WATER AGENCIES' STANDARDS

Design Guidelines for Water and Sewer Facilities

SECTION 7.1
STORAGE FACILITIES

7.1.1 PURPOSE

This section provides information needed to develop contract documents including design plans and specifications for the construction of storage facilities (reinforced concrete reservoirs, steel tanks, standpipes, etc.) for both potable and recycled water.

7.1.2 STANDARD TERMS AND DEFINITIONS

Wherever technical terms or pronouns occur in these guidelines or in related documents, the intent and meaning shall be interpreted as described in Standard Terms and Definitions.

7.1.3 GUIDELINES

It is the responsibility of the user of these documents to make reference to and/or utilize industry standards not otherwise directly referenced within this document. The Engineer of Work may not deviate from the criteria presented in this section without prior written approval of the Agency's Project Manager.

Potable water storage facilities provide for operational, emergency and fire protection storage. Recycled water is used primarily for supplementing potable water demands for irrigation. This section provides guidance for the design of storage facilities, including steel tanks, steel standpipes, and reinforced concrete storage facilities. This section also provides guidance for the design of projects that demolish or rehabilitate existing steel tanks and steel standpipes. A standpipe is defined as a storage facility where the height is greater than the diameter. The design of circular pre-stressed concrete tanks is not covered in this section. Pre-stressed concrete tanks are applicable in many situations but require specialty design by a licensed structural engineer.

Determining what type of storage facility should be used for a project should be based on a case by case basis. Each site is unique and requires analysis by the Engineer of Work in determining whether steel or concrete would be most appropriate. The attached memo, Attachment A, from the City of San Diego provides information to aid the engineer in determining what type of reservoir is preferable for any given project.

7.1.4 CODES AND STANDARDS

Codes and standards used in the design of storage facilities include selected codes and standards issued by the following organizations:

Abbreviation	Code or Standard Organization
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
FAA	Federal Aviation Administration
IEEE	Institute of Electrical and Electronics Engineers
ISA	Instrument Society of America
MSS	Manufacturers Standardization Society, Inc.

NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
PCA	Portland Cement Association
SEAC	Structural Engineers Association of California
UBC	Uniform Building Code
UL	Underwriters Laboratory, Inc.
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code

7.1.5 STEEL TANKS AND STANDPIPES

A. Site Design Guidelines

The Engineer of Work reviews all available information including a pre-design report, technical memos, geotechnical and/or prepares reports which will include a preliminary evaluation of constraints that may affect the site layout and design. The Engineer of Work ensures that the designated site has sufficient area, is located at the proper elevation, and has adequate drainage.

The Engineer of Work evaluates the following issues when situating the storage facility on the site:

- Access and parking
- Flood protection
- Grading and drainage
- Yard piping
- Land ownership and zoning
- Setbacks
- Landscaping and irrigation
- Overflow piping
- Sub-drain system
- Site lighting
- Site utilities
- Geotechnical conditions
- Aesthetics
- Conveyance of overflow offsite
- Space provisions for future telecommunications tower(s) - (case-by-case basis)

Construction drawings for storage facility site improvements must include the following information:

- Project location map and vicinity map.
- Survey controls identifying the site by map number, lot number or other identifier linked to the most recent legal title document, and other control features including benchmarks. Survey control must be in accordance with the requirements in the WAS. In addition, two temporary benchmarks and two horizontal control points must be set near the site, and shown on the plans, at locations that cannot be disturbed during construction.
- Site plan, showing the proposed civil works at the site, the existing site topography, and the site boundary.

1. Access and Parking

Adequate right-of-way must be provided for vehicular access and turnaround, and for the supply pipeline and drain. A 18-foot minimum width paved strip area must be provided around the tank, on the turnaround area, and on the driveway to the street or the access area. Pavement design is based on a 4-inch plant mix pavement with a seal coat. Curbs and gutters are designed in accordance with the San Diego Area Regional Standard Drawings G-1 through G-6.

Access roads at storage facilities must allow positioning a truck-mounted crane of the size required to remove the largest piece of equipment on the site. Sufficient space must also be provided to park two 3-ton maintenance trucks. The Engineer of Work should avoid placing access roads and parking over piping penetrations through storage facility walls to avoid shear loadings.

2. Flood Protection

The floor elevation of buildings at the storage facility must be at least 2 feet above the 100-year flood elevation determined by the Federal Emergency Management Agency.

3. Grading and Drainage

The grading plan must be developed in accordance with the requirements of the latest edition of the UBC and the governing Agency's Grading Ordinance. Recommendations of the site geotechnical report are incorporated in the grading design. Where conflicts exist between the code and ordinance and the geotechnical report, the more stringent requirements must be adopted. Overall grading for the site is conservative and allows flexibility to allow future modifications or facility expansion at the site.

The site shall be graded with a slope downward from the tank in all directions. The storage facility shall be positioned and the site developed to ensure a uniform soil bearing condition. The footing and floor are placed on either native earth material or structural fill. The storage facility may not be situated with a portion on native material and a portion on fill. Over-excavation of the site may be required to provide placement of the storage facility on similar materials.

Drainage design must conform to regional standards including NPDES criteria or the individual Agency's drainage criteria. The applicable standards used should identify design criteria and methods for calculating drainage runoff and sizing underground piping, slotted drains, open channels, ditches, and appurtenances.

4. Yard Piping

Yard piping and exposed piping at storage facilities must be either steel or ductile iron pipe, as described in the WAS. Yard piping may transition to PVC offsite. Linings and coatings of piping must conform to the requirements in the WAS.

Water service to the site must be equipped with a reduced pressure backflow protection device installed after the water meter. The site water piping system shall include a minimum 3/4-inch diameter water riser and hose bib in a protected location as required for site wash down. Parking posts must be provided around the reduced pressure backflow prevention device.

Unless otherwise approved by the Engineer of Work, mainline valves are of the same diameter as the pipeline.

5. Land Ownership and Zoning

Storage facility sites may not be located on easements, but should be entirely located on Agency-owned land, fee title. A zoning variance may be required for storage facility sites.

6. Setbacks

Adequate setback from property lines must be provided to conform to local ordinances and codes. The distance between the structures is determined by access requirements, piping requirements, and future expansion plans. Sufficient setback is also provided to allow for fill, cut, or fill transition to existing contour elevations at property lines.

7. Landscaping and Irrigation

Storage facility sites are landscaped in a manner to meet community standards and conform to the individual Agency's landscape criteria. The landscape design should extend the concepts established for the materials and form of the storage facility and blend with adjacent areas. Landscape designs must be developed by a Licensed Landscape Architect.

The landscape development of storage facility sites shall be kept to a minimum and should be low maintenance. Irrigation systems and plant material are installed outside the Agency's security fence unless it is absolutely necessary to screen objectionable views of a facility from the community or to prevent the erosion of manufactured slopes.

Landscaped areas must have automatically-activated irrigation systems with a reduced pressure backflow prevention assembly and water service meter at the connection to the water main. A framed, laminated control schematic drawing of the irrigation system must be mounted inside the cabinet door of the irrigation controller.

8. Security Fencing

Storage facility sites are normally enclosed by a 6 or 8-foot high perimeter security fence with a barbed wire top. The fence shall be chain-link or architectural wrought iron meeting community architecture requirements. The fence shall be webbed to reduce the station visibility as required by community architecture review. A 6 or 8-foot high masonry brick wall around the storage facility could also be provided, as appropriate, for architectural reasons. All accessible valves, vaults, water fixtures, and irrigation system fixtures shall be located inside the security fence. Specific fencing height and materials must be determined on a case-by-case basis. An intrusion alarm should be considered at the front gate as may be required by the Project Manager. The security fence must be placed, wherever possible, on or immediately adjacent to the property line.

9. Site Lighting

Storage facility site lighting must be controlled by a photocell equipped with a manual on/off controller. Outdoor lighting shall be selected to reduce glare over the surrounding area and is vandal-resistant. The Engineer of Work shall coordinate with the Federal Aviation Administration regarding the need for lighting the top of the tank.

10. Site Utilities

During the design process, coordination with representatives of local utility agencies is required. The Pre-design Report or Technical Memo for the project presents available information on utilities which might be affected by construction of the project.

11. Geotechnical Conditions

The geotechnical consultant or subconsultant develops and implements a program of geotechnical testing to provide relevant design parameters for the storage facility.

12. Aesthetics

Views of the facility from areas surrounding the storage facility site shall be analyzed and alternatives evaluated to harmonize the appearance of the storage facility with its surroundings.

B. Structural Guidelines

1. Reference Standards and Codes

The latest editions of the following standards and codes apply to the design of steel tanks and standpipes:

- Building Code Requirements for Minimum Design Loads in Building and Other Structures, ASCE 7 by the American Society of Civil Engineers and ANSI A58.1 by the American National Standard Institute.
- Title 24, Part 2, California Building Code.
- Uniform Building Code (UBC) of the International Conference of Building Officials, as adopted by the City of San Diego Municipal Code.
- American Institute of Steel Construction, Specification of the Design, Fabrication, and Erection of Structural Steel for Buildings, AISC Publication No. S-326.
- American Institute of Steel Construction (AISC) Manual of Steel Construction, Allowable Stress Design (ASD).
- Specification for the Design of Cold Formed Steel Structural Members by American Iron and Steel Institute (AISI).
- Standard Specifications for Open Web, Longspan, and Deep Longspan Steel. Joists and Joist Girders.
- API documented rules for the design and construction of large welded, low pressure storage tanks, API STD 620.
- The boiler and pressure vessel code (ASME).
- Welded Steel Tanks for Water Storage, ANSI/AWWA D100.
- Welded Steel Tank for Oil Storage, ANSI/API STD 650. Structural Welding Code - Steel, ANSI/AWS-D1.1.
- Specifications for Welding Sheet Steel instructions, ANSI/AWS D1.3-98.
- Building Code Requirements for Reinforced Concrete, ACI 318, and commentary ACI 318R, as contained in UBC.
- Concrete Manual by the U.S. Bureau of Reclamation.
- Concrete Reinforcing Steel Institute (CRSI) Handbook.
- "Formulas for Stress and Strain" by Roark and Yong.
- Standard of the Occupational Safety and Health Administration (OSHA).
- AWWA Standard for Coating Steel Water Storage Tanks, ANSI/AWWA D102.
- Automatically Controlled Impressed-Current Cathodic Protection for the Interior of Steel Water Tanks, ANSI/AWWA D104.
- Steel Tanks for Liquid Storage by American Iron and Steel Institute (AISI).
- Factory coated bolted steel tanks for water storage, ANSI/AWWA D103.

