CITY OF
PALO ALTO

Santa Clara Valley
Water District

PRELIMINARY DESIGN FOR PHASE 3 RECYCLED WATER DISTRIBUTION SYSTEM

VOLUME 1

RMC
water and environment

WOODARD & CURRAN

FEBRUARY 2018

National Experience. Local Focus.

CITY OF PALO ALTO

Santa Clara Valley Water District

Palo Alto – Northwest County Recycled Water Strategic Plan

Preliminary Design for Phase 3 Recycled Water Distribution System Final Report

Prepared by:

RMC water and environment

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List of Abbreviations

AACE	Association for the Advancement of Cost Engineering
ABJ	Auger bore and jack
AFY	Acre feet per year
BPS	Booster pump station
CCI	Construction cost index
EIR	Environmental Impact Report
ENR	Engineering News Record
EPS	extended period simulation
ESDC	Engineering services during construction
FPVC	Fusible polyvinyl chloride
ft	feet
GB	Guided boring
GBAXIS	Guided boring with Vermeer AXIS machine
gpd	gallons per day
gpm	gallons per minute
HDD	Horizontal direction drilling
HDPE	High density polyethylene
hp	horsepower
ID	Inner diameter
in	inch
IPR	Indirect potable reuse
kWh	Kilowatt-hour
LF	Linear-foot
MG	million gallons
MGD	million gallons per day
MT	Microtunneling
$NPSH_a$	Net positive suction head available
$NPSH_r$	Net positive suction head required
O&M	Operations and maintenance
OD	Outer diameter
OH&P	Overhead and profit
PDR	Preliminary Design Report
PR	Pipe ramming

psi	pounds per square inch
PTGABJ	Pilot tube guided auger bore and jack
PTGPR	Pilot tube guided pipe ramming
RFI	Request for information
RO	Reverse osmosis
rpm	rotations per minute
RWPS	Recycled Water Pump Station
RWQCP	Regional Water Quality Control Plant
SCVWD	Santa Clara Valley Water District
STA	Station
TDH	Total dynamic head
VFD	Variable frequency drive
WSE	Water surface elevation

Chapter 1 Project Description

The City of Palo Alto (City), in collaboration with the Santa Clara Valley Water District (SCVWD), is considering construction of the of the Phase 3 expansion of the City's non-potable recycled water distribution system (Phase 3). This preliminary design report is intended to advance the prior facilities development work from the December 2008 Recycled Water Facility Plan [1] to a 30% preliminary design level of development, with updated construction cost estimates. If the City chooses to construct the Phase 3 expansion, this preliminary design report will be used to pursue funding and financing and will serve as the basis for final design of the Phase 3 facilities.

1.1 Existing Phase 2 System

In 2008, the City completed the Phase 2 recycled water distribution system that included a recycled water pump station (RWPS) at the existing Regional Water Quality Control Plant (RWQCP) and conveyance pipelines to Shoreline Golf Course and the surrounding business park as illustrated in Figure 1-1.

A recycled water pump station (RWPS) at the RWQCP boosts recycled water into the Phase 2 system for delivery to Mountain View customers. Currently, the RWPS delivers a peak flow rate of 2,085 gallons per minute (gpm) to Mountain View and approximately 695 gpm to two Palo Alto customers [3].

1.2 2008 Phase 3 Facility Plan

The 2008 Facility Plan included a market study of potential recycled water use in the project area, a list of recommended customers for recycled water service, their estimated recycled water demands and a proposed distribution system to serve those demands. The project described in the Facility Plan is the basis for this preliminary design effort. Unless specifically noted herein, the proposed Phase 3 recycled water facilities and design criteria are consistent with the 2008 Facility Plan.

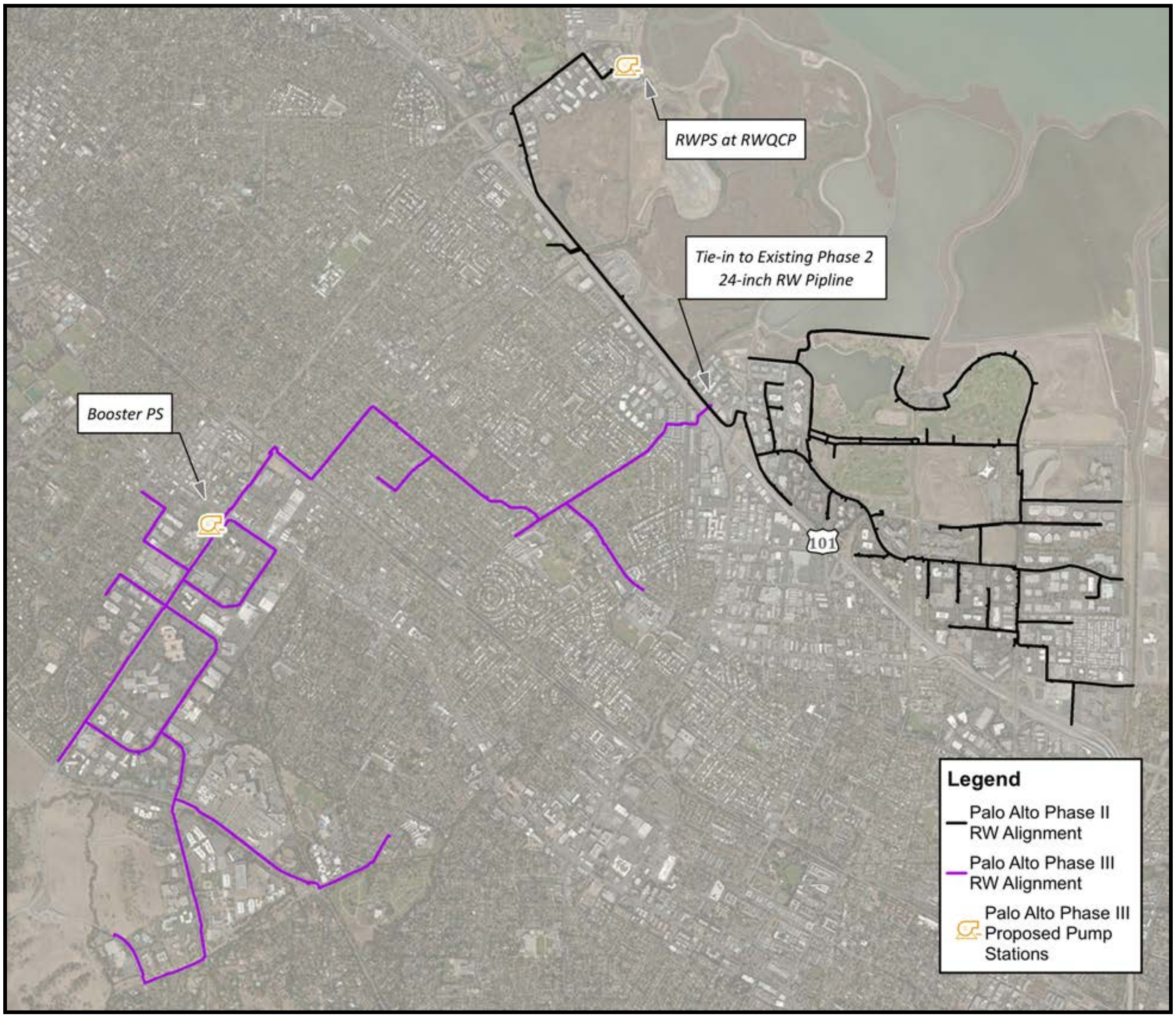
1.3 Phase 3 Preliminary Design Approach

The preliminary design activity is focused on the following areas:

- Potential customer verification and recycled water demand updates
- System hydraulics assessment and surge evaluation
- Pipeline and pump station sizing and design criteria development
- Further development of pipeline special crossings at creeks, roadways and railroads
- Pipeline alignment refinement with consideration to existing utilities and tree impacts
- Phase 3 construction cost estimate development
- Development of a Class 3 (AACE International) construction cost estimate that the City will use to determine how to proceed with project implementation.

The basis for the Phase 3 pipeline alignments was developed in the 2008 Facility Plan and the City of Palo Alto Recycled Water Project Environmental Impact Report (EIR) certified in 2015 [2]. This preliminary design report includes pipeline alignment refinements.

Figure 1-1: Palo Alto and Mountain View Recycled Water System



Chapter 2 Updated Recycled Water Demands

As part of the larger Northwest County Recycled Water Strategic Plan, an update to the Phase 3 market assessment was performed to update recycled water customers and demands in the 2008 Facility Plan and to identify additional customers that could be served from the Phase 3 system. The market survey and demand update are summarized in the October 2017 draft final Business Plan for Phase 3 Expansion Project. The updated demands are summarized below.

2.1 Updated Potential Phase 3 Demands

2.1.1 Annual Average and Maximum Day Demands

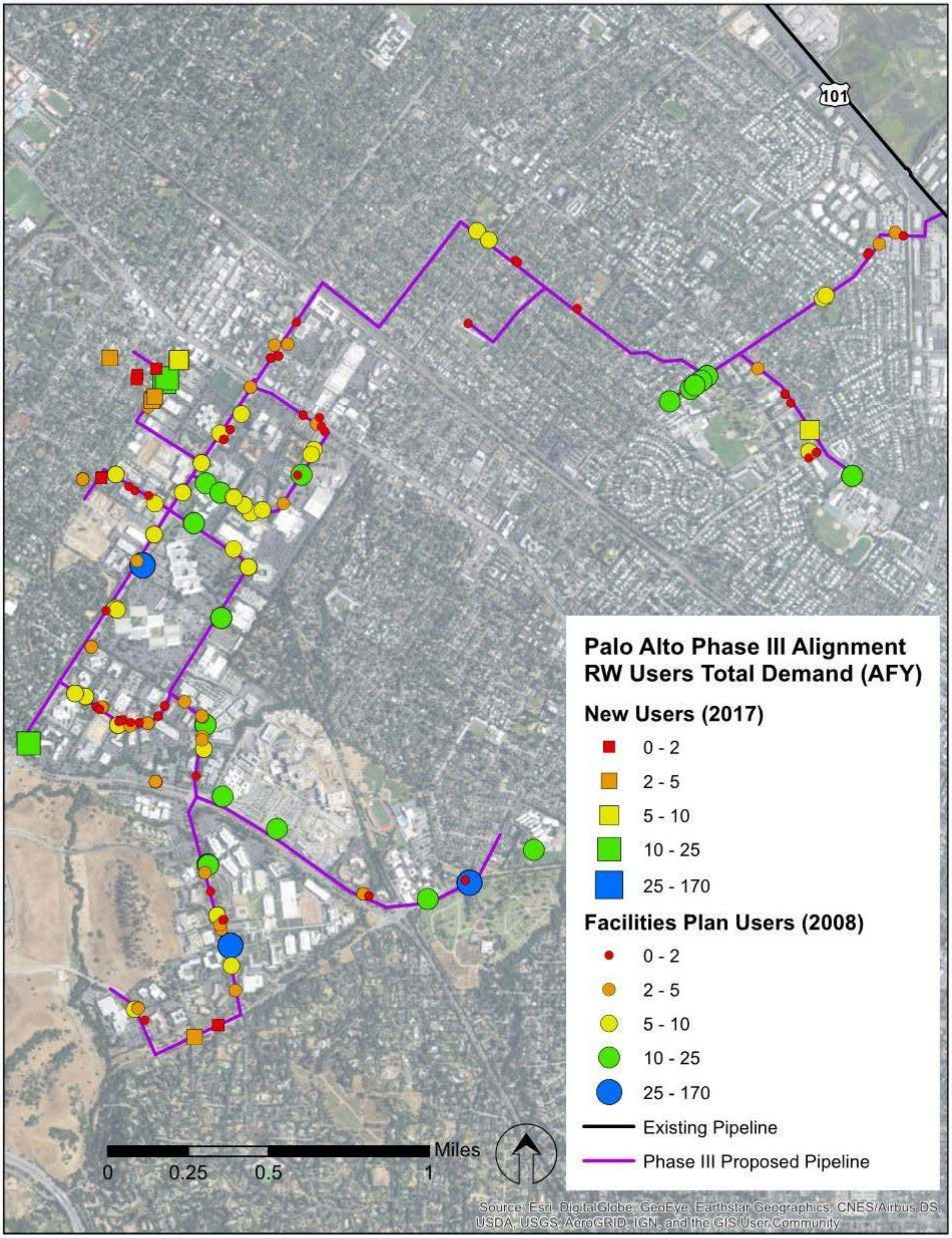
The updated potential annual average recycled water demand for Palo Alto's Phase 3 recycled water system service area is 810 acre-feet per year (AFY). The updated target recycled water users, new users that have been identified since the 2008 Facility Plan, and the updated Phase 3 alignment are shown in Figure 2-1.

Updated potential recycled water demand estimates for each customer, including a breakdown of total demand for each customer, is included in Appendix B. August is the maximum demand month based on the City's 2016 water use data. The maximum day demand, defined as the average daily demand in August 2016, for the Phase 3 service area was 1.5 million gallons per day (MGD).

2.2 Other Demands

The City's Phase 3 recycled water system will be connected to the Phase 2 system near the intersection of U.S. Route 101 and Corporation Way. New potential Palo Alto customers along the Phase 2 system include several auto dealerships and the Baylands Athletic Center on Geng Road near the RWQCP. These demands were added to the hydraulic model for evaluation of the Phase 3 system.

Figure 2-1: Updated Phase 3 Alignment and Recommended Project Target Recycled Water Uses



Chapter 3 Phase 3 System Hydraulic Evaluation

A hydraulic model of the proposed Phase 3 system was previously created in the H2ONet software platform as part of the 2008 Facility Plan. The model has been converted to the InfoWater software platform (Innovyze InfoWater Suite 12.3, Update #3) and updated to include additional branch and backbone pipeline extensions to serve additional recommended customers presented in Chapter 2 and to include three storage scenarios, described in Section 3.1. The model utilized an extended period simulation (EPS) to simulate system hydraulics over multiple 24-hour maximum day demand periods.

3.1 Hydraulic Model Configurations

The Phase 3 system will be divided into two pressure zones, with the Booster Pump Station (BPS) at El Camino Real and Page Mill Road separating Zone 1 (lower) from Zone 2 (upper). The model was used to evaluate three Phase 3 system configurations representing different system storage assumptions:

- The *Baseline* configuration does not include operational storage and would therefore be operated as a closed system. The Baseline configuration represents the 2008 Facility Plan recommended system.
- The *Max Day Tank* configuration includes a storage tank in Zone 2 sized to provide all recycled water required in Zone 2 during a maximum demand day over an 8-hour irrigation period to reduce the required BPS capacity and to simplify system operations. This configuration is intended for assessment of whether a tank should be added to the Phase 3 improvements.
- The *Half Max Day Tank* configuration also includes a tank in Zone 2, but the tank is sized to provide half of the demand during a maximum demand day over an 8-hour irrigation period to reduce the required capacity of the BPS and to simplify system operations. This configuration is intended for assessment of the impact of tank size on system sizing requirements.

The model results for the three configurations were compared and used to determine the cost effectiveness of adding storage to Zone 2.

3.2 Modeling Parameters

Modeling of the Phase 3 system was performed using the parameters and criteria described below.

3.2.1 Maximum Day and Peak Hour Demands

Phase 3 demands are summarized in Chapter 2, detailed in Appendix B, and more fully described in the draft final Business Plan for Phase 3 Expansion Project dated October 2017. Customer demands were grouped and allocated to modeled demand nodes based on proximity so that individual pipes in the model carry the required flow to serve customers.

The model also accounts for both existing and new demands on the existing Phase 2 distribution system. This includes peak hour demand serving existing (Animal Services Facility and Greer Park) and new (auto dealerships and the Baylands Athletic Center) Palo Alto customers, and City of Mountain View customers in the Shoreline business park area. Based on the original agreement between the City and the City of Mountain View from 2005, the total peak demand for the Mountain View system was modeled as 2,083 gpm. The maximum historic flow from the RWQCP was approximately 2,800 gpm, and 2,083 gpm of this peak demand was delivered to Mountain View. The hydraulic boundary condition for the Phase 3 system limits the peak hour flow rate delivered to Mountain View at 2,083 gpm and 65 psi. An amendment to the agreement between the cities was approved in August 2017 [3]. The maximum capacity and minimum delivery pressure to Mountain View are 2,085 gpm and 65 psi, respectively, under the current agreement. The difference between the modeled peak demand for Mountain View and the peak demand stated in the amended agreement is negligible and does not impact the overall modeling analysis and results.

This recycled water flow and pressure to Mountain View represents the peak flow from the RWQCP. Mountain View could provide larger peak flows by constructing operational storage to store recycled water during off peak periods for delivery to its customers during peak periods.

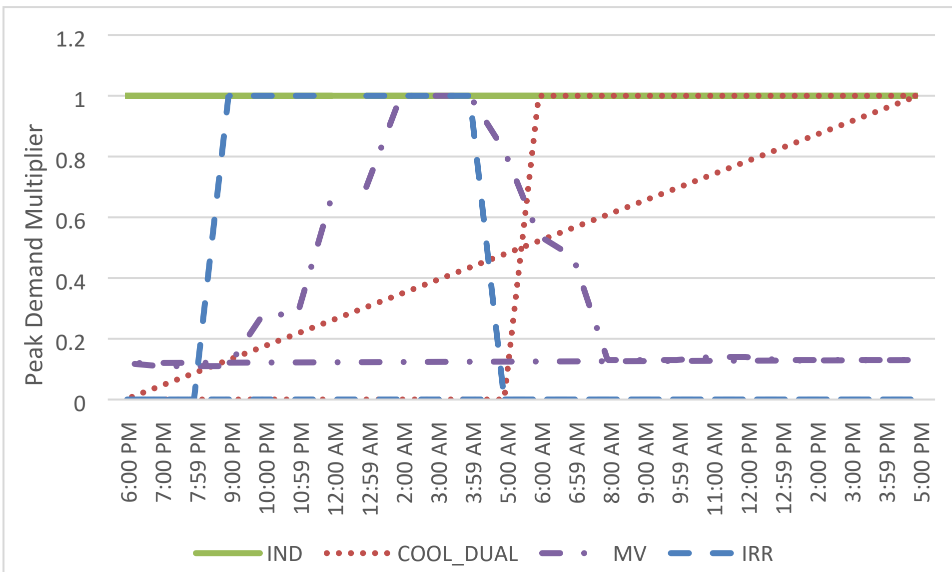
3.2.2 Maximum Day Demand Patterns

Each demand node in the model is applied a diurnal pattern based on usage type. The hydraulic model demands were classified based on the following usage types:

- Industrial (IND)
- Cooling tower and dual plumbing (COOL_DUAL)
- Mountain View (MV)
- Palo Alto irrigation (IRR)

The patterns for each of these demand types over a maximum demand day are depicted in Figure 3-1. Peak hour demand has a demand factor of one (1). The development of these demand patterns is described in the Model Development TM, attached as Appendix C.

Figure 3-1: Modeled Customer Demand Patterns



3.2.3 Hydraulic Criteria

The hydraulic criteria used in the modeling of Phase 3 distribution system are summarized in Table 3-1. In general, the minimum pressure criterion establishes the hydraulic grade line (HGL) required, which in turn helps define pumping requirements. The maximum head loss criterion generally governs pipe sizing.

Table 3-1 Hydraulic Criteria

Description	Value
Minimum Pressure at Mountain View Connection (psi)[1]	65
Maximum Flow to Mountain View (gpm)[1]	2,083
Minimum Pressure at Phase 3 Customer Connections (psi)	40
Maximum Customer Pressure[2] (psi)	120
Minimum Pipe Size (in)	6
Maximum Head Loss (feet per 1,000 feet of pipe)	5

Notes:

1. Minimum Mountain View service flow and pressure from Mountain View and Palo Alto agreement dated January 2005. The agreement was amended in August 2017, with a maximum flow to Mountain View of 2,085 [3]. The difference in maximum flow delivered to Mountain View does not impact the modeling analysis and results.
2. Several Zone 2 demand nodes exceed the maximum pressure criterion at times, which is acceptable to maintain minimum service pressures elsewhere. Customers with high pressures will require a pressure regulating valve on the service line.

3.3 Modeling Results for Facility Sizing

The results for the three modeled configurations are summarized in this section. These results are the basis for sizing of the Phase 3 facilities and preparation of preliminary design for the pump station and special pipeline crossings. The preliminary design does not include a Zone 2 tank facility, but the advantages and disadvantages of including a tank in the system are discussed at the end of this chapter for consideration by the City. Detailed results for the scenarios with tanks can be found in the Model Development TM attached as Appendix C.

3.3.1 Pipelines

The Phase 3 pipeline segments and recommended diameters for the Baseline (no tank), Max Day Tank and Half Max Day Tank configurations are shown in Figure 3-2, Figure 3-3 and Figure 3-4, respectively, and summarized in Table 3-2.

