6.5.5 Inter-zone Pumping Capacity Analysis

Section 6.1 examined the supply capacity of each region of the water system. This section summarized the pumping capacity needs of each as they relate to both supply and inter-zone pumping. While Section 6.1 determines the adequacy of supply at a regional level, this section aims to assure each pressure zone can move water internally to satisfy the system demand from either an internal supply source or through transfer of water from a neighboring zone. An individual pressure zone analysis for pumping capacity is included in Appendix 6C of this chapter. The table below summarizes the assumed firm pumping capacities for each pressure zone including unit wells and booster pumping station units which deliver water to water demand within each pressure zone.

Table 6-12 – Summary of Pressure Zone Firm Pumping Capacity

Zone		Facility	Source	Capacity (gpm)	Capacity (mgd)
East Side	**3**	115 - 1	Zone 6e	2,100	3.0
		115 - 2	Zone 6e	2,100	3.0
		129 - 1	Zone 6e	400	0.6
		129 - 2	Zone 6e	400	0.6
		129 - 3	Zone 6e	1,200	1.7
		129 - 4	Zone 6e	1,200	1.7
		215 - 1	Zone 6e	900	1.3
		215 - 1	Zone 6e	970	1.4
		~~UW 25~~	~~UW 25~~	~~2,100~~	~~3.0~~
				Zone 3 Firm Capacity	**13.3**
	4	UW 9	UW9	1,700	2.4
		~~UW 31~~	~~UW 31~~	~~2,100~~	~~3.0~~
				Zone 4 Firm Capacity	**2.4**
	5	213 - 1	6e	300	0.4
		~~213 - 2~~	~~6e~~	~~500~~	~~0.7~~
				Zone 5 Firm Capacity	**0.4**
	6e	UW 7	UW 7	2,100	3.0
		UW 8	UW 8	1,650	2.4
		UW 11	UW 11	2,100	3.0
		~~UW 13~~	~~UW 13~~	~~2,100~~	~~3.0~~
		~~UW 15~~	~~UW 15~~	~~2,100~~	~~3.0~~
		UW 29	UW 29	1,100	1.6
				Zone 6e Firm Capacity	**10.0**
West Side	**6w**	~~UW 6~~	~~UW 6~~	~~2,100~~	~~3.0~~
		~~UW 14~~	~~UW 14~~	~~2,100~~	~~3.0~~
		UW 17	UW 17	2,100	3.0
		UW 18	UW 18	2,200	3.2
		UW 19	UW 19	2,100	3.0
		UW 24	UW 24	2,100	3.0
		UW 27	UW 27	2,100	3.0
		UW 30	UW 30	2,100	3.0
				Zone 6w Firm Capacity	**18.2**
	7	106 - 1	Zone 6w	2,100	3.0

Zone		Facility	Source	Capacity (gpm)	Capacity (mgd)
		106 - 2	Zone 6w	2,100	3.0
		118 - 1	Zone 6w	1,000	1.4
		118 - 2	Zone 6w	1,000	1.4
		118 - 3	Zone 6w	1,000	1.4
		~~UW 12~~	~~UW 12~~	~~2,100~~	~~3.0~~
		UW 20	UW 20	2,000	2.9
				Zone 7 Firm Capacity	**13.1**
	8	UW 16	UW 16	2,100	3.0
		~~UW 26~~	~~UW 26~~	~~2,200~~	~~3.2~~
		UW 28	UW 28	2,100	3.0
				Zone 8 Firm Capacity	**6.0**
	9	120 - 1	Zone 8	2,100	3.0
		~~120 - 2~~	Zone 8	~~2,100~~	~~3.0~~
				Zone 9 Firm Capacity	**3.0**
	10	126 - 1	Zone 8	2,100	3.0
		~~126 - 2~~	Zone 8	~~2,100~~	~~3.0~~
		128 - 1	Zone 8	Removed from Service	
		128 - 2	Zone 8		
		128 - 3	Zone 8	1,000	1.4
		*128 - 4	Zone 8	1,000	1.4
				Zone 10 Firm Capacity	**4.5**

The analysis included in this section compared the firm supply and inter-zone pumping capacity of each pressure zone with the projected pressure zone demands developed in Chapter 3. Results of this analysis are summarized below. The table below summarizes the mass balance supply & inter-zone pumping capacity analysis described in this section. Some zones are reliant on pumping station capacity to supplement well supply. It should be noted that the results presented below are for each pressure zone independent from other pressure zones and should not be added.

The values in the Table 6-13 below combine both pumping capacity and supply to each pressure zone and does not account for pressure zone dependencies. A negative value means a deficiency in firm capacity, while a positive number means a surplus in pumping capacity. In this case, a surplus of pumping capacity does not mean a surplus of water supply, as is the case in the supply analysis section.

Each pressure zone must be able to deliver water to itself equal to its own projected maximum day demand. A surplus firm inter-zone pumping capacity is interpreted as the pressure zone has a sufficient number of pumping units. A deficient firm inter-zone pumping capacity is interpreted that more pumping units, not necessarily new unit wells, are required.

The computer model analysis will determine the effectiveness of the existing pumping facilities and whether locations and capacities of existing pumps are adequate, based on hydraulic limitations.

Table 6-13 – Summary of Firm Pumping Capacity Mass Balance by Pressure Zone

Pressure Zone	Firm Capacity (mgd)	Design Year 2020		Design Year 2040	
		Demand (mgd)	Mass Balance (mgd)	Demand (mgd)	Mass Balance (mgd)
3	**13.3**	4.2	9.1	6.2	7.1
4	**2.4**	2.7	**-0.3**	3.4	**-1.0**
5	**0.4**	0.9	**-0.4**	0.9	**-0.4**
6e	**10.0**	11.4	**-1.4**	11.7	**-1.7**
6w	**18.2**	16.9	1.3	18.4	**-0.2**
7	**13.1**	5.2	7.9	5.1	8.0
8	**6.0**	8.1	**-2.1**	9.3	**-3.3**
9	**3.0**	1.4	1.6	1.3	1.7
10	**5.8**	2.7	3.1	4.1	1.7

-1.0 Indicates a supply and/or inter-zone transfer deficiency.

1.0 Indicates adequate supply and/or inter-zone transfer pumping capacity.

Table 6-14 – Inter-Zone Pumping Capacity Deficiencies

Deficiency ID	Pressure Zone	2020 Supply Deficiency (mgd)	2040 Supply Deficiency (mgd)
T.01	Zone 4	-0.3	-1.0
T.02	Zone 5	-0.4	-0.4
T.03	Zone 6e	-1.4	-1.7
T.04	Zone 6w	-	-0.2
T.05	Zone 8	-2.1	-3.3

6.5.6 Storage Capacity Analysis

This sections examines the storage capacity of each pressure zone. While the previous section examined the supply capacity of the pressure zones in groups called hydraulic regions, this section presents the results of an independent examination of each pressure zone for storage. Water storage tanks play an important role in the operation of a water system by sustaining system pressure and supplying water when needed. These facilities are noted in Table 6-15 below. The elevated storage tanks as well as some reservoirs provide “floating” storage for the system meaning, they supply flow from the tank via gravity. Other storage tanks, located at Unit Wells rely on a booster pumping station to pump water from the tank to the distribution system. For the “pumped” storage facilities considered in the analysis, volumes of pumped ground storage tanks were calculated according to the total pumping capacity of the reservoir's booster station for 3 hours, which represents water available for fire protection.