2. Design Loads

The following criteria define the minimum design loads to be used in the design of steel tanks and standpipes. Without limiting the applicability of other criteria, all design loads must conform to or exceed the requirements of the UBC and all applicable requirements of other documents referenced above.

a. Dead Loads

Dead loads, which shall be defined as the weight of all permanent construction, including equipment and piping, permanently connected to the tank, is determined using the following unit weights:

- Steel 490 pcf
- Concrete 150 pcf
- Aluminum 169 pcf

Dead loads shall include allowances for the following items:

- All equipment and piping permanently attached to and considered part of the structure, including future equipment and piping.
- Structural steel platform framing and floor plates (based on 20 pst).
- Heavy beams or girders, such as those required to carry loads other than platform live loads.
- Piping 12-inches in diameter and smaller shall be treated as a uniformly distributed load. A typical minimum value of 20 psf is used.Piping larger than 12-inches in diameter shall be treated as a concentrated load.

b. Live Loads

Live loads in addition to concentrated loads shall be determined as follows:

- Roof Loads: in accordance with ASCE 7/ANSI A58.1 USC, ANSI/AWWA D100 or local code, whichever is more stringent.
- Stairs, Platforms, and Walkways: 100 psf or local code, whichever is more stringent.
- Minimum concentrated load on ladders and stairs: in accordance the requirements of ANSI-A58.1, OSHA, Cal-OSHA, or local codes, whichever is greatest.

c. Wind Loads

Wind loads must be in accordance with ASCE 7/ANSI A58.1, USC, ANSI/AWWA D100 and ANSI/AWWA D103, on the basis of a minimum basic wind speed of 100 mph and appropriate exposure, or on the requirements of local code, whichever is more stringent. The design is governed by maximum wind or maximum seismic load, whichever is greater.

d. Hydrostatic and Hydrodynamic Loads

Hydrostatic loads shall be based on water when the tank is filled to overflowing. The unit weight of water is 62.4 pcf. Hydrodynamic loads shall be determined in accordance with the Seismic Loads described in this section.

e. Lateral Soil Loads

For all yielding structural components, lateral soil loads shall be determined by using active soil pressure conditions as recommended in the geotechnical report.

For all non-yielding structural components, lateral soil loads shall be determined by using passive soil pressure conditions as recommended in the geotechnical report.

A minimum surcharge pressure equal to an additional 2 feet of soil shall be used for all structures adjacent to traffic loading conditions.

Seismic soil loads shall be determined in accordance with the Seismic Loads described below.

f. Seismic Loads

Seismic loads shall be established in accordance with typical standards and/or the Agency. The following criteria provide the basic guidelines for determining design ground accelerations and seismic forces:

- Seismic soil loads shall be determined in accordance with the recommendation given in the geotechnical report.

- Response spectra with damping factors of 0.5%, 2.0% and 5.0% shall be used for the seismic design for the appropriate level of shaking and type of structure.

- Site-specific ground acceleration, response spectra, and design recommendations presented in the geotechnical report shall be used to determine seismic loads.

Hydrodynamic loads shall be determined in accordance with standard methods for Water Retention Structures.

g. Miscellaneous Loads

The following shall be considered in the design:

- Miscellaneous loads of a special nature, such as thrust from expansion joints, and special appurtenances.

- Surcharge loads, such as those due to adjacent structures and vehicular loads.

- Thermal loads, where applicable.

- Operating pressure forces and test forces and loads.

- Construction loads and conditions.

3. Loading Combinations

Loading shall be calculated for different conditions. As a minimum, the following loading conditions shall be determined:

a. Full tank or standpipe: hydrostatic loading, plus hydrodynamic loading, plus seismic forces due to dead loads.

b. Empty tank or standpipe: static soil pressure (active or passive) plus seismic soil pressure plus seismic forces due to dead load plus permanent surcharge.

4. Allowable Stresses

Allowable stresses must conform to the following:

a. For steel plate and structural steel, allowable stresses shall be in accordance with the requirements of ANSI/AWWA D100.

b. For tank concrete footings, allowable stresses shall be in accordance with the requirements of ACI 318.

c. For wind and seismic loading conditions, allowable stresses may be increased by 33%.

d. For wind and seismic design, allowable stresses have a factor of safety of 1.5 against overturning and sliding.

5. Roof Design

The roof must be a structural-steel-supported, steel-cone roof with a slope of 1:12. The Engineer of Work selects this roof type or considers using either a “knuckle” type roof or aluminum geodesic-type roof depending upon the application and other considerations. If the appearance of the roof is of sufficient importance to justify the additional cost, an elliptical "water bearing" type of roof may be specified. If the roof is supported on a central column which requires lateral bracing, the design must include separate trolley tracks below each set of lateral braces.

The roof shall be designed for the loading and allowances in accordance with the requirements of paragraph 7.1.5.B.2, and the minimum live load is 20 psf.

The roof plate that is not in contact with water shall be at least 3/16-inch thick; the roof plate submerged in water during normal operations shall be 1/4-inch minimum (knuckle or cone type). A corrosion allowance shall not be required for the roof plate. The roof plate construction must be in accordance with the standard practice of ANSI/AWWA D100. Full penetration welds are used to join the roof knuckle together. The roof plate is connected to the support members. In general, all welds within the tank must be continuous.

Roof supports shall be hot-rolled structural shapes with a minimum thickness of 3/16 inch. Shapes and bars should not be submerged in water with the exception of ladders. Lateral bracing of the roof rafter compression flanges shall be assumed to be provided by the roof plate.

Bolts, washers and nuts installed inside the storage facility shall be Type 316 stainless steel and must have isolation bushings for separation from steel.

Columns shall be fabricated from a sealed steel pipe welded at both ends. The column base shall be fabricated from steel plate and designed for a maximum allowable soil bearing in the geotechnical report. The column base should be welded to the bottom plate, but must be restrained from any lateral movement.

6. Wall Design

The wall design must be in accordance with ANSI/AWWA D100 and ANSI/AWWA D103 standards. Applicable loadings and allowable stress must be as described in paragraphs 7.1.5.B.2 and 7.1.5.B.4, respectively.

All wall plate is rolled, regardless of material thickness.

The design fabrication and inspection requirements specified in ANSI/AWWA D100 and ANSI/AWWA D103 are considered, except that only steel that complies with ASTM A-36 or ASTM A131 material requirements shall be used. The lowest 1-day mean ambient temperature at the tank site shall be generally 45°F.

A corrosion allowance shall be specified for the tank if required. Minimum tank wall thickness must be in accordance with the requirements of ANSI/AWWA D100 and ANSI/AWWA D103.

The tank wall shall be designed for stability without the requirement for intermediate girders on the inside or outside surface of the wall.

Freeboard between maximum fluid level and the top half of the roof shell shall be provided to accommodate for the sloshing of fluid induced by seismic loading so as not to overstress the roof plate, roof members, and the connection.

7. Floor Design

Floor plates shall be lap welded continuously from the top of the plate with a minimum thickness of 5/16 inch. Sketch plates shall be 1/16 inch thicker than the rest of the floor plates. The floor plate shall be extended a minimum of 1 inch beyond the exterior of the wall. The joint between the wall and the bottom plate shall be continuously welded from inside and outside of the tank wall.

A corrosion allowance, if required, shall be added to the minimum requirements of the standards.

8. Anchor Bolts

Anchor bolts shall be designed to resist safely the uplift resulting from the overturning moment about the axis of the base of the tank or standpipe. Use the applicable Agency standard for additional guidance on anchor bolt design. Anchor bolt nuts shall be torqued after filling the storage facility and again before acceptance by the Agency.

9. Footings and Foundations

A ring wall footing shall be used. The top of the ring wall footing shall be approximately 6 inches above finished grade. The minimum depth of the ring wall footing below the bottom of the tank shall not be less than 2 feet.

The ring wall footing shall be reinforced to resist the lateral soil pressure of the confined earth. The width and height of the ring footing shall be sized for the loadings in paragraph 7.1.5.B.2 and the allowable soil bearing pressure recommended in the geotechnical report. The minimum width shall be not less than 2.5 feet.

A compressive strength of 4,000 psi shall be used for the concrete, and 60,000 psi yield strength shall be required for reinforcing steel. Concrete cover for reinforcing bars must be in accordance with the requirements of ACI 318. The alternative design method shall be recommended for the design reinforcement.

C. Mechanical Guidelines

1. Storage Facility Hydraulics and Piping

The Engineer of Work refers to the Predesign Report prepared by the Agency or by consultant for available information on the storage facility piping configuration and capacity, storage facility size, high water elevation, and the adequacy of the overflow and drain pipes. Valves and piping shall be provided to meet special conditions at the site. Required anchors, supports and thrust blocks shall be provided as required to resist all loads and forces imposed by the conditions of service. Piping and valves shall be tested in accordance with WAS. The tank shall be electrically insulated from the attached pipeline by means of insulating couplings or sections of PVC pipe.

All valving for the tank can be above or below ground. If the valving is below ground, a concrete vault is required. Note that not all tanks will require an altitude valve or vault. The vault should be per the applicable Agency standard. The vault must be adequate to carry intermittent H-20 loading and have a stairway or ladder and sump. Altitude valves must be of the type listed in the WAS Approved Materials list. Two-way valves shall be acceptable on tanks of less than 2 million gallons. A bypass shall be provided around the altitude valve.

a. Inlet and Outlet

Inlet and outlet piping shall be designed to maximize water circulation inside the tank. If possible, a 180 degree separation between the inlet and outlet piping shall be desirable to promote circulation. Provision of a diffuser on the inlet assists to disperse inflow to the tank and encourage circulation as well. As a general rule, separate inlet and outlet pipes shall be used. The inlet and outlet pipes can penetrate either the bottom plate or come in on the side walls. Site constraints and Agency preference will dictate this method of design. The pipe penetration opening through the bottom or side plate must be reinforced in accordance with the requirements of ANSI/AWWA D100.

Reinforced concrete vaults shall be provided to house rubber-seated butterfly or gate valves on inlet and outlet piping. Inlet and outlet valves may be equipped with battery-powered electric actuators for automatic isolation following an earthquake (see paragraph 7.1.5.D). Valve vaults must be designed for H-20 traffic loads and must be easily accessible for storage facility shutdown. A storage facility bypass pipeline is provided to accommodate shutdowns. In-line valves are the same diameter as inlet/outlet piping. Piping under the storage facility is encased in concrete. If valves are located away from the storage facility, there is a flexible coupling in the inlet and outlet lines with sufficient flexibility to accommodate differential settlement.

A restrained Dresser type coupling shall be provided on the vertical riser of the inlet pipe. The coupling should be located above pavement grade. A 125-pound flanged overflow nozzle must be installed, with a 1-inch, extra heavy threaded coupling and plug in the bottom of the nozzle for testing. A 1-inch, extra heavy outlet coupling and corporation stop are also provided in the lower ring of the standpipe.

b. Drain

A drain pipe shall be installed through the bottom plate or floor of the tank. The drain pipe is of adequate size and has sufficient slope to dispose of drainage water. The pipe shall be of a suitable type and pressure class to accommodate operation under pressure, if required. If the tank is unanchored, the location of the penetration in the bottom plate must conform with the requirements of ANSI/AWWA D100. The drain line may be discharged to a drainage structure or facility common with the overflow pipe.