Figure 3-2: Phase 3 Pipe Diameters for Baseline (No Tank) Configuration

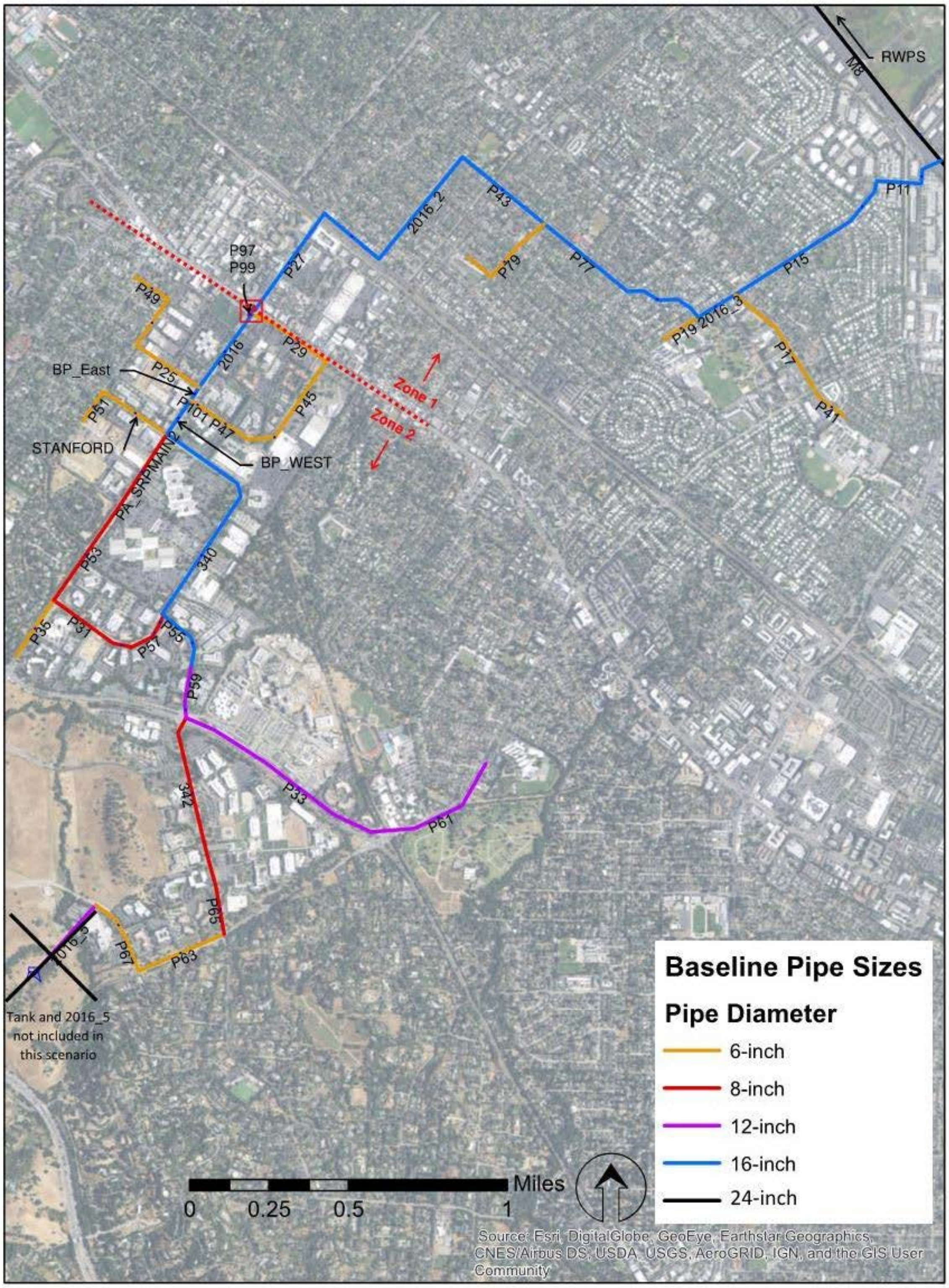


Figure 3-3: Max Day Tank

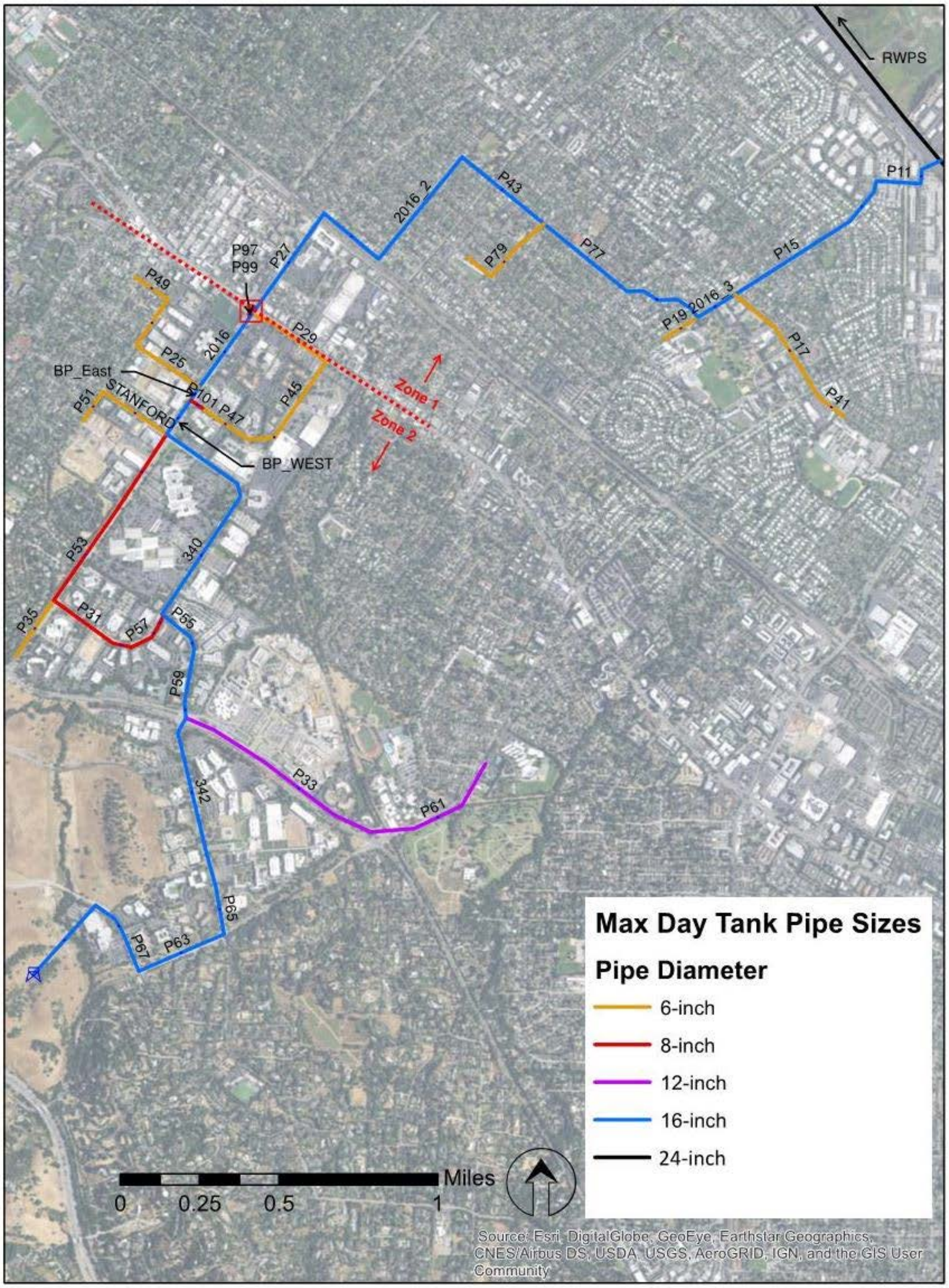


Figure 3-4: Half Max Day Tank

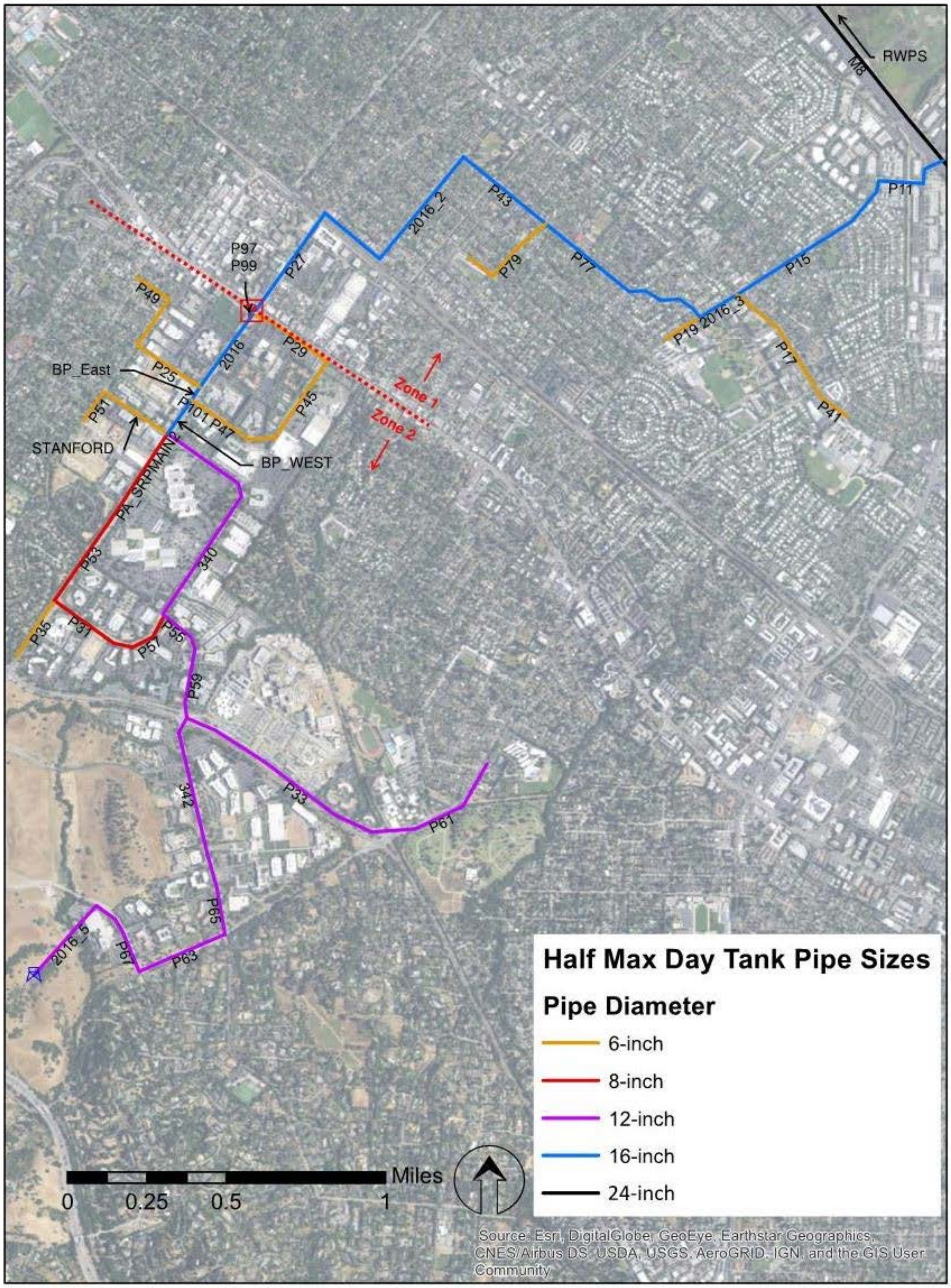


Table 3-2: Comparison of Modeled Pipe Sizing

Pipe Segment ID	Segment Length (feet)	Modeled Pipe Size (in)		
		Baseline (No Tank)	Max Day Tank	Half Max Day Tank
2016	1,493	16	16	16
2016_2	3,369	16	16	16
2016_3	722	16	16	16
2016_5	1,554	N/A	16	12
340	4,039	16	16	12
342	2,360	8	16	12
BP_EAST	253	16	16	16
BP_WEST	689	16	16	16
P101	235	6	8	6
P11	1,316	16	16	16
P15	3,084	16	16	16
P17	1,771	6	6	6
P19	677	6	6	6
P25	2,181	6	6	6
P27	1,979	16	16	16
P29	1,473	6	6	6
P31	1,525	8	8	8
P33	3,617	12	12	12
P35	1,125	6	6	6
P41	986	6	6	6
P43	1,760	16	16	16
P45	1,529	6	6	6
P47	1,356	6	6	6
P49	666	6	6	6
P51	586	6	6	6
P53	1,838	8	8	8
P55	1,101	16	16	12
P57	575	8	8	8
P59	842	12	16	12
P61	2,415	12	12	12
P63	1,546	6	16	12
P65	1,355	8	16	12
P67	1,349	6	16	12
P77	3,112	16	16	16
P79	1,750	6	6	6
P93	223	8	8	8
P97	120	16	16	16
P99	129	16	16	16
PA_SRPMAIN2	1,502	8	8	8
STANFORD	1,265	6	6	6

Note: Green highlight indicates smaller modeled diameter compared to other configurations.

3.3.2 Pump Stations

There are two pump stations modeled in the system, one at the RWQCP (RWPS) and a booster pump station (BPS) that provides required pressure to Zone 2.

The peak hour demand pumping requirements at the RWPS were modeled using a constant head tank at the pump station representing the discharge pressure from the RWPS. The RWPS discharge pressure was adjusted within the model by shifting the constant head tank water surface elevation up and down to satisfy minimum pressure criteria for the Mountain View connection, the Zone 1 Palo Alto customers, and the BPS. The BPS was modeled using a modeled pump curve and variable operating speed to satisfy the demand and pressure criteria for Zone 2. A more detailed description of the operating and control strategies of the RWPS and BPS are provided in Section 4.1.7 and Section 4.2.4.

The design duty point identified for the two pump stations are shown in Table 3-3. System curves were developed to support pump selection for the baseline system configuration are included in Figure 3-5 and Figure 3-6. The pump operating point during peak hour demand period is highlighted in red in each curve. The development of the system curves is detailed in Appendix C.

Table 3-3: Modeled Pump Station Peak Hour Performance Requirements

Description	Baseline Configuration		Max Day Tank Configuration		Half Max Day Tank Configuration	
	RWPS	BPS	RWPS	BPS	RWPS	BPS
Required Flow (gpm)	5,836	2,402	5,836	1,430	5,836	1,278
Discharge Head[1] (feet)	200	198	200	163	200	150

1. Discharge head includes the modeled RWPS constant head tank static lift and the modeled pumping head at the BPS plus an additional 5 feet and 8 feet of pump station losses, respectively, to be verified during final design. RWPS discharge pressure is relatively constant to satisfy Mountain View requirements.

Figure 3-5: RWPS (Zone 1) System Curve for All Scenarios

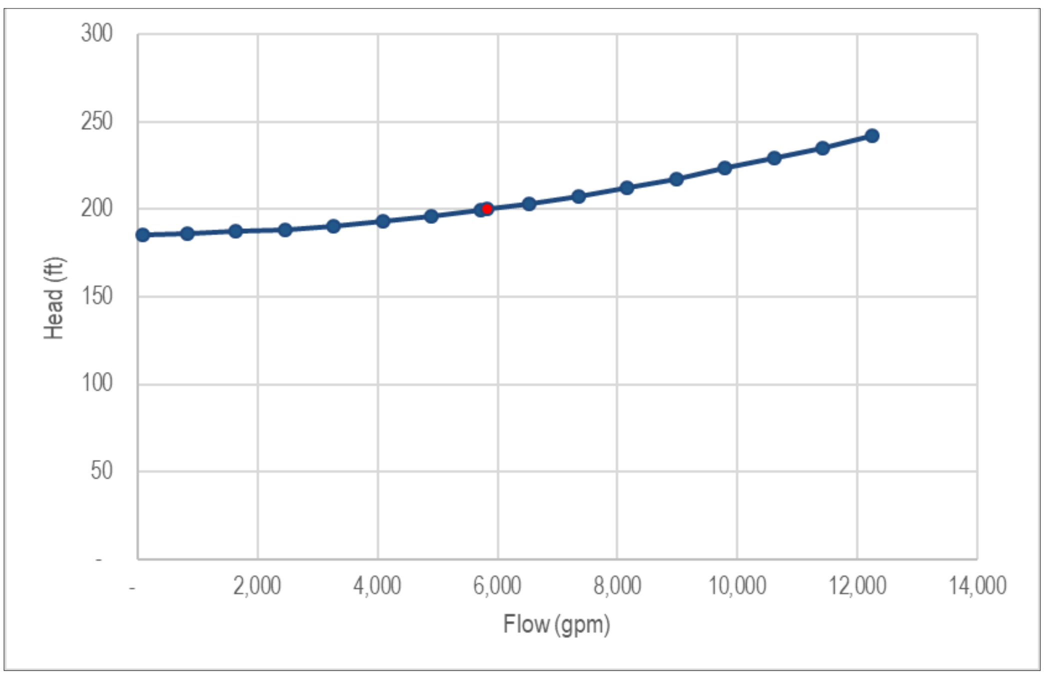
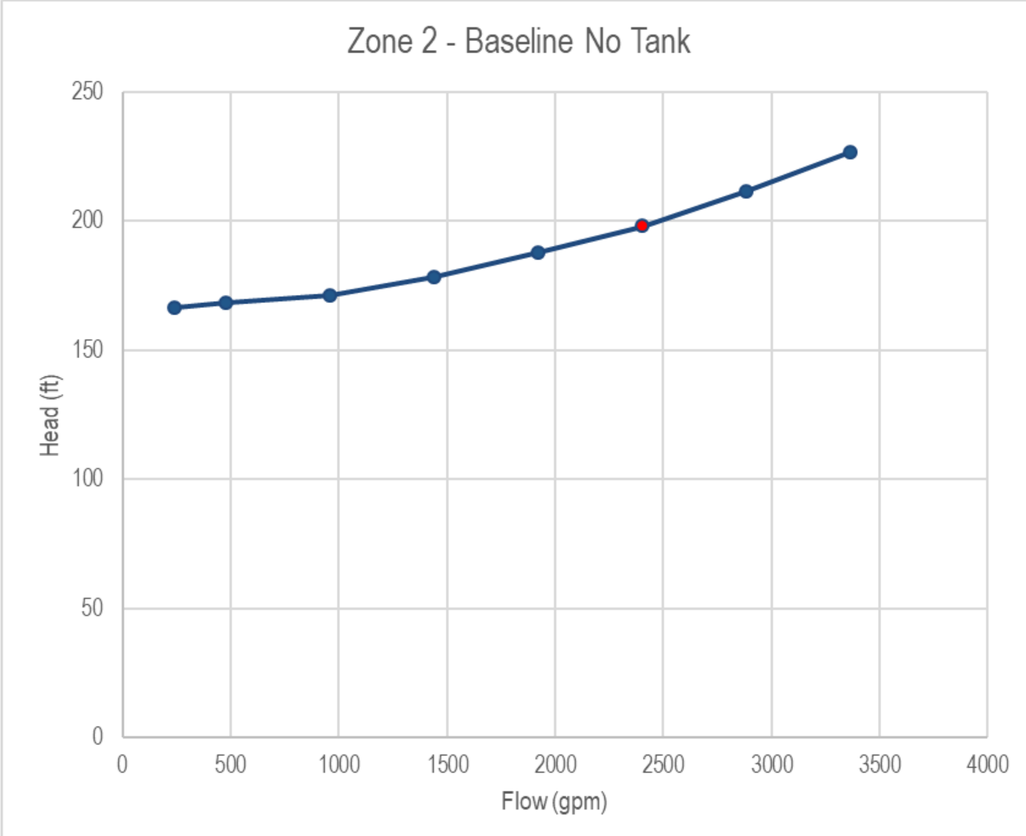


Figure 3-6: BPS (Zone 2) System Curve for Baseline Configuration



3.3.3 Zone 2 Storage Tank Sizing

The recommended storage tanks sizes for the two Max Day Tank and Half Max Day Tank configurations are Table 3-4.

Table 3-4: Recommended Tank Sizing

	Max Day Tank Configuration	Half Max Day Tank Configuration
Operational Volume (MG)[1]	1.2	0.6
Maximum Side Water Depth (ft)	24	24
Tank Diameter (ft)	97	69

Note:

1. Operational volume does not include one foot of dead storage at bottom and clearance above the high-water level to the roof of the tank. Actual tank will be taller than the side water depth shown.

3.4 Surge Evaluation

A surge evaluation was performed by GEI Consultants using the hydraulic model of the Phase 3 system described above and is included in Appendix D.

The existing RWQCP RWPS includes a 3,400-gallon air-over-water surge control tank to mitigate Phase 2 system transients. The design of that surge control system provided for a 30% air volume in the tank, allowing for sufficient recycled water volume to “fill” any down surges on pump failure and adequate air “cushion” to dampen the returning upsurge waves. The City has verified that the tank is currently operated as designed. Additionally, a 6-inch combination air release and air and vacuum relief valve was included in the original 2006 design at Station 34+35 to prevent formation of a vapor cavity in the pipeline as the transient down surge travels along the pipeline after a sudden pump shut down (e.g. a power outage). The City has verified that this valve is installed and working as designed.

The Phase 3 surge analysis evaluated pumping operations recommended above at the RWPS and the BPS. The Phase 3 distribution system was studied under the condition of a simultaneous power outage at the two pump stations for the hydraulic configurations described above with a storage tank on the Zone 2 system (Max Day Tank and Half Max Day Tank configurations) and without a storage tank on the Zone 2 system (Baseline configuration).

Results of the analysis indicate the potential for damaging vapor cavity formation and collapse in the pipeline without appropriate surge control components. The recommended components for a system without a Zone 2 tank (Baseline configuration) are:

- Provide a minimum 2-inch vacuum relief valve on the suction side of the BPS, at the top of Hillview Drive (system high point), and the end of the Zone 2 system (another high point) on Deer Creek Road.
- Provide minimum 1-inch vacuum relief valves at each customer connection upstream of the meter and meter stop valves or at comparable locations on the distribution mains to allow air entry as the Phase 3 system drains or provide sufficient vacuum relief at appropriate points along the pipeline.
- Verify proper operation of the existing RWPS surge control system and vacuum relief valve on the Phase 2 system at Station 34+35. This has been verified by the City.

