Chapter 4
Existing Water System

4 Introduction

This section provides a brief description of the major components and operational pressure zones which make up the Madison Water Utility (MWU) existing water system. In addition to MWU's regulations, policies and operational objectives were obtained and reviewed as part of the Operation Evaluation task.

4.1 Water System Summary

The Madison water system consists of 22 active water supply wells, 10 Interzone pumping stations, 12 distribution storage facilities and over 900 miles of water system piping which ranges in size from 1-1/2 to 24 inches in diameter. Water storage facilities include distribution storage and well storage reservoirs. Well storage is defined as a ground storage tank that is filled only by a water supply well. The water in the reservoir is then pumped into the distribution system for filling of the distribution storage tanks and delivery of water to customers. The distribution storage tanks maintain system pressure (Hydraulic Grade) and contain reserve storage. The "distribution storage" facilities currently include four ground level reservoirs, seven elevated tanks and one standpipe serving as distribution "floating" storage. One exception is distribution storage reservoir 115 which is directly off the distribution system through a pressure sustaining valve. Stored water is then re-pumped to the distribution system by nearby Booster Station 115. The water system is divided into 10 pressure zones to help provide adequate water pressures throughout the system. These pressure zones are noted in Table 4-1 according to name and number.

Table 4-1 – Pressure Zone

Location	Zone Number	Hydraulic Grade (ft)
East	3	1139.6
	4	1046.5
	5	1140.0
	6e	1080.0
West	6w	1054.0
	7	1170.0
	8	1200.0
	9	1224.0
	10	1320.0
	11	1300.0

4.2 Facility Definition

The MWU Water System is made up of three primary facility types:

- Deep Well Supply
- Booster Station (with one or more pumps)
- Reservoir or Storage Tank

The Madison water system was developed around a typical facility configuration which includes of one deep water supply well, a small ground level reservoir and a pump house containing both the deep well and the booster pumping unit (or units) which deliver water to the distribution system. This common facility is referred to as a “unit well”. MWU considers the “unit well” as a “single” functioning facility. This report will also consider the “unit well” as a facility category separate from other facilities, which include the other deep wells in the system, (which are not associated with other unit well components), storage tanks and interzone booster stations. A more detailed definition of the major facility types, is provided below.

4.2.1 Unit Wells

Nineteen (19) of the twenty-two (22) deep wells are of the unit well design. No two “unit wells” in MWU are identical, but the majority include a consistent configuration of a deep well, a line shaft turbine well pump, an above grade reinforced concrete reservoir (of between 100,000 and 1,500,000 gallons), and one booster pumping station with one or more booster pumps, discharge piping with valves and meters, electrical and mechanical components, and a chemical feed system consisting of fluoride addition and chlorine gas for disinfection. These facility components are typically housed in a masonry structure faced with stone or brick masonry. The three major unit well components (well, booster pump, and reservoir) are dependent on the other two major components to allow for the delivery of well water into the distribution system. Hence, if one major component of a unit well is unusable it is likely that the entire unit well is unusable or would require some modification for return to service. For example, unit wells with large reservoirs could be used as a “dump and re-pump” storage facility even if the deep well were taken out of service. Unit wells with small reservoirs would not have enough storage to be utilized effectively as a “dump and repump” storage facility. The remaining three deep wells, not meeting the above “unit well” definition is discussed in more detail below.

4.2.2 Independent Deep Wells

Deep wells 9, 20, and 26 are not considered true “unit wells” since they pump directly to distribution storage tanks and provide “floating storage” for the water system. As a result, water is delivered directly to the distribution system without additional pumping from secondary booster pumps. The connected floating storage tanks operate independently of the attached deep well, in other words, if the unit well becomes unusable, the storage tank can still function to serve the distribution system.

4.2.3 Interzone Booster Station

Interzone booster pumping station work to transfer and move from one pressure zone into another. Many of the Interzone booster pumping facilities are located near a distribution storage facility which service as either a supply or discharge point for the pumping station. Interzone booster stations are different than well booster pumps in that they deliver water from one zone into another rather than from a unit well reservoir. An exception to this is Booster station 9 which is a high service booster station located at Unit Well No.9. This booster station can work to provide extra pumping from the nearby standpipe as needed. This allows for the entire contents of Reservoir 9 to be used while sustaining system pressures.

Booster Station 9 is a high service booster station located in the same structure as Independent Deep Well 9. A 3.0 MG standpipe (Reservoir 9) is also located on site. Booster Station 9 can be utilized to pump out the contents of the standpipe if desired. This has the advantage of being able to utilize all of the storage on-site while still maintaining adequate system pressures during periods when water levels in the standpipe drop more than 30 to 40 feet.

4.2.4 Distribution Storage

Distribution storage facilities are connected directly to the distribution system and “float” on the hydraulic grade of the water system. These facilities can include ground storage reservoirs, standpipes or elevated water storage tanks. An exception to this would be Reservoir 115 (E.L. Nordness) which is considered distribution storage by utilized pumps to move water from the tank to the distribution system. This reservoir is filled from the distribution system during non-peak demand hours and pumped back into the distribution system during periods of high demand. This reservoir is often referred to as a “dump and re-pump” facility as water is dumped from the distribution system and then re-pumped back into the system. If the pumps at this facility were not in place, water could not be delivered to the distribution system by gravity flow as the other “floating” distribution storage tanks function.

4.3 Facility Numbering Sequence

Though the course of time, a numbering sequence has been developed by MWU and is used in this report to identify the various system components. The sequence starts with the well numbers and all facilities included at the site. For unit wells that service the same pressure zone, for example, Unit Well No.3, includes Well No.3, Booster Station No.3 and Reservoir No.3. Facilities that are sequenced in the 100’s are geographically remote from a Unit Well and provide an independent function. For example, Booster Station 126, which is located at Well No.26, pumps to fill the highpoint tower (126). Those facilities that would be next in line are numbered in the 200’s. An example of this would the Sprecher tower (225) which is served by Booster Station 125 and the nearest Unit Well (25). All Interzone pump stations are numbered in the 100’s and 200’s.A listing of existing MWU facilities and associated identification numbers are summarized in Table 4-2, along with their commonly used names where considered appropriate.