An eccentric plug valve shall be installed on the drain line. A vault adjacent to the ring wall footing is required for housing the drain valve. A steel grate shall be added around the inlet to the drain.

c. Overflow

The overflow pipe shall be sized to discharge the maximum fill rate of the tank. The overflow is located in an internal or external location. The overflow pipe should be braced against the tank wall. The Engineer of Work designs the overflow system to ensure that water in the storage facility is protected from cross-contamination with surface water. The overflow pipe has an air gap separation, with flap gates and/or bug screening and low pressure flapper-type closure at overflow/drain piping outlet.

The overflow funnel shall not be less than 6 inches below the bottom of the shell vents. The overflow pipe flange clears the tank shell by 14 to 16 inches.

d. Recirculation Piping and Pumps

Where recommended in the Pre-design Report or directed by the Agency's Project Manager, recirculation piping and pumps shall be provided to afford additional circulation in the storage facility. Pumps and drives must be suitable for outdoor installation, and are housed in a locked security cage. The pumping system will be designed to re-circulate the entire volume of the storage facility in less than 3 days. The recirculation piping draws water from the tank outlet and conveys water to the tank inlet. Where there is a common inlet/outlet line, recirculation shall be from the inlet/outlet line to 75% of the height of the tank.

e. Wall Wash Down System

A wall-mounted pipe shall be provided on the interior of the storage facility to facilitate wash down and cleaning of the tank.

f. Sample Taps

Sample taps shall be provided at various levels in storage facilities. A locked access to the sample taps will be provided at the exterior base of the tank or standpipe. A minimum of four 3/4-inch sampling taps shall be provided. Three of the taps must protrude a distance of 1 foot into the tank and be separated vertically at 2 feet, 6 feet and 10 feet above the floor to represent water quality from the bottom to the top of the tank. A fourth sample point shall be located near the bottom of the tank, flush with the inside face of the tank. An additional sample tap shall be provided in the recirculation piping if recirculation piping is used.

g. Chlorine Injection Points

Chlorine injection points shall be provided and equipped with locking covers. Injection points are located on the inlet pipe to the storage facility.

h. Pump Connection

Depending upon the Agency's preference, a 6-inch diameter flanged pump connection shall be provided on the side of the tank. The connection shall be located 18 inches above the adjacent ground on aboveground tanks and on the pipe upstream of the altitude valve on buried tanks. A 6-inch flanged plug valve shall be provided on connections.

i. Baffling

Where recommended in the Pre-design Report or directed by the Agency's Project Manager determines if internal baffling should be recommended to improve circulation and water quality in the tank. On tanks greater than 10 million gallons, it may be necessary to computer model to identify improvements that optimize flow patterns, reduce short-circuiting, and minimize water age. The need for computer modeling will be determined on a case-by-case basis.

2. Re-Chlorination

Water quality and level of chlorine residual maintained in the storage facilities will be of concern. The need to provide re-chlorination of the water entering the reservoir must be considered on a case-by-case basis. The Engineer of Work verifies the need for re-chlorination facilities with the Agency's Project Manager, and in consultation with the Agency's Operations Department.

At a minimum, the design shall include chlorine analyzers, sampling ports and a flanged connection for future chlorine injection. The chlorine analyzer will be housed in a NEMA 4X enclosure.

Hypochlorination using sodium hypochlorite shall be the preferred method for disinfection. Two hypochlorination options are available: (1) the use of commercial grade sodium hypochlorite, with a 14-day supply stored at the site, or (2) onsite generation of sodium hypochlorite.

If a disinfection facility shall be required, the disinfection and analyzer equipment will be housed in a permanent structure along with sodium hypochlorite solution tanks. To determine the best combination of tanks, tank sizes are evaluated on the basis of proposed dosage rates. The tanks shall be made of fiber-reinforced plastic and provided with sight glasses.

The disinfection system maintains the chlorine residual within the range of 0.5 to 2 mg/l. Diluted sodium hypochlorite solution shall be injected into a wall wash down header. The hypochlorination system shall be sized to increase the chlorine residual in the storage facility by 0.2 mg/l over a 3-day period of continuous operation.

The sampling and monitoring system allows the return of sample water back to the storage facility to minimize water wastage. Appropriate pressure and flow for injecting sodium hypochlorite solution will be achieved using metering pumps. The sodium hypochlorite feed rate must be adjusted manually. Automatic adjustment from the analyzer will not allowed.

3. Access

A minimum of three access manways must be provided. Two 36-inch minimum diameter hinged-type manholes are provided at the bottom shell course. One 36-inch by 48-inch rectangular access hatch shall be provided in the roof. The design of the manway and reinforcement around the openings must conform to the requirements of ANSI/API Standard 650.

If requested by the Agency's Project Manager, a galvanized steel or stainless steel ladder should be provided at the outside of the tank and should extend to the roof. Safety climbs will be provided instead of safety cages at all ladders. Anti-climb provisions will also be provided on all ladders.

A platform with galvanized steel grating and railing shall be provided and installed on the roof adjacent to the ladder. The roof manway and ladder must be provided near the roof platform for access to the tank interior.

The revolving roof ladder, if required, shall be galvanized and designed to clear the roof manhole and all electrical conduit and cathodic protection equipment on the roof. Roller wheels must be provided at the pivot end. In general, a safety tie-down system with O-rings to clamp onto and a cable system can be used in lieu of the ladder.

Ladders, safety climbs, platforms, and guardrails must meet Cal-OSHA General Industry Safety Orders and the following requirements:

a. Spacing between vertical members on ladder guard cage should be no greater than 15 inches center-to-center.

b. Ladder rungs must have a minimum diameter of 3/4 inch.

c. Distances between the first rungs of ladders and top steps should be no more than 12 inches. Where there is no step, the first step must be no more than 18 inches above grade.

d. Rungs clear width shall be greater than or equal to 16 inches.

e. Clearance on the climbing side of the ladder to the nearest obstruction must be at least 36 inches.

f. Clearance between back of ladder and the tank shall be over 7 inches.

g. The dismount railing at the roof shall be 42 inches tall and 18 to 24 inches wide. A chain shall be provided between dismount railings.

h. Rails should be not less than 2 inches by 3/8 inch.

i. Safety climb devices with a pivot dismount pole should be provided on all exterior and interior ladders where required.

j. Provide O-rings, hold-downs and other safety hook-up points on exterior and interior for attachment of safety cables and harnesses.

4. Vents

A vent shall be installed at the center of the tank roof or where applicable depending on the design. The vent shall be sized to prevent pressure buildup during the inlet and outlet operation at the maximum hydraulic rate. A type 316 stainless steel insect screen shall be provided in the vent.

A rotary ventilator, if required, will be provided on the center of the roof. The ventilator should be sized appropriately for the specific tank, made of aluminum, and provided with cross braces and a type 316 stainless steel screen in a detachable frame.

Side ventilators with galvanized frames and type 316 stainless steel screens, if required, should be placed in each top shell plate above the maximum water surface in the tank. Side ventilators should be provided with drip troughs to intercept condensed enamel fumes from the inside of the roof and prevent the same from running out of the vents and down the outside wall of the standpipe.

5. Tank Appurtenances

Appurtenances at steel tanks and standpipes include the following equipment:

a. A davit crane and winch system shall be installed on access platforms over 25 feet in height. The davit crane and winch should be rated for a minimum load of 1,000 pounds. The working platform and railing at the davit location provides for safe operation, with a minimum platform size of 6 feet by 5 feet. The railing around the platform shall be at least 42 inches tall with a lower kickplate of 4-inch minimum height above the platform and a 24-inch opening in the railing for access.

D. Instrumentation and Control Guidelines

Instrumentation and control systems at storage facilities consist of level monitoring, storage facility inlet and outlet valve position monitoring, a seismic isolation valve system, chlorine disinfectant and injection control system, recirculation systems, and intrusion alarm systems.

1. Telemetry/Control and Communications

This paragraph describes telemetry/control and communications requirements for supervisory control and data acquisition (SCADA) remote terminal units (RTUs). A programmable logic controller (PLC) interfaces between the site instruments and the radio transceiver and/or leased-line modem. The storage facility RTU is polled by the Central Control System, which shall be programmed in accordance with the storage facility control philosophy, as defined in the Contract Documents. This strategy should be originally defined in the Pre-design Report and the detailed control strategies should be prepared by the Engineer of Work in coordination with the Agency's Operation's Department's Telemetry, Power, and Control Group.

2. Level Monitoring

The below grade storage facilities level sensor shall be an ultrasonic level transmitter that produces a 4-20 mA signal proportional to the measured height of the water in the storage facility. The transducer should be mounted on a 3-inch ANSI flange at the top of the storage facility and the transmitter control box is mounted 4.5 feet above finished ground. The control box integral digital level readout indicates the tank level in feet and inches.

High and low level switches shall be provided as a back-up to the level transmitter. The level switch shall be of the inductive type with cable-suspended electrodes held by an electrode holder mounted on a 3-inch ANSI flange at the top of the storage facility. The switches and the level transmitter shall be connected to the PLC. Dual cell storage facilities are provided with level instrumentation in each cell.

Above grade storage tanks and standpipes level transmitters shall be the pressure sensing type, connected to a vessel bottom flange by 1/2-inch diameter 316 S8 tubing. The transmitter shall be provided with an integral digital display calibrated to feet of water level.

Above grade tanks and standpipes requiring local level indication shall be provided with a target and gauge board assembly. The vertical moving pointer shall be actuated by an internal float riding on two bottom-anchored guide cables. All components in contact with water must be type 316 stainless steel.

3. Inlet/Outlet Valves

Storage facility isolation butterfly valves shall be provided with valve position limit switches to report valve status to the Central Control System.

4. Seismic Isolation Valve System

Where recommended in the Pre-design Report or directed by the Agency's Project Manager, seismic isolation valves shall be included.

There are three primary functions of a seismic isolation valve:

a. provide remote operator control to open isolate a tank under normal or seismic conditions;

b. Isolate a tank from the pressure zone, should the operator deem it suitable to withhold the water inventory in the tank from leaking out of broken distribution system pipes. The water in the tank can then be made available for fire fighting at some time after the earthquake has occurred, but before the pressure zone can be re-supplied with additional water; i.e. water treatment plants; and

c. Isolate the tank from the distribution system to prevent rapid loss of water through broken pipes that could result in high life safety risk to nearby people.

