



Chapter 8 Storage Analysis

2020 City of Billings Water Master Plan
(Draft)

City of Billings, MT



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Introduction

The City of Billings water system includes 18 reservoirs. The Heights Water District (HWD) has three reservoirs that serve their water system which is Zone 2E. Summary descriptions and locations of the City’s reservoirs were provided shown in Chapter 2, while the criteria for evaluating the adequacy of storage was presented in Chapter 4. The focus of this chapter is to document the analysis of the existing storage reservoirs’ ability to meet the prescribed performance criteria and to provide supporting recommendations for additional storage needs if required. Potential sites for recommended reservoirs are then hydraulically analyzed in the water model.

Storage Analysis

The criteria established in Chapter 4 was used in conjunction with the demand projections by pressure zone in Chapter 3 to calculate the storage requirements for each pressure zone. These requirements are summarized by criteria and pressure zone in Tables 8-1 through 8-3. Table 8-1 is based on current demand; Table 8-2 is based on the 2030 demand projections and Table 8-3 is based on the 2040 projections. All storage requirements are summed together to get the total storage requirements in a specific zone when that zone is under stress from a fire flow demand condition. The storage requirements excluding the fire storage needs are also summed together and are presented in the last column of the supporting tables. This total represents the storage requirements in each zone during normal operating conditions and absent of a fire flow demand in the zone.

Table 8-1. Current Storage Available and Requirements

Pressure Zone	Total Storage Volume (MG)	Total Effective Storage Volume (MG)	Operational Storage (MG)	Fire Storage (MG)	Emergency Storage (MG)	Total Storage Required (MG)	Total Storage Required Without Fire (MG)	Excess Storage Without Fire (MG)
Ex. WTP	10.4	5.2 ^a						5.20
Zone 1	6.25	3.81 ^b	2.31	0.63	7.69	10.63	10.00	(6.18)
Zone 2	9.0	9.0	1.31	0.63	4.37	6.30	5.67	3.33
Zone 2E	8.0	8.0	1.07	0.63	3.55	5.25	4.62	3.39
Zone 3	7.5	7.5	1.37	0.63	4.56	6.56	5.93	1.57
Zone 3E	4.0	4.0	0.34	0.30	1.15	1.79	1.49	2.51
Zone 3S	0.06	0.06	0.01	0.30	0.02	0.33	0.03	0.03
Zone 4	2.25	2.25	0.66	0.30	2.19	3.14	2.84	(0.59)
Zone 4E ^c								
Zone 4N			0.06	0.18	0.21	0.45	0.27	(0.27)
Zone 4S	0.75	0.75	0.06	0.30	0.22	0.58	0.28	0.47
Zone 5	0.10	0.10	0.03	0.63	0.12	0.78	0.15	(0.05)
Zone 5W			0.03	0.18	0.10	0.31	0.13	(0.13)

Table 8-1. Current Storage Available and Requirements

Pressure Zone	Total Storage Volume (MG)	Total Effective Storage Volume (MG)	Operational Storage (MG)	Fire Storage (MG)	Emergency Storage (MG)	Total Storage Required (MG)	Total Storage Required Without Fire (MG)	Excess Storage Without Fire (MG)
Zone 6			0.05	0.30	0.15	0.50	0.20	(0.20)

Notes

^a The clearwells remain half full for CT and pump requirements

^b For Willett Reservoir only 20% of the volume is usable

^c Zone 4E is combined with Zone 3E for the storage evaluation

Table 8-2. 2030 Storage Available and Requirements

Pressure Zone	Total Storage Volume (MG)	Total Effective Storage Volume (MG)	Operational Storage (MG)	Fire Storage (MG)	Emergency Storage (MG)	Total Storage Required (MG)	Total Storage Required Without Fire (MG)	Excess Storage Without Fire (MG)
WEWTP ^d	2.0	1.0						1.00
Ex. WTP	10.4	5.2 ^a						5.20
Zone 1	6.25	3.81 ^b	2.37	0.63	7.91	10.91	10.28	(6.47)
Zone 2	9.0	9.0	1.63	0.63	5.43	7.68	7.05	1.95
Zone 2E	8.0	8.0	1.32	0.63	4.41	6.36	5.73	2.27
Zone 3	7.5	7.5	1.73	0.63	5.75	8.11	7.48	0.03
Zone 3E	4.0	4.0	0.41	0.30	1.37	2.07	1.77	2.23
Zone 3S	0.06	0.06	0.01	0.30	0.02	0.33	0.03	0.03
Zone 4	2.25	2.25	0.81	0.30	2.71	3.82	3.52	(1.27)
Zone 4E ^c								
Zone 4N			0.16	0.18	0.55	0.89	0.71	(0.71)
Zone 4S	0.75	0.75	0.07	0.30	0.23	0.59	0.29	0.46
Zone 5	0.10	0.10	0.04	0.63	0.12	0.79	0.16	(0.06)
Zone 5W			0.03	0.18	0.11	0.32	0.14	(0.14)
Zone 6			0.05	0.30	0.16	0.51	0.21	(0.21)

Notes

^a The clearwells remain half full for CT and pump requirements

^b For Willett Reservoir only 20% of the volume is usable

^c Zone 4E is combined with Zone 3E for the storage evaluation

^d New West End WTP clearwell assumed to be 2.0 MG with 1.0 MG usable



Table 8-3. 2040 Storage Available and Requirements

Pressure Zone	Total Storage Volume (MG)	Total Effective Storage Volume (MG)	Operational Storage (MG)	Fire Storage (MG)	Emergency Storage (MG)	Total Storage Required (MG)	Total Storage Required Without Fire (MG)	Excess Storage Without Fire (MG)
WEWTP ^d	2.0	1.0						1.00
Ex. WTP	10.4	5.2 ^a						5.20
Zone 1	6.25	3.81 ^b	2.43	0.63	8.10	11.16	10.53	(6.72)
Zone 2	9.0	9.0	1.90	0.63	6.35	8.88	8.25	0.75
Zone 2E	8.0	8.0	1.62	0.63	5.41	7.66	7.03	0.97
Zone 3	7.5	7.5	2.49	0.63	8.29	11.41	10.78	(3.28)
Zone 3E	4.0	4.0	0.47	0.30	1.56	2.32	2.02	1.98
Zone 3S	0.06	0.06	0.01	0.30	0.02	0.33	0.03	0.03
Zone 4	2.25	2.25	0.95	0.30	3.15	4.40	4.10	(1.85)
Zone 4E ^c								
Zone 4N			0.25	0.18	0.84	1.27	1.09	(1.09)
Zone 4S	0.75	0.75	0.07	0.30	0.23	0.60	0.30	0.45
Zone 5	0.10	0.10	0.04	0.63	0.13	0.79	0.16	(0.06)
Zone 5W			0.03	0.18	0.11	0.32	0.14	(0.14)
Zone 6			0.05	0.30	0.17	0.51	0.21	(0.21)

Notes

- ^a The clearwells remain half full for CT and pump requirements
- ^b For Willett Reservoir only 20% of the volume is usable
- ^c Zone 4E is combined with Zone 3E for storage evaluation
- ^d New West End WTP clearwell assumed to be 2.0 MG with 1.0 MG usable

Two things to note about the effective storage column. The clearwells at the existing Water Treatment Plant (WTP) need to remain at least half full for chlorine contact time requirements; half of the clearwell total volume is shown as effective. For Willett Reservoir only the top 25% is effective to work with the Leavens Reservoir and pressure requirement of Zone 1; the effective Willett volume is 0.81 MG resulting in a total effective Zone 1 storage of 3.81 MG.