Recommended measures for a Zone 2 that includes a reservoir (Max Day Tank and Half Max Day Tank configurations) are the same except that vacuum relief is not required at each customer connection. The free water surface at the storage tank will prevent the system from draining when water is in the tank.

3.5 Impact of Zone 2 Tank

This section presents the advantages and disadvantages of including a Zone 2 tank in the Phase 3 project.

3.5.1 Tank Siting, Capital and O&M Cost Considerations

A tank in the Phase 3 system would require finding and acquiring an acceptable tank site in the hills above the west side of the Stanford Research Park. Pipelines would need to be extended to the tank and the additional facilities would need to be addressed from a permitting and environmental review perspective. If a steel tank is used, the tank would need to be re-coated every 5 to 10 years. A pre-stressed concrete tank could reduce maintenance costs, but would increase initial capital costs compared to a steel tank. A storage tank would add to the capital cost of the project and would increase operations and maintenance costs.

3.5.2 Pipe Size Considerations

As shown in Table 3-2, the two system configurations with tanks result in larger pipe sizes due to the need to convey peak demand flows to customers from the tank at the west end of the Zone 2 system. Pipe sizes are smaller for the Baseline configuration because only the end demands are conveyed to the end of the system from the BPS. Larger pipe sizes result in added capital cost and increased water age during the low demand winter months, which incrementally increases annual O&M costs.

3.5.3 Pump Station Sizing Considerations

The tank would serve half or all the peak demand depending on the configuration, which would reduce the BPS capacity requirement by 53% for the Half Max Day Tank configuration and 60% for the Max Day Tank configuration when compared to the Baseline configuration. Pumping head would also be reduced due to less friction loss due to the reduced flow and larger piping. As a result, the required horsepower for the BPS would be reduced under both configurations with tanks.

3.5.4 Operations Considerations

The primary advantage of storage within Zone 2 would be the free water surface that allows for simpler system operation and control. Varying system demands would be easily accommodated by the storage tank versus a closed system, such as the Baseline configuration, which must have a reliable pressure control loop that attempts to match instantaneous flow and pressure requirements using pump speed control. Operators and engineers tend to prefer a system with a free water surface because these types of systems are simpler and less prone to mechanical, electrical and control failures.

Having a system storage tank offers more flexibility in operating the recycled water system and increases the overall reliability of the system in serving its customers. The tank could also be an important component in managing system water quality, particularly during low demand months when turnover in the piping system is much reduced. The tank could be outfitted with a chlorination system to boost chlorine in the system and flush the system pipes with “fresh” recycled water.

3.5.5 Future Indirect Potable Reuse (IPR) Operations

Due to its elevated location, a storage tank could be used to convey recycled water to recharge ponds to the north or serve injection wells in the central part of the City without additional pumping during off peak irrigation periods.

3.5.6 Summary of Advantages and Disadvantages of Operational Storage

The advantages and disadvantages are summarized in Table 3-5.

Table 3-5: Advantages and Disadvantages of Zone 2 Operational Storage

Advantages of Operational Storage	Disadvantages of Operational Storage
• Operational flexibility	• Permitting and environmental clearances
• System reliability	• Siting challenges
• Stable pump station operation	• Property acquisition
• Reduced pump station capital costs	• Additional pipe length
• Reduced pump station power costs	• Increased pipe sizes
• Leveraging for future IPR	• Additional tank O&M cost
	• Additional tank capital costs

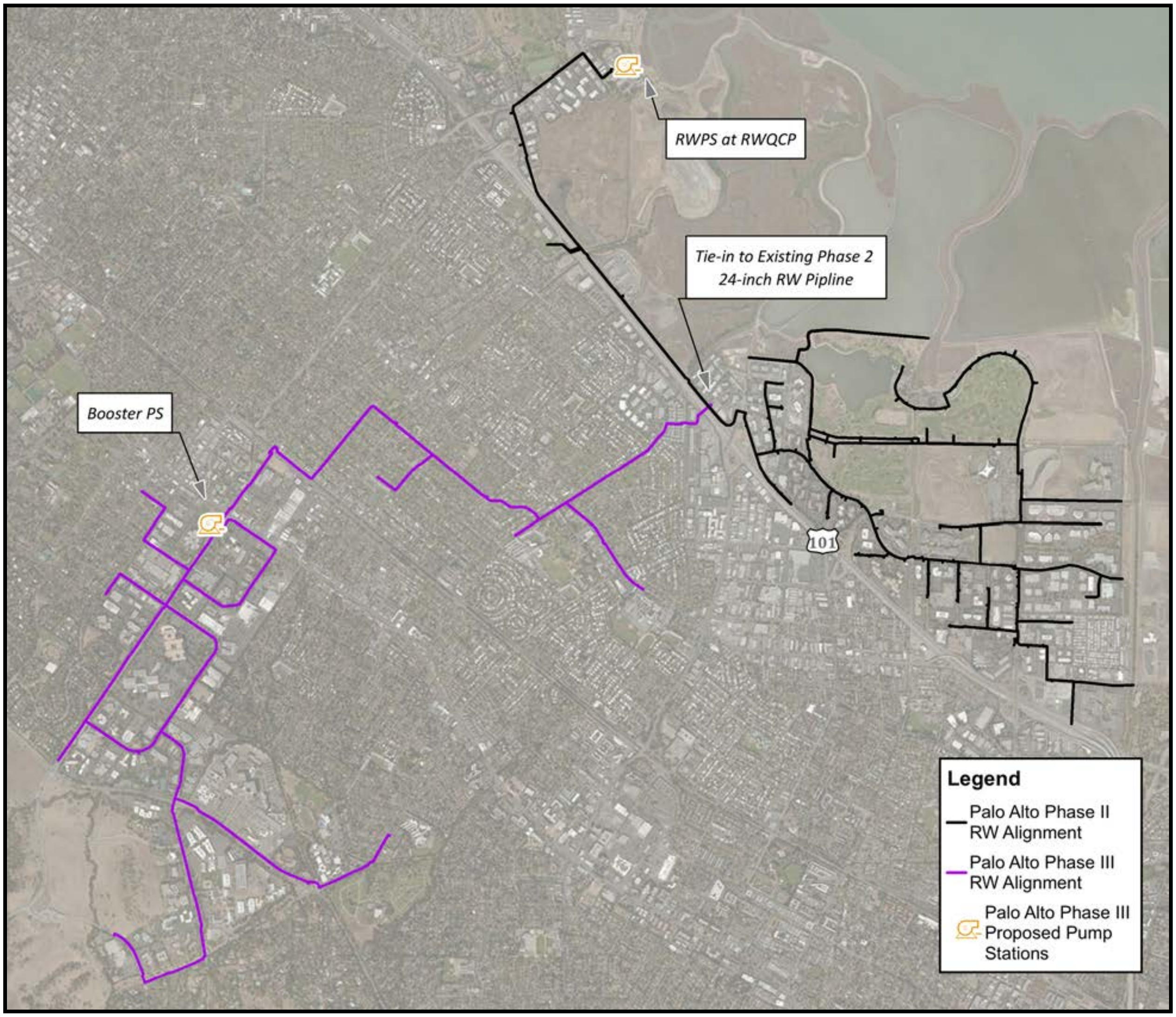
Chapter 4 Pump Station Preliminary Design Development

The project components described in this chapter were developed using the results of the customer demand updates presented in Chapter 2, the hydraulic evaluation presented in Chapter 3 and the planning and design criteria presented in this chapter. As defined in the scope of work, the sizing of the facilities presented in this chapter were based on the baseline scenario of the hydraulic model (no Zone 2 tank).

4.1 Recycled Water Pump Station at RWQCP

The pump station that supplies the City's existing recycled water system and the proposed Phase 3 expansion is located at the RWQCP, as shown on Figure 4-1. This Section describes the existing conditions and configuration of the RWPS, evaluates existing pump capabilities and the proposed modifications to the RWPS to meet Phase 3 maximum (peak hour) design flows.

Figure 4-1: Existing PA System and Proposed Phase 3 Overview Map



4.1.1 New Recycled Water Pump Station Concept

Initially it was assumed that the Phase 3 expansion would require construction of a new recycled water pump station because of flow and power requirements that exceed the capabilities of the existing RWPS. Initial work on preliminary design included meeting with City staff at the RWQCP to discuss siting and pump station capacity requirements.

The primary siting options for a new pump station at RWQCP consisted of modifying the existing Administration Building to accommodate construction of a new recycled water pump station or constructing a new pump station elsewhere within the RWQCP site. A new pump station on a cleared area of the RWQCP site would have resulted in a simple and efficient layout with a full-service life (all new construction) and a function tailored to serving the Phase 2 and Phase 3 recycled water distribution system customers. This approach would have the added benefit of simplified construction and simplified options to increase pumping capacity in the future. The City elected to not consider a new pump station as described in the next section.

4.1.2 Existing RWPS

Due to limited available space at the RWQCP, combined with a desire to maximize the reuse of existing equipment and infrastructure, City direction was to limit improvements to within the footprint of the existing Administration Building and to reuse the existing RWPS equipment to the extent possible. Per the City, occupancy of the ground floor of the Administration Building will end in 2021, freeing the ground floor space and other basement space for RWPS expansion and modifications. The portion of the basement that is currently composed of general storage, outreach material storage, lab space, cleaning room and gym space will become available for new piping and equipment once the occupancy is ended.

A modified RWPS would be needed as soon as enough Phase 3 customers are connected to the completed Phase 3 distribution system or as soon as the City commissions its advanced water purification treatment facilities, which would prompt additional Mountain View demand on the Phase 2 system and Palo Alto customers on the Phase 3 system. The advanced water purification treatment facilities are expected to be online sometime between 2019 and 2022 [4].

The existing RWPS is in the southeasterly quadrant of the basement level of the existing Administration Building at the RWQCP. It consists of two suction lines to a single suction manifold, three horizontal split case pumps, a smaller jockey pump, discharge pipe manifold flow meter (in vault outside of building) and a surge control tank. The configuration of components is shown in the drawings in Appendix A.

The RWPS is supplied from the adjacent Tanks 1 and 2 in the northwesterly and southwesterly quadrants of the Administration Building, which in turn are fed from the existing chlorine contact basin. Tank 3 is also hydraulically connected to the RWPS and is assumed to “float” with the level in Tanks 1 and 2.

The existing recycled water pumps have design capacities and performance as indicated in Table 4-1. The pumps discharge to a 24-inch diameter discharge manifold pipe that routes to an electromagnetic flow meter and surge control tank outside the Administration Building, then to Embarcadero Way where it becomes a 30-inch diameter transmission pipeline to the south serving the Phase 2 pipeline system.

Table 4-1: Summary of Existing RWPS Design Capacity[3]

Description	Pump No. 1	Pump No. 2 (Jockey)	Pump No. 3	Pump No. 4	Firm Capacity[1]	Hydraulic Capacity[2]
Design Flow (gpm)	1,328	350	1,328	1,328	3,006	4,334
Pumping Head (feet)	231	235	231	231	231	231
Rated Motor Horsepower (hp)	125	40	125	125	290 (connected)	415 (installed)
Maximum Motor Speed (rpm)	3,600	3,600	3,600	3,600	N/A	N/A

Notes:

1. Firm capacity is defined as the pumping capability with one of the largest pumps out of service.
2. Hydraulic capacity is with all pumps running, assuming electrical system can feed all pumps during concurrent operation. Assumes that required discharge head at 4,334 gpm would be the same as the firm capacity head (3,006 gpm), which is not representative of actual conditions. Actual hydraulic capacity will be lower.
3. Pump design data taken from the Aurora Pump Data Sheet, dated October 16, 2007, provided by the City and included in Appendix K.

Actual RWPS flow and pressure data indicate a pump operating point with considerably lower discharge head and flow for the large pumps. The pumps appear to be operating at reduced speed and potentially to the right of the design point indicated in Table 4-1. This is illustrated in Table 5-2. It is likely the City operates the large pumps at lower speed to move the operating point left along the pump curve to a more preferred operating point with better efficiency. The low flow data also indicates that the jockey pump is used often, which is not normally recommended because there is no standby jockey pump. Another contributing factor is that the Phase 2 demand has not reached the levels projected during design of the facility.

4.1.3 Pump Station Hydraulic and Design Criteria and Considerations

An upgraded RWPS must meet the following conditions:

- The existing RWPS capacity must be modified to provide a firm capacity of 5,836-gpm at a total discharge head of approximately 200 feet.
- Existing large pumps should be retained in service, if practical.
- Expanded peak demand period service to Mountain View may be possible initially, but to meet Phase 3 demands it is expected that a cap on Mountain View flows will be required equal to its contractual limit (2,083-gpm at 65-psi pressure, measured at the Phase 3 connection to the existing 24-inch recycled water backbone pipeline).
- There will need to be sufficient supply (treatment capacity) of recycled water to the RWPS to meet peak system demands.
- There will need to be adequate supply side conveyance hydraulics to the modified RWPS upstream of the storage tanks. Evaluation of hydraulic capacity upstream of the storage tanks is beyond the scope of this preliminary design. The City needs to verify that adequate recycled water supply is available and it can be conveyed to Tanks 1 and 2 while maintain at least the minimum water level in Tanks 1 and 2.
- Minimum allowable hydraulic grade line at pump suction should be at least two feet above pump impeller. This would be achieved assuming the City's current operational scheme to shut down the RWPS on low suction pressure when the water level in the storage tanks drops below 5 feet.

- The RWPS must deliver hour flow (up to the cap identified above) at a minimum of 65 psi to the Mountain View connection point, immediately downstream of the Phase 3 connection point. Initial hydraulic modeling shows that maintaining minimum delivery pressure at the booster pump station establishes the RWQCP RWPS discharge head requirement. Maintaining a minimum of 40 psi at the BPS results in a delivery pressure of approximately 73 psi at the Mountain View connection point under peak flow conditions, which meets the City's contractual obligation.
- The existing surge control and metering facilities must be operating and fully functional.
- The RWPS must be able to meet low demand conditions, potentially as low as 20-gpm. To meet this low flow demand, the existing jockey pump will be retained within the RWPS. The jockey pump is metered separately on its pump discharge to cover extreme low flows that cannot be accurately measured by the 24-inch meter.

The composition of the peak hour demands used to establish the pumping requirements for the RWPS is shown in Table 4-2. Details on the Phase 3 demands are described in Chapter 2 and Appendix B.

Table 4-2: Peak Hour Demands from RWPS

Recycled Water Customers	Peak Hour Demand (gpm)
Proposed Palo Alto Phase 3 Peak Demand	2,781
Contracted Mountain View Phase 2 Peak Demand	2,083
Existing and Proposed Palo Alto Phase 2 Demand	972
Total	**5,836**

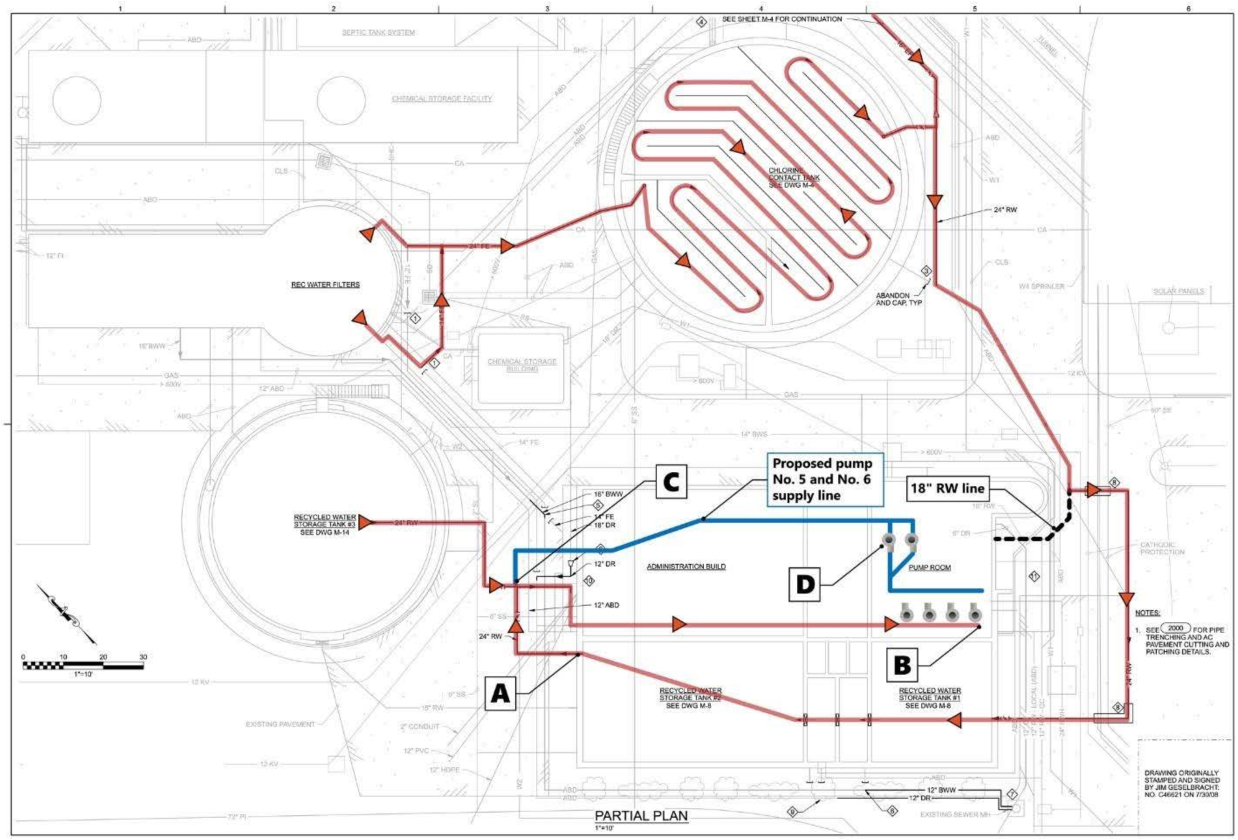
The preliminary design recommendations and configuration for the RWPS modifications are based upon the above design criteria. Should the above conditions change, the City will need to re-evaluate the hydraulics and preliminary design recommendations.

4.1.4 Suction Hydraulics

To reuse the existing RWPS components, it is critical to review the suction side hydraulics for the RWPS. The peak flow rates during the summer months are expected to more than double, which will result in additional suction head loss and reduced $NPSH_a$ at the pumps.

The red line shown in Figure 4-2 illustrates the circuitous flow path from the tertiary filters to the existing RWPS. Two filter effluent pipes combine into a single feed into the Chlorine Contact Tank and discharge into the tank through a vertical diffuser pipe. The Chlorine Contact Tank is a circular tank with serpentine baffles to increase contact time. Chlorinated effluent enters a vertical diffuser annular space and flows over a conical weir into the effluent pipe riser and travels south to Storage Tank 1, on the southwesterly quadrant of the Administration Building. A secondary supply line, originating from the Main Treatment Plant chlorine contact basin and operating at a lower HGL, also connects just downstream of the Chlorine Contact Tank, serves as a backup supply connection, and is valved off from the chlorinated recycled water line. The buried 18-inch / 24-inch chlorinated recycled water line routes around the Administration Building to Tank 1 and includes an 18-inch connection to the RWPS suction manifold through the southeasterly wall of the basement. The main branch enters Storage Tank 1 then recycled water flows to Storage Tank 2 through several submerged wall openings, then exits through a 24-inch pipe, makes various turns, ultimately reaching the RWPS pumps as a second supply connection via the 24-inch pipe, which is located underneath the basement floor and emerges in the Pump Room. Just downstream of Storage Tank 2, there is also a connection to Storage Tank 3, which adds about 100,000 gallons of storage. When the connecting supply/discharge line is open, Storage Tank 3 floats on the level of Storage Tanks 1 & 2. The proposed fifth and sixth pumps and associated supply lines are shown in blue in Figure 4-2.

Figure 4-2: Recycled Water Flow Path



Note: Background drawing is part of the, 'Project Plans for the Construction of: Palo Alto Regional Water Quality Control Plant Recycled Water Contact Chamber Retrofit', Sheet C-3, dated July 2008 and prepared by Waterworks Engineers.

$NPSH_r$ of the primary pumps at their design condition is 18.3 feet, as shown in the Aurora product data sheet provided in Appendix K. Analysis of the suction hydraulics into the RWPS pumps at the new capacity of 5,836-gpm reveals that at the minimum tank level (elevation 5.0 feet, as defined by the City), $NPSH_a$ at the pumps (37 feet), is sufficient when suction supply is limited to the Storage Tank 2 connection (18-inch connection at the southeast side is closed). Maximum suction manifold velocity would be 5.7 feet per second (fps), assuming only the 3 pumps are operating. The suction manifold also supplies the golf course, the backwash waste, so the actual manifold velocities are higher, which would be at the high end of the recommended velocity range. This suggests that additional supply connections should be provided to improve overall suction hydraulics and provide some operational flexibility in configuring the suction piping to accommodate ongoing operations and maintenance of the RWPS piping system.

Assuming that Tanks 1 and 2 control the RWPS suction hydraulic grade line, with a flow path from the tanks (Point A) to the junction (Point C) to the pump suction (Point B), the minimum tank operating level of 5 feet is sufficient to provide at least 2 feet of head at the pump suction under peak demand suction hydraulic conditions. Table 4-4 presents the calculated hydraulic grade line from the tanks to the pump suctions.

