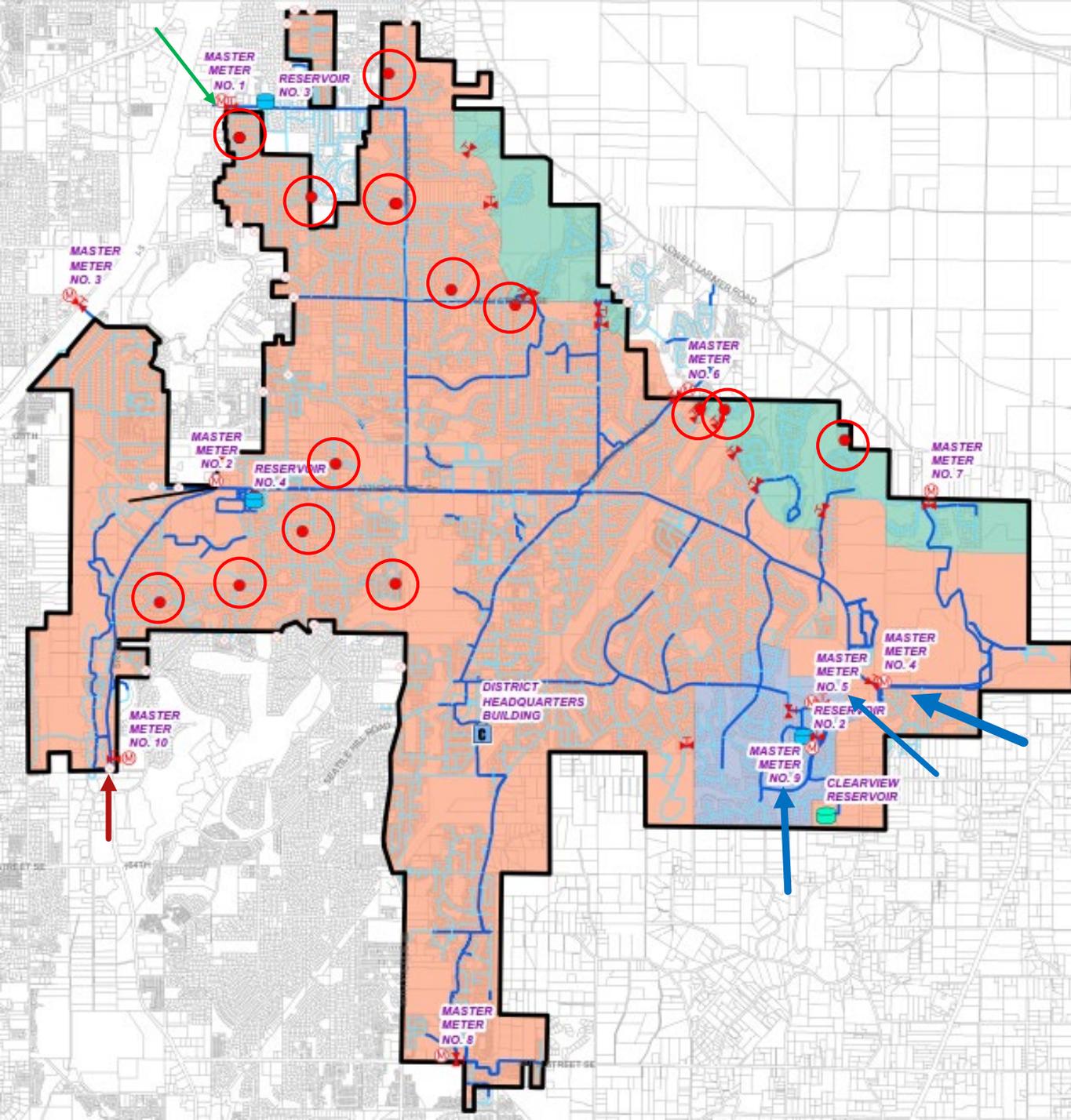
Diameter, in	Linear Feet	Percent
4	21,757	2.3
6	140,199	14.6
8	546,945	57.0
10	12,946	1.3
12	142,640	14.9
16	48,778	5.1
39	4,100	0.4
42	41,800	4.4
Total	959,165	100

Water System Background

Area of low chlorine residual are located throughout the distribution system.