Table 4-2 – Facility Numbering Sequence

Well	Well Pressure Zone	Transferred to Zone via Booster Station	Zone Served via Tank
6	6w	Zone 7 via Station 106	Zone 6w via Tank 106
7	6e		
8	6e		
9	4		Zone 4 via Tank 9
11	6e		
12	7 & 8		
13	6e	Zone 5 via Station 213	Zone 5 via Tank 313 Zone 6e via Tank 113
14	6w		
15	6e	Zone 6e via Station 115 Zone 3 via Station 115 Zone 3 via Station 215	Zone 3 via Tank 315
16	8		
17	6w		
18	6w	Zone 7 via Station 118	
19	6w		
20	7	Zone 9 via Station 20	Zone 7 via Tank 20 Zone 9 via Tank 120
24	6w		
25	3		Zone 3 via Tank 225
26	8	Zone 10 via Station 26	Zone 8 via Tank 26 Zone 10 via Tank 126
27	6w		
28	8	Zone 11 via Station 128	Zone 11 via Tank 228
29	6e	Zone 3 via Station 129	Zone 6e via Tank 229
30	6w		
31	4		

4.4 Unit Wells

Table 4-3 provides information on the production capacity for the nineteen (19) unit wells, and three (3) independent deep wells. Well pump capacities provided in Table 4-3 are the listed outputs for the well pump, which signifies production capacity.

Table 4-3 – Unit Wells

Well Number	Service Zone	Flow Rate (gpm)	12-Hour Capacity (mgd)	24-Hour Capacity (mdg)
6	6w	2,400	1.73	3.46
7	6e	2,100	1.51	3.02
8	6e	1,800	1.30	2.59
9[1]	4	1,700	1.22	2.45
11	6e	2,000	1.44	2.88
12	7 & 8	2,400	1.73	3.46
13	6e	2,200	1.58	3.17
14	6w	2,400	1.73	3.46
15	6e	2,200	1.58	3.17
16	8	2,400	1.73	3.46
17	6w	1,800	1.30	2.59
18	6w	2,200	1.58	3.17
19	6w	2,100	1.51	3.02
20[1]	7	2,000	1.44	2.88
23	6e	Abandoned		
24	6w	2,100	1.51	3.02
25	3	2,200	1.58	3.17
26[1]	8	2,200	1.58	3.17
27	6w	2,200	1.58	3.17
28	8	2,200	1.58	3.17
29[2]	6e	1,200	0.84	1.74
30	6w	2,200	1.58	3.17
31	4	2,200	1.58	3.17

[1]Indicates Independent Deep Well – Water delivered directly to distribution

[2] Supply capacity from Well 29 is limited by the filter capacity

4.5 Interzone Booster Stations

Eight interzone Booster Stations transfer water from one pressure zone to another. Table 4-4 shows the combined capacities of the booster pumps at each of the interzone booster pumping stations.

Table 4-4 – Interzone Transfer Stations

Pumping Station Number	Suction Pressure Zone	Discharge Pressure Zone	Pump Configuration	Firm Pumping Capacity (gpm)	Firm Pumping Capacity (mgd)
106	6w	7	Two @ 3.0 mgd	2,100	3.0
213	6e	5	One @ .43 mgd One @ .72 mgd	300	0.43
115*	6e	6e	Two @ 3.0 mgd	2,100	3.0
115	6e	3	Two @ 3.0 mgd	2,100	3.0
118	6e	7	Three @ 1.4 mgd	1,950	2.8
120	7	9	Two @ 3.0 mgd	2,100	3.0
126	8	10	One @ 2.0 mgd One @ 3.0 mgd	1,390	2.0
128	8	11	Two @ 1.4 mgd	970	1.4
129	6e	3	Two @ 0.6 mgd Two @ 1.7 mgd	2,015	2.9
215	6e	3	One @ 1.3 mgd One @ 1.4 mgd	900	1.3

* Reservoir 115 has the capacity to pump to either Zone 6e or Zone 3 in its fill and repump mode.

4.6 Distribution Storage Facilities

Five elevated tanks, four ground level reservoirs and one standpipe provide distribution storage for the MWU. These facilities are noted in Table 4-5. All facilities provide “floating” storage for the system except for Reservoir 115 (E.L Nordness) which is a “dump/re-pump” facility. Booster capacity at Reservoir 115 consists of 2 pumps @ 2,100 gpm to Zone 6 east and 2 @ 2,100 gpm to Zone 3 for a total booster capacity of 5.0 mgd.

Table 4-5 – Distribution Storage Facilities

Tank Number	Pressure Zone	Volume (gallons)	Overflow Elevation (feet)
315	3	500,000	1137.6
225	3	500,000	1139.6
9	4	3,000,000	1046.5
313	5	300,000	1140.0
113	6e	1,032,000	1080.0
106	6w	6,000,000	1054.8
20	7	4,200,000	1170.6
120	9	100,000	1244.6
26	8	4,000,000	1200.0
126	10	250,000	1320.6
229	6e	6,000,000	1080.0
228	11	1,000,000	1300.0

4.7 Water System Schematic

The System Schematic of the Water System along with a color-coded map of the existing water system is included in the Chapter 4 Appendix

4.8 Madison Water Utility (MWU) Policy Review

The primary regulations and policies need to be followed by MWU are enforced by state of Wisconsin agencies or have been created by the Madison Water Board through the authority of the City of Madison.

4.8.1 State Regulating Agencies

Primary operations of MWU are regulated at the state level by the Department of Natural Resources (DNR) and the Public Service Commission of Wisconsin (PSC). MWU is required to meet the minimum drinking water quality standards and administrative code requirements for a municipal water utility as enforced by DNR. DNR conducts annual inspections and regularly scheduled sanitary surveys of all public water systems and utilities to ensure compliance with standards and code requirements.

PSC is also a state agency with regulatory authority over public water utilities. PSC has the authority to regulate rates, fee schedules, and other financial-related operations of MWU. Another primary function of PSC is to review and approve all major construction projects and other improvements requested by public water utilities, to ensure the improvements provide commensurate benefits to the utility’s ratepayers. MWU files an Annual Report to PSC every year by March 31st summarizing annual financial and operational data.

4.8.2 Madison Water Board Policies and MWU Service Goals

Pursuant to City of Madison General Ordinance 13.01 and subject to the authority of the Mayor and Common Council, the Madison Water Utility Board is charged with management and operation of MWU. All authority and accountability delegated by the Water Utility Board to the staff of MWU is delegated through the General Manager. MWU’s General Manager is accountable to the Board’s for MWU’s performance, achievement utility goals and objectives, and conduct in providing water utility services to City residents and businesses.

The Board’s primary policy goal for MWU operations states that “Madison Water Utility consumers receive an adequate quantity of high quality water for consumption and fire protection at a reasonable financial and environmental cost.”

