GILLETTE MADISON PIPELINE PROJECT (GMPP)
TECHNICAL MEMORANDUM #6

FINAL

TO:	Mike Cole, P.E., City of Gillette
FROM:	Jason Schaefer, EIT, BMcD Dan Korinek, P.E., BMcD
DATE:	July 20, 2010
JOB NO.:	BMcD # 54432, MMI #4776.001
RE:	Determination of Storage Requirements
CC:	Darin Brickman, P.E., BMcD Casey Hanson, P.E. MMI Carl Anderson, P.E., MMI Mike Kaczmarek, P.G., MMI Bryan Clerkin, P.E., WWDC
ATTACHMENTS:	

☐ **Urgent** ☐ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **For Your Use**

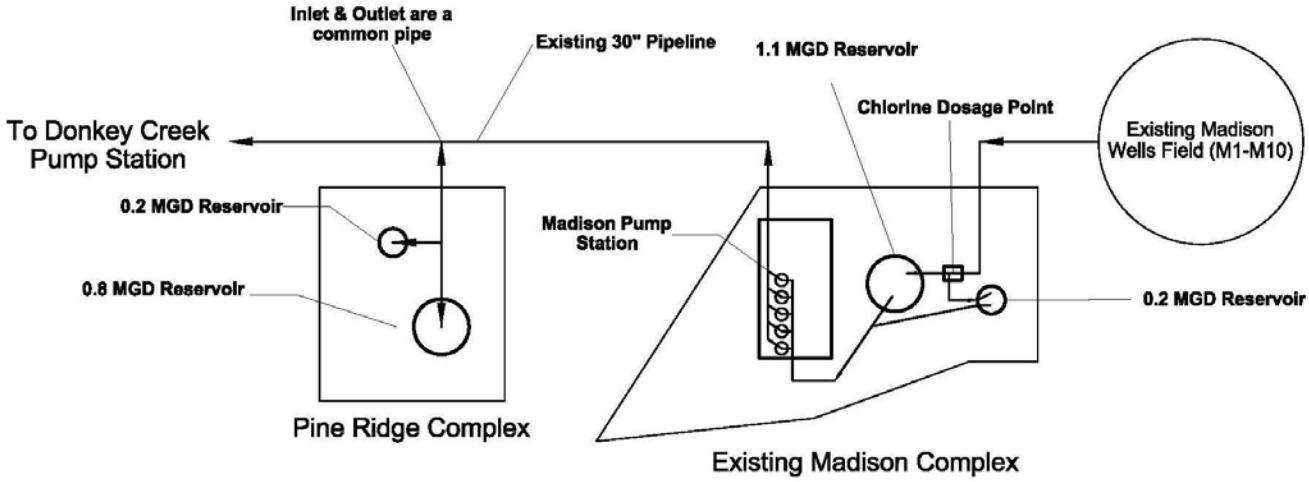
INTRODUCTION AND BACKGROUND

The City of Gillette currently utilizes 26 groundwater wells to provide potable drinking water to their customers. Ten (10) of the wells penetrate the Madison aquifer and 16 wells penetrate the Fort Union and Fox Hills/Lance aquifers. Fort Union and Fox Hills/Lance wells discharge to Pump Station #1 where chlorination occurs. Currently, Madison water is pumped from the wells and chlorinated prior to entering two storage reservoirs located on the existing Madison Complex. These reservoirs feed the Madison Pumping Station which delivers the water to two storage reservoirs at the Pine Ridge site. From the Pine Ridge storage reservoirs the water flows by gravity to the Donkey Creek Pump Station where it is once again "boosted" to the City of Gillette.

The Madison Pump Station site has two storage reservoirs: a 1.1 million gallon (MG) reservoir constructed in the early 1980's and a 0.2 MG reservoir constructed in the mid-2000's. The Madison Pump Station also contains gaseous chlorine feed equipment. Chlorine solution is added in a meter vault located just east of the 1.1 MG storage reservoir. The Pine Ridge

storage reservoirs include one 0.8 MG reservoir built in the early 1980s and one 0.2 MG reservoir built in the mid-2000's. The existing Madison and Pine Ridge facilities are illustrated in Figure 1.