Table 6-15 – Summary of Water Storage Facilities

Zone	Facility	Storage Type	Tank Capacity (MG)
6w	Res 14	Pumped	0.15
	Res 18	Pumped	0.48
	Res 19	Pumped	3.00
	Res 24	Pumped	4.00
	Res 27	Pumped	0.32
	Res 30	Pumped	0.40
	Res 106	Pumped	6
	Zone 6w Total (MG)		**14.3**
7	Res 20	Floating	4.2
	Zone 7 Total (MG)		**4.2**
8	Res 16	Pumped	0.28
	Res 26	Pumped	3.00
	Zone 8 Total (MG)		**3.3**
9	Res 120	Floating	1.00
	Res 20	Pumped	0.40
	Zone 9 Total (MG)		**1.4**
10	Res 26	Floating	1.00
	Res 126	Floating	0.25
	Res 228	Floating	1.00
	Zone 10 Total (MG)		2.25

Zone	Facility	Storage Type	Tank Capacity (MG)
3	Res 25	Pumped	0.3
	Res 115	Floating	1.5
	Res 225	Pumped	0.5
	Res 229	Pumped	0.0
	Res 315	Floating	0.5
	Zone 3 Total (MG)		**2.8**
4	Res 9	Floating	0.8
	Res 31	Pumped	1.5
	Zone 4 Total (MG)		**2.3**
5	Res 313	Floating	0.3
	Zone 5 Total (MG)		**0.3**
6e	Res 7	Floating	0.50
	Res 13	Pumped	0.15
	Res 15	Pumped	0.15
	Res 115	Pumped	1.500
	Res 229	Floating	4.000
	Zone 6e Total (MG)		**6.3**

Only those pumped storage facilities with backup power are included in the table above.

Appendix 6C includes a comprehensive storage analysis of each pressure zone. The storage facilities in each pressure zone and then compare to the goals of Chapter 2.

Table 3-9 below summarizes the mass balance storage capacity analysis included in Appendix 6C. Some zones are reliant on pumping station capacity and the availability of standby power to provide access to available storage volume.

The computer model analysis will determine the effectiveness of the existing storage facilities and whether locations and capacities of storage tanks are adequate, based on hydraulic limitations and in in addition to water tank mass balance. Through the 2020 design period, all pressure zones with the exception of zone 5 indicate adequate storage capacities. The storage shortage identified for zone 5 may potentially be addressed by an upgrade to pumping capacity into the pressure zone.

Table 6-16 – Summary of Water Storage Pressure Needs

Zone	Available Storage Capacity (mg)	2020 Storage Mass Balance (mg)	2040 Storage Mass Balance (mg)
3	2.83	0.61	-0.04
4	2.31	0.75	0.57
5	0.30	-0.23	-0.22
6e	6.30	2.27	2.30
6w	8.34	0.67	0.30
7	4.20	0.62	0.73
8	3.28	0.59	0.47
9	1.40	0.24	0.73
10	2.25	0.81	0.49

6.5.7 Summary of Water Supply, Transfer and Storage Deficiencies

The previous sections have developed a list of potential water system deficiencies related to supply, transfer and storage of water. The analysis indicates that in the short term 2020 planning period all of the hydraulic regions with the exception of region C will be in need of additional water supply. The mass balance exercise also revealed that some of these supply deficiencies may possibly be addressed through the transfer of water from one side of the water system to the other.

Projections for the 2040 planning period indicate additional water supply need which may not be satisfied through water transfer alone. Various water supply and transfer alternatives to address these deficiencies will be examined in Chapter 7.

Additionally, each individual pressure zone was examined for inter-zone water transfer. In other words, each zone was examined to assure that water could be derived within the zone to meet peak water system demands from firm pumping capacity (from wither unit wells or booster pump stations). This analysis revealed potential pumping shortages in zones 4, 5,6e, 6w and 8 for both the 2020 and 2040 planning periods.

Finally, water storage availability was examined and limited storage deficiencies were revealed. While the analysis did indicate some level of storage volume shortage in zone 5, it may potentially be remedied by an increase in pumping capacity to the zone.

Alternatives to address deficiencies listed in the previous section will be presented in Chapter 7. Each potential alternative will be analyzed according to the Utilities asset management plan.

6.6 System Static Pressure Analysis

The existing water system contains nine pressure zones, upon Zone 10 and Zone 11 being fully merged. The purpose of pressure zones is to provide pressures meeting MWU pressure guidelines established in Chapter 2 to the customers in the City, each according to their respective ground elevation.

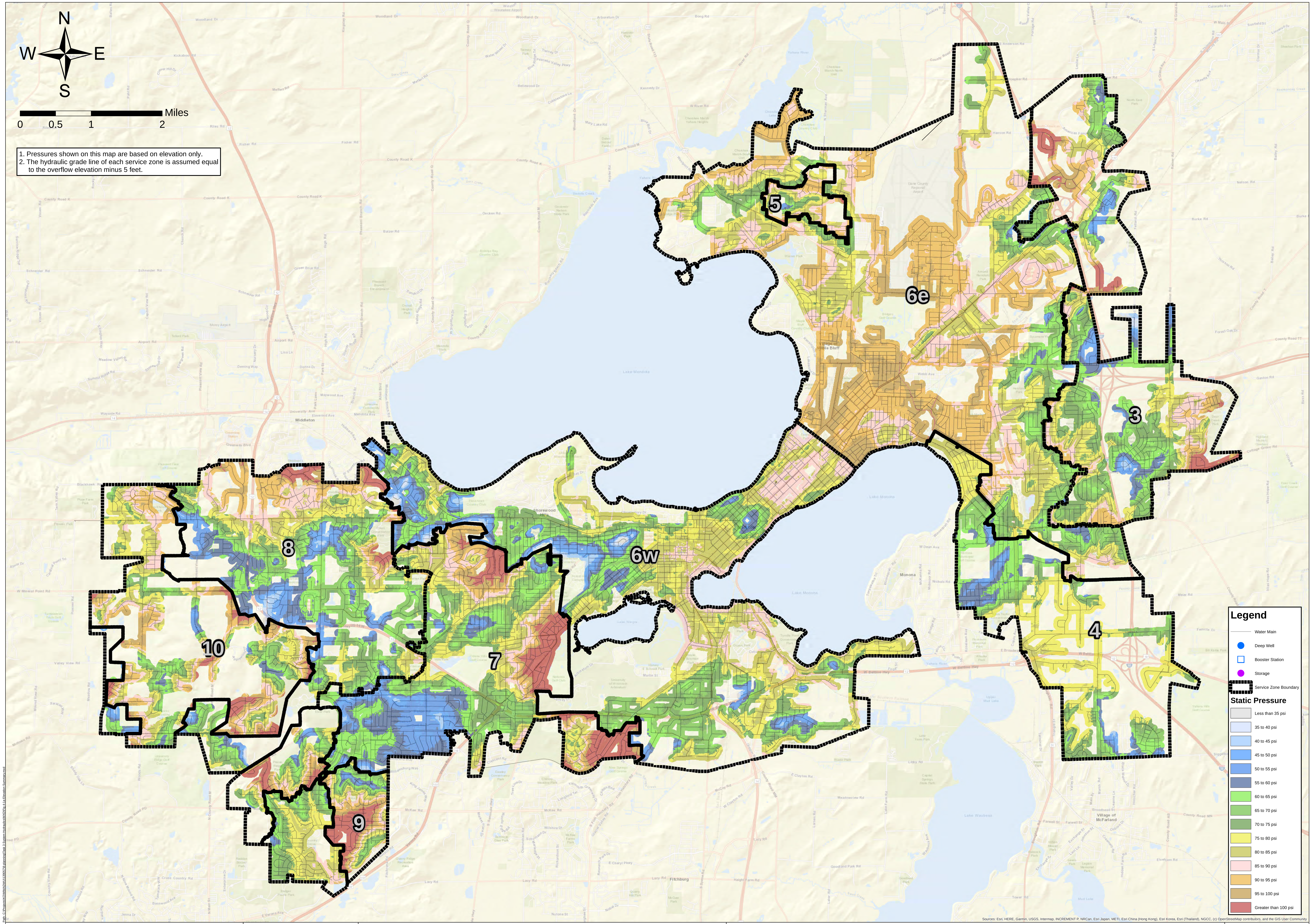
This section performs an analysis of the ground elevations in the City, and identifies deficiencies due to elevation only and not due to pressure loss in water mains or pressure gain from pumping stations. This section will help determine if a deficiency could be solved by moving a zone boundary rather than in constructing additional infrastructure.

Appendix 3-B of Chapter 3 previously looked at pressure zone elevations in order to validate planned pressure zone boundaries for water needs planning. This section will more closely examine the performance of each pressure zone. Figure 6-9a shows what the pressure in the existing pipe network system would be if determined by the overflow elevation of the zone using existing pressure zone boundaries. Figure 6-9b shows what the pressure in the future Pressure zone would be if determined by the overflow elevation of the zone using future pressure.

