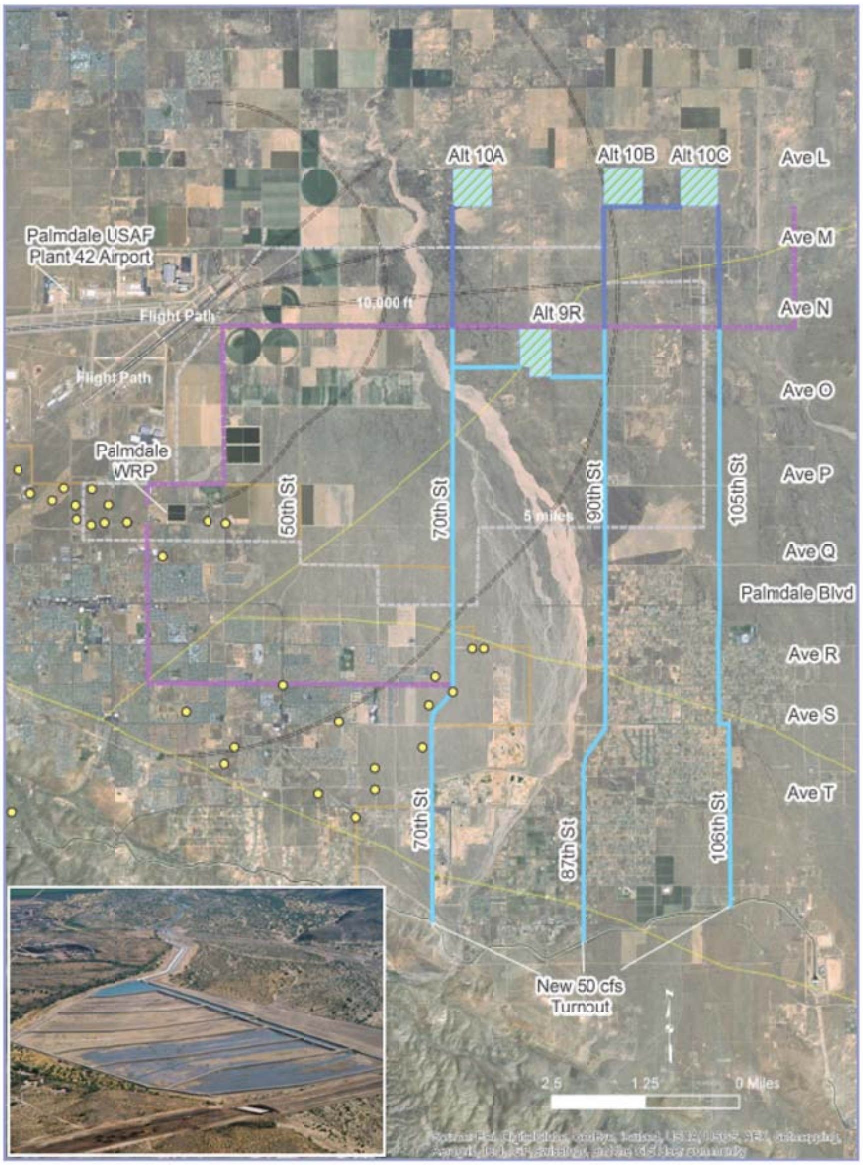
Palmdale Water District
Littlerock Creek Groundwater Recharge and Recovery Project Feasibility Study

Volume I - Final Report | February 6, 2015



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Littlerock Creek Groundwater Recharge and Recovery Project

