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MEMORANDUM

TO: LWWSD – Justin Clary, PE, Bill Hunter, PE, and Rich Munson

FROM: Brian Smith, PE and Melanie Mankamyer, PE

SUBJECT: Division 7 Reservoir – Additional Items for FEMA Funding Application

DATE: December 28, 2020

Introduction

LWWSD has requested assistance with a number of items related to the FEMA Funding Application for replacement of the Division 7 Water Reservoir. This current memorandum builds and expands on the previously issued memorandum titled "Division 7 Reservoir – Seismic Upgrades and Maintenance vs. Replacement" dated February 8, 2018. Additional items addressed in the current memorandum include:

- Analysis of the expected duration of a reservoir outage in the case of a severe earthquake that would impact the existing seismically vulnerable Division 7 reservoir
- Analysis of the population that would be impacted by an unexpected outage of Division 7 reservoir
- Capital cost estimate of two welded steel water reservoirs (an alternative to the two concrete reservoirs as detailed in the previous memorandum)
- Life cycle cost analysis of new concrete reservoirs and new welded steel reservoirs – comparing capital and maintenance costs to achieve 100 year life of reservoirs

Reservoir Outage Duration

Although a seismic event could have a range of impacts on the existing Division 7 reservoir depending on the severity of the seismic event, we can categorize potential damage as either allowing the reservoir to remain in service (even if perhaps water level needs to be decreased to decrease risk) or catastrophic damage that causes complete failure of the reservoir that renders it useless for water storage. For this analysis, we will only address complete failure of the reservoir. The Reservoir Seismic Vulnerability Assessment (December 2016 by BHC Consultants) concluded that catastrophic failure of the reservoir is a possibility in a seismic event.

If a seismic event results in catastrophic failure of the Division 7 reservoir, the portions of the water system that rely on this water storage (as discussed in the next section of this memorandum) will have no water available until either temporary or permanent storage can be constructed, tested, and brought online. This is because the existing Division 7 reservoir is a single reservoir with no backup storage in place to serve its service area.

The length of time it would take to construct permanent water storage sufficient to replace the failed Division 7 reservoir is significant. It is expected that if a seismic event were to occur and the existing reservoir failed, the only feasible action to take would be to put temporary water storage facilities in place to replace the Division 7 reservoir so that water could be delivered to customers. The pressure for some customers may be sub-standard and storage volume would be less than required for the interim period until permanent storage could be constructed. Therefore, when we talk about an "outage duration", it is important to acknowledge that there is likely to be several stages of outage, as illustrated in Figure 1.

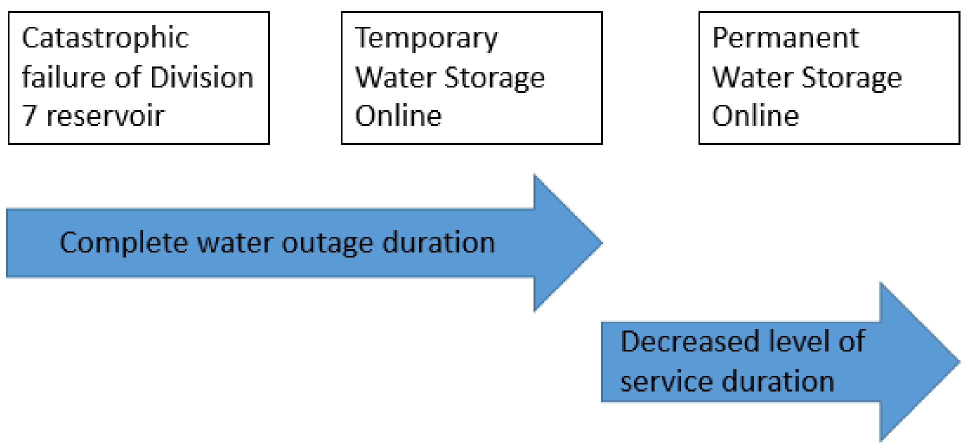


Figure 1: Anticipated stages of "outages" following catastrophic failure of Division 7 reservoir