The following list describes elevation based pressure zone deficiencies:

Table 6-17 – Static Pressure Deficiencies by Pressure Zone

Pressure Zone	Deficiency ID	System Deficiency
Zone 3	PZ.3.01	Zone 3 is currently mostly undeveloped. Areas to the far east of the system, which dominantly exist in areas designated for conservation open space, have elevations which would cause the pressure to exceed 100 psi.
	PZ.3.02	Zone 3 contains undeveloped highlands in the center of the zone which may experience pressures less than 40 psi. As these areas develop, MWU will need to determine with the developer(s) if a site specific versus area-wide booster station is required.
	PZ.3.03	Zone 3 contains pockets of low elevation where pressure would exceed 100 psi.
Zone 6w	PZ.6w.01	Areas around Reservoir 106 in Zone 6w experience low pressure due its relatively high elevation. (Near Zone 7)
	PZ.6w.02	Areas west of Unit Well 14 in Zone 6w experience low pressure due its relatively high elevation. (Near Zone 8)
Zone 7	PZ.7.01	The east-central area of Zone 7 in the vicinity of Nakoma Road experiences high pressure due its relatively low elevation.
	PZ.7.02	The southeast area of Zone 7 in the vicinity of BPS 118 experiences high pressure due its relatively low elevation.
Zone 10	PZ.10.01	Zone 10 is currently mostly undeveloped. As these areas in Zone 8 and 10 develop Zone boundaries will be established to manage pressures to desired levels.



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Project: MADWU 139057
Print Date: 12/13/2018

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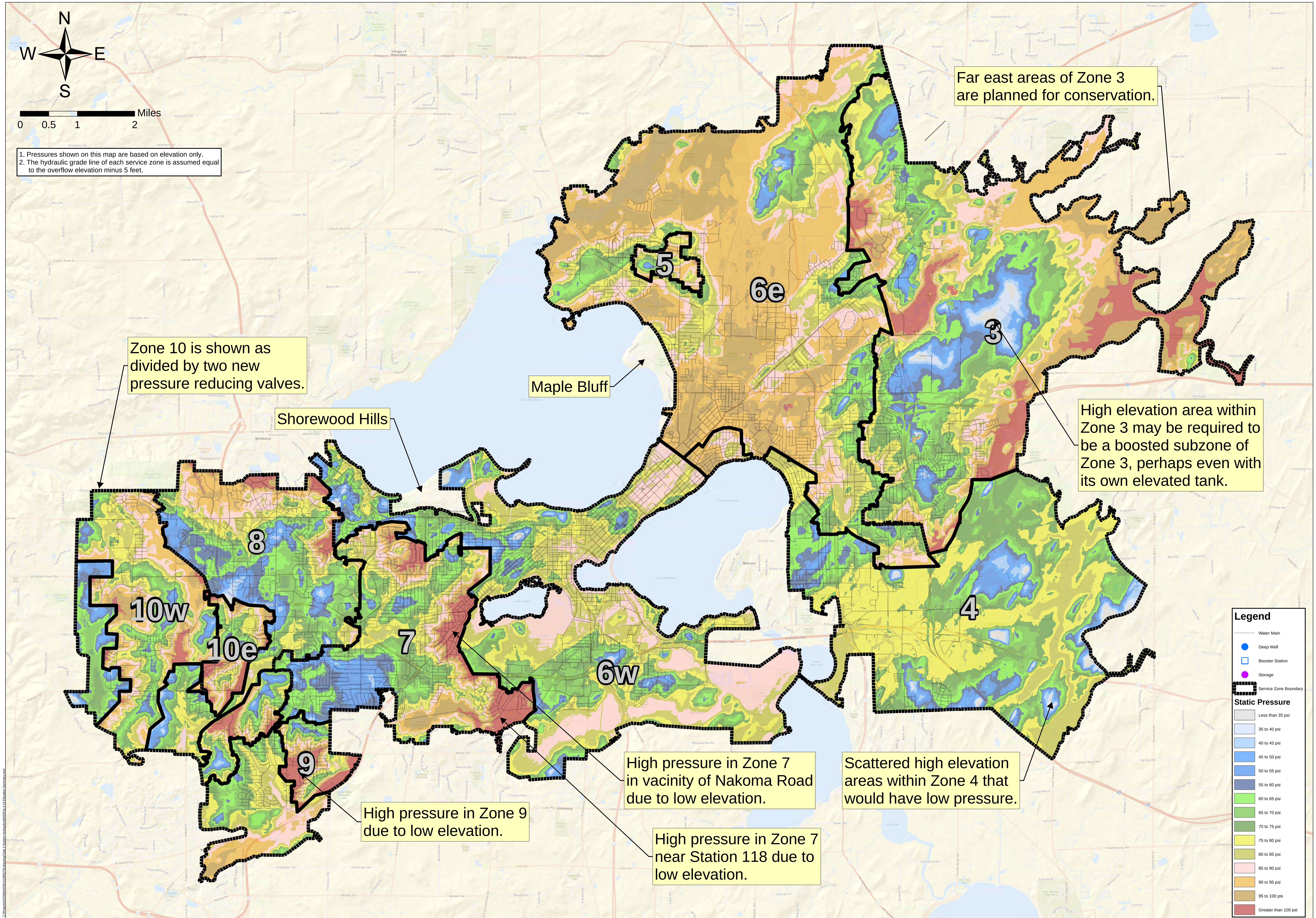
Elevation Study of Existing Pipe Network

Hydraulic Analysis Report
Madison, Wisconsin

Map
6-9a



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Elevation Study of 2040 Service Area

Hydraulic Analysis Report
Madison, Wisconsin

Map
6-9b

6.7 Current Water System - Hydraulic Modeling Deficiency Analysis

The previous sections of this report analyzed the water system through conventional engineering practice by simply comparing the existing facility design capacities with projected water system demand. This analysis aims to identify potential water system performance issues related to undersized facilities or other factors. For this analysis, it is assumed that all facilities are online for the purposes of determining deficiencies due to hydraulics limitations, not related to facility failures. The deficiencies identified in the previous sections regarding mass balance with respect to facility failures will be addressed in Chapter 7 as well as any major deficiencies revealed from the sections that utilize water system modeling. All modeling assumes the projected maximum 10-day demand on the system.

In addition to existing facilities, the following improvements to the water system were assumed as if existing to make the water model finish a 10-day scenario with 2020 demands without hydraulic imbalances (see Section 7.1.3 of Chapter 7):

1. For modeling purposes, the high service pumps at BPS 213 were modeled as replaced with the pumps from retired BPS 125 in order to meet the deficiencies for storage and firm inter-zone pumping capacity for Zone 5. This is currently planned to occur in 2021.
2. For modeling purposes, the high service pump at Unit Well 8 was modeled as replaced with pump and variable frequency drive unit with a steeper pump curve, higher shut off head, and pressure modulation, as the current pump curve is too flat for the operating point. It is noted that this assumption is based on the upgrade of Unit Well 8 due to water quality issues moving forward. In the event that Unit Well 8 is abandoned, reliance on this facility for needed supply capacity is not possible.
3. For modeling purposes two pressure reducing valves were modeled in Zone 10, one at Watts Road & South Junction Road and the other at Waldorf Boulevard & Mid Town Road, to address the difference in overflow elevation between Reservoir 126 and Reservoir 228.

The following sections examine the existing system, except with the above changes to the system included.

6.7.1 Maximum 10-Day Demand Simulation of Existing System

A 10-day extended period (10-Day EPS) simulation was performed on the existing system with the changes stated above. All water mains which were included in Chapter 5, were included in this scenario. Controls were set up to simulate a maximum day demand, with numerous wells operating continuously to sustain system demands for a 10-day period of maximum water use (see Chapter 5 for description of selected 10-day period).

The outputs from the water model are shown in Appendix 6D the modeling maps document the resulting water system conditions over the 10-day modeling period. Each map depicts maximum or minimum system pressure, maximum velocities, water tank levels and pump outputs. These maps can then be utilized to identify system deficiencies related to system. The Table below summarizes the results from each of the modeling maps.

