CITY OF JUNCTION CITY
Water System Master Plan
Junction City, Oregon

CHAPTER 9
WATER STORAGE EVALUATION

Chapter Outline

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CHAPTER 9

9.1 INTRODUCTION

The emphasis of this chapter is shifted from the water storage inventories of Chapter 4 and placed on the hydraulic design and performance of existing and future reservoirs.

Although closely integrated with the overall water distribution system as discussed in Chapter 8, this report presents water storage as a separate discussion to focus on several key issues unique to this subset of the distribution system. Capital costs for the recommendations presented in this chapter appear in Chapter 10.

9.2 EVALUATION CRITERIA

Net storage volume, system pressures, water quality, and redundancy are some of the factors used to evaluate the suitability of existing and planned water storage facilities. The parameters presented in this section will be utilized in the analysis and recommendations of Sections 9.3 and 9.4 to follow.

9.2.1 Storage Volume

The primary function of water storage is to provide a reserve of water to equalize daily variations between supply and consumer demand, serve fire-fighting needs, and meet system demands during an emergency interruption of supply.

The overall storage within a system can be divided into the several categories. The following sub-paragraphs define these storage allocation categories.

- Operational Storage—Storage volume within the upper elevation of a tank used by the system operators to control the start and stop of supply pumps.
- Equalization Storage—Storage that is utilized to meet consumer demands in excess of supply or production capabilities. The equalization storage volume required is typically determined as either a percentage of the maximum day demand (MDD), generally 20 to 40%, or by determining the deficit between the peak hour demand (PHD) and the available supply for a determined duration—generally 2 to 4 hours.
- Fire Storage—Storage that is required to satisfy the single largest flow demand in the system. Fire storage volume is calculated by multiplying the stipulated fire flow rate by its required duration. As discussed in Chapter 5, this report utilizes the fire flows established by the City's design standards. The most stringent fire flow condition is a 4-hour 6,000 gpm event that equates to a total fire flow volume of 1.44 MG.
- Emergency Storage—Storage that is required to meet demand during emergency situations such as power outages, pipeline failures or natural disasters. The amount of emergency storage provided can be highly variable depending upon the reliability and diversity of supply sources, an assessment of risk and the desired degree of system reliability.

- Pumped Storage—Stored water that lies below the minimum operating level of the distribution system. This water must be pumped into the distribution system, or elevated tank before it can be utilized. In the event of a pump station outage, the stored water is unavailable.
- Dead Storage—The volume of unusable water stored in a reservoir that lies below the minimum operating level, excluding pumped storage. Dead storage is eliminated from the Junction City system in the event all ground storage (pumped storage) facilities are provided with backup power systems.

9.2.2 System Pressure

In most municipal distribution systems, the service pressure is determined by the free water surface elevation of the storage reservoirs serving the system. Service pressures begin with available static pressure created by elevated reservoirs and are reduced en-route to the consumer by friction losses in the pipe network.

Service pressures at the point of delivery typically range from 40 to 80 psi. Pressures below this range cause inaccuracies in customer meters and flow reductions during periods of high demand whereas pressures above this range can damage domestic plumbing systems. The Oregon Plumbing Specialty Code[26] (OPSC) defines 80psi as the maximum unregulated pressure for domestic service. Service pressures above this range must be reduced with a pressure regulating valve. This plan recommends an operating pressure range between 40 and 76 psi.

9.2.3 Water Quality

There are no specific regulatory requirements for water turnover rates in storage facilities, but industry sources suggest a complete water turnover be accomplished every 3 to 5 days[27]. Experiences with reservoirs with cement-based internal surfaces suggest a slightly higher turnover rate of 5-7 days[28].

Historically water storage facilities are operated at near full levels to maintain system pressure and maximize storage volumes for emergencies; however, in times of non-emergency the large storage volumes reserved for fire fighting can create water quality problems. Degraded water quality in storage facilities is frequently the result of under utilization and poor mixing during filling cycles.

As water ages, there is also a greater potential for disinfection by-product (DBP) formation. The combined effects of elevated pH due to prolonged water contact with new interior concrete surfaces, elevated temperatures associated with long detention times, and higher chlorine dosages experienced during rechlorination efforts can increase the formation of DBPs.

In summary, excessive water age can result in a diverse set of problems ranging from the loss of residual disinfectant, problems with bacterial proliferation or regrowth, increased formation of DBPs, taste and odor problems as well as temperature and pH instabilities.