Temporary water storage was discussed in the 2018 memorandum with respect to erecting temporary storage to serve the system while the existing Division 7 reservoir was out of service for seismic retrofits and re-coating. That discussion focused on a temporary storage solution that would be erected in place and included a NSF 61 certified liner with a storage volume of about 48,000 gallons that was 4.5 ft tall. This was the solution that was discussed because it appeared to be the most acceptable overall solution for a planned outage. But in the current scenario of an unexpected catastrophic failure of the Division 7 reservoir, the priorities would likely be different than for a planned outage. The first priority would be getting temporary storage in place as quickly as possible in a safe manner. The most likely temporary storage solution in this scenario would be to bring in one or more portable steel tanks, each approximately 10,000 gallons, and connect them to the existing tank piping. This solution was not discussed in the previous memo because conversations with the companies that rent these tanks (Baker Corp, etc.) indicated that they do not typically have tanks that have NSF 61 certified liners, and they are used for a variety of liquid storage purposes. To use them for potable water would require a thorough cleaning and disinfection. In the current scenario with the focus on getting water flowing to customers who need it, it is expected that the lack of NSF 61 certification on the tank interior would be acceptable for the interim period. The temporary storage solution discussed in the 2018 memorandum would require clearing a 46 x 46 ft level pad, time to ship the materials from the east coast, and time to erect the temporary tank. These items would take, at best, weeks to complete. Assuming that one or more of the portable steel tanks are available (they may be in high demand following a seismic event), it could be installed and operational in as little as 3 days (given the time to clean, disinfect, and receive satisfactory bacteriological results).

Based on the above discussion, the “complete water outage duration” shown in Figure 1 could be as short as 3 days if everything worked out optimally. A more realistic complete water outage duration is likely more like one week considering logistics of acquiring a suitable tank and getting it to the site.

The temporary storage solution discussed with one or more portable steel tanks results in a decreased level of service for the customers until permanent storage can be constructed. This decreased level of service is discussed in the 2018 memorandum and includes substandard water pressure for the customers served in the gravity pressure zone of the reservoir (because the tank would have a height of 10 ft or less, compared with the current tank height of 35 ft) and the operational challenge for operators to start up and shut down the water treatment plant frequently to avoid overflowing the small temporary storage volume or having it go dry. If five 10,000 gallon tanks were in place for the temporary solution, it would take approximately 45 minutes to fill the storage. If only one 10,000 gallon tank could be sourced, it would take 9 minutes to fill the tank – the water treatment plant is not optimized to run for such a short duration. This increases the risk of a treatment violation.

Because of the decrease in level of service during a temporary storage solution, the reservoir "outage duration" could be considered to be the time from failure of the Division 7 reservoir until permanent storage was constructed and operational. This also could occur if a suitable temporary storage solution could not be sourced.

Time to construct permanent storage replacement for a failed Division 7 reservoir is estimated in Table 1, given that minimum timelines for each step are accelerated compared to normal because of the emergency nature of the situation. Maximum durations are shown based on the concept that construction resources will likely be in very high demand following a large seismic event, and this could result in significant delays in construction timelines.

Table 1: Anticipated Duration of outage until permanent water storage constructed and operational

Step	**Anticipated Duration**	
	Minimum	**Maximum**
Design of permanent storage solution	4 weeks	6 weeks
Regulatory review and approval of design	2 weeks	4 weeks
Contractor pricing for permanent storage solution	1 week	3 weeks
Construction of permanent storage solution	• Submittals and material procurement: 4 weeks • Site prep: 1 week • Yard piping: 3 days • Foundation: 2 days • Structure: 1 week • Disinfection and testing: 3 days • Piping connections: 1 day	• Submittals and material procurement: 16 weeks • Site prep: 2 weeks • Yard piping: 1 week • Foundation: 1 week • Structure: 2 weeks • Disinfection and testing: 3 days • Piping connections: 2 days
Total Outage Duration until permanent storage operational	**14 weeks, 2 days (100 days)**	**35 weeks, 5 days (250 days)**

The range of 100 days to 250 days is a wide range because of the significant unknowns regarding resource availability following a seismic event. To give a single number for the estimated outage duration, the average of this range, 175 days, is likely a reasonable estimate.