4.8.2.1 Water Quantity

The Board’s policies include references to drinking water quality. MWU will provide current and future customers with water that meets or exceeds industry-accepted levels of service for fire protection and pressure.

Specifically, this is defined as:

- Water delivered to hydrants at proper flow rates for fire protection.
- Water delivered to the customer tap at a pressure that meets industry-accepted low, high, and emergency operation criteria.

Water used for outdoor irrigation under drought-free conditions.

4.8.2.2 Water Quality

Similar to water quantity, the Board’s policies include references to drinking water quality service goals. MWU consumers are to receive high quality water that meets or is better than all primary and secondary drinking water standards, including their public notification requirements, and complies with Board-adopted water quality goals.

The Board and MWU staff recognize that drinking water standards are subject to revision and that new compounds of concern may be identified in the future by the U.S. Environmental Protection Agency (EPA). Therefore, MWU maintains a “Watch List” of potential compounds of concern for each MWU unit well that are increasing and may approach the primary and secondary drinking water standards. MWU’s Watch List identifies which wells may require further action.

MWU provides information related to water quality via the Utility website at the following location:

https://www.cityofmadison.com/water/water-quality

4.8.2.3 Reliability

Public water utilities need to provide reliable service under all normal operating conditions. In general, MWU’s service reliability goals include that all City residents will receive water which is consistent in its availability and quality. In particular:

- Residents will experience minimal unplanned service interruptions.
- Residents will receive adequate notice of planned service interruptions.
- Residents will receive adequate notice of planned maintenance work that would significantly reduce water flow or pressure, and/or cause water discoloration.

4.8.2.4 Affordability

MWU’s operating policies also include statements about the cost of MWU service. It is an operating goal that Utility customers pay an affordable rate for water, which includes costs for financing of necessary replacement of water distribution plant and needed improvements to water treatment systems.

With a goal of maintaining affordable water rates, MWU has the following operating objectives:

- Maintain water rates between the 25th and 75th percentile for Class AB utilities (those serving 4,000 customers or more) in Wisconsin.
- Apply to PSC for any needed increase in revenue (i.e., rate increase) that does not exceed an annualized rate of 9 percent per year.
- Generate sufficient revenues to meet its PSC authorized return on MWU’s net investment rate base. By achieving this return, MWU will have sufficient revenue for reinvestment in system improvements, and continue to fund annual system operation and maintenance expenses.
- Strive to maintain water rates that will complement and support economic growth in the City of Madison.

4.8.2.5 Sustainability

Sustainable operations and stewardship of resources are included in MWU’s operating policies. MWU recognizes that City residents will benefit from a sustainably managed groundwater supply that ensures that water is available to protect public health, and to maintain and improve the economy and environment in Madison, now and in the future. To meet these objectives, MWU adheres to the following operating policies:

- Aquifers and wells are monitored and the data evaluated to identify trends in water levels and potential contaminants.
- Appropriate city, county, state and federal agencies will be called upon to enforce all pollution control and prevention measures within their authority to protect water quality in the wellhead protection area of each MWU unit well.
- MWU’s Conservation Plan is monitored and evaluated regarding progress to fulfill its goals.

The water supply system is monitored and expanded as needed so that the pumpage from individual unit wells does not exceed 50 percent of the annual rated capacity of the unit well.

4.9 Overview of Facility Operation

A key task of the Operation Evaluation for the Master Planning Study was the discussion of system operations with the four MWU operators who control the pumping operations of the supply facilities. MWU has four full-time OP2 system operators, who work 12-hour rotating shifts in the Utility SCADA system room on the second floor of the MWU Office. One of their primary job responsibilities is to monitor and control the operation of MWU's supply pumping facilities distributed throughout the system.

The OP2 Operators who were interviewed over a two day period on January 5-6, 2017 were:

- Dave Lynch OP2 for 32 years (33 years with MWU)
- Karmjit Singh OP2 for 30 years (30+ years with MWU)
- Tom Arneson OP2 for 10 years (25 years with MWU)
- Kara Jeffries OP2 since November 2016 (19 years with MWU)

The SEH team performing the operator interviews were:

- Patrick Planton, Randy Sanford and John Thom

Each interview lasted a duration of approximately two hours and covered a range of 10 topics, including:

- General System Operation Information
- Operation and Control of the Smaller West Side Pressure Zone Facilities
- Operation and Control of the Smaller East Side Pressure Zone Facilities
- Operation and Control of the Large Pressure Zones: 6E and 6W
- Normal System Operating Issues
- Season Operating Conditions
- Emergency Operations
- Unit Well Water Quality Issues on Operations
- System Alarms and Operator Response
- SCADA System Issues

The following sections briefly summarize the key findings and conclusions from the OP2 operator interviews conducted. A full summary of the responses to the 55 questions posed to the MWU system operation team is included in Appendix 4B.

4.9.1 General System Operation Information

The Madison water system is a large and complex system, and the schematic is included in Appendix 4B. The MWU water system is fully monitored by SCADA. Well pumps operate automatically according to the water level in the receiving reservoir. Booster pumps vary in control: some have variable frequency drives (VFDs) and some do not. Most booster pumps are operated "in-hand" manually by operators, except where booster pumps are programmed to maintain tank levels, such as Station 215 and Reservoir 315.

For many booster stations, operators have the ability to operate the booster pump from a selection of 2 or 3 different control arrangements (flow based, pressure based, fire flow). In all cases, the operators are in persistent awareness of the pressures and levels in the system.

The MWU staffs four operators, three of which have been operating the Madison water system for over 25 years. The supervision and judgement of these four operators is critical to the performance of the water system. The MWU issues directives to the operators on general system operation that all operators follow, but each operator has a slightly unique and subjective control strategy depending on the needs of them system during their shift (see Appendix 4B). Operators quickly make immediate and necessary changes when pressures suddenly drop due to main breaks or excessive demands.

Normally, the operators check the levels in the large reservoirs upon the start of their 12-hour shifts. Operators “pass the baton” from one to the next, informing the next operator of any concerns or matters arising pertinent to the next shift. After an operator starts his/her shift and understands how the system is behaving based on the previous operator’s decisions and advice, the operator will make his/her adjustments to the system based on the changing dynamics of the system. Normally, an operator will have in his/her mind the pumping stations that probably need to operate for the typical demands of that day, at that time of day, and in that season of the year.