Final Report

06 February 2015

Prepared for

Palmdale Water District
2029 East Avenue Q
Palmdale, CA 93550

K/J Project No. 1344505*00

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List of Acronyms

$/AF	dollars per acre-foot
AE	Applied Earthworks, Inc.
AF	acre-feet
AF/yr	acre-feet per year
AFY	acre-feet per year
AVGB	Antelope Valley Groundwater Basin
Basin	Antelope Valley Groundwater Basin
bgs	below ground surface
BO	biological opinions
CDFW	California Department of Fish and Wildlife
CDPH	California Department of Health
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
CO_2	carbon dioxide
CWA	Clean Water Act
DDW	Division of Drinking Water
Delta	Sacramento–San Joaquin Delta
District	Palmdale Water District
DWR	California Department of Water Resources
ea	each
EM	effluent management
FAA	Federal Aviation Administration
FESA	Federal Endangered Species Act
fpd	feet per day
fps	feet per second
ft msl	feet above mean sea level
ft	feet
FTE	full-time equivalent
GAC	granular-activated carbon
gal	gallons
GAMA	Groundwater Ambient Monitoring and Assessment Program

GHG	greenhouse gas
gpm	gallons per minute
Helix	Helix Environmental Planning
HFB	horizontal flow barrier
hp	horse power
hypo	hypochlorite
IBS	Interbed Storage
IPR	indirect potable reuse
JPA	Joint Powers Authority
kW	kilowatt
kWh	kilowatt hour
LACSD	Los Angeles County Sanitation District
LADWP	Los Angeles Department of Water and Power
LAWA	Los Angeles World Airports
lb	pound
LCGRRP	Littlerock Creek Groundwater Recharge and Recovery Project
LF	linear foot
LOCWTP	Leslie O. Carter Water Treatment Plan
MCL	maximum contaminant level
MDD	maximum daily demand
mg/L	milligrams per liter
mgd	million gallons per day
MODFLOW	modular finite-difference flow model
MOU	Memorandum of Understanding
NMFS	National Marine Fisheries Service
O&M	operation and maintenance
PHAST	A Computer Program for Simulating Groundwater Flow, Solute Transport, and Multicomponent Geochemical Reactions
PHREEQC	A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations
PHPP	Palmdale Hybrid Power Plant
ppd	pounds per day
PTRR	Percolation Test Results Report
PWD	Palmdale Water District

ROI	return on investment
RWC	recycled water contribution
RWQCB	Regional Water Quality Control Board
SCE	Southern California Edison
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TM	Technical Memorandum
TMR	telescopic mesh refinement tool
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAAC	Wildlife Attractants Advisory Circular
WRP	Water Reclamation Plant
WTP	water treatment plant

Executive Summary

The overarching goal of the Littlerock Creek Groundwater Replenishment and Recovery Project (LCGRRP) Feasibility Study is to investigate the feasibility of a groundwater banking, storage, and extraction program on behalf of the Palmdale Water District (PWD or District). The selected project alternative will help meet future water demands and improve water supply reliability. New facilities will be constructed to recharge and recover State Water Project (SWP) water as well as recycled water. Infrastructure will include new spreading grounds to recharge water as well as recovery facilities. Recycled water will be replenished continuously with surplus SWP water stored during normal and wet years allowing for the efficient utilization of SWP water when available. The recovery of potable groundwater would also be continuous as a base flow potable water supply at production rates to enable PWD to meet all future water demands when combined with existing supply facilities.

Projected Water Demands & Supplies

PWD serves a combination of residential, commercial, and industrial users, with essentially no agriculture. Their current system provided approximately 23,000 AF/yr in 2013 and 2014. Table ES-1 provides a water demand projection for PWD's service area, based on a preliminary draft version of PWD's Water Master Plan, which is currently being updated. A land use analysis indicates that demand will be 44,600 AF/yr under buildout conditions. By 2040, demand is projected to be 31,100 AF/yr. For the 50-year financial analysis of the LCGRRP from 2018 through 2067, the demand in 2067 is projected to be 39,160 AF/yr.