Population Impacted by Reservoir Outage

In order to analyze the population that would be impacted by an outage of the Division 7 reservoir, two figures are helpful. One is the Hydraulic Profile that shows system connectivity in Figure 3.3 of the current Water System Plan. This shows connectivity and which pressure zones can be fed from the various sources. The pressure zone map can be seen in Figure E-1 (Appendix E) of the current Water System Plan. Figure 3.3 shows that two pressure zones, PZ-15-SV and PZ-19-SV, can only be fed from the Division 7 reservoir. A complete outage of the reservoir means that there is no way to feed water to these portions of the water system, since the supply pumps (WPD7) are constant speed pumps and cannot be operated like a booster pump system. Typical system operation is such that PZ-2-SV is fed from the Division 7 reservoir, but this pressure zone could be fed from PZ-3-SV which is supplied by the Division 22 reservoirs.

But an outage of the Division 7 reservoir means that large portions of the distribution system (PZ-2-SV, the Division 30 reservoir and all portions of the system fed from that reservoir) would need to be supplied from the Division 22 reservoir instead of the Division 7 reservoir. This means that the Division 22 storage volume would be insufficient for the population it was serving (not enough standby storage to be prepared for additional potential issues with the water supply). Operations should shift so that the Geneva reservoir fed PZ-4-G, which would mean that the Geneva reservoir is feeding more connections than it has capacity for, but that lessens the stress on the Division 22 reservoirs. In this way, the entirety of the South Shore water system would be impacted by an outage of the Division 7 reservoir. Because 370,000 gallons of storage are needed at Division 7, and overall system storage capacity needs are approximately 2,000,000 gallons, this means that the overall south shore system would lose 19% of its required storage volume capacity.

The entirety of the South Shore water system would also be impacted in other ways as well. Once temporary storage was in place to serve those portions of the system that can only be fed from the Division 7 reservoir (temporary storage discussed in the previous section of this memorandum), it will make operations at the treatment plant significantly more difficult because of the frequent and short duration fill cycles for the temporary storage. This would mean frequent and short run cycles at the water treatment plant, which it is not optimized for, unless other physical changes were made to the system facilitate this emergency operation scheme (such as installing a bypass pipe and valve around the Div 22 transmission line check valve so that Div 22 could provide flow back to CT tank which could be pumped to Div 7 temporary storage). These impacts to the treatment system could increase risk of treatment upsets if the treatment plant is starting up and shutting down more frequently than it is intended to do, and would stress overall operations, requiring significant additional operator's labor time to operate the system in this emergency manner. These items, and the costs of the emergency response and fixes, would negatively impact the whole District financially in a more significant way than proactively replacing the reservoir would do.

In all these ways, the entire south shore system with a population served of 10,028 would be impacted by a loss of the Division 7 reservoir due to a seismic event.

Capital Cost Estimate of Two New Welded Steel Reservoirs

The estimated capital cost to replace the existing Division 7 water reservoir with two appropriately sized concrete water reservoirs was presented in the February 8, 2018 memorandum, and this estimate has been updated and included as Table 2 in this current memorandum.

As requested, we also compiled a capital cost estimate if the two appropriately sized reservoirs were constructed of welded steel instead of concrete. This is shown in Table 3.

Estimates indicate that constructing the two reservoirs out of welded steel would require a capital investment of roughly 50% more than constructing the reservoirs out of concrete. Life expectancy and maintenance needs of concrete vs. welded steel reservoirs are discussed in the subsequent section of this memorandum.

Table 2

LAKE WHATCOM WATER AND SEWER DISTRICT — **12/21/2020**
Division 7 Reservoir Replacement
Preliminary Cost Estimates

Prepared by: **Brian Smith, PE and Melanie Mankamyer, PE, Wilson Engineering LLC**

Wilson Job No.: **2019-104**

Preliminary Cost Estimates - Replace Div 7 Reservoir with Two Concrete Reservoirs

