Evaluation of Water Distribution and Storage System
Blue Lake Springs Mutual Water Company – Water Master Plan

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This technical memorandum presents a planning level evaluation of the existing water distribution and storage facilities serving the Blue Lake Springs Mutual Water Company (BLSMWC) water system. This technical memorandum is the fourth of a series of five memorandums which, when combined, will be a portion of the complete Water Master Plan. This memorandum is organized into the five sections, with subsections, listed as follows:

1. **Existing Water Distribution and Storage System**
   - **1.1 Background**
   - **1.2 Existing Water Storage**
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2. **Water System Requirements**
   - **2.1 Storage**
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   - **4.1 Hydraulic Model Simulations**
   - **4.2 Distribution System Improvements Priority Schedule**

1 EXISTING WATER DISTRIBUTION AND STORAGE SYSTEM

1.1 Background

The original Blue Lake Springs development was constructed in the mid-1970's. To serve potable drinking water to the development, a water distribution system was constructed using a combination of 6-inch asbestos cement (AC) pipe and 1.5 to 4-inch polyvinyl chloride (PVC) pipes. The AC pipe was placed around the perimeter of the Blue Lake Springs development with the smaller PVC pipe placed behind the housing parcels (back-lots), and in some of the public streets. The original distribution system had 7 redwood storage tanks that provided the operational pressure to five individual pressure zones. The pressure zones were named based on the tanks that served those pressure zones, described in more detail below.

Since the 1990's the water company has actively replaced the smaller PVC piping to meet two main objectives: 1) to bring all piping into the public rights-of-way (streets) where it easier to maintain and access; and, 2) to upsize all pipes to a minimum pipe size of 6-inch diameter. This initiative would also bring the system to the minimum State and local (Calaveras County Water District) standards. Therefore, the oldest pipe in the system is the original AC pipe and PVC pipe smaller than 6-inches at about 40 years old, while all other water mains range in age from approximately 5 to 20 years of age.

Two, new 750,000-gallon bolted steel storage tanks (Tank 4 and Tank 6) were installed in 1992 to replace the smaller redwood tanks that had served five individual pressure zones. These and other improvements resulted in the creation of additional pressure zones, without any formal re-naming of the pressure zone system. Through this evaluation at least two additional pressure zones were identified from the pressure reducing stations located within pressure zones. When Tank 4 was erected a separate transmission line was also constructed from the treatment plant to fill Tank 4 (the lower of the two) and an intermediate booster station (Cypress Booster Station) was constructed between Tank 4 and Tank 6 that would allow Tank 4 to fill Tank 6. As those facilities exist today, the transmission line that fills Tank 4 is now interconnected to the distribution system through pressure reducing valves at three locations and the Cypress Booster Station is no longer functional.

Plate 1, attached, provides a map of the existing water distribution and storage system.

1.2 Existing Water Storage

There are a total of four water storage tanks in the system. Two of the tanks are located in the distribution system and provide the operational pressure to the system. One tank is used at the treatment plant for chemical disinfection contact (i.e. clearwell storage) and is a supply to the booster pumps that fill the distribution storage tanks. There is also a small tank used in the treatment process as backwash storage and recovery. The booster pumps at the treatment plant deliver water from the clearwell storage to the distribution system at pressure sufficient to fill the storage tanks. Water is stored in the distribution tanks to maintain operational pressure throughout the system and to hold a reserve volume of water for firefighting and other emergency uses (discussed in more detail in the evaluation below). **Table 1** below summarizes the system storage information.

Table 1
System Storage

Name	Location	Year Installed	Construction	Service	Nominal Capacity
Tank 6	Distribution (El. 4550)	1992	Glass-fused bolted steel	Distribution Storage	750,000 gal.
Tank 4	Distribution (El. 4361)	1992	Glass-fused bolted steel	Distribution Storage	750,000 gal.
Tank 8	WTP (El. 4065)	2007	Glass-fused bolted steel	Clearwell Storage	150,000 gal.
Backwash	WTP	2007	Glass-fused bolted steel	Filter Backwash	30,000 gal.

1.3 Existing Water Distribution System

The water system is situated in mountainous terrain with varying topography at elevations ranging from approximately 3,800 to 4,500 feet above mean sea level. The water system is divided into multiple pressures zones that are regulated by pressure reducing stations and isolation valves, both of which maintain a range of operable pressures in the system.

The system contains an estimated 203,887 lineal feet (38.6 miles) of mainline piping, 44 pressure reducing stations (11 are either not functioning or shut-off), two storage tanks, approximately 90 fire hydrants, as well as a multitude of isolation valves, air release valves, and blow-offs. There are a total of 2,024 service laterals, and approximately 1,715 of those are currently active. Water service laterals were originally installed using polybutylene tubing and the newer and repaired laterals use polyethylene (PE) tubing. At the water service, there is typically a service box with a shut-off valve, and where mainline pressures are too high the water services are equipped with a pressure regulator. Newer services are being equipped with water meters, but a majority of the existing services do not have meters.

The approximate lengths of the existing mainline piping sizes in each pressure zone are shown in **Table 2**, below. In total, there is an estimated 203,887 feet of mainline piping ranging in size from 1-inch to 8-inch diameter. There is approximately 36,356 feet of AC pipe and 167,369 feet of PVC pipe. All of the AC pipe is 6-inch diameter and is from the original installation. PVC pipe ranges in size from 1-inch to 8-inch and ranges in age. The PVC pipe that is smaller than 6-inch diameter (approximately 92,743 feet) is from the original installation. The 6" and 8" PVC pipe (74,665 feet) is from the mainline upgrades that were made since the 1990's.

The water system has five pressure zones that were defined with the construction of the original development. The zones were originally supplied by 7 redwood tanks, which have since been removed and replaced the two bolted steel tanks. The original descriptions of the pressure zones used herein are those that the water company is familiar with, which is based on the old redwood tank naming. The zone names are Zone 1, Zone 2/3, Zone 4/5, Zone 6/7, and Zone 13 (named based on development Unit #13). A sixth small pressure zone is located near Tank 6 where five lots are fed off of a small booster station.

