3. The out-of-plane capacity of the north, south, and west walls can be increased by the addition of a concrete overlay using shotcrete methods of placement. This technique involves sandblasting the existing wall and installing a grid of epoxy dowels so that the shotcrete portion and the existing wall work together to resist loads. This concept is depicted on Figure 4.
4. The base support of the wall can be enhanced by providing a cast-in-place concrete footing along the north, south, and west walls. This concept is depicted on Figure 4.

5.3 Replacement Alternatives

Replacement alternatives will provide the highest reduction in seismic risk, but will have varying storage volumes due to the tank size and shape. Replacement reservoirs are typically constructed of circular prestressed concrete, welded steel, bolted steel, and cast-in-place concrete of varying shapes. Each construction type often presents unique advantages that may make it more feasible or attractive for a given project. Two alternatives that are deemed the most appropriate for the given site are presented to assist SWD with identifying those strategies that most effectively improve the reliability of the water supply system. These alternatives are referred to as 3A and 3B and are described in the following sections.

Some aspects of the site and operations are not specifically known at this time. Therefore, for planning purposes, the following simplifying assumptions have been made in the development of these replacement strategies. These assumptions should be carefully reviewed and, if needed, should be added to the replacement alternatives as required:

- The existing soils require no additional improvement or replacement.
- Deep foundations, such as piles, are not required.
- The hydraulic grade line of the replacement reservoir matches existing.
- The replacement reservoir will be partially buried.
- The bottom of a new reservoir will not be any deeper than the existing reservoir.
- Water quality improvements, provided by baffling and mixing, for example, are not considered.
- Dewatering is not considered.
- An underdrain system is not included.
- Temporary water storage and piping throughout the duration of construction.
- Soft costs for permitting, engineering, etc. are not included.

5.3.1 Alternative 3A – One New Circular Prestressed Concrete Tank

Alternative 3A is a replacement option that involves the demolition of the existing reservoir and construction of one new circular prestressed concrete tank within the footprint of the demolished reservoir. The existing footprint is rectangular, measuring 170 feet by 250 feet. A circular concrete tank does not optimally fit within the footprint. Consequently, with an operating level that matches the existing level, the replacement reservoir will have a substantially smaller volume of 3.0 MG, which is 50 percent of the original storage capacity. In order to recover the full storage volume, either two separate tanks or one much taller tank would be required. Given the location of the reservoir, raising the height substantially above the existing reservoir height is not considered to be feasible due to potential objections by the adjacent residents. The site may be able to accommodate two tanks, but this would require additional piping revisions across the entire site. Therefore, only the single tank replacement alternative was considered for this evaluation. For a plan and section view of Alternative 3A, refer to Figure 3 and Figure 6, respectively.

The following elements are considered to be necessary scope items for Alternative 3A:

- Demolition.
- New inlet, outlet, and overflow piping.
- Tank appurtenances.
- Backfill and site work.

Prestressed concrete tanks are typically designed and constructed in accordance with American Water Works Association (AWWA) Standard D110 and may be a Type 1 or Type 3. Type 1 tank walls are comprised of a cast-in-place concrete core wall that is wrapped with a post-tensioned, high-strength 7-wire strand that is covered with shotcrete. The strands and shotcrete are installed with a patented wrapping machine that rides on top of a footing extension and requires approximately 10 feet of additional space outside of the tank perimeter. Type 1 walls are also vertically post-tensioned with high strength rods located within the core wall and uniformly spaced. The strand wrapping and vertical post-tensioning pre-compress the wall to the extent required to ensure that the walls remain under a net compression load throughout the life of the tank. A Type 3 tank wall is similar, except that the core wall is constructed with precast concrete wall panels that include a corrugated steel deck diaphragm on the exterior side. Most of the prestressed concrete tanks installed in areas of high seismicity, such as Southern California, have Type 1 walls.

The foundation of the tank is typically constructed with a thickened edge footing at the wall, a thinner membrane slab at the interior, and concrete footings on top of the floor slab to support column loads. The tank may be covered with a flat concrete roof or a concrete dome. The flat concrete roofs will require columns with drop panels. The connection of the roof to the wall is typically flexible, allowing the roof to expand and contract with temperature changes.

