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Technical Memorandum

Prepared for: City of Albany

Project Title: Water Distribution System Optimization

Project No.: 154258

Technical Memorandum

Subject: Water Distribution System Optimization

Date: April 1, 2022

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Section 1: Introduction

The purpose of this project is to help the City of Albany (City) optimize operation of its drinking water distribution system. Brown and Caldwell (BC) used the current hydraulic model (originally created in 2015) and data provided by the City to evaluate and recommend practical steps the City can take to meet its goals and objectives around:

- System pressures: Maintaining adequate pressures for all customers
- Water quality: Limiting disinfection byproducts (DBPs) and improving chlorine residual
- Reservoir storage: Maintaining enough storage to meet daily and emergency needs
- Efficient operations: Avoiding unnecessary pumping and flushing

To help meet these goals and objectives, the following tasks were performed:

Model Update and Baseline Analysis. BC updated the model to include a winter scenario that more appropriately reflects the lower winter demands, as well as the current winter operational strategy. Demands for automatic flushing stations were also added to the model. The updated model was used to provide baseline distribution system conditions (e.g. pressure, water age) for comparison with possible changes. Water age, which is usually correlated with chlorine residual and DBPs, will be used as a surrogate for identifying water quality concerns in the distribution system.

Storage and Distribution Analysis. Water age is often significantly influenced by the volume of storage in the water system. BC evaluated the water system demands and storage to determine storage volume options, including potential seasonal adjustments. BC also investigated the current pressure zones boundaries to determine if any improvements were possible at the extremities of the elevations in the zones.

Water Quality Analysis. A brief analysis of water quality data was performed to evaluate the likely drivers of DBPs and low chlorine residual, and to provide recommendations for improving water quality in the distribution system.

Alternative Evaluation. BC used the hydraulic model to investigate the impact of changes to operational strategies on water age. Fourteen alternatives were identified for assessment. Changes were evaluated individually and compared to the baseline results.

Alternatives Selection. Based on the results of the previous tasks, two feasible distribution system operational strategies were selected. The effect on pressure, water age, fire flow capacity, and energy usage were evaluated and compared.

Documentation. This TM documents the results of the analysis.

Figure 1 shows a map of the water system, including sample stations and flushing stations.

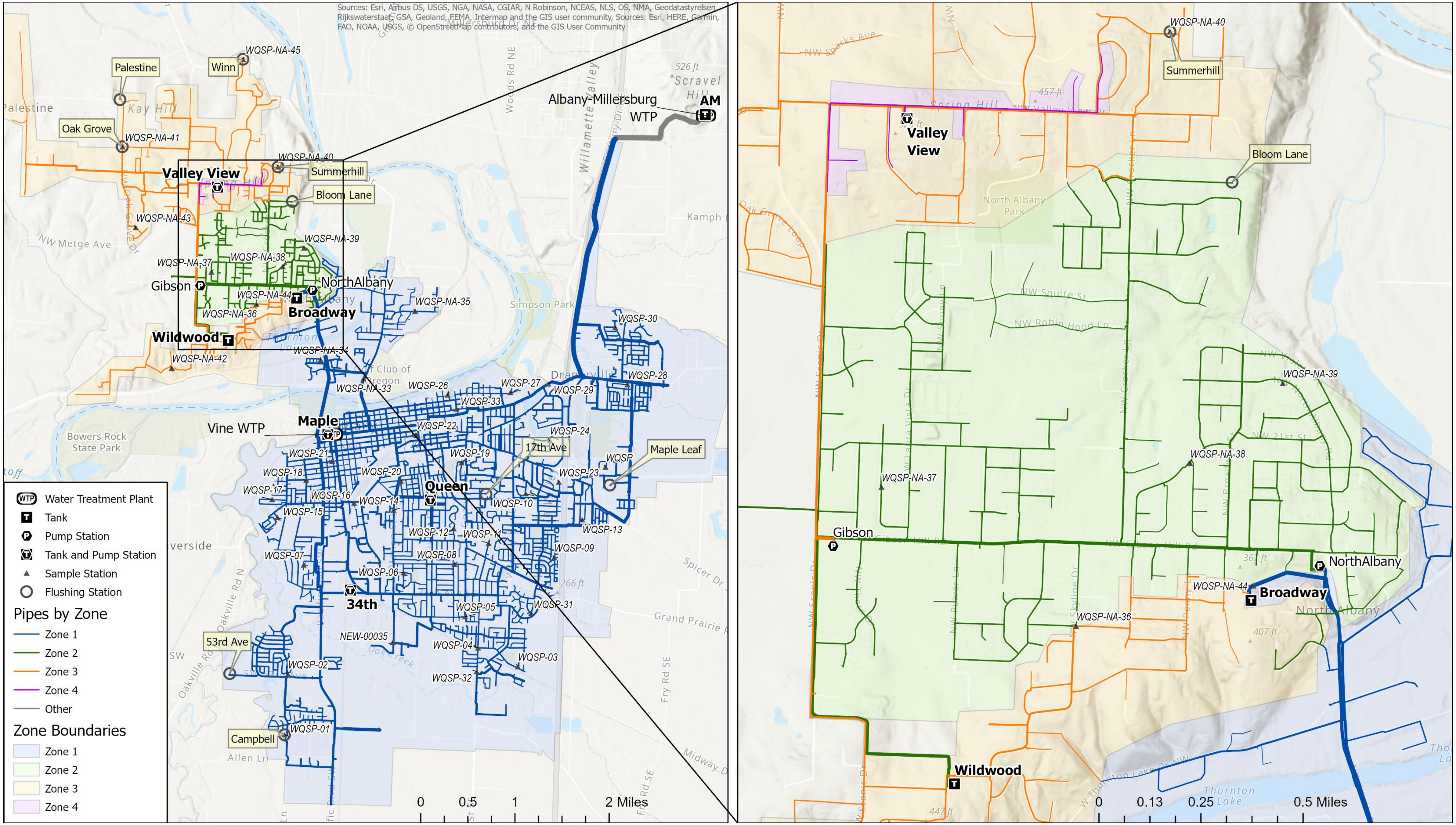


Figure 1. Water System Map

Section 2: Evaluation Criteria

This analysis used the City WaterGEMS extended-period simulation hydraulic model, previously created and updated by BC. The model was updated to include the latest demands and control strategy. A selection of distribution system criteria was provided by the City and are shown in Table 1.

Table 1. Evaluation Criteria

Criterion		Value
Pressure	Minimum operating	40 psi
	Maximum operating	80 psi
	Minimum during MDD plus fire demands	20 psi
Maximum Velocity	Distribution pipes (< 16-inch)	10 feet/second
	Transmission pipes (>= 16-inch)	5 feet/second
Water Quality	Minimum chlorine residual (goal)	0.2 mg/L free chlorine
	DBPs goal (running annual average)	0.040 mg/L TTHM
		0.030 mg/L HAA5
Reservoir Storage	Equalization Fire Emergency	Provide adequate capacity for each pressure zone

MDD = maximum day demand

mg/L = milligrams per liter

TTHM = total trihalomethanes

HAA5 = haloacetic acids

Section 3: Model Update

The hydraulic model was updated to include recent demands and operational controls. Five years of SCADA records provided by the City were reviewed to determine the typical winter and summer operations for key facilities. Table 2 shows the typical operations at each facility for winter (November-March) and Summer (April-October).

<table>
<tr><th colspan="3">Table 2. Typical Operations</th></tr>
<tr><th>Facility</th><th>Winter (November- March)</th><th>Summer (April – October)</th></tr>
<tr><td>A-M Water Treatment Plant (WTP)</td><td>Produces water 24 hours/day, typically about 4.5 mgd</td><td>Produces water 24 hours/day, typically about 9 mgd</td></tr>
<tr><td>Vine WTP</td><td>Produces water between approximately 10 am and 4 pm, typically about 1 mgd</td><td>Produces water between approximately 7 am and 4 pm, typically about 2.5 mgd</td></tr>
<tr><td>Maple Tank</td><td>Minimum of 10 ft, typical max of 25 ft</td><td>Minimum of 10 ft, typical max of 35 ft</td></tr>
<tr><td>Vine WTP High-Service Pumps</td><td>Between 11 am and 11 pm, usually operate pump 3 and/or pump 4</td><td>Between 8 am and 11 pm, usually operate pump 3 and/or pump 4</td></tr>
<tr><td>Albany Pressure-Reducing Valve (PRV) Station</td><td colspan="2">Valve cycles between 60 psi and 70 psi, with slightly higher pressures in the summer. Model setting of ~64 psi (378 ft HGL) in the afternoon or if Broadway tank is full, 72 psi (396 ft HGL) to fill Broadway.</td></tr>
<tr><td>34th Tank and Pump Station (PS)</td><td colspan="2">Every other day (alternate days with Queen), pump water level down to 24 feet between 1 am and 9 am, then fill to 30 feet between 9 pm and 11 pm. No seasonal changes.</td></tr>
<tr><td>Queen Tank and Pump Station (PS)</td><td colspan="2">Every other day (alternate days with 34th), pump water level down to 24 feet between 1 am and 9 am, then fill to 30 feet between 9 pm and 11 pm. No seasonal changes.</td></tr>
<tr><td>North Albany PS</td><td colspan="2">If Wildwood tank water level < 13.0 ft (typically about 4 am – 6 am), then turn on until level > 17.3 ft (typically about 10 am – 1 pm). Some seasonal variation of the hours.</td></tr>
<tr><td>Gibson Hill PS</td><td colspan="2">If Valley View tank water level < 28 ft (typically about 2 am), then turn on until level > 35 ft (typically about 8 am). Some seasonal variation of the hours.</td></tr>
<tr><td>Valley View PS</td><td colspan="2">Always on, maintaining 50 psi at pump discharge. SCADA indicates this varies from 40-65 psi.</td></tr>
</table>

The hydraulic model demands were updated to include a winter scenario that appropriately reflects the lower demands and the worst case for water age. In addition, current demands at flushing stations were added to the model. These flushing stations are used to improve water quality at the far ends of the system.

Figure 2 shows the winter demand, average day demand (ADD), and maximum day demand (MDD) calculated from SCADA records for 2008-2018. These include non-revenue water (NRW) and flushing demands, but do not include Millersburg demand. 2018 demands were used for this evaluation because only partial 2019 data was available at the start of this project. The demands used for evaluation are listed in Table 3.

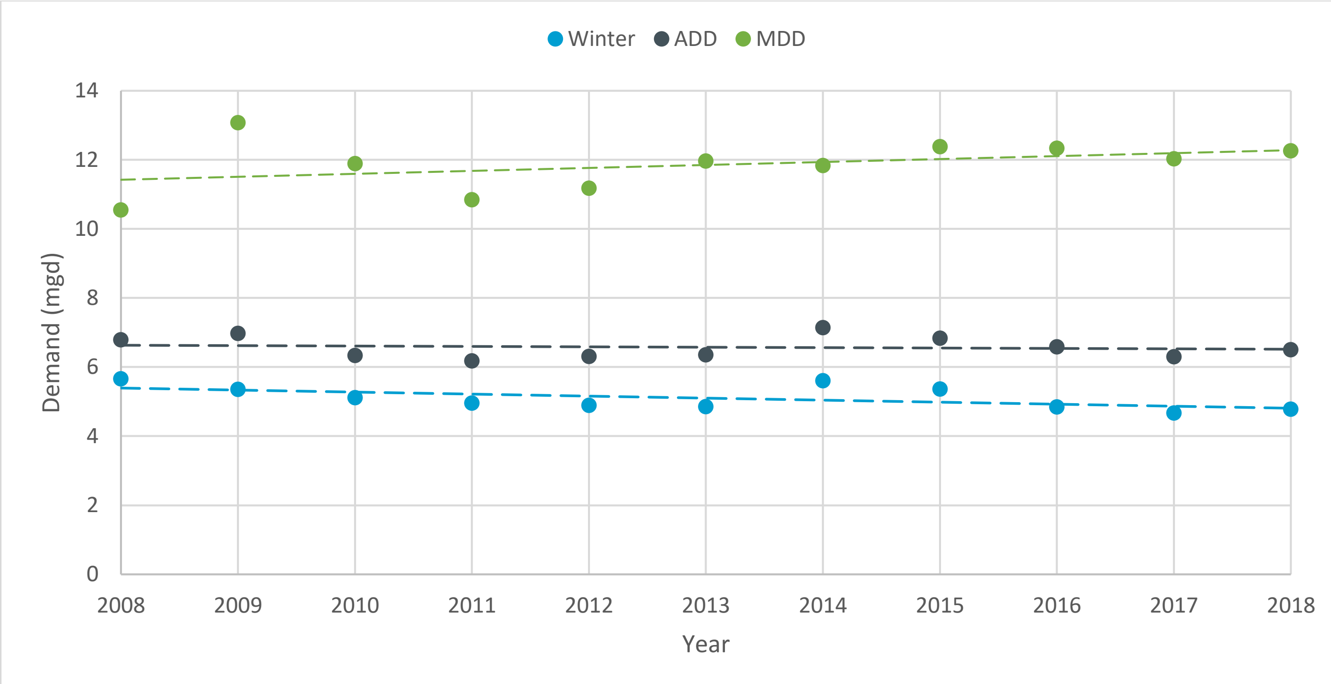


Figure 2. 2008 to 2018 Demands

Table 3. Demands Used for Evaluation				
Zone	Demand (mgd)			Winter-to-Summer Scaling Factor
	Average Winter [1]	2018 ADD [3]	2018 Summer (MDD) [2]	
Zone 1	4.15	5.45	9.89	2.38
Zone 2	0.32	0.59	1.28	4.00
Zone 3 & 4	0.30	0.46	1.09	3.63
Total System	4.77	6.50	12.27	2.74

1. 2016-2018 average for winter months (Nov, Dec, Jan, Feb, Mar)

2. ADD not used for hydraulic model evaluation

3. July 25, 2018

mgd = million gallons per day

Flushing station flow data was provided by the City and added to the model. The nine flushing stations and their demands are listed in Table 4. Approximately 111,000 gallons per day (gpd) is currently flushed on a daily basis. Most flushing stations are operated at night, but the Campbell station is operated during the day due to nighttime noise complaints by residents.

Table 4. Flushing Stations							
Zone	Station	Size (inches)	Start Time	Duration (hours)	Total Daily Duration (hours)	Estimated Instantaneous Rate (gpm)	Average Daily Volume (gal)
Zone 1	17th	1	2 am	4	4	30	7,200
	53rd	1	1 am	3	3	28	5,040

Table 4. Flushing Stations							
Zone	Station	Size (inches)	Start Time	Duration (hours)	Total Daily Duration (hours)	Estimated Instantaneous Rate (gpm)	Average Daily Volume (gal)
	Campbell	2	1 pm	4	4	204	48,960
	Maple Leaf	1	1 am	1	1	38	2,280
Zone 2	Bloom	1	1 am	2	2	56	6,720
Zone 3	Oak Grove	2	2 am, 4 am	1	2	101	12,120
	Palestine	1	2 am	4	4	22	5,280
	Summerhill	2	2 am, 4 am	1	2	100	12,000
	Winn	2	4 am, 6 am	1	2	94	11,280
						Total:	110,880

Section 4: Baseline Evaluation

The model was used to evaluate baseline existing conditions for comparison with possible changes. A brief water quality evaluation was also performed using publicly available water quality data.

4.1 Baseline Results

The average water age, available fire flow, and minimum pressure results of the baseline model analyses are shown on the following figures. The water age analysis assumed all tanks are completely mixed. Fire flow results show the available fire flow during MDD at a pressure of 20 psi. Figure 3 shows the baseline average age map, Figure 4 shows the baseline available fire flow map, and Figure 5 shows the baseline minimum pressure map. Figure 6 shows a comparison of the winter and summer water age at the flushing stations and tanks. There is a significant seasonal difference in water age, particularly in North Albany, due to the lower demands in winter (see Table 3).