Red dots indicate areas where chlorine < 0.2 mg/L measured between 2015-2017.

Areas of low residual appear to be near Reservoirs 3 and 4.



Strategy

- Distribution system water quality sampling to quantify parameters.
- Initial hydraulic modeling to identify water age throughout system.
- Reservoir mixing investigation.
- Bench-scale chlorine decay tests.

Distribution System Water Quality

SLWSD collected chlorine, pH, and temperature at 8 locations daily for one month.

February 2018 (winter), August 2018 (summer), and September 2019 (summer)

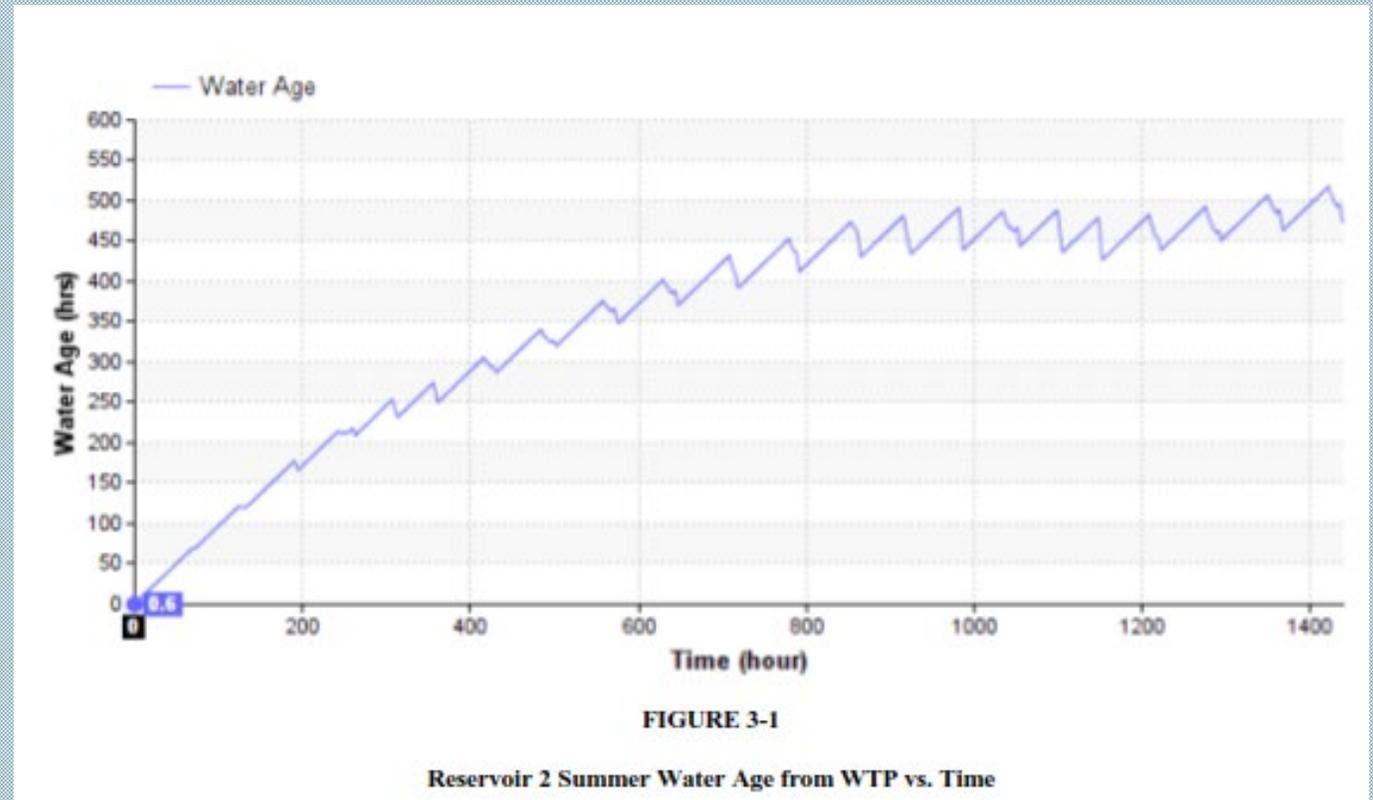
	Chlorine, mg/L				Temperature, °C			
	Low	Average	High	Range	Low	Average	High	Range
Winter 2018	0.19	0.72	0.96	0.77	6.2	7.4	9.2	3.0
Summer 2018	0.26	0.62	0.86	0.60	18.8	20.7	23.8	5.0
Summer 2019	0.25	0.68	1.13	0.88	18.3	20.5	23.9	5.6