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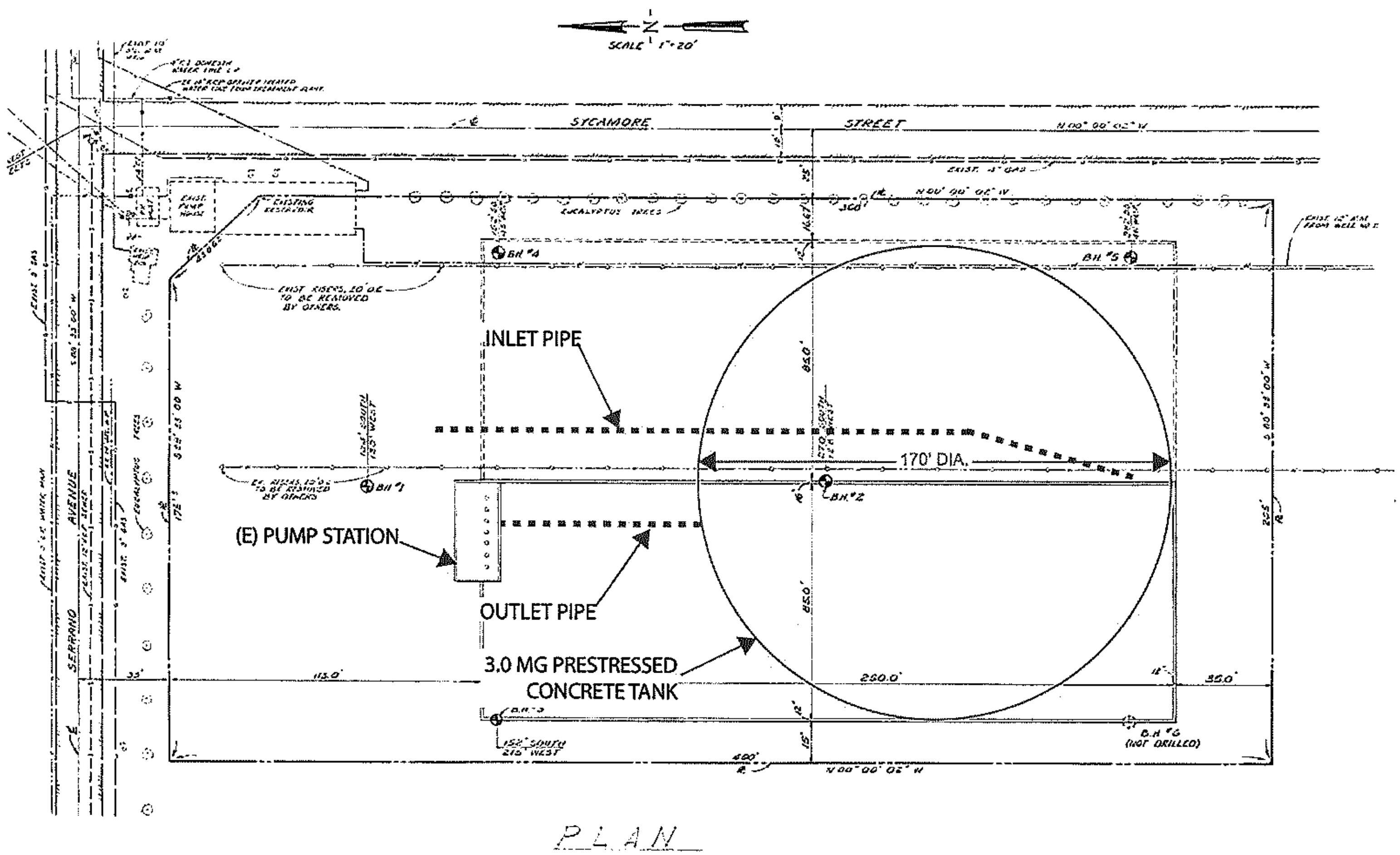

Figure 6
Alternative 3A Plan –
New Circular Prestressed
Concrete Tank

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AWWA D110 Type 1, prestressed concrete tanks have an excellent performance record in major earthquakes, such as the 1971 Sylmar and 1994 Northridge earthquakes. Reconnaissance reports for the 1994 Northridge earthquake indicated no damage to prestressed concrete tanks that were in close proximity to the epicenter.