[26] State of Oregon, 2008
[27] Kirmeyer et al, 1999
[28] Baur, 1988

9.2.4 Pumped Storage

Distribution systems such as Junction City's that utilize groundwater sources and have relatively flat topographies result in systems where every unit of storage is considered pumped storage. For this reason pumped storage is not segregated in storage calculations. Clearly, the provision of emergency backup power and redundant pumping is critical for systems that rely heavily on pumped storage. The reliability of the pumping systems serving storage facilities are evaluated in Chapter 6.

9.2.5 Redundancy

A lack of redundancy with regard to storage facilities is most frequently encountered when a reservoir must be taken off-line for cleaning, inspection or maintenance. While some of these procedures can be accomplished with a facility on-line, others such as internal recoating cannot. It is therefore recommended that the planning and construction of reservoir improvements provide the City operators with the flexibility to maintain these important facilities.

Storage redundancy is also critical in the wake of natural disasters. As discussed in previous chapters, seismic events present the largest natural disaster threat to these structures.

9.3 WATER STORAGE ANALYSIS

9.3.1 Net Storage Volume

The total recommended storage in the system is the sum of operational, equalization, fire, and emergency storage. Two methods for calculating the components of net storage were utilized. An important assumption utilized by both calculation methods is that the water supply delivered from the existing well pumps (or future water treatment plant) is never less than MDD.

Two factors common to the calculation methods are the quantification of fire storage and dead storage. An evaluation of each follows. First, fire storage for both methods was calculated using the fire flows defined in the City's Public Works Design Standards as previously described. The total fire suppression volume is simply the product of the maximum fire flow rate and the duration of the event. A 4-hour 6,000 gpm fire results in volume of 1.44 MG. Second, dead storage is set to zero. This reasonably assumes that all ground storage pumping facilities will be provided with auxiliary power and are capable of rapidly mobilizing all of the ground storage volumes.

The first calculation method quantifies equalization storage as 25% of MDD[29] and emergency storage as 100% of MDD. Given an ADD:MDD peaking factor of 2.70, this effectively creates a 2.7 ADD window for emergency repairs. Total storage recommended by this method is displayed in Figure 9-1. The chart assumes that maximum fire flows will be 4,000 gpm for 4 hours until 2013 when they increase to 6,000 gpm for 4 hours. This two-tier approach was used because, although the City design standards require the higher design flow for new commercial and industrial facilities, they currently have insufficient storage for the 6,000 gpm 4 hour fire. The figure shows a dashed line below the upper leg of the Method 1 curve. This line is an extension of the 4,000 gpm 4 hour criterion and has been included to illustrate the effect of the reduced fire

[29] Mays, 2000

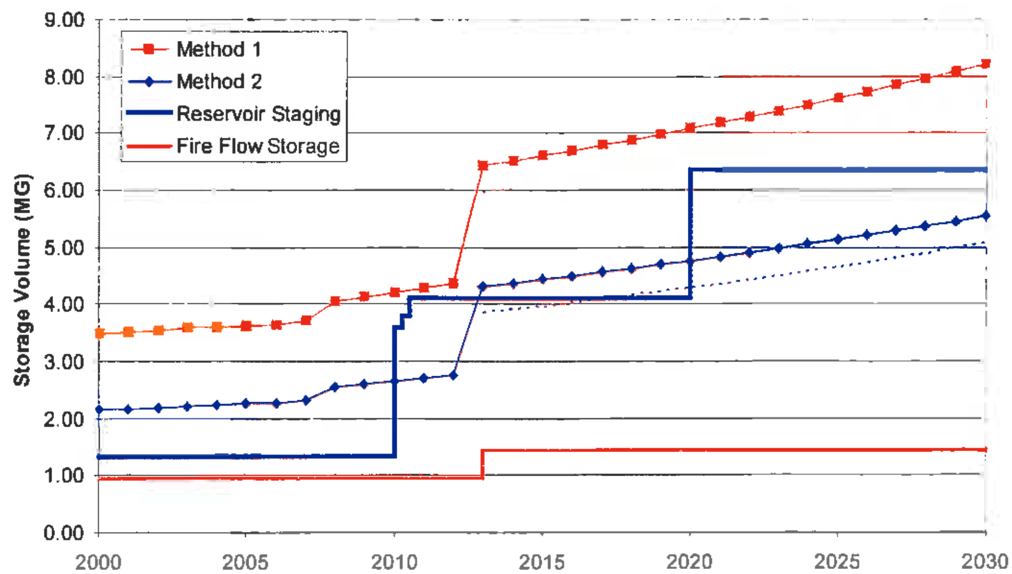
flow standard. The reservoir staging curve represents the construction sequence of new reservoirs as shown in Table 9-1.