Table 4-3: Peak Demand Suction HGL at RWQCP

Flow (gpm)	Pumps	Pt A[1]	Pt C[3]	Pt B[2]	Pt D[4]
5,836	4 pumps active (3 pumps on existing suction and 1 on proposed second supply manifold)	5.0	4.3	1.6	4.2

Notes:

1. Point A indicates the discharge location of Storage Tanks 1 and 2 at minimum water surface elevation of 5 feet, which is the City's low suction shut down elevation-.
2. Point B represents the discharge location of the furthest downstream existing pump. Elevation at centerline of existing pumps is -2.2 feet. Elevations are based on the Mean Sea Level Datum, U.S. C&GS 1967 Releveling.
3. Point C represents the junction of the existing pump supply pipeline and the additional proposed pump supply line.
4. Point D represents the proposed Pump Nos. 5 and 6. Centerline at these pumps is assumed equal to that of the existing pumps at Point B.
5. See Appendix F for additional information.

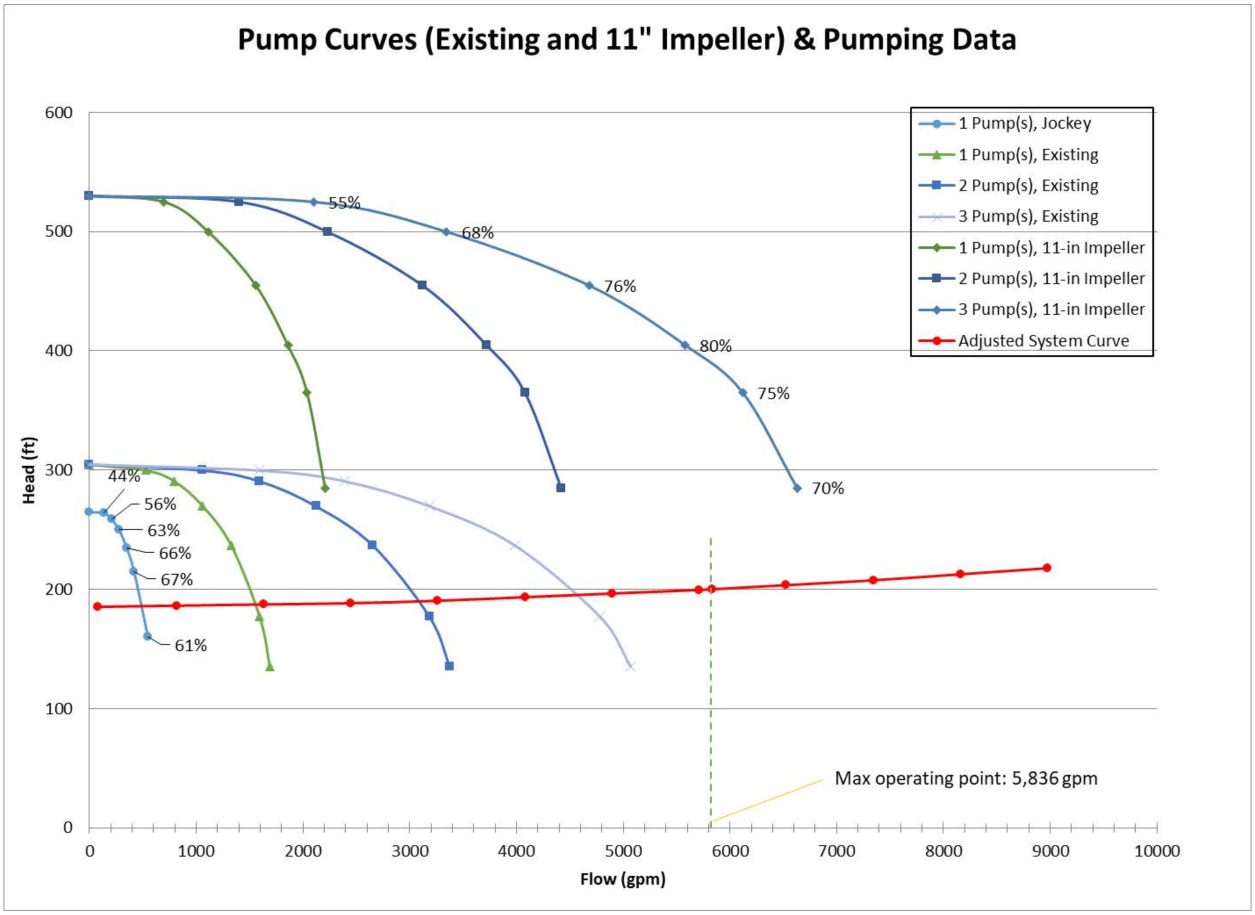
4.1.5 RWPS Configuration for Phase 3

Several pump modifications and configuration options were considered and are presented below.

Retrofit RWPS Pumps

The simplest potential modification would be to retrofit the existing large RWPS pumps with larger impellers and motors to achieve a firm pumping capacity equal to the peak hourly demand with Phase 3 customers connected. This would allow a relatively low capital investment at the RWQCP to meet the overall system needs. Figure 4-3 illustrates the modeled system curve for Zone 1, the existing pump performance curves and the maximum impeller size performance curves for three existing large RWPS pumps. It is clear the system curve is too flat for an impeller retrofit and the three existing duty pumps are insufficient to meet peak future demand. Also, a fourth pump would be needed regardless to provide firm capacity (three duty pumps and a standby).

Figure 4-3: Pump Curves with Existing and Enlarged Impellers



Replace RWPS Pumps

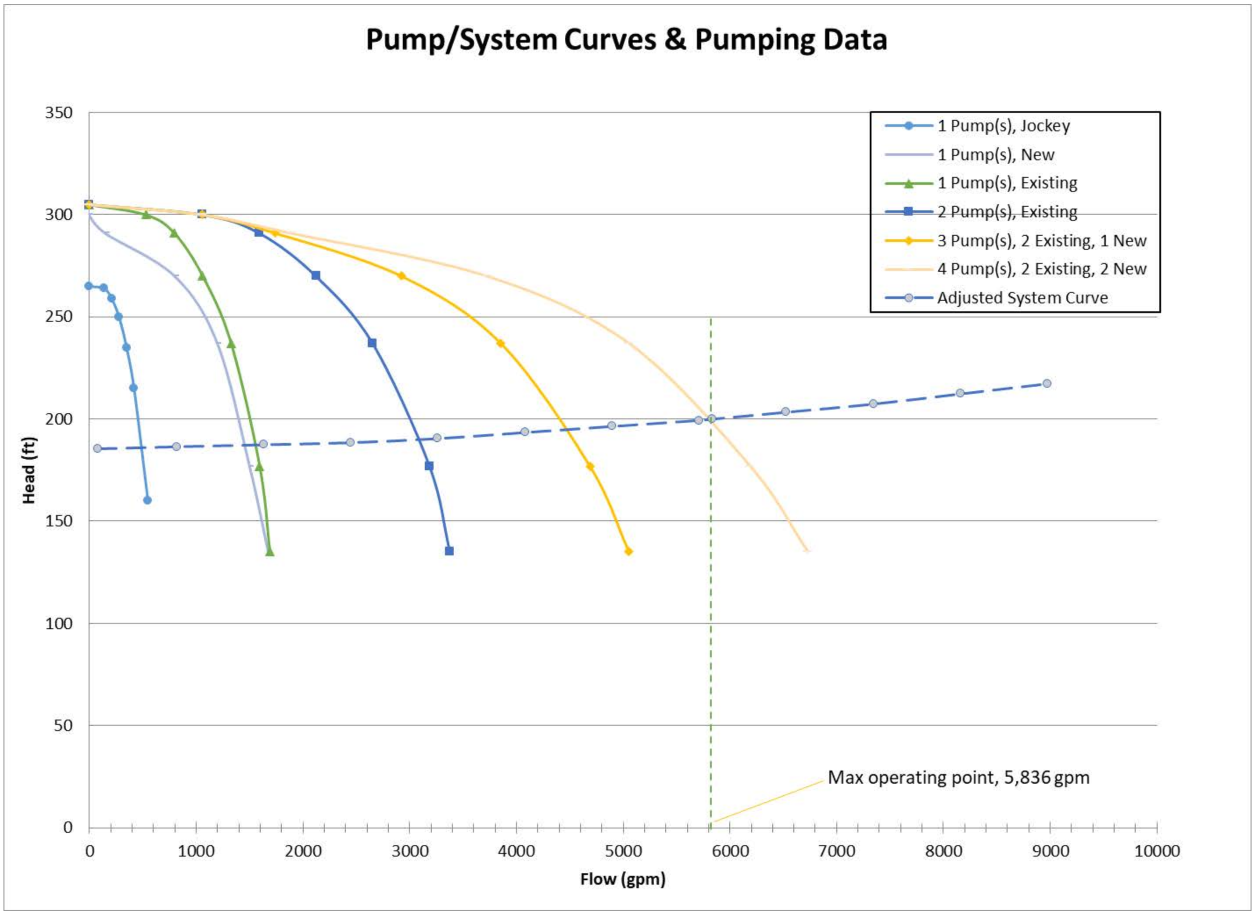
The RWPS pumps were installed in 2008. Replacing the existing RWPS pumps with larger pumps would meet the RWPS performance requirements. This approach was discussed with the City and rejected due to the need to replace costly assets with significant remaining service life.

Add Pumps

Maximizing reuse of the existing RWPS pumps would require adding pumps to meet the new RWPS performance requirements. As shown in Figure 4-4, adding a fourth and fifth full size pump (Pump Nos. 5 and 6, respectively) with a slightly lower performance curve (smaller impeller trim) than the existing large RWPS pumps results in good full speed performance against the modeled system curve. Installation of the fourth and fifty pumps would provide firm capacity with one of the existing large pumps as a standby.

Adding two new pumps to the existing RWPS is recommended for serving peak demand for current contractual Mountain View obligations and existing and new recycled water customers in Palo Alto.

Figure 4-4: Pump and System Curve Data with 4 Duty Pumps



Future Expansion

Providing for further expansion of capacity or higher \ Zone 1 pressure beyond the requirements to accommodate Phase 3 demands will require significant improvements or a new RWPS. Assessment of future expansions for the facility are beyond the scope of this study.

4.1.6 RWPS Modifications Preliminary Layout

The proposed configuration for adding two pumps to the RWPS is shown in Drawing M-1 in Appendix A. The new pumps will be located along the northwesterly wall of the basement pump room, currently occupied by variable frequency drives (VFDs) for the four RWPS pumps.

To provide operational flexibility and improved suction hydraulics to the RWPS, Golf Course, Backwash Supply pumps (8 total), a new 18-inch supply connection is recommended for the new RWPS Pump 5 and 6. This line would be routed from the northwest side of the Administration Building, across the existing basement floor (exposed and on pipe supports) to Pumps 5 and 6. The existing pumps on the existing 18-inch supply manifold will remain and the suction hydraulics are expected to be similar, though at a slightly lower HGL.

The existing discharge manifold will need to be modified to provide a connection to Pumps 5 and 6. The modifications will consist of extending the manifold and providing a 16-inch outlet for the pump discharge connection. To achieve this, the existing insulation and Victaulic cap will be removed and a new 24”x16” tee will be installed with the existing Victaulic cap re-installed at the end of the tee main run. Photos 1 and

2 on Drawing D-2 of Appendix A show the proposed re-routing of the Marsh Pump discharge pipe and a fire sprinkler pipe to provide clearance for the manifold extension and pump discharge for Pumps 5 and 6. Photo 3 on Drawing D-2 of Appendix A shows the removal and extension of the existing 24-inch manifold to accommodate the discharge from Pumps Nos. 5 and 6.

The surge analysis performed by GEI Consultants (refer to Appendix D) found that the existing surge protection system at the RWQCP is adequate for the Phase 2 and Phase 3 design flows in Zone 1.

Electrical gear, VFDs and related equipment would be located in the ground floor space of the Administration Building. Currently, VFDs are in the basement level, which is subject to flooding in the event of a pipe break or inadvertent opening of a valve or end cap. There is existing electrical raceway, conduit and junction box clutter in the Administration Building. Removal of unneeded electrical equipment could be a benefit to the City related to ongoing O&M of the RWPS and other pumping systems in the basement.

A new power supply and service entrance would be needed for the increased electrical load for the RWPS this is described in Section 4.4.

4.1.7 Operating and Control Strategies

The operation and control of the RWPS is expected to be similar to the current operational strategy, which relies on controlling pump starts and stops as well as speed to maintain discharge pressure within a range that is adequate for serving the Phase 2 customers. Pressure signals from a pressure transducer on the pump station discharge would be input into a control loop that signals pumps to turn on or off and controls the speed of the pumps using variable frequency drives (VFD) to maintain pressure within the pre-selected operating pressure range.

This control scheme will need to be adjusted to allow for a variable pressure dead band to provide the necessary minimum suction pressure to the Phase 3 BPS under varying demand conditions. At low system flows when discharge pressure requirements to meet demand are reduced at RWPS due to lower head losses, the BPS will still require enough pressure to keep the operating head of the BPS pumps within an acceptable range on the pump curves. This will require some control system programming that uses pressure instrument readings at the BPS to determine the required RWPS discharge head/speed at the RWQCP.

4.1.8 Next Steps and Considerations

The City needs to verify hydraulics and operations through existing upstream production process units and piping prior to initiating final design of the RWPS improvements. This includes an assessment of the components upstream of Tanks 1 and 2. The City should consider developing and implementing a testing program for the system under higher flow conditions to understand how the hydraulic grade line will change under the proposed design flow conditions.

4.2 Booster Pump Station

A BPS is needed to provide adequate pressure to higher elevation Phase 3 customers southwest of El Camino Real. Hydraulic modeling indicates the proposed site at the westerly corner of El Camino Real and Page Mill Road will have adequate suction side pressure from the RWQCP RWPS, and pressures upstream of the BPS will be marginal in this area for adequate customer service.

4.2.1 Siting

The BPS site identified in the 2015 EIR [2] is in an existing parking lot for the Stanford/Palo Alto Community Playfields. The booster pump station would be installed in an underground vault structure and would occupy several existing parking spaces along with a parking lot island. A site plan of the proposed BPS facility is provided in Appendix A Drawing C-1.

Utilities and Auxiliary Systems

Page Mill Road area is congested with City-owned and privately-owned utilities. Further utility verification will be required during final design to refine the location of the pump station and avoid conflicts with existing utilities and uses of the property. The preliminary BPS site is intended to minimize impacts to parking spaces and avoid rerouting the existing sidewalk along the northwest side of Page Mill Road. Access to the station by City staff would be via the parking lot.

Power service is available from the City power distribution system. The City will need to review the power requirements for the BPS and determine the best approach for providing adequate power supply. Space has been allocated on the site plan for a pad-mounted transformer. The BPS will require a 480-volt service and will include a 120-volt transformer for lighting, outlets, and ventilation loads.

A sump pump will be installed in a sump within the vault and would discharge to an existing City storm drain. The sump pump discharge location would be identified during final design of the BPS.

Forced air ventilation will be provided using exhaust and intake fans and louvers. The ventilation will provide for a minimum of 10 air changes per hour. Exposed electrical gear will be provided integral air conditioning capability as needed for protecting equipment.

A hydropneumatics bladder or diaphragm tank will be provided and located adjacent to the transformer pad to serve low flows below the turndown capability of the pumps, which is approximately 500-gpm minimum.

Property Ownership

The park is owned by Stanford and leased to the City of Palo Alto. The City will need to work with its Stanford partner to verify the feasibility of this site. Other sites for the pump station could be available, but would require securing an easement over private property at one of the office building complexes nearby and potentially additional environmental review.

4.2.2 Pump Station Hydraulic and Design Criteria

Table 4-4 is a summary of the hydraulic and design criteria for the proposed BPS. These criteria are based on the Baseline configuration with no Zone 2 storage tank.

Table 4-4: BPS Hydraulic and Design Criteria (No Zone 2 Tank)

Description	Criteria
Design Flow (gpm)	2,402
Design Discharge Head (feet)	175
Modeled Minimum Flow (gpm)	155
Design Minimum Flow (gpm)	20
Pump Station Turndown	20:1
Hydro-pneumatic Bladder Tank Volume (gal)	4,000
Hydro-pneumatic Tank Operating Volume (gal)	425
Minimum Suction Pressure (psi)	40
Maximum Discharge Head (feet)	198
Pump Configuration (duty + standby)	3+1
Pump Type	Vertical In-Line, Single Stage, Skid Mounted Package
Pump Control	Variable Frequency Drive
Pump Motor Rating (hp)	75
Pump Maximum Speed (rpm)	1,800
Pump Suction Size (in)	5
Pump Discharge Size (in)	5
Pump Minimum Efficiency at Design Flow and Head (%)	70
Suction and Discharge Manifold Pipe (in)	10
Flow Metering (in)	10-inch Mag Meter
Pump Reverse Flow Protection	Check Valve by Package Vendor
Pump and Pump Station Isolation	Resilient Seated Butterfly Valve by Package Vendor
Surge Control	Vacuum Relief Valve on Suction Supply Slow Closing Air and Vacuum Valve on Discharge Manifold Hydro-pneumatic Tank on Discharge Manifold

4.2.3 Preliminary Pump Station Configuration and Layout

The required flow and head for the BPS fits within the operating range of a vendor assembled, skid mounted, packaged pump station. A packaged unit is more economical than a customized design and can be shop assembled and tested, then shipped to the site for simple installation and connection to the recycled water supply and discharge pipes and power supply. Pump starters and controls, including VFDs can be mounted in panels integral to the skid, eliminating the need for MCC lineups that add to the overall footprint.

Preliminary drawings are included in Appendix A. The vault structure will provide a weather proof enclosure for the pumps with sound attenuation to minimize noise impacts at the playfields. Alternatively, the pump station could be at grade and exposed to the elements with a fence or wall designed to provide noise attenuation. The design will allow for the skid to be lowered into the vault by crane through a removable precast concrete paneled roof. Large double leaf hatches would be provided in the roof panel(s) for equipment removal and replacement long-term. A stairway will provide access to the pump room, which will be secured by a locked doorway at the bottom of the stairway.

Rainwater failing directly into the stairwell would be collected in a sump and removed by a duplex sump pump that would discharge to the City storm drain system. Electrical service entrance and metering would be located on top of the vault structure, with distribution down into the vault and the skid package panels.

A pad-mounted transformer will likely be necessary to step down the power supply to 480 volts. The pad mounted transformer would be located adjacent to the vault structure, enclosed with a fence or wall for security and aesthetic screening.

An approximately 6-foot diameter, 20-foot long hydro-pneumatic tank will be oriented along Page Mill Road between the sidewalk and curb and will be enclosed by a fence or block wall.

Modifications to the existing parking lot would include construction of new curb to surround the pump station, reconstructing curb and sidewalks disturbed during construction, repaving, and re-striping of parking spaces. Landscaping of the area around the BPS would be provided to screen the transformer and hydro-pneumatic tank.

4.2.4 Operating and Control Strategies

The BPS would operate based on maintaining downstream pressure, similar to the RWQCP RWPS. The pumps would activate when discharge pressure reaches a preset value. Operating pressure would be maintained within an operating dead band to maintain the minimum service pressure at the highest elevation customer by turning on/off pumps and controlling pump speed via the VFDs. When pressure falls below the operating dead band, the speed of the pumps operating would increase up to 100% speed, and if pressure does not increase to within the operating range, then another duty pump would be activated and speed is reduced to minimum and slowly ramped up to achieve operating pressure within the operating dead band. On rising pressure above the dead band, pump speed would be slowed and pumps are deactivated until pressures are within the dead band. The hydro-pneumatic tank will serve as a buffer to minimize pump start time intervals during low flow periods. The hydro-pneumatic tank is a passive component utilizing a diaphragm or bladder to push water at pressure into the system when pumps are not operating.

Operation of the BPS will also impact operation of the RWPS. At low flow conditions with the BPS operating, the RWPS will operate to keep the BPS suction pressure at 40-psi to allow the BPS pumps to operate within a stable region on their rated pump curve. A PLC and RTU will be provided at the BPS to facilitate control and coordination between the two pump stations.

4.3 Pump Station Structural Design Criteria

For Phase 3 components that include structures or structural modifications, the design of the structures and modifications will be based on recognized and governing industry standards and will be performed using industry accepted software and design tools. Materials of construction will include concrete, structural steel and aluminum. Loading conditions will be based on California Building Code Chapter 16 and ASCE 7, latest approved editions. Appendix E includes a Technical Memorandum prepared by TJC and Associates, Inc. addressing the basic structural design criteria for the project.

4.4 Pump Station Electrical, Instrumentation and Controls System Design Criteria

The two pump stations will require electrical, instrumentation and control systems elements. Appendix G describes the proposed design criteria for the pump stations, which are summarized below. Appendix G also includes the proposed single line diagrams and piping and instrumentation diagrams.

The project requires significant modification of the existing RWPS. To make room for additional pumps, the existing pump VFDs will be relocated to a new electrical line up on the ground floor of the Administration Building. A new feeder circuit will be needed to the building to address additional connected load at the RWPS. New instrumentation will be added to the RWPS to allow for better automatic control of the RWPS, which is necessary because of the addition of the in-line BPS facility. These two pump stations must operate together to avoid system transients and nuisance pump trips, which will require the City to integrate the overall system control.

The BPS will require a new 480-volt power service from the City and a means of communication with the City SCADA system. The BPS will include a skid mounted, vendor assembled and tested unit complete with panels for housing VFDs and a PLC for pump station control. Signals will be sent from the PLC to the SCADA RTU for remote monitoring and system control.