Table ES-1: Projected Retail Demands

Year	Annual Average Demand (AF/yr)
2015	24,809
2020	25,900
2025	27,200
2030	28,500
2035	29,800
2040	31,100
2045	32,457
2050	33,873
2055	35,350
2060	36,892
2065	38,502
2070	40,181
2075	41,934
2080	43,764
Buildout	*44,600*

Existing supply is acquired from SWP allocation, local surface water, and groundwater. However, the Basin has been in an overdraft condition (i.e., pumping greater than natural recharge) since approximately 1930. As a result, groundwater sources are in the midst of an adjudication process. Based on feedback from District staff, it is assumed that the District will receive a groundwater right of 7,200 AF/yr effective in 2022, with a four-year tapering period prior to this year. Assuming the District receives the projected average allocation of 58% of its 21,300 AF/yr Table A Amount from the SWP (12,354 AF/yr) and 4,000 AF/yr of local surface water, then it will begin to face a deficit by 2021. By 2040, it is estimated that the deficit will reach approximately 7,500 AF/yr. By 2067, this deficit would reach approximately 15,600 AF/yr, and at buildout this deficit would reach 21,000 AF/yr. Without long-term water supply storage, in dry years when the SWP allocation is less than 58%, these deficits would be much larger.

Based on an optimization analysis of water treatment plant utilization as it relates to the capacity of the water bank, it is determined that moderate utility of the water treatment plant, defined as serving 25 percent of overall water demand, provides the optimal water supply mix that maximizes utility of existing facility assets and minimizes future additional Table A purchases.

Figure ES-1 presents the projected annual water supplies and demand under long-term average hydrological conditions.