4.9.2 Operation and Control of Smaller West Side Pressure Zones

4.9.2.1 Service Zone 7

Zone 7 contains two unit wells, one elevated reservoir, and two booster stations. Zone 7 floats on Reservoir 20. Zone 7 is mostly manually control, except for Unit Well 20. Unit Well 20 automatically maintains the level in Reservoir 20 when operating, otherwise Unit Well 12 is lead. Station 106 acts as a primary lag station behind the unit wells to draw additional supply from Zone 6W. Station 118 is used as a secondary lag station behind 106. Because Zone 7 serves Zone 9, supply quickly becomes a concern to the operators if one well is not operating properly.

4.9.2.2 Service Zone 8

Zone 9 contains three unit wells and one elevated reservoir. Zone 8 floats on Reservoir 26. Zone 8 is mostly manually control, except for Unit Well 26. Unit Well 26 automatically maintains the level in Reservoir 26 if operating. Unit Well 16 rotates with Unit Well 26 which also used as the primary lead unit well. Unit Well 28 is used as the lag unit well behind Unit Wells 16 and 26. Because Zone 8 serves Zones 10 and 11, supply quickly becomes a concern to the operators if one well is not operating properly. However, in the near future, Unit Well 12 will be incorporated with Zone 8.

4.9.2.3 Service Zone 9

Zone 9 contains one booster station and one elevated reservoir. Zone 9 floats on Reservoir 120. Zone 9 is self-operating. Station 120 automatically maintains the level in Reservoir 120 by drawing water from Zone 7.

4.9.2.4 Service Zone 10

Zone 10 contains one booster station and one elevated reservoir. Zone 10 floats on Reservoir 126. Zone 10 is self-operating. Station 126 automatically maintains the level in Reservoir 126 by drawing water from Zone 8. Zone 11 will be integrated into Zone 10 in the near future.

4.9.2.5 Service Zone 11

Zone 11 contains one booster station and no elevated reservoirs. Zone 11 is self-operating. Station 128 maintains pressure and flow into Zone 11 by drawing water from Zone 8. Zone 11 will be combined with Zone 10 in the near future and retired from service. New Reservoir 228 will be constructed in 2017 with an altitude valve.

4.9.3 Operation and Control of Smaller East Side Pressure Zones

4.9.3.1 Service Zone 3

Zone 3 contains one unit well, two elevated reservoirs, and three booster stations. Zone 3 floats on Reservoirs 225 and 315. Zone 3 is a combination of manual and automatic control. Unit Well 25 is the primary source for Zone 3, with Stations 115 High, 129, and 215 supplement from Zone 6E. Unit Well 25 booster pumps are operated to maintain the water level in Reservoir 225. Station 115 High booster pumps are operated to maintain the water level in Reservoir 315, drawing water from Reservoir 115. Operators may operate Stations 129 and 215 to supplement flow. Station 125 is permanently offline.

4.9.3.2 Service Zone 4

Zone 4 contains one well and one elevated reservoir. Zone 4 floats on Reservoir 9. Zone 4 is self-operating. Unit Well 9 currently is the only source in Zone 4 until Unit Well 31 is constructed. Well 9 automatically maintains the level in Reservoir 9. Booster 9 is used for emergency pumping only and is generally not operated.

4.9.3.3 Service Zone 5

Zone 5 contains one booster station and one elevated reservoir. Zone 5 floats on Reservoir 313. Zone 5 is self-operating. Station 213 automatically maintains the level in Reservoir 313 with water drawn from Zone 6E.

4.9.4 Operation and Control of Large Pressure Zone 6E

Zone 6E contains seven unit wells and two elevated reservoirs. Zone 6E is manually controlled, and all unit well booster pumps are operated by operators according to a number of control arrangements. Based on water quality, some unit wells are operated throughout the year and others seasonally. Unit Wells 7, 15, and 29 are lead unit wells. Unit Well 29 normally operates 24 hours per day at half capacity. The Utility may plan to operate Unit Well 7 similarly to Unit Well 29 in the near future. Unit Wells 11 and 13 serve as lag stations year-round. Unit Wells 8 and 23 are seasonal lag stations and are less preferred to operate than Unit Wells 11 and 13.

Zone 6E floats on Reservoirs 229 and 113. In addition to the elevated storage and unit well storage, operators can use 115 as storage for Zone 6E. While the primary purpose of 115 is fire protection, the operators use 115 as a means to balance supply and demand throughout the day. Water is typically dispensed from Zone 6E into Reservoir 115 at night. Additional daytime supply is provided through Station 115 low during the day from Reservoir 115. MWU to provide fill and pump times. 115 low acts as fire protection.

4.9.5 Operation and Control of Large Pressure Zone 6W

Zone 6W contains eight unit wells and one elevated reservoir. Zone 6W floats on Reservoir 106. Zone 6W is manually controlled, and all unit well booster pumps are operated by operators according a number of control arrangements. Based on water quality, some unit wells are operated throughout the year and others seasonally. Unit Wells 14, 18, 19, 24, 30 are lead unit wells. Unit Wells 14 and 30 are typically operated 24 hours per day throughout the year. Unit Wells 6, 17 and 27 are typically operated as lag unit wells, with Unit Wells 17 and 27 operated seasonally. When Unit Well 17 is online during the summer, Unit Well 17 is a lead unit well while Unit Well 24 is a lag unit well.

4.9.6 Normal System Operating Issues

The Madison Water system is large and complex and inherently contains some issues in day to day operation. Some of these issues are summarized in this section.

Station 118 is normally not used by operators, and is used only if required for system sustainability. Operators and staff have observed main breaks occur in Zone 7 while Station 118 operates. Station 118 exists in a low area with discharge pressures exceeding 100 psi.

Unit Well 20 supplies Zone 7 while the Unit Well 20 booster pumps (Station 120) serve Zone 9. Pressure surges have been observed by operators and staff under certain conditions at Station 120. As described by the Utility, the pressure surges occur in the scenario while Zone 7 has several pumping stations operating (i.e. 106, 118 and/or Unit Well 12) and Station 120 shuts down.

Unit Well 13 historically has been a favored well by operators as a lead well in Zone 6E. However, with the construction of new Reservoir 113, Unit Well 13 is no longer operated as substantially as in the past. Operators have observed a tendency of Reservoir 113 to overflow while Unit Well 13 is operating.

4.9.7 Seasonal Operating Conditions

The MWU operates the system differently from season to season. Demands in the summer can be almost double the demands in the winter, thus more supply is needed in the summer than in the winter. Unit Wells 8, 17, 23, 27 and 28 are seasonal wells, meaning they are generally off during the winter. The remaining unit wells are generally used in all seasons, some continuously and some as-needed.