Chapter 5 Pipeline Preliminary Design Development

This chapter focuses on the following areas:

- Developing pipeline extensions from the 2008 Facilities Plan system needed to serve new customers identified in Chapter 2
- Conducting a utility investigation to assist with alignment refinement
- Conducting a tree reconnaissance to assist with alignment refinement
- Defining pipeline design criteria, including alignment and pipeline materials
- Desktop assessment of corrosion potential and corrosion mitigation in the project area
- Limited study of traffic control considerations in the project area and general traffic control strategies

5.1 Pipeline Alignment

A proposed alignment was selected in preparing the 2008 Facilities Plan that best served identified potential recycled water customers in the Stanford Research Park vicinity. That initial proposed alignment, which was also used for the project description in the 2015 EIR document [2], began with a connection point to the 2006 Palo Alto-Mountain View Recycled Water Project at the intersection of East Bayshore Road and Corporation Way. The primary backbone alignment crossed under Highway 101 and ran along Fabian Way, East Meadow Drive, Cowper Street, El Dorado Avenue and Alma Street. The alignment then crossed under the Caltrain tracks and along Page Mill Road to El Camino Real. The backbone alignment continued along Page Mill Road to Hanover Street, along Hanover Street and Hillview Avenue to Arastradero Road, terminating along Deer Creek Road at the westernmost customer connection. The alignment stays within public streets. Smaller diameter recycled water laterals extend from the backbone to individual customers away from the backbone pipeline. Lateral pipelines alignments follow the shortest available path from the backbone to the customer utilizing public roads.

The alignment proposed in this Preliminary Design builds from the 2008 Facilities Plan alignment. Additional information on utilities, tree and tree canopy, and constructability were considered, resulting in alignment refinements to minimize impacts and improve constructability. The updated alignment is described Section 5.1.4. The following sections describe the basis that was used when refining the alignment of the new recycled water pipeline.

5.1.1 Horizontal Alignment Basis

The following criteria was used as a basis for horizontal placement of the alignment:

- Based on the size of recycled water pipe being installed, assumed widths of corridors or “slots” were developed that would be necessary for construction in City streets. The minimum slot width provides for a four-foot clearance between the new recycled water pipeline and existing utilities (wall-to-wall clearance). The City has an additional standard requiring approximately two feet between adjacent trench walls (existing utility and proposed recycled water), to prevent the existing coarse grained trench backfill from sloughing into the recycled water pipeline trench and to allow sufficient space for future maintenance. For areas where a corridor allowing four-foot clearances to existing utilities is not available, additional approval is required from the Water, Gas & Wastewater (WGW) Engineering Department per the City standards. Clearances of less than one-foot are not permitted.
- In accordance with the State of California Water Resources Control Board (SWRCB), Division of Drinking Water (DDW) guidelines, disinfected tertiary recycled water pipes should be separated from potable water pipes by at least four feet horizontally, which is consistent with the City’s

primary separation criteria for new pipeline construction. Where this separation is not possible, the use of high density polyethylene (HDPE) pipe material with no joints will likely be allowed as a special exception by DDW.

- Should the Phase 3 distribution system be re-purposed to convey purified water, additional clearances need to be considered to be consistent with the guidelines for potable water. The alignment was refined to provide a 10-foot separation horizontally from sanitary sewer pipeline (edge-to-edge) where feasible. Where not possible, the use of HDPE pipe material with no joints will likely be allowed as a special exception by DDW.
- In utility-congested streets without an available alignment slot meeting the clearance criteria, recycled water pipeline alignments made use of abandoned utility alignments in a remove and replace approach to construction.
- The alignment was further refined to reduce the impact on trees located along the alignment. Pipeline construction (trenching) can impact tree canopies that overhang into the streets, or damage the roots during excavation if the work is adjacent to the curb. Any damage can compromise the stability of the tree, resulting in elevated risk of falling. Section 5.3.10 describes the tree reconnaissance assessment that was performed along the proposed alignment. Where practical, the alignment was shifted to avoid tree root zones, loosely defined as within the tree drip line, which is the extent of the tree's canopy. In locations where pipeline relocation was not feasible, tree removal and replacement may be required. Further definition of tree impacts will be performed during final design in coordination with the City's Urban Forestry Section
- The alignment location within traffic lanes is important to help minimize impacts on traffic during construction. Generally, lanes closer to the sidewalk were preferred to keep traffic to one side of the work zone. Turn lanes at intersections with four or more lanes were also used to simplify temporary traffic movements during construction.

It should be noted that the City Utilities Department has plans for future water main replacement along the recycled water pipeline corridors. The final recycled water pipeline alignments need to be reviewed with the Utilities Department to ensure adequate slots for both future pipelines.

5.1.2 Vertical Alignment Criteria

The preliminary design of the Phase 3 distribution pipelines is presented for horizontal alignment in the Appendix L drawings. The pipeline profiles will be developed during final design using the following criteria:

- Depth of cover for the pipelines will meet the City of Palo Alto Water, Gas & Wastewater Utility Standards – 2013 (Utility Standards) requirements where possible. Table 5-1 presents the depth of cover requirements for high density polyethylene (HDPE DR 11) water main installation from Section 2660.

Table 5-1: City of Palo Alto Utilities Standards Depth of Cover Requirements[1]

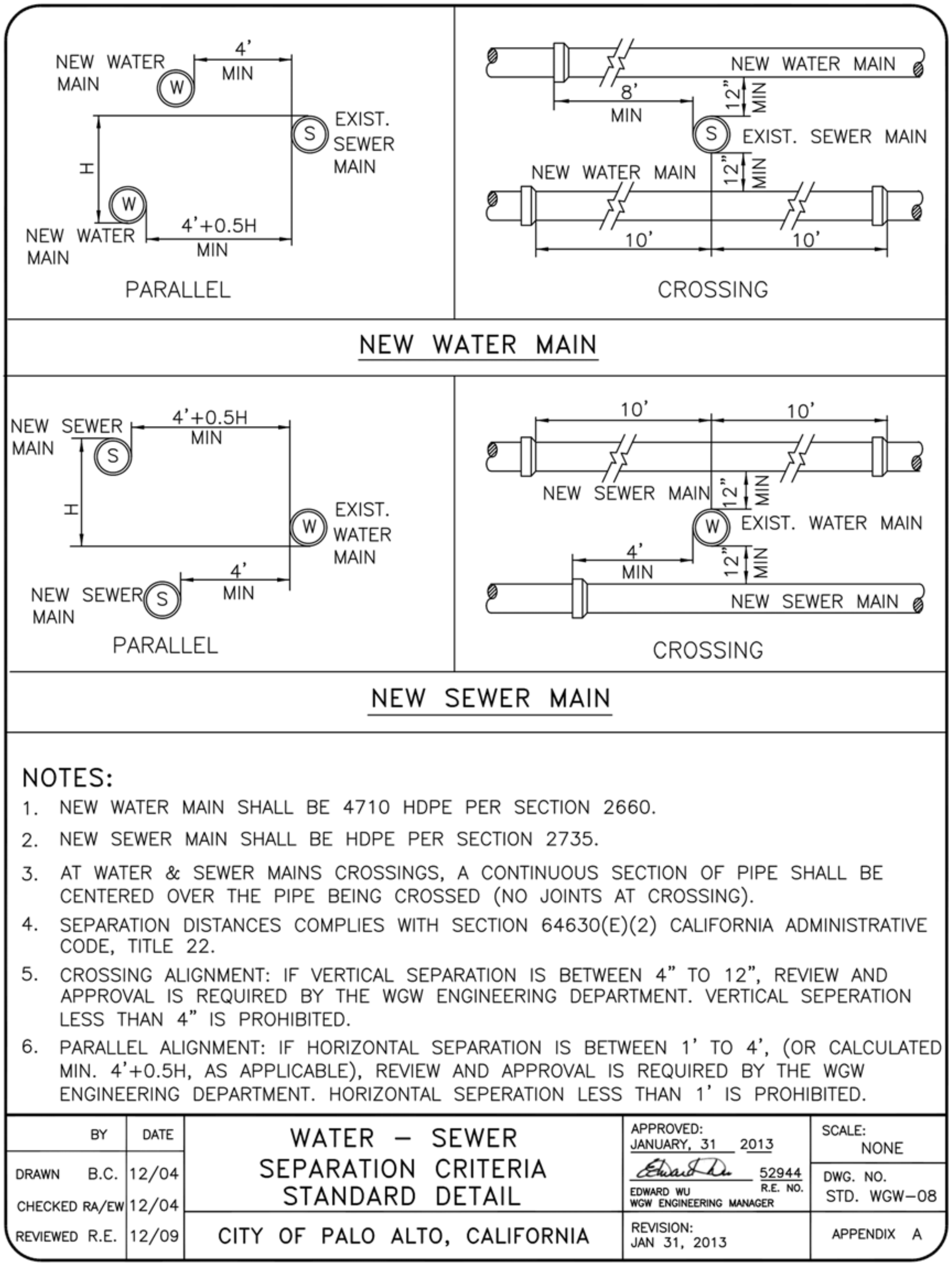
Pipe Diameter (OD)	Minimum Depth of Cover	Maximum Depth of Cover
8-inch	3 feet	4.5 feet
10- to 20-inch	4 feet	4.5 feet

Notes:
1. From Section 2660 of the City of Palo Alto Water Gas and Wastewater Utility Standards dated 2013.

In areas where utility congestion within a street does not allow for shallow cover depths, the pipeline profile will be lowered to clear the majority of existing utilities. The maximum depth of cover of 4.5 feet will likely be exceeded to avoid numerous changes in vertical alignment.

- Vertical separation requirements from the Utility Standards are presented in Figure 5-1. The requirements are equal to or exceed the requirements from Section 64630(E)(2) of the California Administrative Code, Title 22. Due to the source water for the recycled water being a municipal wastewater stream, this assessment conservatively assumes the recycled water pipeline will follow the guidelines for new sewer pipelines. The vertical separation requirements call for:
    - 12-inch minimum clearance (edge-to-edge) when crossing above or below existing water mains.
    - 10-foot minimum horizontal distance between the existing water main being crossed over and joints on the new main. This requirement is not expected to have a significant impact on recycled water pipeline profiles for HDPE pipelines.
    - 4-foot minimum horizontal distance between the existing water main being crossed under and joints on the new main. This requirement is not expected to have a significant impact on recycled water pipeline profiles for HDPE pipelines.

Figure 5-1: City of Palo Alto Water – Sewer Separation Criteria Standard Detail



Notes:

1. From the City of Palo Alto Water Gas and Wastewater Utility Standards dated 2013

5.1.3 Alignment Lengths and Sizing

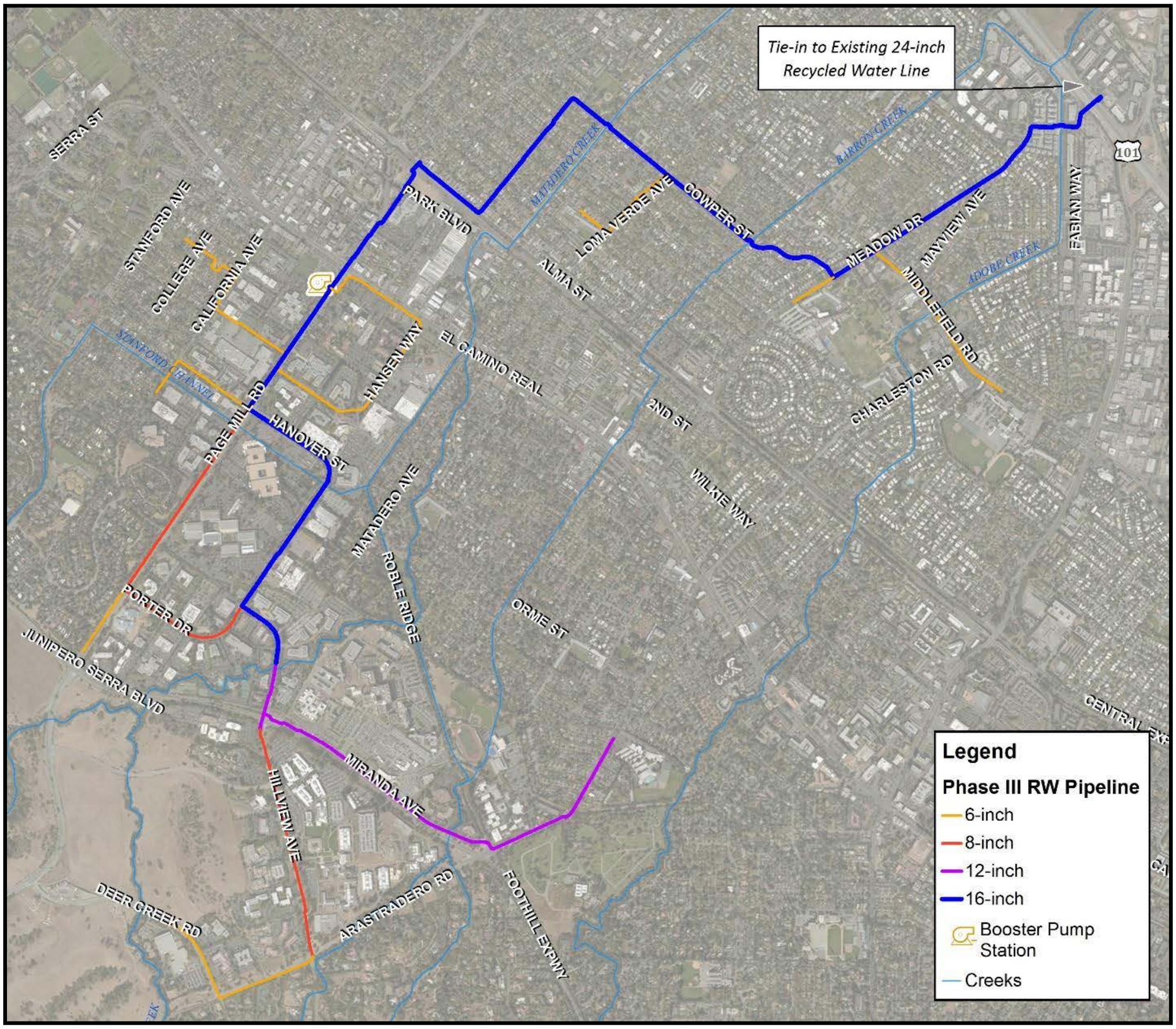
The proposed Phase 3 distribution system will consist of approximately 11.2 miles of pipeline. A summary of pipe sizes and lengths is provided in Table 5-2. The lengths presented account for alignment adjustments made through the refinement process based on the criteria presented in Section 5.1.1. The table also includes HDPE nominal outer diameter (OD) size equivalents to the inner diameter sizes (ID) presented in the hydraulic modeling results.

Table 5-2: Phase 3 Pipeline Sizes and Lengths

Modeled Pipe ID (in)	Length of pipe (LF)	HDPE DR 11 ID (in)	HDPE DR 11 Nominal OD (in)
6	19,167	6.96	8
8	9,036	8.67	10
12	7,715	12.91	16
16	23,243	16.15	20

Notes:
1. HDPE pipe sizes are IPS (outside diameter controlled) based on AWWA C906 and provided by P&F Distributors.
2. Pipe sizes are based on modeling results described in Chapter 3.

Figure 5-2: Phase 3 Recycled Water Distribution Pipeline Sizes Map



5.1.4 Alignment Descriptions

Table 5-3 and Table 5-4 present descriptions of the alignment, separated into distinct reaches for backbone and lateral pipelines, respectively. Table 5-5 and Table 5-6 provide a reach by reach description of utility congestion, traffic impacts, tree impacts and special crossings along the backbone and lateral pipeline alignments, respectively. The alignments are presented in the Appendix L drawings

Table 5-3: Backbone Pipeline Alignment Description

Alignment Reach	Station	Diameter	Alignment Description
Bayshore Rd and Corporation Way to Fabian Way and East Meadow Dr	10+00 to 17+00	16-inch	Alignment begins by tying in to existing 24" reclaimed water line on Bayshore Rd and travels northeast on Corporation Way. The pipeline then drops into a casing under Highway 101 to the southwest, then rising out of the casing and turning south on Fabian Way to East Meadow Dr.
Fabian Way and East Meadow Dr to East Meadow Dr and Cowper St	17+00 to 61+75	16-inch	Alignment travels west on East Meadow Dr crossing over Adobe Creek. It then turns southwest with East Meadow Dr. The alignment then turns west at Cowper St
East Meadow Dr and Cowper St to Cowper St and El Dorado Ave	61+75 to 111+00	16-inch	Alignment follows Cowper west and crosses Barron Creek and Matadero Creek. The alignment then turns southwest at El Dorado Ave.
Cowper St and El Dorado Ave to Page Mill Rd	111+00 to 147+00	16-inch	Alignment travels southwest on El Dorado Ave before turning northwest on Alma St. The alignment then turns to the north side of Alma St at the crossing location. The alignment tunnels under Alma St and the Caltrain right-of-way to an empty parcel. The alignment picks up where the tunnel crosses Page Mill, removing the remainder of the crossing casing to the abandoned lot.
Page Mill Rd from Caltrain Crossing to Hanover St	147+00 to 191+50	16-inch	Alignment travels southwest on Page Mill Rd and crosses under El Camino Real. At the Stanford/Palo Alto Community Playing fields, the alignment enters the BPS. The alignment then continues southwest on Page Mill Rd before turning southeast on Hanover St.
Page Mill Rd and Hanover St to Hillview Ave and Miranda Ave	191+50 to 244+50	16-inch, 12-inch	Alignment follows Hanover St and then turns southeast on Hillview Ave where it is reduced to a 12-inch line. The alignment then crosses the Bay Division Pipelines and Foothill Expressway via HDD. The alignment backbone ties into the HDD crossing at Hillview Ave and Miranda Ave via an electrofusion saddle and tapping valve.
Hillview Ave and Miranda Ave to Arastradero Rd and Donald Dr	244+50 to 317+29	12-inch	Alignment travels southeast through the planters between Miranda Ave and Foothill Expressway. The alignment then enters Miranda Ave before turning northeast on Arastradero Rd. The alignment ends at Donald Dr where the last customer is located.

Table 5-4: Lateral Pipelines Alignment Descriptions

Alignment Reach	Station	Diameter	Alignment Description
Middlefield Rd	A10+00 to A39+10	6-inch	Lateral branches off from the backbone alignment at Station 54+40 on East Meadow Dr. The lateral travels southeast on Middlefield Rd past Charleston Rd.
East Meadow Dr	B10+00 to B17+00	6-inch	Lateral branches off from the backbone alignment at Station 61+75. The lateral continues southwest on East Meadow Dr for less than a block.
Loma Verde Ave to Bryant Street	C10+00 to C27+85	6-inch	Lateral branches off from the backbone alignment at Station 93+00 on Cowper St. The lateral travels southwest on Loma Verde Ave before turning northwest on Bryant St.
El Camino Real to Hansen Way	D10+00 to D57+67	6-inch	Lateral branches off from the backbone alignment at Station 169+40 at the BPS. The lateral crosses Page Mill and travels northeast before turning southeast on El Camino Real. It then turn southwest on Hansen Way to loop back to the alignment backbone at Station 184+00
California Ave to Wellesley St	E10+00 to E40+00	6-inch	Lateral branches off from the backbone alignment at Station 181+50 on Page Mill Rd. The lateral travels northwest between office parks to California Ave before turning northeast. The lateral then travels northwest on Wellesley St and ends at Cameron Park
Hanover St to Dartmouth St	F10+00 to F28+60	6-inch	Lateral branches off from the backbone alignment at Station 191+40 on Page Mill Road. The lateral travels northwest on Hanover St before. It then turns southwest on California Ave, ending at Dartmouth St.
Page Mill Rd to Porter Dr and Hillview Ave	G10+00 to G65+13	8-inch	Lateral branches off from the backbone alignment at Station 191+40 on Page Mill Road continues southwest. It then turns southeast on Porter Dr and loops back with the alignment backbone at Hillview Ave.
Page Mill Rd	H10+00 to H21+32	6-inch	Lateral branches off from the lateral at Station G43+00 at Page Mill Rd and Porter Dr. The lateral continues southwest on Page Mill Rd to north of Junipero Serra Blvd.
Hillview Ave to Arastradero Rd and Deer Creek Rd	J10+00 to J77+50	12-inch, 8-inch, 6-inch	Lateral branches off from the backbone alignment at Station 250+50 on Hillview Ave and Miranda Ave. The lateral travels south on Hillview, where the size is reduced from 12-inch to 8-inch. At Arastradero Rd the size is reduced to 6-inch. The lateral then heads northeast up Deer Creek Rd.

Table 5-5: Alignment Backbone Setting and Impacts

Alignment Reach	Station	Utility Congestion	Traffic Impacts	Tree Impacts	Special Crossings
Bayshore Rd and Corporation Way to Fabian Way and East Meadow Dr	10+00 to 17+00	Bayshore Rd: Low utility congestion Corporation Way: Moderate utility congestion, allows enough space for trenchless pit. Highway 101: No utility congestion Fabian Way: Heavy utility congestion, one available corridor.	Low traffic impacts north of Highway 101. Moderate traffic in connector streets south of Highway 101.	Three trees located above crossing casing may require removal and two trees impacted due to vibrational impacts from microtunneling.	310-foot microtunnel crossing under Highway-101. Bore Pit Location: Space System Loral parking lot Receiving pit Location: Corporation Way Casing: 36-inch steel
Fabian Way and East Meadow Dr to East Meadow Dr and Cowper St	17+00 to 61+75	East Meadow Dr: Utility congestion ranges from moderate to heavy.	The alignment is restricted to one lane of East Meadow Dr to limit impacts on traffic.	Two trees impacted and one tree removal required approaching East Meadow Dr bridge crossing Adobe Creek. Tree at corner of East Meadow Dr impacted by alignment placement.	55-foot planter box crossing over Adobe Creek on the East Meadow Dr Bridge
East Meadow Dr and Cowper St to Cowper St and El Dorado Ave	61+75 to 111+00	Cowper St: Utility congestion ranges from moderate to heavy. Remove abandoned gas line to fit the alignment in corridor.	Low traffic impact in residential streets.	No trees impacted.	30-foot crossing over Barron Creek hung from the downstream side of the Cowper St Bridge. 35-foot crossing over Matadero Creek hung from the downstream side of the Cowper St Bridge.