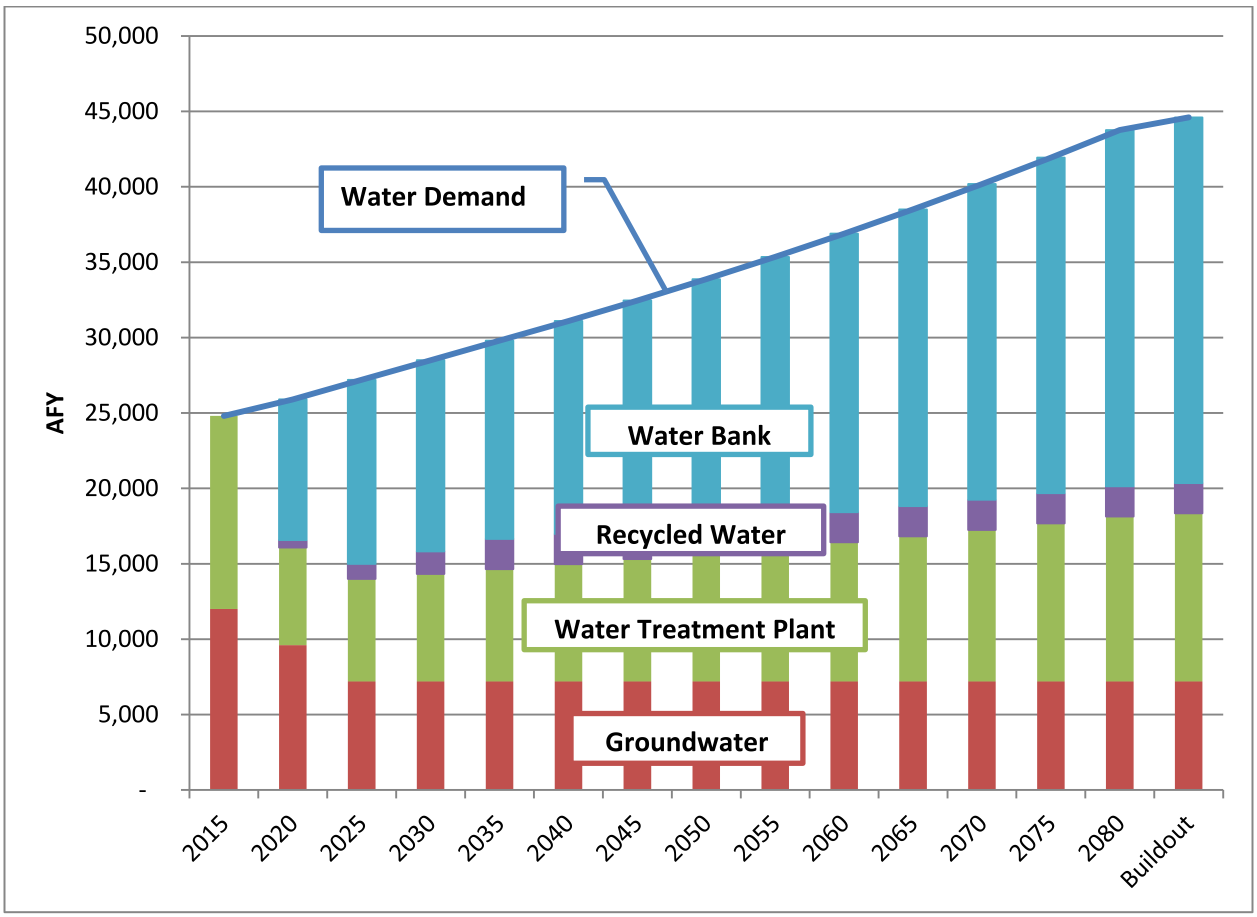


Figure ES-1: Projected Annual Water Supplies & Demand

Facility Sizing

Based on the water supply mix previously described, Table ES-2 provides a summary of the project facility sizes, which are applicable to every alternative.

Table ES-2: Facility Sizing Summary

Facility	Capacity
Turnout	50 cfs
SWP Raw Water Pipe	30-inch
Recycled Water Turnout	20-inch
Combined Raw/Recycled Water Pipeline	36-inch
Net Recharge Area	60 acres
Gross Recharge Site	160 – 175 acres [a]
Number of Recovery Wells	16 – 33 [b]

Notes:

a) Alternatives 6, 7, 8, and 9 require 175 acres. These alternatives straddle the Buttes and Lancaster sub-basins, and require additional land to separate the two sets of recharge basins.

b) Number of recovery wells is based on the following well capacity assumptions for each sub-basin:
   - 500 gpm for Pearland sub-basin
   - 600 gpm for Buttes sub-basin
   - 1,200 gpm for Lancaster sub-basin

Recycled Water

PWD is taking proactive steps towards expanding the use of non-potable water to meet a variety of non-potable and indirect potable uses through the formation of a Joint Powers Authority (JPA) with City of Palmdale. One of the PWD goals is to utilize any available recycled water for groundwater replenishment as part of the optimal blend of supply alternatives to address future needs. The recycled water can be supplied to PWD from the Sanitation Districts of Los Angeles County (LACSD) Palmdale WRP, which currently produces about 10,000 AF/yr of Title 22 recycled water.

To project future supplies, it was assumed that recycled water from Palmdale WRP would grow linearly at the same rate as potable demands; approximately 0.9 percent per annum on an average basis in the 2015-2040 period. It is estimated that the total recycled water supply from Palmdale WRP will grow to about 12,500 AF/yr by 2040 and 18,100 AF/yr by buildout. It is anticipated that the recycled water use for landscape irrigation will not exceed 2,000 AF/yr at buildout. In addition, approximately 4,000 AF/yr of recycled water is planned for use at a nearby power plant. Figure ES-2 projections of recycled water supply availability for the Project through 2040.