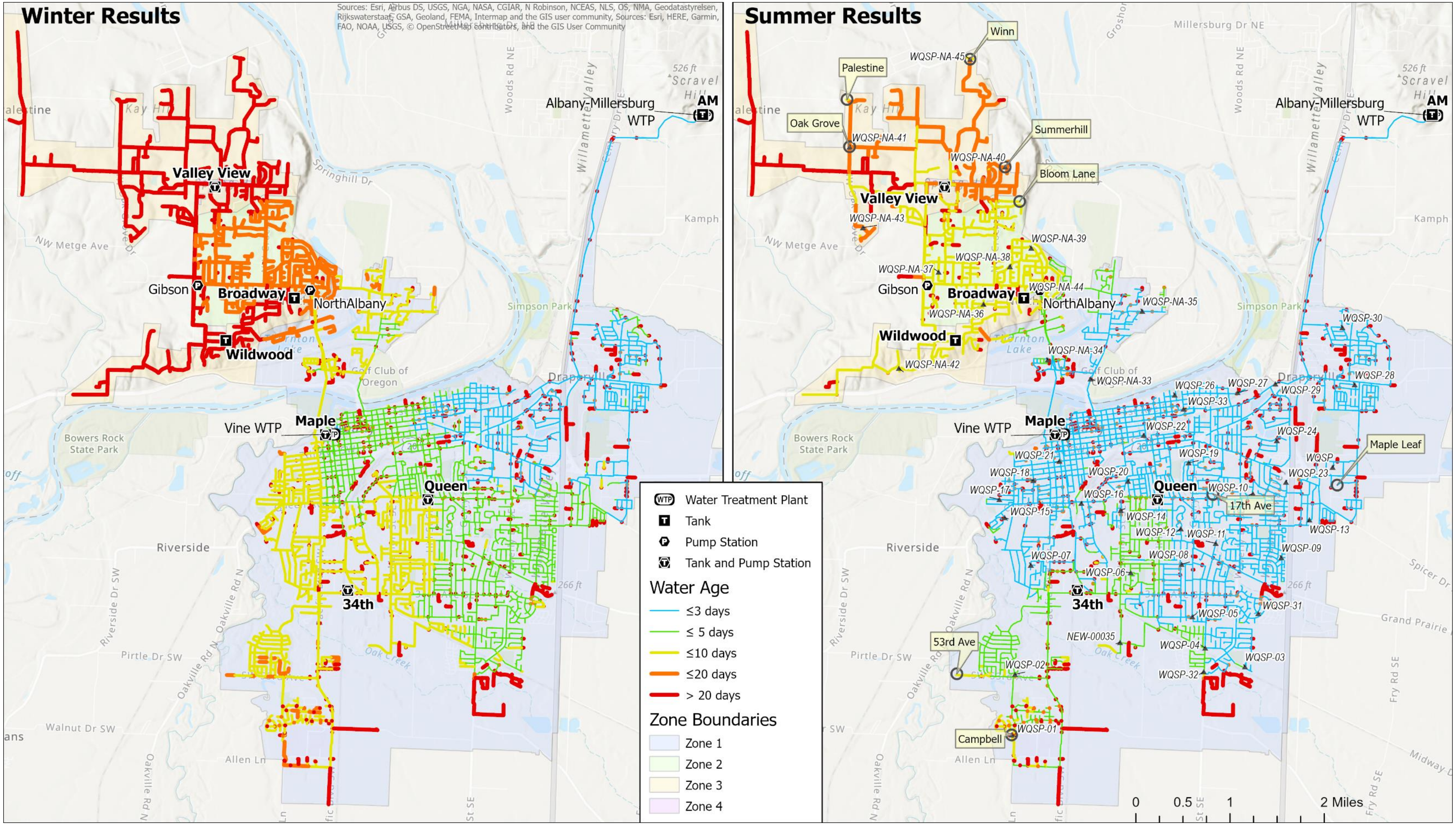


Figure 3. Baseline average water age map

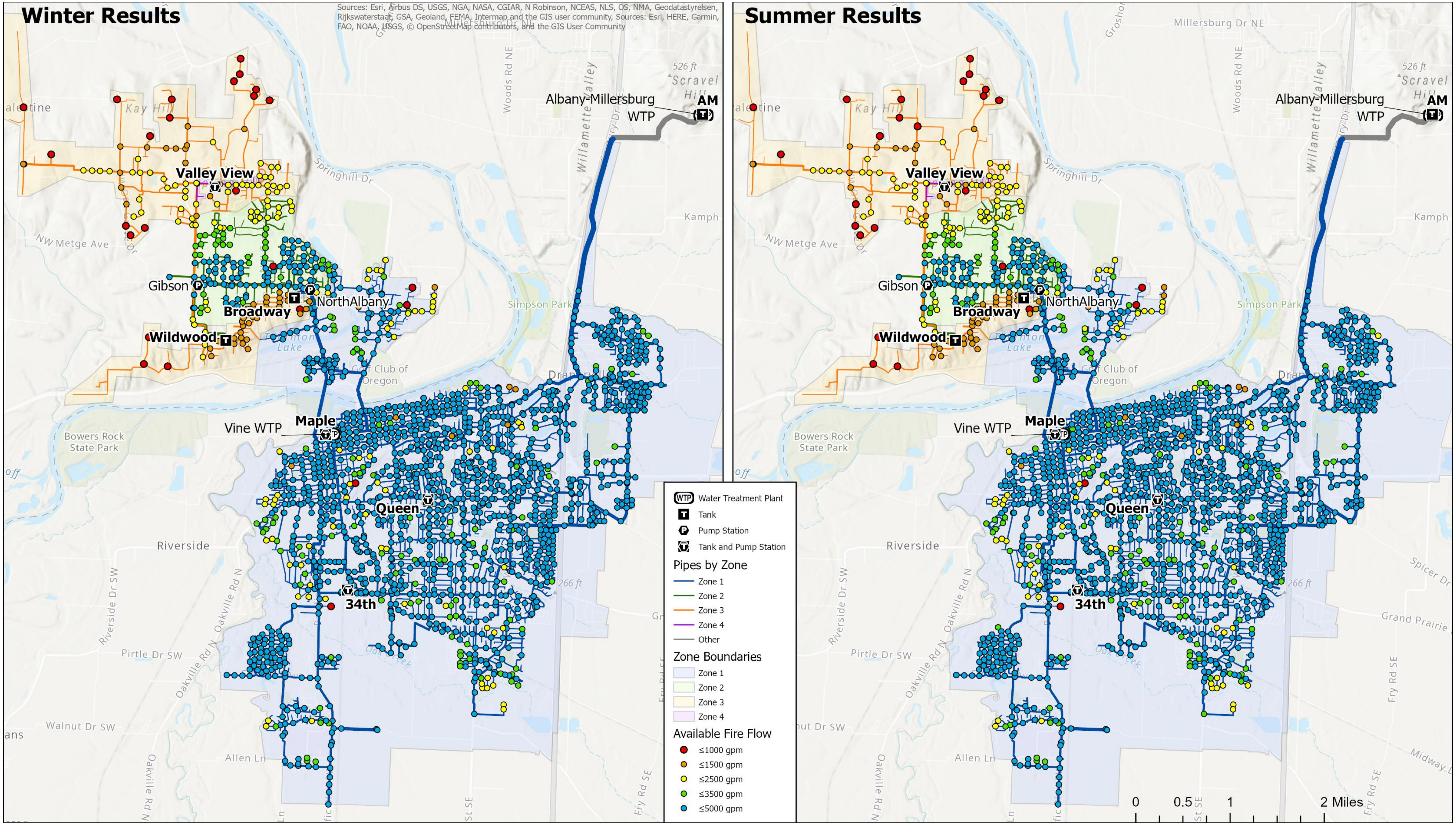


Figure 4. Baseline available fire flow map

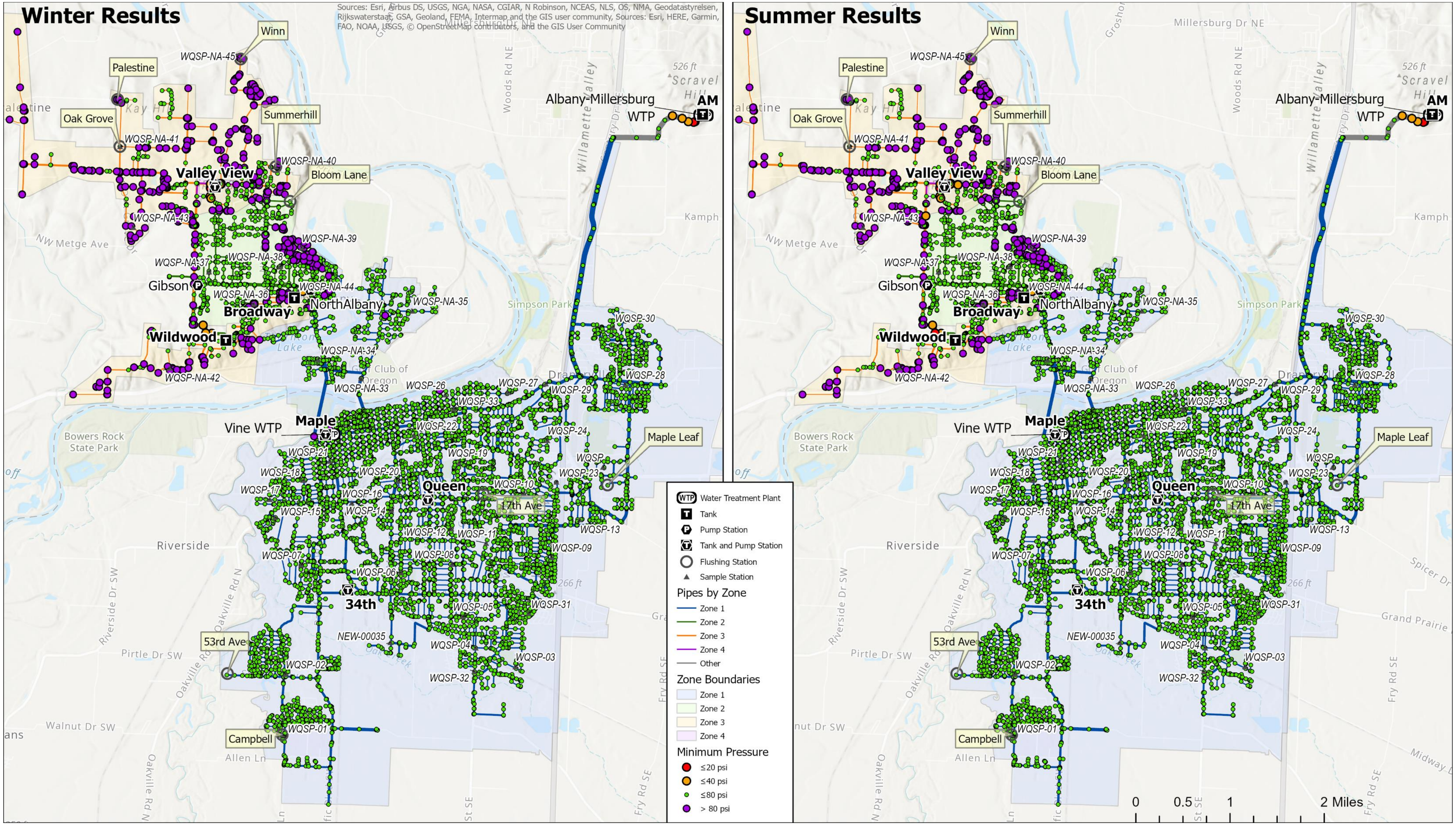


Figure 5. Baseline minimum pressure map

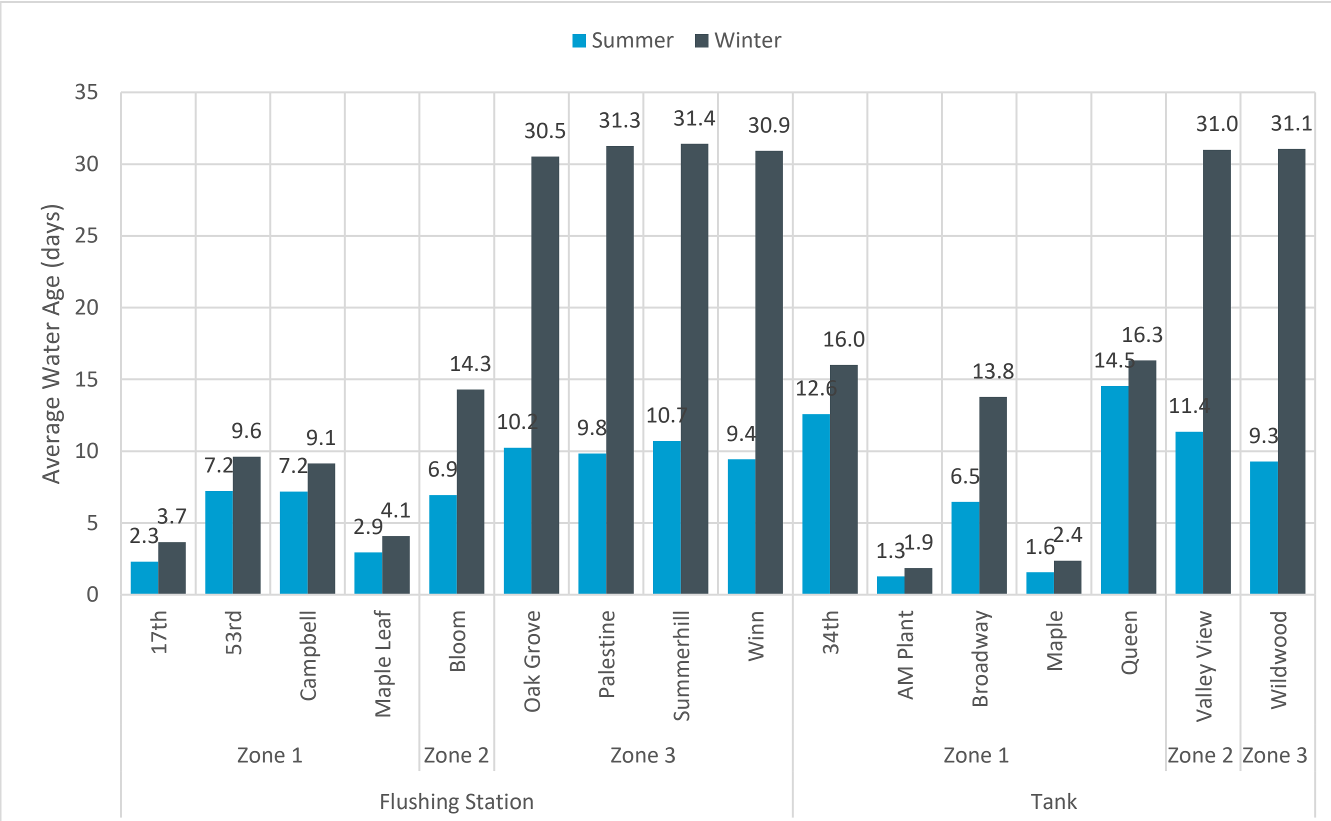


Figure 6. Baseline water age at tanks and flushing stations

4.2 Water Quality Observations

The main objective of the water quality evaluation was to evaluate the likely drivers of DBPs and low chlorine residual and to provide recommendations to limit DBPs and improve chlorine residual in the City's distribution system. Water quality data were obtained from the Oregon Public Health Drinking Water Online website (https://yourwater.oregon.gov/)

Two factors influence chlorine stability and DBP formation in distribution systems: 1) the water itself (composition and concentration of organic and inorganic compounds, microbial concentration and activity, etc.), and 2) the distribution system (water age, distribution system configuration, pipe material and diameter, etc.). In this evaluation, total organic carbon (TOC) concentration was used to characterize the water's organic content and its ability to consume chlorine residual and form DBPs. Water age was used to characterize the impact of the distribution system.

4.2.1 Chlorine

Free chlorine residuals measured from May 26, 2017 through October 4, 2019 at the nine flushing stations were used for this evaluation. The sample results are presented on Figure 7 and Figure 8. Chlorine residuals fluctuated significantly at each station. Because they are located closer to the WTPs, the two flushing stations located in downtown Albany in Zone 1 (17th Avenue and Maple Leaf) generally showed higher free chlorine residuals than stations located at the peripheries of Zone 1 (Campbell and 53rd Avenue) and in Zones 2 and 3. As expected, the lowest residuals were measured in Zone 3.