Sloshing water loads can be substantial within a reservoir during an earthquake. Freeboard is required to limit the surcharge that the sloshing water can impart to the roof structure. The tank will require a nominal amount of freeboard above the HGL, but because the roof is constructed of concrete, it can be designed to absorb a significant amount of the sloshing surcharge load. Other tank roof structures that are built of a lighter material, such as wood or steel, will often require a greater amount of freeboard.

5.3.2 Alternative 3B – New Concrete Tank Within the Tank

Alternative 3B is a replacement option that involves the partial demolition of the existing reservoir and construction of a new cast-in-place concrete reservoir within the limits of the existing vertical concrete walls at the perimeter. The structure is assumed to have a framing system with the following features:

- New elevated concrete slab.
- New supporting concrete beams and columns.
- New concrete walls at the perimeter.
- Maintenance of the existing common unit-dividing wall.

In addition to the structural elements, alternative 3B is assumed to include the following scope items:

- Demolition of the roof slab, roof beams, and columns.
- New overflow piping.
- Tank appurtenances.

The HGL is assumed to match that of the existing reservoir at an elevation of 395.50. The construction of the replacement reservoir within the existing reservoir plan causes a reduction in the available storage volume. The replacement tank volume is estimated to be approximately 5.2 million gallons.

This replacement alternative maintains the original common wall to provide a separation that can be used to isolate each side to facilitate maintenance. Other considerations or versions of this alternative are possible, some of which are noted as follows:

- Install a low-profile aluminum roof – This type of roof system includes aluminum panels that are supported on aluminum framing and stainless steel columns. This system utilizes horizontal truss members in lieu of a diaphragm and will likely require interior braced frames. This option may be more cost effective than a replacement concrete roof and it will not be subject to concrete cracking. The materials are appropriate for exposed use within a reservoir and should be sufficiently durable throughout the life of the structure. The perimeter wall design will need to be more robust as an aluminum roof is typically not strong enough to provide lateral support to the wall.

- Replace the west unit only – The east unit has some deterioration, but not to the severity that was observed at the west unit. It may be feasible to limit replacement work to the west unit now and defer replacement of the east unit to the future when the condition has deteriorated further. The new replacement at the west unit would also serve to improve the reliability of the reservoir if the middle wall were maintained for potential isolation. If the east unit suffers damage in a major earthquake and the west unit performs as it is designed, then the units could be isolated allowing continued operation at the site with minimal interruption to service.
- Remove the common wall or modify it – The common wall might not present the best flow characteristics for water quality. In such a case, it may be desirable to remove the common divider wall and provide new baffling or cut additional holes in the common wall.

The cast-in-place concrete construction does not pre-compress the concrete and it will be subjected to net tension loads over the course of its life. Performance during major earthquakes has been good, but increased damage and/or leakage is anticipated compared to prestressed concrete tanks.

For a section view of Alternative 3B, refer to Figure 7 and Figure 8.The plan of the reservoir essentially remains unchanged.

5.3.3 <u>Alternative 3C – New Welded Steel Tank at Another Site</u>

The Smith Reservoir may be replaced by constructing a new reservoir at another site while the operation of Smith Reservoir is maintained. At this time, an alternative site has not been acquired and/or selected. It is assumed that a new site would be located in the vicinity of the existing Lockett Reservoir. For the purpose of this evaluation, the following details of the site and tank have been assumed:

- 5.0 MG welded steel tank with a diameter of 185 feet and a side water depth of 25 feet. The operating depth approximately matches that of the Lockett Reservoir.
- The tank is founded at finished grade on top of a concrete ring wall footing with sand infill.
- The tank has a single inlet/outlet pipe.
- Approximately 75 percent of the site requires leveling (4-foot average fill removal with no difficult excavation work).