Figure 1. Existing Madison and Pine Ridge Facilities



As part of the GMPP a new well field expansion is proposed near the existing Pine Ridge locations. This technical memorandum refers to this expansion as the new Madison Well Field. Technical Memorandum #2 discusses the new well field siting in detail. The new Madison Well Field will require either a dedicated disinfection system or a larger overall disinfection system to provide a chlorine residual for the entire Madison supply. Technical Memorandum #13 discusses alternatives for disinfection of water from the expanded Madison well field.

IN TOWN STORAGE REQUIREMENTS

Consideration should be taken for an additional 23.10 million gallons of effective water storage to sustain the City of Gillette's current operational philosophy of maintaining emergency storage to meet 24-hour peak day demands. Possible locations for new storage include the Southern Tank Site (Z1R4) and the Antelope Valley Site (Z1R5). Both of these sites currently have enough land area to accommodate an additional 6 million gallons (3 MG at each site). Other storage sites would be added as system demands increase over the next 30 years. One possible area would be the higher elevations around Sleepy Hollow, or the existing tank site above Crestview.

The WDEQ storage requirements (Chapter 12 Section 13) for a system 0.5 MGD or greater is to provide clearwell and system storage capacity equal to 25% of the design maximum daily demand, plus added fire storage based on recommendations established by the State Fire Marshall or local fire agency.

As demand increased for the City of Gillette consideration should be taken to supply additional in town storage that complies with the WDEQ standard and the City of Gillette's current operational philosophy. Table 1 is the additional storage required by a 10-year epoch assuming the City of Gillette's current operational philosophy of maintaining emergency storage to meet

24-hour peak day demands. Similar to the discussion in TM #3 regarding needs by epoch, the peak demand from the new system and number of wells needed in year 2010 includes all regional demand assuming no contribution from regional systems. Until the GMPP is constructed and in operation this is an unrealistic assumption, but it was included herein for comparison purposes.

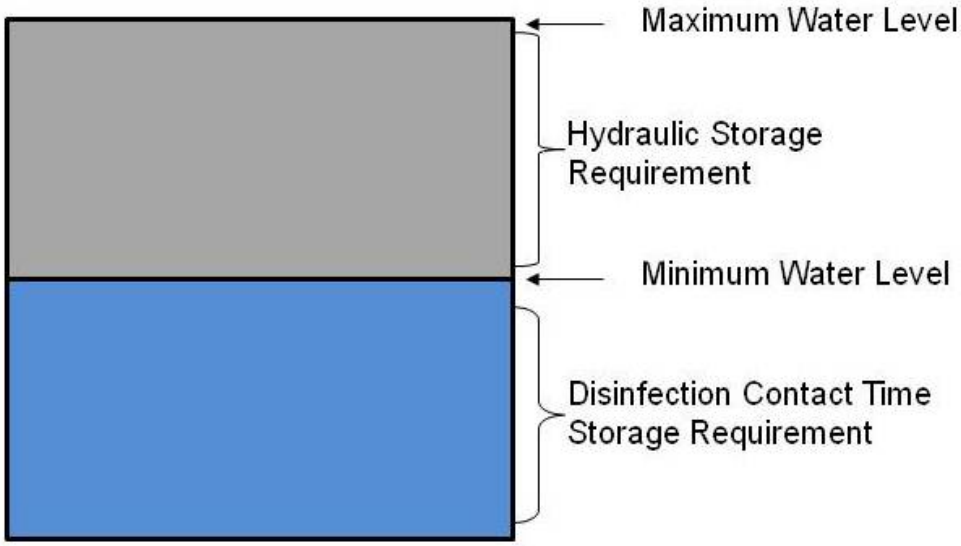
Table 1. Additional Storage Required by a 10-Year Epoch