Alignment Reach	Station	Utility Congestion	Traffic Impacts	Tree Impacts	Special Crossings
Cowper St and El Dorado Ave to Page Mill Rd at Caltrain Crossing	111+00 to 147+00	El Dorado Ave: Heavy utility congestion. Remove abandoned gas line to fit the alignment in corridor. Alma St: Light utility congestion. Caltrain right of way: Light utility congestion.	The alignment is located in the middle turning lane to limit impacts on traffic on Alma St, which is an arterial street.	One tree impacted at El Dorado and Waverley St.	310-foot microtunnel crossing under Alma St and Caltrain Railway. Bore Pit Location: Empty lot on Page Mill Rd Receiving Pit Location: Widened sidewalk area on north end of Alma St Casing: 36-inch steel
Page Mill Rd from Caltrain Crossing to Hanover St	147+00 to 191+50	Page Mill Rd to El Camino Real: Heavy utility congestion. Remove abandoned gas line to fit the alignment in corridor. Page Mill Rd to Hanover St: Light utility congestion in southeast bound lanes. Remove abandoned gas line to fit the alignment closest to sidewalk.	The alignment is restricted to one lane of Page Mill Rd to limit traffic impacts on arterial street.	Three trees impacted on Page Mill Rd between Park Blvd and the merge with Oregon Expy. Two trees impacted at El Camino Real crossing pit. One tree removal required and one tree impacted at BPS,	200-foot microtunnel crossing under El Camino Real Bore Pit Location: Page Mill Rd Receiving Pit Location: Page Mill Rd Casing: 36-inch steel
Page Mill Rd and Hanover St to Hillview Ave and Miranda Ave	191+50 to 244+50	Hanover St: Heavy utility congestion. Hillview Ave: Heavy utility congestion. SFPUC Bay Division Pipelines require trenchless crossings.	The excavation to HDD for the tie in at Miranda Ave is located in the middle turning lane on Hillview Ave to Foothill Expressway.	Three trees impacted on Hanover St at Sta 219+50.	Overcrossing of Matadero Creek culvert at Hillview Ave. 350-foot HDD crossing under SFPUC Bay Division Pipelines and Foothill Expressway along Hillview Ave

Alignment Reach	Station	Utility Congestion	Traffic Impacts	Tree Impacts	Special Crossings
Hillview Ave and Miranda Ave to Arastradero Rd and Donald Dr	244+50 to 317+29	Miranda Ave: Utility congestion ranges from moderate to light. Arastradero Rd: Moderate utility congestion.	The alignment is restricted to one lane in Miranda Ave and Arastradero Rd to limit impacts on traffic.	Alignment shifted south to avoid removal of two trees in median between Miranda Ave and Foothill Expy. The trees remain impacted. Alignment shifted away from curb on Miranda Ave to avoid removal of three trees. Alignment shifted away from curb on Arastradero Rd to avoid impacts to multiple trees.	Overcrossing of Barron Creek culvert at Miranda Avenue.

Table 5-6: Alignment Lateral Setting and Impacts

Alignment Reach	Station	Utility Congestion	Traffic Impacts	Tree Impacts	Special Crossings
Middlefield Rd	A10+00 to A37+82	Middlefield Rd: Moderate utility congestion	Moderate traffic impact on residential arterial street.	Alignment shifted away from curb to avoid impacts to multiple trees on Middlefield Rd.	55-foot planter box crossing over Adobe Creek on the East Meadow Dr Bridge
East Meadow Dr	B10+00 to B17+00	East Meadow Dr: Moderate utility congestion	The alignment is restricted to one lane of East Meadow Dr to limit impacts on traffic.	Alignment shifted away from curb to avoid impacts to multiple trees on East Meadow Dr.	None
Loma Verde Ave to Bryant Street	C10+00 to C27+95	Loma Verde Ave: Moderate utility congestion Bryant Street: Moderate Utility congestion	Low traffic impact in collector and residential streets.	Alignment shifted away from curb to avoid impacts to multiple trees on Loma Verde Ave and Bryant St.	None
El Camino Real to Hansen Way	D10+00 to D57+67	Page Mill Rd: Low utility congestion on northeast bound turning lane. El Camino Real: Moderate utility congestion Hansen Way: Moderate to heavy utility congestion	High impact on traffic at Page Mill turning lane to El Camino Real, intersection of two major arterial streets. Alignment restricted to one lane of to reduce impacts on traffic.	Six trees impacted on El Camino Real between Page Mill Rd and Hansen Ave. Alignment shifted away from curb to avoid impacts to multiple trees on Hansen Ave.	None
California Ave to Wellesley St	E10+00 to E40+25	Office Park to California Ave: No utility congestion California Ave: Heavy utility congestion. Remove abandoned gas line to fit the alignment in a corridor. Wellesley Ave: Moderate to heavy utility congestion in narrow street	Low traffic impact in collector and residential streets.	Two trees impacted in office park between Page Mill and California Ave. Alignment moved from Williams St to Wellesley Ave to avoid impacts to trees and utility congestion. One tree impacted at bend in Wellesley Ave.	None

Alignment Reach	Station	Utility Congestion	Traffic Impacts	Tree Impacts	Special Crossings
Hanover St to Dartmouth St	F10+00 to F28+40	Hanover St: Moderate utility congestion California Ave: Heavy utility congestion. Remove abandoned gas line to fit the alignment in a corridor.	Low traffic impact in collector and residential streets.	Alignment shifted away from curb to avoid impacts to multiple trees on California Ave.	None
Page Mill Rd to Porter Dr and Hillview Ave	G10+00 to G65+13	Page Mill Rd: Light utility congestion Porter Dr: Moderate utility congestion	High impact on traffic at Page Mill Rd, arterial street.	Two trees impacted on Porter Dr.	None
Page Mill Rd	H10+00 to H21+40	Page Mill Rd: Light utility congestion	High impact on traffic at Page Mill Rd, arterial street.	No trees impacted.	None
Hillview Ave to Arastradero Rd and Deer Creek Rd	J10+00 to J72+75	Hillview Ave: Moderate to heavy utility congestion Arastradero Rd: Moderate to light utility congestion Deer Creek Rd: Moderate to light utility congestion	High impact on traffic at Hillview Ave and Arastradero Rd, arterial streets. Moderate traffic impact at Deer Creek Rd, connector street.	No trees impacted.	350-foot HDD crossing under SFPUC Bay Division Pipelines and Foothill Expressway along Hillview Ave

5.2 Utilities Investigation

Refinement of the Phase 3 recycled water distribution system pipeline alignments was primarily based on an initial utilities investigation. The following sections detail the process of utility collection and summarize the results of the investigation.

5.2.1 Approach

Available utility information was obtained using the following steps:

- Submitted Underground Service Alert (USA) design inquiry tickets for the project area through the website: usanorth.811.org. Service area and utility contacts were generated from the USA design ticket. Due to the alignment length and the limitations of the USA website, the alignment required multiple design inquiries for complete coverage of the Phase 3 pipeline alignments.
- Obtained City-owned utility information from City staff. City utilities include water, sewer, storm, gas, electric and fiber optic cable facilities.
- Contacted agencies listed in the USA design tickets. A utility information request letter (Utility 'A' Letter) with a map of the proposed alignment was submitted to each utility by the Utilities Department. GIS or CAD files of the utility improvements were requested, where available. Otherwise, hard copy or PDF maps would be acceptable for subsequent digitization.
- Communicated with utility owners to ensure the correct point of contact was identified. The identified point of contact was involved in facilitating the transfer of utility maps. Contact logs were maintained for correspondence with each utility representative. Utility representative responses and communications were documented in an Excel tracking spreadsheet, which is provided in Appendix M.
- Utility maps that were received in GIS or CAD format were incorporated into a master utility map drawing. PDF maps or other forms of mapping were digitized by overlaying the maps on orthorectified aerials (obtained from the USGS Earth Explorer website [5]). Overlain utility maps were traced into GIS for incorporation into the master utility map drawing.

5.2.2 Existing Utility Information

Table 5-7 provides a summary of utility owners and agencies that were contacted and responses that were received from each contact. The utility maps were incorporated into the alignment drawings for assessment available corridors along the proposed alignment.

Table 5-7: Utility Agency Contact Information and Responses

Utility Company	Utility Contact	Contact Info	Response Received
AT&T California	Kyeisha Warrick-Grant	(408) 635-8767	*Fiber Maps Received*
AT&T Local (TCA)	Maria Guzman	(213) 787-9996	*Overview Fiber Maps Received*
City of Palo Alto	Silvia Santos	(650) 566-4520	*Water, Sewer, Storm, Electric, Fiber, Gas Maps Received*
Comcast	Dori Woodstrup	(707) 759-4070 ext. 253	*Fiber Maps Received*
California Water Service - Los Altos	Sean Lombardi	(650) 917-0152	*No Conflict Confirmed*

Utility Company	Utility Contact	Contact Info	Response Received
Google	fiber-support@google.com	-	*Will not provide maps*
Verizon (MCI WorldCom)	Investigations@verizon.com	(813) 740-1231	*Overview Fiber Maps Received*
Level 3 Communications (MPower Communications)	Patrick Provost	1 (877) 366-8344	*Overview Fiber Maps Received*
PG&E	Building and Renovation Service Center	1 (877) 743-7782	*Gas Maps Received*
Point to Point Inc.	Bill Hoover	(916) 861-222 ext. 2	*Fiber Maps Received*
Purissima Hills Water	Patrick Walter	(650) 948-1217	*Water Maps Received*
Qwest Communications	Daniel Grow	(408) 487-6197	*Overview Fiber Maps Received*
Stanford University Utilities	Jay Marianowits	(650) 725-0746	*No Conflict Confirmed*
Stantec Consulting Group	Wendy Chen	(650) 444-6537	*Remediation System Maps Received*
Space Systems/Loral	inquiries@sslmda.com	(650) 521-6348	*No Response Received*
Sprint	Russell Mix	(650) 533-3438	*Fiber in Caltrain ROW, Maps not provided*
Valley Transportation Authority	Victoria King-Dethlefs	(408) 321-5856	*Bus and Rail Route Maps Received*
XO Comm SVCS	Chad Auchey	(510) 580-6363	*Fiber Maps Received*
Zayo - California	Manuel Valencia	(925) 413-0170	*Overview Fiber Maps Received*

It should be noted that existing utility locations shown in the Appendix L drawings are approximate and are subject to adjustment based on further utility research and field verification during final design. The existing utilities shown were digitized "as is" based on information provided by the utility owner. The level of accuracy is undetermined. Overview maps provided by some utility agencies were incorporated into the mapping, however they were not taken into consideration for horizontal alignment placement due to the small scale of overview maps. Detailed design, utility research and field verification will be necessary to adequately portray existing utilities and develop future contract documents.

5.3 Pipe Design Criteria

5.3.1 Pipe Materials

The Phase 3 pipeline components will be designed consistent with the Utility Standards. Supplemental design criteria and exceptions to the Utility Standards are noted below along with a summary of the primary design criteria presented in Table 5-8.

Table 5-8: Summary of Pipeline Design Criteria

Item	Criteria
Hydraulics and Sizing	
Maximum Operating Pressure	125 psig
Design Working Pressure	200 psig
Design Additional Transient Pressure	30 psig
Test Pressure	200 psig at lowest point
Minimum Pipe Size	6-inch (ID)
Maximum Pipe Size	16-inch (ID)
Pipe Materials	
Open Cut, Trenchless in Casing, Direct HDD Trenchless	HDPE (AWWA C906 and Utility Standards)
Field Joints	Butt End Fusion
Field Closures	Electrofusion Coupling
Fittings	• Fabricated Mitered HDPE, for 8-inch IPS and larger • Molded HDPE for smaller than 8-inch IPS
Casing Pipe	Welded Steel (ASTM B53), unlined and uncoated
Field Joints	• Full Penetration Butt Welds • Perma-lok Casing Joint
Open Cut in Contaminated Soil	Ductile Iron Pipe (AWWA C151 and Utility Standards)
Above Grade on Culvert and Bridge Structures	Ductile Iron Pipe (AWWA C151 and Utility Standards)
Field Joints and Fittings	DIP - Flanged and Restrained MJ, Flex-Tend where ground is settling relative to structure
Pipe Supports	• Fabricated Steel brackets and saddle supports where hung • Concrete encasement where in planter or adjacent to bridge railing
Corrosion Protection	• Polyethylene sleeve (AWWA C105) for DIP and DIP fittings • Galvanic anode system for metallic pipeline • Epoxy coating on miscellaneous metallic piping components
Tracing	#10 AWG Copper, Blue Insulation with 5 lb anode on each isolated string
Customer Connections	
Service Line Material	HDPE
Utility Standard Service and Meter Detail (by Service Line Size)	• 4-inch through 8-inch – WD-03A • 2-inch – WD-02A or WD-01A

Item	Criteria
Customer Service Line	Not in Project
Appurtenances	
Isolation Valves	Gate (AWWA C515)
End Configuration	• 12-inch and less – HDPE Fusible Ends • Larger than 12-inch – Mechanical Joint or Flanged
Location	• Maximum 1000 feet • Downstream ends of tees and crosses
Air Valve	• Combination, Air Release, Air and Vacuum at high points as required • Locate above ground to minimize pipeline depth at high points
Blowoffs	• Blowoffs at dead ends and opportunistic locations adjacent to larger sewers for draining pipeline to sewer
Corrosion Protection	
Buried Metallic Components	Galvanic Anode
Recycled Water Component Marking	
Pipeline	DIP Pipe, Fittings and Couplings – encase with Purple PE sleeve and place purple marking tape one foot over the pipe HDPE Pipe – Extruded purple line integral to pipe wall
Above Grade Pipe, Valves	Epoxy coat, color purple (Pantone 512)
Valve Can and Utility Box Covers	Marked “Recycled Water” and color purple

5.3.2 Pressure Class Requirements

Pipeline materials will be specified to achieve a pressure rating of 150 psi, minimum. Hydraulic modeling results described in Chapter 3 indicate the system will see a maximum operating pressure of approximately 85 psi in Zone 1 (at the RWQCP RWPS discharge) and approximately 125 psi in Zone 2 at the discharge site of the BPS. The Utility Standards require a pressure class of 200 psi or greater. Because of potential future uses for the Phase 3 system, this pressure class is appropriate to be consistent with the Utility Standards and to provide flexibility to modify Phase 3 operation.

5.3.3 Pipe Material and Size

Pipe material for open cut installation will be HDPE, except in areas of known soil contamination, which would require ductile iron pipe and fittings. Refer to Table 5-8 for other installation types and materials.

Minimum pipe size for the Phase 3 system will be 6-inch inside diameter, which equates to the minimum 8-inch size IPS (outside diameter) sizing required for water mains. The maximum pipe size is 16-inch inside diameter, which is a 20-inch DR 11 HDPE pipe size IPS.

5.3.4 Appurtenances

The Phase 3 distribution system will require various pipeline appurtenances to facilitate proper operation and facilitate maintenance and repairs. The following criteria will apply.

Line Isolation Valves

Line isolation valves will be provided at tees, crosses and at a maximum spacing to facilitate dewatering of the pipeline to perform maintenance and repairs. The valves will be gate valves as specified in the Utilities Standards. The maximum spacing will be 1,000 feet.

Blowoffs

Blowoffs provide a means to depressurize and dewater the pipeline. Blowoffs can also be used to turn over water in the system during periods of low or no flow to avoid water quality problems associated with high water age in the system. The blowoff is opened and the system is pressurized to push flow to the blowoff and to a discharge point on the sewer or tanker truck.

Blowoffs will be as defined in the Utility Standards and will be located at dead end pipelines and at strategic locations along the pipeline coincident with a larger sewer trunk.

Air Valves

Air valves are provided to manage air accumulation in a pressurized system and to allow air to enter or exit the pipeline system during draining or filling, respectively. Air valves are located at high points in the pipeline system. The three types of air valves are:

- Air Relief Valve (ARV): This valve type releases under system pressure small volumes of air that come out of solution in the recycled water and collects at a high point.
- Air and Vacuum Release Valves (AVAR): This type of valve allows large volumes of air to enter and exit the pipeline system during filling or draining, or in the event of a pipeline break or rupture to prevent the pipe from collapsing under vacuum pressure conditions.
- Combination Air Valves (CAV): This type of valve accomplishes both functions of the ARV and the AVAR.

5.3.5 Customer Connections

Recycled water services will consist of a service line from the recycled water main to the customer meter and meter box in accordance with the Utility Standards. Each service line size will be determined based on customer preferences and historic water use intended to be served with recycled water. Meter sizes will be sized to match the service line or smaller if the minimum demand warrants. Smaller meters are more accurate in registering low flows through the meters.

Approximate existing meter location data of customers was provided by the City in GIS shapefile format. The meter locations are displayed in the alignment drawings in Appendix L. Approximate service alignments are shown connecting the meters to the new recycled water pipeline in straight, perpendicular lines. These services locations and alignments will need refining once meter locations have been verified to avoid existing utility conflicts and tree roots (discussed in Section 5.3.6). The size of the existing customer services and meters is not known, thus the required size of each service cannot be determined at this time.

The customer list presented in Appendix B shows a total of 108 potential customers along the alignment. Several of these customers have multiple meters for potable, irrigation and industrial purposes. It is assumed that connection to existing irrigation meters can be done to avoid replacement of the meter. The remaining connections are assumed to require new meters. Recycled water service lines are required for all customer connections. Table 5-9 summarizes customers and meter requirements based on the City-provided water billing data. The service connection configurations will need to be verified in final design.

Table 5-9: Assumed Customer and Meter Connections

	Customers[1]	New Meters
Service to Existing Type W-7 Irrigation Meter (reuse existing meter)	60	0
Services Requiring New Meters and Meter Boxes	48	132
Total	**108**	**132**

Notes:
1. Several large customers have multiple irrigation meters serving a parcel

5.3.6 Installation Considerations

Construction of the Phase 3 pipelines will involve staking of the alignment, potholing of crossing and adjacent utilities, trenching, pipeline fusing and installation, backfilling and restoration of the roadway surface. These are briefly described below.

Preconstruction Potholing

Initial work in pipeline construction will involve staking the design alignment and performing potholing of existing crossing and adjacent utilities that could conflict with the design pipeline alignment. A USA call will be made requiring utility owners along the alignment to mark their underground facilities. Construction pot holes are then performed, typically using a small backhoe or vacuum methods, to expose the utility, which is then located by survey or other methods and verified against the design location. Adjustments to the pipeline alignment and profile can then be made where existing utilities, as verified through potholing, conflict with the design alignment and profile. All utilities crossing or within 4 feet of the design alignment will be potholed by the construction contractor.

Trenching

Once the design alignment and profile have been validated through potholing, the contractor can initiate trenching, which will be largely contained within City streets. The minimum trench section will be based on the Utility Standards, modified based on findings of a final design geotechnical investigation. Trenches for recycled water pipe will be overexcavated to provide a minimum 6-inch thick bedding for the flexible HDPE pipe. Where ground conditions are wet or unsuitable for proper pipe and backfill placement, the trench can be further overexcavated to stabilize the trench bottom using coarse drainrock material and filter fabric.

Pipe Stringing and Fusing

As trenching is being performed, HDPE pipe will be strung along the alignment and the fusing operation will commence a short distance behind the trench heading. HDPE pipe will be delivered by truck in approximately 40-foot lengths to remain within limitations for standard trucking.

Fusing can occur above the trench or in the trench using special equipment. All fused joints will be inspected and fusing date recorded to ensure quality. Once a suitable length of pipe has been fused, the pipe string will be placed into the trench. Field closures between successive pipe strings will be accomplished using electrofusion sleeve couplings. These will be allowed only to make field closures.

Trench Backfilling

Once the pipe is in place on the compacted bedding, backfilling around the pipe will commence. The backfill around the pipe from the bedding to 1-foot above the pipe (pipe zone) is the most critical for a flexible pipe material. Proper compaction around the lower half of the pipe (the haunches) must be obtained to limit the vertical and horizontal deflection of the pipe due to the trench backfill on top of the pipe and any live loading on the restored street above the pipe. A stiff backfill and stiff pipe wall soils allows the pipe to only deflect slightly to mobilize the soil strength to support the pipe. Improper compaction in this zone can allow excessive deflections, potentially resulting in trench settlement and excessive pipe deflection. Final design of the pipeline installation will address the trench wall soils (native) and appropriate backfill materials.

Backfill above the pipe zone will be placed and compacted to achieve a proper subgrade for street restoration.

Pavement Restoration

Pavement restoration will be performed once the pipeline has been fully backfilled and hydrostatically tested. When backfilling the trench is complete, temporary asphalt concrete (AC) will be placed for street surfacing. Once testing is complete and appurtenances are fully complete, the contractor will sawcut the edges of the trench to provide a line straight line, and remove or cold mill a T-cut portion of the plug and existing pavement in accordance with Utility Standards. Then a full AC pavement restoration will be constructed across the T-cut. During final design, the City may elect to do a wider pavement restoration, particularly in areas with poor existing pavement. This can be accomplished with additional cold milling and construction of an AC overlay across the milled section to maintain existing pavement grades.