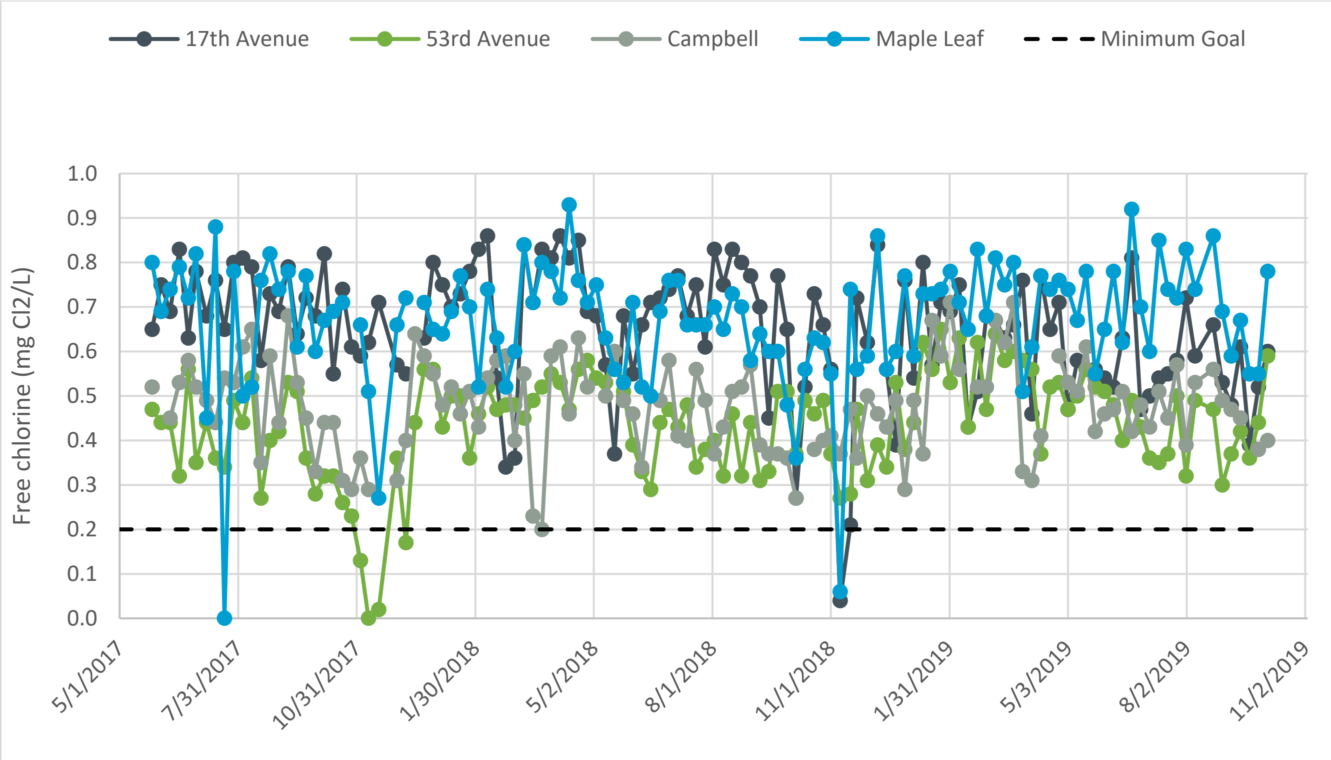


Figure 7. Free chlorine residuals measured at Zone 1 flushing stations

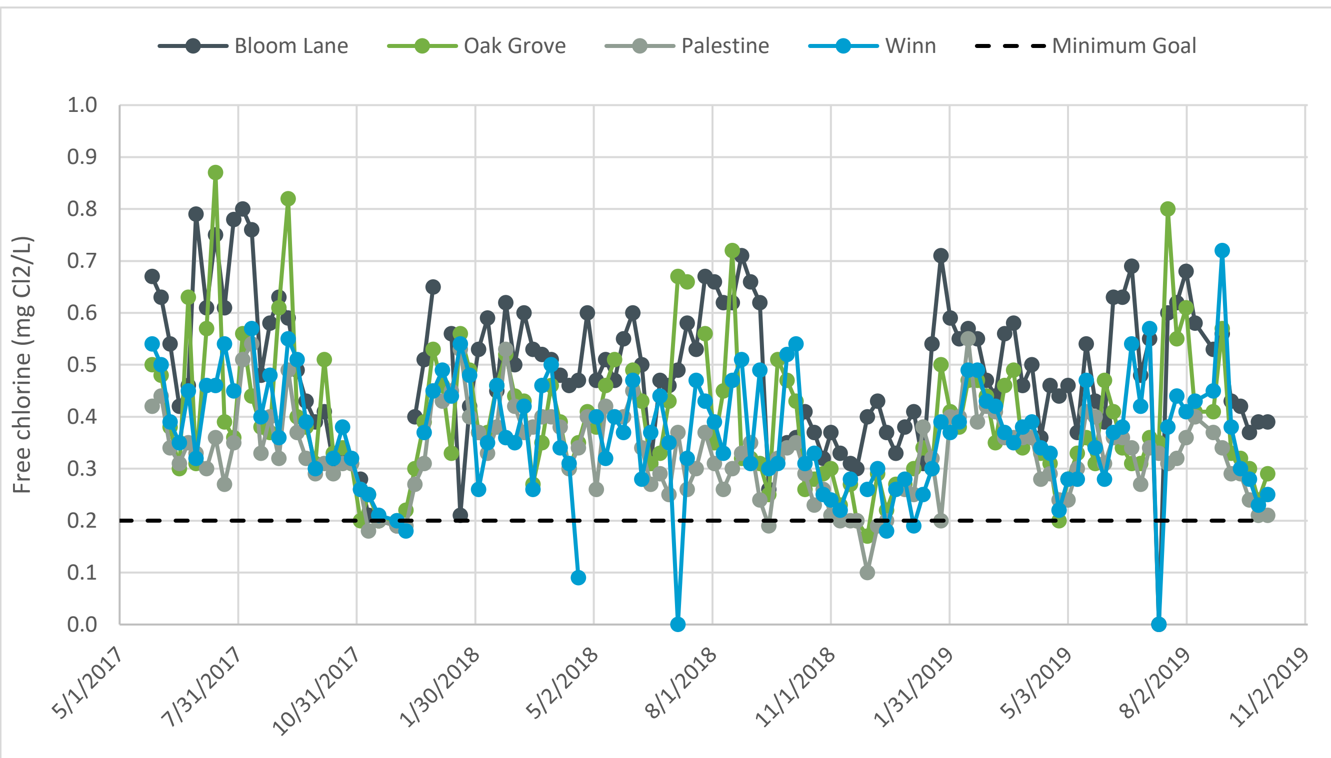


Figure 8. Free chlorine residuals measured at Zones 2 and 3 flushing stations

Strong correlations (R^2 of 0.82) were observed between average free chlorine residual and winter water age (from the baseline model simulations) at each flushing station. Summer water age and chlorine residual did not show a very strong correlation (R^2 of 0.59). Similar results were obtained when correlating the median free chlorine residuals and water age at each flushing station (R^2 of 0.81 and 0.58 for winter and summer respectively; data not shown). As shown in Figure 9, water age appears to be an important driver for free chlorine residual in the winter. Reducing water age would likely result in increased chlorine residual, particularly in the winter.

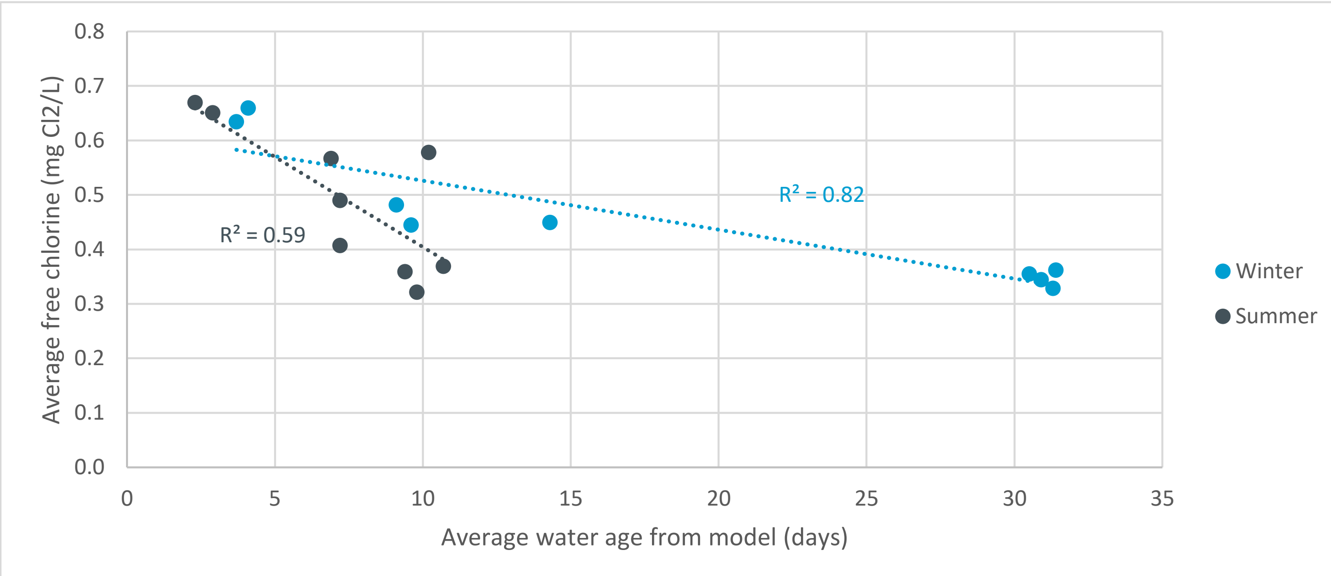


Figure 9. Average free chlorine residuals vs. average water age at each flushing station

Another option for increasing free chlorine is with chlorine booster stations. Because Zones 2 and 3 experience the lowest free chlorine residual, the North Albany or Gibson Hill PSs would be good locations for adding chlorine. If the City decides to consider a chlorine booster station, BC recommends a more thorough water quality analysis, including looking at chlorine residual at all 40+ sampling sites.

4.2.2 Total Organic Carbon

Total organic carbon (TOC) concentrations are measured quarterly in the raw and treated water of the Vine WTP, and near monthly at the A-M WTP. TOC concentrations after August 2018 were not available for the A-M WTP. When comparing both WTPs, Figure 10 shows similar TOC concentrations in the raw and treated waters.

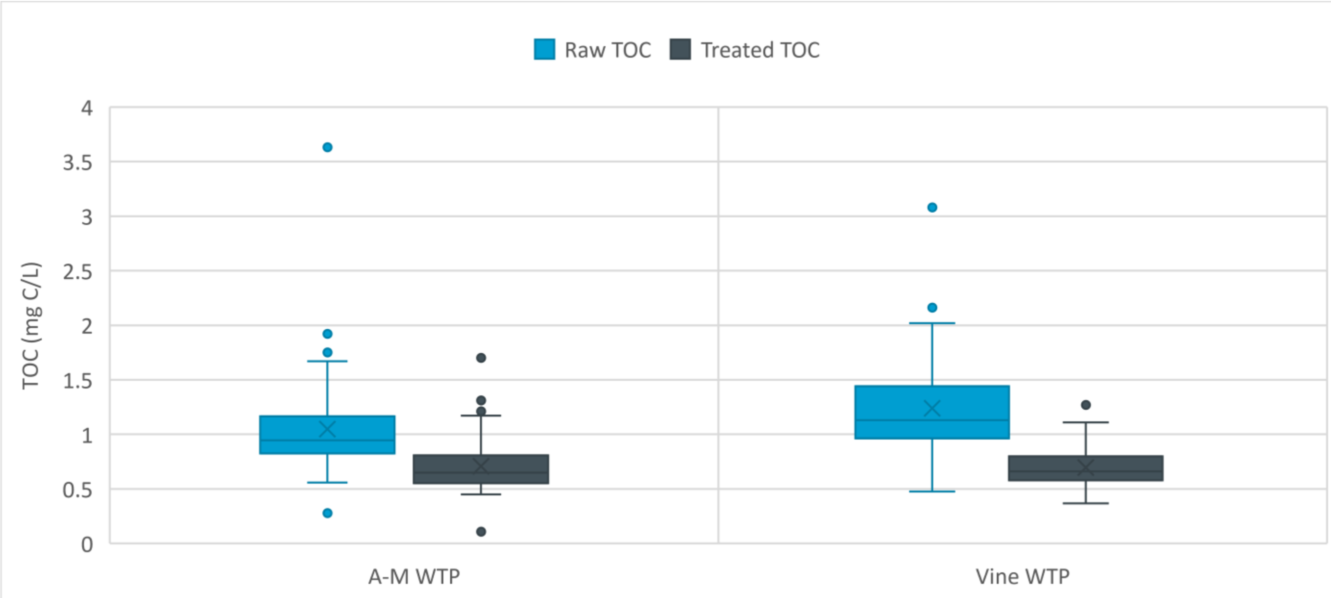


Figure 10. WTP TOC raw and treated water concentrations

January 1, 2007 through August 16, 2018

Typically, treated water TOC concentrations should better characterize chlorine residual in distribution systems than raw water TOC concentrations. For this evaluation, however, the effect of both raw and treated water TOC concentrations on free chlorine residuals was examined considering that treated water TOC data were not available for the treated water of the A-M WTP after October 2014. TOC concentrations measured at the A-M WTP were correlated with flushing stations located in Zone 1. TOC concentrations measured at the Vine WTP were correlated with flushing stations located in Zones 2 and 3. Correlation coefficients are summarized in Table 5. Results did not show correlations except between raw water TOC concentrations and free chlorine residuals measured at the Bloom Lane flushing station. This suggests that organic material is not likely to be a significant driver of chlorine decay in the City's distribution system.

Table 5. Correlation Coefficients Between TOC and Chlorine Residuals

Zone [1]	Flushing Station	Correlation Coefficient (R^2)	
		Raw Water TOC	Treated Water TOC
Zone 1	17th Avenue	0.09	
	53rd Avenue	0.01	
	Campbell	0.04	
	Maple Leaf	0.01	
Zone 2, 3 or 4	Bloom Lane	0.74	0.018
	Oak Grove	0.37	0.00
	Palestine	0.28	0.00
	Summerhill	0.25	0.01
	Winn	0.45	0.05

1. TOC concentrations measured at the A-M WTP were correlated with flushing stations located in Zone 1, TOC concentrations measured at the Vine WTP were correlated with flushing stations located in Zones 2, 3 and 4.

4.2.3 Disinfection Byproducts

Total Trihalomethane (TTHM) and HAA5 concentrations measured at eight distribution sites between January 2015 and January 2020 were used for this evaluation. Results obtained at each site are shown in

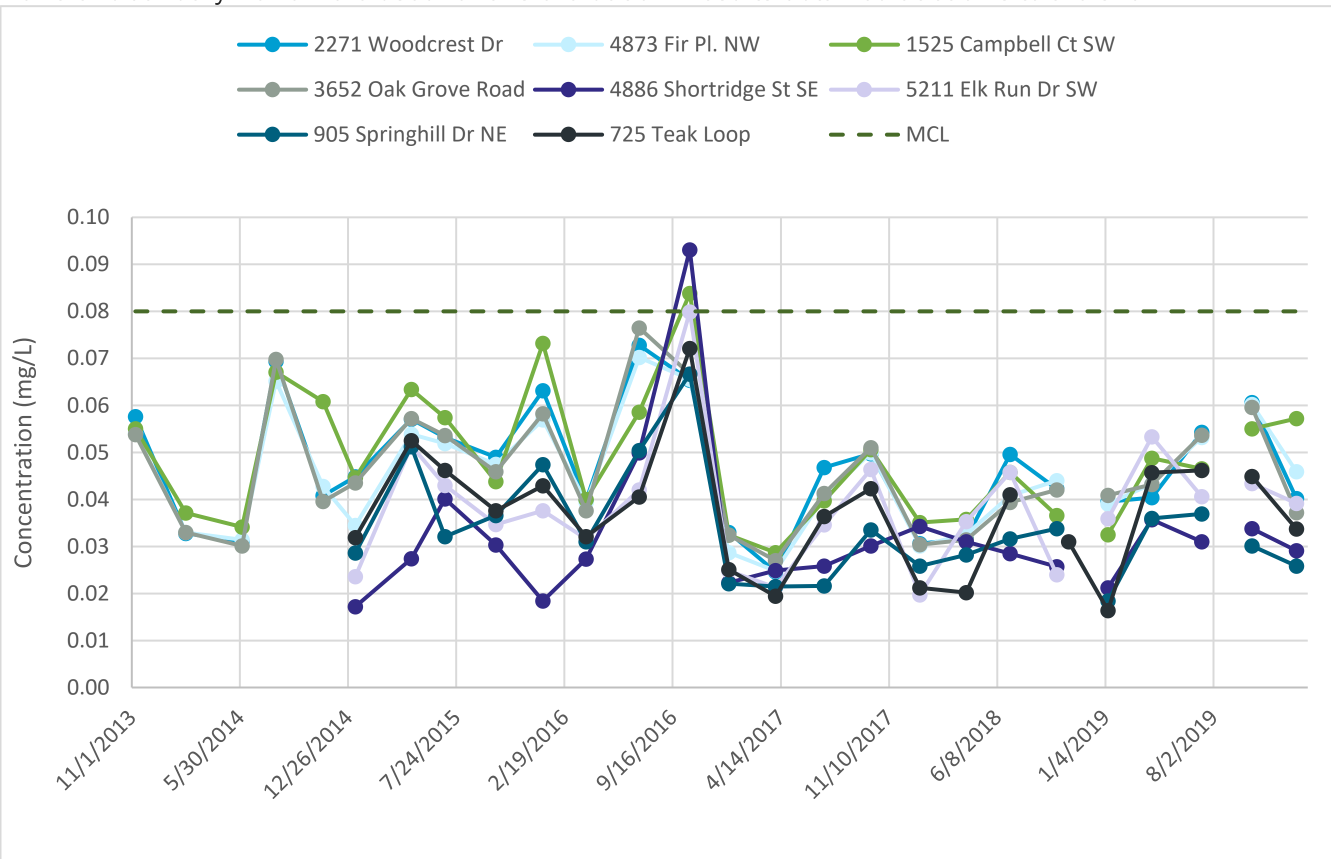


Figure 11 and Figure 12. The results indicate that all sampling sites remain compliant with the TTHM maximum contaminant level (MCL) of 0.080 mg/L, although individual concentrations at or above the MCL have occurred at times. As expected, sampling sites located closer to the WTPs showed lower TTHM concentrations than sites located further from the WTPs.