Unit Wells 7 and 29 in Zone 6E and Unit Wells 14 and 30 in Zone 6W continuously pump all hours of the day throughout the year, except during maintenance. Normally, Unit Wells 13 and 15 lag in Zone 6E, then followed by the other wells in Zone 6E. Likewise, Unit Well 19 lags in Zone 6W, then followed by the other wells in Zone 6W.

Unit Well 9 in Zone 4 continuously cycles the level in Reservoir 9 throughout the year. Unit Well 20 in Zone 7 continuously cycles the level in Reservoir 20 throughout the year. Unit Well 26 in Zone 8 continuously cycles the level in Reservoir 26 throughout the year. Unit Well 25 in Zone 3 continuously cycles the level in Reservoir 225 throughout the year.

4.9.8 Emergency Operations

The Madison water system, as with all large systems, has many opportunities for emergency situations to arise, and the operators and staff must be immediately able to respond. The Madison Water system is always supervised by a trained and qualified operator. Typical types of emergencies include: power outage, fire, water main break, chlorine residual loss, and pump failure.

The operators mentioned a concern regarding the scarcity of supply in the western smaller zones: Zones 7, 8, 9, 10 and 11. Historically, when a unit well is offline due to maintenance or failure in either Zone 7 or Zone 8, the western smaller zones become difficult to maintain supply in. The western smaller zones are comparable in service area to Zone 6W. Zone 6W contains eight until wells, while the western smaller zones contain a total of five unit wells. Per the water system schematic, Zone 6E is able to supplement Zone 7 through 106 and 118. Zone 7 completely supplies Zone 9 through 120. Zone 8 completely supplies Zone 10 through 126 and Zone 11 through 128. The future update to the Unit Well 12 will interconnect Zone 7 with Zone 8 and will convert Unit Well 12 into a two zone well.

The Madison water system over time has been developed with much redundancy and factors of safety. However, some facilities may lack redundancy to some degree. For instance, Unit Wells 6, 8, 11, 13, 14, 15, 23 have only one booster pump, and not a redundant pump. Thus, if a booster pump fails, the entire unit well site is offline.

4.9.9 Unit Well Water Quality Issues on Operations

This section provides a synopsis of the water quality in the various water supply wells and identifies the wells that may be at risk for water quality restrictions. Information related to wells with deficient water quality will help inform future water system improvement decisions. The wells with listed water quality concerns are included in the comprehensive water system deficiency list which is introduced in Chapter 3 of the master plan.

4.9.9.1 Wells with Good Water Quality

The following unit well facilities are generally considered to have good water quality that is either inherent in the well water quality or enhanced via water treatment processes:

1. Unit Well 7 post treatment
2. Unit Well 12
3. Unit Well 13
4. Unit Well 16 – potential of sodium & chloride issues in long term.
5. Unit Well 20
6. Unit Well 25
7. Unit Well 26
8. Unit Well 29 post treatment

4.9.9.2 Wells under close surveillance

The following unit well facilities exhibit water quality traits that are less than desirable. As such they are monitored closely, some may require treatment in the future:

1. Unit Well 6 – History of VOC's that could require treatment at some point in the future.
2. Unit Well 8 – Elevated iron and manganese. VOC contamination is possible due to proximity to point source. Treatment is planned in the future.
3. Unit Well 9 – History of VOC's that could require treatment at some point in the future.
4. Unit Well 11 - History of VOC's that could require treatment at some point in the future.
5. Unit Well 14 – Concerns with high sodium and chloride due to road salt; high probability of exceedance if mitigation is not provided. Contains 1,4 dioxane.
6. Unit Well 15 – Has an air stripper to remove VOC's; Air stripping is not mitigating the PFSA's and 1,4 dioxane present.
7. Unit Well 17 – History of iron and manganese; has difficulty maintaining disinfectant residual.
8. Unit Well 18 – History of VOC's that could require treatment at some point in the future.
9. Unit Well 19 – History of radium, iron and manganese; future treatment is planned.
10. Unit Well 23 – History of elevated iron and manganese that result in colored water complaints; also contains elevated sodium and chloride. Planned to be abandoned in the near future.
11. Unit Well 24 – History of radium, iron and manganese; poor quality
12. Unit Well 27 – History of iron, manganese and radium that could require treatment in the future. Radium levels pose a moderate probability of exceedance.
13. Unit Well 28 – History of elevated iron and manganese that result in colored water complaints; may require treatment in the future.
14. Unit Well 30 – History of elevated iron and manganese; treatment is planned in the future.

4.9.10 System Alarms and Operator Responses

The SCADA system allows operators to monitor and control facilities remotely. However, issues have been discovered over time in how pumps respond during communication failures. When the communications to a facility fails, operators reported that the facilities may continue to run in manual mode if last set in manual mode. Thus, a pumping station may not shut down to prevent over-pressure or overflow of a tank during a communication failure. Likewise, operators reported communication failures may cause pumps that are off to remain off, thus potentially not providing enough supply to the system.

Chlorine residual is an essential part of the Madison water system, as chlorine residual protects the customers from the spread of water-borne illness. Operators reported that is if the chlorine injection rate at a unit well drops below 0.2 ppm, the unit well will shut down and send an alarm. Operators mentioned that chemical alarms are among the most urgent types of alarms.

The operators indicated a concern regarding the number of alarms in the system. Some alarms, like tank or pit temperature are much less critical than chemical alarms, intrusion alarms, overflow alarms, and pump failure alarms. An issue the MWU faces is the use of many alarms in the system and there is potential for optimizing the use of alarms more strategically.

The MWU staff suggested the need for suction pressure lockouts on interzone booster stations. Suction pressure on booster stations should be maintained so that all service connections in the upstream zone are 35 psi or higher in pressure. Over-pumping through a booster station from a service zone would cause suction pressure to fall below NR 811 limits. Likewise, over-pressure lockouts could help prevent main breaks and protect customers from pressures exceeding 100 psi per NR 811, such as at Station 118.

4.9.11 SCADA System Issues

During a field review and from discussions with MWU staff and operators, needs for the SCADA system were discussed, which are listed below:

1. Add a virtual switch and event log to monitor who operated SCADA and what changes were made during the shift. This increases accountability and record keeping.
2. Install a large central SCADA screen at the main office of the operators to see all system parameters simultaneously. A central screen would require a more map integrated view of the system showing all pertinent information spatially.
3. Site connected by fiber should be completely split from sites connected by radio.
4. Radio sites may struggle with blocked signals due to leaves.
5. Reduce number of alarms.
6. Include an interactive SCADA & GIS overall system map showing all facilities and that would give some guidance to the operating regarding past history & criticality of the facility.