Unless a credible life safety or other threatening situation occurs, it is not generally advisable for seismic isolation valves to automatically close and isolate all water from a pressure zone. This type of automatic closure could leave a pressure zone with no available source of water to fight fires immediately after an earthquake. This guideline could be relaxed if fire department and water department emergency coordination capability can be demonstrated to be reliable under post-earthquake conditions. In this case the isolated tank could be opened within, at most, 1 or 2 minutes, once it is deemed that the situation warrants the need for fire flow water from the isolated tanks.

For pressure zones which are served by two or more tanks, it shall be acceptable to isolate the tanks automatically (or remotely) under earthquake conditions, except for the largest tank. Assuming pipeline damage has occurred in that zone, the non-isolated tank can be expected to drain (go empty) within hours, depending on the nature and location of the pipeline damage and hydraulics of the zone, and assuming, also, no manual intervention (manually closing valves) has taken place in this time frame. If a fire ignites in that zone after the time the first tank goes empty, but before the zone can be re-supplied with additional water from water treatment plants, the isolated tank(s) can be opened to provide fire flows for that fire.

For tanks where it shall be deemed suitable by the Engineer of Work and the Agency's Project Manager to add seismic isolation valves, the valves should have the following attributes:

Remote Seismic Isolation Valves. Two sensors should be used to detect situations where operators (via SCADA) decide to close (or partially close) a valve. One signal should indicate that a large earthquake has occurred. This can be demonstrated by sensing that a suitably high and long duration level of shaking has occurred. This can be measured by ground acceleration, velocity or shaking-energy-type sensors. The settings to indicate that a large earthquake has occurred should be set such that high frequency short duration accelerations (truck vibration, shock loads) do not falsely indicate a large earthquake. The second signal should indicate a sudden loss of pressure or increase in flow of water leaving the tank. A programmable logic controller (PLC) can be developed to automatically determine if both conditions have occurred. If both conditions have occurred, then the remote operator can send a signal to the isolation valve to close completely or partially. The partial closure could be used to throttle back the water flows. There should be an alternate power supply to operate the instrument sensors, the SCADA system, and to actuate the isolation valve, which does not depend on electric or gas supply from San Diego Gas and Electric, under post-earthquake conditions. The power supply should be sized to provide 4 full valve cycles (i.e., two close and two open). Prominently placed instructions should be located at the valve to allow manual over-ride of the seismic isolation valve.

Automatic Seismic Isolation Valves. Two sensors should be used to make the decision to automatically close a valve to isolate a tank. One signal should indicate that a large earthquake has occurred. This can be demonstrated by sensing that a suitably high and long duration level of shaking has occurred. This can be measured by ground acceleration, velocity or shaking energy-type sensors. The settings to indicate that a large earthquake has occurred should be set such that high frequency short duration accelerations (truck vibration, shock loads) do not falsely indicate a large earthquake. The second signal should indicate a sudden loss of pressure or increase in flow of water leaving the tank. A programmable logic controller (PLC) can be developed to automatically determine if both conditions have occurred. If both conditions have occurred, then the PLC can send a signal to the isolation valve to close completely. There should be an alternate power supply to operate the instrument sensors and actuate the isolation valve, which does not depend on electric or gas supply from San Diego Gas and Electric, under post-earthquake conditions. The power supply should be sized to provide 4 full valve cycles (Le., two close and two open). Prominently placed instructions should be located at the valve to allow manual over-ride of the seismic isolation valve.

A fire hydrant or similar type outlet should be placed between the tank and the seismic isolation valve to allow the fire department to draft directly from the tank under emergency conditions.

Design details for the seismic isolation valve may include the following:

The seismic detector, upon verification that a seismic event with a magnitude higher than its set point has occurred, closes the storage facility isolation valves by actuating the inlet and lor outlet isolation valve electric actuators. If the isolation valve is a single altitude valve, Cia-Valve or similar, the valve should be provided with a valve closing solenoid to be tripped by the seismic controller, in addition to the specified valve position limit switch.

The seismic detector shall be connected in a "voting" scheme, where the valve closure command shall be issued only when an additional signal either high flow or low pipeline pressure denotes that a pipeline failure has occurred. A strategic location shall be selected for a pressure transmitter and/or flow transmitter on the inlet or outlet pipeline to suit each storage facility design.

The seismic detector shall be provided with a back-up 24 vdc battery pack to sustain operation for at least 12 hours. The seismic detector control unit shall be installed in the RTU control panel with the PLC and telemetry equipment. Seismic sensors should be ideally mounted in a "free field" condition in a suitable enclosure; or may be mounted on a suitable high frequency structural wall or column. The seismic sensor(s) shall be connected to the control unit with manufacturer furnished cables. Alarm contacts shall be provided and connected to the PLC. Through the PLC, the seismic detection system accepts the remote valve closure command from the Central Control System as well as "system disarm" and reset command.

The isolation valves electric motor actuators shall be 24 volts dc type, connected to a 24 vdc battery and charger with sufficient power to actuate the valves four times (two closures and two openings).

5. Site Intrusion Alarm

The storage facility site shall be provided with intrusion switches on hatches, maintenance access openings, entrance gates, and electrical panels. Intrusion switches shall be connected to the PLC which will be programmed with an adjustable time delay upon entrance to allow the operator to disable the alarm before it is broadcast by the telemetry system. The disarm/reset controls should be located in a convenient location for authorized personnel operation.

6. Chlorine Injection Instrumentation

Where recommended in the Pre-design Report or directed by the Agency's Project Manager, residual chlorine shall be monitored in a continuous sample stream by a Hach model CL 17 colorimetric type chlorine analyzer and its output signal used to pace the chlorine injection pumps. The transmitter produces an isolated 4-20 mA output to the PLC proportional to chlorine residual. Field selectable ranges shall be between 0 and 5 mg/I. The PLC should be programmed with a 3-mode proportional integral derivative controller to pace the chlorine injection pumps.

The liquid level in the sodium hypochlorite storage tanks shall be monitored by an ultrasonic level transmitter with local indication at the truck loading fill port and a 4-20 mA level signal to the PLC. Telemetry signals and alarms to the Central Control System include residual chlorine concentration, sodium hypochlorite tank level, pump, failure, sample flow low, and analyzer common alarm.

A liquid level indicator shall be required; and is a direct reading gauge with a type 316 stainless-steel float inside the tank and an indicator board mounted on the outside of tank.

E. Cathodic Protection Guidelines

Guidelines regarding cathodic protection systems shall be per each Agency's standards and the general corrosion standards in the WASDG.

F. Electrical Guidelines

1. Purpose

This section provides guidance in the design of electrical facilities for storage facilities, the conduct of special studies (including relay coordination, short circuit, voltage drop and motor starting analyses). The work may also entail collection of data such as soil resistivity and historical electrical loads.

2. Electrical Codes and Standards

Storage facility electrical system design must comply with electrical codes, ANSI, NEC, UL, NEMA, and IEEE, as applicable.

3. Electrical Criteria

Electrical designs promote the commonality of hardware, the use of proven hardware, and the use of current technology. All electrical service cabinets and other free standing equipment must have seismic braces to satisfy code requirements

The voltage drop at the motor terminals must not exceed 15%. Feeder and branch circuit conductors are sized so that their combined voltage drop does not exceed 5% with a maximum of 3% in either feeder or branch circuit.

Utilization voltage ratings shall be as follows:

a. Motors smaller than 3/4 hp shall be 115 volts, single phase, 60 Hz.

b. Motors 3/4 hp and larger shall be 440 volts, 3 phase, 60 Hz.

c. Miscellaneous non-motor loads of 0.5 kW and less shall be rated at 115 volts.

d. Non-motor loads larger than 0.5 kW shall be rated at 440 volts, 3 phase, unless this voltage rating is not available for the equipment selected.

e. All ac control power circuits shall be 120 volts.

f. All instrumentation power supplies shall be 120 volts ac.

g. Special purpose dc control circuits may be 125 volts, 48 volts, or 24 volts.

Motors must have the following features:

a. Heavy duty, 100,000 hour rated bearings.

b. Oil-lubricated motors shall be equipped with a visual oil level indicator.

c. Locked rotor must comply with NEMA Code "F" or better.

d. Motors for water pumps shall be hollow shaft type for ease of adjustment of impeller by means of adjusting a nut at the top of the impeller.

e. Motors have winding over-temperature safety switch.

f. Motors have strip-type heater elements that automatically disconnect.

4. Interfaces

At storage facilities with a pumping station, electrical facilities must also comply with the Agency’s standards. The electrical design shall be coordinated with the cathodic protection system to avoid possible interference between the storage facility grounding system and the cathodic protection system.

5. Electrical Service and Distribution

Distribution (utilization) voltages at the storage facility site shall be 480 V, 208 V, and 120 V unless other voltages are required for special cases. Incoming service voltages must be coordinated with SDG&E.

The storage facility power distribution system shall be designed such that no single fault or loss of the preferred power source results in disruption (either extended or momentary) of electrical service to more than one of the vital components. Vital and non-vital components serving the same function shall be divided as equally as possible between at least two MCCs or distribution panels.

The electrical power distribution system incorporates redundant power sources. The requirement for redundant supply shall be waived only in consultation with the Project Manager. Incoming power metering has the capability for remote reading via a modem.

Outdoor installations have non walk-in, weatherproof enclosures.

6. Electrical Equipment

Electrical equipment shall be sized to continuously carry all electrical loads without overloading. Equipment and materials shall be rated to withstand and/or interrupt the available fault currents, with at least a 20% reserve margin for electrical load growth. Electrical power conductors shall be sized according to the heating characteristics of conductors under fault conditions.

a. Distribution/Lighting Panels: All panels shall have non-fusible disconnects in the main panel to open circuits during repair work. All breakers should have "lockout" safety switches. 25% spare breakers are provided for future expansion.

b. Motor Control Centers: Motor control centers at storage facilities must conform to the requirements of the applicable Agency.

c. Switchgear: Switchgear requirements must conform to the requirements of the applicable Agency.

7. Grounding

All feeders have an equipment grounding conductor in the same raceway. Non-current carrying metal parts of equipment, all enclosures, and the raceway are grounded by an equipment ground conductor contained in the raceway, cable or run with the circuit conductors in the same raceway. Equipment grounding conductors must be sized according to NEC Table 250.

The grounding system in the storage facility area shall be coordinated with the cathodic protection system design to ensure that grounding does not hasten corrosion of pipe, tanks, and equipment.

8. Instrument Power

All 120 V power to instruments and instrument panels shall be derived from a dedicated instrument power panel from a shielded transformer. A general lighting and convenience receptacle panel may not be used to serve above loads. Instrument panels must be in a NEMA 3 or NEMA 4 enclosure.

An uninterruptible power supply (UPS) shall be provided for all main control panels, RTUs, RIOs, PLCs, and all other process controllers to provide continuous conditioned power. The UPS are sized to provide 30 minutes of standby power.