Construction Year: **2021**

Item Description	Quantity	Unit	2020 Unit Price	Amount
CONSTRUCTION				
a. Mobilization (10%)	1	LS	$ 83,426	**$ 93,000**
b. Temporary Erosion and Sediment Control (1%)	1	LS	$ 8,260	**$ 9,200**
c. Storage Improvements				
Concrete storage tank 185,000 Gallon 30 ft dia x 35 ft height (installed by supplier, prevailing wages)	2	EA	$ 223,000	$ 427,064
Reservoir railing	2	EA	$ 10,000	$ 23,485
Tree removal	1	LS	$ 30,000	$ 35,227
Clearing and grubbing	1	LS	$ 10,000	$ 11,742
Site earthwork	1	LS	$ 90,000	$ 105,682
Overflow piping	500	LF	$ 100	$ 58,712
Piping from new tank to existing, 12" diameter	500	LF	$ 100	$ 58,712
Manual valve on one tank outlet (other tank to have isolation valve with electronic actuator, priced with ShakeAlert Integration)	1	EA	$ 2,000	$ 2,348
Surface restoration / planting mitigation	1	LS	$ 20,000	$ 23,485
Stormwater management	1	LS	$ 8,000	$ 9,394
Electrical, telemetry and instrumentation	1	LS	$ 100,000	$ 117,424
Subtotal				**$ 873,276**
d. Access Road Improvements				
Clearing / grubbing / grading	1	LS	$ 15,000	$ 17,614
Base Course (6-in)	180	Ton	$ 40	$ 8,455
Top Course (3-in)	90	Ton	$ 50	$ 5,284
Geotextile (triax grid)	700	SY	$ 3	$ 2,466
Stormwater management	1	LS	$ 5,000	$ 5,871
Subtotal				**$ 39,689**
SUMMARY				
Subtotal				$ 1,015,165
Contingencies	15%			$ 152,300
Sales Tax	8.5%			$ 99,235
Preliminary Estimated Construction Costs				**$ 1,267,000**
Permit Fees	2.2%			$ 28,000
Easement Acquisition				$ 5,500
DOH Project Report				$ 20,000
Topographic Survey	2%			$ 24,400
Geotechnical Investigation				$ 10,700
Engineering Design	10%			$ 121,700
Construction Phase Engineering/Inspection	10%			$ 125,300
Construction Phase Surveying	1%			$ 12,600
NEW CONSTRUCTION TOTAL PROJECT ESTIMATED COST				**$ 1,616,000**
Demolition of Existing Division 7 Steel Reservoir (including permit fee and sales tax)				$ 172,000
NEW CONSTRUCTION PLUS DEMO TOTAL PROJECT ESTIMATED COST				**$ 1,788,000**

Year when maintenance task anticipated to be needed

Item Description	Quantity	Unit	2020 Unit Price	2071 Amount	2091 Amount	2111 Amount
MAINTENANCE TO PROVIDE 100 YEAR SERVICE LIFE						
Assumed annual inflation rate for maintenance tasks	3%					
a. Concrete Reservoir Interior Lining	8,011	Sq FT	$66.66	**$ 2,411,314**		
b. Concrete Reservoir Interior Lining Maintenance	1	EA	$50,000		**$ 407,768**	**$ 736,474**
c. Concrete Reservoir Leak Repair	1	EA	$30,000	**$ 135,463**	**$ 244,661**	**$ 441,884**

TOTAL ESTIMATED MAINTENANCE COSTS OVER 100 YEAR SERVICE LIFE	**$ 4,377,564**
TOTAL ESTIMATED CONSTRUCTION AND MAINTENANCE COSTS OVER 100 YEAR SERVICE LIFE	**$ 6,165,564**

Table 3

LAKE WHATCOM WATER AND SEWER DISTRICT 12/21/2020
Division 7 Reservoir Replacement
Preliminary Cost Estimates

Prepared by: Brian Smith, PE and Melanie Mankamyer, PE, Wilson Engineering LLC

Wilson Job No.: 2019-104

Preliminary Cost Estimates - Replace Div 7 Reservoir with Two Welded Steel Reservoirs