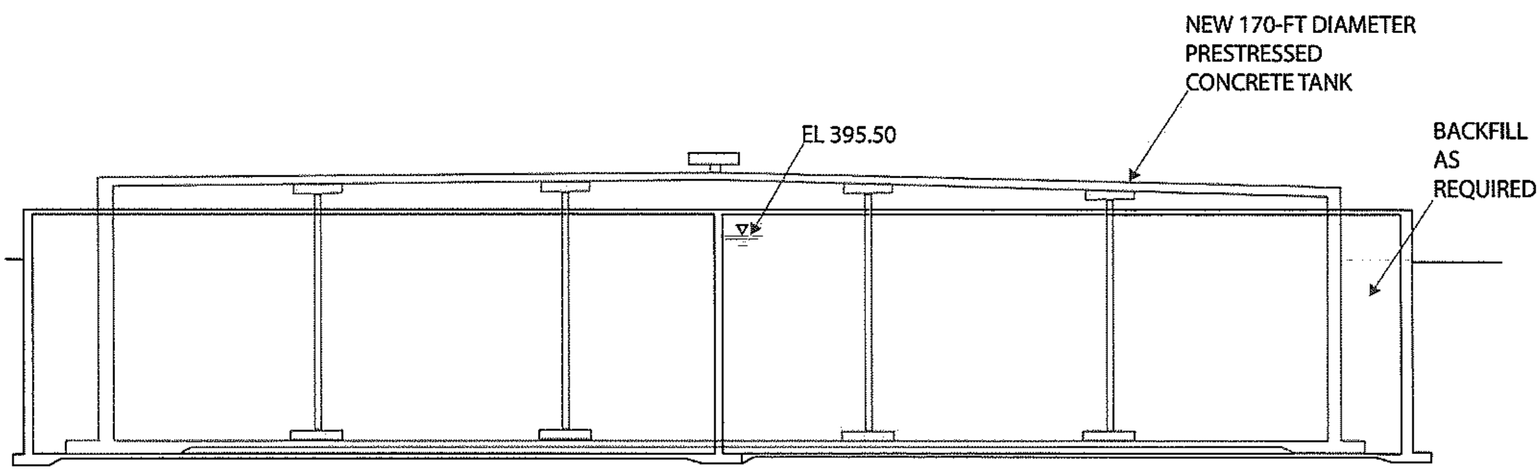

Figure 7
Alternative 3B Section – New Circular Prestressed Concrete Tank

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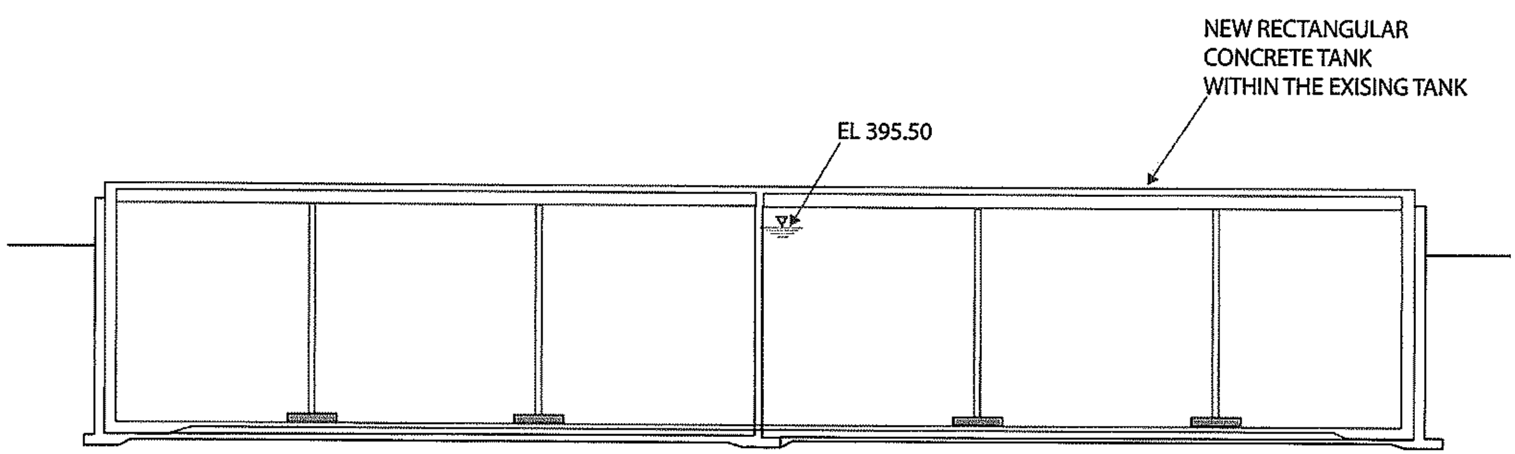

Figure 8
Alternative 3B Section – New Concrete Tank within the Tank

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- The site is 2.5 acres in size and relatively flat with no major obstacles to remove other than grasses and bushes.
- 8-foot galvanized steel with barbed wire fence around the site.
- Asphalt pavement over 80 percent of the site with landscaping over 20 percent of the site.