Year	Peak Day Demand (MGD)	Additional Storage Needed (MG)
2010	24.6	11.6
2020	28.4	15.4
2030	31.6	18.6
2040	35.3	22.3

TRANSMISSION MAIN STORAGE REQUIREMENTS

A new storage reservoir will be designed to serve two purposes. The first function of the reservoir is to provide storage for ideal hydraulic conditions. The second function of the reservoir is to provide the required disinfection contact time. The storage volume requirement for the disinfection contact time will be calculated with the storage volume at the minimum water level in the reservoir. Figure 2 illustrates the storage requirements in one reservoir. As seen by the diagram, the portion of the storage reservoir above the minimum water level would satisfy the hydraulic storage requirement and the portion of the storage volume below the minimum water level would satisfy the disinfection contact time requirement.

Figure 2. Diagram of Storage Requirements



The design storage volume required for hydraulic conditions will be determined from the hydraulic model. The disinfection contact time will be determined by the disinfection contact time between the chlorine dosage point and the first customer. For the analysis in this technical

memorandum, we are using a conservative approach by assuming the first user to be located at the Pine Ridge site.

DISINFECTION CONTACT TIME

The minimum storage volume discussed in the disinfection contact time section below correlates to the disinfection contact time storage requirement not the total hydraulic and disinfection contact time storage requirement. If the water level drops below the minimum water level the required disinfection contact time may not be met.

The Wyoming Department of Environmental Quality (WDEQ) standards regarding disinfection contact time were reviewed to determine the applicable requirements for the disinfection system. Chapter 3, Section 10 of the WDEQ standards states "Where free chlorine residual is provided, ½ hour contact time shall be provided for ground waters."

Disinfection contact time occurs in storage reservoirs and pipelines. Before finalization of the facilities required to achieve the disinfection contact time the following information is required:

1. Pipe layout with chlorine dosage points.
2. Location of the first customer.
3. Reservoir locations.

Technical Memorandum 13 – Evaluation of Disinfection Alternatives and Technical Memorandum 8 – Transmission Pipeline Alignments and Diameter discuss possible alternatives for the pipe layout near the existing Madison Pump Station, near the new Madison well field, and at the existing Pine Ridge storage reservoirs.

To determine an appropriate contact time in a storage reservoir an effective volume of the reservoir must be determined. The effective volume of the reservoir is determined by the low water level in the storage reservoir and the baffling factor. The baffling factor (β factor) corresponds to the amount of baffling in a reservoir and was determined from the EPA *LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual* for the calculation of the detention time in each storage reservoir. Table 2 identifies β factors for varying baffle conditions in a reservoir. The β factor and the low water level volume for the reservoir decreases the total volume of the reservoir to an effective volume for calculation of the minimum detention time in the reservoir.

Table 2. Baffling Classifications.

Baffling Condition	β Factor	Baffling Description
Unbaffled (mixed flow)	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities.
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles
Average	0.5	Baffled inlet or outlet with some intra-basin baffles.
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.
Perfect (plug flow)	1.0	Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles.

Source: LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual

The following sections discuss the existing site and the amount of chlorine contact time in the system. The assumed disinfection contact time for each water supply is discussed based on pipeline layouts identified in Technical Memorandum #8 and #13.

The β value for the 1.1 MG Madison reservoir and 0.2 MG Madison reservoir were determined to be 0.1. The Pine Ridge reservoirs currently have a single inlet/outlet connection. Therefore, the last water entering the reservoir is the first water exiting the reservoir. This does not allow the potential for disinfection contact time within the reservoirs corresponding to a β factor of zero. The minimum level volume will be determined from the hydraulic analysis being performed.

The existing reservoirs could be modified with baffles and new inlets/outlets to allow for additional disinfection contact time. The new water storage reservoir will be designed as a well baffled (Superior) reservoir corresponding to a baffling factor of 0.7.