Construction Year 2021

Item Description	Quantity	Unit	2020 Unit Price	Amount
CONSTRUCTION				
a. Mobilization (10%)	1	LS	$ 132,426	**$ 144,000**
b. Temporary Erosion and Sediment Control (1%)	1	LS	$ 8,260	**$ 9,200**
c. Storage Improvements				
Welded steel storage tank 185,000 Gallon 30 ft dia x 35 ft height (installed by supplier, prevailing wages)	2	EA	$ 468,000	$ 936,000
Reservoir railing	2	EA	$ 10,000	$ 23,485
Tree removal	1	LS	$ 30,000	$ 35,227
Clearing and grubbing	1	LS	$ 10,000	$ 11,742
Site earthwork	1	LS	$ 90,000	$ 105,682
Overflow piping	500	LF	$ 100	$ 58,712
Piping from new tank to existing, 12" diameter	500	LF	$ 100	$ 58,712
Manual valve on one tank outlet (other tank to have isolation valve with electronic actuator, priced with ShakeAlert Integration)	1	EA	$ 2,000	$ 2,348
Surface restoration / planting mitigation	1	LS	$ 20,000	$ 23,485
Stormwater management	1	LS	$ 8,000	$ 9,394
Electrical, telemetry and instrumentation	1	LS	$ 100,000	$ 117,424
Subtotal				**$ 1,382,212**
d. Access Road Improvements				
Clearing / grubbing / grading	1	LS	$ 15,000	$ 17,614
Base Course (6-in)	180	Ton	$ 40	$ 8,455
Top Course (3-in)	90	Ton	$ 50	$ 5,284
Geotextile (triax grid)	700	SY	$ 3	$ 2,466
Stormwater management	1	LS	$ 5,000	$ 5,871
Subtotal				**$ 39,689**
SUMMARY				
Subtotal				$ 1,575,101
Contingencies	15%			$ 236,300
Sales Tax	8.5%			$ 153,969
Preliminary Estimated Construction Costs				**$ 1,966,000**
Permit Fees	2.2%			$ 28,000
Easement Acquisition				$ 5,500
DOH Project Report				$ 20,000
Topographic Survey	2%			$ 24,400
Geotechnical Investigation				$ 10,700
Engineering Design	10%			$ 193,100
Construction Phase Engineering/Inspection	10%			$ 198,800
Construction Phase Surveying	1%			$ 12,600
NEW CONSTRUCTION TOTAL PROJECT ESTIMATED COST				**$ 2,460,000**
Demolition of Existing Division 7 Steel Reservoir (including permit fee and sales tax)				$ 172,000
NEW CONSTRUCTION PLUS DEMO TOTAL PROJECT ESTIMATED COST				**$ 2,632,000**

Year when maintenance task anticipated to be needed

Item Description	Quantity	Unit	2020 Unit Price	2041 Amount	2061 Amount	2081 Amount	2101 Amount
MAINTENANCE TO PROVIDE 100 YEAR SERVICE LIFE							
Assumed annual inflation rate for maintenance tasks	3%						
a. Welded Steel Reservoir Re-coating, interior	10,207	Sq FT	$15.00	**$ 284,822**	**$ 514,420**	**$ 929,100**	**$ 1,678,059**
b. Welded Steel Reservoir Re-coating, exterior	8,011	Sq FT	$15.00	**$ 223,544**	**$ 403,745**	**$ 729,209**	**$ 1,317,033**

TOTAL ESTIMATED MAINTENANCE COSTS OVER 100 YEAR SERVICE LIFE	**$ 6,079,933**
TOTAL ESTIMATED CONSTRUCTION AND MAINTENANCE COSTS OVER 100 YEAR SERVICE LIFE	**$ 8,711,933**

Useful Life and Life Cycle Cost Analysis – Concrete Vs. Welded Steel Reservoirs

In order to compare the alternatives of constructing the two replacement water reservoirs out of concrete or welded steel, we analyzed the expected life of each and expected maintenance tasks and costs over that life span.

Please see Attachment 1 for an opinion on the expected life of a concrete water reservoir from a structural engineer with significant experience in concrete structures. In summary, his opinion is that with crack injection and/or tank lining as needed throughout the life of the structure, a 100 year life expectancy is reasonable to assume for a concrete potable water reservoir.