Table 2
Approximate Length (feet) of Water Mains by Pressure Zone
Existing Water System

	1"-1.5"	2"	2.5"	3"	4"	6"	8"	Total by Zone
Zone 1	3,738	7,494	2,788	1,550	1,160	11,868	735	**29,333**
Zone 2/3	17,359	6,086	1,963	2,094	1,490	6,824	2,306	**38,123**
Zone 4/5	10,231	5,635	2,064	639	1,832	26,607	-	**47,008**
Zone 6/7	9,701	9,637	3,738	210	1,147	40,193	5,427	**70,053**
Zone 13	-	2,078	-	-	109	17,183	-	**19,370**
Total by Size	**41,029**	**30,930**	**10,553**	**4,493**	**5,739**	**102,676**	**8,468**	**203,887**

2 WATER SYSTEM REQUIREMENTS

This section presents key design criteria used to assess the existing Blue Lake Springs system and to develop recommended changes incorporated in the Capital Improvement Program. Included in the following are requirements for water system storage and distribution. Applicable standards from regulatory and public agencies are presented.

2.1 Storage

Storage capacity is usually defined by four components, which are: operational, fire, emergency and unusable.

2.1.1 Operational Storage

Operational storage is required to equalize supply and demand over periods of short-term high consumer demand (i.e., peak-hour flow). The amount of water needed for operational storage is equal to the difference between the peak-hour demand and the maximum source capacity over the expected duration of a peak-hour demand. The duration of a system's peak hour demand can be measured with specific diurnal demand monitoring. In the absence of a specifically defined period, as measured in the field, it is specified in the California Waterworks Standards (§64554) for a water system such as Blue Lake Springs (with more than 1,000 service connections) to be for at least four hours.

2.1.2 Fire Storage

Fire storage is the volume of water held in residence for the sole purpose of providing an adequate amount of water for firefighting purposes. Fire storage derives directly from fire flow rate and duration, both specified by the local fire protection agency. For the existing Blue Lake Springs system, the Ebbetts Pass Fire District has specified fire flow requirements to meet the minimum standards of the California Fire Code of 1,500 gpm for a two-hour duration.

2.1.3 Emergency Storage

Emergency storage is the volume of water held in residence to accommodate demand requirements in the event of prolonged power outages, mainline breaks, or other interruptions in supply. The amount of storage for this purpose can be determined by the operational protocol of the water purveyor based upon the amount of time which is expected to pass before a hypothetical emergency can be corrected. Factors such as location (remoteness), desired degree of system dependability, cost, and water quality issues all influence the amount of emergency storage. There are no regulatory requirements for emergency storage; however, CDPH has indicated that an emergency storage component of one maximum-day event is recommended for all water systems. That recommendation is utilized in this Master Plan.

2.1.4 Unusable Storage

Unusable storage is the fraction of total storage that is not readily accessible during regular operation due to the location of the tank overflow and the locations of inlet and outlet piping in proximity to the top and bottom of the tank. For the purpose of this Master Plan, an assumed amount of 5 percent of nominal tank volume is deemed to be unusable.

2.2 Distribution

Distribution systems requirements focus on construction and operation standards to meet minimum system performance standards under normal and fire flow demand scenarios. There are different public codes and agencies that dictate these standards, such as those set forth in the California Waterworks Standards, American Water Works Association, California Plumbing Code, California Fire Code, California Public Utilities Commission, and local standards such as those set forth by the Calaveras County Water District and the Ebbetts Pass Fire District. Details of these standards as they related to this evaluation are presented below.

2.2.1 System Pressures and Pipe Diameter

Distribution system requirements in the Waterworks Standards (§64573 and §64602) focus on newly installed water mains which must have a minimum diameter of four inches and on distribution system construction, operation, and maintenance to assure that the minimum operating pressure in the water main at the user service line connection throughout the distribution system is not less than 20 pounds per square inch (psi) at all times. The California Plumbing Code specifies a maximum supply pressure to the service line of 80 psi, and where supply pressures are above 80 psi the code requires installation of a pressure regulator and strainer at the service line. The California Public Utilities Commission, in General Order 103, specifies each water system to be operated in a manner to assure minimum operating pressure at each service connection is not less than 40 psi nor more than 125 psi. General Order 103 requires a minimum pipe diameter of 6-inch for mainlines used in conjunction with a fire protection system, or otherwise no less than 4-inches.

The Calaveras County Water District (CCWD) specifies a minimum water main size of 6-inches in diameter, except that 4-inch may be allowed on cul-de-sacs where no fire hydrants will be connected and length of pipe is less than 500-feet. CCWD also specifies a minimum pressure of 40 psi under peak hour demands (PHD) and a minimum pressure of 20 psi under fire flow scenarios. Maximum system pressures specified in the CCWD standards are the same as in the plumbing code (maximum 80 psi or require a regulator at the service). CCWD also specifies a mainline pressure reducing station (PRV) to maintain mainline pressures to no more than 120 psi.

Because the CCWD standards are in general agreement with the other governing codes, if not more detailed, and they are in agreement with good engineering practice, those standards are utilized in this Master Plan for assessment of the existing distribution system and for sizing of recommended improvements. Application of those standards, discussed in the evaluation of the distribution system (Section 4 below), was made at the larger of the peak hour flow rate or the combination of maximum day flow rate plus the specified fire flow rate. The projected future water requirements at build-out (and associated fire flows) were considered in assessing the existing distribution piping and in sizing recommended improvements in the Capital Improvement Program.