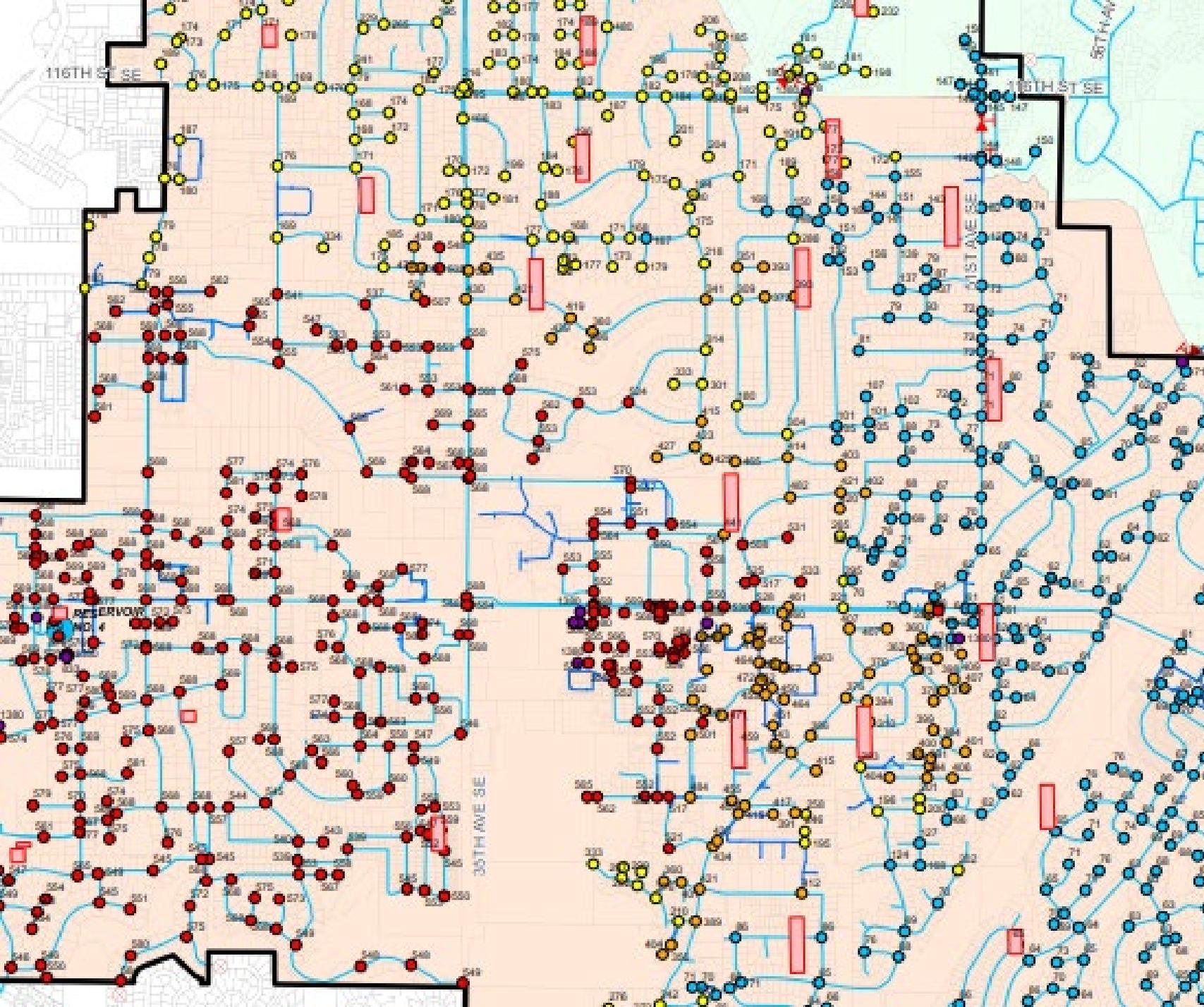
Slightly lower average chlorine during the summer along with higher temperatures.