4.10 MWU SCADA System

The MWU owns and operates a robust SCADA network, overseeing all facilities in the water system. In general, operators are able to view and operate all wells, booster pumps, chemical systems, return-flow valves, VFD settings, and treatment operations from the central SCADA computer. Data for all facilities is recorded in one minute intervals and is permanently stored in a database owned by the Utility. Historical data can be queried to see all discrete and analog signals recorded by the SCADA network.

The SCADA records 1,407 analog signals and 61 discrete signals. Examples of analog signals include tank levels, station discharge pressure, station flow rate, well flow rate, return-flow rate, chemical injection, and pump speed. Examples of discrete signals include pump on/off signals, altitude valve open/close signals, and return flow open/close signals.

MWU provided a complete export of all historical SCADA data in the system on 5-minute intervals for the period of 7/11/2016 to 7/17/2016. SEH processes and separated the data to be either imported into the water model or compared with the water model results. Pump speed patterns and SCADA diurnal demand patterns were imported into the water model. Tank levels, station discharge pressures, and station flow rates were compared graphically against the outputs of the water model, with an error tolerance of 10 percent. Calibration parameters and results are further discussed in the Calibration Verification memo in Task 2.

4.11 MWU Water Conservation Program

Madison Water Utility developed a water conservation plan in 2007 in a close relationship with the City and citizens. The goal of the conservation plan was to strategize water reduction while increasing customer participation and appreciation for diminishing groundwater tables.

Since the implementation of the conservation plan in 2007, the Utility has observed multiple changes in the City's water use. Some factors were directly related to action items in the conservation plan and others were not related to the conservation plan. The City website provides an online tool to help customers estimate potential water use reductions, and some customers have utilized that tool. Other customers have taken advantage of rebate programs for high efficiency appliances and toilets. Some water use reduction has been due to climate differences from year to year. Other water use reduction has been due to reduction in population density in single family homes to an all-time low of 2.0 persons per home. As time progressed, the Utility has observed less interest in highly watered green lawns as compared to 10 – 20 years ago.

MWU up to this report planned to reduce residential sales to 58 gallons per capita per day (gpcd) by year 2020. MWU has been seeking to incorporate commercial and industrial water conservation and/or water audits.

Updated water conservation assumptions will be included in future water needs planning. Three different water use rates (low, medium and high) will be used to project three different water needs projections across a range of population growth rates. Conservation and population growth are further discussed in Chapter 3.

4.12 Design Guideline Criteria (Level of Service Memo Update)

The Design Guideline Criteria memo (formerly called the Level of Service memo) has been developed to document criteria for evaluating the performance of existing facilities and for designing future facilities. This criteria is a combination of regulations established by the Wisconsin Department of Natural Resources (DNR), Madison Water Utility (MWU) service level goals, and industry standards.

Often the DNR establishes a minimum level of service, which is exceeded by MWU goals. The Design Guideline Criteria memo contains general guidelines, provides a framework in which to evaluate the performance of the existing system, and provides a framework to evaluate recommended facilities to serve future growth or changes in the distribution system. These recommendations were originally developed for the Madison Water Utility by Black & Veatch Corporation in 2011. This update reviews previous recommendations and expands upon them.

Topics the Level of Service Memo addresses include:

- Unit Well Capacity
- Regulatory Issues
- Pressure
- Energy Management
- Pipelines
- Emergency Response
- Booster Station Capacity
- Finances
- Storage Capacity
- Customer Service
- Fire Protection
- Provisions for Growth
- Water Quality
- Redundancy and Reliability

The full Design Guideline Criteria Memo can be found in Appendix 6-A.

4.13 Criticality of Facilities

Madison Water Utility operates multiple water system facilities, as previously discuss. Each facility carries some degree of importance and criticality to the water system.

The criticality of each facility can be characterized using the following three questions:

1. What is the consequence of failure?
2. What means and methods can be used to offset the failure?
3. What administrative or maintenance practices can be used to prevent the failure?

As MWU grows with the community and maintains its growing water system, a careful balance of needs versus revenues must be carried out.

4.14 Utility Finances

Part of maintaining a water system is handling finances. MWU serves water to approximately 68,600 customers. Each customer is metered and billed. In 2018, MWU received approximately $35 million in revenue from its customers. This pool of revenue is carefully and responsibly divided among the various needs of the water system to maintain the water system and protect public health.

Due to PSC requirements, MWU has used “debut financing” to finance capital improvements for decades. As the capital improvement program has ramped up to replace and renew aging infrastructure, the debt load has grown. The PSC and MWU are concerned with this growing debt load and have reduced capital spending and are investigating other project financing options. Pay as you go financing or expense depreciation may be an option for future project financing. Balancing raising rates with water affordability will be required for the capital improvement program to remain sustainable.

A more recent financial plan was developed which in turn helped to inform the current iteration of the Capital Improvement Plan, Included in Appendix 8A

4.15 Capital Improvements Planning (CIP)

With the growth of a water system comes a growth in water needs, which poses a need to construct facilities as appropriate. As time passes, facilities age and require maintenance, and after enough time may require complete replacement.

Planning for water system capital improvements for a water system requires prudent engineering practice, defensible projections of need, and a thorough understanding of the nature of the existing water system. This Master Plan Update provides the necessary framework to update the existing capital improvements plan.

A capital improvements plan considers facilities and the water main pipe network. A proper CIP balances maintenance and new construction, and efficiently constructs facilities in a manner than tracks with the expansion of the water system and connecting new customers. Service to existing customer must also be maintained, which requires water main rehabilitations and replacements. Some water main replacements are necessary to accommodate new facilities.

Appendix 8A includes the 10-year Capital Improvement Plan which was developed in 2023.

4.16 Technology Upgrades

Each facility in the water system is controlled by a control panel which was constructed with the technology at the time of construction. Technology changes from year to year, and the computer control and telemetry of facilities is often outdated faster than the facility itself. Thus, it is necessary to budget for technology improvements on top of the capital improvements plan.

Chapter 5

Water Model Update & Development

5 Water Model Update

The computer model is a powerful tool that can simulate water system operation with significant accuracy and reliability. Scenarios are developed using a mass balance approach and then tested using the water system computer model. This approach will save time and effort and allow multiple scenarios to be considered but only a few will require fill analysis.

MWU developed a model of its own system in the late 90's and has been updating and recalibrating it over the past 20 years. During the past two decades modeling technology has improved and expanded. The MWU system model was recalibrated for this water master plan using AMI data and asset information from the existing GIS database. This methodology will provide the most up to date evaluation of proposed alternative possible.