Welded steel tanks typically have a lower capital cost for at-grade construction compared to other alternatives and can be erected relatively fast. However, these tanks require a protective coating on the interior and exterior to protect it from corrosion. The tank will require a recoating every 20 to 30 years, which can be a substantial cost. Estimates for recoating a tank can be highly variable depending on the type of coating, condition of the tank steel, general work restrictions, and air quality regulations. Cathodic protection can also provide additional protection, but at an ongoing cost.

The seismic performance of properly designed welded steel tanks can be excellent, provided those inherent vulnerabilities are carefully addressed. Such vulnerabilities include the tendency for the shell to buckle, excessive pipe restraint, tank uplift, and sloshing of water surcharge to the tank roof. These vulnerabilities were manifested in the 1994 Northridge Earthquake and subsequent large earthquakes throughout the world since that time. Numerous welded steel tanks failed with collapse, severe damage, foundation scouring, and loss of the tank contents. Welded steel tanks designed in accordance with current AWWA D100 standards are anticipated to have a significantly improved seismic performance compared to its predecessors. Fittings at pipe inlets and outlets should include flexible connections that allow for differential movement between the tank and the surrounding grade.

Leakage from a welded steel tank is expected to be minimal provided the tank is maintained in excellent condition.

The cost estimate for developing an alternative site with a 5.0 MG welded steel tank, given the assumptions noted in this section and the exclusions identified in Section 5.3, is estimated to be $5.2 million.

When comparing steel tanks with concrete tanks, to understand the true cost of ownership, consideration of the recoating costs at recurring intervals in the future is recommended. For this evaluation, recoating is assumed to occur every 25 years at a cost of $1.5 million. For a 50-year tank life, the total cost without inflation and interest considerations is $8.2 million, which includes two recoatings and the initial capital cost.

5.3.4 Alternative 3D – New Prestressed Concrete Tank at Another Site

Alternative 3D involves the replacement of Smith Reservoir with a 5.0 MG prestressed concrete tank at another site with the same assumptions and exclusions that were described for Alternative 3C. A discussion of prestressed concrete tanks is included in Section 5.3.1 of this report.

The cost estimate for developing an alternative site with a 5.0 MG prestressed concrete tank, given the assumptions noted in this section and the exclusions identified in Section 5.3, is estimated to be $6.6 million.

5.4 Other Improvements

Improvements to the site may be integrated with either of the replacement alternatives. For this study, no specific improvements were identified by SWD staff beyond that necessary to address deteriorated conditions and seismic vulnerabilities. However, each replacement alternative offers potential space on the roof structure or within the site to add improvements such as solar power panels. The impact of any planned improvements at the site may need to be considered when weighing the costs of each alternative against one another. A feasibility study of the implementation of specific improvements, however, is beyond the scope of this study. The addition of solar panels has been recently integrated with reservoir seismic retrofit projects for other municipalities.

6.0 CONCLUSION

The goal of the structural evaluation of the Smith Reservoir was to identify specific seismic vulnerabilities and deficient structural conditions for the purpose of improving the overall reliability of the water storage facilities at the site. Our findings presented in this report identify numerous seismic vulnerabilities and deficient conditions that warrant either a retrofit/rehabilitation or complete replacement of the reservoir. Mitigation strategies for operational, retrofit, and replacement alternatives were developed and presented in this report along with cost estimates for each to assist SWD in the selection of a mitigation strategy that is most suitable for Smith Reservoir.

Given a myriad options for improving the reliability of a reservoir, making a decision to select a path forward can be difficult. The approach used in this evaluation was to identify a retrofit option that most effectively, makes use of the existing structure and to counterbalance that option with replacement alternatives that we believe are suitable for water storage projects at the existing site. The replacement alternatives can provide for a service life of at least 50 years. On the other hand, the service life that a retrofit/rehabilitation project can provide will be limited because the materials will continue to deteriorate. If some form of a retrofit/rehabilitation alternative is implemented, we recommend that a condition assessment be performed every 10 to 15 years and maintained as required. It is difficult to know how much additional effort will be required to maintain a rehabilitated structure; therefore, the risk for future repair costs is considered to be relatively high compared to replacement alternatives.

Many factors will need to be considered by SWD in the ultimate selection of a path forward. We are available to assist with the further development of a strategy to mitigate the observed deficiencies and identified seismic vulnerabilities for the Smith Reservoir.

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