Table 6-18 – 2020 Maximum 10-Day Demand Simulation Deficiencies

Region	Map	Type	Deficiencies Identified
A	Map D-1a	Min Pressure	Reservoir 113 struggles to maintain minimum levels over the 10 day period due to undersized water main around or near the facility.
	Map D-1b	Max Pressure	
B	Map D-2a	Min Pressure	Major system limitations were not identified.
	Map D-2b	Max Pressure	
C	Map D-3a	Min Pressure	System modeling revealed areas with low system pressure near zone boundaries. Additional other areas exhibited higher than desired pressures. These same pressure limitations were also identified in the static pressure analysis and can potentially be addressed through zone boundary modifications.
	Map D-3b	Max Pressure	
D	Map D-3a	Min Pressure	System modeling revealed areas with low system pressure near zone boundaries. These pressure limitations can potentially be addressed through zone boundary modifications.
	Map D-3b	Max Pressure	

The existing structure of the water distribution system has the ability to sustain the water system under the projected 2020 maximum day demand. However, there are areas that would benefit from various improvements.

Major deficiencies identified are included in the table above. There were also some areas were found to experience at least one 15 minute interval of pressure below 40 psi during the maximum 10-day demand, as shown in Appendix 6D. These areas were generally in relatively high elevations compared to the pressure zone, in areas of small main, & areas remotely situated from the majority of the pressure zone. For example, nodes around Unit Well 14 experienced low pressure when demand exceeded the capacity of Unit Well 14 and pressure drop from the main part of Zone 6w occurred. For another example, the area in Zone 7 between Reservoir 20 and Unit Well 12 experienced low pressure due to elevation.

6.7.2 Steady State Simulation of Existing System

The maximum 10-Day EPS of the existing system demonstrated how well the supply and inter-zone pumping facilities can sustain storage and pressure in the system. To some degree, the maximum 10-Day EPS also demonstrated where pressures are affected by the arrangement of the water main network. In order to more quickly identify hydraulic restrictions in the water main network, a steady state analysis was utilized. The steady state analysis can be used to check the pipe velocities at a selected moment in time. The results of this analysis are documented contained in Appendix 6C. The steady-state analysis assumes the tank levels and diurnal demands which were observed during the morning peak (around 7 a.m.) of the maximum day in 2012. The peak factors are shown in Table 6-1 as ratios of the maximum day demand. The results in the table below were derived from data found in Chapter 3.

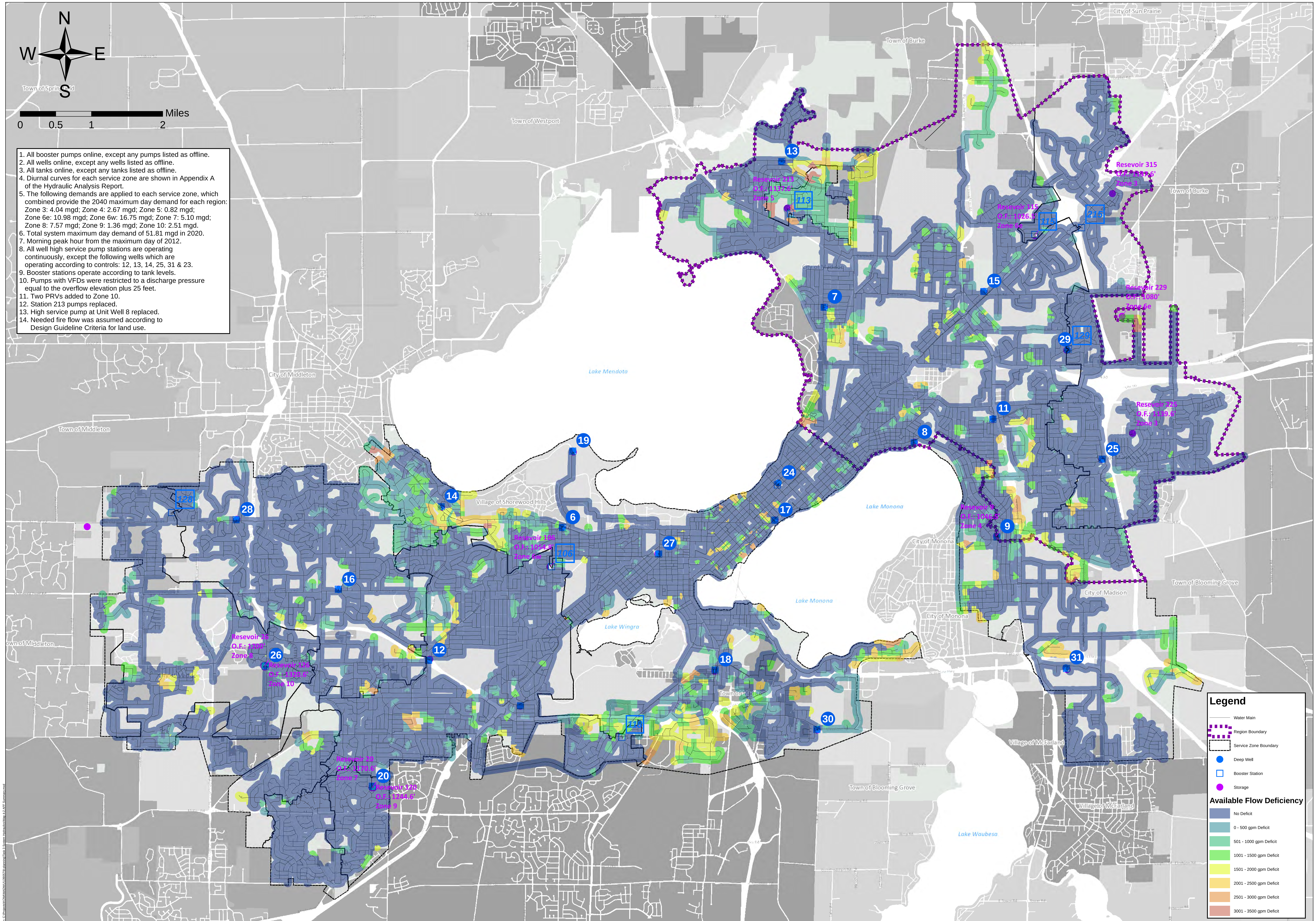
Table 6-19 – Max Day 2012 Morning Peak Factor

Pressure zone	Actual Time	Factor
3	7:00 AM	1.34
4	8:00 AM	1.35
5	6:00 AM	1.67
6e	9:00 AM	1.27
6w	9:00 AM	1.32
7	8:00 AM	1.47
8	7:00 AM	1.32
9	6:00 AM	1.67
10	7:00 AM	1.59

The steady state fire-flow evaluation can reveal areas of weak fire protection and low residual pressure during fire flow events. Model outputs will be presented as available flow while maintaining a minimum system pressure of 20 psi. Per industry standards.

Land use was the basis of comparison for needed fire flow, according to the goals of Chapter 2. Where no goal was set, the minimum requirement of 1,000 gpm at 20 psi was assumed. Pipes with a peak velocity exceeding 5 fps are highlighted.

Figure 6-10 identifies deficiencies regarding fire protection. Areas which are estimated to have less available flow than the assumed fire protection according to land use highlighted according to level of deficiency.



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Steady State Available Flow Deficiencies

Hydraulic Analysis Report
Madison, Wisconsin

Figure 5-10

6.7.3 Conclusions of Modeling of Existing System

After the completion of the water model analysis exercise documented above, the following provides for a brief summary of potential system deficiencies based on water model observations. The observations below will help to develop a plan for future system improvements explored later in Chapter 7.

6.7.3.1 Pipeline Deficiencies

6.7.3.1.1 Water Main Bottlenecks

For purposes of this analysis, pipes with high velocities will be referred to as “bottlenecks”. Bottlenecks exists where a large flowrate of water relative to the pipe diameter is forced to pass through that particular pipe resulting in high velocity.

The following types of pipe network bottlenecks are generally tolerable depending on the circumstance:

1. Discharge piping of pumping stations, as long as the travel distance is short enough to control backpressure.
2. Discharge piping of elevated tanks, as long as the travel distance is short enough to control pressure loss from the tank to the pressure zone.
3. Pipes directly connecting pressure reducing valves between pressure zones as customers around the pressure reducing valve have acceptable pressure.