2.2.2 Fire Flow Requirements

The specified fire flow is dictated by the California Fire Code, which specifies a minimum flow rate and duration based upon the type of building construction and size of floor plan. The fire flow rate is defined as the water supply flow rate that is available for firefighting purposes while maintaining a minimum system residual pressure of 20 psi. The fire code sets a minimum fire flow requirement of 1,000 gpm for a 2-hour duration for residential dwellings (one- and two-family dwellings) that are up to 3,600 square feet. All other types of buildings require a minimum fire flow of 1,500 gpm for a 2-hour duration. Fire flow rate and duration requirements increase with building sizes above 3,600 square feet. The fire code also allows up to a 50 percent reduction to the required fire flow if houses are equipped with approved sprinkler systems. In communication with the local fire suppression agency, the Ebbetts Pass Fire District, the minimum fire flow desired for fire fighting purposes for this system is 1,500 gpm at a 2-hour duration. A target fire flow of 1,500 gpm will be utilized in the Master Plan for assessing the existing distribution piping and sizing recommended improvements in the Capital Improvement Plan.

3 STORAGE EVALUATION

3.1 Adequacy of Existing Storage Capacity

The total storage requirement in the system is the sum of the four individual components of storage: operational storage, fire storage, emergency storage, and unusable storage. Table 3, below, summarizes the storage requirements.

- *Operational Storage* - To meet an estimated four-hour "peak hour" demand at build-out of 560 gpm, with available supply from sources at a design capacity of 400 gpm, required operational storage would be approximately 40,000 gallons.
- *Fire Storage* – For the minimum fire flow requirement (1,500 gpm) and duration (2 hours), specified by the local Ebbetts Pass Fire District, required fire storage is 180,000 gallons.
- *Emergency Storage* – At the projected maximum day demand at build-out (375 gpm) over a 24-hour duration, required emergency storage is approximately 540,000 gallons.
- *Unusable Storage* – With an assumed five percent unusable storage, approximately 40,000 gallons of the total storage requirement is deemed unusable.

The storage requirement is slightly less than 800,000 gallons at build-out of the water system (see **Table 3**, below). The existing capacity of all storage tanks combined (Tanks 4, 6 and 8) is nominally 1,650,000 gallons. Based on total storage requirements and total storage capacity, no additional storage is needed in the system.

Tank 6, being the highest elevation storage in the system, can serve water pressure to the entire system. Tank 6 alone has a capacity that meets the storage requirements of the existing system, and marginally meets it for the build-out of the system. If Tank 4 were offline temporarily then the system could be served by Tank 6. While Tank 4 has the same capacity as Tank 6, it is lower in elevation and would require a pump to move water to the higher pressure zones (i.e. Zone1, Zone 6/7 and Zone 13). The Cypress Booster Station was intended for that purpose but is not currently operable. Upgrades are recommended to enable the system to be fed off of Tank 4 in the event that Tank 6 were offline. This can accomplished in different ways, such as modifications to the Cypress Booster Station (which has had operational problems in the past and is currently out of service). One conceptual alternative would be to install a new booster station near the Tank 4 site that would be used to maintain pressure in the tank transmission line (which is common to both tanks at a pressure identical to Tank 6).

Table 3
Storage Requirements (gallons)

Storage Components	Existing Water System	Build-Out
Operational Storage Requirement *PHD minus supply x 4 hr*	30,000	40,000
Fire Storage Requirement *1500 gpm x 2 hr (residential)*	180,000	180,000
Emergency Storage Requirement *MDD x 24 hr*	455,000	540,000
Unusable Storage Requirement *5% nominal tank size*	35,000	40,000
Total Storage Requirement	700,000	800,000

3.2 Improvements to Existing Tank Sites

The existing storage tanks have been inspected and found to be generally in good condition, with the exception of leaking that has been occurring at the base of Tank 4, discussed in further detail below. Given the relatively new age and relative condition of storage tanks, no replacement of tank structures is included in this Master Plan. Routine operation and maintenance should include a regular inspection program to continually assess tank conditions, outside and inside.

The Tank 4 site shows signs of leaking at the base of the steel ring. The water company is currently in consultation with different professionals on this issue including the tank manufacturer, a structural engineer, and a geotechnical engineering firm. The objective currently is to determine the cause of leak, whether it is a structural concrete issue within the foundation and the bolted steel starter ring, or whether it is a soil stability issue (e.g. differential settlement and/or slope failure). A geotechnical study will be required if it appears to be an issue with the soil. Further evaluation is required to determine if the problem can be fixed through modifications of the tank site. If Tank 4 is required to be brought offline for repairs, the entire system can be served by Tank 6 with sufficient storage capacity, as discussed above.

In review of the distribution system, it was observed that Tank 4 has a pronounced lower water-turnover rate than Tank 6. Theoretically, the average water residence time in Tank 4 is approximately 16 days (not accounting tank short-circuiting). The low turnover rate is attributed to the limited demand from Tank 4, which serves water only to Zone 4/5 (approximately 20 percent of the overall water demand). Tank 4 has sufficient elevation head to serve a larger percentage of the system; however, the current pressure zone and isolation valve configurations limit Tank 4 influence to only Zone 4/5. Potential system modifications and operational practices could, in concept, improve the influence of Tank 4 over a larger portion of the distribution system. Hence, this would improve the turnover rate and lessen the complexity of the system. This is not specifically identified as an improvement item and merits further detailed evaluation; however, some concepts were considered in the development of future pipeline improvements discussed in the distribution system evaluation, below.

4 WATER DISTRIBUTION SYSTEM EVALUATION

Evaluation of the distribution system as part of this Master Plan effort included review of available system mapping; meeting with water company personnel to review pipe sizes, types, and age in existence; making updates to the current base map of the system to include changes made from pipeline projects; and installation and downloading of pressure dataloggers throughout the water system. Meetings with water company staff were also held to discuss unique pipe and valve configurations, pressure reducing valve settings, and to identify problematic areas such as areas of low or high pressure and areas subject to high or abnormal leakage rates. Updates to the base map to make it reflect actual field conditions required review of several "as-built" pipeline project plans and additional meetings with staff to iteratively compare, review and edit overall system maps.