Also, Zone 4E is shown in the tables but has no storage requirements. Since Zone 4E is very small it is being evaluated in conjunction with Zone 3E. Zone 2E also doesn't show storage requirements since it is in the Heights Water District (HWD).

In evaluating storage for a specific zone, storage in another directly connected zone can be allocated to the zone being analyzed if the following criteria are met:

- ◆ The zone stored water is being allocated from has excess storage.
- ◆ If excess stored water needs to be pumped to the zone being analyzed, the pumps and associated controls need to have reliable backup or standby power.

- ◆ If excess stored water is being allocated to a lower pressure zone that is being analyzed, the transfer mechanism needs to have reliable backup or standby power if it includes electric actuation or control and the transfer mechanism should not be normally isolated.

Another key concept when analyzing storage is that it is assumed that there is only one fire occurring in the distribution system at a time.

A spreadsheet was used to evaluate separate storage requirements for each pressure zone when there is fire in that pressure zone. The analysis includes moving storage volume from zones with excess storage to zones with deficient storage per the criteria noted above. The spreadsheet also includes brief summaries of where water was moved and when new storage facilities were added. The storage analysis spreadsheets for Current, 2030 and 2040 are included in the appendix.

The following summarizes the resulting analysis of the City's storage system under current and future projected demand conditions.

Current Storage Analysis

As shown, Zone 1 has the largest deficit at nearly 7 MG when there is a fire in the zone. Zone 4 also has a significant deficit of nearly 1 MG with a fire in that zone. Storage deficits are also identified in Zones 5, 5W and 6.

The analysis indicates that even with the large deficit in Zone 1, there is enough storage with the clearwells at the existing WTP and Zone 2 to cover the deficit. However, since Zone 1 is a major zone and serves many critical hospitals and industrial customers, relying on moving a large amount of water from two zones increases the operational risk of meeting the City's desired level of service under emergency conditions. As such, an increase in Zone 1 storage is recommended.

In contrast to the Zone 1 storage deficit, the Zone 4 deficit can be operationally met by excess storage in Zone 3, and the Zone 4N deficit can be met by excess storage in Zone 3E. While the deficit in Zone 5W could be met by Zone 4 storage, utilizing Zone 4 storage does not meet the zone transfer criteria as Zone 4 does not have excess storage. Because of the current issues with turnover in Zone 4 storage, a new reservoir isn't recommended at this time.

A new Zone 5 reservoir is recommended to meet Zone 5 and 6 storage deficit and would benefit Zone 4 storage if a zone transfer station is installed in Waldo Pump Station. Zone 5 reservoir is recommended because Zone 3 is the first lower zone that has excess storage, presenting operational challenges to meet fire flow conditions in the upper zones. For example, if there is a fire in Zone 6, the large pump in Christensen would need to turn on which would start draining Logan Reservoir and require the large pump in Waldo to be turned on. The Christensen pump would be pumping into a closed loop and the large pump in Waldo is bigger than the one in Christensen. The combination of trying to meet a fire demand in a closed loop, different sized pumps and Logan being small results in it being difficult for an operator to keep Logan full without overflowing. Additionally, an electric actuated valve on the fill pipe to Waldo Reservoir needs to be manually controlled to fill Waldo. Also, when there is a fire demand in Zone 5/the Airport, it would be difficult to meet

the needs with Logan only having a 100,000-gallon capacity, the Waldo pump capacity at 2500 gpm and a potential fire flow demand of 3500 gpm.

New 3 MG Zone 1 and 1 MG Zone 5 reservoirs are also recommended. However, if a site can be found large enough and adequate funds are available, a larger Zone 1 reservoir would be a more desirable solution to meet the storage deficits.

2030 Storage Analysis

The 2030 analysis shows that Zone 3 now has a deficit when there is a fire in that Zone. Zone 3 is anticipated to have the highest growth. Water could be allocated from Zone 2 or the clearwell of the WEWTP. A new Zone 3 reservoir would not yet be required but is recommended because of the anticipated growth and the benefit of solidifying the West End distribution system. At a minimum, a Zone 3 reservoir should be planned for in case growth is faster than anticipated. Since the Zone 4 deficit is over 1.5 MG with a fire in that zone, a new Zone 4 reservoir is recommended. The Zone 4 reservoir addition will also enable the City to meet the Zone 5W deficit without breaking one of the operational rules or criteria. The Zone 4N deficit has grown to nearly 1 MG under the projected 2030 demand conditions, but Fox reservoirs are projected to still have sufficient excess storage to meet this need.

New 3 MG Zone 3 and 2 MG Zone 4 reservoirs are recommended.

2040 Storage Analysis

The 2040 requirements show there isn't enough storage in the existing WTP clearwells and Zone 2 to cover the Zone 1 deficit. As discussed under the current demand conditions analysis, a Zone 1 reservoir was recommended for operational reliability, but would definitely be needed by 2040 based on the demand projections in this zone. A 3 MG Zone 1 reservoir is shown in the analysis. Even with a new 3 MG Zone 3 reservoir, a deficit is still projected in Zone 3. Water allocated from the WEWTP clearwell(s) could cover the deficit.

No new reservoirs are required, however an additional Zone 1 reservoir could be planned for since there are no other reservoirs needed.

Existing Reservoirs

Evaluating the condition of existing facilities is not part of this master plan. However, the City has three reservoir improvement projects in the Capital Improvements Plan (CIP), and the Staples Standpipe is currently off-line.

Staples 6 MG Reservoir

The Staples 6 MG Reservoir has had significant repairs on two occasions due to major leaks. The first repair was to replace structural damage of the concrete floor around the inlet/outlet. The second repair, fixed leaking primarily between the wall and floor joint. The latter was considered to be a temporary repair and was completed in 2010. No leakage has been noted in the reservoir perimeter drain.

There have been previous discussions with City staff regarding the need to improve the short and long-term reliability of the Staples Reservoir. A summary of these are:

- ◆ Install a false structural floor above the existing floor.

- ◆ Build a new reservoir within the walls of the existing reservoir.
- ◆ Demolish the existing reservoir and build a new reservoir.

Given the significant difference in the approach for this reservoir, an evaluation should be performed to determine the best alternative for the City. Addressing the issue has been delayed for several years due to the reservoir not leaking. Completing a significant Staples Zone 2 reservoir project needs to be compared to the benefits of new storage in Zone 1 and Zone 5. Leak detection could be installed in the manhole where the perimeter drain is routed and used as a performance indicator to support further delaying the financial implications of remediating the Staples Reservoir.

Of note, the City has currently budgeted \$4 Million to replace this reservoir. This amount would potentially fund the construction of a smaller 3 MG reservoir which would reduce the Zone 2 storage volume by 3 MG. The City could consider taking some risk and leaving the 6 MG as is and put the CIP money towards a 3 MG Zone 1 reservoir. If the 6 MG begins to leak, it could be taken off-line and the overall storage would be the same as replacing it with a smaller reservoir. The recommended alternatives evaluation should consider the operation performance and risk of these alternatives relative to the storage needs of Zone 2 and the storage reliability of the system as a whole.

Logan Painting

Repainting of Logan is scheduled. If a new Zone 5 reservoir is constructed, there would be the option of demolishing Logan and allocate the repainting money towards the Zone 5 project.