The following types of bottlenecks are generally of concern depending on the circumstance:

1. Anywhere where the restriction is causing unacceptable pressure & pressure fluctuations to downstream customers.
2. Undersized water mains which restrict necessary fire protection capacity.
3. Water mains which cause significant head loss from one area of a pressure zone to another area of the same pressure zone, such as one elevated tank is not able to fill another elevated tank in the same pressure zone.
4. Water mains which cause pumping stations to push against high back pressure, causing localized high pressures and wasting energy.

With these assumptions in mind, the following bottleneck deficiencies were found in the water main pipe network, as highlighted in Figure 6-11. Deficiencies are also stated on the MWU Water System Deficiencies List in Appendix 6H. The deficiency ID for each segment is identified in the following sections.

1. Zone 5:
    a. **Segment H.01 -** 230 feet of 6-inch main at the corner of Esch Lane & Lake View Avenue between the Reservoir 313 and the 12-inch main could be replaced with 12-inch main; this particular 6-inch main is restricting flow from Reservoir 313 (Deficiency ID: H.01))
    b. **Segment H.02 -** 470 feet of 6-inch main along Lake View Avenue between the 12-inch and the intersection with Hanover Street could be replaced with 12-inch main; this particular 6-inch main is restricting flow from Reservoir 313 (Deficiency ID: H.02).
    c. **Segment H.03 -** 500 feet of 6-inch main along Hanover Street between the intersection with Lake View Avenue and the intersection with Longview Street could be replaced with 12-inch main; this particular 6-inch main is restricting fire protection (Deficiency ID: H.03).
2. Zone 7:
    a. **Segment H.04 -** 50 feet of 12-inch main connecting the 16-inch main at the intersection of Hillcrest Drive & Glenway Street could be replaced with 16-inch main; the current condition is restricting a new (2014) 16-inch transmission main with a very old (1924) section of 12-inch transmission main (Deficiency ID: H.04).

b. **Segment H.05 -** 910 feet of 6-inch main along Hillcrest Drive between the intersection with Larkin Street and the intersection with Westmorland Boulevard could be replaced with 12-inch main; this section of 6-inch main is restricting a 12-inch transmission main (Deficiency ID: H.05).

6.7.3.1.2 Zone Boundary Pipelines (Zone dead ends)

Various parts of the water main pipe network experienced deficiencies due to pressure zone isolation. An example of this is the far northwest reach of Zone 6w around Unit Well 14. Many other water mains exist in the area, but are isolated from Zone 6w due to zone boundaries. Pressure zone boundaries are typically established within the existing water main grid by closing various isolation valves to prohibit flow between zones. However, these isolation points can limit the performance of connecting water main. The water system modeling analysis revealed that some of these isolation points along zone boundaries

Deficiencies observed in the maximum 10-day EPS modeling with all facilities online and active. Deficiencies are also stated on the MWU Water System Deficiencies List in Appendix 6H. The deficiency ID for each segment is identified in the following sections.

1. Zone 5:
   a. **Segment H.06 -** A 6-inch check valve is recommended at the intersection of Browning Road & Kipling Drive to allow water from Zone 6e into Zone 5 to assist fire protection in Zone 5 (Deficiency ID: H.06).
   b. **Segment H.07 -** A 6-inch check valve is recommended at the intersection of Havey Road & Mandrake Road from Zone 6e into Zone 5 to assist fire protection in Zone 5 (Deficiency ID: H.07).
2. Zone 6w:
   a. **Segment H.08 -** A 10-inch pressure reducing valve is recommended at the intersection of Old Middleton Road & North Whitney Way from Zone 7 into Zone 6w to assist fire protection in Zone 6w (Deficiency ID: H.08).
   b. **Segment H.09 -** A 6-inch pressure reducing valve is recommended at the intersection of Park Way & North Kenosha Drive from Zone 7 into Zone 6w to assist fire protection in Zone 6w (Deficiency ID: H.09).
   c. **Segment H.10 -** A 6-inch pressure reducing valve is recommended at the intersection of South Highland Avenue & Hillside Avenue from Zone 7 into Zone 6w to assist fire protection in Zone 6w (Deficiency ID: H.10).

6.7.3.1.3 Global Water Main Network Restrictions

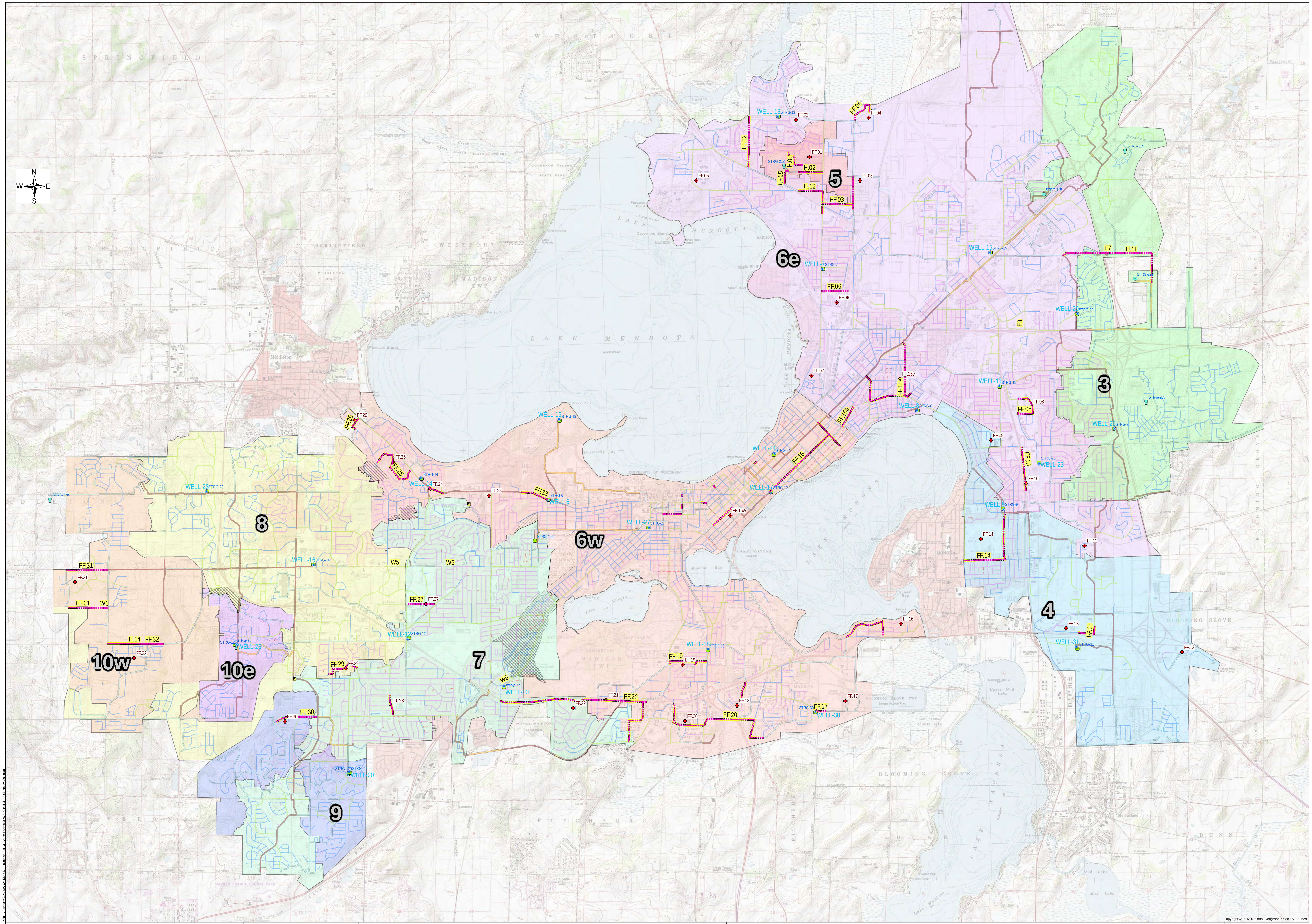
Steady State modeling versus EPS modeling have different advantages and disadvantages. Steady state modeling enables a person to see a snapshot of the system in a single moment in time, eliminating the noise of all other time steps. EPS modeling allows the water system to respond to itself over time, enabling a person to see how pressures fluctuate over time and how storage facilities gain or lose over time.