A computerized system hydraulic model was then developed from the updated base map to simulate system performance under various customer demands and fire flow scenarios. The results were evaluated relative to the distribution system performance requirements discussed above. The model assisted in developing a plan for mainline replacements and system upgrades to bring the distribution system into compliance with applicable water demand and pressure requirements. Since this resulted in a recommended mainline replacement program that is substantial in scope (i.e. nearly 50-percent of the pipelines are to be replaced), an evaluation was also conducted to prioritize pipeline upgrade projects.

This evaluation is divided into two main headings. The first (Section 4.1) discusses the hydraulic model and the results of hydraulic simulations for the existing and conceptual future water system. Based upon those findings from the hydraulic simulations, a second part of the evaluation (Section 4.2) was developed, which presents a project-specific prioritized improvement schedule.

4.1 Hydraulic Model Simulations

The updated base map was used to develop a computer based hydraulic model of the distribution system using the Infowater software. Infowater uses the "gradient algorithm" (hybrid method) to solve pipe flow (friction loss) and mass conservation (node balance) equations that characterize a distribution system. The software uses an ArcGIS interface making it possible to construct, manipulate, view model elements in a graphical environment, and overlay with GIS database systems.

The principal benefit of a hydraulic model is that it provides computational and graphical means to identify and assess the strengths and weaknesses of a water supply, storage, and distribution system. For the analysis in this Master Plan, system weaknesses were considered to be areas of low or high pressure during normal, peak, and/or fire flow demand scenarios. System weaknesses were also considered to be areas with limited fire flow or no fire flow availability.

4.1.1 Model Inputs

The system model is comprised of lines representing distribution mainlines (by size, length and type) and nodes representing points where mainlines connect. Inputs to the model include the following:

- Each node is provided an elevation (relative to mean sea level) and can have a water demand (outflow) or water supply (inflow) applied.
- Water demand consists of customer water demand, fire demand, or a combination of both. Water demands are assigned at nodes based on the number of service connections along the connected mainlines. The future water demand at build-out (i.e. 2,024 service connection) was used in all simulations.
- Water supply in the Blue Lake Springs model derives from the water treatment plant and the elevated storage tanks (Tank 4 and Tank 6).
- The water treatment plant in the model uses the clearwell as a supply tank for the booster pumps to deliver water to the system and the tanks.
- Pump curve information is provided for the booster pumps.
- The tanks are assigned a starting tank level.
- Pressure reducing valves are assigned the pressure setting of the downstream side of the PRV station.

The elevations in Blue Lake Springs vary over 700 feet throughout the system, so elevations were a critical input. Using ArcGIS, a digital elevation model (DEM) was obtained from a Calaveras-Tuolumne National Elevation Dataset that was updated in 2011 having a vertical accuracy within 1 foot and a horizontal resolution of 10 feet. The DEM was imported to the model to update elevations for all junctions, tanks, valves, and pumps in the system.

Pipe roughness factors are also an input to the model and are a function of pipe material and condition. The condition of existing distribution piping could not be observed directly so pipe condition was estimated based on the age and material of pipelines. Using available information, general roughness coefficients (Hazen-Williams) were assigned to each pipe as follows: AC pipe - 120 and PVC pipe – 140.

Additional inputs to them model were the pressure settings on PRV stations and isolation valve closures. The Blue Lake Springs system has forty-four (44) PRV stations, some that were later identified in the base map update and model development phases. Positions of normally closed isolation valves and setting for all PRVs were a critical input to the model that required field evaluation. Some PRVs were also identified as being shut-off, not functioning, or had settings set low enough to only be activated in during extreme flow condition (e.g. fire flow). This step was related with calibration, discussed below.

4.1.2 Model Calibration

A standard procedure for model calibration is to compare actual hydrant flow and system pressure to the simulated system flow and pressure. The simulated system flow and pressure is compared to field data as a method of estimating the model's accuracy. If necessary, parameters (i.e. roughness coefficients) are adjusted as a means of calibrating the model. Since hydrant flow data were not available from the water system or from the local fire suppression agency, and hydrant flow data could not be collected due to timing of the evaluation and water conservation concerns, an alternate means of calibration was used that provided sufficient accuracy and understanding of the predictive capability of this model for the purposes of this assessment. To ultimately improve the accuracy it is recommended that the model be calibrated with the use of actual hydrant flow data.

The water system was monitored for a 6-week period of time using pressure data loggers installed at nine different locations. System records were also reviewed to determine the current water system production, demand in each pressure zone, and storage tank levels during the time of monitoring. Those system conditions were used as inputs to the model. The demand and pressure data were then introduced into the model to compare against simulated computer runs. From those comparisons, minor corrections were then made that included the addition of PRV stations and normally closed isolation valves (neither that were identified on earlier maps). After those corrections were made, the simulated pressures in the system were within 2- to 11-percent of the actual pressure measurements, which is within the acceptable range for a system of this size and complexity. Therefore, an 11 percent factor is included where minimum or maximum pressure requirements are used; for example a minimum pressure of 22 psi was used for fire flow assessments even though the code requirement is 20 psi minimum. Given the available data, the percentage of accuracy is considered acceptable.

The results of the model calibration data are presented in **Table 4**, below.

Table 4
Calibration Data (psi)

Pressure Data Location	Unit 2 Lot 129	Unit 2 Lot 297	Unit 5 Lot 683	Unit 5 Lot 596	Unit 8 Lot 60	Unit 9 Lot 43	Unit 9 Lot 37	Unit 11 Lot 104	Unit 13 Lot 164
Pressure Range (Datalogger)	116 - 124	57 - 60	78 - 85	67 - 71	124 - 130	113 - 117	78 - 85	43 - 49	153 - 165
Model Simulation (March 2014 Conditions)	118	65	83	70	118	120	81	49	165
Accuracy (%)	2%	11%	2%	1%	7%	4%	1%	7%	4%

4.1.3 Simulation of Existing System

The model is run under steady-state simulations as a way to assess the condition of the distribution system under various demand and tank level scenarios. The model was used to analyze system performance under three demand scenarios:

- Existing System Average Day Demand (ADD) – see results on **Plate 2**, attached;
- Existing System Peak Hour Demand (PHD) – see results on **Plate 3**, attached;
- Existing System Fire Flow Availability on Maximum Day Demand (MDD) – see results on **Plate 4**, attached.