The second calculation method is described in the Washington State Department of Health's Water System Design Manual[30], and requires an additional storage allowance for operational storage. Operational storage is the volume within the upper elevation of a reservoir used by system operators to control the start and stop of supply pumps. The need to provide equalization, fire, or emergency flows, may reasonably occur at any point in the operational call sequence for water. Accordingly, it is recommended that operational volumes be considered separate from equalization volumes. The overall elevation difference (storage volume) required by the pump control system is determined by the type of instrumentation, the number of pumps in a reservoir fill sequence, and operator preferences. For the purposes of this report an operational volume of 10 percent is utilized over and above equalization volumes.

Equalization storage is defined as the difference between PHD and total supply or treatment capacity for a duration of 2.5 hours. Emergency storage calculated by this method recognizes that for water systems with multiple supply sources, an emergency constitutes removal of the largest supply source while other sources remain on-line. This is conventionally defined as the firm capacity of a system. An emergency event has a 2-day duration and requires daily emergency storage volumes equivalent to one ADD volume, less the production volume of the in service sources over this period. In cases where firm pumping capacity exceeds ADD (as with Junction City), a minimum threshold of 200 gallons per EDU for the two-day event is recommended. For the purposes of this report a minimum threshold of 100 gallons per capita was utilized.

Figure 9-1 shows the storage volumes required by these two methods and the proposed storage development sequence. The recommended construction sequence of reservoirs as illustrated in the figure appears in Table 9-1.

Figure 9-1 | Projected Storage Volumes



The storage need as established by Method 2 is slightly favored, as it provides a more accurate accounting of equalization storage for a system with multiple water sources.

As the preceding figure shows, Junction City has traditionally operated with storage volumes well below the recommended threshold, but has successfully leveraged the lack of storage with a large capacity well pumping system. It should also be noted that although the current pumping system (comprised of four active wells) provides satisfactory mechanical pumping redundancy, the lack of emergency backup power for each of the wells compromises this redundancy. The provision of backup power at each of the wells as recommended in Chapter 6 is aimed at resolving this disparity.

The proposed schedule for storage improvement projects is outlined in Table 9-1. The cumulative storage volumes of this table assume that the existing 1.25 MG ground storage reservoir can be retrofitted to meet current seismic standards and the facility can be suitably maintained until the year 2030. As an economical alternative to structural modifications, the operating level in the tank may be lowered to meet the seismic requirements. This negligible change in volume is not considered in this analysis. At the very minimum this facility should remain in service until it can be replaced by the proposed 2.25 MG ground storage facility near the proposed treatment plant on Elm Street.

Table 9-1 | Reservoir Staging

Year	Facility (MG)	Location	Cumulative Storage (MG)
2010	+ 2.25 GS	Water Treatment Plant in Town	3.60
2010	+ 0.30 EL	Water Treatment Plant in Town	3.90
2010	- 0.10 EL	Existing Elevated (removal)	3.80
2010	+ 0.30 EL	DOC Complex	6.05
2020[1]	+ 2.25 GS	Water Treatment Plant in Town	6.35

GS = Ground Storage EL = Elevated Storage

[1] Date to be confirmed

9.3.2 Water Quality

9.1.1.1 Existing System Water Quality

Water quality in the City's existing elevated reservoir is excellent. This reservoir benefits from high turnover rates and a central location relative to demands. Theoretical reservoir turnover during MDD and ADD periods ranges from 1 to 3 hours and exceed the industry's goal of 3-5 days.

The existing 1.25 MG ground storage reservoir is hydraulically isolated from the distribution grid because of its low hydraulic grade line and requires regular management to maintain water quality. Operations staff monitor the chlorine residual in this tank and periodically activate the south fire pump to transfer water into the distribution grid and elevated storage tank.

[30] WA DOH, 2001

9.1.1.2 Future System Water Quality

Control of water between the two ground storage tanks at the WTP will be handled by automated valves through the SCADA interface. Disinfection contact time will be a product of the two tanks. A booster pump station will be provided to transfer water from this reservoir into the new elevated tank. The new ground storage tank will be operated as a fully mixed vessel and water age in the combined ground storage system will likely be on the order of 5 days.