Fox Replacement

The original Fox welded steel reservoir is scheduled to be replaced as opposed to recoating it. Since Zone 3E has almost enough storage with only one reservoir, if the paint on the existing reservoir fails, the City could consider just taking this reservoir off-line and repurpose the replacement money towards higher priority water system projects.

Staples Standpipe

The 0.5 MG Staples Standpipe is currently off-line due to an existing waterline leaking. The City is considering leaving the reservoir off-line. To assess this condition, the hydraulic model was used to evaluate the affect off leaving the Standpipe off-line. The results of the modeling simulation indicates that at current demand and the Zone 3 pump on a VFD operating, there are essentially no changes in the distribution system pressure. If the constant speed pump is used instead of the VFD pump, then there would be a 3 psi pressure increase in the Staples Pump Station and a 5 psi increase in the distribution system. As demands increase to 2030 maximum day demands (MDD) the pressure increase is less.



Site Selection and Model Analysis

Zone 1 Reservoir

Site Location

A reservoir near Leavens and at Willett have been considered. The issue with a Willett site is that only about the top 25% of the reservoir would be effective, making this site less desirable. A site near Leavens would be ideal if cost effective and the City could overcome the challenges associated with removing houses in the area of the potential site.

Another option near Leavens that would not require removing houses is the Montana State University Billings (MSUB) parking on the south side of Rimrock Road a half block west of the Leavens Reservoir. The City has had preliminary discussions with MSUB about this potential site. This would be an ideal location hydraulically. Another potential location would be Swords Park just southwest of Walter Pump Station. The MSUB and Swords Park sites are shown in Figure 8-1.

Model Analysis

Due to the distance of the Swords Park location from the existing reservoirs, the water model was used to evaluate how the Swords Park location would float with the other existing reservoirs. At 2040 MDD, reservoir levels for Willett, Leavens and a Swords reservoir track very well. As is the case currently during high demands, Willett level runs higher but only by about two feet more than the Swords reservoir. The Swords reservoir compared to Leavens ranges from matching Leavens to being about a foot higher than Leavens. The result of the model analysis is that the Swords reservoir actually works better with Willett than Leavens does.

Concerns

- ◆ New reservoir floating at same hydraulic grade with the Leavens and Willett Reservoirs. However, the model shows it would work well.
- ◆ Public concerns with aesthetics.

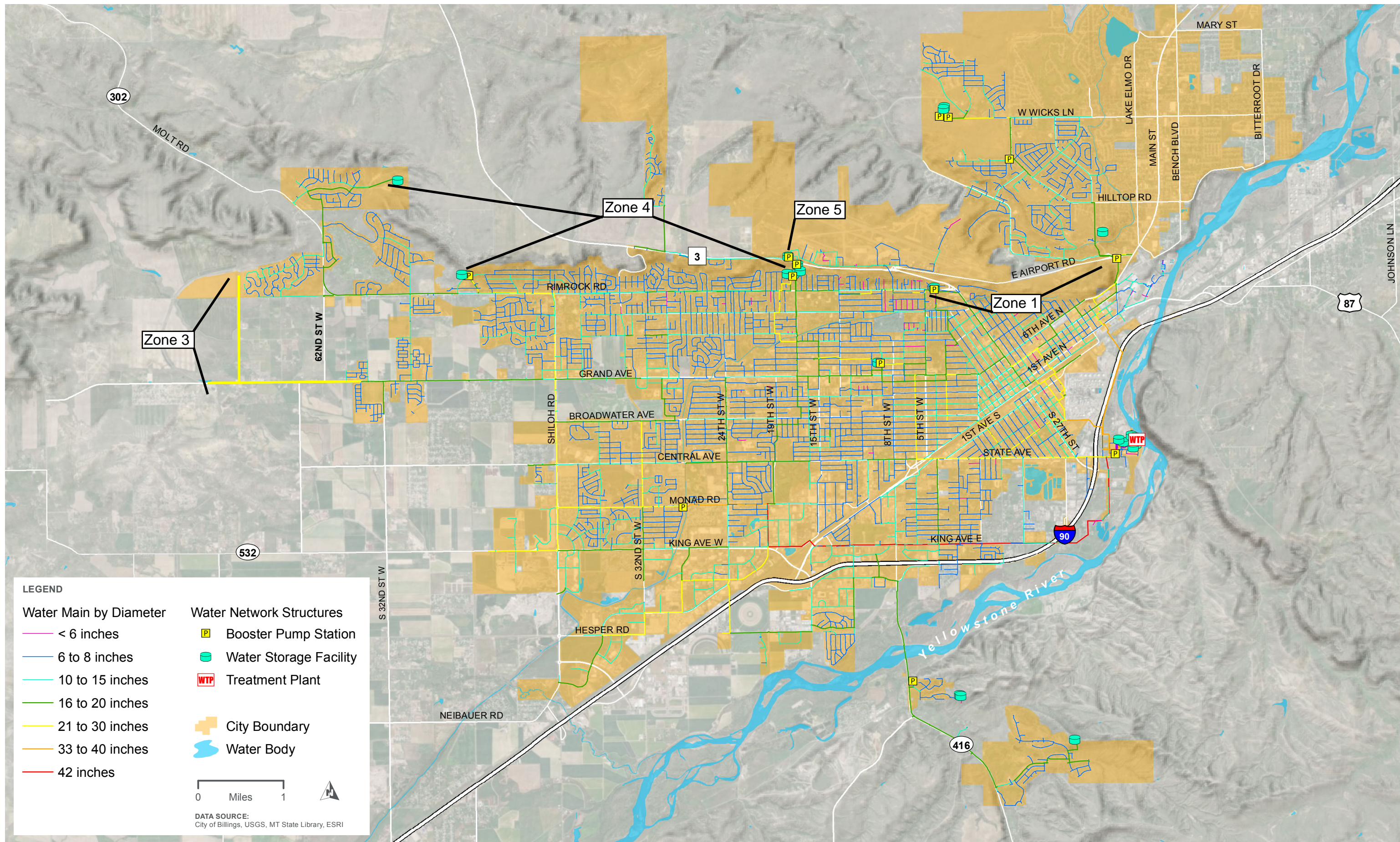
Recommendation

If a site near Leavens cannot be obtained, then locating a reservoir in Swords Park would be recommended. Depending on the location chosen, the reservoir could be mostly exposed to save construction cost or be partially buried to improve aesthetics. This location is on City property which would save money and eliminate the difficulty in obtaining property. A reservoir as large as 6 MG is needed but a 3 MG reservoir is recommended to more cost effectively match the overflow and floor of Leavens which is 20 feet deep. A 6 MG reservoir 20 feet deep would be more costly per gallon. The inlet/outlet waterline could be routed in the Chief Black Otter Trail and connect into the existing 16-inch Zone 1 waterline just south of Walter. The fill and draw of the reservoir would keep the 16-inch line fresh and allow it to be readily available to be used by Walter to feed Zone 2E and/or Zone 3E.

CIP Items and Triggers

The CIP items and triggers include:

- ◆ 3 MG Reservoir. Trigger - a Zone 1 reservoir is needed now.