9. Emergency Power

Requirements for emergency power shall be described by each Agency's standards. Diesel engine units may be installed with special approval from the Agency's Operations Division. If required, an automatic transfer switch is provided.

10. Lighting

The California State Energy Conservation Standards apply where applicable. Voltage for lighting systems shall be as follows:

a. Outdoors: High pressure sodium type, 277 or 115 volts, with a photoelectric cell and a timer in parallel and a manual override.

Illumination levels shall be as follows:

a. Electrical equipment rooms: 40 footcandles
b. Exterior lighting: 0.1 to 1 footcandle
c. Mechanical equipment rooms: 30 footcandles

Lighting adjacent to stairs and ladders shall be switched. The pathway to the main lighting switch shall be lighted with non-switched lighting fixtures.

All other outdoor lighting around storage facilities shall be controlled by photoelectric cells with a parallel timer and a manual bypass with key-operated switching.

Exterior lighting with go-minute capacity emergency battery back-up packs shall be provided at the property entrance gate to unattended storage facilities.

11. Receptacles

The convenience GFCI receptacles throughout the outside of the facility must be 20-amp, NEMA 5-20-R, 120-volt grounding type located so that all working areas can be reached by a 50-foot extension cord. 480 V, 3-wire, 4-pole twist lock receptacles shall be provided so that the receptacles can be reached by a 50-foot-long cord. All outdoor receptacles in wet areas shall be in weatherproof enclosures installed in secured locations.

12. Additional Requirements

The Contract Documents include the requirements for:

a. Provision for testing and written certification of ground fault testing.

b. Spare parts and service for all major electrical equipment, including motors, emergency generators, electrical switchgear, and MCCs shall be available in Southern California in 24 hours of notification.

c. If required by the Federal Aviation Administration (FAA), obstruction lights, wiring and conduit shall be provided.

G. Architectural and Landscaping Guidelines

Each storage facility structure should be evaluated based on its surroundings, designed to fit the local setting, and complement surrounding adjacent land use. The Engineer of Work should consider the following:

1. The design approach shall be flexible and creative; adapted to the unique conditions at each storage facility site. There is no single theme/style for storage facility structures.

2. Construction material and plantings should be evaluated and selected according to requirements of function such as durability, aesthetics, maintenance, and cost-effectiveness.

3. The design shall be well conceived and of lasting aesthetic value, putting public funds to good use.

4. Color is in accordance with local community input.

H. Storage Facility Construction, Filling, Disinfection and Testing

1. Storage Facility Construction

In addition to the requirements of relevant AWWA specifications, all intersections of horizontal and vertical welds in the tank or standpipe shell must be inspected by radiographic methods and provisions made to deliver the film to the Project Manager upon completion of the work.

Sand for the cushion under the tank or standpipe shall be thoroughly dry, where the use of dry sand is practical. Under unusual conditions and when necessary, the sand may be pre-oiled, in which case the cushion must be rolled with a heavy roller and finished slightly higher than shall be required if dry sand is used, to take into account the compaction of the cushion under load, which might result in the standpipe floor being lower than the top of the foundation.

A clearance of 1/4 inch shall be provided between the outside edge of the floor plate and the side of the sand cushion depression in the foundation.

In testing the floor with hot oil, the oil should be injected very slowly to avoid displacing the sand and ensure complete coverage. This test is performed only in the presence of the Agency’s Inspector.

2. Filling, Disinfection and Testing

Before filling the tank or standpipe for testing, the walls shall be thoroughly washed and the tank disinfected.

The overflow pipe shall be tested by filling it with water before filling the tank or standpipe and before connecting to the drain line. Considerable time and large quantities of water have been lost due to leaks discovered in overflow pipes after tanks or standpipes are filled.

After the tank or standpipe is filled, the plug on the bottom side of the overflow nozzle shall be removed to determine whether leaks have occurred in the overflow pipe since the original test was made.

Anchor bolt nuts shall be torqued after filling the tank or standpipe and again before acceptance by the Agency.

Site piping and valves shall be pressure tested in accordance with the WAS.

7.1.6 REINFORCED CONCRETE STORAGE FACILITIES

This guideline governs the design of buried and partially buried, cast-in-place, reinforced concrete storage facilities. The function of partially buried storage facilities shall be identical to that for buried concrete storage facilities. Partially buried concrete storage facilities have features similar to those for buried storage facilities, except that the structures are designed to be backfilled to a level below the roof elevation.

Storage facilities may consist of a single or dual basin configuration with hopper-shaped bottom(s). A dual basin design separated by a common wall is the most common storage facility configuration.

A. Site Design Guidelines

Site design guidelines for buried and partially buried reinforced concrete storage facilities shall be essentially identical to those for steel tanks as described in paragraph 7.1.5.A. Site grading prevents site drainage from gaining access to the top of buried storage facilities, and the earth blanket on the top of a buried storage facility provides a minimum of 1% grade from the roof ridge line to the perimeter of the storage facility.

The underdrain system provided consists of a grid of drain pipes beneath the floor of the storage facility and around its perimeter. The underdrain system reduces the uplift forces that occur when the storage facility is drained and detects excessive leakage from the storage facility. The underdrain system needs to be laid out in zones, no bigger than 20,000 ft^2 each, so a leak can be located in a specific area. Water collected in the drain piping system is discharged to an underground vault. An inspection manhole shall be provided at the vault for direct observations of leakage. Drain rock shall be provided beneath the storage facility and pea gravel shall be placed around the underdrain piping.

As part of the storage facility design, volume calculations shall be required to establish the volume of the storage facility at 0.1-foot increments between the high water level and the floor level at the sump. The reduction in volume attributed to the overflow device and the roof columns shall be included in the calculations.

B. Structural Guidelines

1. Reference Standards and Codes

The latest editions of the following standards and codes govern the design of buried and partially buried reinforced concrete storage facilities:

a. Building Code Requirements for “Minimum Design Loads in Buildings and Other Structures,” ASCE 7 by the American Society of Civil Engineers, and ANSI A58.1 by the American National Standards Institute.

b. Title 24, Part 2, California Building Code.

c. UBC of the International Conference of Building Officials.

d. Building Code Requirements for Reinforced Concrete, ACI 318, and commentary, ACI 318R, as contained in the UBC.

e. Environmental Engineering Concrete Structures, ACI 350R.

f. “Concrete Manual,” U.S. Bureau of Reclamation.

g. Concrete Reinforcing Steel Institute (CRSI) Handbook.

h. "Rectangular Concrete Tanks," Portland Cement Association (PCA).

i. "Moments and Reactions for Rectangular Plates," Engineering Monograph No. 27, U.S. Department of the Interior Bureau of Reclamation.

j. Structural Welding Code - Steel, ANSI/AWS-D1.1.

k. Recommended Lateral Force Requirements and commentary (commonly known as "Blue Book"), Seismology Committee of the Structural Engineers Association of California (SEAOC).

l. "Formulas for Stress and Strains," Roark and Young.

m. Standards of the Occupational Safety and Health Administration.

n. State of California Construction Safety Orders, Cal-OSHA.

o. Book 2, Chapter 8, Seismic Criteria.

2. Design Loads

The following criteria define the minimum design loads for buried and partially buried concrete storage facilities. Without limiting the generality of the other requirements of these criteria, all design loads must conform to or exceed the requirements of the UBC and all applicable requirements of the documents referenced in A above.

a. *Dead Loads*

Dead loads for various construction materials shall be as follows:

- Steel: 490 pcf
- Concrete: 150 pcf
- Aluminum: 169 pcf

In addition to the dead load of the basic structural elements, the following items shall be included in the dead load:

- All equipment and piping permanently attached to and considered part of the structure, including future equipment and piping.
- Piping of 12-inch diameter and smaller shall be treated as uniformly distributed loads. A typical minimum value of 20 psf shall be used.
- Piping larger than 12 inches in diameter shall be treated as concentrated loads.

b. *Live Loads*

Live loads, in addition to concentrated loads, shall be determined as follows:

- Roofs that require vehicular access for maintenance require H-20 traffic loads.
- Roof Loads: in accordance with the ASCE 7/ANSI A58.1 UBC, or local code, whichever will be more stringent.
- Stairs, Platforms, and Walkways: 100 psf or local code, whichever will be more stringent.

- Minimum concentrated load on ladders and stairs: in accordance the requirements of ANSI-A58.1, OSHA, Cal-OSHA, or local codes, whichever will be greatest.

- Mechanical and electrical equipment areas shall be designed for a minimum of 100 psf live load. Additional consideration shall be given for the type, size, and weight of specific equipment and the maintenance equipment in determining the actual design live load and concentrated loads.

c. *Wind Loads*

Wind loads must be in accordance with the ASCE 7/ANSI A58.1, and the UBC on the basis of a minimum basic wind speed of 100 mph and appropriate exposure, or on the requirements of local code, whichever will be more stringent. The design shall be governed by maximum wind or maximum seismic load, whichever will be greater.

d. *Hydrostatic and Hydrodynamic Loads*

Buried and partially buried storage facilities shall be considered environmental engineering structures and shall be designed for hydrostatic forces imposed by the fluid contained in them. The unit weight of water is 62.4 pcf. All environmental engineering structures will be designed for hydrodynamic forces using ground acceleration and the response spectra identified in the project geotechnical report, and the requirements of paragraph 7.1.6.B.2.f.

e. *Lateral Loads*

Buried and partially-buried concrete storage facilities shall be designed for the following applicable pressures:

- For all yielding structural components, lateral soil loads shall be determined using active soil pressure conditions recommended in geotechnical report.

- For all nonyielding structural components, lateral soil loads shall be determined using passive soil pressure conditions recommended in the geotechnical report.

- A minimum surcharge pressure equal to an additional 2 feet of soil shall be used for all structures adjacent to traffic loading conditions.

- Hydrostatic pressure imposed by the contents of the storage facility shall be considered.

- Hydrostatic pressure imposed by groundwater conditions, in addition to lateral soil pressure, shall be considered in the design. Lateral pressure distribution will be as recommended in the geotechnical report.

- Seismic soil pressure shall be in accordance with the requirements of paragraph 7.1.6.B.2.f.

f. *Seismic Loads*

Seismic loads shall be developed in accordance with accepted Seismic Criteria:

- When selecting ground motions for seismic design, consider requirements for uninterrupted operation after a major earthquake.

g. *Impact and Vibration Loads*

For structures carrying live loads that include impact, the assumed live loads shall be increased in accordance with the Specification of the Design, Fabrication, and Erection of Structural Steel for Buildings, AISC Publication No. S-326. All forces produced by the equipment or machinery that vibrates shall be considered in the design of supporting structures, and information on the magnitude of these forces shall be obtained from the respective equipment suppliers. Impact forces due to operations, including surging fluid, shall be considered in the design.

h. *Miscellaneous Loads*

Miscellaneous loads of a special nature, such as thrust from expansion joints or loads at special appurtenances, shall be considered in the design. Other examples of miscellaneous loads include:

- Surcharge loads, such as loads due to adjacent structures and vehicular loads.
- Thermal loads, where applicable.
- Operating pressure forces, forces due to moving fluids, and test forces and loads.
- Construction loads and conditions.
- Equipment load caused by removal of valves, etc.