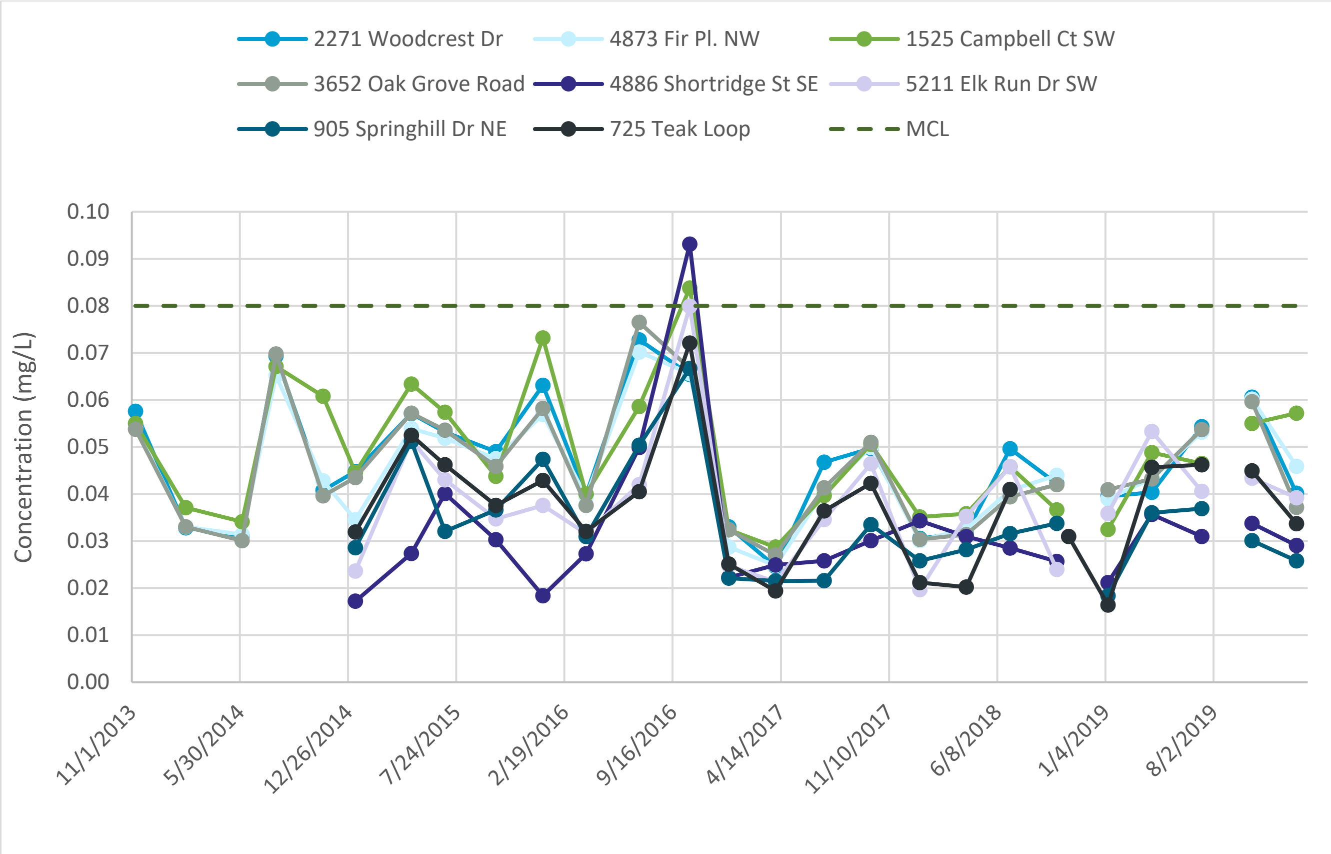


Figure 11 also indicates that HAA5 concentrations have remained well below the MCL of 0.060 mg/L, and concentrations were fairly consistent throughout the distribution system.

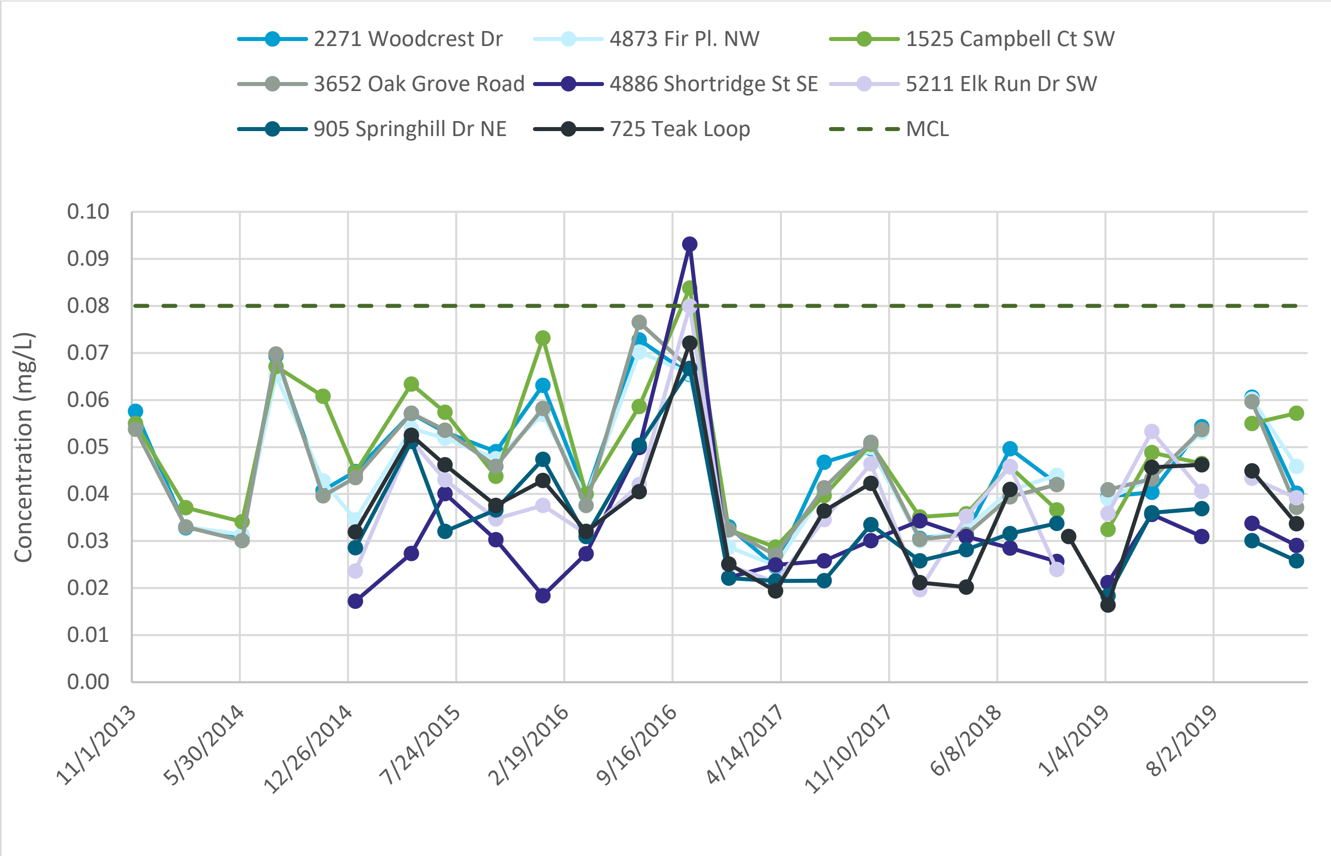


Figure 11. TTHM Concentrations measured at the DBP sample stations

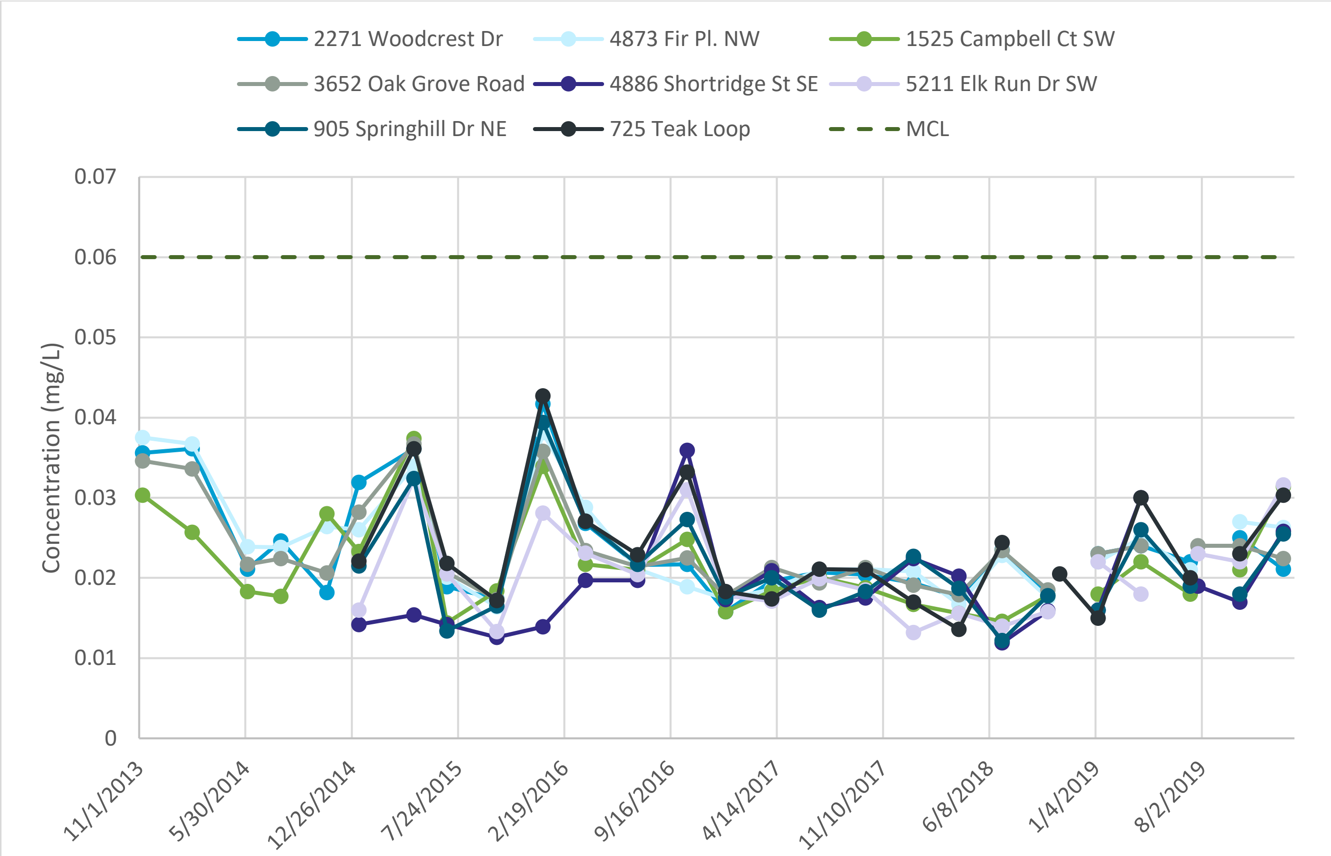


Figure 12. HAA5 Concentrations measured at the DBP sample stations

TTHM concentrations have varied substantially over the years and seasons. The highest concentrations were observed in summer and fall 2016. TTHM concentrations have generally been highest in summer and fall of each year, a trend that is typically expected. HAA5 concentrations were also higher in 2015 and 2016 than in subsequent years; however, seasonal variability of HAA5 concentrations was not as pronounced as for TTHM concentrations.

Some correlation was observed between average TTHM concentrations of each sampling site and their respective average water ages (see Figure 13). The correlation between average HAA5 concentrations and average water ages was much less pronounced. Similar trends were observed between median TTHM concentrations and water ages, and between median HAA5 concentrations and water age. These results suggest that the distribution system has some impact on TTHM formation, but little impact on HAA5 concentrations.

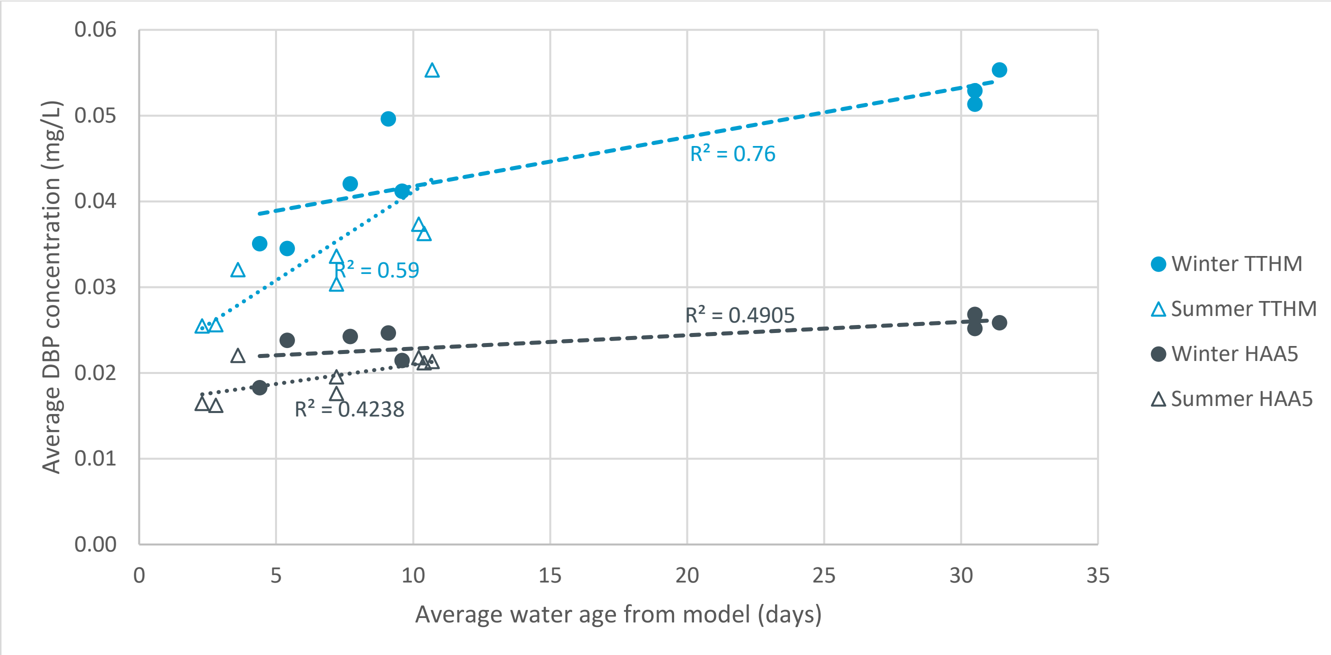


Figure 13. Average DBP concentrations vs. water age at DBP sampling sites

Four of the eight DBP sampling sites are located at or near flushing stations. These sites were used to examine potential correlations between DBP concentrations and free chlorine residuals. Results showed no correlations for either TTHM or HAA5, and the highest R^2 for any of the sampling sites was 0.17.

TOC concentrations measured at the A-M WTP were correlated with DBP sampling sites located in Zone 1. TOC concentrations measured at the Vine WTP were correlated with sampling sites located in Zones 2 and 3. Only raw water TOC data were available for the A-M WTP, but raw and treated TOC data from the Vine WTP were correlated with their respective sampling sites. Results did not show any correlations: all R^2 were lower than 0.18. This suggests that organic material is not likely to be a significant driver of DBP formation in the City's distribution system.

4.2.4 Summary of Water Quality Observations

Free chlorine residuals and DBP concentrations were analyzed in light of estimated water age of each sampling site and TOC concentrations measured in the raw and treated waters of both WTPs. Results indicate that reducing water age may significantly improve chlorine stability and help preserve chlorine residual. Reducing water age may also help limit DBP concentrations, particularly TTHM. Chlorine residual and DBP concentrations did not show any correlations with TOC concentrations, suggesting that improving water quality by modifying treatment strategy at the WTPs would not improve chlorine stability or DBP formation. Installation of a chlorine booster station could be investigated as an additional step toward improving chlorine residual in North Albany.

Section 5: Storage and Distribution Analysis

Storage in a distribution system serves several primary purposes:

1. Supply peak flow to customers so supply sources only need to be sized to produce the average rather than the peak demand.
2. Provide water during an emergency when the supply source is offline.
3. Provide water to fight fires. Fire demands are frequently higher than normal demands and the capacity of the source.

The volume of required storage for a water system typically consists of three components: (1) equalization, (2) fire, and (3) emergency storage. Equalization storage is the volume of water required to meet demands that are greater than the average daily demands. Fire storage is a volume reserved to supply the largest fire demand for the duration of a fire event. Emergency storage is a volume reserved to provide water during events such as power outages, maintenance, natural disasters, facility failures, etc.

It is helpful to think of the three types of storage schematically, as shown on Figure 14. The top portion of the tank contains the equalization storage, which increases and decreases throughout the day as water usage changes. Below that is the fire storage, which must be at an appropriate elevation to supply fire demands when the equalization storage is depleted. At the bottom is the emergency storage. Some utilities decide to vary the amount of storage to retain by season.