Existing Madison Wells

The existing Madison wells (M-1 through M-10) have a total capacity of 11.1 MGD (7,734 gpm) and a firm capacity of 9.5 MGD (6,565 gpm)). The Madison Pump Station has a total capacity of 14 MGD (9,700 gpm) with a firm capacity of 10 MGD (7,000 gpm). The disinfection system would be designed for the total capacity of the pump station, and allow for a future well at the existing Madison well field. Assuming a layout similar to TM-13 Alternative Layout 1, disinfection contact time would be through the existing Madison storage reservoirs and pipeline to the Pine Ridge site. The 30” pipeline from the Madison Pump Station to the Pine Ridge site is approximately 4875 feet. Table 3 represents the contact time in the existing Madison reservoirs if sodium hypochlorite is dosed prior to the storage reservoirs.

Table 3. Existing Madison Wells Disinfection Contact Time.

Location	Total Volume (gals)	Minimum Volume (gals)	β Factor	Effective volume (gals)	Flowrate (MGD)	Detention Time (min)
Existing 1.1 MG Reservoir	1,108,000	554,000[1]	0.1	55,400	14	6
Existing 0.2 MG Reservoir	204,000	102,000[1]	0.1	10,200	14	1
Existing 30" Pipeline	179,000	179,000	1.0	179,000	14	18
Total	**1,491,000**			**55400**		**25**

Notes:
1. Assumes the 1.1 MGD and 0.2 MGD reservoirs are always greater than half full.

With the existing infrastructure, the contact time is approximately 25 minutes between the chlorine dosage point and the Pine Ridge site. The disinfection contact time would be met if an additional reservoir is built near the existing Pine Ridge Reservoirs (See the combined new and existing Madison Wells Section).

New Madison Wells

As indicated in Technical Memorandum #3, the required new firm capacity of the Madison wells will be 16,000 gpm. Given an estimated well production of 1,400 gpm, a total of 12 wells would meet the firm capacity requirement. As such, a total of 13 new wells will ultimately be installed in the new Madison well field with a total capacity of 18,200 gpm, or 26.2 MGD. Assuming a layout similar to TM-13 Alternative Layout 1, disinfection contact time would be through a new storage reservoir at Pine Ridge or the New Madison Well Field and the pipeline to the Pine Ridge site. The new 36” pipeline from the new Madison Well Field to the Pine Ridge site would be approximately one mile. Table 4 represents the contact time in the 36” pipeline to Pine Ridge and a new storage reservoir.

Table 4. New Madison Wells Disinfection Contact Time.

Location	Total Volume (gals)	Minimum Volume (gals)	B Factor	Effective volume (gals)	Flowrate (MGD)	Detention Time (min)
New Storage Reservoir	370,000	370,000	0.7	259,000	26.2	15
New 36" Pipeline	279,000	279,000	1	279,000	26.2	15
Total	**649,000**			**259,000**		**30**

Table 3 indicates that 15 minutes of detention time are achieved through a new 36” pipeline for one mile. An additional 15 minutes of detention time would be required from a well baffled reservoir that has a minimum disinfection contact volume of 370,000 gallons.

Combined New and Existing Madison Wells

Under a combined scenario, the capacity of the reservoir would need to be large enough for both the existing Madison pump station (14 MGD) and the new Madison wells (26.2 MGD) for a maximum capacity of 40.2 MGD. Assuming a layout similar to TM-13 Alternative Layout 4, disinfection contact time would be through a new storage reservoir at the Pine Ridge site. Since the first customer is assumed to be at the Pine Ridge site no disinfection contact time is achieved through a pipeline. Table 5 represents the contact time in a new storage reservoir at

the Pine Ridge site. Refer to the next section for possible modifications to the existing Pine Ridge reservoirs to achieve disinfection contact time.