3. Loading Conditions

Structures shall be designed for various loading conditions. As a minimum, the following load combinations will be determined:

a. Tank Full Without Backfill: Dead load plus hydrostatic loading plus hydrodynamic loading plus seismic forces resulting from dead loads.

b. Tank Empty: Dead load plus static soil pressure (at rest) plus seismic soil pressure plus seismic forces resulting from dead loads, including earth blanket on roof.

c. Tank Full With Backfill: Hydrostatic loading plus static soil pressure plus dead load and live load plus hydrodynamic pressure plus seismic soil pressure plus seismic force due to dead load and soil cover.

d. Equipment loads where truck or other equipment shall be loaded on roof for removing equipment.

4. Allowable Stress

Allowable stress for reinforced concrete structures must be in accordance with ACI 318/ACI 350R. Allowable stresses may be increased by 33% for seismic loading.

5. Structural Design Requirements

Reinforced concrete storage facilities shall be considered environmental engineering (hydraulic) structures and shall be designed for strength and serviceability. Designs will be prepared using the strength design method or, as an alternative, the working stress design method. Designs must meet the following requirements:

- Structural designs of reinforced concrete environmental engineering structures and support facilities will be in accordance with the general requirements of ACI 318 and ACI 350R.
- Design criteria shall be established within the limitations of the UBC and the ACI.

a. *Strength Design Method*

The following guidelines govern the strength design method (ACI 318):

- All concrete support facility structures not considered environmental engineering structures shall be designed by the strength design method.
- The strength design method will not be recommended for the design of environmental engineering structures. If the strength design method is used, however, the load factors of ACI 318 will be modified in accordance with ACI 350R. The load factor modifications shall be in accordance with Section 2.6.5 of ACI 350R.
- Serviceability requirements for support facilities and environmental engineering structures must be in accordance with the provisions of ACI 318 and Section 2.6.6 of ACI 350R.

b. *Working Stress Design Method*

If the working stress design method is adopted, the design must be in accordance with ACI 318, Appendix A, including the exceptions.

c. *Minimum Strengths*

Minimum strength for concrete and reinforcing steel shall be as follows:

- Concrete: 28-day compressive strength of 4,000 psi.
- Reinforcing steel: Yield strength of 60,000 psi per ASTM A615.

d. *Joints*

Expansion, contraction, and construction joints must be provided in accordance with ACI 350R to afford flexibility and accommodate differential movement, temperature stress, and shrinkage stress. All joints in environmental engineering structures where watertightness is required will be provided with waterstops and sealant. All joint detailing, types, and locations must be in accordance with Section 2.8 of ACI 350R. The locations of all joints shall be shown on the construction drawings.

Expansion joints shall be provided at abrupt changes in the structural configuration. The maximum recommended spacing of expansion joints shall be 120 feet. If storage facilities remain empty for extended periods, a closer spacing should be used.

Construction joints shall be used to dissipate shrinkage stresses, where required. Where used, the spacing of construction joints shall be at intervals of less than 24 feet, unless additional reinforcement is provided in accordance with Figure 2.5 of ACI 350R. For environmental engineering structures in seismically active zones, partial construction joints shall be used where 50% of the reinforcement passes through the joint.

Construction joints shall be positioned to cause the least impairment of the strength of the structure, to provide a logical separation between sections of the work, and to facilitate construction. All reinforcement shall be continued across or through the joint unless designed as a contraction or expansion joint.

6. Detailing

Detailing shall be performed in accordance with the seismic provisions of the following codes and references:

a. UBC

b. Provisions in Chapter 21 of ACI 318

c. Provisions in ACI 350R

Detailing of different structural elements ensures that ductility and other requirements will be in accordance with the requirements of the UBC and the SEAOC "Blue Book."

7. Water tightness and Cracking

To maintain watertightness of the structure, cracking and crack widths must be kept to a minimum. Cracking can be kept to a minimum by proper design, reinforcement distribution, and spacing of joints. The use of a large number of smaller diameter bars of main reinforcement shall be preferred over the use of an equal area of larger bars. Maximum bar spacing should not exceed 12 inches. Additional horizontal reinforcement placed in the bottom 3 feet of the wall reduces the tendency for vertical cracking.

8. Design Requirements for Major Elements

a. *Roof*

- The following guidelines shall be used when designing below-grade or exposed reinforced concrete roof systems:
- Use a flat slab system with a suggested column spacing of 20 feet, center-to-center.
- Consider the effect of relative rigidity when the concrete storage facility roof is rigidly connected to the tank walls. The effect of daily temperature fluctuation on exposed concrete roof slabs shall be a consideration for partially-buried storage facilities.
- For large, exposed, storage facility roof structures where expansion joints will be required, provide ductile moment resisting frames or the combination of sheer walls and ductile moment frames to resist seismic forces.
- Reinforcing required by structural design and reinforcing required to meet minimum code requirements run continuously through roof construction joints.

b. *Walls*

Walls shall be designed in accordance with the following:

- For a single-story closed storage facility, the wall acts as a vertical slab with continuity at both top and bottom. Moment distribution can be used to obtain the effects of continuity with the base and top slab. Reinforcing details at corners should be considered to handle the local effect of continuity around the corner.
- Walls should be designed for the loading conditions given in paragraph 7.1.6.B.3.
- The walls should be designed for passive pressure due to retained soil.
- Joints shall conform to paragraph 7.1.6.B.5.

Provide adequate freeboard between the maximum fluid level and the top of the wall to accommodate for the sloshing of fluid induced by an earthquake to prevent excessive stresses at the roof and connections with the roof.

c. *Foundations and Floor Slabs*

Unless groundwater or other geotechnical requirements dictate a mat foundation, the foundation should consist of a spread footing cast monolithically with the floor slabs. Design floor slabs as a membrane-reinforced concrete slab carrying all loads (i.e., concrete, water, superstructure, etc.) to the foundation. This floor slab shall be provided with construction joints detailed and spaced to allow movement at these joints and to adequately tolerate differential settlement and shrinkage stresses. Joints must be in accordance with the recommendations of ACI 350R.

The reinforcing shall be discontinuous at all floor slab joints, except for the first joint parallel to the exterior and center walls. All reinforcing shall be continuous across this first joint. All floor slab joints have a sealant groove and shall be provided with water stop.

Slab-on grade storage facility floors shall be designed and detailed as mat foundation carrying all loads except for the water, which is directly carried by soil to permit foundation and concrete volume change movements while carefully controlling crack widths. The bottom of the slab should be a reasonable level for ease in excavation, and the top surface should slope a minimum of 1% along a longer distance for cleaning and drainage. Column footings shall be placed monolithically and on top of the membrane slab to reduce stress concentration and to permit slab curling while controlling cracking. Give careful attention to corner detail to maintain continuity between walls and base slab.

C. Mechanical Design Guidelines

1. Inlet and Outlet

Inlet and outlet piping must be steel pipe, mortar-lined and coated, conforming to the requirements of the WAS. Yard piping and exposed piping must also conform to the requirements of the WAS. Yard piping may transition from steel pipe to another material type if allowed by the WAS.

Design the inlet pipe to ensure water circulation inside "the storage facility. Provide baffles if necessary. Valve vaults shall be provided for inlet and outlet control valves as described in paragraph 7.1.6. C.1.

Space reinforced concrete piers accordingly to support the pipe and to protect against uplift of the pipe due to buoyancy.

Place the outlet pipe in the outlet sump, located away from the inlet pipe, to accomplish maximum water circulation within the storage facility. Provide a grate over the sump.

Place the outlet sump near the corner of the basin diagonally opposite the inlet valves to promote water circulation within the storage facility. The Engineer of Work designs the outlet to be non-vortexing under maximum flow rate (pumps at full capacity) and with the water level at 5 feet above the top of the curb at the outlet sump. The slope from the toe of the 5:1 slope to the top of the outlet sump may vary from 1 % to 0.5% depending on the size of the storage facility. The elevation of the finished floor at the sump shall be determined by the Engineer of Work. A curb with mud gates shall be provided around the outlet sump. A stainless-steel handrail shall be placed around the perimeter of the outlet sump and a permanent stainless steel ladder shall be provided for access to the sump. The top of the sump shall be the lowest part of the storage facility floor. The sump shall be at least three column lines from the nearest wall.

A submerged emergency shut-off (sluice gate or butterfly valve) shall be provided in the outlet sump. In the event of an outlet pipe failure, the emergency shut-off provides a means for preventing the storage facility from draining completely, thus preventing structural damage to the storage facility.

2. Overflow System

A rectangular overflow weir structure cantilevered from the wall shall be provided. A steel pipe located at the invert connects the overflow to an appropriate point of discharge. The size of the overflow and the pipe shall be designed for the maximum fill rate. For dual basins, flow is through an opening in the dividing wall within the overflow structure. An air vent connected to the overflow pipe shall be provided to vent the trapped air in the pipe. The end of the pipe has a flap gate or insect screen.

The overflow pipe shall be designed to discharge to an energy dissipater at a maximum flow rate to be determined by the Engineer of Work. The Engineer of Work designs the energy dissipater to ensure that water within the storage facility is protected from cross-contamination with surface water.

3. Storage Facility Access

Access through the roof to the floor and the overflow structure shall be required. A stainless-steel or aluminum stairway, cantilevered from the wall, is the recommended access to the storage facility floor. Aluminum hatches with locking devices shall be provided to limit unauthorized access. The hatches shall be designed for the anticipated live loads. Where applicable for vehicular access on concrete reservoirs, use H-20 loading.

4. Roof Vent

A minimum of four vents will be provided for each basin. Vents shall be sized for the maximum inflow or discharge rate to prevent pressure buildup inside the storage facility. A bumped head, with mesh screen, shall be located on top of the vent above the finished grade.

5. Sample Taps

Sample taps will be provided at various levels in the storage facility. A locked access to the sample taps shall be provided at the exterior of the storage facility at ground level.

A minimum of four 6-inch diameter sample ports will be provided that extend through the concrete wall of the storage facility. These sample ports are separated vertically. Sampling taps (3/4-inch diameter) are located on each sample port. Three of the taps must protrude a distance of 1 foot into the storage facility and be separated vertically to represent water quality from the facility at different heights. The fourth tap draws samples from near the bottom of the tank and shall be flush with the inside face of the tank.

A fifth 3/4-inch sample tap shall be provided in the recirculation piping if recirculation piping is used.