LEGEND

Water Main by Diameter	Water Network Structures
— < 6 inches	P Booster Pump Station
— 6 to 8 inches	 Water Storage Facility
— 10 to 15 inches	WTP Treatment Plant
— 16 to 20 inches	 City Boundary
— 21 to 30 inches	— Water Body
— 33 to 40 inches	
— 42 inches	

0 Miles 1

DATA SOURCE:
City of Billings, USGS, MT State Library, ESRI

POTENTIAL NEW STORAGE RESERVOIRS LOCATION
FIGURE 8-1





Zone 5 Reservoir

Site Selection

A recent evaluation looked at ground storage along Rod & Gun Club road as well as a new elevated reservoir adjacent to Logan. Project cost and water age concerns postponed design/construction of the reservoir. Although the Rod & Gun Club road location allowed for a less expensive ground reservoir, the waterline length to get to this location was nearly two miles, had areas of difficult construction along Highway 3, and was very deep for the buried or mostly buried reservoir options. In addition to the cost of the waterline, the volume of the waterline negatively affected water age in the system.

In consideration of these factors an elevated reservoir is recommended for Zone 5 and is proposed to be located on the City-owned property adjacent to Logan. An elevated reservoir is more expensive than ground storage, but the overall project cost is nearly the same as the ground storage/pipeline alternative and has less risk of difficult waterline construction. In addition, the water volume of the inlet/outlet piping is negligible for a reservoir at the Logan site minimizing water age.

Model Analysis

As part of the master plan the model was used to compare water age with the existing system versus a new 1 MG reservoir adjacent to Logan. The model showed a decrease in water age in a larger reservoir. This is based on current operation versus potential future operation. Currently, because the reservoir capacity is so small, Waldo pumps are operated frequently and so the reservoir level doesn't vary much with the majority of the water from the Waldo pumps going directly into Zone 5. The result is that water does not turn over frequently in the reservoir. Operation for a larger reservoir would be to let it fill and draw more by operating the Waldo pumps less frequently and thus have quicker turnover.

Concerns

- ◆ Water age in the distribution system.
- ◆ For the option of a reservoir near Rod & Gun Club Road concerns would be:
 - Purchasing private property for the reservoir
 - Routing of a waterline along Highway 3 to connect reservoir to Zone 5
 - Cost of waterline to the reservoir
 - Additional water age from waterline going to the reservoir

Recommendation

A new elevated composite reservoir is recommended adjacent to the Logan Reservoir with the overflow to match Logan. The reservoir can be operated about 2/3 full to help reduce water age until demands in Zone 5 and 6 increase. The pedestal could be used for a new Zone 6 pump station when Zone 6 needs more pumping capacity than the Christensen Pump Station provides. The reservoir could be connected to Zone 5 at the same site. Inlet/outlet piping should be configured to accomplish turnover and mixing in the reservoir. Christensen suction pulling directly from the reservoir would also increase turnover.

CIP Items and Triggers

The CIP items and triggers include:

- ◆ New 1 MG elevated composite reservoir and associated piping. Trigger - Needed now.

Zone 3 Reservoir

Site Location

To minimize the visual aesthetic impacts of a new reservoir, the site assessment focused on locations where the additional storage could be provided from ground storage instead of an elevated reservoir. One location was near 70th St. West and Rimrock Road intersection near the railroad tracks. Based on Google Earth, the ground elevation just south of the tracks appears to be suitable for a mostly exposed reservoir. The ground elevation on the north side of the tracks would work for a mostly buried reservoir. The second general location identified is just southeast of 74th St. West and Grand Ave. These locations are shown in Figure 8-1.

Operationally, either location would tie into Zone 3 at the 20-inch waterline in Grand Ave. near 58th St. W. Both locations would be relatively close to the Zone 3 Chapple reservoirs. The more northern option would require about two and a half miles of waterline to connect to the waterline in Grand and the southern option just less than two miles of waterline. The construction for the waterline though would be straightforward and would be beneficial as the future as Zone 3 expands to the west.

Model Analysis

The model was used to analyze how a new Zone 3 reservoir would operate with the Chapple reservoirs and the Staples Standpipe. The Zone 3 reservoir operation was analyzed with the following assumptions:

- ◆ 2030 MDD
- ◆ 20-inch waterline from the Zone 3 reservoir to the 20-inch on Grand
- ◆ A new waterline not installed in 48th St. from Hesper Avenue to Grand.

Based on these assumptions the Zone 3 reservoir level would be operating higher than levels in Chapple. Further analysis was completed with a 24-inch waterline going from Grand and 48th to the Chapple reservoirs. This waterline resulted in Chapple levels being higher than the Zone 3 reservoir level but by less than 1 ft on average. An altitude valve could be installed on the inlet/outlet of the Zone 3 reservoir instead of the waterline between Grand and the Chapple reservoirs. The altitude valve would allow the Chapple reservoirs to fill completely and then the Chapple reservoirs would need to drop before the levels in the Zone 3 reservoir would drop.

Concerns

- ◆ New reservoir floating at same hydraulic grade with the Chapple reservoirs.
- ◆ Purchasing private land for constructing a reservoir.



Recommendation

Either reservoir location works well with the Chapple reservoirs. Surveying the potential locations is recommended to confirm proper ground elevations for ground storage or partially buried reservoirs configuration and then begin negotiating with owners to purchase land. A 20-inch waterline is recommended for connecting the new reservoir to the 20-inch waterline Grand. Additionally, a 24-inch waterline is recommended between Chapple and 48th and Grand to help match the water levels between the new reservoir and Chapple.

CIP Items and Triggers

The CIP items and triggers include:

- ◆ Purchase land for reservoir. Trigger - as soon as a site location study is completed, and budget allows.
- ◆ Construct 3 MG reservoir. Trigger - when Zone 3 maximum day demands reach 10.5 mgd. This is estimated to be around 2026. If a Zone 1 reservoir is built first, the Zone 3 Reservoir could be delayed longer as more Zone 2 excess storage could be allocated to Zone 3.
- ◆ 20-inch waterline from the new reservoir to the existing waterline in Grand and a 24-inch waterline from 48th and Grand to Chapple. Trigger - constructed at same time as reservoir.

Zone 4 Reservoir

Site Location

A second Zone 4 reservoir was planned for installation to the west of the existing Ironwood Reservoir on existing City-owned property. The primary advantage of this location is the assurance that it would match the water surface elevation with the existing reservoir. The disadvantage is the City would have nearly all the Zone 4 storage in one location, a situation similar to Zone 2 and Zone 3 storage situations. Other potential locations could be at the Chapple site and the Staples site. At Chapple, the elevated reservoir would be about 130 ft tall and at Staples the reservoir would be about 230 ft tall. A Zone 4 Chapple reservoir level would operate about two feet higher than the Ironwood Reservoir because of the close proximity to the Chapple Zone 4 pumps. An altitude valve at Chapple would help the Ironwood turnover. A Staples reservoir would act similar to the Waldo Reservoir. At times it would float well with Ironwood and at other times it would need to be isolated.

Concerns

- ◆ Hydraulic connection between the Ironwood Reservoir and a reservoir at a different location.
- ◆ A second reservoir at the Ironwood site would result in nearly all Zone 4 storage at one location.

Recommendation

An elevated reservoir at the Staples site would be the most expensive and the least hydraulically balanced with Ironwood. An elevated reservoir at Chapple would be a little more expensive than one at Ironwood but would reduce the risk of one waterline to and from nearly all the Zone 4 storage. However, an elevated Chapple reservoir could have aesthetic concerns. It is recommended to explore the public acceptance of an elevated reservoir at Chapple and evaluate the risk of the geology and falling rock from the Rims. If these items prove acceptable, then the City should consider constructing the new reservoir at Chapple. The second option would be a second reservoir at Ironwood. In both cases the City owns land for a reservoir.