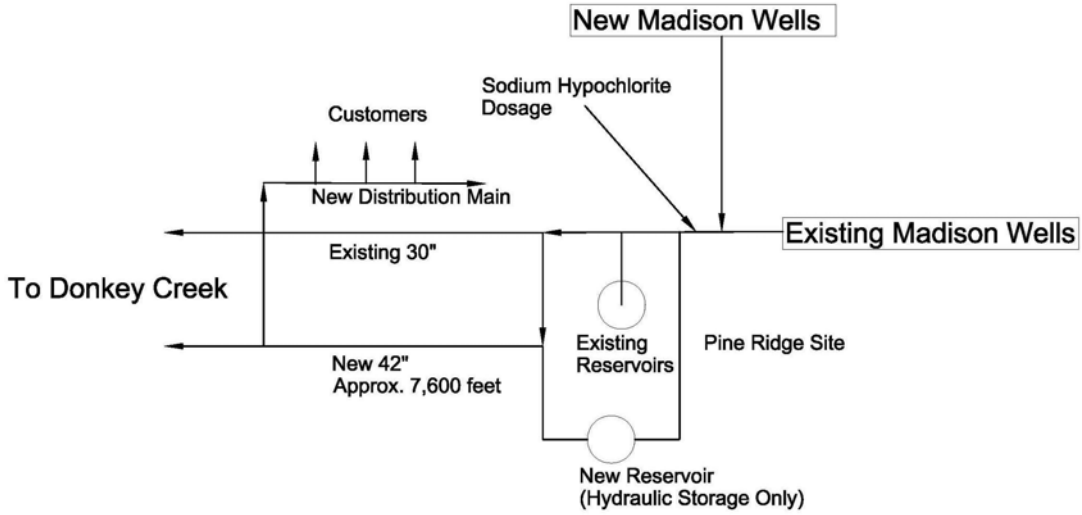
Table 5. New and Existing Madison Wells Disinfection Contact Time.

Location	Total Volume (gals)	Minimum Volume (gals)	β Factor	Effective volume (gals)	Flowrate (MGD)	Detention Time (min)
New Storage Reservoir	1,200,000	1200000	0.7	840,000	40.2	30
Total	**1,200,000**			**840,000**		**30**

Table 4 indicates that 30 minutes of detention time can be achieved through a new well-baffled reservoir with a minimum volume of 1.2 MG.

To reduce the size of the new storage reservoir, the disinfection contact time could also be met through the pipeline before the first customer's taps. The pipe arrangement near the Pine Ridge site would be modified similar to Figure 3. With this arrangement, the disinfection contact time would be met in the new 42" and existing 30" pipeline before the first customer. The new reservoir would be designed for hydraulic considerations only, reducing the size of the new reservoir. Approximately, 7,600 feet of pipeline will accomplish 30 minutes of detention time at 40.2 MGD. The customers between the existing Madison site and the location of the requirement disinfection would be supplied with water from a small 8-inch to 12-inch distribution main for approximately 11,550 feet depending on the type and number of customers. The existing taps would be removed from the existing Madison pipeline and connected to this new distribution main, ensuring minimum disinfection contact times have been met prior to delivery. The City of Gillette have a few customers (3 active customers, 1 water loadout station, and 2 new customers that will be activated in the next 2 to 3 months) connected to the Madison Pipeline between Pine Ridge and the Madison PS that would be connected to the new 8-inch to 12-inch distribution main.

Figure 3. Pipe Arrangement with Disinfection Contact Time in New Pipeline.



MODIFICATION TO EXISTING STORAGE RESERVOIRS

As discussed earlier, the existing storage reservoirs could be modified to allow for additional disinfection contact time. Additional contact time would be achieved by adding baffles and separating the inlet and outlet of the reservoir. Refer to Table 1 for β factors achieved from baffling conditions in a reservoir. If the existing Pine Ridge storage reservoirs were modified with separate inlet and outlets along with baffles inside the reservoir, the β factor of the reservoir could be changed from zero to 0.7. Table 6 represents the additional disinfection contact time at 40.2 MGD that could be achieved from the reservoirs if the existing reservoirs were modified. City of Gillette staff have indicated that in the summer, the Pine Ridge system is operated between 75-100% full.