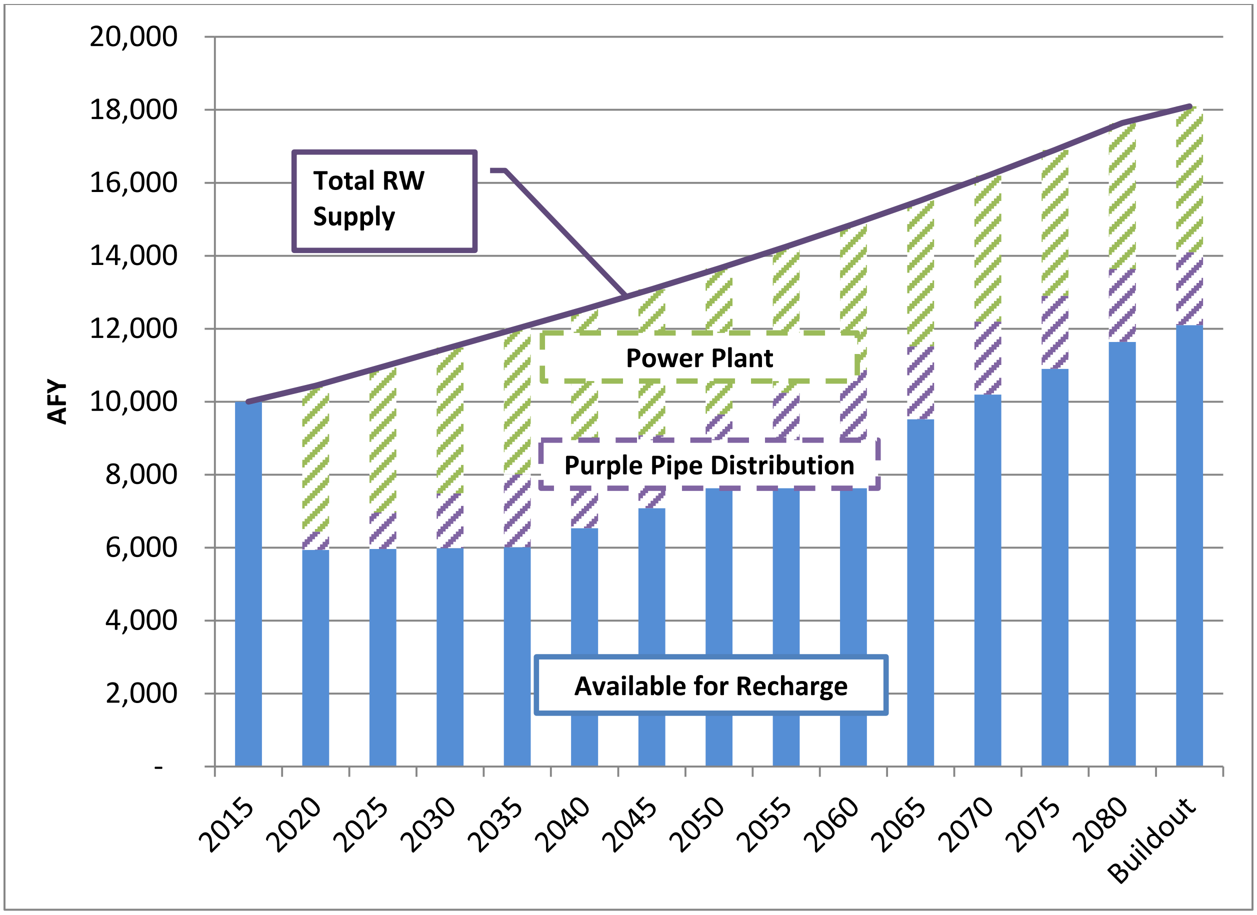


Figure ES-2: Projections of Recycled Water Supply Availability for Groundwater Recharge

Biological Constraints

A biological resources investigation was provided based on a literature review and reconnaissance survey of the recharge basin alternative sites. An analysis of the alternatives for the LCGRRP found no major biological resources constraints on any alternative site outside of Littlerock Creek based on the information available. Alternative Site 10B is potentially constrained by the historic record of Mohave ground squirrel in the southern end. A single low-sensitivity species was observed (loggerhead shrike), and the site was assessed as having high potential for only one listed species potentially requiring consultation and permitting with California Department of Fish and Wildlife (CDFW) (Mohave ground squirrel). No sensitive plant species were observed, and the project site has low potential for any to occur.