The following water quality monitoring and management measures are suggested for this facility;

- Instrumentation to monitor flow rate and volume into and out of the reservoir
- Inlet and outlet sampling for chlorine residual, DBPs and temperature
- Temperatures and water samples extracted from various elevations within the reservoir

The 0.3 MG elevated reservoir at the DOC complex will need to be managed as a first-in first out facility with automated valves. In conceptual form, two lines (reservoir inlet and outlet lines) will branch off the 24-inch transmission. A valve on each of these lines, as well as one on the transmission line between the inlet and outlet lines, will allow flow to be directed into the reservoir and then out to the DOC distribution grid. During periods of maintenance, the reservoir can be taken off-line by closing the inlet/outlet valves and opening the mainline valve to serve the facility directly from the transmission main. This operational mode, and flow path through the reservoir, will ensure a frequent turnover in the reservoir.

The volume of water stored in the 24-inch transmission pipe from the south edge of town to the DOC facility and including the reservoir is roughly equivalent to 10 days of ADD for the fully staffed and populated DOC and DHS facilities. Water age in the transmission line will be the longest in the early stages of occupation and will decrease as additional demands come on-line.

Careful consideration will need to be given to the operation of the transmission from the day it is commissioned until the DOC and DHS facilities begin to populate. The large volume of water in this line and low demand during this period will require close attention to water quality.

9.3.3 System Pressure

Junction City currently operates with a distribution system pressure between 60 and 62 psi. The upper static pressure limit of 62 psi is governed by the overflow elevation of the existing elevated reservoir. Minimum distribution system pressures during MDD conditions are typically observed along the south edge of town in the vicinity of Prairie Road and range from 50-55 psi.

The water distribution system in the core area of downtown Junction City consists primarily of cast iron and asbestos cement pipe. Due to the pipe material, and age, the calibrated hydraulic model utilized roughness factors representing high friction losses for this portion of the distribution system. This region of older rougher pipe creates a loss of conductivity for water that flows through and out of the down town area. A large amount of water production and storage infrastructure is located inside this core area and includes the future WTP, existing and future ground storage tanks, as well as the proposed elevated reservoir.

Several modeling scenarios were evaluated to determine an appropriate hydraulic grade line (HGL) for the new elevated reservoir. A HGL equivalent to the existing elevated reservoir was insufficient to deliver the full range of demands to the DOC and DHS facilities within an acceptable pressure range. It was determined that a new HGL of 492.0 (25-feet higher than the existing elevated reservoir) is capable of serving ADD demands in the southernmost end of the UGB over a pressure range of 60-63 psi. Maximum steady state system pressure is 76 psi in the northwest corner of town and occurs during periods of minimum demand. Pressure at this location ranges from 71 to 73 during periods of MDD.

Raising the system HGL is an important operational improvement because it provides a strong base level of gravity driven supply to the southern end of the industrial corridor. It also provides an offset to the increased pipe headlosses in the older pipe of the core municipal areas.

9.3.4 Pumped Storage

This plan recommends equipping the new ground storage transfer/booster station with emergency backup power and sufficient mechanical system redundancy to ensure that all water from the ground storage facility can be readily transferred into the elevated tank or distribution grid. The pump station will be sized for a firm capacity equal to MDD plus the maximum required fire flow.

9.3.5 Redundancy

The most common need for storage redundancy arises when a particular storage facility must be removed for inspections or maintenance. Although inspections and minor maintenance can sometimes be performed with the reservoirs in service, in the long run more intensive rehabilitation will require a given facility to be taken out of service. Repainting can often take from 60 to 90 days. For this reason redundant reservoirs in each class of storage (elevated vs. ground storage) are recommended.

The existing ground storage reservoir will be required to remain in service until the new 2.25 ground storage tank comes on-line. Seismic and internal improvements to this tank will be deferred until it can be taken off-line. The new reservoir will not be able to be removed from service (nor should it need to be) until the second 2.25 MG ground storage reservoir is constructed. Similarly, maintenance of the new elevated reservoir at the WTP site, or the elevated reservoir at DOC complex, will require the use of the other as a redundant facility.

9.4 Recommended Improvements

This report recommends that the City move to construct new storage facilities equal to or greater than the Method 2 storage estimates described in Figure 9-1. Specifically, the new 2.25 ground storage reservoir at the WTP site should be constructed first, followed by the new elevated reservoir at this same site. Construction of the elevated reservoir at the DOC site should either be concurrent or follow immediately. The second 2.25 MG ground storage tank at the WTP site should be developed no later than 2020.

The calculated storage projections of this chapter are provided as conventional guidelines that frame the storage issue. As can be seen from this chapter, and the discussion in Chapter 6, a close relationship exists between the level and reliability of the water supply pumping system and net system storage. In the event the storage recommendations of this chapter are not implemented or deferred, and storage remains below the projected minimum, the City should ensure that commensurate improvements be made to the water supply pumping system to suitably satisfy storage deficits with pumping capacity. This puts a much higher emphasis on new well development and will likely require the replacement of several existing well pumps.