Table 6 Modification of Existing Pine Ridge Reservoirs

Location	Total Volume (gals)	Minimum Volume (gals)	B Factor	Effective volume (gals)	Flowrate (MGD)	Detention Time (min)
Existing 0.8 MG Reservoir	859,000	644,250	0.7	450,975	40.2	16
Existing 0.2 MG Reservoir	198,000	148,500	0.7	103,950	40.2	4
Total	**1,057,000**			**450,975**		**20**

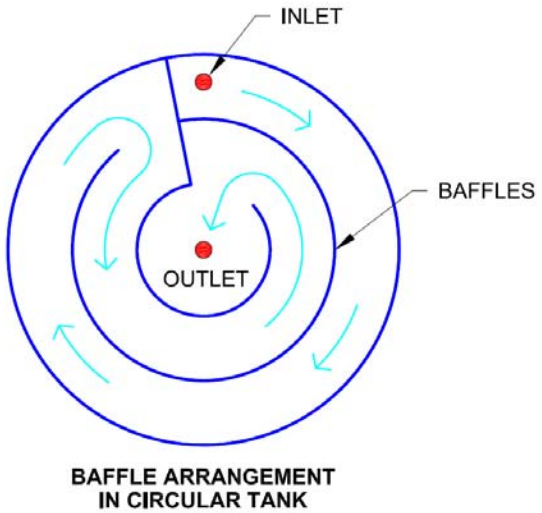
Notes:

1. Assumes the 0.8 MGD and 0.2 MGD reservoirs are always greater than 75% full.

These modifications to the existing Pine Ridge storage reservoirs assuming the total flow rate of the system would result in a detention time in the reservoir of 20 minutes assuming the reservoir water levels are always greater than 75% full. During the modifications to the existing storage reservoirs, the Madison well system will not be able to operate at full capacity and still achieve the required disinfection contact time. A new 410,000 gallon reservoir would be required in addition to the existing reservoirs to achieve the additional 10 minutes of detention time required.

Modification of the existing reservoirs to separate the inlet/outlet and add baffles would reduce the size requirement of the new reservoir by approximately 790,000 gallons. Modification of the existing reservoirs to add baffles would include adding concentric steel plate baffle curtains that would need to be welded to the floor and supported at the top with steel beams or welded into the roof structure (see Figure 4). It is likely that the entire reservoir interior and exterior would need to be sandblasted and recoated due to the extensive welding on the baffle plate system. The coating on typical steel reservoir is a significant portion of the total cost of the reservoir, usually 30-40% of the total cost. The baffle plates would equal or exceed the amount of plate used on the exterior wall of the existing reservoir and therefore be cost prohibitive. We recommend that based on disinfection contact time and hydraulic storage requirements the City should not pursue modifications to the existing storage reservoirs. If the existing Pine Ridge Reservoirs are not baffled they will not provide disinfection contact time, but will provide storage for hydraulic requirements as they do currently.

Figure 4. Baffle Requirement is a Circular Reservoir.



HYDRAULIC ANALYSIS CONSIDERATIONS

A hydraulic analysis has been prepared to evaluate the hydraulic storage times for the existing Madison System and to analyze providing some similar level of service for the new installation. The full system hydraulic analysis for this project is being performed under Technical Memorandum 7 and has confirmed this hydraulic analysis. Only the Pine Ridge storage is evaluated herein. Considering the preliminary new Madison Well Field location sited north of Pine Ridge per Technical Memorandum 2, no changes are proposed at this time for hydraulic storage improvements at the Madison storage reservoirs. When the existing maximum fill rate of 8,800 gpm is considered at Pine RIdge in conjunction with the total Pine Ridge reservoir volume of 1.0 MG the resultant total retention time is 113 minutes or slightly under 2 hours. City of Gillette staff have indicated that in the summer, the Pine Ridge system is operated between 88-100% full, and in the winter between 75-100% full. With a total reservoir height of 58.5 feet, these ranges equate to 51.5-58.5 feet and 43.9-58.5 feet, respectively. Under the summer operating scenario, when peak flows are most likely to occur, the indicated range equates to a volume of 12% of the total existing Pine Ridge storage, or approximately 120,000 gallons. This effective hydraulic storage equates to a hydraulic retention time of 14 minutes. However the retention time reduces to approximately 3-4 minutes with the larger reservoir out of service. City of Gillette staff have indicated that when the larger reservoir is out of service, the 3-4 minute time can be challenging to work with.