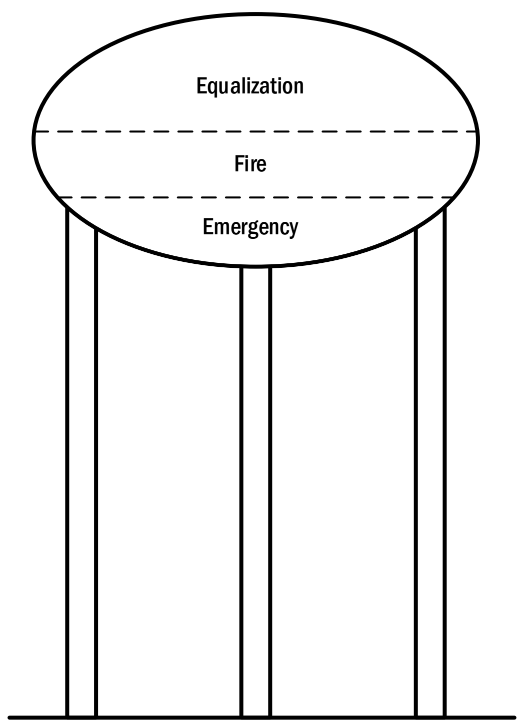


Figure 14. Storage allocation illustration

There are few firm guidelines for determining how much storage is required in each category as it can depend on many factors, including pumping capacity, distribution system configuration, number and size of other storage tanks in the pressure zone, variation in pressure zone demands, and the level of risk the utility is willing to tolerate. The State of Oregon does not have any specific minimum storage volumes guidelines.

5.1 Zone Boundaries Evaluation

Storage needs are based on demands in specific pressure zones. Prior to moving forward with zone-by-zone demand evaluations, the ideal tank service areas were compared with the existing pressure zone boundaries to investigate if there were specific areas that could be better served with modifications to the pressure zone boundaries.

The maximum service elevation for a pressure zone is calculated by subtracting the minimum pressure criteria (40 psi, converted to feet) from the tank base elevation. Likewise, the minimum service elevation is calculated by subtracting the maximum pressure criteria (80 psi, converted to feet) from the tank overflow elevation. This method does not account for friction losses due to demands or changes when pumping. Table 6 lists the ideal service elevations based on the pressure criteria, and Figure 15 shows these areas with the existing pressure zones. The results of the investigation show that there do not appear to be any areas that would benefit from being served by another pressure zone.

Table 6. Ideal Tank Service Elevations

Tank	Elevation (feet)			
	Base	Overflow	Maximum elevation served at 40 psi	Minimum elevation served at 80 psi
Broadway	346	385	254	200
Wildwood	430	450	338	245
Valley View (all)	520	560	428	375

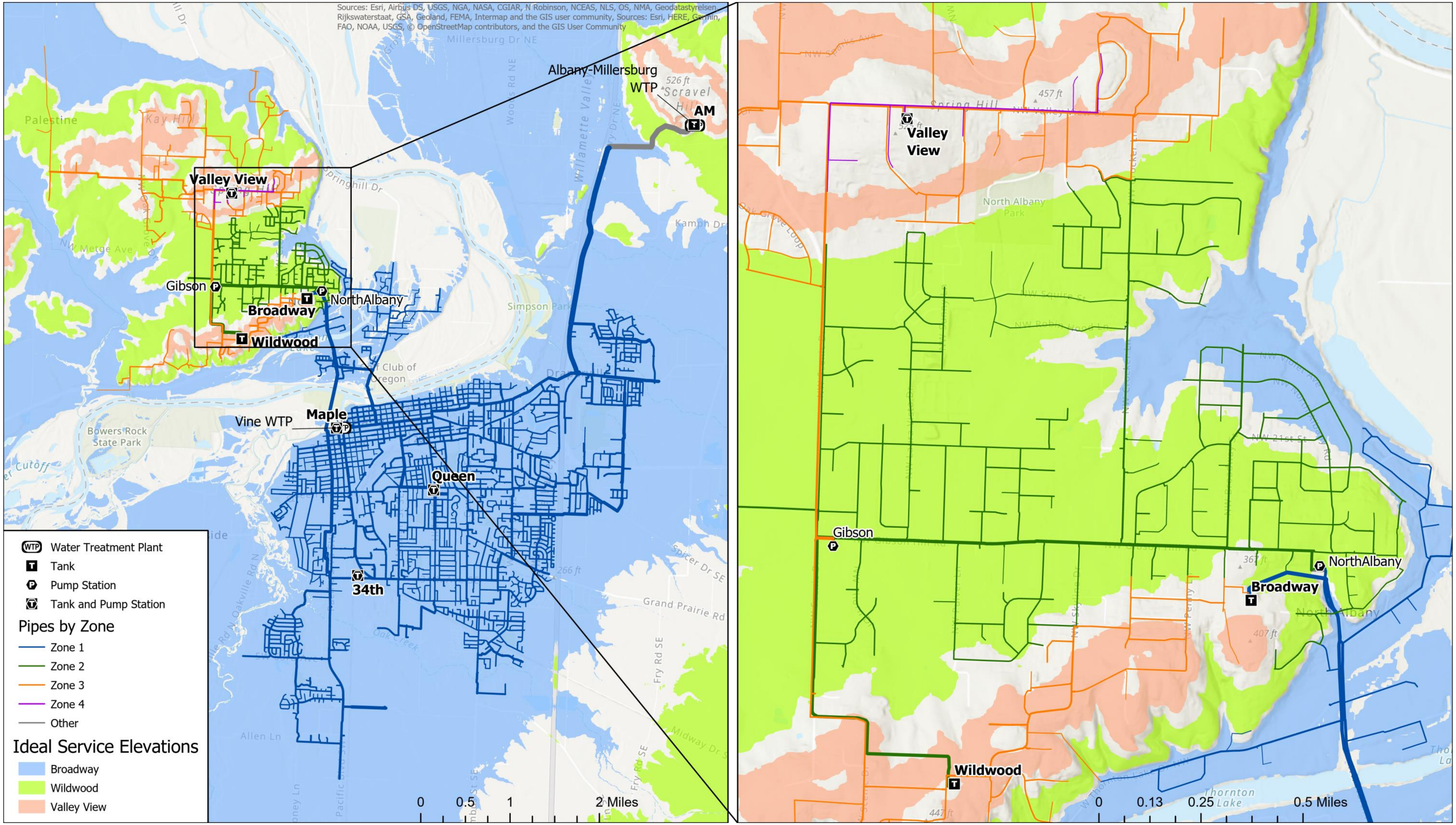


Figure 15. Ideal tank service areas

5.2 Equalization Storage

Equalization storage is used to supply daily peak demand so that the WTPs only needs to produce the average daily demand. Equalization storage can be calculated by comparing the average daily pumping or supply to the diurnal pattern (which shows the changing demands over a 24-hour period) as shown on Figure 16. Equalization is also frequently calculated as a fixed percentage of the daily demand. American Water Works Association (AWWA) states that for large systems, equalization storage is typically 15 to 20 percent of the daily demand but may exceed 30 percent for small areas (AWWA 2012). Currently, the City's equalization storage volume requirement is 25 percent of MDD. Table 7 shows possible seasonal equalization storage requirements calculated from the diurnal pattern or as 25 percent of the average demand.

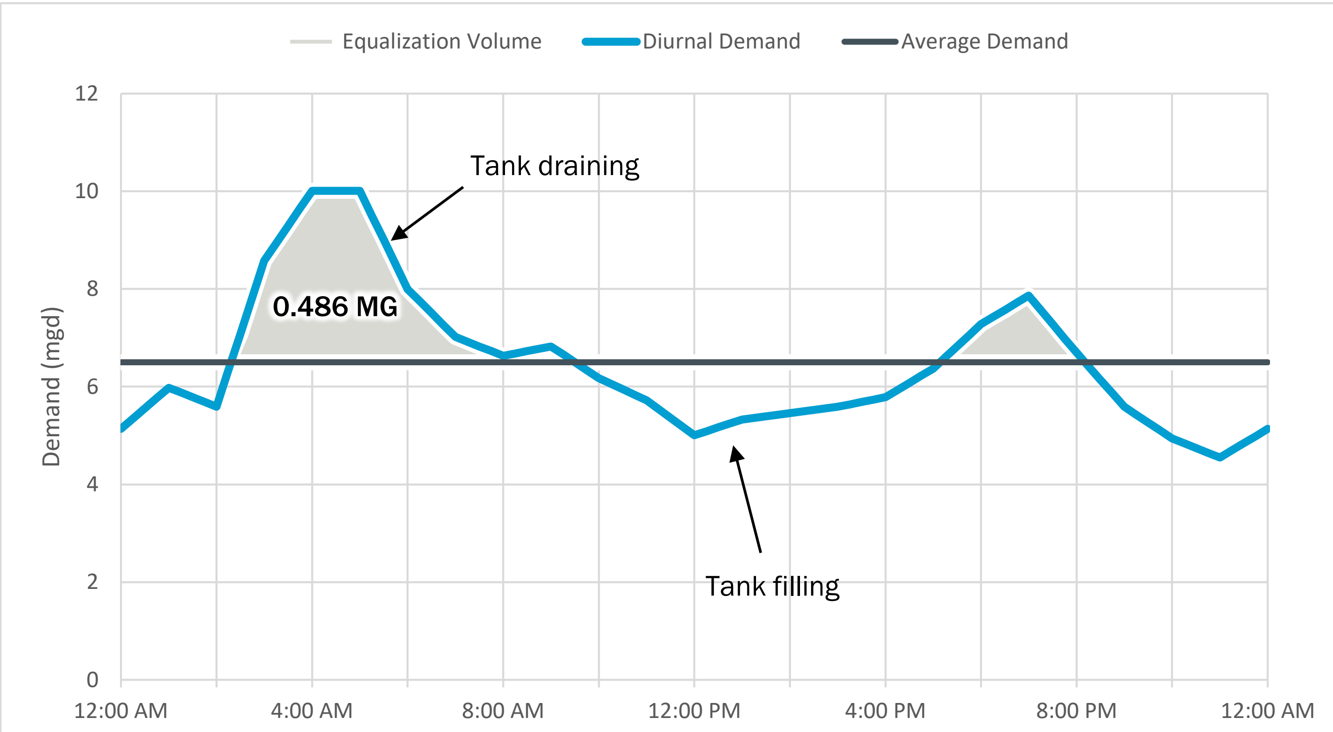


Figure 16. Storage from diurnal example (Zone 1 ADD)

Table 7. Possible Equalization Storage Requirements									
Zone	2018 Demand (mgd)			Equalization Storage (million gallons [MG])					
				Calculated from Diurnal Pattern			25% of Average Demand		
	Winter	ADD	MDD	Winter	ADD	MDD	Winter	ADD	MDD[1]
Zone 1	4.15	5.45	9.89	0.37	0.49	0.88	1.04	1.36	2.47
Zone 2	0.32	0.59	1.28	0.03	0.05	0.11	0.08	0.15	0.32
Zone 3 & 4	0.30	0.46	1.09	0.03	0.04	0.10	0.08	0.11	0.27
Total System	4.77	6.50	12.27	0.42	0.58	1.09	1.19	1.63	3.07

1. Current City requirements

5.3 Fire Storage

Fire storage volume is determined by multiplying the maximum fire flow demand in the zone by the duration of the fire. The City's fire flow demand requirements for each land use type are shown in Table 8. Fire storage typically does not change throughout the year.

<table>
<tr><th colspan="5">Table 8. Fire Flow Demand Criteria</th></tr>
<tr><th>Land Use Type</th><th>Fire Flow Demand (gpm)</th><th>Duration (hours)</th><th>Volume (gal)</th><th>Present in Zone(s)</th></tr>
<tr><td>Residential - Low Density</td><td>1,500</td><td rowspan="2">2</td><td>180,000</td><td>1, 2, 3, 4</td></tr>
<tr><td>Residential - Medium density</td><td>2,500</td><td>300,000</td><td>1, 2</td></tr>
<tr><td>Residential - High density</td><td rowspan="4">3,500</td><td rowspan="4">3</td><td rowspan="4">630,000</td><td>1</td></tr>
<tr><td>Commercial</td><td>1</td></tr>
<tr><td>Mixed use</td><td>1</td></tr>
<tr><td>Institutional (hospital/jail)</td><td>1</td></tr>
<tr><td>Industrial</td><td rowspan="2">5,000</td><td rowspan="2">4</td><td rowspan="2">1,200,000</td><td>1</td></tr>
<tr><td>Schools</td><td>1, 2</td></tr>
</table>

The 5,000-gpm fire flow demand for industrial and school land use results in a very large fire flow volume for Zones 1 and 2. The maximum fire flow that the Insurance Services Office uses to calculate a community's Public Protection Classification (PPC) is 3,500 gpm for 3 hours (AWWA 2008). This value is commonly used for calculating the required fire storage. A recent AWWA journal article also suggests that fire flow requirements have not kept up with improvements in fire protection for buildings, resulting in too much fire flow capacity and a negative impact on water quality (Gibson 2019). Table 9 lists the fire storage for each zone that BC recommends based on the land use and PPC requirements.

Table 9. Fire Storage Requirements

Zone	Maximum Fire Demand (gpm)	Duration (hours)	Fire Storage (MG)
Zone 1	3,500	3	0.63
Zone 2	3,500	3	0.63
Zone 3 & 4	1,500	2	0.18
Total System			1.44

5.4 Emergency Storage

Emergency storage is the component most dependent on the requirements and risk tolerance of the water provider. Emergency storage is usually specified as a number of days of average demand. To minimize the impact on water age, some water utilities a) reduce the emergency storage requirement if multiple redundant sources of supply are available; b) decide that it is overly conservative to assume that an emergency and fire will occur at the same time; or c) have seasonal storage requirements to reflect demands at different times of the year. Table 10 lists possible seasonal options for the City to consider for emergency storage.

Table 10. Possible Emergency Storage Requirements			
Zone	1 day of Average Demand		
	Winter	ADD [1]	MDD
Zone 1	4.15	5.45	9.89
Zone 2	0.32	0.59	1.28
Zone 3 & 4	0.30	0.46	1.09
Total System	4.77	6.50	12.27

1. Current City requirements

5.5 Total Storage Requirements

The total storage required is the sum of equalization, fire, and emergency storage. Table 11 shows the current City storage criteria, with two options for seasonal adjustments based on Sections 5.1 through 5.3:

- **Option 1:** Seasonal equalization storage calculated from diurnal pattern, fire storage from Table 9, and 1-day of seasonal emergency storage
- **Option 2:** Seasonal equalization storage calculated as 25 percent of the average demand, fire storage from Table 9, and 1-day of seasonal emergency storage

While emergency and fire storage in higher elevation zones can typically be considered available to lower zones, for the purpose of calculating required storage, it was assumed storage is not shared between zones. This is a more conservative assumption that results in a higher total required volume. In reality, if a fire or emergency depletes storage in one zone, system operators will activate pumps or valves to supply additional water from another zone.

Table 11. Total Storage Requirements Options							
Zone	Current City Criteria	Seasonal Option 1			Seasonal Option 2		
		Winter	ADD	MDD	Winter	ADD	MDD
Zone 1	9.12	5.15	6.57	11.40	5.81	7.44	12.99
Zone 2	1.54	0.97	1.27	2.03	1.02	1.37	2.23
Zone 3 & 4	0.91	0.51	0.68	1.37	0.56	0.75	1.55
Total System	11.58	6.63	8.52	14.80	7.40	9.57	16.77

The City currently has 21.1 MG of total storage, of which 3.85 MG is designated for the City of Millersburg and chlorine contact time, leaving 17.2 MG available to the water system. The available storage volumes are listed in Table 12, and shown on Figure 17 through Figure 19, as well as the typical minimum volume observed from 2019 SCADA records. Ideally, the minimum volume in storage on a typical day will never drop below the level equal to the fire + emergency storage volume, ensuring that there is always enough water in the tanks to fight a fire and/or supply the system during an emergency. Because the Queen and 34th pumps do not have permanent backup power, the volume in their respective tanks may not be immediately available in an emergency in which there is a power outage. The City does however have mobile generators dedicated for these pumps.