The LCGRRP is not expected to require federal permits from United States Fish and Wildlife Service (USFWS) or the United States Army Corps of Engineers (USACE), unless desert tortoise is determined to occupy impact areas, which is unlikely, or the USACE takes jurisdiction over Littlerock Creek, which based on preliminary assessment is unlikely. Alternative Sites 3, 10, 10A, and 10C are considered the least-constrained, respectively. Impacts to Littlerock Creek would require a Section 1602 Streambed Alteration Agreement from CDFW.

Cultural Constraints

A cultural resources investigation was conducted in accordance with CEQA. No Native American cultural resources are known to exist within the immediate study area. Native American individuals and organizations were contacted to elicit information and/or concerns regarding cultural resource issues related to the proposed project. Comments received stated that Littlerock was a drawing area for Native American people. As such, it was suggested that an archaeological and Native American monitor be present for new development in undisturbed areas. It was also noted that the study area has been occupied continuously by Native American ancestors, and it was recommended that a culturally-affiliated Native American monitor to be present during all ground-disturbing activities. The Tribal Historic and Cultural Preservation Representative for the Fernandeño Tataviam Band of Mission Indians indicated that the study area is located in a culturally sensitive area.

When the project proceeds to preliminary design, an intensive Phase I pedestrian survey of the direct impact areas is recommended.

Preliminary Alternatives

Ten preliminary alternatives were developed for proposed recharge sites. The location of proposed recharge sites and pipelines for each alternative is shown on Figure ES-3. Generalizations regarding the alternatives include:

- Alternatives 1 and 2 assume run-of the river for recharge, with Alternative 1 delivering imported water directly from the East Branch. Alternative 2 would utilize a pipeline to deliver from the East Branch to a point in the Creek about half-way to Palmdale Boulevard; thus, avoiding most of the quarries. These alternatives do not utilize recycled water.

- Alternatives 3 through 10 assume pipeline delivery of imported water from the East Branch directly to constructed recharge basins, with no water in or from the creek.

- Alternatives 7, 8, and 9 are within the limits of the Los Angeles World Airport (LAWA) 17,000-acre property that was acquired in the 1960s for a regional airport that was never constructed. Alternative 6 is mostly within LAWA property.

- Alternative 10 is located within an area designated by LACSD for a future Effluent Management Site.

The scoring and ranking of the ten preliminary alternatives was performed in a matrix. This matrix includes a list of the ten economic and non-economic criteria, weight of each criteria, scores for each alternative, weighted scores for each alternative, total weighted score for each alternative, rank of each alternative, and comments on the scoring. The alternatives ranking matrix is presented in Table ES-3.

Based on the screening of the 10 alternatives, alternatives 9 and 10 were found to be more favorable than the other alternatives. In turn, these two alternatives were refined to generate four refined alternatives - Alternatives 9R, 10A, 10B, and 10C.