Hydraulic Modeling

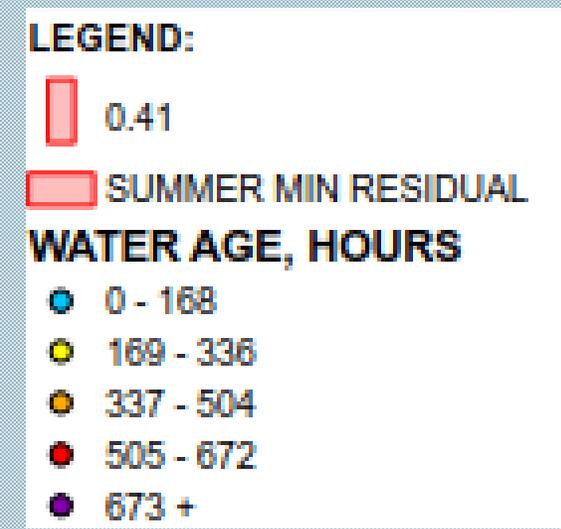
- Extended period modeling of the system was used to investigate the system.
- 2018 water use data used for model demands, reservoir levels, master meter flows.
- 60 day runs.

Analysis provided information about water age from WTP at various places in the system.





Model showed age correlated with residual.

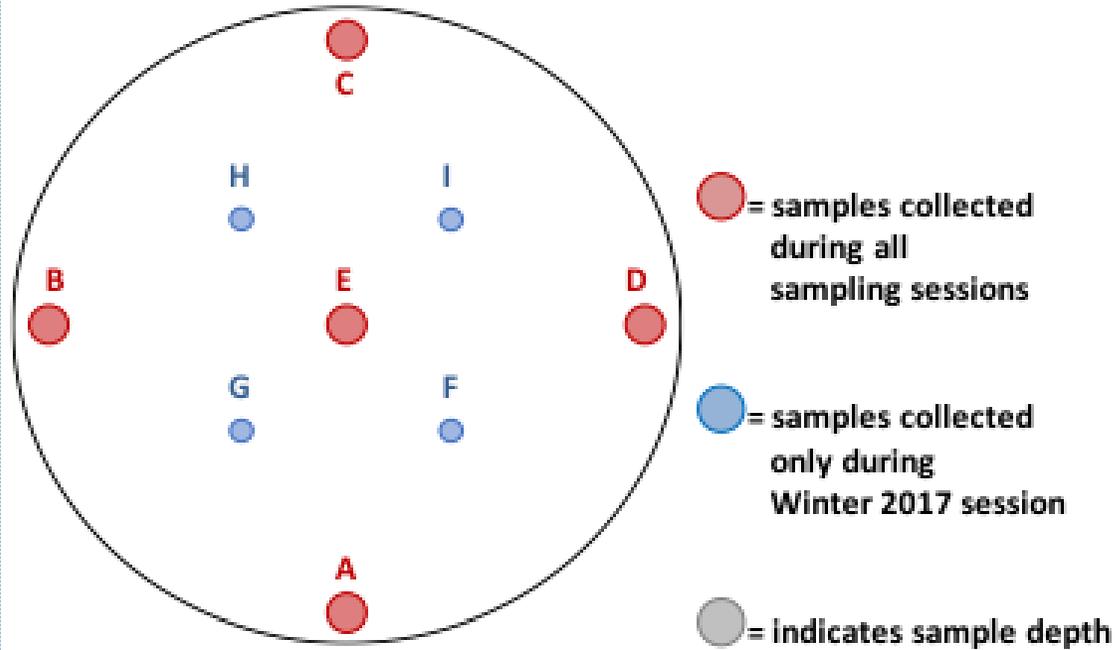


Reservoir Investigation

- The three large reservoirs were suspected of having areas of stagnation that could provide low chlorine water at times.
- A water quality sampling regime was developed to sample water quality throughout the reservoirs during Nov/Dec. 2017, Aug. 2018, Aug 2019.