Tree Roots

Tree roots encountered during construction of the pipeline will need to be protected to avoid damage and detrimental impacts to the trees health. Negative impacts on trees during construction can include mechanical injury to roots, and compaction of soil around roots, which can denigrate root function or inhibit growth of new roots. Although the proposed pipeline was located to stay clear of tree protection zones (TPZ) where possible, a number of trees are located in areas where alternative alignments were not practical. For areas where pipeline trenching is within the TPZ the City's Tree Technical Manual and Municipal Code Chapter 8.10.030 shall be adhered to. These sections provide required and recommended practices depending on the designation of the impacted tree. Consultation with the City's Urban Forestry Section will be initiated during final design

Utility Crossings

When crossing existing utilities, the proposed pipelines will rise or fall to achieve proper vertical clearances as stated in Section 5.1.2. The location, depth and size of the utility being crossed will be determined through research, and confirmed through potholing as described earlier. Structural support may be needed to stabilize and protect utilities where soil is disturbed underneath the utility. In areas where multiple utilities must be crossed, trenchless construction could be utilized to safely place the pipeline under the utilities.

5.3.7 Special Crossings

The proposed alignment includes multiple special crossings of highways, creeks, railways and thoroughfares. A complete accounting and discussion of special crossings can be found in Chapter 6.

5.3.8 Corrosion Considerations

As a part of the pipeline preliminary design, a desktop soil corrosivity study was conducted by JDH Corrosion Consultants, Inc. The results of the study are presented in the Corrosion Mitigation Technical Memorandum in Appendix N.

Available soil data collected from throughout the City of Palo Alto was examined, and each sample location was designated with a level of corrosivity based on the available data. The sample locations near the Phase 3 alignment were rated "corrosive." For the installation of the Phase 3 pipelines, cathodic protection would be required to provide adequate protection of the ductile iron fittings and valves on the HDPE pipe system, and any metallic piping and casings used for crossings and appurtenances. Galvanic cathodic protection is recommended, and would consist of galvanic nodes connected to buried metallic elements to deliver a constant current output to keep the piping component anodic compared to the cathodic sacrificial anode.

5.3.9 Traffic Control Considerations

An initial traffic control study was performed by Mark Thomas & Company, Inc. The results of the study are presented in the Traffic Control Study in Appendix O. The study focused on traffic control required for trenchless crossings along the alignment and a representative street intersection. Example diagrams of lane closures and traffic routing signage placement were also developed and are included in Appendix O.

5.3.10 Tree Considerations

A tree reconnaissance was conducted by RHAA to assist with alignment refinement and to help meet the requirements of the City's Tree Technical Manual. The Preliminary Tree Preservation Analysis is included as Appendix P.

The tree reconnaissance was conducted by identifying tree species and sizes from a distance during field visits. Trees were mapped and grouped into size group based on diameter-at-breast-height (DBH). Using the PG&E Tree Root Interference Assessment document as a guideline, appropriate offset distances were defined for the DBH categories. The proposed pipeline alignment was refined to minimize alignment placement within the offset distances determined for individual trees where practical. In areas where alignment relocation was not reasonable due to utility congestion within the street, trees were marked for potential impact mitigation or removal and replacement. A preliminary summary of trees potentially impacted along the alignment is provided in Table 5-10. Further work in assessing impacts to trees will be performed in final design.

Table 5-10: Preliminary Tree Preservation Analysis Summary

DBH (inch)	Trees to Remain	Trees Potentially Removed	Trees Potentially Impacted
3 – 11	908	3	6
12 – 24	1,290	5	16
25 – 36	564	3	5
36+	145	1	6
Total	**2,907**	**12**	**33**

5.3.11 Permitting Considerations

Environmental permitting will follow the required mitigation measures established in the 2015 EIR. The table from the EIR summarizing all identified potential impacts and the recommended mitigation measures has been presented in Appendix Q. This table includes details on potential impacts during construction of the pipeline, permits required, and mitigation measures that should be implemented to limit impacts to less than significant.

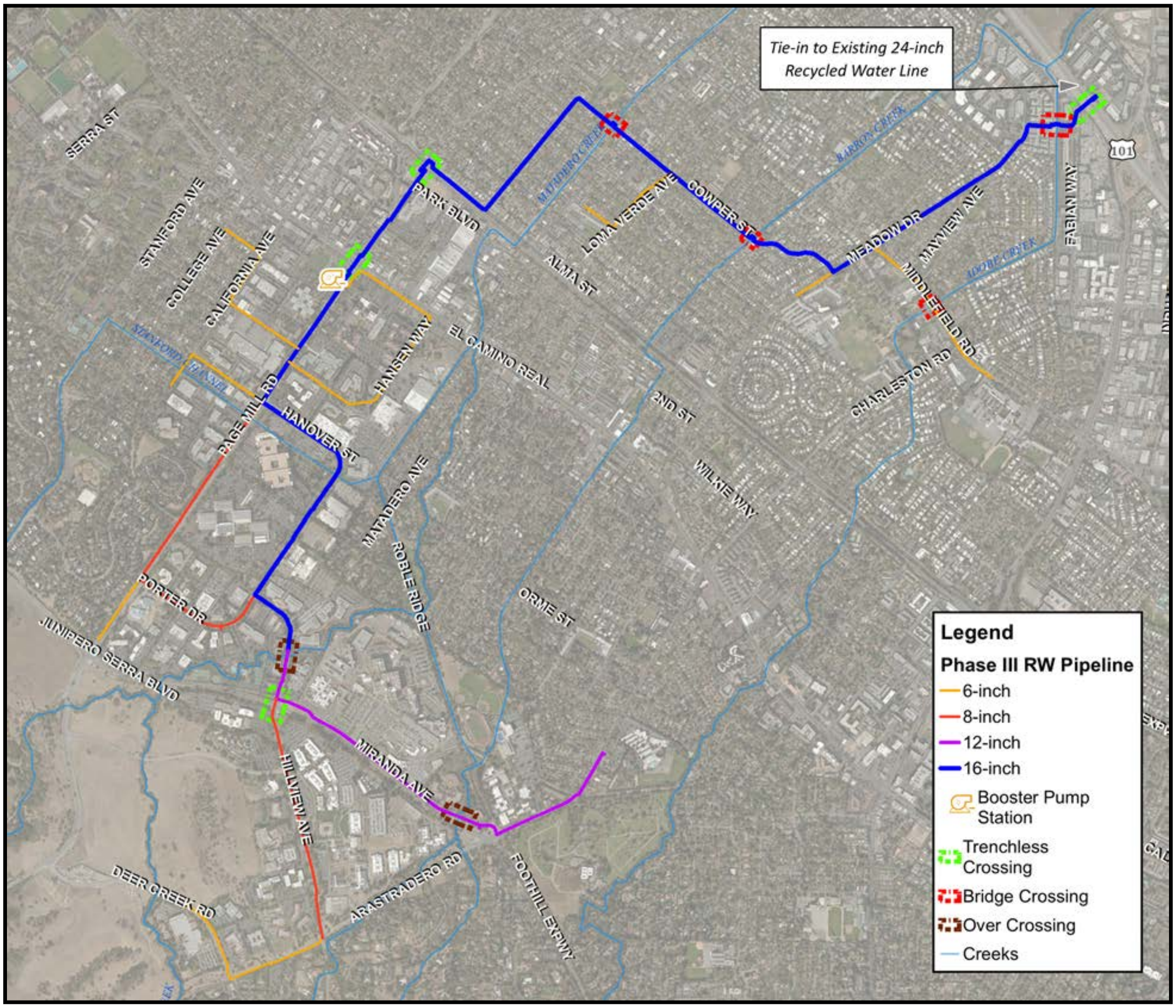
Chapter 6 Special Crossings Preliminary Design Development

The proposed Phase 3 pipeline alignment includes ten special crossings (e.g. bridge, creek, railroad). A range of crossing methods were evaluated to develop recommendations for the preferred crossing method at each location. Each special crossing was evaluated as a potential trenchless underground crossing. Where feasible, crossings were also evaluated for alternative, less costly construction methods.

The special crossing locations are listed below and shown in Figure 6-1 as well as individually on Drawings C-2 through C-9 in Appendix A:

- Caltrans Highway 101 at Corporation Way
- Adobe Creek, on East Meadow Dr. (downstream)
- Barron Creek, on Cowper St. (downstream)
- Matadero Creek, on Cowper St (downstream)
- Caltrain and Alma Street
- Caltrans Highway 82/ El Camino Real, on Page Mill Road
- Matadero Creek, on Hillview (upstream)
- Foothill Expressway, on Hillview
- Adobe Creek, on Middlefield Rd. (upstream)
- Barron Creek, on Miranda Ave (upstream)

Figure 6-1: Phase 3 Special Crossings



6.1.1 Geology and Geotechnical Information Research and Trenchless Installation Methods

A critical factor in selecting trenchless installation methods are the geologic conditions along the crossing, including the presence of groundwater. The following sub-sections detail the geologic conditions found along the pipe alignment and provide a subsequent analysis of the recommended crossing concepts.

Cal Engineering & Geology, Inc. (CE&G) performed a desktop review of available geotechnical and geologic data and information to summarize geological conditions at the ten special crossing locations. A Preliminary Geotechnical Data Report is included in Appendix H. The report also provides recommendations for geotechnical field investigation to support future design.

Based on the geologic and geotechnical conditions described in Appendix H, an initial assessment of potential feasible trenchless installation methods was developed by DCM Consulting, Inc. (DCM). The range of feasible trenchless construction methods are described in a technical memorandum in Appendix I and include the following:

- Conventional auger bore and jack for steel casing installation
- Pilot tube guided auger bore and jack for steel casing installation
- Pipe ramming for steel casing installation
- Pilot tube guided pipe ramming for steel casing installation
- Guided boring for steel casing installation
- Microtunneling for steel casing installation
- Horizontal directional drilling for direct HDPE installation
- Guided boring with Vermeer AXIS machine for direct HDPE installations greater than 12-inches inside diameter

6.1.2 Non-Trenchless Installation Methods

Where feasible, above-grade pipe bridges were considered as an alternative crossing method. Pipe bridges generally lower cost and allow for reduced permitting efforts and traffic control during construction compared to the trenchless methods. Separate pipe bridges and the use of existing bridges and culvert structures for hanging the pipe were considered. Where crossing over an existing culvert, open cut methods could be used if there is adequate cover over the box culvert.

6.1.3 Recommended Special Crossings Approach

The following sections describe the recommended approach for each special crossing. Crossing attributes such as settlement limitations, geotechnical setting, traffic, existing structure configuration and constraints, potential pit locations, and crossing lengths were considered to determine recommended crossing methods.

Caltrans Highway 101

The Highway 101 crossing, which spans from Corporation Way to the existing parking lot at Space Systems Loral is approximately 350 feet long. Trenchless undercrossing methods are required at this location to meet Caltrans requirements for utility crossings under freeways. Non-trenchless methods were not considered for this crossing.

Criteria driving the selection of trenchless construction methods includes settlement control within the Caltrans right-of-way, installation tolerance and ability to accommodate groundwater. Microtunneling offers the least risk for large settlements and is the recommended trenchless method for this crossing. The casing should be installed at a depth of cover of about 20 feet to limit surface settlement. The crossing would include a 36-inch steel casing with a 16-inch pipeline installed inside the casing.

Adobe Creek at East Meadow Drive

The crossing of Adobe Creek at East Meadow Drive is approximately 55 feet long. At this location, Adobe creek is a concrete-lined channel with 11-foot sidewalls. A trenchless crossing of Adobe Creek at Middlefield Road using horizontal directional drilling is recommended because of the length of the crossing and the geotechnical setting. The short length of the undercrossing allows for reduced layout areas for surface fusion of HDPE pipe. Since the creek channels are concrete lined, the risk for inadvertent fluid returns is reduced.

Due to the prioritization of non-trenchless methods, utilization of the East Meadow Drive Bridge structure is recommended as an alternative crossing method. The width of the bridge allows room for the pipeline to be installed between the roadway curb and the pedestrian sidewalk at grade over the bridge. A planter box could be constructed around the pipeline to cover and protect the pipe from damage.

Barron Creek at Cowper Street

The crossing of Barron Creek at Cowper Street is approximately 30 feet long. At this location, Barron Creek is a concrete-lined channel with 7-foot sidewalls. A trenchless crossing of Barron Creek at Cowper Street using horizontal directional drilling is recommended because of the length of the crossing and the geotechnical setting. The short length of the undercrossing allows for reduced layout areas for surface fusion of HDPE pipe. Since the creek channels are concrete lined, the risk for inadvertent fluid returns is reduced.

Due to the prioritization of non-trenchless methods, utilization of the Cowper Street Bridge structure is recommended as an alternative crossing method. It is recommended that the pipeline be hung from the side of the bridge via pipe supports. The pipeline material will be welded steel rather than HDPE to provide adequate structural support for hanging. Typical details for pipe bridge supports are shown in Drawing C-10 in Appendix A.

Matadero Creek at Cowper Street

The crossing of Matadero Creek at Cowper Street is approximately 35 feet long. At this location, Barron Creek is a concrete-lined channel with 12-foot sidewalls. A trenchless crossing of Matadero Creek at Cowper Street using horizontal directional drilling is recommended because of the length of the crossing and the geotechnical setting. The short length of the undercrossing allows for reduced layout areas for surface fusion of HDPE pipe. Since the creek channels are concrete lined, the risk for inadvertent fluid returns is reduced.

Due to the prioritization of non-trenchless methods, utilization of the Cowper Street Bridge structure is recommended as an alternative crossing method. It is recommended that the pipeline be hung from the side of the bridge via pipe supports. The pipeline material will be welded steel rather than HDPE to provide adequate structural support for hanging. Typical details for pipe bridge supports are shown in Drawing C-10 in Appendix A.

Caltrain and Alma Street

The crossing of Caltrain and Alma Street which spans from the northern side of Alma to the open lot on Page Mill Road, is approximately 200 feet long. Trenchless undercrossing methods are required at this location due to meet Caltrain requirements for utility crossings under railroad rights-of-way. Other criteria driving the selection of trenchless construction method include settlement control within the Caltrain right-of-way, installation tolerance and ability to accommodate groundwater. Microtunneling offers the least risk for large settlements and is the recommended trenchless method for this crossing. The casing should be installed at a depth of cover of about 20 feet to limit surface settlement. The crossing would include a 36-inch casing with a 16-inch pipeline installed inside the casing.

Non-trenchless methods were not considered for this crossing.

Caltrans Highway 82 (El Camino Real) at Page Mill Road

The crossing of Caltrans Highway 82 (El Camino Real), which spans from the planter area on the northern side of Page Mill to the planter area of the Stanford/Palo Alto Community Playing Fields, is approximately 150 feet to 250 feet long, depending on traffic control constraints on Page Mill Road. Microtunneling offers the least risk for large settlement and is the recommended trenchless method for this crossing. The pipeline should be installed within a casing at a depth of cover of about 20 feet to limit surface settlement. The crossing would include a 36-inch casing with a 16-inch pipeline installed inside the casing.

If allowed by the City and Caltrans, open-cut trench methods could be considered for the El Camino Real crossing. This would require traffic control to limit traffic disruption on the busy thoroughfare. This crossing could potentially be performed as night work to reduce traffic impacts.

Matadero Creek at Hillview Avenue

Matadero Creek transitions to a 15-foot deep pipe culvert at Hillview Avenue. It is recommended that the pipeline be installed via open-cut trench over the Matadero Creek culvert to reduce costs that would be involved with trenchless undercrossing of the culvert. If the clearance above the culvert to the road surface is not adequate to fit the RW pipe, the alignment could be located in the sidewalk at the crossing location to construct a planter box similar to the bridge crossings to cover and protect the pipe from damage.

Foothill Expressway at Hillview Avenue

The crossing of the Foothill Expressway is approximately 300 to 400 feet long as a function of traffic control restraints on Hillview Avenue. The assessment of subsurface conditions presents a variety of viable trenchless methods for this crossing, including conventional auger bore and jack, microtunneling, and horizontal directional drilling. This crossing also includes the crossing of SFPUC's Bay Division Pipeline, which runs parallel to Foothill Expressway on the northern side. The length of the crossing is driven by existing utility congestion within the intersection as well as distance needed to provide adequate vertical clearance below the Bay Division Pipeline. The recommended method for the trenchless undercrossing of Foothill Expressway is horizontal directional drilling. Horizontal directional drilling also provides the flexibility to change the direction of the horizontal alignment between the entry and exit points of the crossing, which may be necessary to avoid conflict with existing utilities within Foothill Expressway.

Alternatively, Foothill Expressway could be crossed using the conventional auger bore and jack method with a shorter crossing length. This would require the jacking and receiving pits to be located closer to the intersection, possibly occupying the turning lanes on Hillview Avenue. This would require traffic control to limit traffic disruption on the busy thoroughfare.

Non-trenchless methods were not considered for this crossing.

Adobe Creek at Middlefield Road

The crossing of Adobe Creek at Middlefield Road is approximately 40 feet long. At this location, Adobe Creek is a concrete-lined channel with 10-foot sidewalls. A trenchless crossing of Adobe Creek at Middlefield Road using horizontal directional drilling is recommended because of the length of the crossing and the geotechnical setting. The short length of the undercrossing allows for reduced layout areas for surface fusion of HDPE pipe. Since the creek channels are concrete lined, the risk for inadvertent fluid returns is reduced.

Due to the prioritization of non-trenchless methods, utilization of the Middlefield Road Bridge structure is recommended as an alternative crossing method. The width of the bridge allows room for the pipeline to fit between the roadway curb and the pedestrian sidewalk at grade over the bridge. A planter box could be constructed around the pipeline to cover and protect the pipe from damage.

Barron Creek at Miranda Avenue

Barron Creek transitions to a 12-foot deep pipe culvert at Miranda Avenue. It is recommended that the pipeline be installed via open-cut trench over the Barron Creek culvert to reduce costs that would be involved with trenchless undercrossing of the culvert. If the clearance above the culvert to the road surface is not adequate to install the pipe with sufficient cover, the alignment could be located adjacent to the sidewalk at the crossing location to construct a planter box to cover and protect the pipe from damage.

Chapter 7 Cost Estimate

7.1 Basis for Estimate

This Section provides an overview of the approach and methodology used to develop the estimate of probable construction costs for the baseline Phase 3 project. The estimated costs represent the Engineer's opinion based on the current state of development for the project components. Specific information on the unit costs and source for each element is identified in the unit cost spreadsheets that are part of the detailed cost estimate provided in Appendix J.

7.1.1 Cost Estimate Classification

The Association for the Advancement of Cost Engineering International (AACE International) has developed a cost estimate classification system that provides guidelines for applying the general principles of estimate classification to project cost estimates. The five estimate classes are presented in AACE International Recommended Practice No. 56R-08 (Cost Estimate Classification System – As Applied for the Building and General Construction Industries). The guideline establishes a relationship between the project maturity (i.e. project definition as percent of complete definition) and the accuracy and methodology used to produce the cost estimate. Based on the level of project definition, the cost estimates developed for this Report are Class 3 as defined by Publication 56R-08. The accuracy range for a Class 3 estimate is between 10% below and 10% above expected average bid cost.

7.1.2 Cost Estimating Approach

Cost estimates have been developed based on preliminary facility layouts and design criteria for the pump stations and special pipeline crossings. The pipeline costs represent the facilities presented in the 2008 Facility Plan, except for additional pipeline length and revised sizing. The unit cost for pipeline open cut construction has been updated to reflect current pricing. Construction costs were estimated using unit costs developed from past construction projects, industry costs estimate resources (primarily RS Means 2017 Heavy Construction Cost Data) as well as engineering allowances based on judgement and previous project experience. O&M costs are based on estimated labor hours, consumables, significant regular O&M activities (e.g. recoating of exposed metallic surfaces) and power costs.

7.1.3 Raw Construction Cost

Raw construction costs are estimated by major work or component line item based on a unit cost multiplied by estimated quantity taken from the preliminary design drawings. Unit costs were developed using:

- RS Means Heavy Construction Cost Data, 2017 (RS Means);
- Manufacturer's equipment proposals; and
- Experience with prior projects and activities of similar size or configuration.

Historic unit cost or out-of-area unit cost information was adjusted to August 2017 dollars for the project vicinity using Engineering News Record's (ENR) Construction Cost Index (CCI) and the RS Means Location Factor.

7.1.4 Cost Estimate Benchmark Index

The Phase 3 construction cost estimate presented herein is benchmarked to ENR CCI for San Francisco. The estimate is in August 2017 dollars, with and ENR CCI SF index of 12,037.

7.1.5 Construction Cost Allowances and Contingencies

From the raw construction cost subtotal, several construction cost factors are applied to develop an estimated total construction cost. The construction cost factors used are listed below.

- **9% Sales Tax on Materials.** A Class 3 estimate uses installed unit cost metrics that include both raw materials and installation (i.e. labor, materials and equipment). Sales tax on materials was estimated as 9.0% (local sales tax) applied to 50% of Divisions 2-17 cost. The assumption is that materials and equipment represent 50% of the raw construction cost.
- **30% Construction Contingency.** The construction contingency is defined as unknown costs due to incomplete engineering during the preliminary design phase and uncertainty about full scope of the project. The contingency reflects the upper bound accuracy range for this Class 3 estimate. As design development proceeds, the contingency should be reduced and at the completion of design, only a change order allowance should remain. The contingency is applied to the construction cost subtotal that are estimated as a percentage of defined project costs (i.e. raw construction cost subtotal). As the level of project definition and understanding increases and the level of unknown decreases, the construction contingency typically decreases. For this report, a construction contingency of 30% was applied to the raw construction cost estimates.
- **10% Market Adjustment Factor**– This project is expected to begin construction in 2019. To account for bidding market price increases, a Market Adjustment Factor of 10% has been applied.