Table 12. Available Storage

Zone	Name	Volume (MG)			Observed[2] Water Levels (ft)	Observed Minimum Volume[3] (MG)
		Total	Unavailable Volume[1]	Remaining Available		
Zone 1	A-M WTP	5.7	3.35	2.35	29 - 37	0.78
	Maple	2.0	0.5	1.5	10.5 - 27	0.04
	Broadway	8.2	-	8.2	29.5 - 34	6.20
	Queen	0.9	-	0.9	23.5 - 30	0.70
	34th	2.0	-	2.0	23.5 - 30	1.47
Zone 2	Wildwood	1.2	-	1.2	13 – 17.3	0.75
Zone 3 & 4	Valley View	1.1	-	1.1	28 – 34.8	0.77
Total		21.1	3.85	17.2		10.71

1. Reserved for Millersburg and/or chlorine contact time.

2. Typical levels observed in 2019 SCADA records. There appears to be little seasonal variation in tank levels.

3. Does not include any unavailable volume.

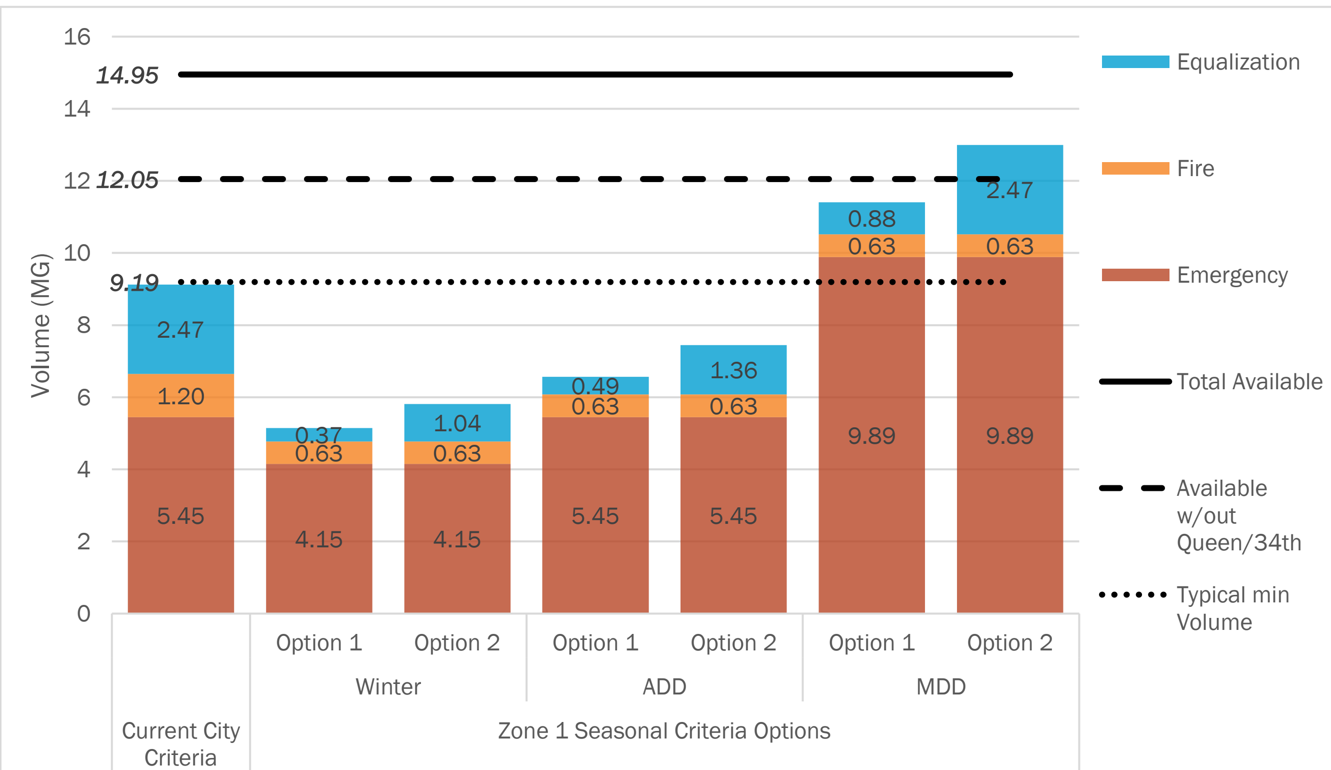


Figure 17. Zone 1 storage volumes

Figure 18. Zone 2 storage volumes

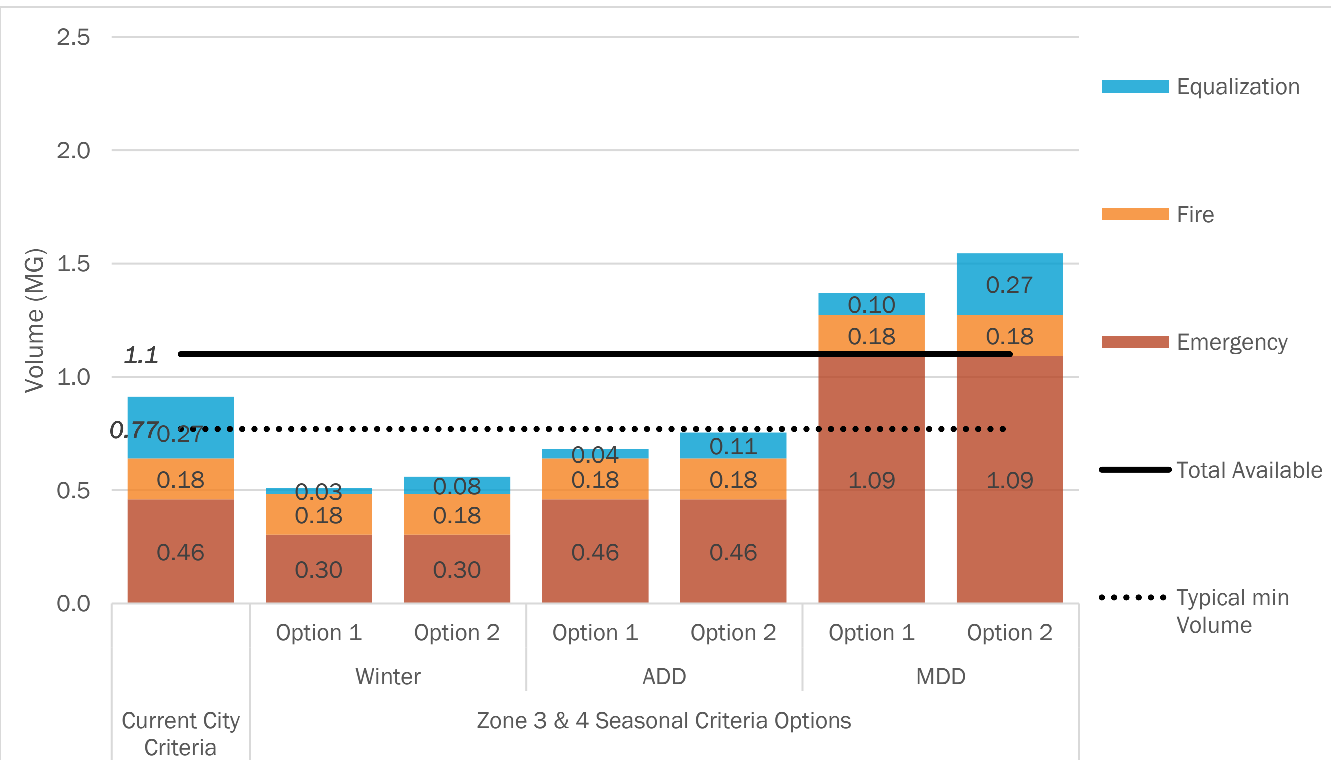


Figure 19. Zones 3 & 4 storage volumes

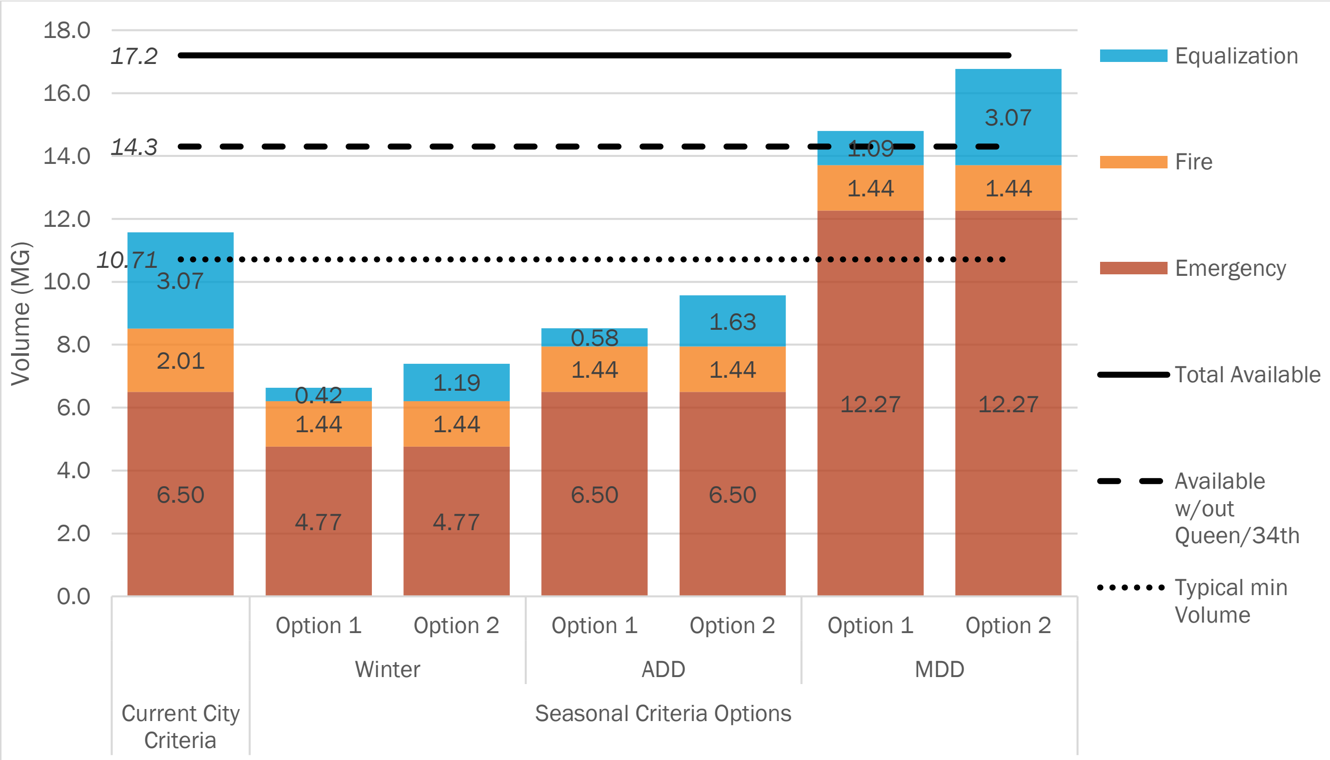


Figure 20. Total system storage volumes

The figures show that the City has excess storage, particularly in Zone 1. Even with the City's current criteria, the tanks in Zone 1 could be cycled to a lower level every day (approximately 6.7 MG instead of 9.2 MG). Reducing the volume in the winter, either by cycling tanks at a lower level or by taking Queen and 34th offline, will likely have a significant effect on the water age by reducing the hydraulic residence time.

Section 6: Operational Alternatives

Fourteen operational alternatives were identified for evaluation and comparison with the baseline water age results. Each alternative included only one change at a time so the impact of the change could be clearly identified and compared to the baseline results. Table 13 lists the alternatives and provides a brief description of the change in each. Each alternative was evaluated for water age in the model for a 60-day winter demand simulation.

Table 13. Optimization Alternatives

Alternative		Description
No.	Name	
1	No flushing	Existing operations, no flushing demands. Used to determine impact of flushing.
2	Seasonal Vine	Vine WTP off during the winter. No other changes.
3	Peak hour Vine	Change the high-service pump schedule to supply water during peak hour demand. No other changes.
4	Night Vine	Operate Vine WTP and high-service pumps only at night, between 10 pm and 4 am (winter).
5	Continuous Vine	Operate Vine WTP at a lower flow rate but produce water continuously (approximately 2 mgd in the winter). High-service pumps operate continuously.
6a	Direct to Broadway	Close valves and install up to 1,100 ft of pipe to force all Vine WTP flow to go to directly into Broadway before entering the system. No other changes. See Figure 21.
6b	Direct to Broadway - valves only	Close valves to force Vine WTP flow to go toward Broadway before entering the system. No other changes. See Figure 21.
7	Queen off	Queen tank and PS offline. No other changes
8	34th off	34th tank and PS offline. No other changes
9	Queen and 34th off	Both Queen and 34th tanks and PSs offline. These tanks are strong candidates for removal due to the age of the facilities and the wasted energy filling and repumping.
10a	Lower tank cycling	Cycle the Broadway, Queen, and 34th tanks the same volume but at a lower elevation range. The minimum level in each tank was based on the calculated fire and emergency volume from Section 5.4, approximately 8.5 MG for the whole system. The old and new ranges for each tank are listed below: Tank — Old Range (ft) — New Range (ft) Broadway — 26 to 34 — 17 to 24 Queen — 24 to 30 — 5 to 10 34th — 24 to 30 — 5 to 10
10b	Deeper tank cycling	Cycle existing tanks deeper, e.g., from 4 to 30 feet instead of 24 to 30 feet. The minimum level was based on the calculated fire and emergency volume from Section 5.4, approximately 7.5 MG for the whole system. The old and new ranges for each tank are listed below: Tank — Old Range (ft) — New Range (ft) AM Plant — 27 to 35 — 27 to 38 Broadway — 26 to 34 — 18 to 34 Queen — 24 to 30 — 5 to 27 34th — 24 to 30 — 5 to 21
11	Remove Wildwood	Abandon the Wildwood tank and use PRVs to serve Zone 2 from Zone 3. Would also require synchronizing the operation of the North Albany and Gibson Hill PSs and constructing a new tank at the Valley View site to replace the Wildwood volume.
12	Pump synchronization	Operate the Vine High Service PS and the North Albany PS whenever the Gibson Hill PS is running to try and force more fresh water directly to Zones 3 & 4.

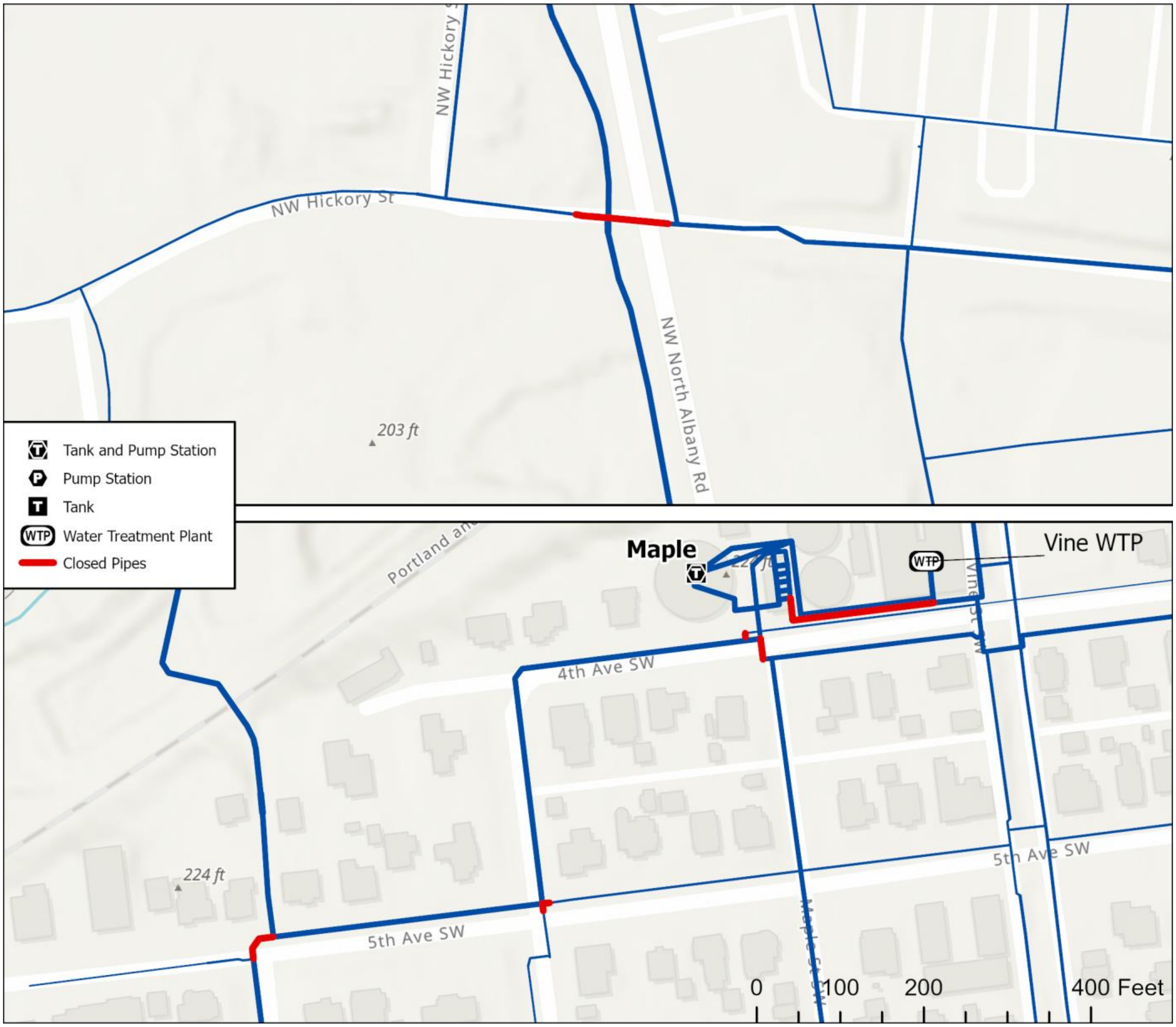


Figure 21. Closed pipes for Alternatives 6a and 6b

6.1 Alternative Results Summary

Table 14 shows the water age results for each flushing station and tank, compared to the baseline water age results. Green indicates a reduction in water age, with darker green indicating more reduction. Red indicates an increase in water age.