In line with this opinion, we developed cost estimates for maintenance tasks that are expected to result in a 100 year service life for the two concrete reservoirs. In this way, we are able to appropriately compare capital and maintenance costs for concrete reservoirs against the equivalent capital and maintenance costs for welded steel reservoirs over a 100 year timeframe.

The maintenance costs are summarized at the bottom of Tables 2 and 3 and include an inflation factor of 3% per year. For the concrete reservoirs, we included both a complete tank lining at 50 years and subsequent lining maintenance as well as crack injection for leak repair starting at year 50 and every 20 years after that in order to remain conservative with regards to required maintenance to achieve a 100 year life. The interior lining cost is based on a NSF61 certified, 120 mil thickness 100% solids epoxy coating. Steel reservoirs' primary preventative maintenance cost consists of re-coating the interior and exterior of the tanks to prevent corrosion. The frequency of this re-coating is estimated at 15 to 20 years (based on current coating systems, as discussed in the 2018 memorandum), and the cost analysis is based on the upper end of this range at 20 years.

Table 4 is also included and shows the applicable anticipated costs if the District were to leave the existing Division 7 reservoir in place and perform the recommended seismic upgrades and coating work.

Table 4

LAKE WHATCOM WATER AND SEWER DISTRICT — **12/22/2020**
Division 7 Reservoir Rehabilitation
Preliminary Cost Estimates

Prepared by: **Brian Smith, PE and Melanie Mankamyer, PE, Wilson Engineering LLC**

Wilson Job No.: **2019-104**

Preliminary Cost Estimates - Rehabilitate Div 7 (Seismic Retrofits, Re-coatings, Repairs)

Item Description	Quantity	Unit	Unit Price	2020 Amount
CONSTRUCTION				
a. Mobilization (10%)	1	LS	$ 63,999	**$ 64,000**
b. Coating work				
If lead is present on exterior coating, need containment for abrasive blasting	1	LS	$ 95,481	$ 95,481
Remove existing coating from interior and exterior and replace coating	29,385	SF	$ 15	$ 440,800
Subtotal				**$ 536,281**
c. Structural repair of roof support header as detailed in December 13, 2012 assessment	1	LS	$ 15,914	**$ 15,914**
d. Provisions for providing temporary water storage while tank is out of service				
Rental of temporary potable water storage tank assembly (48,600 gallons) for 5 months with freight	1	LS	$ 25,732	$ 25,800
Temporary Erosion and Sediment Control	1	LS	$ 5,000	$ 5,000
Tree removal, clearing and grubbing, and earthwork to provide 46 ft by 46 ft level pad for temporary tank	1	LS	$ 35,000	$ 35,000
Labor to assemble temporary tank, fill, disinfect, and disassemble temporary tank	1	LS	$ 12,000	$ 12,000
Temporary piping to temporary tank (install, test, disinfect appprox 100 ft, 8 inch)	1	LS	$ 10,000	$ 10,000
Subtotal				**$ 87,800**
SUMMARY				
Subtotal				$ 703,995
Contingencies	15%			$ 105,599
Sales Tax	8.5%			$ 68,815
Preliminary Estimated Construction Costs				**$ 879,000**
ted Project Costs of Seismic Retrofits from BHC (includes construction, tax, engineering)				$ 721,000
Engineering Design	5%			$ 43,950
Construction Phase Engineering/Inspection	10%			$ 87,900
GRAND TOTAL				**$ 1,732,000**

Item Description	Quantity	Unit	2020 Unit Price	2041 Amount	2061 Amount	2081 Amount	2101 Amount
				Year when maintenance task anticipated to be needed			
MAINTENANCE TO PROVIDE 100 YEAR SERVICE LIFE							
Assumed annual inflation rate for maintenance tasks	3%						
a. Welded Steel Reservoir Re-coating, interior	17,523	Sq FT	$15.00	**$ 488,979**	**$ 883,150**	**$ 1,595,068**	**$ 2,880,870**
b. Welded Steel Reservoir Re-coating, exterior	11,545	Sq FT	$15.00	**$ 322,166**	**$ 581,868**	**$ 1,050,919**	**$ 1,898,076**