This section examines deficiencies of the water main network on a global level, identified according to how tanks recover from demands and how pressures fluctuate. In EPS modeling, flow velocity is not the only determinate in how a water system experiences head loss from one area to another: travel distance and demand also factor in. The local bottlenecks identified in Section 6.4.1 were local deficiencies based on goals of Chapter 2 and were not a complete list of all potential water main deficiencies.

The following deficiencies were identified in the maximum 10-day EPS modeling and/or the steady state modeling of the system with all facilities online and active. Deficiencies are also stated in Appendix 6H. The deficiency ID for each segment is identified in the following sections.

1. Zone 3:
   a. **Segment H.11 (D.01) -** In Map F-4a, Reservoir 225 had difficulty filling with Unit Well 25 offline. Pressure zone 3 currently lacks a major transmission main connecting the north side and to the south side. All pumping station besides Unit Well 25 are within the north side.
2. Zone 6e:
   a. **Segment H.12 (D.02) -** In Map D-1a, Reservoir 113 dropped as much as 15 feet below overflow in the EPS simulation. Currently, the system has a regional bottleneck in the vicinity of the intersection of Troy Drive & North Sherman Avenue. MWU already has in its capital improvement plan to construct a new transmission mains to remove this bottleneck (Deficiency ID: H.12).
   b. **Segment H.13 (D.03) -** Reservoir 229 is currently connected to Zone 6e by a single 20-inch transmission main. The lack of redundancy to this storage facility is considered a deficiency for this zone. (Deficiency ID: H.13).
   c. **Segment H.14 (D.04) -** The south side of Zone 6e contains a lobe which extends between Zone 3 and Zone 4, in the vicinity of Orlando Bell Park. This area in various scenarios experienced low pressure due to high head loss. A pressure reducing valve currently exists at Buckeye Road & Thompson Drive to allow Zone 3 to feed this remote area of Zone 6e. However, as seen in scenarios such as Map F-1a, Reservoir 225 becomes highly stressed if the pressure reducing valve opens to assist Zone 6e. While the pressure reducing valve is helpful to the area, the peak water demand should be drawn from Zone 6e, posing a need to examine alternatives for transmission mains from the main part of Zone 6e to this lobe (Deficiency ID: H.14
3. Zone 10:
   a. **Segment H.15 (D.05) -** There are multiple local dead ends and a divide in Zone 10 which exists due to the absence fully developed trunk water main. (Deficiency ID: H.15).

MWU has other transmission mains already in its capital improvements plan based on previous water system studies. All water mains from previous studies which are planned to be constructed are included in Figure 6-12. The transmission mains for the Zone 6e deficiency around Reservoir 113 described above are also shown in Figure 6-12. As alternatives are analyzed in Chapter 7 additional water mains may be added as necessary to aid in the operation of various facility alternatives.



![SEH] ![Madison Water Utility]

Madison Water Utility

Project: MADWU 139057
Print Date: 12/13/2018

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Madison, WI 53719-1137
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Toll Free: 800.732.4362
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Legend

Deficeincy Type
- Hydraulic/Pipeline Def.
- Fire Flow Def.
- Water Transfer (BPS)
- Flow Control
- PRV
- UW
- wPRVs
- wDeepWell

StorageType
- Ground
- Station
- Elevated
- wBooster

Existing Water Main
Diameter
- < 6"
- 6"
- 8"
- 10"
- 12"
- 14"
- 16"
- 18"
- 20"
- 24"

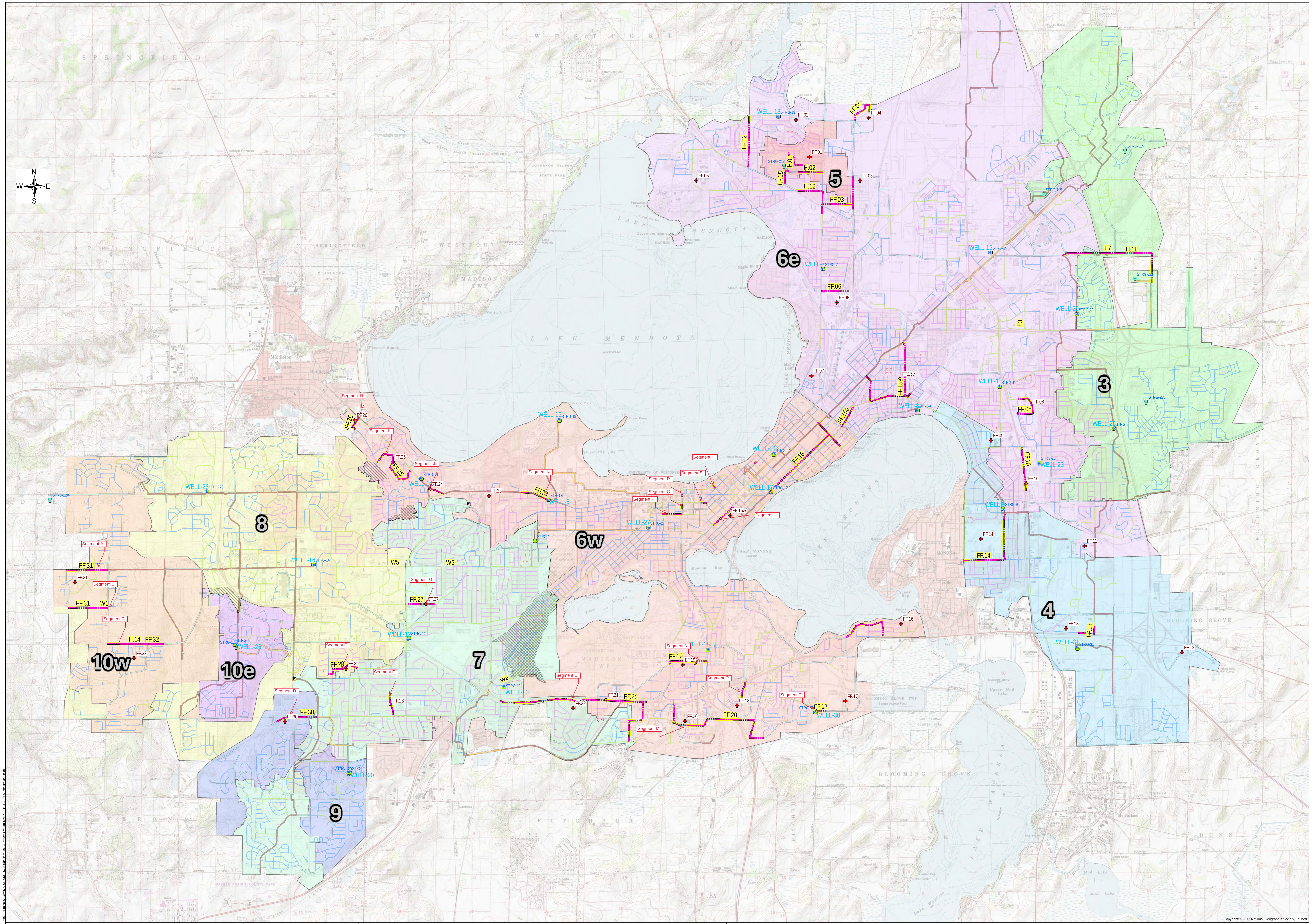
Pressure Zones
Zone
- 10e
- 10w
- 3
- 4
- 5
- 6e
- 6w
- 7
- 8
- 9
- Potential Pressure Zone Changes

USA Topo Maps

Water System Deficiency Summary

Hydraulic Analysis Report
Madison, Wisconsin

Figure
6-11



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StorageType
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- Station
- Elevated
- wBooster

Existing Water Main

Diameter
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- 6"
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- 12"
- 14"
- 16"
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- 20"
- 24"

Pressure Zones

Zone
- 10e
- 10w
- 3
- 4
- 5
- 6e
- 6w
- 7
- 8
- 9
- Potential Pressure Zone Changes

USA Topo Maps

Water System Deficiency Summary

Hydraulic Analysis Report
Madison, Wisconsin

Figure
4-3

6.7.4 Consequence of Failure Simulations

Facilities are likely to be offline at some point during their useful life for routine maintenance & repairs. As the term useful life implies, there is also an end to the useful life of a facility. Similar to the mass balance analysis of firm supply & inter-zone pumping capacity, the water model can be used to identify deficiencies due to facility failures & maintenance.