Table 14. Alternative Water Age Results Summary

Location			Change in Average Water Age for Each Alternative Compared to Baseline (days)													
			1	2	3	4	5	6a	6b	7	8	9	10a	10b	11	12
Flushing Stations	Zone 1	17th	1.0	-0.5	0.4	0.1	1.1	-0.1	-0.1	0.0	0.0	0.0	0.0	1.7	0.0	0.0
		53rd	9.1	-0.3	0.6	-0.2	-0.4	-0.2	-0.1	-0.7	-1.1	-1.6	-1.4	3.2	-0.1	-0.1

Table 14. Alternative Water Age Results Summary

Location			Change in Average Water Age for Each Alternative Compared to Baseline (days)													
			1	2	3	4	5	6a	6b	7	8	9	10a	10b	11	12
		Campbell	1.3	1.2	0.8	-0.3	0.5	-0.4	-0.2	-0.6	-2.0	-2.5	-1.8	2.0	-0.2	-0.3
		Maple Leaf	1.6	-0.3	0.1	0.1	0.6	-0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
	Zone 2	Bloom	1.7	2.5	-0.4	0.7	3.2	-2.5	-0.8	0.3	-0.4	-0.5	-2.8	2.3	19.6	14.3
	Zone 3	Oak Grove	6.9	1.1	-1.6	-0.1	1.5	-2.2	-1.3	-0.7	-1.3	-1.7	-6.5	-0.1	0.4	26.0
	Zone 3	Palestine	6.5	1.2	-1.6	0.0	1.6	-2.1	-1.2	-0.7	-1.3	-1.7	-6.9	0.1	-3.6	25.2
	Zone 3	Summerhill	6.6	1.0	-1.7	-0.2	1.4	-2.3	-1.4	-0.9	-1.5	-1.9	-6.3	2.1	0.9	24.7
	Zone 3	Winn	8.0	1.4	-1.3	0.5	1.8	-1.9	-1.0	-0.5	-1.1	-1.4	-5.5	2.9	3.4	25.2
Tanks	Zone 1	34th	0.4	-1.4	0.5	-1.1	1.5	-0.4	0.0	-0.9	NA	NA	-7.4	-3.0	-0.1	-0.3
Tanks	Zone 1	A-M WTP	0.0	-0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tanks	Zone 1	Broadway	1.8	1.9	-1.3	-0.3	2.7	-1.4	-1.6	-0.2	-0.8	-1.0	-3.6	0.9	0.2	0.0
Tanks	Zone 1	Maple	0.0	NA	-0.1	-0.3	0.4	0.0	0.0	0.0	0.0	0.0	-0.4	-0.3	0.0	0.0
Tanks	Zone 1	Queen	0.6	-0.7	0.9	-0.5	1.6	-1.1	-0.8	NA	-0.1	NA	-7.2	-8.8	-0.5	-0.2
Tanks	Zone 2	Valley View	6.2	1.0	-1.7	-0.2	1.3	-2.3	-1.4	-0.8	-1.4	-1.9	-6.0	1.9	2.6	25.0
Tanks	Zone 3	Wildwood	9.4	0.5	-2.8	-1.1	1.0	-2.8	-2.0	-1.8	-2.3	-2.7	-9.8	-7.0	NA	27.4

It appears possible to achieve a several-day reduction in water age throughout the system with operational changes, primarily lower tank cycling, which decreases the hydraulic residence time associated with the tanks. Lower water levels in Queen, and 34th will also reduce energy consumption by decreasing the amount of repumping occurring at these locations. Combining Alternatives 6 (a or b) with 10a will likely result in further water age reductions. As the North Albany area experiences growth, demands will increase, and water age will likely decrease. Flushing simulates this effect by artificially increasing the demand.

Changing the hours that the Vine WTP operates (Alternatives 2-5) had less of a beneficial effect on water age than the other alternatives that were evaluated. Alternatives 2 and 5 resulted in increased water age at most locations. Alternatives 3 and 4 resulted in decreased water age in North Albany, but increased age in Zone 1. Daily tank turnover, regardless of when in 24 hours it occurs, appears to be more effective than changes to WTP operations.

Nighttime Vine WTP operations (Alternative 4) was of particular interest to the City as previous reports had suggested that night operations might be beneficial. However, the results for this mode of operation are mixed. Water age will decrease in some locations and increase in others.

In Brown and Caldwell's experience with water providers throughout the country, there is no single best practice for supply operations. Some systems operate WTPs continuously, while others operate only as needed to refill system storage.

Section 7: Combined Alternatives

Four combinations of alternatives from Section 6 were modeled to determine if better water age could be achieved by combining the most promising alternatives. The operational changes for each option are listed in Table 15. All other facilities not listed operate as they currently do.

Table 15. Combined Alternative Options-System Changes

Location	Option A		Option B		Option C		Option D	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Vine WTP	No change from existing operations				Same total duration, but shift hours to supply water during peak hour demand		Same total duration, but shift hours to supply water only at night	
Broadway	Allow level to fluctuate between approximately 17 and 24 ft							
Queen	Allow level to fluctuate between approximately 5 and 10 ft							
34th	Allow level to fluctuate between approximately 5 and 10 ft							
Flushing Stations	Current flushing rates/duration		No flushing		Current flushing rates/duration			
Other	Close valves to send Vine WTP flow directly to Broadway							
Summary	Alt 6b + Alt 10a		Alt 1 + Alt 6b +Alt 10a		Alt 3 + Alt 6b + Alt 10a		Alt 4 + Alt 6b +Alt 10a	

Table 16 shows the change in the average water age (compared to the baseline scenario) at the flushing stations and tanks. Reductions in water age for Options A, C, and D are similar. The increase in water age for Option B suggests that flushing during the winter is necessary, even with changes to tank operating levels. Flushing could likely be eliminated in the summer, except at the 17th, Maple Leaf, and Winn stations.

Table 16. Results Summary Compared to Baseline

Location			Change in Average Water Age (days), Compared to Baseline							
			Winter				Summer			
			Option A	Option B	Option C	Option D	Option A	Option B	Option C	Option D
Flushing Stations	Zone 1	17th	-0.1	0.9	-0.1	-0.2	0.0	0.2	0.1	0.0
		53rd	-1.2	7.4	-1.1	-1.5	-2.0	-1.5	-1.7	-2.0
		Campbell	-1.7	-0.3	-1.5	-1.9	-2.3	-2.8	-2.0	-2.3
		Maple Leaf	0.0	1.6	0.0	-0.1	0.0	1.3	0.1	0.0
	Zone 2	Bloom	-4.1	-3.9	-5.9	-2.1	-2.2	-2.0	-2.5	-1.4
	Zone 3	Oak Grove	-7.6	0.4	-8.8	-5.7	-2.8	-2.2	-2.6	-2.6
		Palestine	-8.1	-0.2	-9.2	-6.2	-2.1	-1.7	-2.1	-1.7
		Summerhill	-7.6	0.3	-8.3	-5.3	-2.3	-1.8	-2.3	-1.9
		Winn	-7.2	1.7	-7.4	-4.5	-1.2	0.8	-0.9	-0.7
Tanks	Zone 1	34th	-7.3	-7.3	-7.4	-7.4	-6.9	-6.8	-6.4	-6.7
		AM Plant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Broadway	-5.0	-4.7	-4.9	-1.2	-2.0	-1.8	-1.3	-1.1
		Maple	-0.3	-0.3	-0.4	-0.1	0.0	0.0	0.0	-0.1
		Queen	-7.4	-7.9	-8.0	-7.4	-8.6	-8.5	-8.0	-8.1

Table 16. Results Summary Compared to Baseline

Location		Change in Average Water Age (days), Compared to Baseline							
		Winter				Summer			
		Option A	Option B	Option C	Option D	Option A	Option B	Option C	Option D
Zone 2	Valley View	-7.4	0.1	-8.2	-5.1	-2.9	-2.3	-2.9	-2.3
Zone 3	Wildwood	-10.9	0.3	-11.5	-8.5	-1.4	-1.3	-1.0	-1.4

Water age, available fire flow, and minimum pressure resulting from the final options are shown on Figure 22 through Figure 26. The fire flow and minimum pressure results are identical for Final Options A, B, and C. Based on these results, it may be possible to reduce or discontinue flushing at several locations without adversely affecting the water quality (compared to the baseline scenario). The most significant reductions in water age occur in the winter scenario. For all options, there is minimal impact on system pressures. In Zone 1, which is the only zone affected, there are no customers that see pressures less than the 40-psi limit. The lowest pressure in Zone 1 is 44 psi, and only 4 junctions are below 50 psi.

There is some impact on available fire flow. As shown in Figure 25 and Table 17, thirteen additional locations (shown in red) will no longer be able to supply the required fire flow due to the reduction of pressure associated with operating Broadway at a lower level.