- A raft was used to obtain the samples under a stringent water quality protocol.

Reservoir Investigation

RESERVOIR PLAN



RESERVOIR ISOMETRIC

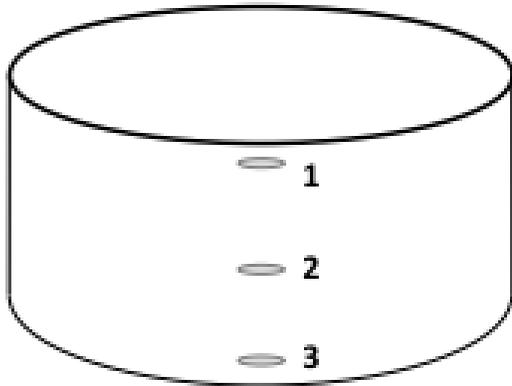


FIGURE 4-6

Typical Reservoir Sampling Location Arrangement



Reservoir Investigation

The investigation showed that the reservoirs were well-mixed with no pockets of stagnation.

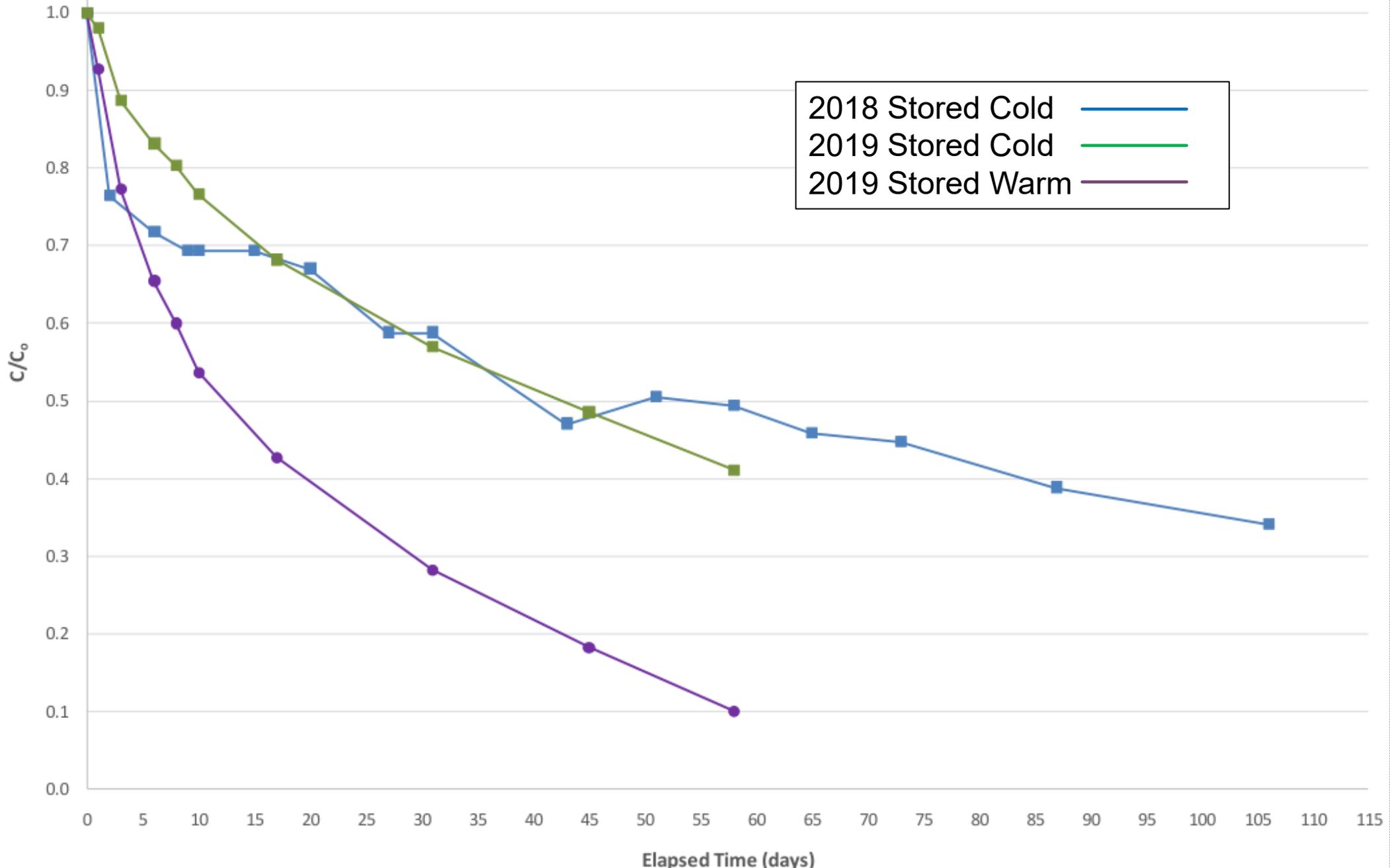
Chlorine Residual, mg/L							
	Reservoir 2			Reservoir 3	Reservoir 4		
	12/2017	8/2018	8/2019	11/2017	12/2017	8/2018	8/2018
Min	0.50	0.36	0.55	0.30	0.27	0.30	0.39
Max	0.91	0.40	0.75	>2.0	0.57	0.42	0.42
Ave	0.61	0.37	0.65	0.39	0.34	0.33	0.40