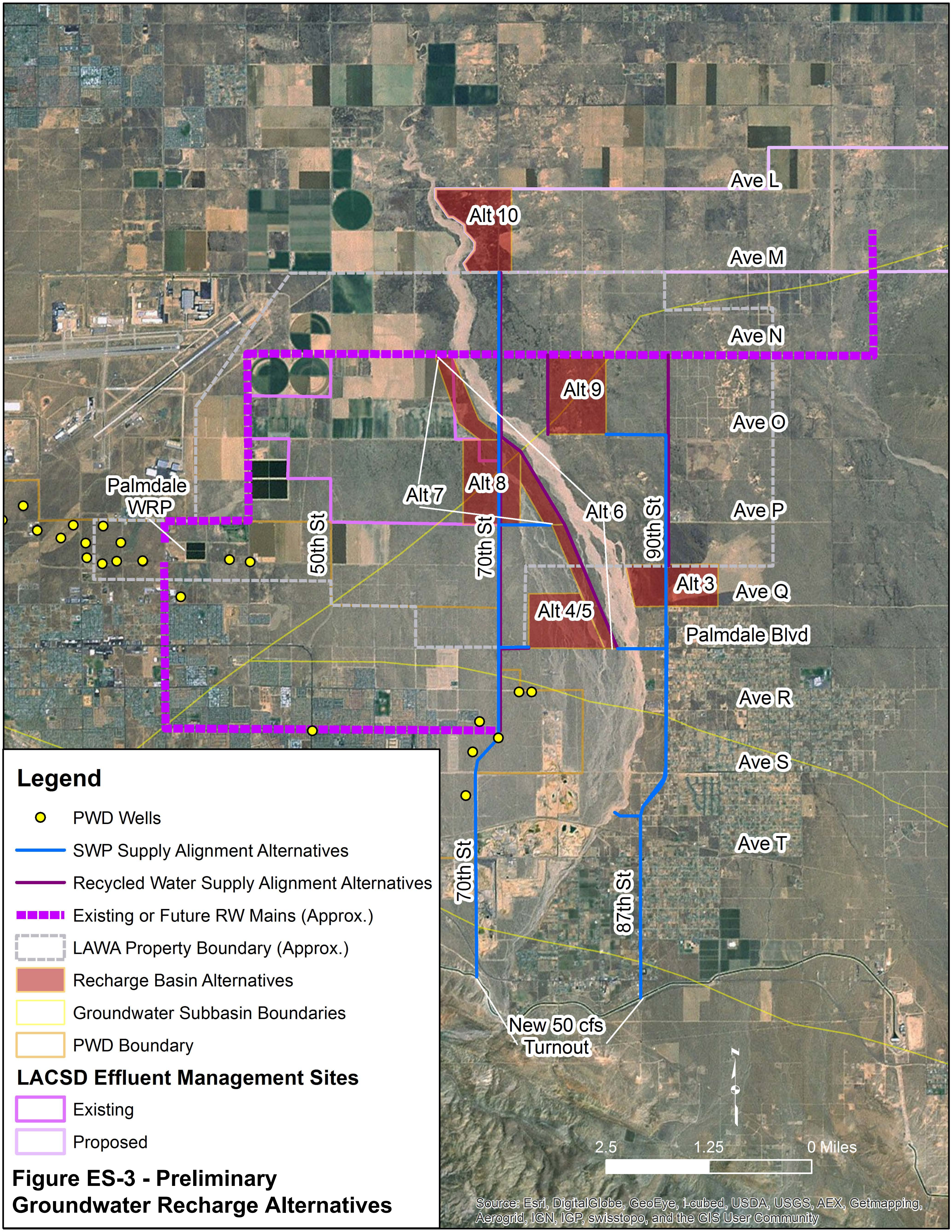


Figure ES-3 - Preliminary Groundwater Recharge Alternatives

Table ES-3: Littlerock Creek Groundwater Recharge and Recovery
Project Ten Preliminary Alternatives Scoring and Ranking