It is recommended that the reservoir system consisting of both the new and existing reservoirs at Pine Ridge be able to provide 15 minutes of storage nominally and at least 5 minutes of storage with the largest reservoir out of service. With the combined Madison sources producing a peak day firm capacity rate of 22,500 gpm, 15 minutes of storage would correspond to 337,500 gallons, and 5 minutes of storage would correspond to 112,500 gallons of storage. Considering the existing capacity of 120,000 gallons for the scenario discussed above, an additional 217,500 gallons of storage would be required in the new Pine Ridge reservoir to meet the nominal 15 minutes of storage considering hydraulics. With the new reservoir out of service

(largest hydraulic storage volume), the system would still be able to provide just over the minimum 5 minutes of storage.

It would be possible to add further storage to the new Pine Ridge reservoir to increase the hydraulic retention time. This would provide an added margin of safety and slightly more system storage in the event of a well field outage or other interruption to service in the Madison well field area. For comparative purposes, a 30 minute retention time would require an additional 555,000 gallons above the existing storage system, while a 60 minute retention time would require an additional 1,230,000 gallons above the existing storage system.

HYDRAULIC AND DISINFECTION CONSIDERATIONS

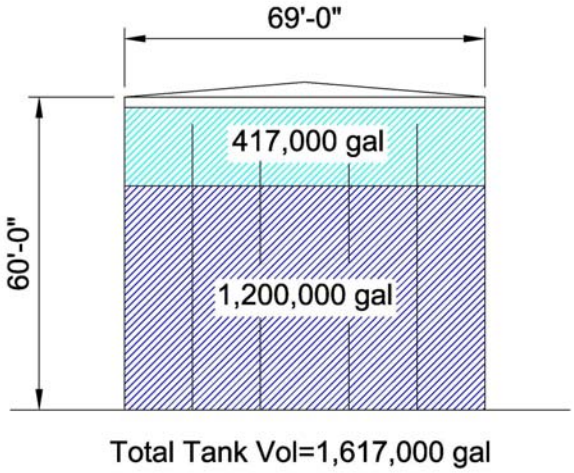
Table 7 shows the total capacity of the new Pine Ridge Reservoir if the disinfection contact time is achieved through a new reservoir. The reservoir was calculated with 30 minutes of disinfection contact time below the minimum water level for disinfection contact time requirements and 15 minutes of storage between the minimum and maximum water levels for hydraulic requirements.

Table 7. Pine Ridge Storage Requirements.

Storage	Volume (gals)
Disinfection Contact Time	1,200,000
Hydraulic Storage	217,500
Total	**1,417,500**

As discussed previously, the disinfection contact time volume is required below the minimum water level (elevation 4528.90) and the hydraulic storage volume is required between the minimum water level elevation (4528.90) and the high water elevation (4543.50). Due to the elevation requirement for each storage category to provide the necessary function, combining the two storage reservoirs as one makes the hydraulic storage portion of the volume considerably greater than required due to the footprint of the reservoir. Refer to Figure 5 for the actual reservoir size requirements due to the geometry. As you can see the resulting capacity would be 1,617,000 gallons resulting in 199,500 gallons of unnecessary additional storage.

Figure 5. Schematic of Total Reservoir Volume.