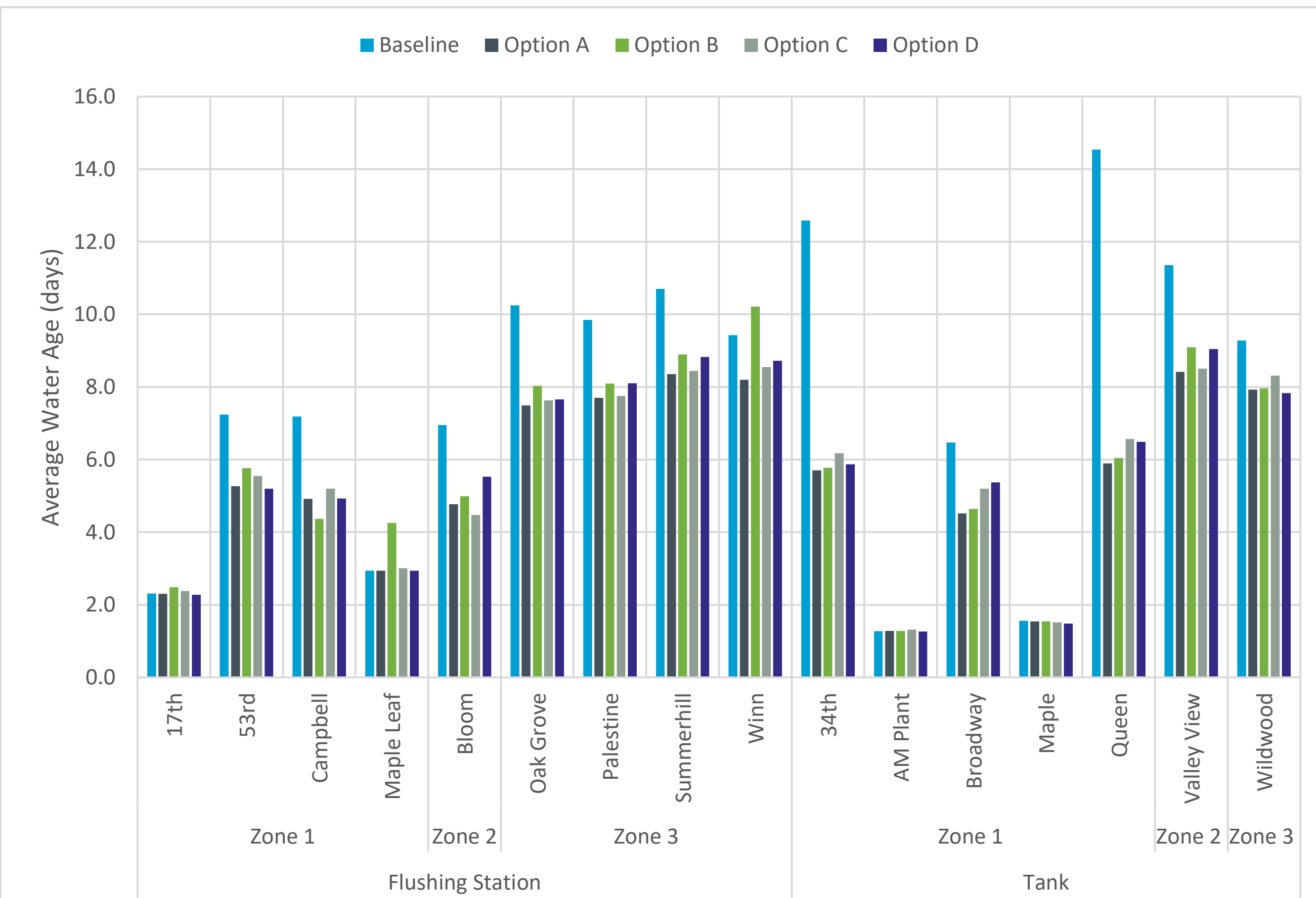


Figure 22. Summer water age at tanks and flushing stations

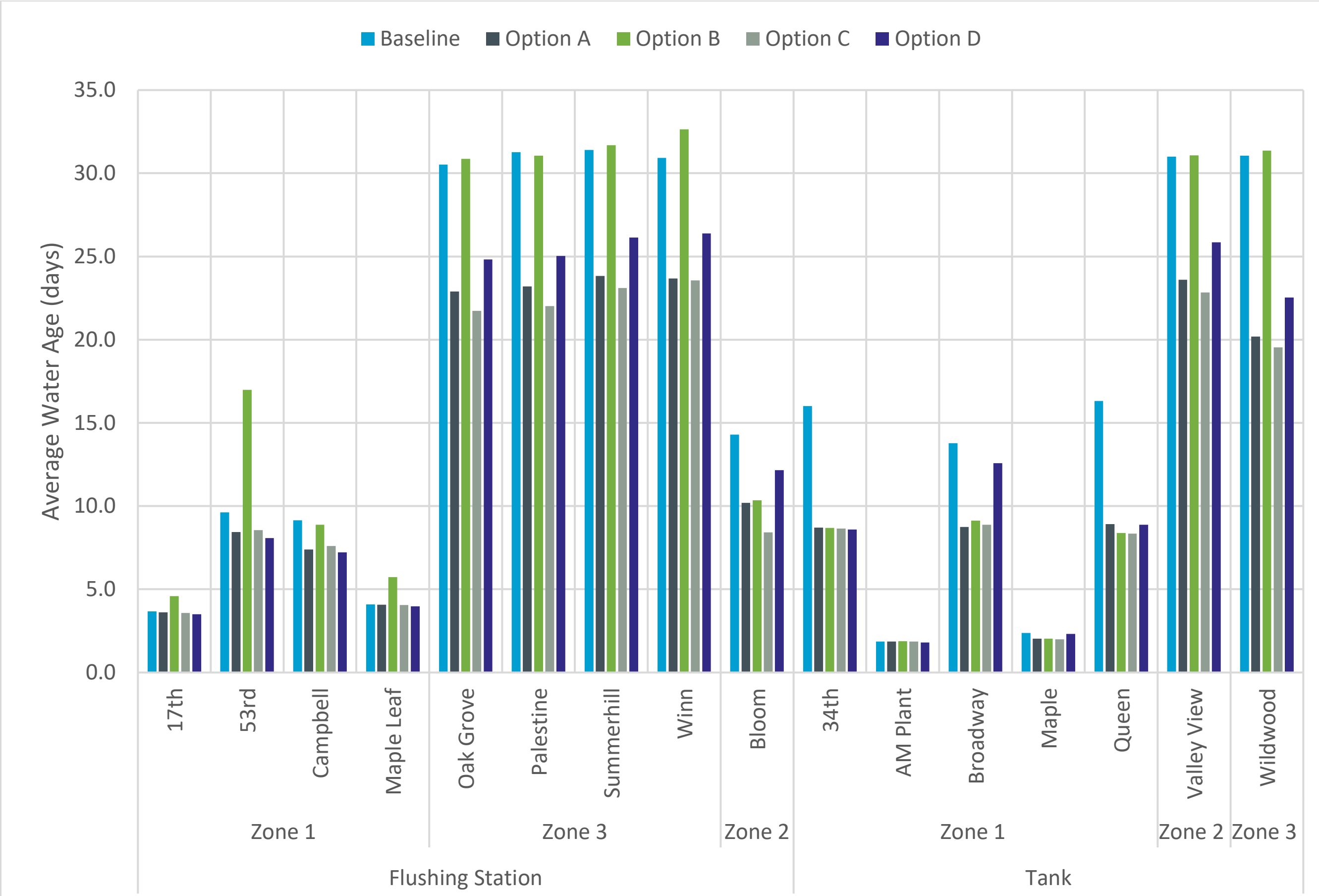


Figure 23. Winter water age at tanks and flushing stations

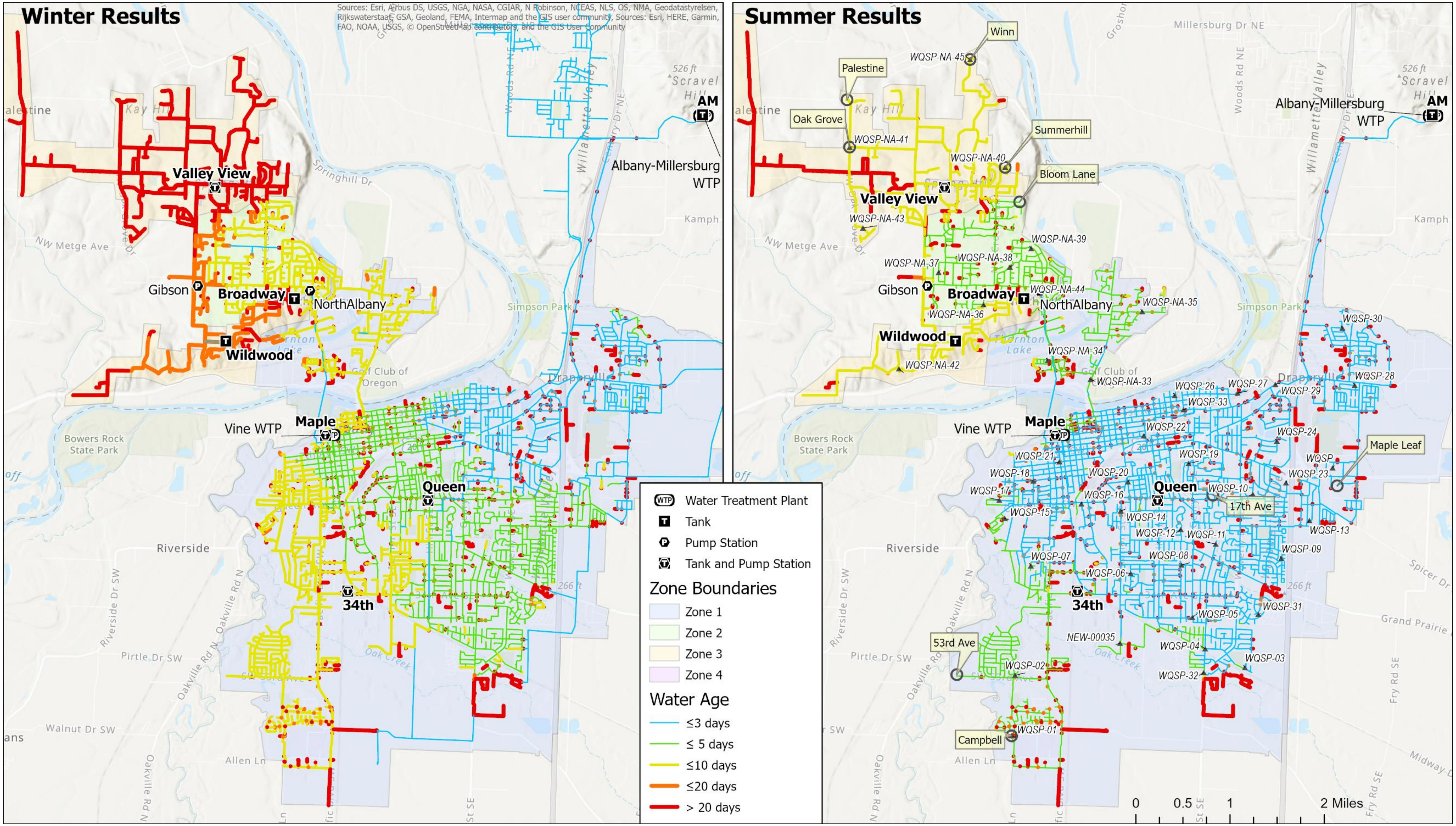
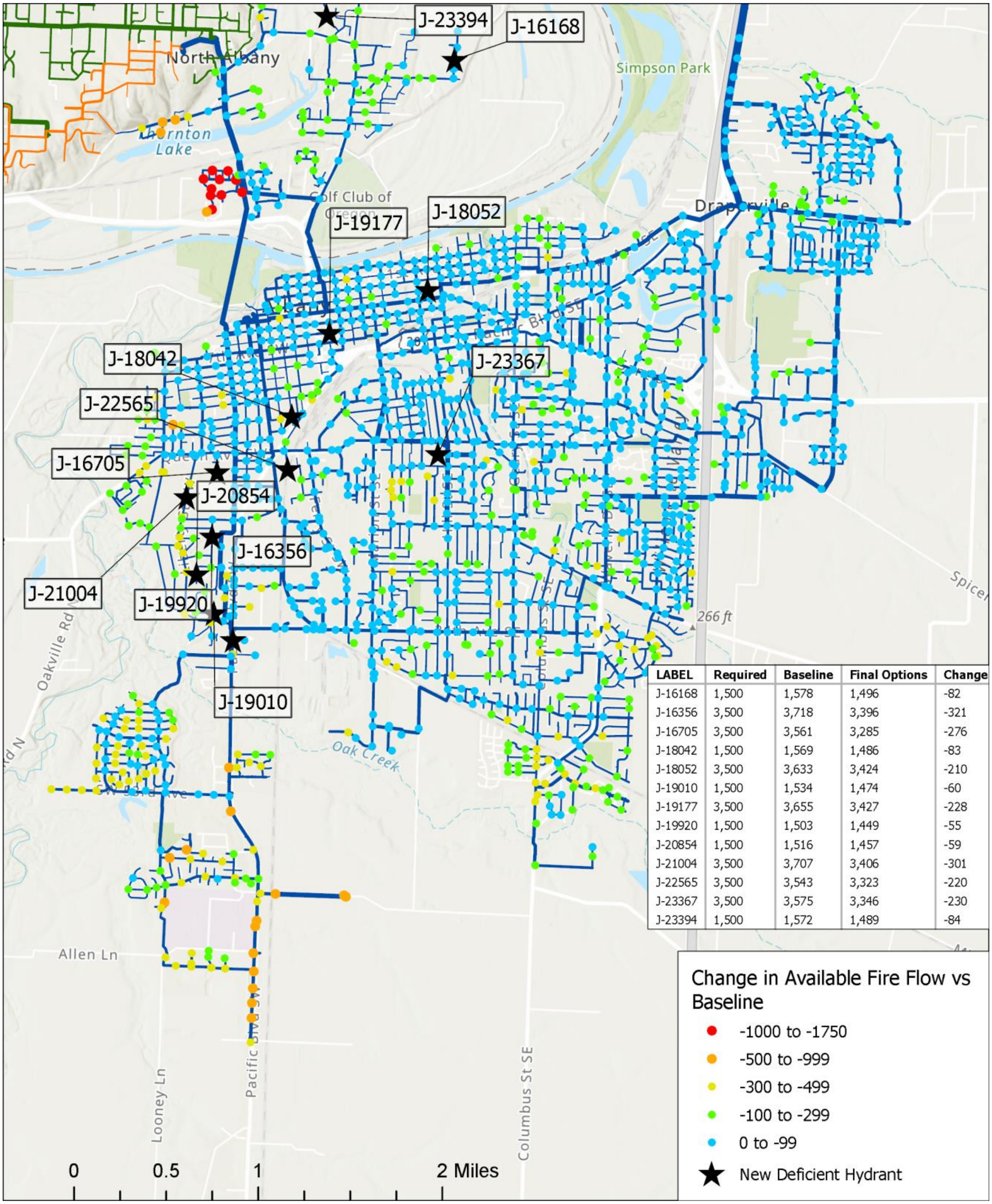


Figure 24. Option A water age results



LABEL	Required	Baseline	Final Options	Change
J-16168	1,500	1,578	1,496	-82
J-16356	3,500	3,718	3,396	-321
J-16705	3,500	3,561	3,285	-276
J-18042	1,500	1,569	1,486	-83
J-18052	3,500	3,633	3,424	-210
J-19010	1,500	1,534	1,474	-60
J-19177	3,500	3,655	3,427	-228
J-19920	1,500	1,503	1,449	-55
J-20854	1,500	1,516	1,457	-59
J-21004	3,500	3,707	3,406	-301
J-22565	3,500	3,543	3,323	-220
J-23367	3,500	3,575	3,346	-230
J-23394	1,500	1,572	1,489	-84

Figure 25. Change in available fire flow map

Broadway water level: Baseline = 34 ft, Option A/B/C/D = 17 ft

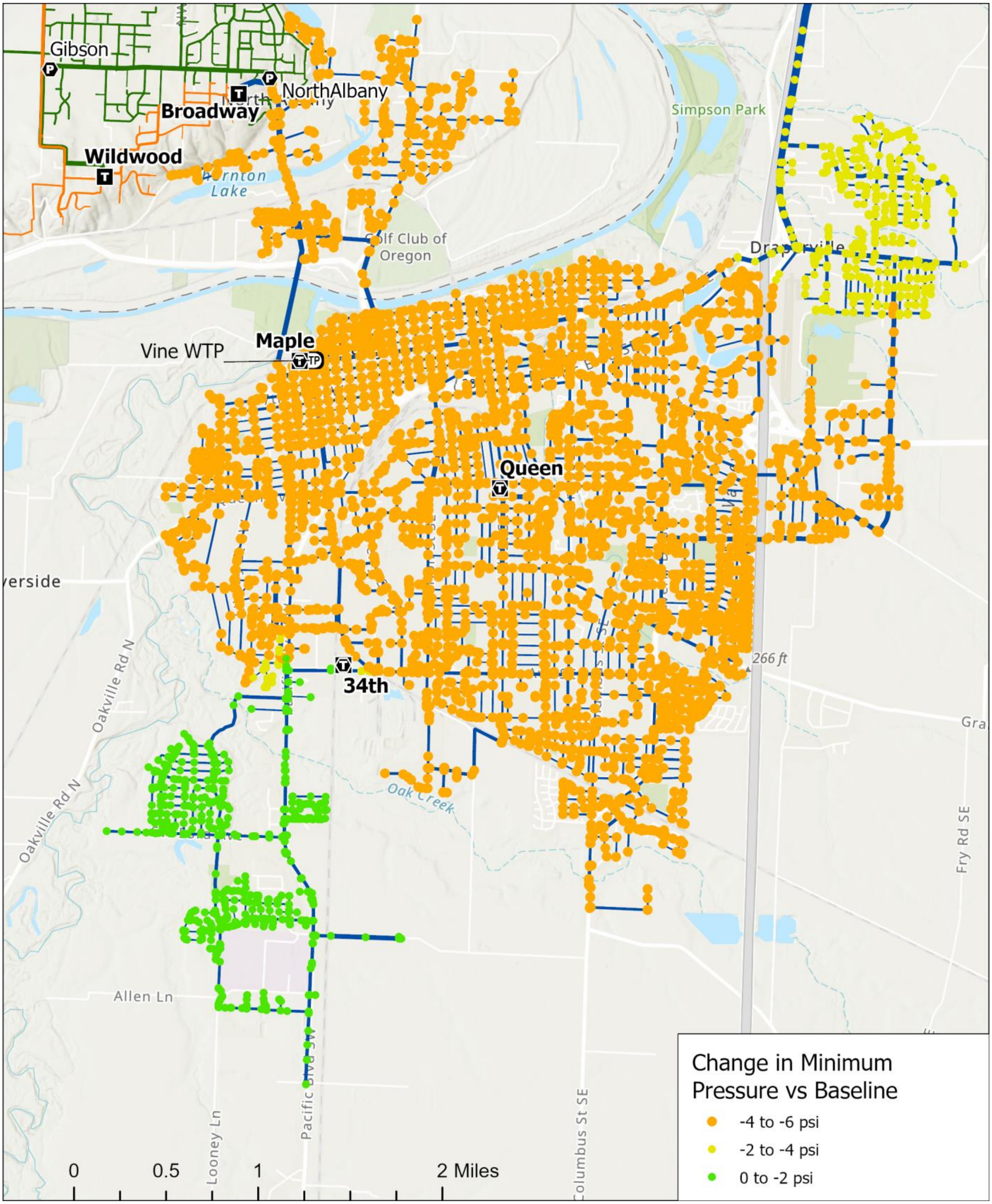


Figure 26. Change in minimum pressure map

Table 17 shows the model junctions that are not able to meet the fire flow requirements for the Baseline scenario and the Final Option scenarios. Forty-four locations did not meet the fire flow requirements for the Baseline scenario. Thirteen additional locations became deficient with the Final Option scenarios, primarily due to the lower Broadway level.

Table 17. Zone 1 Fire Flow Deficiencies

Model Junction	Required Fire Flow (gpm)	Available Fire Flow (gpm)			Model Junction	Required Fire Flow (gpm)	Available Fire Flow (gpm)	
		Baseline	Option A/B/C/D				Option A/B/C/D	Baseline
J-21588	1,500	1,489	1,414		J-21770	3,500	2,955	2,822
J-12241	1,500	1,403	1,329		J-22190	3,500	2,951	2,793
J-13631	1,500	1,396	1,325		J-22347	3,500	2,876	2,670
J-20398	1,500	1,215	1,140		J-22440	3,500	3,345	3,148
J-21630	1,500	823	779		J-22884	3,500	2,525	2,374
J-22313	1,500	393	373		J-22990	3,500	1,139	1,090
J-23645	1,500	1,176	1,121		J-23031	3,500	2,165	2,058
J-12272	3,500	3,452	3,291		J-23111	3,500	1,140	1,091
J-15830	3,500	3,470	3,246		J-23233	3,500	3,183	3,009
J-12441	3,500	1,629	1,555		J-23322	3,500	3,342	3,164
J-12698	3,500	3,342	3,155		J-23419	3,500	2,531	2,381
J-12817	3,500	3,134	2,936		J-23464	3,500	2,023	1,938
J-13228	3,500	1,564	1,492		J-23466	3,500	1,855	1,793
J-14429	3,500	436	417		J-23656	3,500	530	525
J-15269	3,500	3,344	3,166		J-23669	3,500	2,916	2,784
J-16035	3,500	1,378	1,315		J-16168	1,500	1,496	1,578
J-17043	3,500	3,296	3,099		J-16356	3,500	3,396	3,718
J-17580	3,500	1,689	1,621		J-16705	3,500	3,285	3,561
J-18252	3,500	1,727	1,648		J-18042	1,500	1,486	1,569
J-18380	3,500	3,401	3,262		J-18052	3,500	3,424	3,633
J-18915	3,500	2,127	2,023		J-19010	1,500	1,474	1,534
J-19028	3,500	2,581	2,446		J-19177	3,500	3,427	3,655
J-19319	3,500	1,079	1,031		J-19920	1,500	1,449	1,503
J-19807	3,500	2,551	2,376		J-20854	1,500	1,457	1,516
J-20338	3,500	3,497	3,254		J-21004	3,500	3,406	3,707
J-20631	3,500	3,000	2,771		J-22565	3,500	3,323	3,543
J-20927	3,500	2,034	1,947		J-23367	3,500	3,346	3,575
J-21455	3,500	3,036	2,857		J-23394	1,500	1,489	1,572
J-21600	3,500	1,881	1,784					

Note: Red text = hydrants that are now deficient with the changes for Option A/B/C/D compared to the Baseline

Note: Broadway water level: Baseline = 34 ft, Option A/B/C = 17 ft

Section 8: Conclusions

The evaluation results in several conclusions and feasible operational improvements:

1. Water age and water quality appear to be strongly influenced by the total system demand. Water age in the summer when demand is high is significantly lower than in the winter when demand is low.
2. Changing the hours that the Vine WTP operates (Alternatives 2-5) had less of a beneficial effect on water age than the other alternatives that were evaluated. In the best-case, changing Vine WTP operations to supply water during peak hour demands (Alternative 3), would result in decreased water age in North Albany, but increased age in Zone 1. This is illustrated in Table 14. Daily turnover, regardless of when in 24 hours it occurs, appears to be more effective than changes to WTP operations. Nighttime Vine WTP operations (Alternative 4) was of particularly interest to the City. However, the results for this mode of operation are mixed. Water age will decrease in some locations and increase in others. No change to plant Vine WTP operational hours is recommended based on the alternatives evaluated in this report.
3. Based on the current City storage criteria, several tanks could be operated at lower levels, particularly Broadway, Queen, and 34th. Water age in North Albany and the southwest corner of the City would be significantly reduced as a result of these changes. These changes could be easily implemented seasonally and could be simply changed back as needed (e.g. if/when demands increase). Another benefit of these changes will likely be reduced energy consumption due to less repumping at Queen and 34th.
4. Another simple, easily reversible, option that significantly reduces water age in North Albany is to close a selection of valves near the Vine WTP and in North Albany. This measure helps to direct water more efficiently from the Vine WTP to the Broadway tank. This, again, is a step that could be easily implemented and reversed if needed.
5. Option A, (a combination of items 3 and 4 from above) would result in a significant reduction in water age in North Albany, particularly in the winter. In the summer, these changes could potentially be enough to reduce or eliminate the need for flushing at most locations (see Option B).
6. Another option for the City to consider for further improving water quality in North Albany is to install a chlorine booster and reduce chlorine dosing at the WTPs. This may be a relatively simple solution for reducing DBP formation potential and improving chlorine residual. Further water quality study and testing is recommended to evaluate the feasibility of this option.

References

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