Chapter 2 will guide the consequence of failure simulations similar to the hydraulics analysis, previously completed in this chapter. When analyzing each hydraulic region, the following criteria shall maintained:

1. System-wide supply shall meet maximum day demand with three wells offline.
2. Supply & inter-zone firm pumping capacity into each region shall meet the region's maximum day demand with one well offline in Region B & D and two wells offline in Regions A & C (firm capacity), not exceeding three wells offline system-wide at a time.

A scenario matrix of potential failure scenarios was generated as a part of the Master Plan Update. Each hydraulic region was modeled separately as an isolated unit, representative of the existing system with 2020 max 10-day demands. As such, two facilities were taken offline for each scenario.

6.7.4.1 Region A (Zones 3, 5 & 6e)

Region A was tested for a variety of consequence of failure scenarios. The following combination of failures were tested and are shown in the associated maps:

1. Unit Well 7, Unit Well 29 & one pump at BPS 129 (Maps F-1a & F-1b).
2. Unit Well 13 & Unit Well 15 (Maps F-2a & F-2b).
3. Unit Well 8 & Unit Well 11 (Maps F-3a & F-3b).
4. Unit Well 23 & Unit Well 25 (Maps F-4a & F-4b).
5. All of BPS 115 High (Maps F-5a & F-5b).
6. All of BPS 115 Low & one pump at BPS 215 (Maps F-6a & F-6b).

The following deficiencies were identified when various unit wells were offline or pumping stations were at firm capacity **during the 2020 maximum 10-day demand period**:

1. Overall Impact:
   a. With two wells offline, Region A struggles for supply during the maximum 10-day demand. Scenario 2 caused the greatest number of failures in Region A among the six scenarios tested. Unit Well 13 directly fills Reservoir 113, which in turn supports BPS 213 to fill Reservoir 313. Unit Well 15 supports the hydraulic grade line of the northeast area of Zone 6e. With these two wells offline, Reservoirs 315, 115, 225, 229,113 and 313 all completely drained at some point during the simulation.
2. Zone 3:
   a. In Map F-4a, Reservoir 225 empties when Unit Well 25 is offline, causing pressures to fail in the south side of Zone 3. This poses the need for either additional pumping sources into the south side of Zone 3 or more water main capacity from north to south in Zone 3. This deficiency was previously highlighted along Felland Road and shown in Figure 6-11.
3. Zone 5:
   a. To satisfy fire protection capacity requirements in Zone 5 on the max day, two pumps each rated for 1,000 gpm and a backup generator will be installed at BPS 213 (Construction currently scheduled for 2021). Gravity flow from the elevated tank would provide the required fire protection capacity and the pumps will provide for the peak hour demand during the fire. A standby generator at BPS 213 would mitigate the identified storage deficiency by providing reliable supply during a 12 hour power outage and sufficient capacity to satisfy peak hour demand during a fire.

4. Zone 6e:
    a. With two wells out of service in Region A, Reservoir 229 drains to very low levels during the 10-day simulation. Draining Reservoir 229 demonstrates the need for more supply & Inter-zone Pumping Capacity into Region A. Alternatives to correct this deficiency will be investigated.
    b. With two wells out of service in Region A, Reservoir 113 drains up to 25 feet. Draining Reservoir 113 illustrates the need for more supply & Inter-zone Pumping Capacity into Region A & more water main capacity from the main part of Zone 6e to Reservoir 113, as described in Section 4.4.1.3. Alternatives to correct this deficiency will be investigated.
    c. With two wells offline in Region A, pressure in the southern area of Zone 6e drops to the setting of the Buckeye Road pressure reducing valve. When the pressure in this area drops the pressure reducing valve opens and Reservoir 225 is stressed. This area in the vicinity of Orlando Bell Park is remotely located from the rest of Zone 6e. Additional water main capacity may be recommended to increase the transmission capabilities to this area. Alternatives to correct this deficiency will be investigated.

6.7.4.2 Region B (Zone 4)

Region B was tested for a variety of consequence of failure scenarios. The following combination of failures were tested and are shown in the associated maps:

1. Unit Well 9 (Maps F-1c & F-1d).
2. Unit Well 31 (Maps F-2c & F-2d).

The following deficiencies were identified when various unit wells were offline or pumping stations were at firm capacity **during the 2020 maximum 10-day demand period**:

1. With one well offline, Region B is able to endure the maximum 10-day demand, where supply is lacking, the storage in Zone 4 can offset supply deficit for 1-2 days.
2. Unit Well 31 has more impact when offline than Unit Well 9, simply due to the slightly higher capacity of Unit Well 31. The Unit Well 31 pumping units would normally be set to maintain pressure, while Unit Well 9 is normally operated to maintain tank level. Reservoir 31 is online whether Unit Well 31 is online or offline with three pumping units at Unit Well 31 to ensure the storage in Reservoir 31 is available to Zone 4 when required.

6.7.4.3 Region C (Zones 6w, 7 & 99)

Region C was tested for a variety of consequence of failure scenarios. The following combination of failures were tested and are shown in the associated maps:

1. Unit Well 14, Unit Well 18 & one pump at BPS 120 (Maps F-1e & F-1f).
2. Unit Well 19 with Reservoir 19 online & Unit Well 30 (Maps F-2e & F-2f).
3. Unit Well 6 & Unit Well 24 with Reservoir 24 online (Maps F-3e & F-3f).
4. Unit Well 12 & Unit Well 27 (Maps F-4e & F-4f).
5. Unit Well 20 (Maps F-5e & F-5f).
6. Unit Well 17 & one pump at BPS 106 (Maps F-6e & F-6f).

The following deficiencies were identified when various unit wells were offline or pumping stations were at firm capacity **during the 2020 maximum 10-day demand period**:

1. Overall Impact:
   a. With two wells offline, Region C is able to endure the maximum 10-day demand. When supply is lacking, the storage in Reservoirs 106, 20 and 120 can offset supply deficit and then recover.
2. Zone 6w:
   a. With two unit wells out of service, Zone 6w is able to endure the maximum 10-day demand. When supply is lacking, the storage in Reservoir 106 can offset supply deficit and then recover.
   b. Unit Well 14 in Scenario 1 was found to have the highest impact if offline among the six scenarios tested. A substantial pressure drop occurred in the area around Unit Well 14 in Map F-1a. The impact of Unit Well 14, however, is local to the area around Unit Well 14.
3. Zone 7:
   a. With one unit out of service, whether a single booster pump or a borehole well pump, Zone 7 is able to endure the maximum 10-day demand, where supply is lacking, the storage in Reservoirs 20 can offset supply deficit and then recover.
4. Zone 9:
   a. With one booster pump out of service at BPS 120, Zone 9 is able to endure the maximum 10-day demand. Reservoir 120 levels did not indicate stress.

6.7.4.4 Region D (Zones 8 & 10)

Region D was tested for a variety of consequence of failure scenarios. The following combination of failures were tested and are shown in the associated maps:

1. No failures (Maps F-1g & F-1h).
2. One pump at BPS 126 (Maps F-2g & F-2h).
3. One pump at BPS 128 (Maps F-3g & F-3h).
4. Unit Well 28 (Maps E-4g & E-4h).
5. Unit Well 16 (Maps F-5g & F-5h).
6. Unit Well 26 (Maps F-6g & F-6h).

The following deficiencies were identified when various unit wells were offline or pumping stations were at firm capacity **during the 2020 maximum 10-day demand period**:

1. Overall Impact:
   a. Even with all facilities online, Region D lacks sufficient supply to sustain 2020 maximum 10-day demand. As previously demonstrated, Region D has an anticipated deficiency in supply.
2. Zone 8:
   a. With any one well offline, Reservoir 26 would empty entirely during the maximum 10-day demand, which would cause Zone 10 run short of water supply which would cause zone 10 to rely on zone 8 to satisfy system demand at lower system pressures.
3. Zone 10:
   a. Due to the dependency on Zone 8, Zone 10 would lose supply if Zone 8 lost supply. However, with one pumping unit offline, Zone 10 could endure the maximum 10-day demand if Region D collectively had enough supply. As previously demonstrated, Zone 10 has surplus pumping capacity from Zone 8 to offset an offline booster pump.
   b. Zone 10 behaved similarly between Scenario 2 and Scenario 3. The assumption which caused this to be true is that the two pressure reducing valves to be added to Zone 10 have the ability to return flow from the downstream side to the upstream side. If this is not constructed as stated, then Reservoir 126 would be more immediately affected if one pump were offline at BPS 126.