6. Washdown System

A washdown piping system shall be mounted on the interior wall of the storage facility. The minimum design flow rate shall be 25 gpm per nozzle. It is assumed all nozzles will be operating simultaneously per basin. Maximum size of nozzle shall be 1 1/2 inches, unless otherwise approved. Minimum design pressure shall be 50 psi (static) at the hose connection.

7. Disinfection

Facilities shall be provided for rechlorination of water in concrete storage facilities as described in paragraph 7.1.5.C.1.a. Chlorine injection points will be provided and equipped with locking covers.

8. Recirculation Piping and Pumps

Recirculation piping and pumps shall be provided as described for steel tanks and standpipes in paragraph 7.1.5.C.1.d.

9. Appurtenances

Davit crane and winch systems must conform to the requirements in paragraph 7.1.5.C.5.

D. Instrumentation and Control Guidelines

Instrumentation and control systems for buried and partially buried reinforced concrete storage facilities must conform to the requirements in paragraph 7.1.5.D.

E. Cathodic Protection Guidelines

Cathodic protection systems should be per WAS.

F. Electrical Guidelines

Electrical systems for buried and partially buried reinforced concrete storage facilities must conform to the WAS.

G. Architectural and Landscaping Guidelines

Architectural design for buried and partially buried reinforced concrete storage facilities must conform to the requirements in paragraph 7.1.5.G.

H. Storage Facility Construction, Filling, Disinfection, and Testing

Storage facility construction, filling, disinfection and testing must conform to applicable portions of paragraph 7.1.5.H.

7.1.7 Demolition of Existing Storage Facilities

Design for the demolition of an existing storage facility includes removal and disposal of the concrete or steel storage facility, concrete foundation, and aboveground appurtenances. Buried utilities shall be abandoned in-place unless otherwise directed by the Agency's Project Manager.

Removal of the existing coating and recoating may require that the site be classified as a lead paint removal project, depending on the lead content of the original paints used. If the site is classified as a lead paint removal site, the Engineer of Work incorporates the procedure developed by the applicable Agency for removal of lead based paints from the exterior and interior surfaces of the standpipe. The Agency manages and directs all aspects of lead-based paint removal from the facility. The Engineer of Work also provides for the removal of asbestos or other hazardous material from the site.

Final features of the site shall be decided on a case-by-case basis. Improvements largely depend on the anticipated future use of the land such as a park or parking area, or the site may be prepared for sale of the property. The Engineer of Work coordinates the final site features with the Agency Project Manager.

7.1.8 Rehabilitation of Existing Storage Facilities

Rehabilitation of an existing storage facility shall be intended to include all the design features described in earlier sections of this Section, including:

- Site Design Guidelines
- Structural Guidelines
- Mechanical Design Guidelines
- Instrumentation and Control Guidelines
- Cathodic Protection
- Electrical Guidelines
- Architectural Guidelines
- Storage Facility Construction, filling, Disinfection and Testing

Site improvements may include repairs or improvements to existing pavement, fencing, lighting and security.

The Engineer of Work performs a structural analysis that meets the intent of the WAS and the Agency's guidelines. The Agency's guidelines may be used for seismic evaluation and upgrade of existing structures.

The Agency performs a storage facility coating adhesion test and makes recommendation for further work. The Engineer of Work incorporates the recommendations into the project.

Removal of the existing coating and recoating may require that the site be classified as a lead paint removal project, depending on the lead content of the original paints used. If the site is classified as a lead paint removal site, the Engineer of Work incorporates the procedure developed by the individual Agency's practices for removal of lead based paints from the exterior and interior surfaces of the standpipe. The Agency manages and directs all aspects of lead-based paint removal from the facility. The Engineer of Work also provides for the removal of asbestos or other hazardous material from the site.

All electrical conduit and appurtenances shall be upgraded to meet current code requirements, including the installation of weatherproof conduit, fittings, receptacles, and appurtenances, and the installation of ground fault circuit interrupters (GFCIs).

Improvements for each reservoir must be approached on a case-by-case basis. The Engineer of Work coordinates improvements with the Agency's Project Manager.

7.1.9 Reference

A. Should the reader have any suggestions or questions concerning the material in this section, contact the member agencies listed.

B. Attachment "A" listed below forms a part of this section to the extent referenced and is referred to in the text as needed.

ATTACHMENT "A"

DATE ISSUED:	January 21, 2005	Report No. 05-024
ATTENTION:	Natural Resources and Culture Committee	
	Agenda of January 26, 2005	
SUBJECT:	Water Tank Selection Comparison: Steel versus Prestressed Concrete	

SUMMARY

THIS IS AN INFORMATION ITEM ONLY. NO ACTION IS REQUIRED ON THE PART OF THE COMMITTEE OR THE CITY COUNCIL.

BACKGROUND

During the Council action to approve the award of a construction contract for the Black Mountain Road Recycled Water Tank Project, Council requested an informational item (report) be prepared by Engineering and CIP Management Division comparing a steel tank versus a prestressed concrete tank.

This report provides the basic information regarding storage tanks of common size used in the water distribution system for the City of San Diego.

The water utility industry has wrestled with this matter for many years. For most utilities, it comes down to a matter of preference, local vendor support, and specific site conditions.

DISCUSSION

The Water Department has a large variety of water storage tanks throughout its distribution system ranging from 0.1 to 35 million gallons (MG)[1]. There are both buried (either fully or partially) and above grade facilities. Of the buried facilities, none are constructed of welded steel plate (WSP) due to the resulting aggressive corrosion degradation and steel's ductility. These facilities are either reinforced (cast-in-place) concrete (RC) or pre-stressed concrete (PSC) to withstand the compressive forces of the soil in addition to the expansive forces of the water. Focusing our attention then on the above-grade comparisons of WSP and PSC water storage facilities, these reservoirs are generally circular to minimize construction cost per gallon and to provide enhanced structural rigidity and seismic resistance. They are typically located at a high point in the service area (e.g. top of a hill) and are often visible from a significant distance. Their visibility requires non-technical community input regarding exterior coating colors and/or landscaping requirements to screen the facility from view. These factors always play a part in the selection process for a new facility.

Without exception, the smallest above grade storage tanks are of WSP construction and the largest are PSC. This arrangement is consistent throughout the water utility industry including the Water Department. The larger storage facilities are also typically associated with water treatment and transmission facilities (clearwells) rather than distribution systems (tanks & reservoirs). The Water department currently has 7 WSP facilities with a total potable water storage capacity of 14.9 MG and approximately 240 MG of potable water storage capacity in 21 concrete facilities including PSC, reinforced concrete, and concrete lined (Attachment 1). Currently, the largest WSP reservoir in the country is located in Austin, TX[2], the 34 MG Martin Hill Reservoir. The Water Department's 35 MG Earl Thomas Reservoir is the largest PSC

---

1 The City of San Diego Water Department 2003 Data Manual lists 46 tanks and reservoirs. Some of the smallest at 6000 to 16400 gallons are actually welded steel hydropneumatic tanks and fall into a different classification than the tanks and reservoirs discussed in this document.

2 http://www.ci.austin.tx.us/water/demandplan.htm; http://www.kleinfelder.com/news/Trinity%20Tank.html

reservoir in the world[3]. This report shall focus on the common tank sizes found in water distribution systems.

Typically the constructed capital cost is the overwhelming factor in the selection process for a storage tank. The distribution of WSP tanks in smaller sizes, less than 1 MG, and PSC reservoirs in larger sizes, greater than 10 MG, reflects this distribution. However, the constructed capital cost should not be the basis by which a facility is selected. The Present Value or life-cycle cost is the preferred economic analysis to compare different conditions and scenarios in an engineering environment. When performing a life-cycle cost analysis, there is a size range that provides competitive Present Value costs for tanks constructed of either material. This range, 1-5 MG, is illustrated in the adjacent table and in Attachment 2.

Present Value (Nearest $1,000)		
	Steel	Prestressed Conc.
1 MG	$1,125,000	$1,100,000
3 MG	$2,328,000	$2,135,000
5 MG	$3,630,000	$2,990,000
10MG	$5,804,000	$4,715,000

LIFE CYCLE COSTS

The life-cycle cost or the cost to build, maintain, and operate a facility should be considered and compared to properly select a reservoir type. In a life-cycle cost analysis, basic assumptions are made regarding the intended use of the facility and how long the facility shall be used. These assumptions can be as sophisticated as a complete asset management plan or as simple as a guess. This often makes an apples-to-apples comparison between materially different facilities a challenge. When calculating life-cycle costs, assumptions as to the service life, inflation rate, interest rate, and maintenance period must be made. Understandably, the assumptions presented by manufacturers and vendors are often biased to the desired result. For our report, we shall assume that the fundamental engineering aspects of the site are the same for both types of tanks; that geotechnical parameters do not influence the selection; and that the service life is over 60 years with a full replacement at year-72. This is a reasonable and slightly conservative life-cycle. We shall also assume that the operational costs (cleaning, disinfection, sampling, etc.) for both types will be the same for a given size reservoir and may thus be removed from the analysis.

COATING SYSTEMS

In this report, we shall assume that the interior and exterior coating systems (paints, epoxies, polyurethanes, etc.) are the same products with the same application costs. This is a balanced compromise in that we also assume the interior coating system is on the same cycle as the exterior coating system. In actual practice, the interior application is more sophisticated due to National Sanitary Foundation (NSF) and American Water Works Association (AWWA) water quality and potability requirements. The interior often is an Occupational Safety and Health (OSHA) confined space requiring specialized equipment and personnel. The interior environment is high humidity and must be dehumidified to properly apply new coatings with commensurate curing conditions. Also, it is often inaccessible except through roof hatches and scaffolding. Therefore, interior coating systems are often patched and re-coated in lieu of a complete removal and reapplication. This presents its own set of problematic variables in the coating system integrity but means the interior coating system life-cycle costs are probably lower than presented. Conversely, the exterior is readily accessible, by design, and the coating systems used are more common and easily applied. Matched with exterior exposure conditions, these coating system maintenance cycles are often less than 12 years which would correlate to increased life-cycle costs for this portion.

RESERVOIR STRUCTURE GEOMETRY

We have also assumed a general geometric configuration for our tanks. In practice, they tend to be similar in height but have a variety of roof configurations from a full hemisphere on a WSP tank to an essentially flat roof for a PSC tank. As a compromise for surface area, we have averaged the application area of a hemisphere with that of a circle as a standard cover. Exceptions to this assumption are standpipes which by definition are taller than their diameter, are generally constructed of WSP, and frequently are 75 to 100 feet above grade from base to roof. Coating maintenance for a standpipe can therefore be substantially higher than a comparable volume WSP reservoir.