As such we have developed two other potential scenarios to achieve both the volume required for disinfection contact time and hydraulics as follows:

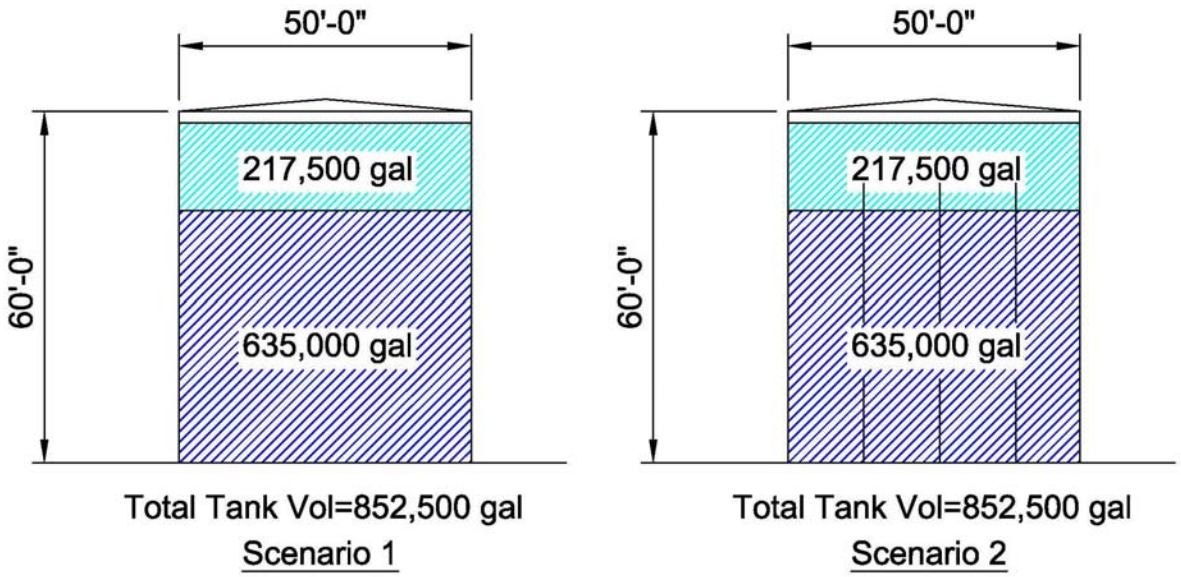
Scenario 1

A. Install a new reservoir (~0.85 MG) at the Pine Ridge site for only hydraulic considerations. (See Figure 6)
B. Utilize existing 30-inch and new 42-inch lines for first 7,600 feet from the tank discharges to achieve 30 minutes of contact time. During evaluations of pipeline material scenarios we will evaluate if it might be necessary to upsize the 42-inch pipeline for this stretch.
C. Connect a new 8-inch or 12-inch distribution main to the 42-inch and/or 30-inch transmission lines at the 7,600 foot location. Extend the distribution piping for approx. 11,550 feet to serve existing residents including the resident near the Madison site.

Scenario 2

A. Install baffling to both the 0.2 MG and 0.8 MG existing reservoirs at Pine Ridge.
B. Separate the inlet and outlet of the Pine Ridge reservoirs.
C. Install a new reservoir (~0.85 MG) at Pine Ridge that is well-baffled. (See Figure 6)

Figure 6. Scenario 1 & 2 Schematic of Reservoir Volumes.



CONCLUSIONS

We recommend Scenario 1 to achieve the required disinfection contact time and hydraulic storage at the Pine Ridge site for the following reasons:

- Capital Cost: Scenario 1 has a considerably smaller reservoir than the original concept shown in Figure 5 and no reservoir baffles. The cost difference in reservoir sizes and baffling is considerably more than 11,550 feet of additional 8" to 12" distribution main for customers near Pine Ridge and Madison.
- Operating and Maintenance Cost: The reservoir in Scenario 1 is smaller and has no baffles compared to the concept shown in Figure 5. Although the size is the same as the reservoir shown in scenario 2, scenario 1 does not require any baffling. Maintaining the Scenario 1 reservoir will be considerably less than the other options.
- Footprint: Since Scenario 1 has a smaller reservoir, the total site area will be decreased.
- Wasted Volume: The reservoir in Figure 5 has approximately 0.2 MG more capacity in the hydraulic storage portion of the reservoir than required. This is unnecessary storage.
- Cathodic Protection: Scenario 2 includes baffles that require additional cathodic protection, for the metal surfaces.