CIP Items and Triggers

The CIP items and triggers include:

- ◆ Evaluate new Zone 4 reservoir location. Trigger – as soon as funds are available.
- ◆ New Zone 4 reservoir. Trigger – Zone 4 has the second largest storage deficient currently. The deficit can be accounted for from excess Zone 3, but Zone 3 is the fastest growing pressure zone and all storage will soon be required for Zone 3. Zone 4 storage should be added as soon as the evaluation is complete, and funds are available in relation to other storage needs.

Wintertime Storage Requirements

During late fall, winter and early spring, water system demands are substantially lower than summertime demands. Lower demands result in less storage volume requirements. The fire demands stay the same, but operation and emergency storage requirements are less. Currently, from the beginning of October through April, demands are less than 20 mgd. With that, a storage evaluation was completed for a 20 mgd demand. The details of the evaluation are included in Appendix 8B.

The results of this wintertime storage evaluation are that the Staples 6 MG, the Chapple 2 MG and one of the Fox reservoirs could be taken off-line in the winter to reduce water age in the system.

The benefit is a reduction in water age and likely better overall water quality. The detriment is the labor or cost required to empty and clean out the reservoirs when taken off-line and then disinfecting them when they are put back on-line.

If low chlorine residuals are experienced or high disinfection byproducts in the outer portions of the distribution system during lower demands, then the City should consider taking reservoirs off-line and incorporate this as part of this Standard Operating Procedures.

Summary and Recommendations

As discussed, Zone 1 and Zone 4 have the largest storage deficits. Zone 5 and 6 have the highest potential risk when it comes to fire protection. Zone 3 is the fastest growing zone. To meet the diverse needs of the City's water system, the storage recommendations in order of importance are as follows:

1. New Zone 5 elevated reservoir next to Logan Reservoir.
2. Further evaluate Zone 1, Zone 3 and Zone 4 reservoir locations as well as options for Staples 6 MG and the welded steel Fox reservoir repair or replacement.
3. New Zone 1, 3 MG reservoir located at MSUB Foundation parking lot or Swords Park west of Walter Pump Station. Evaluation of location could be included with Item 2.
4. New Zone 4, 2 MG reservoir.
5. New Zone 3, 3 MG reservoir.



Appendix 8A – Storage Analysis Calculations

Table 8A-1

Peak Day Demand (mgd)	Current Storage Requirements (MG)								Zone 1 Fire				Zone 2 Fire				Zone 3 Fire				Zone 3E Fire				Zone 3S Fire				Zone 4 Fire			
	Exist WTP	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description
15.38	5.20						10.00	(6.18)	6.81	3.48	1.72	To Z1	6.18	3.48	1.72	To Z1	6.18	2.85	2.35	To Zone 1	6.18	2.85	2.35	To Zone 1	6.18	2.85	2.35	To Zone 1	6.18	2.85	2.35	To Zone 1
8.73	3.81	2.31	0.63	7.69	10.63	10.00	(6.18)	6.81	3.48	1.72	From Z2, Clearwells	6.18	3.48	1.72	From Z2, Clearwells	6.18	2.85	2.35	From Z2, Clearwells	6.18	2.85	2.35	From Z2, Clearwells	6.18	2.85	2.35	From Z2, Clearwells	6.18	2.85	2.35	From Z2, Clearwells	
7.10	9.00	1.31	0.63	4.37	6.30	5.67	3.33		3.33	0.00	To Z1		2.70	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1	
9.12	8.00	1.07	0.63	3.55	5.25	4.62	3.39						2.70	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1	
2.29	7.50	1.37	0.63	4.56	6.56	5.93	1.57		0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.22	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²	
0.04	4.00	0.34	0.30	1.15	1.79	1.49	2.51		0.27	2.24	To Z4N, Could use for Zone 1 ³		0.27	2.24	To Z4N, Could use for Zone 1 ³		0.27	2.24	To Z4N, Could use for Zone 1 ³		0.27	1.94	To Z4N, Could use for Zone 1 ³		0.27	2.24	To Z4N, Could use for Zone 1 ³		0.27	2.24	To Z4N, Could use for Zone 1 ³	
4.37	0.06	0.01	0.30	0.02	0.33	0.03	0.03			0.03				0.03				0.03				0.03			0.27		0.00	From Z4S			0.03	From Z4S
	2.25	0.66	0.30	2.19	3.14	2.84	(0.59)	0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	
0.42																																
0.43	0.00	0.06	0.18	0.21	0.45	0.27	(0.27)	0.27		0.00	From Z3E	0.27		0.00	From Z3E	0.27		0.00	From Z3E	0.27		0.00	From Z3E	0.27		0.00	From Z3E	0.27		0.00	From Z3E	
0.23	0.75	0.06	0.30	0.22	0.58	0.28	0.47			0.47				0.47				0.47				0.27	0.20	To Z3S ⁴			0.47			0.47	To Z3S ⁴	
0.20	0.10	0.03	0.63	0.12	0.78	0.15	(0.05)	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	
0.30	0.00	0.03	0.18	0.10	0.31	0.13	(0.13)	0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	
	0.00	0.05	0.30	0.15	0.50	0.20	(0.20)	0.20		0.00	From Z5	0.20		0.00	From Z5	0.20		0.00	From Z5	0.20		0.00	From Z5	0.20		0.00	From Z5	0.20		0.00	From Z5	
48.61								9.13	8.13	Totals		8.50	7.50	Totals		8.50	7.50	Totals		8.50	7.50	Totals		8.77	7.77	Totals		8.80	7.80	Totals		

Current Storage Requirements Continued (MG)								Zone 4E Fire				Zone 4N Fire				Zone 4S Fire				Zone 5 Fire				Zone 5W Fire				Zone 6 Fire				
Exist WTP	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	
5.20							5.20						2.85	2.35	To Zone 1		2.85	2.35	To Zone 1		2.85	2.35	To Zone 1		2.85	2.35	To Zone 1		2.85	2.35	To Zone 1	
3.81	2.31	0.63	7.69	10.63	10.00	(6.18)		6.18		0.00	From Z2, Clearwells	6.18		0.00	From Z2, Clearwells	6.18		0.00	From Z2, Clearwells	6.18		0.00	From Z2, Clearwells	6.18		0.00	From Z2, Clearwells	6.18		0.00	From Z2, Clearwells	
9.00	1.31	0.63	4.37	6.30	5.67	3.33			3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1		3.33	0.00	To Z1	
8.00	1.07	0.63	3.55	5.25	4.62								0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.9	0.67	To Z4, Could use for Zone 1 ²		0.9	0.67	To Z4, Could use for Zone 1 ²	
7.50	1.37	0.63	4.56	6.56	5.93	1.57			0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.72	0.85	To Z4, Could use for Zone 1 ²		0.9	0.67	To Z4, Could use for Zone 1 ²		0.9	0.67	To Z4, Could use for Zone 1 ²	
4.00	0.34	0.30	1.15	1.79	1.49	2.51			0.45	2.06	To Z4N, Could use for Zone 1 ³		0.45	2.06	To Z4N, Could use for Zone 1 ³		0.45	2.06	To Z4N, Could use for Zone 1 ³		0.45	2.06	To Z4N, Could use for Zone 1 ³		0.45	2.06	To Z4N, Could use for Zone 1 ³		0.45	2.06	To Z4N, Could use for Zone 1 ³	
0.06	0.01	0.30	0.02	0.33	0.03	0.03				0.03				0.03				0.03				0.03				0.03				0.03		
2.25	0.66	0.30	2.19	3.14	2.84	(0.59)		0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	0.72	0.13	0.00	To Z5W*, from Z3	0.90	0.31	0.00	To Z5W*, from Z3	0.90	0.31	0.00	To Z5W*, from Z3	
0.00	0.06	0.18	0.21	0.45	0.27	(0.27)							0.45		0.00	From Z3E	0.45		0.18	From Z3E	0.45		0.18	From Z3E	0.45		0.18	From Z3E	0.45		0.18	From Z3E
0.75	0.06	0.30	0.22	0.58	0.28	0.47				0.47				0.17				0.47				0.47				0.47				0.47		
0.10	0.03	0.63	0.12	0.78	0.15	(0.05)		1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.20	0.12	New 1 MG Res., ¹ to Z6	1.00	0.20	0.12	New 1 MG Res., ¹ to Z6	1.00	0.20	0.75	New 1 MG Res., ¹ to Z6	1.00	0.50	0.45	New 1 MG Res., ¹ to Z6	
0.00	0.03	0.18	0.10	0.31	0.13	(0.13)		0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	0.13		0.00	From Z4 *	0.31		0.00	From Z4 *	0.31		0.18	From Z4 *	
0.00	0.05	0.30	0.15	0.50	0.20	(0.20)		0.20		0.00	From Z5	0.20		0.00	From Z5	0.20		0.00	From Z5	0.20		0.00	From Z5	0.20		0.00	From Z5	0.50		0.01	From Z5	
								8.68	7.68	Totals		8.68	7.68	Totals		8.68	7.68	Totals		9.04	8.04	Totals		9.34	8.34	Totals		9.34	8.34	Totals		