The following paragraphs outline specific storage improvements. Capital costs for each of the recommended improvements are presented in Chapter 10.

9.4.1 Existing Ground Storage

This report recommends that the existing 1.25 MG ground storage reservoir remain in service. Reservoirs often provide critical service to the municipal population in the aftermath of a seismic event and as such it is recommended that a complete structural survey and evaluation be completed to evaluate its remaining useful life, ability to withstand seismic events and to identify rehabilitation options. The report should specifically review the need for seismic anchors between the tank wall and foundation, all piping penetrations, and should confirm the minimum operating freeboard in the reservoir with regard to seismically generated waves. A reduction in the reservoir operating level may prove to be an economical means of addressing seismic concerns.

The reservoir will be integrated into the design of the new treatment plant and will likely serve as the primary chlorine contact chamber. A review of the most recent reservoir inspection report indicated that this facility was in satisfactory condition.

Facility improvements will include changes to the yard piping and valving, and the installation of new level controls and sampling points. The need for a cathodic protection system will be evaluated. A complete review of the coating system and interior amenities will be performed once the new ground storage facility is in service and the old reservoir can be taken off-line.

9.4.2 Existing Elevated Storage

It is recommended that the existing 0.10 MG elevated reservoir be taken out of service after construction of the new 0.30 MG elevated reservoir at the future WTP site on Elm Street. The minimum operating elevation in the new elevated reservoir will be 25 feet higher than the overflow elevation of the existing reservoir. This difference will hydraulically isolate the existing facility and will require a new booster pump system to periodically circulate the aged water out of the tank into the distribution grid.

Elevated reservoirs are especially vulnerable to seismic damage due to the concentration of mass at the top of the structure. Given the age of this reservoir it is unlikely that the structure meets the current seismic code. Continued use of the facility will require a seismic evaluation followed by structural improvements. Case histories of such improvements to similar structures have demonstrated that the cost of retrofitting the structure is often as high as 80 percent of the replacement cost.

Due to the reservoir's relatively small storage capacity and the cost of these improvements, this report recommends taking the reservoir out of service. The structure currently supports a significant amount of telecommunication equipment. Decommissioning the tank will not preclude its function in this capacity, or its continued role as a historic landmark.

9.4.3 New Ground Storage

9.1.1.3 Phase I

Due to the near term demand increases associated with the DOC and DHS facilities and the City's current storage deficit as shown in Figure 9-1, it is recommended that a new 2.25 MG ground storage facility be constructed at the site of the new water treatment plant. Of the storage improvement projects identified in this report, this reservoir project has been assigned the highest priority. Construction for the DOC and DHS facilities is scheduled to begin in 2010 and will require fire suppression storage for the full duration of construction. It is recommended that the construction of this reservoir and booster pump station begin in the summer of 2009 and be ready for service in June of 2010.

It is likely that this ground-level reservoir will be constructed as a pre-stressed concrete tank. Support equipment at this facility will consist of a pump station designed to transfer water into the new elevated tank sited on the same premises, automated valving, level controls, and related instrumentation.

9.1.1.4 Phase II

This report also recommends the construction of a second 2.25 MG ground storage facility at the treatment plant site no later than 2020. The design of this facility will in all regards be similar to the former reservoir. This second reservoir will complete the storage development plan as outlined in Section 9.3.1 of this Chapter.

9.4.4 New Elevated Reservoirs

This report recommends the construction of two new elevated reservoirs; one at the WTP site in town and a second at the DOC complex south of town.

9.1.1.5 Municipal Reservoir

Based on an assessment of the City's existing elevated reservoir, it is recommended that the City construct a new 0.30 MG elevated reservoir to serve as a replacement for the existing reservoir. The higher grade line of the reservoir will increase distribution system pressures that will benefit municipal and DOC/DHS user groups.

The proposed reservoir is currently envisioned as an all steel welded cylindrical storage vessel approximately 50 feet in diameter and supported by a single large diameter pillar on the order of 25 feet in diameter. As previously discussed it is recommended that the new reservoir be constructed to a new hydraulic grade line to increase distribution system pressures.

9.1.1.6 DOC Reservoir

It is recommended that a replica of the 0.3 MG elevated municipal reservoir be installed at the DOC project site to match the hydraulic grade line of the in-town reservoir. Due to the physical separation between this reservoir and the in-town facilities, it is strongly recommended this reservoir be provided with sufficient instrumentation and automated valving to allow remote operation.