All three storage reservoirs are equipped with passive mixing systems. Reservoir 3 did not have one at start of study, but did by the end of the data collection period.

Chlorine Decay Testing

- Chlorine decay testing was used to observe the chemical reactions with chlorine in the water.
- Samples were taken from Master Meter 5 in January (2018), September (2018), January (2019), and August (2019) to provide both winter and summer samples. Additional samples were taken at reservoirs.
- Chlorine was measured periodically over several days using a Hach 1900 spectrometer.
- Samples were stored in the dark in two conditions:
 - Cool (3-7 °C) in refrigerator
 - Warm (18-23 °C) in a cooler at room temperature

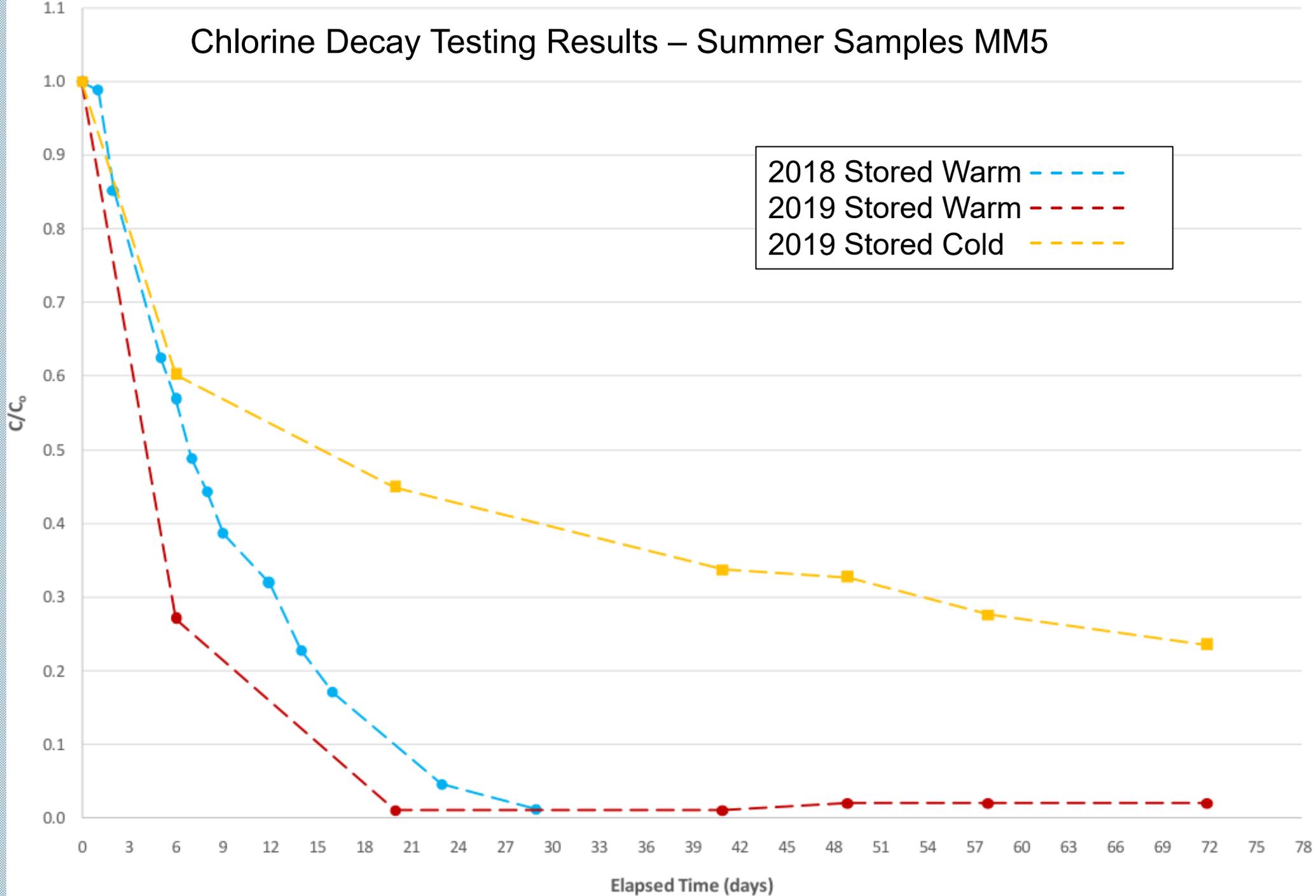
Chlorine Decay Testing Results – Winter Samples MM5



Initial Cl₂ levels
2018 – 0.85 mg/L
2019 – 1.1 mg/L

Winter samples stored at cold temps still have an acceptable chlorine level after 60 days.