The simulations of the above scenarios were used to locate any problem areas in the distribution system. A problem area is defined as any location in the distribution system that resulted in low pressures or high pressures. Low pressures during normal demand (ADD, PHD) are anything below 40 psi. Low pressure on a fire flow simulation is anything below 20 psi. High pressures are anything above 120 psi in any demand scenario.

Simulation results for ADD and PHD scenarios were very similar. **Plate 2** and **Plate 3** (attached) show simulated pressure contours for each scenario, respectively. In both scenarios, pressures throughout the system range from 50 psi to 220 psi. The fact that both simulations result in similar pressures is indicative that the water demand between these scenarios has negligible effect on system performance. Relative to the length of water mainline, the ADD and PHD water demands are low enough that hydraulic frictional losses have minimal effect on system residual pressures.

High pressure areas are observed in the lower elevation areas that are not sufficiently regulated by PRV stations. In addition, the transmission line that fills Tank 4 from the treatment plant is hydraulically connected with Tank 6 and the water treatment plant booster pumps, which results in pressures up to 220 psi at the lower elevations along the transmission main. That transmission line connects to and feeds the distribution system through PRV stations; at each of these connections the results show the contours that reflect the change from the high pressure side to the low pressure side of the PRV. Other than the Tank 4 transmission line, the distribution system has high pressures that range from 140 to 170 psi that occur at lower elevations in the system and have either non-functioning or are otherwise un-regulated.

For maximum day plus fire flow simulations (**Plate 4**) the fire flow was applied at a single hydrant while the system is experiencing the maximum day demand (MDD). The simulations were used to determine the available flow rate from each hydrant in the system while maintaining a minimum residual pressure of 20 psi (again 22 psi was actually used based on the results of calibration). Problem areas are where a hydrant has a fire flow rate that is less than the required fire flow, i,e. 1,500 gpm. There are also areas where there are no fire hydrants in existence and fire flows cannot be delivered.

The results showing the available fire flow of each hydrant are shown on **Plate 4**. The map also shows pipe diameters and highlights the 6-inch and 8-inch pipe, which are the pipes that provide the hydraulic backbone to deliver a majority of the fire flow demand. The results show that the system has a range of fire flow capacities from hydrants ranging from approximately 400 to 2,100 gpm. The variation is based on a combination factors such as pipeline diameters, hydraulic losses in delivering flow, existing pipeline looping to deliver flow, the hydrant's elevation in the system, and any upstream PRV set-points that are along the mainlines delivering water to the hydrants. In short, hydrants that are lower in elevation and have more 6-inch delivery lines are the ones with the higher fire flow capacities.

There are large areas of the system that do not have any fire flow capacity because there are no existing hydrants, which are essentially all of the areas with small (less than 6-inch) pipe. There are also areas with less than the 1,500 gpm fire flow capacity. Those are mostly at high elevation points in Zone 4/5 (which is fed primarily by Tank 4 and not Tank 6), and Zone 13 (which is fed by a single 6-inch line and has a problematic high elevation area on Wawona Way).

4.1.4 Future Water System Development and Simulation

Blue Lake Springs Mutual Water Company has stated an objective to upgrade all pipes in the system to a minimum size of 6-inch diameter and to bring all water mains into the public rights-of-way. With that as a basis, a hydraulic model of a conceptual future distribution system was systematically developed to meet these objectives and also maximize the future availability of fire flow and address the high pressure problems noted in the existing system. **Plate 7** is a map that shows pipe diameters for the future system (it also shows the results of fire flow simulations that are discussed in detail below).

The following elements were incorporated in the conceptual future distribution system:

1. Pipes smaller than 6-inches or located in back-lots were upsized to 6-inch or larger and relocated into the street (this resulted in 35 individual streets requiring new pipe).
2. An 8-inch distribution line is provided from the treatment plant to Blue Lake Springs Dr. to the south, then to Moran Rd., Patricia Ln., and Gertrude Way to provide hydraulic backbone to and from Zone 4/5 to improve fire flows;
3. A 12-inch distribution line from the treatment plant to north on Blue Lake Springs Dr., to Linda Dr., north on Moran Rd., partially on Russell Dr., and from Linda Dr. south on Moran Rd. to Dean Way. Dean Way is all 8-inch and Russell Dr. is partially 8-inch. This improves fire flows in Zone 1.
4. Disconnected the old 6-inch AC pipe from lots behind Silverado Way. The AC pipe was kept active from Cypress Point Booster station to Tank 6. Shutting off the AC pipe would drastically impact fire flows to Unit 13.
5. PRV stations were placed on new mainlines where needed to maintain pressures to below 120 psi throughout the distribution lines (excluding the Tank 4 transmission fill line which requires a high pressure to fill the both tanks).
6. PRV stations that are not functioning in Unit 13 were made functional in the future system to maintain pressures to below 120 psi.

The conceptual future pipeline network is depicted on **Plates 5**, **6** and **7**. The model was used to analyze system performance under the same three demand scenarios as before:

- Future System Average Day Demand (ADD) – see **Plate 5**, attached;
- Future System Peak Hour Demand (PHD) – see **Plate 6**, attached;
- Future System Fire Flow Availability on Maximum Day Demand (MDD) – see **Plate 7**, attached;

Simulation results for ADD and PHD scenarios (**Plate 5** and **Plate 6**) show contours of the simulated pressures. Simulated pressures in the future system range from 50 psi to 120 psi, with the exception of the Tank 4 transmission line and locations just upstream of some PRV stations.