General Note: All values are in millions of gallons (MG)
^{*} Breaks rule - moving water from Zone with a deficiency
¹ New 1.0 MG Zone 5 Reservoir
² Need to add reliable pressure reducing station for going from Z3 to 1 at Voekler Pump Station
³ Need to have reliable pressure reducing station for going from Z3E to Z1 at Walter Pump Station, would need to regularly use Z1 feed to Walter and need permanent backup power for pressure reducing station
⁴ Need to have reliable pressure reducing station for going from Z4S to Z3S at Thomas Pump Station

Table 8A-2

Pk Day	2030 Storage Requirements (MG)								Zone 1 Fire				Zone 2 Fire				Zone 3 Fire				Zone 3E Fire				Zone 3S Fire				Zone 4 Fire			
	Exist WTP	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description				
	Exist WTP	5.20						5.20				To Zone 1		5.15	0.05	To Zone 1		4.52	0.68	To Zone 1		4.52	0.68	To Zone 1		4.52	0.68	To Zone 1		4.52	0.68	To Zone 1
	New WTP	1.00						1.00																								
15.82	Zone 1	3.81	2.37	0.63	7.91	10.91	10.28	(6.47)	7.10		0.00	Z2, Clearwells	6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells
10.85	Zone 2	9.00	1.63	0.63	5.43	7.68	7.05	1.95			0.00	To Z1		1.32	0.00	To Z1		1.95	0.00	To Z1		1.95	0.00	To Z1		1.95	0.00	To Z1		1.95	0.00	To Z1
8.82	Zone 2E	8.00	1.32	0.63	4.41	6.36	5.73	2.27																								
11.50	Zone 3	7.50	1.73	0.63	5.75	8.11	7.48	0.03	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	3.00		2.40	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵
2.73	Zone 3E	4.00	0.41	0.30	1.37	2.07	1.77	2.23		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.22	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³
0.04	Zone 3S	0.06	0.01	0.30	0.02	0.33	0.03	0.03			0.03				0.03								0.27		0.00	From Z4S					0.03	
5.41	Zone 4	2.25	0.81	0.30	2.71	3.82	3.52	(1.27)	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.29	New 2 MG Res. ⁶ to Z5W
1.09	Zone 4E																															
0.45	Zone 4N	0.00	0.16	0.18	0.55	0.89	0.71	(0.71)	0.71		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E
0.24	Zone 4S	0.75	0.07	0.30	0.23	0.59	0.29	0.46			0.46				0.46																	
0.21	Zone 5	0.10	0.04	0.63	0.12	0.79	0.16	(0.06)	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6
0.32	Zone 5W	0.00	0.03	0.18	0.11	0.32	0.14	(0.14)	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4
0.32	Zone 6	0.00	0.05	0.30	0.16	0.51	0.21	(0.21)	0.21		0.00	From Z5	0.21		0.00	From Z5	0.21		0.00	From Z5	0.21		0.00	From Z5	0.21		0.00	From Z5	0.21		0.00	From Z5
57.48									14.16	8.16	Totals		13.53	7.53	Totals		13.53	7.53	Totals		13.53	7.53	Totals		13.80	7.80	Totals		13.53	7.53	Totals	

Pk Day	2030 Storage Requirements Continued (MG)								Zone 4E Fire				Zone 4N Fire				Zone 4S Fire				Zone 5 Fire				Zone 5W Fire				Zone 6 Fire				
	Exist WTP	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description					
	Exist WTP	5.20						5.20						4.52	0.68	To Zone 1		4.52	0.68	To Zone 1		4.52	0.68	To Zone 1		4.52	0.68	To Zone 1		4.52	0.68	To Zone 1	
	New WTP	1.00						1.00							1.00																		
	Zone 1	3.81	2.37	0.63	7.91	10.91	10.28	(6.47)					6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells	6.47		0.00	From Z2, Clearwells	
	Zone 2	9.00	1.63	0.63	5.43	7.68	7.05	1.95			0.00	To Z1		1.95	0.00	To Z1		1.95	0.00	To Z1		1.95	0.00	To Z1		1.95	0.00	To Z1		1.95	0.00	To Z1	
	Zone 2E	8.00	1.32	0.63	4.41	6.36	5.73	2.27																									
	Zone 3	7.50	1.73	0.63	5.75	8.11	7.48	0.03	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	3.00		3.03	New 3 MG Res. ⁵	
	Zone 3E	4.00	0.41	0.30	1.37	2.07	1.77	2.23		0.89	1.34	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³		0.71	1.52	To Z4N, Could use for Zone 1 ³	
	Zone 3S	0.06	0.01	0.30	0.02	0.33	0.03	0.03			0.03				0.03								0.03									0.03	
	Zone 4	2.25	0.81	0.30	2.71	3.82	3.52	(1.27)	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	2.00	0.32	0.41	New 2 MG Res. ⁶ to Z5W	2.00	0.14	0.59	New 2 MG Res. ⁶ to Z5W	
	Zone 4E																																
	Zone 4N	0.00	0.16	0.18	0.55	0.89	0.71	(0.71)	0.89		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E	0.71		0.00	From Z3E	
	Zone 4S	0.75	0.07	0.30	0.23	0.59	0.29	0.46			0.46				0.16																		
	Zone 5	0.10	0.04	0.63	0.12	0.79	0.16	(0.06)	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.21	0.73	New 1 MG Res. ¹ to Z6	1.00	0.51	0.43	New 1 MG Res. ¹ to Z6	
	Zone 5W	0.00	0.03	0.18	0.11	0.32	0.14	(0.14)	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4	0.14		0.00	From Z4	
	Zone 6	0.00	0.05	0.30	0.16	0.51	0.21	(0.21)	0.21		0.00	From Z5	0.21		0.00	From Z5	0.21		0.00	From Z5	0.21		0.00	From Z5	0.21		0.00	From Z5	0.51		0.00	From Z5	
									13.71	7.71	Totals		13.53	7.53	Totals		13.53	7.53	Totals		13.71	7.71	Totals		13.83	7.83	Totals		13.83	7.83	Totals		