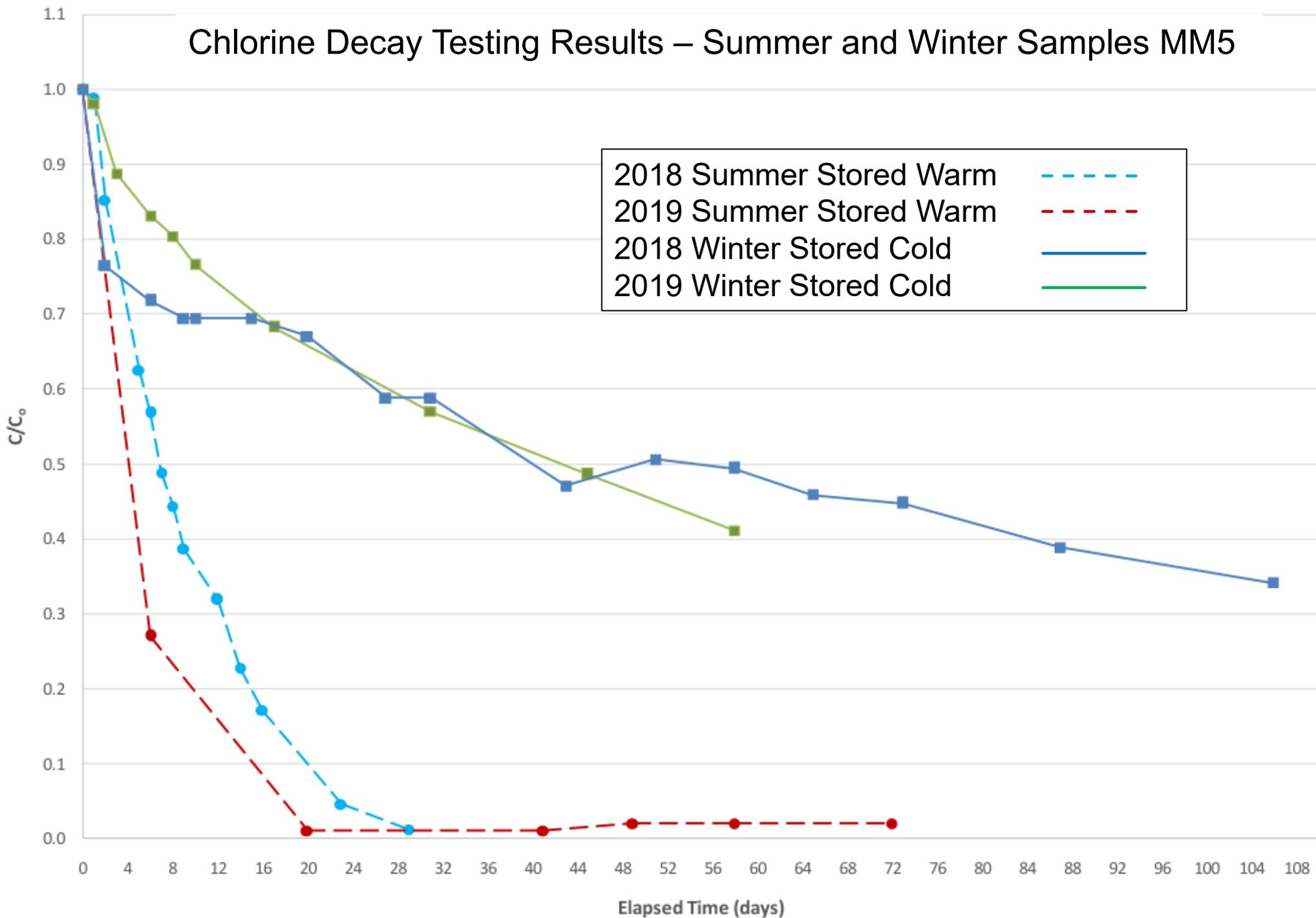
Chlorine Decay Testing Results – Summer Samples MM5



Initial Cl₂ levels
2018 – 0.88 mg/L
2019 – 1.0 mg/L

Summer samples stored at warm temps dropped below 0.2 mg/L by 10-18 days.

Chlorine Decay Testing Results – Summer and Winter Samples MM5



Summer and winter samples when stored at the appropriate temps show a distinct chance of low chlorine residual during the summer.

Winter chlorine residuals do not appear to be as problematic.

Chlorine Decay Testing Summary

The chlorine decay tests showed two trends:

- There is a larger chlorine demand in summer versus winter.
- Higher temperatures increase chlorine decay rate.

Results

- The hydraulic modeling showed areas of the distribution with 20+ days of water age measured from the WTP, especially in areas served by Reservoirs 3 and 4.
- The reservoir investigation showed that the reservoirs were well mixed.
- The chlorine decay tests showed that the higher chlorine demand in the summer coupled with the warmer temperatures seen in the reservoirs and distribution system create high chlorine decay rate with low chlorine after 10-15 days.
- Summer chlorine residuals in some areas of the distribution system could be at risk of <0.2 mg/L chlorine.
- Winter residuals appear less problematic.

Recommendations

- District attempted to improve residuals by optimizing higher Cl₂ sources and increasing reservoir turnover – it helped but challenging and didn't solve the issue.
- Chlorine booster stations were recommended at Reservoir 3 and 4 Booster Stations.
- Can be used seasonally as necessary.
- Installed and ready for service in April 2022.

Chlorine Booster Installation



Questions?

Acknowledgements:

Silver Lake Water & Sewer District Staff



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