The fire flow simulations (**Plate 7**) show an overall improvement throughout the system. Nearly all locations with new pipe will meet or exceed the 1,500 gpm requirement. The only exceptions are three locations that are at the end of streets, at higher elevations, and also at reduced capacity due to existing 6-inch and 8-inch delivery systems from Tank 6 and Tank 4. Those locations are at the end of Russell Dr., the end of Anna Lee Way, and the end of Jerrilynn Dr. Minimum fire flow for these three improved locations is 800 gpm. The future improvements also result in improvement to fire flows in other parts of the system that were are not going to be upgrade. There were improvements to the fire flows in the existing 6-inch pipe in Zone 4/5 by approximately 300 gpm. In Zone 13 fire flows did not change much with the new improvements due limitations caused by the existing 6-inch connection to the balance of the system. Accordingly, increasing the size of the connection would improve fire flows within Zone 13.

4.1.5 Future Water System Recommendations

The conceptual future water system developed as part of this Master Plan was utilized to develop the general upgrades for the Capital Improvement Plan. Due to recommendations made earlier (model calibration via hydrant testing and a re-assessment of pressure zones) it is further recommended the following activities be conducted prior to commencing with any construction activities:

1. Final calibration of the model using actual fire flow test results.

2. Re-assessment of pressure zoning in the system. Preliminarily, a review of system layout, topographical mapping and pressure zoning indicates the system could be operated with as few as 20 PRVs while maintaining 4 to 5 pressure zones. The system currently is defined by 5 pressure zones with 44 PRV stations, while in actuality there are at least 8 operating pressure zones. Reducing PRVs and pressure zones would simplify the system by reducing operational complexity and resources. This would require modification of the existing piping (including recent upgrades that have been made).

4.2 Distribution System Improvements Priority Schedule

This section presents the evaluation of the water distribution system and priority ranking for water infrastructure improvements. The results of hydraulic simulation above are used with the review of pipeline conditions to determine an appropriate project prioritization and phasing schedule.

4.2.1 Infrastructure Replacement Objectives

As stated earlier, the water company’s long-term goal is to upgrade distribution system pipelines with two objectives. The first objective is to replace small diameter pipes (less than 6-inches) with pipe sizes 6-inches or larger to meet minimum standards, which will improve fire flow capabilities and reduce water leakage in the old smaller PVC pipes. The second objective is to relocate all pipelines into the public right-of-way that are currently in the back-lots of homes, which poses problematic maintenance and potential sanitary issues during mainline breakages, as most of the septic systems are in the area of the water mains.

After review of the upgraded water system mapping, it was determined that these objectives would require replacement and/or abandonment of up to approximately 83,560 feet of pipe, all of which is smaller than 6-inches and some of which is in back-lots of homes. A future conceptual distribution system was developed to then serve these areas using 6-inch pipe, or larger if needed, to deliver the minimum target fire flow of 1,500 gallons per minute (discussed above). Total length of the new pipe in the future water system is approximately 67,300 feet and the abandoned pipe is approximately 83,560 feet, which means the conceptual future system could result in a total pipe reduction of up to 16,260 feet.

4.2.2 Evaluation Criteria

Given the extent of the scope of pipeline upgrades, a ranking system was developed with a set of criteria and weights that ranks each potential upgrade according to existing pipeline conditions, susceptibility to leakage, access to mainlines for maintenance and repair, hydraulic performance, and ability to deliver fire flows. The criteria were applied to 39 individual street sections which were evaluated for the upgrades.

Five main criteria utilized are discussed in detail below and include the following heading titles: Leakage, Mainline Access, Fire Flow Coverage, Fire Flow Capacity, and Static Pressure. Every street was rated with a score for each criteria; higher scores equal higher priority for replacement. Scores could range from 1 to 5 for each criterion, with the exception of the Leakage criteria, which was based on the actual number of leakage reports for that street. The evaluation further considered pipeline age, material, and size, however, all upgrades essentially have the same age, material, and are undersized (below 6-inches). Therefore, those categories did not benefit the prioritization of upgrades.

Finally, each criterion was weighted based on its level of importance, which further identified the priority for replacement. Below is a discussion of each criteria, how a score was applied to each individual street, and the relative importance (i.e. weight) for each category.

- **Leakage**
  Leakage was the highest weighted criteria with a weighting factor of 5. Leakage in mainlines is a sanitary concern due to the potential water quality contamination that could occur during any loss of pressure or breach in the pipeline. The water company provided 10 years of complaint records that were reviewed to assess the overall health of the system and determine frequency and location of problematic areas within the distribution system. Complaint records include a wide range of issues with the most common involving leaks at the water service or in the mainline piping, water quality complaints (color or odor), or issues with the customer pressure reducing valves. The complaint records were organized by relevance and plotted on a map that is presented for reference

in **Plate 8**, attached. Each street was given a score equal to the number of documented leakage reports (in the mainline or the service lateral).

- **Mainline Access**
  Mainline access was an indication of whether the houses are served by mainline piping in the street or in the back-lots of the houses. If the houses are served by a back-lot mainline, then that street was given a score of 5; otherwise a score of 1 was assessed. Mainlines located in the back-lots also could pose safety concerns that makes this criteria higher on the importance scale. The main concern with pipes in the back-lots is the lack of control over the facilities and the potential for pipes to be in close proximity to septic systems. A weighting factor of 4 was applied to this criterion.

- **Fire Flow Coverage**
  This criterion appraised the streets based on the proximity of fire hydrants. It was observed that some streets do not have any fire hydrants or have a limited availability of hydrants. Local and state fire standards specify minimum hydrant spacing to minimize response times for fighting fires. This evaluation uses a spacing of 600 feet, in accordance with the California Fire Code and the Ebbetts Pass Fire District standards. Each street was scored relative to the percentage of the street that has fire hydrant coverage (each hydrant covers 600-feet). A score of 5 means the street has zero-percent coverage (no hydrants), and a score of 1 means the street is 100-percent covered (i.e. has at least a hydrant every 600 feet). Intermediate scores are based on partial percent coverage. There are some areas with access to CCWD fire hydrants, and in those cases the CCWD fire hydrant would be used during a fire fighting emergency and is applied to the coverages for that street. A weighting factor of 3 was applied as this is important from a fire protection standpoint but below the priority of leakage in the previous criterions due to the sanitary concerns noted above.