General Note: All values are in millions of gallons (MG)
 * Breaks rule - moving water from Zone with a deficiency
¹ New 1.0 MG Zone 5 Reservoir
² Need to add reliable pressure reducing station for going from Z3 to 1
³ Need to have reliable pressure reducing station for going from Z3E to Z1, would need to regularly use Z1 feed to Walter and need permanent backup power for pressure reducing station
⁴ Need to have reliable pressure reducing station for going from Z4S to Z3S
⁵ New 3 MG Zone 3 Reservoir
⁶ New 2 MG Zone 4 Reservoir

Table 8A-3

Pk Day	2040 Storage Requirements (MG)								Zone 1 Fire				Zone 2 Fire				Zone 3 Fire				Zone 3E Fire				Zone 3S Fire				Zone 4 Fire				
	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description		
	Exist WTP	5.20					5.20				To Zone 1	3.60	1.60	To Zone 1	2.97	2.23	To Zone 1	2.97	2.23	To Zone 1	2.97	2.23	To Zone 1	2.97	2.23	To Zone 1	2.97	2.23	To Zone 1	2.97	2.23	To Zone 1	
	New WTP	1.00					1.00	0.28	0.72	To Z3	0.28	0.72	To Z3	0.28	0.72	To Z3	0.28	0.72	To Z3	0.28	0.72	To Z3	0.28	0.72	To Z3	0.28	0.72	To Z3	0.28	0.72	To Z3	0.28	0.72
16.20	Zone 1	3.81	2.43	0.63	8.10	11.16	10.53	(6.72)	7.35	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	6.72	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	6.72	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	6.72	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	6.72	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	6.72	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	6.72	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	6.72	0.00	New 3 MG Res., ⁷ From Z2, Clearwell	
12.69	Zone 2	9.00	1.90	0.63	6.35	8.88	8.25	0.75			To Z1	0.12	0.00	To Z1	0.75	0.00	To Z1	0.75	0.00	To Z1	0.75	0.00	To Z1	0.75	0.00	To Z1	0.75	0.00	To Z1	0.75	0.00	To Z1	
10.82	Zone 2E	8.00	1.62	0.63	5.41	7.66	7.03	0.97																									
16.58	Zone 3	7.50	2.49	0.63	8.29	11.41	10.78	(3.28)	3.28	0.00	New 3 MG Res., ⁵ from new WTP	3.28	0.00	New 3 MG Res., ⁵ from new WTP	3.91	0.00	New 3 MG Res., ⁵ from new WTP	3.28	0.00	New 3 MG Res., ⁵ from new WTP	3.28	0.00	New 3 MG Res., ⁵ from new WTP	3.28	0.00	New 3 MG Res., ⁵ from new WTP	3.28	0.00	New 3 MG Res., ⁵ from new WTP	3.28	0.00	New 3 MG Res., ⁵ from new WTP	
3.11	Zone 3E	4.00	0.47	0.30	1.56	2.32	2.02	1.98		1.09	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.59	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	
0.04	Zone 3S	0.06	0.01	0.30	0.02	0.33	0.03	0.03															0.27	0.00									
6.30	Zone 4	2.25	0.95	0.30	3.15	4.40	4.10	(1.85)	2.00	0.14	New 2 MG Res., ⁶ to Z5W	2.00	0.14	New 2 MG Res., ⁶ to Z5W	2.00	0.14	New 2 MG Res., ⁶ to Z5W	2.00	0.14	New 2 MG Res., ⁶ to Z5W	2.00	0.14	New 2 MG Res., ⁶ to Z5W	2.00	0.14	New 2 MG Res., ⁶ to Z5W	2.00	0.14	New 2 MG Res., ⁶ to Z5W	2.00	0.14	(0.29)	New 2 MG Res., ⁶ to Z5W
	Zone 4E																																
1.68	Zone 4N	0.00	0.25	0.18	0.84	1.27	1.09	(1.09)	1.09		0.00	From Z3E	1.09	0.00	From Z3E	1.09	0.00	From Z3E	1.09	0.00	From Z3E	1.09		0.00	From Z3E	1.09		0.00	From Z3E	1.09		0.00	From Z3E
0.46	Zone 4S	0.75	0.07	0.30	0.23	0.60	0.30	0.45			0.45			0.45			0.45							0.27	0.18							0.45	
0.25	Zone 5	0.10	0.04	0.63	0.13	0.79	0.16	(0.06)	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	0.73	New 1 MG Res., ¹ to Z6
0.21	Zone 5W	0.00	0.03	0.18	0.11	0.32	0.14	(0.14)	0.14		0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4 *	0.00	From Z4 *	
0.33	Zone 6	0.00	0.05	0.30	0.17	0.51	0.21	(0.21)	0.21		0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.00	From Z5	
68.67									15.07	6.07	Totals	14.44	5.44	Totals	15.07	6.07	Totals	14.44	5.44	Totals	14.44	5.44	Totals	14.71	5.71	Totals	14.44	5.44	Totals	14.44	5.44	Totals	

Pk Day	2040 Storage Requirements Continued (MG)								Zone 4E Fire				Zone 4N Fire				Zone 4S Fire				Zone 5 Fire				Zone 5W Fire				Zone 6 Fire				
	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description		
	Clearwells	5.20					5.20																										
	New WTP	1.00					1.00																										
	Zone 1	3.81	2.43	0.63	8.10	11.16	10.53	(6.72)																									
	Zone 2	9.00	1.90	0.63	6.35	8.88	8.25	0.75																									
	Zone 2E	8.00	1.62	0.63	5.41	7.66	7.03	0.97																									
	Zone 3	7.50	2.49	0.63	8.29	11.41	10.78	(3.28)																									
	Zone 3E	4.00	0.47	0.30	1.56	2.32	2.02	1.98		1.27	0.71	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³	1.09	0.89	To Z4N, Could use for Zone 1 ³
	Zone 3S	0.06	0.01	0.30	0.02	0.33	0.03	0.03																									
	Zone 4	2.25	0.95	0.30	3.15	4.40	4.10	(1.85)																									
	Zone 4E																																
	Zone 4N	0.00	0.25	0.18	0.84	1.27	1.09	(1.09)		1.27	0.00	From Z3E	1.09	0.00	From Z3E	1.09	0.00	From Z3E	1.09	0.00	From Z3E	1.09		0.00	From Z3E	1.09		0.00	From Z3E	1.09		0.00	From Z3E
	Zone 4S	0.75	0.07	0.30	0.23	0.60	0.30	0.45																									
	Zone 5	0.10	0.04	0.63	0.13	0.79	0.16	(0.06)		1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	New 1 MG Res., ¹ to Z6	1.00	0.21	0.73	New 1 MG Res., ¹ to Z6		
	Zone 5W	0.00	0.03	0.18	0.11	0.32	0.14	(0.14)		0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4	0.14	0.00	From Z4 *	0.00	0.00	From Z4 *	0.00	From Z4 *	
	Zone 6	0.00	0.05	0.30	0.17	0.51	0.21	(0.21)		0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.21	0.00	From Z5	0.51	0.30	From Z5
									14.62	5.62	Totals	14.44	5.44	Totals	14.44	5.44	Totals	14.44	5.44	Totals	14.62	5.62	Totals	14.62	5.62	Totals	14.74	5.74	Totals	14.74	5.74	Totals	