7.1.6 Capital Cost Allowances

- **Addenda to EIR.** An Environmental Impact Report (EIR) has been developed for the pipeline associated with this project [2]. An addendum to the EIR will be necessary due to adjustments made to the project during this preliminary design phase. A lump sum amount of $100,000 was applied to as an allowance to cover an EIR addendum.
- **15% Engineering Services (Design) & Administration Services.** Engineering services include field investigations (e.g. surveys, geotechnical reports, hazardous materials investigations), final design, contract document development (i.e. plans and specifications), preparation of detailed cost estimates, and project scheduling. Administration costs include the City's project management and staff time. An engineering and City administrative services allowance of 15% was applied to the total construction cost.
- **10% Construction Management.** Costs for construction management, including inspection, can vary greatly with project size and complexity and whether the Owner performs this work with in-house staff or through a consultant. A construction management factor of 10% was applied to the total construction cost.
- **3% Engineering Services During Construction.** Engineering services during construction (ESDC) includes submittal and request for information (RFI) reviews, design clarifications, and startup support services. An ESDC factor of 3% was applied to the total construction cost.

7.1.7 Operations and Maintenance (O&M) Costs

Operations and maintenance (O&M) requirements were derived from experience on similar projects. Annual O&M unit costs were developed based on experience and input from the City. The three components used to develop annual O&M costs were:

- **Labor** – Labor costs associated with the system O&M is calculated on an hourly basis. The required labor hours are estimated based on experience. The average hourly cost of an O&M personnel, which includes all wages and benefits to the operator, is assumed to be $100 per hour.
- **Power** – Palo Alto's electric rate E-7-1 (Large Commercial, Effective 7-1-17) covers the RWPS and is included in Table 7-1 for FY2018. Energy costs are a combination of an energy charge (per kWh) and a demand charge (per kW). Equipment and systems that consume small amounts of energy relative to compared to pumping equipment, such as lighting and valve actuators, are not included.

Table 7-1: Palo Alto's Electric Rates

Effective 7/1/17	Cost	Unit
Summer energy charge (kWh)	$0.10	kW-hour
Winter energy charge (kWh)	$0.07	kW-hour
Summer demand charge (kW)	$ 23.84	kW
Winter demand charge (kW)	$ 15.59	kW

- **Consumables** - Consumables are a major component of operational expenditures and include resources that are intended and expected to be used and replaced routinely. Consumable costs were estimated as a percentage of the raw construction cost. The annual consumable costs, as percentages of raw construction cost for each construction division, Equipment, Mechanical, Electrical, and Instrumentation and Controls are each 2 percent of the raw construction cost. These consumable costs are not applied to the pipeline portion of the project.

The O&M costs presented in this preliminary design report do not include initial utility set-up costs that the City will incur to set up its recycled water utility. The City should review utility set up costs with the Utilities Department and account for this in budgeting for implementation of the Phase 3 project.

7.1.8 Pipeline Construction

Pipeline construction and O&M costs have been developed for the Project as described in the following sections. Pipeline capital costs include both open-cut and trenchless construction elements of the Phase 3 project.

Pipeline Construction Cost – Open Cut

A pipeline cost estimating tool was used to generate unit costs for underground pipeline construction for pipelines ranging in size from 6- to 16-inch (nominal diameter) assuming an average of 5-foot depth of cover, in urban settings. The estimating tool uses the following to develop installed unit costs:

- Engineering experience and historic bid price data for HDPE pipelines, appurtenances, traffic control, potholing, cathodic protection, excess soil disposal tipping fees, urban setting production rates
- RS Means unit costs for trench shoring, excavation and backfill; backfill compaction; pavement, grinding and milling, aggregate base and pavement restoration; valves, haul to disposal, labor/installation, and dewatering

The tool contains various input parameters including, depth of cover, type of trench backfill and source (i.e. import vs. native material), condition of soil (i.e. clean vs. contaminated), percentage of backfill to be imported, amount of traffic control needed (i.e. none, light, or heavy), percentage of alignment requiring dewatering, production rate, and valve and pothole frequency. Using these inputs, the tool estimates the construction quantities related to buried piping (i.e. excavation volume), and subsequently, the associated unit cost per length of pipe.

For this project, the conveyance pipe material is assumed to be HDPE DR 11 pipe. A range of pipeline unit costs for HDPE sizes 6- to 16-inch nominal diameter are shown in Table 7-2.

Table 7-2: Unit Cost of HDPE Pipe

Nominal Pipe Size	Unit Cost ($/LF)
6-inch	$173
8-inch	$186
12-inch	$236
16-inch	$283

Assumptions:

- Pipeline is in an urban setting
  - AC pavement replacement would be the width of the trench plus 6-inches on each side
  - Heavy traffic control required
  - One pothole per 100 LF of pipe required
- Average depth of cover of 5 feet
- 100% of soil excavated is hauled to a landfill or reused offsite and 100% of soil required for backfill is imported
- Isolation valves and other appurtenances amount to 15% or the pipeline material costs
- No or minimal dewatering for open cut construction
- Production rate ranging from 100- to 150-linear feet of pipeline construction per day depending on pipeline size

Pipeline Construction Cost – Trenchless Installation

Table 7-3 summarizes the unit costs used for trenchless construction. These costs were developed based on a collection of past project experience using microtunneling and HDD crossing technology.

Table 7-3: Microtunnelling and HDD Costs

Element	Unit	Unit Cost
Microtunnel Launch Pit	lump sum	$300,000
Microtunnel Receiving Pit	lump sum	$150,000
Microtunnel Casing and Pipe (36-inch)	Linear foot	$1,728
HDD (24-inch bore diameter)	Linear foot	$528

Other special crossings at creeks include placement of pipeline above ground within planter boxes on bridge sidewalks and hanging pipeline on the sides of bridges. Costs for planter box crossings included an estimated quantity of concrete to be used labor for a concrete crew. Crossings by hanging pipe on the side of bridge include a lump sum estimate per support in addition to steel pipe unit costs per length of the crossing.

Customer Connections

Due to the lack of information available on customer meters, a number of assumptions were made for estimating the cost of customer connections for the Phase 3 Recycled Water system.

Table 7-4 presents the unit costs used for the recycled water service connections. Conservative assumptions were developed to account for the uncertainty in the number, size and location of connections. The unit costs include labor, material and equipment cost for the following:

- An average 4-inch diameter service line from the distribution main to the meter
- Appurtenances include tapping valves and fusion saddles and an allowance for pressure relief valves where necessary
- Allowance for hardscape and turf restoration as necessary

- Where required, a 4-inch compound meter, meter box, and meter valves
- No allowance has been made for any required customer on site retrofits needed to accommodate recycled water service.

Table 7-4: Customer Service Costs

Element	Service Size	Unit	Quantity	Unit Cost
Customer Service (Existing meter reused)	4-inch	Each	62	$10,000[1]
Customer Service (New meter required)	4-inch	Each	132	$15,000

1. Unit costs taken from bid price data from the City of Pleasanton Recycled Water Infrastructure Expansion (2015 bid date).

7.1.9 RWQCP RWPS Construction

Equipment

Pump costs were developed from budgetary quotes obtained from manufacturers for equipment that meets the pump and VFD specifications of the existing equipment. For the pump station equipment, an installation cost of 30% of the quoted equipment cost was used.

Piping, Fittings, Valves

Preliminary pump station layouts were used to estimate quantity take-offs for pipeline length and valves. Cost for valves and pipe were obtained from RS Means, while a miscellaneous piping and valve allowance of $35,000 was included in the estimate. Mechanical and site work items were estimated using adjusted RS Means data.

Electrical and I&C

An estimate was prepared for electrical and controls systems for the RWPS based on vendor quotes, RSMeans unit cost data, and engineering allowances. Refer to Appendix J for additional information.

O&M: Labor, Electricity, and Consumables

Operators are expected to regularly inspect pump stations to exercise valves, inspect pumps, and generally inspect the condition and operation of equipment. This cost estimate assumes 2 hours per working day of the year (520 hours) to inspect the pump stations. Labor associated with replacing consumables is accounted for under consumables costs. Pump station consumables were estimated based on the allowances provided in Section 7.1.7.

RWQCP power consumption was estimated by assuming the pump station delivers 810 AFY over 365 days per year for 8 hours a day at a constant flow rate of 1,637 gpm and constant head of 200 feet. The cost of power is as described in Section 7.1.7.

7.1.10 BPS

Equipment

Pump station skid package costs were developed from budgetary quotes obtained from pump manufacturers. For the pump station skid package, an installation cost of 30% of the raw equipment cost was used in the cost estimate.

Allowances have been provided for ventilation and sump pump equipment based on prior project experience.

Piping, Fittings, Valves

Most of the pipe and valves for the BPS would be included in the pump station skid package cost. Additional piping, valves and appurtenances shown in the layout drawings have been estimated using RS Means 2017 Heavy Construction Cost Data (RS Means) source and a miscellaneous piping and valve allowance of $25,000.

Vault Structure

The vault structure estimate is based on concrete takeoff volumes and unit costs from current construction projects for slab on grade, vertical wall and suspended slab concrete components. Allowances for railings, hatches and miscellaneous structural elements have also been applied to the construction cost estimate.

Site Work

Site work elements have been itemized by line item and unit costs applied using RS Means.

Electrical and I&C

An estimate was prepared for electrical and controls systems for the RWPS based on vendor quotes, RSMeans unit cost data, and engineering allowances. Refer to Appendix J for additional information.

O&M: Labor, Electricity, and Consumables

Operators are expected to regularly inspect the BPS to perform regular inspections and maintenance work, exercise valves, and review BPS monitoring data and trends. An average daily labor usage of 2 hour per working day of the year (520 hours) is assumed for the O&M cost of the BPS. Labor associated with replacing consumables is accounted for under consumables costs. Pump station consumables were estimated based on the allowances provided in Section 7.1.7.

BPS power consumption was estimated by assuming the pump station operates to deliver 697 AFY over 365 days per year for 8 hours a day at a constant flow rate of 1,408 gpm and a constant head of 198 feet. The cost of power is as described in Section 7.1.7.

7.2 Engineer's Opinion of Probable Cost Summary

Table 7-5 below provides a summary of probable capital and O&M costs for the proposed project.

Table 7-5: Summary of Engineer's Opinion of Probable Capital O&M Costs[3]

		RWQCP Pump Station Improvements	Booster Pump Station	Distribution Pipeline	Total
Capital Costs					
Construction Cost Estimate		**$1,292,000**	**$854,000**	**$22,294,000**	**$24,440,000**
Tax on Materials (Applied to half of subtotal)	9%	$53,000	$35,000	$881,000	$967,000
Construction Cost Subtotal		**$1,300,000**	**$900,000**	**$23,200,000**	**$25,400,000**
Market Adjustment Factor	10%	$130,000	$90,000	$2,320,000	$2,540,000
Construction Contingency	30%	$390,000	$270,000	$6,960,000	$7,620,000
Addenda to EIR	-	$-	$-	$100,000	$100,000
Engineering and Administration (Design)	15%	$195,000	$135,000	$3,480,000	$3,810,000
Construction Management	10%	$130,000	$90,000	$2,320,000	$2,540,000
Engineering Services During Construction	3%	$39,000	$27,000	$696,000	$762,000
Total Capital Cost		**$2,200,000**	**$1,500,000**	**$39,100,000**	**$42,800,000**
Annual O&M Costs[4]					
Consumables and Materials (Equipment, Mechanical, Electrical, I&C)		$21,000	$9,000	$-	$30,000
Power		$23,000	$20,000	$-	$43,000
Labor		$52,000	$52,000	$43,000	$147,000
Total O&M		**$100,000**	**$80,000**	**$40,000**	**$220,000**

Notes:

1. Subtotal rounded to nearest hundred thousand
2. Energy is from Palo Alto and provided at an electric rate E-7-1 (Large Commercial, Effective 7-1-17). Energy costs are a combination of an energy charge (per kWh) of $0.10/kWh in the summer and $0.07/kWh in the winter, and a demand charge (per kW) of $23.84/kW in the summer and $15.59/kW in the winter.
3. Costs are in August 2017 dollars. Benchmark for estimate is the ENR CCI SF at 12,037.
4. O&M costs do not include utility set up costs to establish a recycled water utility business.

Chapter 8 Environmental Considerations

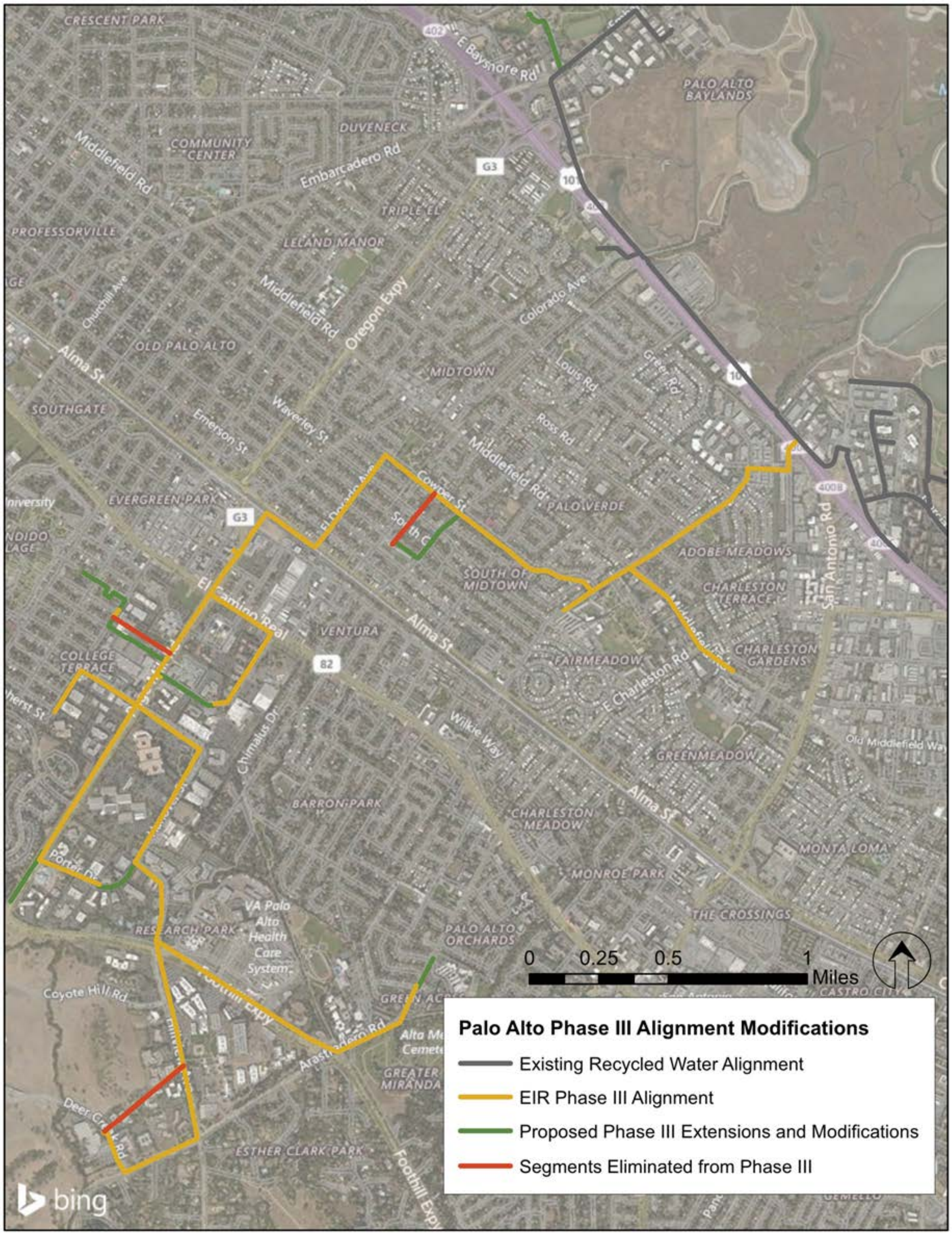
8.1.1 2015 EIR Coverage

The alignment presented in this Preliminary Design Report has been refined and expanded from the alignment presented in the 2008 Facilities Plan and 2015 EIR. The modified portions of the alignment will require an assessment of environmental impacts to consistent with the level of assessment conducted for the 2015 EIR. These modifications are presented in Figure 8-1 and summarized below:

- An extension of the recycled water distribution system at Embarcadero Road. The alignment modification is not analyzed in this report since a separate analysis of the extension was presented in the Preliminary Design Technical Memorandum submitted on January 20, 2017.
- The backbone alignment was extended from Arastradero Rd and Hubbartt Dr to Arastradero Rd and Terman Dr, where a service line can be placed to reach Terman Park.
- The lateral connecting the backbone alignment at Cowper Street directly to El Carmelo Elementary School was replaced with a lateral that travels south on Loma Verde Ave and turn northwest on Bryant St to reach the school.
- The lateral on El Camino Real and Hansen Way was extended to loop back with the backbone alignment at Page Mill Rd and Hansen Way.
- The lateral from Page Mill to California Ave and Cornell St was shifted south to avoid current buildings, and extended to Wellesley St in order to reach Cameron Park.
- The lateral on Page Mill Rd and Porter Dr was extended to loop back with the backbone alignment at Hanover St and Hillview Ave.
- A lateral was added to the lateral at Page Mill Rd and Porter Dr extending southwest on Page Mill Rd to north of Foothill Expy.
- The lateral looping with the lateral ending at Deer Creek Rd was removed.

Additionally, an alignment modification that was identified in the Business Plan as requiring further EIR assessment was removed from the alignment proposed in this report. The lateral at Deer Creek Rd was extended to the driveway of a potential customer. However, upon review of approximate meter locations, the extension of the lateral was determined to be unnecessary. This portion of the alignment no longer needs additional EIR assessment.

Figure 8-1: Alignment Modifications from 2015 EIR



8.1.2 Required Supplemental CEQA Documentation

The proposed modifications from the 2015 EIR project description consist of extensions and realignments within City streets. These modifications result in the same environmental impacts as identified in the 2015 EIR and no new impacts are likely. As such, an amendment to the EIR is justified to document the modified project and its incremental changes in impacts. This amendment does not need public circulation and is adequate under CEQA.

8.1.3 Environmental and Construction Permitting Requirements

The Phase 3 recycled water project will require certain permits. Permitting requirements have not been fully defined through preliminary design but may include those listed below. Further development of the design and consultation with the permitting agencies is needed to identify the specific permitting needs and related permit requirements for construction of the Phase 3 project.

Environmental permits for the Phase 3 project could include:

- 401 Water Quality Certification from the Regional Water Quality Control Board (RWQCB)
- Stream Alteration Agreement from California Department of Fish and Wildlife (CDFW) for creek crossings

Construction permits for the Phase 3 project could include:

- Utilities Encroachment Permit from the State of California Department of Transportation (CalTrans)
- Encroachment Permit from the City of Palo Alto
- Construction and Maintenance Agreement with the Peninsula Corridor Joint Powers Board (Caltrain)
- Encroachment Permit from Santa Clara County
- Encroachment Permit from San Francisco Public Utilities Commission (SFPUC)
- Encroachment Permit from the Santa Clara Valley Water District (SCVWD)
- Easement Agreement from Stanford University

Chapter 9 Next Steps

The following items are identified as steps that will need to be addressed in the next phases of design:

- Further clarification is needed for defining the division of responsibilities for operation of the system between the City's Public Works department and Utilities department.
- The operational costs presented in this preliminary design report account for labor associated with operations and maintenance of the system. They do not account for costs associated with setting up and running the recycled water utility business or other administrative labor components. These costs should be accounted for by the City.
- The Phase 3 recycled water system presented in this preliminary design report provides redundancy in pump components for increased system reliability. The design does not provide for emergency power because of its non-life critical function. Factoring additional redundancies into the design may be needed based on the City's policy decisions related to minimum levels or service for customers. Communication with customers will help determine the system requirements.
- The RWPS and the BPS must be linked via a telemetry network to allow for synchronized and integrated operations. Data and control telemetry will need to be accounted for in future design.
- Pipe routing for the RWPS at the RWQCP will need to be coordinated with the new RO facility planned at the RWQCP.
- Pipeline alignment final design will need to be coordinated with the City's WGW Utility department to avoid construction within corridors reserved for future water line replacements. Potential efficiency can include construction of the new recycled water pipeline in corridors occupied for replaced water lines.
- Customer connection information is currently limited. The cost allocation amount is conservative to reflect the potential costs given the number of unknowns. The question of which parties would be financially responsible for the new meters is a policy decision, and will need to be addressed by the City.

References

[1] RMC, 2008. *City of Palo Alto Recycled Water Facility Plan*. December, 2008.

[2] RMC, 2015. *City of Palo Alto Recycled Water Project Environmental Impact Report*. July, 2015.

[3] City of Palo Alto, 2017. *Amendment No. 1 to the First Amended and Restated Contract No. C059999 Between the City of Palo Alto and the City of Mountain View*. August, 2017.

[4] Engelage, Samantha, Email to Mike Matson providing timeline for Advanced Water Purification Project. October 12, 2017.

[5] United States Geologic Survey. https://earthexplorer.usgs.gov/