- **Fire Flow Capacity**
  For those streets that do have some level of fire flow coverage, the model of the existing system was utilized to determine the rated capacity of those hydrants. Capacity is defined as the amount of available fire flow the hydrant can deliver while also maintaining a minimum residual of 20 psi throughout the system. The target fire flow for this system is 1,500 gpm. Streets that have hydrants with a capacity that is 1,500 gpm or greater get a low priority score of 1. Flows less than 600 gpm are given a high priority score of 5. This also means that streets with zero fire flow coverage (from the previous criterion) will also have zero fire flow capacity and will be scored accordingly in this section. The weighting factor applied was 2 as priority should first be for streets with zero coverage before streets with some level of fire flow coverage.

- **System Pressure**
  In the evaluation of the hydraulic performance of the system discussed in the previous section, it was noted that the distribution system does not appear to have low pressure problems. Low pressures are defined as pressures below 40 psi during normal demand scenarios (ADD, MDD, PHD). Results of hydraulic modeling simulations discussed above identified areas of high pressure, which are defined as pressures above 120 psi in accordance with CCWD standards. Ideally, system pressures would be kept below 80 psi to avoid the need for installing pressure regulators at the customer service, but pressures up to 120 psi are allowable if the customer services are equipped with regulators, which are an added cost and maintenance item. Areas of high pressure are also prone to leakage in the older, smaller PVC pipe. Therefore, addressing areas of high pressure in the system was the focus of this criterion. Streets with system pressures below 80 psi received a lower priority score of 1. Streets with pressures below 120 psi received a mid-range score of 3. Streets with pressures above 120 psi received a high priority score of 5. The weighting factor for system pressures was 1 as it is less critical than the criterion presented above.

4.2.3 Priority Ranking

The streets identified for pipeline upgrades were evaluated and ranked according to the criteria discussed above, and those results are presented on **Table 5** below. Total ranking scores ranged from 20 to 68. Streets were assigned priorities of high, medium, or low based on the total ranking score, as follows:

- High (score equal to or greater than 57);
- Medium (score of 46 to 57);
- Low (score below 46)

The results of the pipeline upgrade prioritization were plotted on a map and are shown on **Plate 9**, attached.

Table 5
Mainline Evaluation and Priority Ranking

Category			Leakage	Mainline Access (back lots)	Fire Flow Coverage	Fire Flow Capacity	System Pressure	Total
Criteria			# Leakage Reports	5: in back 1: in street	5: no coverage 1: fully covered	5: <600 gpm 4: <900gpm 3: <1200 gpm 2: <1500 gpm 1: >=1500gpm	1: <=80 psi 3: <=120 psi 5: >120 psi	
Weight			5	4	3	2	1	
Road	Pressure Zone	Unit						
Wawona Way	6/7	10,11	4	5	5	5	3	**68**
Castlewood	6/7	11	4	5	5	5	3	**68**
Patricia (E)	4/5, 2/3	3,5	4	5	4	5	5	**67**
San Ramon	6/7	11	3	5	5	5	3	**63**
Blue Lake Springs (N)	1	4	2	5	5	5	5	**60**
Patricia (W)	4/5	5,7	3	5	4	4	3	**58**
Gertrude	4/5	5	2	5	5	5	2	**57**
Seminole	6/7	11,12	3	5	4	4	2	**57**
Meadow	6/7	10,12	4	5	4	1	3	**57**
Colleen	4/5	7	2	5	5	5	1	**56**
Kiote Hills	6/7	11,12	4	5	3	1	3	**54**
Moran (N)	1	1	5	1	3	5	5	**53**
Blue Lake Springs (S)	2/3	4	1	5	5	5	3	**53**
Anna Lee (N)	4/5	3	4	1	5	5	3	**52**
Baywood View	6/7	11	4	5	1	4	1	**52**
Shirley	4/5	5	1	5	5	5	1	**51**
Rainy (W)	4/5	5	3	5	4	1	1	**50**
Dean	1	1,2	5	1	3	4	3	**49**
Julia	2/3	2	3	1	5	5	3	**47**
Moran (S)	2/3	3	1	5	2	5	5	**46**
Jerrilynn	4/5	5	2	5	3	3	1	**46**
Moran (M)	2/3	2	3	3	1	5	5	**45**
Linda	1	4	2	5	3	1	3	**44**
Anna Lee (S)	2/3	3	2	1	5	5	3	**42**
Dianna	2/3	3	1	1	5	5	5	**39**
Michelle	4/5	5	2	5	2	1	1	**39**
Cypress Point	6/7	10	2	5	1	1	3	**38**
North Sierra	6/7	11	1	5	1	3	3	**37**
Almaden	6/7	11	1	5	1	4	1	**37**
Dawyn	2/3	2	2	1	3	5	1	**34**
Silverado	6/7	11	0	5	1	4	3	**34**
Russell	1	1	1	1	4	5	1	**32**
David Lee	1	1	1	1	4	5	1	**32**
Marylynn	2/3	2	1	1	3	5	3	**31**
Kuehn	1	1,2	1	1	3	5	3	**31**
Helen	2/3	2	1	1	2	5	3	**28**
Jeannie	4/5	5	0	5	1	2	1	**28**
Rainy (E)	2/3	3	2	1	1	1	3	**22**
Shannon	2/3	2	0	1	3	2	3	**20**

4.2.4 Project Planning and Phasing

The priority ranking table presented above was used to organize pipeline upgrades into individual projects. The projects were organized by area with a focus on streets that ranked higher on the priority list. Incidental connecting streets were included in replacement areas higher priority to minimize construction disruption and provide for construction/hydraulic continuity. For instance, adjacent streets that may have had lower priorities, were incorporated into the larger projects. To lengthen the capitalization periods for the improvements, project sizes were planned at approximately 10,000 feet per project, which resulted in seven individual projects.