5.1 Model Background

MWU invested in a Water Master Plan, dated December 2008 (2008 Water Master Plan), which included updating and calibrating the MWU's water model. In 2012, MWU invested in updating the master plan and water model to focus on changes to the east side of the water system. Changes including splitting Zone 6 into Zone 6e and 6w, and also merging Zones 1, 2 and 3 into new Zone 3. The water model was generally updated on the east side to year 2012.

SEH was provided the water model from the 2012 update which included various small updates since 2012. The pipes in the model on the west side were from 2005 and required an update. See "Existing 2016 Madison Water Model Audit" memo dated November 9, 2016 in Appendix 5B. Facilities were reviewed and documented in the "Review of Madison Water Facilities in Model" dated December 5, 2016 in Appendix 5B.

After the preliminary water model audit, SEH collaborated with the Utility and began to make changes to the water model. Changes to the water model are concisely listed in "Madison Water Model Changes" memo dated May 22, 2017 in Appendix 5D.

5.2 Model Update with AMI Data

MWU completed the installation of an AMI system in 2014 and has complete customer water demand available for the 2018 Master Plan Update. Six representative days between 2014 and 2016 were selected by SEH and approved by MWU, and these six days are listed in Table 1. MWU provided the following datasets in Access format:

- AccountExtract – 11/3/2016 – Superseded by CISDataExtract2 – 3/17/2017
- BillingExtract – 11/3/2016
- IntervalReads – One for each date – hourly volumes for each meter = 1.6 million rows
- RegisterReads – 11/3/2017 – One total volume for each meter = 66,000 rows
- qryRegReads2016 – One text files for each month in 2016 containing register reads for each meter each day

Table 5-1 – AMI Representative Day Diurnal Peak Factors

Date	Represents	Day of Week	Peak Ratio (MH:AH)	Minimum Ratio (MinH:AH)	Total Sales (mg)
2/25/2016	AWD (Weekday)	Thursday	1.53	0.48	22.40
2/27/2016	AWD (Weekend)	Saturday	1.55	0.45	21.78
6/15/2016	ASD (Weekday)	Wednesday	1.41	0.29	24.96
6/18/2015	ASD (Weekend)	Saturday	1.39	0.54	25.50
7/27/2014	Maximum Day	Sunday	1.38	0.61	26.80
7/14/2016	Calibration Day (Macro)	Friday	1.32	0.60	28.83

AH: Average hourly demand of that particular day, or total demand divided by 24

MH: Maximum hour of that particular day

MinH: Minimum hour of that particular day

Data was processed in Access. The coordinates of Parcel centroids were calculated and paired to each meter (C_RemoteID) based on the parcel number (C_RollNumber) in CISDataExtract2. Based on the parcel centroids, all meters were brought into GIS and were assigned their corresponding service zone based on the service zones in the GIS provided by MWU. A final table (WaterMetersZones) was exported that included the meter number (C_Remote), parcel number (C_RollNumber), X coordinate (XCoord), Y coordinate (YCoord), meter type (C_Service), Service Zone (Pressure_Zone), meter customer type (C_Accounttype), and converted meter number (Meter_ID). WaterMetersZones was paired with each IntervalReads table and macro-processed to generate service zone diurnal curves and point demands. Meters containing a C_Service of 40 and 41 were reported to be storm and sanitary deduct meters and were removed from processing.

July 14, 2016 (20160714) was the calibration day and was selected for maximum day pumpage. Point demands for 20160714 were imported into the model and spatially assigned to nodes based on closest pipe proximity and distance weighted distribution to nodes. System-wide, 28.83 million gallons of sold water were assigned to the system, (19,700 gpm), distributed between each service zone as delineated in GIS. Because this volume only accounts for AMI metered sales as interpreted by SEH and not total pumpage, SCADA data was consulted for total pumpage.

5.3 Model Update with SCADA Data

MWU provided 5-minute data for all signals in its SCADA system for the period of 7/11/2016 to 7/17/2016. Data for 7/14/2017 was specifically used for macro-calibration. Following the updated water system schematic, tank volume curves, tank levels, and pumping station flow rates, 5-minute diurnal curves were generated for each service zone along with total pumpage through the service zone. AMI sales distribution was uniformly scaled in each service zone to match total pumpage, according to the ratio (Total Pumpage / AMI sales) of each service zone. For all service zones, except Zone 6w and Zone 3, the diurnal curve for the service zone matched the diurnal curve calculated from SCADA.

Service Zone 6w and Zone 3 had unique circumstances in calibration. Zone 6w experienced a very large main break at 2200 Fish Hatchery Road on the order of 8,000 gpm lasting for 2 hours. This was measured by comparing the SCADA diurnal curve to the AMI diurnal curve for the service zone. MWU confirmed the large main break.

Zone 3 is the only zone with two floating tanks. Unit Well 25 was offline for maintenance during the calibration day of 7/14/2016. Booster 129 and 125 do not have flow meters nor have flow meter data in the SCADA. Booster 125 was permanently shut down in 2010 when a zone boundary revision was completed. However, in the 2016pmp.xls rounder data, the hidden 125 tab showed pump operation during the period when which Unit Well 25 was being serviced. Thus, on the calibration day, the flow rates of 129 and 125 were not known, nor was the operation of 125 known.

5.3.1 Control Data

Controls were imported from historical 5-minute SCADA data and from controls shown in Appendix 5B "Madison Water Utility SCADA Screen Shots 01-05-2017" except where historical SCADA data recorded otherwise. All reservoirs were assigned an initial level equal to the level in the SCADA at midnight 7/14/2016, except Reservoir 113 which was out of service. All well pumps were set up to maintain the level of the receiving reservoir as in the control screenshots, except Unit Well 25 which was out of service. All booster pumps were operated at the speeds recorded in the SCADA in 5 minute intervals throughout the 24 hour period. Exceptions are Stations 113, 125, 128, and 29. Station 113 and 125 did not have historical SCADA data available. Station 128 was set to maintain a fixed pressure similarly to the historical settings, but did not account for pump switchovers. Station 129 did not have historical data on flow. Station 29 was operated in a manual fashion which did not match the recorded speed data available, so the pumping rate of booster 29 was set to match the historical flow rate as a VFD.