TOTAL ESTIMATED MAINTENANCE COSTS OVER 100 YEAR SERVICE LIFE	**$ 9,701,097**
TOTAL ESTIMATED REPAIR AND MAINTENANCE COSTS OVER 100 YEAR SERVICE LIFE	**$ 11,433,097**

As indicated in Tables 2, 3, and 4, the option to replace the existing Division 7 reservoir with two appropriately sized concrete reservoirs (Table 2) has the lowest capital costs as well as the lowest maintenance costs over a 100 year life span of the reservoirs. In addition to cost, there are five other distinct advantages that replacing the Division 7 reservoir with two new reservoirs has over rehabilitating it that are discussed in the 2018 memorandum. They are reiterated here:

1. Water Quality – The existing Division 7 reservoir is significantly oversized and results in an excessive average water age of 4.6 days. The hydraulic residence time in the reservoirs proposed (2 appropriately sized reservoirs) would be 2.1 days under average day demand in a build-out scenario. This would be within the AWWA recommendation of less than 2.5 days average hydraulic residence time and would help improve water quality in terms of less formation of disinfection by-products and better maintenance of chlorine residual in the distribution system.
2. Improved Water Pressure – Installing new storage 25 feet higher than the existing reservoir will improve water pressure for those houses immediately adjacent to the reservoir. The increased pressure will not negatively impact the system in terms of over pressurizing or decreasing pumped flow excessively.
3. Resiliency – Having two parallel water storage reservoirs provides substantially improved system resiliency in case of emergency (earthquake or unexpected failure of one tank) or typical maintenance. Having the ability to keep one reservoir in service while taking the other out of service will improve the District's ability to serve their customers efficiently.
4. Maintenance Logistics – Current interior coatings for a steel reservoir need to be replaced/refurbished every 15-20 years. This requires the tank to be taken out of service for the work, and this is significantly challenging with only one tank.
5. Construction/Operation Feasibility – Refurbishing the existing Division 7 reservoir would require temporary storage during construction that would either be prohibitively expensive or would make operation of the system during construction very challenging. It is unknown if the limited temporary storage proposed (48,000 gallons, lower height) would be acceptable to the water system operator, the fire department, or the Department of Health. Constructing two new reservoirs allows the existing tank to remain in service during construction.

Therefore, replacing the existing Division 7 reservoir with two appropriately sized concrete reservoirs remains the recommended alternative.

Attachment 1

A well designed concrete water storage tank should have a useful service life of at least fifty years. As noted in American Concrete Institute A350-01, Code Requirements for Environmental Engineering Structures

> When all relevant loading conditions are considered, the design should provide adequate safety and serviceability, with a life expectancy of 50 to 60 years for the structural concrete….

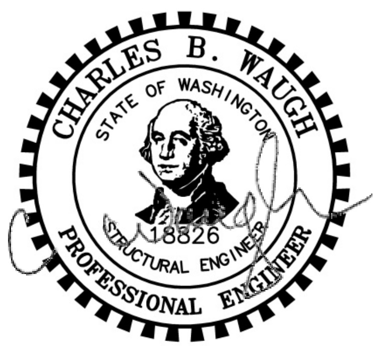
That appears to be a conservative estimate, in line with most design standards which are promulgated to reduce risk to a very minimum. Materials (notably admixtures) are improving, as are procedures for design that better take account of shrinkage and other effects that would impact life.

Note that A350 is generally used for wastewater, not fresh water. Again, the implication is that 50 – 60 years is a conservative service life. When deterioration is noted (by leaking or regular inspection) crack injection and/or tank lining can further extend the service life. 100 years is a reasonable life to consider in such a case.

For example, The Granary redevelopment on the shoreline in Bellingham has a basement that sits approximately 15' below salt water. The building was built in 1928, and according to records publicly available from the County Assessor, the expected remaining life is 50 years. Having been the structural engineer who worked on the redevelopment, I believe that to be accurate.

To sum up, my recommendations are as follows:

(1) Expect a service life of 50 years without major maintenance to structure
(2) At times of cleaning, watch for signs of deterioration
(3) At some point (50 – 60 years on) the tank can be repaired to extend the life to 100 years total



12-11-2020