The "weighted rank" for each project delineated the recommended phasing of projects. The list of projects and their associated weighted ranks are presented in **Table 6**, attached. Each project is also listed with information including street name, approximate lineal footage, starting and ending points of the pipeline, and the existing and new pipe diameters.

Enclosures

Table 6 – Mainline Replacement Projects

Plate 1 – Existing Water System Map

Plate 2 – Simulation of ADD (Existing System)

Plate 3 – Simulation of PHD (Existing System)

Plate 4 – Simulation of Fireflow Plus MDD (Existing System)

Plate 5 – Simulation of ADD (Future System)

Plate 6 – Simulation of PHD (Future System)

Plate 7 – Simulation of Fireflow Plus MDD (Future System)

Plate 8 – Complaint Record Map

Plate 9 – Project Priority Ranking

Plate 10– Distribution System Projects

Table 6
Blue Lake Springs Mutual Water Company
Mainline Replacement Projects

#	Project	Road	Ranking Priority	Pressure Zone	Unit	Start Point	End Point	Existing Size (in)	Replacement Size (in)	Length (ft)
1	Wawona Project	Wawona Way	**68**	6/7	10,11	Castlewood	End of Line	(2.5), (2), (1.5)	6	1928
		Castlewood	**68**	6/7	11	Wawona	Seminole	(2.5), (2)	6	1972
		Meadow	**57**	6/7	10,12	Brae Burn	Kiote Hills	(2), (1.5)	8, 6	2805
		Seminole	**57**	6/7	11,12	Silverado	El Ranchero	(2), (1)	6	2673
		Cypress Point	**38**	6/7	10	Meadow	End of Line	(1.5)	8, 6	1052
			59							**10430**
2	Patricia Project	Patricia (E)	**67**	4/5, 2/3	3,5	Moran	Gertrude	(2), (1.5), (1)	8, 6	2191
		Patricia (W)	**58**	4/5	5,7	Getrude	George Ann	(2.5), (2), (1.5)	8	1972
		Gertrude	**57**	4/5	5	Rainy	Patricia	(2.5), (2), (1.5)	8	2147
		Colleen	**56**	4/5	7	Patricia	End of Line	(2), (1.5)	6	964
		Moran (S)	**46**	2/3	3	Rainy	End of Line	(1.5)	8, 6	2849
			56							**10123**
3	Blue Lake Springs Project	Blue Lake Springs (N)	**60**	1	4	Linda	Meadow Ct	(2)	12, 8	2410
		Blue Lake Springs (S)	**53**	2/3	4	Meadow Ct	Moran	(2), (1.5)	8	1753
		Moran (N)	**53**	1	1	Hwy 4	Marilynn	(3), (2.5), (1.5)	12, 6	3068
		Moran (M)	**45**	2/3	2	Marilynn	Rainy	(2.5), (1.5), 1.5	8	3725
		Linda	**44**	1	4	Moran	Blue Lake Springs	(2)	12	745
			51							**11701**
4	San Ramon Project	San Ramon	**63**	6/7	11	Wawona	Kiote Hills	(2), (1.5), (1)	6	1578
		Kiote Hills	**54**	6/7	11,12	Castlewood	Seminole	(2)	6	1841
		Baywood View	**52**	6/7	11	Almaden	End of Line	(2.5), (2), (1.5)	6	1797
		Almaden	**37**	6/7	11	Seminole	Baywood View	(2)	6	438
		North Sierra	**37**	6/7	11	Castlewood	End of Line	(2.5)	6	657
		Silverado	**34**	6/7	11	North Sierra	Baywood View	(6), (2.5)	6	1534
			49							**7845**
5	Rainy Project	Shirley	**51**	4/5	5	Patricia	End of Line	(1.5), (1)	6	833
		Rainy (W)	**50**	4/5	5	Anna Lee	Michele	(2), (1.5)	6	1740
		Jerrilynn	**46**	4/5	5	Jeannie	End of Line	(1.5), (1)	6	1227
		Anna Lee (S)	**42**	2/3	3	Rainy	Dianna	2, 1.5	6	1972
		Michelle	**39**	4/5	5	Rainy	Jeannie	(1.5)	6	657
		Dianna	**39**	2/3	3	Rainy	End of Line	3	6	1052
		Jeannie	**28**	4/5	5	Jerrilynn	Shirley	(2.5), (1)	6	657
		Rainy (E)	**22**	2/3	3	Moran	Anna Lee	4	6	1400
			40							**9538**
6	Dean Project	Dean	**49**	1	1,2	Moran	Nola	4, 2.5	8, 6	3068
		Russell	**32**	1	1	Moran	End of Line	2, 1.5	12, 8, 6	3068
		David Lee	**32**	1	1	Russel (N)	Russel (S)	2	6	1315
		Kuehn	**31**	1	1,2	Moran	End of Line	2.5	6	701
			38							**8152**
7	Julia Project	Anna Lee (N)	**52**	4/5	3	Gloria	Rainy	1.5	6	1972
		Julia	**47**	2/3	2	Nola	Gloria	2	6	1534
		Dawyn	**34**	2/3	2	Moran	Marilynn	1.5	6	964
		Marilynn	**31**	2/3	2	Moran	Nola	3, 2	6	2367
		Helen	**28**	2/3	2	Moran	Marilynn	2.5	6	920
		Shannon	**20**	2/3	2	Nola	Julia	1.5	6	1753
			36							**9510**

Legend

(red)	High Priority
(orange)	Medium Priority
(green)	Low Priority
(#)	Existing pipe in back of lots