3 http://www.dyk.com/AboutUs/Alvarado.html

RESERVOIR MAINTENANCE

Industry maintenance practices are regionally specific. For example, the Mediterranean climate of San Diego differs markedly from the low humidity desert environment of Las Vegas and the humid rainy environment of Seattle. Coating systems in wet climes may have a shorter maintenance cycle than 12 years due to the ubiquitous moisture in the air and ground. This will push the cost of a steel tank up as compared to a PSC over the life of the facility. Compare to a low-humidity desert environment where the coating system cycle may be the half-life of the facility. There is a plethora of variables that add and subtract from the actual costs and for the sake of brevity, this report presumes that these variables balance out in the environment of San Diego.

Lastly, we have concurred with the interest and inflation rate analysis provided by a local PSC tank constructor, DYK, Incorporated (DYK). The general trend in inflation and interest rates is that they are equivalent values and reasonably low. This simplifies the analysis and gives some preference to the higher operation & maintenance (O&M) costs associated with WSP tanks. A summary of the assumptions is presented in Table 1.

Table 1 illustrates the preference for WSP structures in the smaller volumes and PSC structures in the larger volumes. For a utility the size of the City of San Diego, the typical new reservoir volume is 3 to 10MG which concurs with the comparable cost region between WSP and PSC. Adjustment of maintenance practices (assumptions) will sway the decision towards PSC if the maintenance costs increase and towards WSP if they decrease.

Subtle features of each reservoir material or construction may influence the final decision. One such feature is in the AWWA testing requirements for WSP and PSC tanks. By definition, WSP tanks are completely sealed by full welds on all seams. AWWA Specification D 100-96 requires the acceptable leakage rate be zero for a new WSP reservoir installation. Conversely, AWWA Specification D 115-95 allows the acceptable leakage rate for a Class A tank to be less than 0.05% of the full tank volume over 96 hours. In a 3 MG facility, this could be 400 gallons per day. All new reservoir facilities are constructed with an underdrain water collection system to monitor for any seepage and often new PSC reservoirs meet the WSP requirement. An example of where this differentiation may be a factor is the placement of a recycled water storage facility adjacent to a potable water facility. Since the distribution of both water types is similar and requires the same siting conditions for storage facilities, it is anticipated that a hilltop could have both types of tanks. State of California Department of Health Services (CADHS) provides oversight in protecting the potable water distribution system. While there are currently no regulations with respect to recycled water storage facilities, when compared to potable water, recycled water is often treated the same as sewage to protect the potable water distribution system. This would favor constructing a WSP storage facility, for either one or both of the reservoirs, due to its zero seepage allowance if the facilities are co-located on a hilltop.

Physical characteristics of the two materials and their structural behavior come into play when making a site selection. In a perfect world, the desired location is at the necessary elevation that makes the high water line equivalent to the distribution system pressure in the zone served. Unfortunately, we have reality to temper our perfect world and many times have difficulty finding the perfect hilltop location. One method to place the tank at the proper height isn't often seen in San Diego: elevated storage tanks constructed to hold water at a desired system pressure (old University Heights). These facilities are more often found in areas with small topography differences in the service area. Standpipes are another type of elevated storage tank where instead of supporting the tank on legs, the tank extends all the way to the ground. In this scenario, the operational volume is only a fraction of the storage volume and the height is greater than the diameter. Elevated tanks and standpipes are almost exclusively WSP.

San Diego, however, is blessed with a varied topography which allows tank and reservoir placement not only on top of a hill but at a variety of locations from top to bottom. These sites often are partially buried for both structural and foundation stability reasons plus aesthetic reasons for the surrounding community. When considering a reservoir for such a site, PSC facilities are much more rigid and able to accommodate the buried condition. However, they also require a superior foundation with very little to no settlement allowed because they are unable to adjust to the moving ground condition. This often require a larger developed footprint (surface area) to stay away from a cut/fill line on a sloped site and that may require significantly more land acquisition and grading. Alternatively, WSP is able to conform to significant settlement, in geotechnical terms, and still provide functionality because of its ductility; requires a smaller developed site footprint because it can tolerate a foundation made from “fill,” and therefore less land to acquire and/or grade.

One last item to note is the impact of our seismic requirements on the selection of a reservoir. The AWWA standard that governs the design and construction of WSP storage facilities, D 100-96 is currently undergoing a significant revision. The lessons learned from the Northridge earthquake in 1994 are being incorporated into the design and construction standards for the water utility industry. As such, the pipe connections and how they behave during anticipated lateral and vertical movements of water storage facilities may affect the ultimate selection. As written previously, PSC is a very rigid, very stable structure which is not anticipated to move differently than the ground upon which it sits. If site conditions do not conform to uniform ground movement during a seismic event, WSP may be the preferred construction material for both the reservoir and the piping systems connected to it.

CONCLUSION

Within the 1 to 5 MG capacity, WSP and PSC tanks compare favorably. During the investigation for this report, Water Department staff contacted several water agencies in the region of various sizes. While they generally support the observations made in the report, they exhibited some agency bias towards one type of reservoir construction material in their distribution systems: they had either a preponderance of steel tanks or a preponderance of concrete tanks. We interpret this as the familiarity factor. The familiarity factor is exhibited in numerous unwritten policies where utility leaders (senior engineers, supervisors, managers, directors, etc.) are more familiar (comfortable) with a particular material, procedure, policy, engineering design, engineering design firm, etc. This bias is then communicated to the staff in an informal familiarization: if you only work on steel tanks you will tend to prefer steel tanks to the “unknown” concrete tanks. Supporting this bias, equipment for operation and maintenance is procured for the preferred type which tips the balance to incorporating more of the same type of facilities and equipment into the maintenance program. Decades of this practice result in systems having a preponderance of a single type of construction material. This familiarity is also seen in pipeline materials in both water and sewer systems. To the Water Department’s credit, there are a variety of tank types within the distribution system which develops a broader skill set for personnel maintaining the facilities. It also provides an opportunity to evaluate the effectiveness of each facility type in a reasonably controlled environment. From the perspective of the Water Department Engineering and CIP Management Division, the selection of the tank material is as dependent upon the specific site conditions and ultimate function as the tank material itself. A recommendation for using PSC reservoirs over WSP reservoirs cannot be made based on the capital cost alone. A thorough life-cycle analysis should be included during the Predesign or 10% Design Report. At this stage, the site conditions can be evaluated, the ultimate functionality addressed, and specific assumptions about the future site compatibilities and maintenance schedules with respect to the proposed coating system(s) incorporated into the life-cycle cost analysis. The best-value selection for the Water Department can then be made. It can also be noted that most CIP projects involving reservoir and tank construction or rehabilitation also have a significant piping and appurtenance component that may be 50% or more of the total contract price. The incorporation of these appurtenant systems into the reservoir may also factor into the selection process.

Respectfully submitted:

Frank Belock, Jr.	Date	Vic Bianes,	Date
Water Department Director		Water Department Deputy Director	

RMU 2.0

ATTACHMENT 1 – WATER DEPARTMENT WATER STORAGE FACILITIES

	NAME	SHAPE	TYPE**	CAPACITY (MG)
1	MIRAMAR 1	Rec	GUN	20.8
2	MIRAMAR 2	Rec	GUN	31.4
3	ALVARADO EAST	Cir	PSC	21
4	ALVARADO WEST	Cir	PSC	21
5	CARMEL MTN RANCH	Cir	PSC	3.2
6	EARL THOMAS RESERVOIR	Cir	PSC	35
7	MIRAMAR RANCH NORTH RSVR	Cir	PSC	4.5
8	PENASQUITOS	Cir	PSC	5
9	SAN CARLOS RESERVOIR	Cir	PSC	5
10	SCRIPPS RANCH	Cir	PSC	3.2
11	BAYVIEW RESERVOIR	Rec	RC	10
12	BLACK MOUNTAIN RESERVOIR	Rec	RC	25
13	DEL CERRO RESERVOIR	Cir	RC	1.5
14	LA JOLLA CNTRY CLUB RSVR	Rec	RC	0.5
15	LA JOLLA EXCHANGE PL RSVR	Cir	RC	1
16	PACIFIC BEACH	Cir	RC	2.4
17	PT LOMA RESERVOIR	Rec	RC	10.9
18	RANCHO BERNARDO	Rec	RC	10.1
19	SOLEDAD RESERVOIR	Cir	RC	1.26
20	SOUTH SAN DIEGO RESERVOIR	Rec	RC	15
21	UNIVERSITY HGTS RESERVOIR	Rec	RC	11.9
22	CATALINA RESERVOIR	Cir	WSP	1.5
23	COLLEGE RANCH RESERVOIR	Cir	WSP	1.5
24	EMERALD HILLS	Cir	WSP	1.5
25	LA JOLLA VIEW STAND PIPE	Cir	WSP	0.7
26	PARADISE MESA	Cir	WSP	2.5
27	POMERADO PARK	Cir	WSP	5.2
28	REDWOOD VILLAGE	Cir	WSP	2

** Reinforced Concrete (RC)
Prestressed Concrete (PSC)
Concrete Lined – Gunnite (GUN)
Welded Steel Plate (WSP)

ATTACHMENT 2 – STORAGE FACILITY LIFE-CYCLE COST ANALYSIS

	Physical Parameters				Initial Cost			Maintenance Costs per 12-yr[3] cycle (nearest $1,000)		Present Value (Nearest $1,000)	
Size	Height (ft; typ)	Diameter (ft; typ)	Interior Surface Area (sq ft)	Exterior Surface Area (sq ft)	Steel [1]	Conc. [2]	Coating System Avg Cost/sq ft INT & EXT	Steel	Conc.	Steel	Prestressed Conc.
1MG	27	85	21396	15722	$410,000	$800,000	$3.84	$143,000	$60,000	$1,125,000	$1,100,000
3MG	32	130	46252	32979	$808,000	$1,500,000	$3.84	$304,000	$127,000	$2,328,000	$2,135,000
5MG	34	166	71837	50195	$1,285,000	$2,025,000	$3.84	$469,000	$193,000	$3,630,000	$2,990,000
10MG	40	215	117780	81475	$1,974,000	$3,150,000	$3.84	$766,000	$313,000	$5,804,000	$4,715,000

[1] Chicago Bridge & Iron (CBI)
[2] DYK Incorporated (DYK)
[3] Steel Plate Fabricators (SPF)

Notes:
All costs are in US Dollars
No appurtenant items such as piping, pavement, disinfection, etc. are included in the tank cost
Assumes level site with no geotechnical difficulties
Roof surface area is the average between a hemisphere and a flat circle
Interior Surface Area is Wall + Floor + Roof (underside) Exterior Surface Area is Wall + Roof
Service life is 60+ years with full replacement in the 72nd year
Assume interior and exterior coating systems are the same
Water Operations exterior coats every 10 years; Mfg suggests 15: Use 12 year cycle
Interior coating same cycle as exterior for steel tanks.
Assume interest rate equals inflation rate

END OF SECTION