General Note: All values are in millions of gallons (MG)

* Breaks rule - moving water from Zone with a deficiency

¹ New 1.0 MG Zone 5 Reservoir

² Need to add reliable pressure reducing station for going from Z3 to 1

³ Need to have reliable pressure reducing station for going from Z3E to Z1, would need to regularly use Z1 feed to Walter and need permanent backup power for pressure reducing station

⁴ Need to have reliable pressure reducing station for going from Z4S to Z3S

⁵ New 3 MG Zone 3 Reservoir

⁶ New 2 MG Zone 4 Reservoir

⁷ New 3 MG Zone 1 Reservoir



Appendix 8B – Wintertime Storage Analysis

Table 8B-1

Peak Day Demand (mgd)	Current Winterime 20 mgd Demand Storage Requirements (MG)								Zone 1 Fire				Zone 2 Fire				Zone 3 Fire				Zone 3E Fire				Zone 3S Fire				Zone 4 Fire			
	Exist WTP	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description
6.33	Zone 1	3.81	0.95	0.63	3.16	4.74	4.11	(0.30)	0.93		5.20	From Z2	0.30		0.00	From Z2	0.30		0.00	From Z2	0.30		0.00	From Z2	0.30		0.00	From Z2	0.30		0.00	From Z2
3.59	Zone 2	9.00	0.54	0.63	1.80	2.96	2.33	6.67		0.93	5.74	To Z1		0.30	5.74	To Z1		0.3	6.37	To Z1		0.3	6.37	To Z1		0.3	6.37	To Z1		0.3	6.37	To Z1
2.92	Zone 2E	8.00	0.44	0.63	1.46	2.53	1.90	6.10																								
3.75	Zone 3	7.50	0.56	0.63	1.88	3.07	2.44	5.06			5.06								4.43				5.06							5.06		
0.94	Zone 3E	4.00	0.14	0.30	0.47	0.91	0.61	3.39		0.11	3.28	To Z4N		0.11	3.28	To Z4N		0.11	3.28	To Z4N		0.11	2.98	To Z4N		0.11	3.28	To Z4N		0.11	3.28	To Z4N
0.02	Zone 3S	0.06	0.00	0.30	0.01	0.31	0.01	0.05			0.05								0.05			0.05				0.25	0.11	0.00	From Z4S		0.05	
1.80	Zone 4	2.25	0.27	0.30	0.90	1.47	1.17	1.08		0.05	1.03	To Z5W		0.05	1.03	To Z5W		0.05	1.03	To Z5W		0.05	1.03	To Z5W		0.05	1.03	To Z5W		0.05	0.73	To Z5W
	Zone 4E																															
0.17	Zone 4N	0.00	0.03	0.18	0.09	0.29	0.11	(0.11)	0.11		0.00	From Z3E	0.11		0.00	From Z3E	0.11		0.00	From Z3E	0.11		0.00	From Z3E	0.11		0.00	From Z3E	0.11		0.00	From Z3E
0.18	Zone 4S	0.75	0.03	0.30	0.09	0.41	0.11	0.64			0.64				0.64				0.64			0.64				0.25	0.39				0.64	
0.09	Zone 5	0.10	0.01	0.63	0.05	0.69	0.06	0.04	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6
0.08	Zone 5W	0.00	0.01	0.18	0.04	0.23	0.05	(0.05)	0.05		0.00	From Z4	0.05		0.00	From Z4	0.05		0.00	From Z4	0.05		0.00	From Z4	0.05		0.00	From Z4	0.05		0.00	From Z4
0.12	Zone 6	0.00	0.02	0.30	0.06	0.38	0.08	(0.08)	0.08		0.00	From Z5	0.08		0.00	From Z5	0.08		0.00	From Z5	0.08		0.00	From Z5	0.08		0.00	From Z5	0.08		0.00	From Z5
20									2.17	1.17	Totals		1.54	0.54	Totals		1.54	0.54	Totals		1.54	0.54	Totals		1.79	0.79	Totals		1.54	0.54	Totals	

Peak Day Demand (mgd)	Current Winterime 20 mgd Demand Storage Requirements (MG)								Zone 4E Fire				Zone 4N Fire				Zone 4S Fire				Zone 5 Fire				Zone 5W Fire				Zone 6 Fire			
	Exist WTP	Avail	Operational	Fire	Emerg	Total	Total w/o Fire	Surplus w/o Fire	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description	Add Storage	Delete Storage	Net Storage	Description
	Exist WTP	5.20						5.20																								
	Zone 1	3.81	0.95	0.63	3.16	4.74	4.11	(0.30)					0.30		0.00	From Z2	0.30		0.00	From Z2	0.30		0.00	From Z2	0.30		0.00	From Z2	0.30		0.00	From Z2
	Zone 2	9.00	0.54	0.63	1.80	2.96	2.33	6.67						0.30	6.37	To Z1		0.3	6.37	To Z1		0.3	6.37	To Z1		0.3	6.37	To Z1		0.3	6.37	To Z1
	Zone 2E	8.00	0.44	0.63	1.46	2.53	1.90																									
	Zone 3	7.50	0.56	0.63	1.88	3.07	2.44	5.06			5.06								5.06				5.06								5.06	
	Zone 3E	4.00	0.14	0.30	0.47	0.91	0.61	3.39					0.29	3.10	To Z4N		0.11	3.28	To Z4N		0.11	3.28	To Z4N		0.11	3.28	To Z4N		0.11	3.28	To Z4N	
	Zone 3S	0.06	0.00	0.30	0.01	0.31	0.01	0.05			0.05								0.05			0.05								0.05		
	Zone 4	2.25	0.27	0.30	0.90	1.47	1.17	1.08						0.05	1.03	To Z5W		0.05	1.03	To Z5W		0.05	1.03	To Z5W		0.23	0.85	To Z5W		0.05	1.03	To Z5W
	Zone 4E																															
	Zone 4N	0.00	0.03	0.18	0.09	0.29	0.11	(0.11)					0.29		0.00	From Z3E	0.11		0.00	From Z3E	0.11		0.00	From Z3E	0.11		0.00	From Z3E	0.11		0.00	From Z3E
	Zone 4S	0.75	0.03	0.30	0.09	0.41	0.11	0.64							0.64				0.64			0.64									0.64	
	Zone 5	0.10	0.01	0.63	0.05	0.69	0.06	0.04	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.08	0.96	New 1 MG Res. ¹ to Z6	1.00	0.38	0.66	New 1 MG Res. ¹ to Z6
	Zone 5W	0.00	0.01	0.18	0.04	0.23	0.05	(0.05)	0.05		0.00	From Z4	0.05		0.00	From Z4	0.05		0.00	From Z4	0.05		0.00	From Z4	0.23	0.00	0.00	From Z4	0.05		0.00	From Z4
	Zone 6	0.00	0.02	0.30	0.06	0.38	0.08	(0.08)	0.08		0.00	From Z5	0.08		0.00	From Z5	0.08		0.00	From Z5	0.08		0.00	From Z5	0.08		0.00	From Z5	0.38		0.00	From Z5
									1.72	0.72	Totals		1.54	0.54	Totals		1.54	0.54	Totals		1.72	0.72	Totals		1.84	0.84	Totals		1.84	0.84	Totals	

General Note: All values are in millions of gallons (MG)

¹ New 1.0 MG Zone 5 Reservoir