5.4 Macro Verification Calibration (EPS Simulations)

EPS calibration methods include comparisons of model results to measurements made in the field over time. An EPS calibration often involves the simulation of a water system over a selected 24-hour period. Depending on the goals set forth by the project team, a longer period may be selected so that both weekday and weekend demands can be accounted for. For the period selected, it is generally desired to have high demands occurring on the water system so that system facilities are stressed and noticeable pressure drops and high flows can be observed and then eventually simulated in the model. For an EPS model to track with real-world data, representation of existing water system operational procedures and controls would be included in the model. A description of the Macro Calibration process that was conducted for the MWU model is summarized below

5.4.1 Macro Calibration Results

Macro-calibration results are shown graphically and by maps for each service zone in Appendix 5E. Model results are compared to SCADA field measurements with 10-percent error bars for comparison. Where unique circumstances occurred, discussion is provided below.

Unit Well 6: The existing high service pump curve in the model appeared flat, as the model oscillated flow rate rather drastically as the curve was operating to the left. SEH adjusted the pump curve to stabilize the pumping rate, and this is justified in the fact that the VFD speed ratio was fixed according to SCADA with a stable flow rate. The reduction from 97.7 percent to 91.7 percent in VFD speed in the field caused a reduction in flow rate from 2,500 gpm to 2,000 gpm, indicating a flat pump curve. The pump curve was raised 10 feet uniformly to match the flow rate of the SCADA. Based on the reservoir floor elevation in the model, the pumps were raised to an elevation of 885 feet.

Booster 106: The field measurements recorded a 50 percent decrease in flow rate when the pump speed operated at approximately 80 percent. SEH believed this to mean the left side of the pump curve reduced by approximately 12 feet while the right side remained constant, indicating a counterclockwise tilt from the original pump curve.

Unit Well 11: Unit Well 11 tank level was matched to field conditions. To bring the pumping rate in agreement with the field measurements, the pump curve was raised 10 feet uniformly.

Unit Well 12: Unit well 12 ran too high of a flow rate, and reducing the pump (or speed ratio) corrected this. The pump curve was reduced by 24 feet uniformly. Unit Well 12 is being replace in the near future with new piping and high service pumps. The pressure zone boundaries will be changed by the Utility. Thus, the calibration of this facility will soon become obsolete.

Unit Well 13: Ground elevation is approximately 861 feet. The pumps were raised to an elevation of 865 feet.

Unit Well 14: Existing booster pump curve operated 15-20 percent higher than actual flow rate. Discharge pressure was also high, indicating the pump was too powerful (or too high of a speed) as compared to the field. SCADA screenshots do not indicate a VFD, nor does the SCADA historian data. Pump curve was reduced by 20 feet uniformly.

Several short 12-inch segments were found along the 20-inch main to tank 106. C-factors were previously 90 and were raised to 120 on the segments near the tank where bottlenecking was occurring. This bottlenecking through multiple short 12-inch segment affected Units Wells 6, 14, and 27.

Unit Well 15: The field measurements were drastically different than the model in this facility. A new pump curve was developed based on field data, as the model pump curve was not able to push water at the field measured flowrate and discharge pressure.

Booster 115 Low: The pump curve was pushing faster against less head than the field measurement. The field measured 2200 gpm against 33 psi, while the model showed 2400 gpm against 30 psi. C-Factors immediately downstream of the booster station were reduced to 90 from 130 and the pump curve was reduced by 10 feet.

Booster 215: The model included a design point but not pump curve. By tilting the curve around the design point, the pump calibrated.

Unit Well 16: C-factors were slightly adjusted to help the model produce less back pressure. While the model is within 10 percent, this station is running low on flow rate and high on back pressure in the model compared to the field. Other wells in Zone 6w were experiencing this, but C-factors alone would not assist with maximum day velocities being less than 5 fps.

Zone 6w: A main break was discovered in Zone 6w and was discussed above.

Unit Well 27: Required lift was 180 feet and the downstream head was approximately equal to the rest of the service zone. Pump 1 curve was too low and pump 2 curve was too high. No speed values were provided for this station, thus Pump 2 was assumed to operate at a fixed reduce speed when operating.

Zone 3: Small pumps were assumed to be operating in 129. 125 was temporarily online during Well 25 maintenance, but no SCADA data existed for 125. Neither 125 nor 129 contained flow meters. Pumps 3 and 4 operated 7.5 and 6.8 hours on 7/14/2016, but the times and flow rates were unknown. The model had a tendency to overflow tank 315 and not fill 225 unless station 125 was operating. Zone 3 was considered calibrated to the extent of historical information available to SEH. The complexity of all iterations of potential pump operating times and lack of flow rates made calibration of Zone 3 difficult. With 125 offline in all future scenarios and with the addition of the 315 altitude valve, model scenarios in Zone 3 should be generally reasonable, with the exception of no flow meter in 129 to fully check mass balance.

5.5 Micro Calibration (Steady State)

Steady state micro calibration/verification efforts are based on simulation of historical conditions and represents a snapshot of the water while experiencing a particular set of system conditions. The utilization of fire flow tests in steady-state calibration is to replicate a set of induced high flows generated from open and flowing hydrants. For this process it is important to induce significant head loss along the pipes being tested that can be replicated in the model.

5.5.1 Micro Calibration Results

Historical flow tests were provided by MWU showing location, static pressure, residual pressure, and flow rate. Boundary conditions were not provided; thus this information was calibrated with that limitation. For all tests, a fixed average summer day demand based on 6/18/2015 was applied to the system with no diurnal curves (17,411 gpm = 25.07 mgd). All tanks were assumed five feet below overflow.

Three scenarios were tested, low pumping, medium pumping, and high pumping, each with an increasing number of pumping units operating in the system. Low pumping tests the system hydraulics merely against the overflow elevations of the tanks, medium pumping tests the system with the typical wells and booster operating, and high pumping test the system with a large number of pumps and wells operating.

With the base assumptions, 49 of the 58 chosen historical flow tests had less than 10 percent difference between the field static pressure and model static pressure. Of the remaining nine flow tests, seven had less than 13 percent difference between the field static pressure and model static pressure. Two tests were 20 percent and 33 percent different, believed due to pump operating.

Of the 58 tests, 46 tests found agreement within 10 percent in at least one of the three scenarios with assumed boundary conditions (low, medium and high pumping with all tanks 5 feet down). This quick check on the historical flow test without the exact boundary conditions of each still provided a meaningful check to the validity of the model as a whole going forward. Elevations are based on 2-foot LIDAR elevation data and overflow elevation are known. Thus, static pressures of existing and future service area can be well predicted. Virtually all pump curves were tested during macro calibration, and site-specific boundary conditions can be addressed if needed by the Utility.