6.8 Water Quality

Desirable water quality implies water that is clear, tasteless, odorless, and free of chemical and microbiological contaminants. The quality of water delivered by MWU must meet legislated water quality standards, MWU design guidelines and should meet other standards recognized as desirable by the water industry. A sound source of municipal supply must reliably yield raw water quality that is economically treated. MWU and all public utilities are required to meet water quality rules and regulations under the Safe Drinking Water Act. The City must meet all regulations and participate in required programs established the governing bodies, the U.S. Environmental Protection Agency (U.S. EPA) and the Wisconsin Department of Natural Resources (WDNR)

As part of the systems analysis, MWU staff provided comment in regards the water quality produces by the various unit wells. A summary pertinent water quality information for those wells that have potential issues are shown below.

6.8.1 Water Quality Needs Summary

The system's water quality deficiencies were identified by MWU.

1. **Unit Well 6** – VOCs contaminate water from this well. (Deficiency ID: WQ.0106)
2. **Unit Well 8** – Presence of iron and manganese results in poor water quality from this well. Additionally, the water may be contaminated by VOCs. From Kipp Corporation. (Deficiency ID: WQ.0208)
3. **Unit Well 9 -** VOCs contaminate water from this well. (Deficiency ID: WQ.0309)
4. **Unit Well 11** - VOCs contaminate water from this well. (Deficiency ID: WQ.0411)
5. **Unit Well 14** – Well is contaminated by sodium and chlorides found in the water. (Deficiency ID: WQ.0514)
6. **Unit Well 17 -** History of iron and manganese; has difficulty maintaining disinfectant residual. There is a problem with Cl_2 residual could be mixing in the reservoir. (Deficiency ID: WQ.17)
7. **Unit Well 18** – VOCs contaminate water from this well. (Deficiency ID:WQ.0618)
8. **Unit Well 19 -** History of radium, iron and manganese: Treatment is planned to address. (Deficiency ID: WQ.19)
9. **Unit Well 23** – Presence of iron, manganese and radium results in poor water quality from this well. Well 23 us to be abandoned in 2021. (Deficiency ID WQ.0723)
10. **Unit Well 24** – Presence of iron and manganese results in poor water quality from this well. (Deficiency ID WQ.0824)
11. **Unit Well 27** – Presence of iron, manganese and radium results in poor water quality from this well. (Deficiency ID WQ.0927)
12. **Unit Well 28** – Presence of iron and manganese results in poor water quality from this well. (Deficiency ID WQ.1028)
13. **Unit Well 30** – Presence of iron and manganese results in poor water quality from this well. (Deficiency ID WQ.1130)
14. **Reservoir 115** –25% to 40% of this reservoir is turned over daily, therefore, water age is not a concern. (Deficiency ID WQ.12115)
15. **Reservoir 20** –Reservoir is well managed. Water age may not be an issues even without mixing. (Deficiency ID WQ.1320)

Mixers could be added at Reservoirs 19, 24 and 26. These are all large reservoirs.

6.9 Water Facility Renewal

Aging infrastructure, including water system facility buildings represent a future water system need in relation to renewal and replacement. This intends to identify those facilities that may need attention in regards to renewal over the 20 year planning period. The summary of needs was compiled with input from MWU staff. Information regarding needs at various facilities will be helpful in the developing and selecting potential water system improvement alternatives.

6.9.1 Facility Renewal Needs

MWU provided information regarding facility risks based on safety concerns, projected water shortage, or storage loss. The following states facility risks identified, and additional details are in Appendix 6G.

1. **Unit Well 6** – Concerns regarding chemical feed storage, building improvements, risk of mechanical breakdown, and backup power. Primarily at risk for water shortage. (Deficiency ID: A.01)
2. **Unit Well 8** – Concerns regarding chemical feed storage, and building improvements. Primarily at risk for safety concerns. (Deficiency ID: A.02)
3. **Unit Well 9** – Concerns regarding chemical feed storage, and backup power. Primarily at risk for water shortage. (Deficiency ID: A.03)
4. **Unit Well 11** – Concerns regarding chemical feed storage, risk of mechanical breakdown, backup power and loss of redundancy in the system. Primarily at risk for water shortage. (Deficiency ID: A.04)
5. **Unit Well 12** – Concerns regarding chemical feed storage, risk of mechanical breakdown, and loss of redundancy in the system. Well 12 is scheduled to be rebuilt. Primarily at risk for water shortage. (Deficiency ID: A.05)
6. **Unit Well 13** – Concerns regarding chemical feed storage, risk of mechanical breakdown, and loss of redundancy in the system. Primarily at risk for water shortage (Deficiency ID: A.06).
7. **Unit Well 14** – Concerns regarding chemical feed storage, risk of mechanical breakdown, and loss of redundancy in the system. Primarily at risk for water shortage. (Deficiency ID: A.07)
8. **Unit Well 16** – Concerns regarding chemical feed storage, risk of mechanical breakdown, and HVAC. Primarily at risk for safety concerns. (Deficiency ID: A.08)
9. **Unit Well 17** – Concerns regarding roof condition, and risk of mechanical breakdown. Primarily at risk for safety concerns. (Deficiency ID: A.09)
10. **Unit Well 18** – Concerns regarding chemical feed room door. Primarily at risk for safety concerns. (Deficiency ID: A.10)
11. **Unit Well 19** – Concerns regarding roof condition, and risk of mechanical breakdown. Primarily at risk for safety concerns. (Deficiency ID: A.11)
12. **Unit Well 20** – Concerns regarding the specific capacity of the well. Primarily at risk for water shortage. (Deficiency ID: A.12)
13. **Unit Well 23** – Concerns regarding chemical feed storage, building improvements, risk of mechanical breakdown, and loss of redundancy in the system. Primarily at risk for water shortage. (Deficiency ID: A.13)
14. **Unit Well 24** – Concerns regarding chemical feed storage, building improvements, risk of mechanical breakdown, and loss of redundancy in the system. Primarily at risk for water shortage. (Deficiency ID: A.14)
15. **Unit Well 25** – Concerns regarding the specific capacity of the well and chemical feed room door. Primarily at risk for water shortage (Deficiency ID: A.15).
16. **Unit Well 26** – Concerns regarding the specific capacity of the well and chemical feed room door. Primarily at risk for water shortage. (Deficiency ID: A.16)
17. **Unit Well 27** – Concerns regarding the chemical feed room door. Primarily at risk for safety concerns. (Deficiency ID: A.17)

18. **BPS 126** – Concerns regarding the pumping capacity. Primarily at risk for water shortage. (Deficiency ID: A.18)
19. **BPD 129** – Concerns regarding the pumping capacity. Primarily at risk for water shortage. (Deficiency ID: A.19)
20. **BPS 129** – Concerns regarding the pumping capacity and building improvements. Primarily at risk for water shortage. (Deficiency ID: A.20)
21. **BPS 213** – Concerns regarding risk of mechanical breakdown. Primarily at risk for water shortage. (Deficiency ID: A.21)
22. **Res 24** – Concerns regarding the leaks. Primarily at risk for storage loss. (Deficiency ID: A.22)

6.10 Summary of Water System Deficiencies

This chapter utilized specific water system planning tools to identify water system deficiencies and needs based on current water system performance and anticipated system growth. Each of these system deficiencies is related to delivery of quality water at appropriate performance levels. The nexus of this analysis is the development of a compressive anticipated water system deficiencies list which is summarized in Appendix 6H. Each deficiency on the list is identified a deficiency ID, which is stated in the following sections. These deficiencies will be the foundations for proposed system improvements recommended later in Chapter 7 of this master plan which will help guide water system planning decisions for years to come.