			Alternative 1 - Run-of-River Recharge within Pearland Basin			Alternative 2 - Run-of-River Recharge within Pearland and Buttes Basins		
Criteria	Weight	Scoring	Score	Weighted Score	Comment	Score	Weighted Score	Comment
Capital Cost	15%	1 - 5 (Best)	3.65	0.5	$363,630,000	3.62	0.5	$366,700,000
Unit Water Cost	15%	1 - 5 (Best)	3.65	0.5	$1,352	3.62	0.5	$1,364
Recharge and Recovery Capacity	10%	1 - 5 (Best)	2.22	0.2	Pearland and Buttes Basin	2.36	0.2	Buttes and Pearland Basin
Recovery Water Quality	10%	1 - 5 (Best)	3.5	0.4		3.5	0.4	
Environmental Impact	10%	1 - 5 (Best)	2	0.2	Relatively high biological constraints, moderate to high cultural constraints	2	0.2	Relatively high biological constraints, moderate to high cultural constraints
Implementation Risk and Uncertainty	10%	1 - 5 (Best)	2	0.2	Near existing creek/quarry operations	2	0.2	Least known about Buttes basin, potential to be near future creek/quarry operations
Institutional and Private Entity Issues	10%	1 - 5 (Best)	2	0.2	Outside LAWA, quarry operations	3	0.3	Outside LAWA, potential future quarry operations
Recycled Water Recharge Compatibility	10%	1 - 5 (Best)	1	0.1	Not RW compatible	1	0.1	Not RW compatible
Regulatory and Permitting Issues	5%	1 - 5 (Best)	2	0.1	USACE and CDFW	2	0.1	USACE and CDFW
Public Acceptance	5%	1 - 5 (Best)	4	0.2	No RW, recharge in creek	4	0.2	No RW, recharge in creek
Total	**100%**	**5**		**2.67**			**2.77**	
Rank				**10**			**9**	

	Alternative 3 - Off-stream Recharge within the Buttes Basin (East of Littlerock Creek)			Alternative 4 - Off-stream Recharge within the Buttes Basin (West of Littlerock Creek)		
Criteria	Score	Weighted Score	Comment	Score	Weighted Score	Comment
Capital Cost	4.73	0.7	$280,430,000	4.70	0.7	$282,320,000
Unit Water Cost	4.73	0.7	$1,043	4.70	0.7	$1,050
Recharge and Recovery Capacity	2.50	0.3	Buttes Basin	2.50	0.3	Buttes Basin
Recovery Water Quality	5	0.5		5	0.5	
Environmental Impact	4	0.4	Relatively low biological constraints, moderate to high cultural constraints	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints
Implementation Risk and Uncertainty	2	0.2	Least known about Buttes basin, adjacent to existing development	2	0.2	Least known about Buttes basin
Institutional and Private Entity Issues	3	0.3	Outside LAWA, proximity to existing development	3	0.3	Outside LAWA, Air Force buffer zone
Recycled Water Recharge Compatibility	5	0.5	RW compatible	5	0.5	RW compatible
Regulatory and Permitting Issues	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH
Public Acceptance	2	0.1	RW, recharge near creek, near existing development	3	0.2	RW, recharge near creek
Total		**3.72**			**3.66**	
Rank		**3**			**5**	

	Alternative 5 - Off-stream Recharge within the Buttes Basin (West of Littlerock Creek)			Alternative 6 - Off-stream Recharge within the Buttes and Lancaster Basins (Along the Western Edge of Littlerock Creek)		
Criteria	Score	Weighted Score	Comment	Score	Weighted Score	Comment
Capital Cost	4.78	0.7	$277,790,000	4.95	0.7	$267,990,000
Unit Water Cost	4.78	0.7	$1,033	4.95	0.7	$996
Recharge and Recovery Capacity	2.50	0.3	Buttes Basin	3.75	0.4	Buttes and Lancaster Basins
Recovery Water Quality	5	0.5		3	0.3	Impact from Plume
Environmental Impact	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints	2	0.2	Relatively high biological constraints, moderate to high cultural constraints
Implementation Risk and Uncertainty	2	0.2	Least known about Buttes basin	2	0.2	Least known about Buttes basin - portion within, Impact from Plume
Institutional and Private Entity Issues	3	0.3	Outside LAWA, Air Force buffer zone	2	0.2	Portion in LAWA, Air Force buffer zone
Recycled Water Recharge Compatibility	5	0.5	RW compatible	5	0.5	RW compatible
Regulatory and Permitting Issues	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH
Public Acceptance	3	0.2	RW, recharge near creek	3	0.2	RW, recharge near creek
Total		**3.68**			**3.46**	
Rank		**4**			**7**	

	Alternative 7 - Off-stream Recharge within the Buttes and Lancaster Basins (Along the Western Edge of Littlerock Creek)			Alternative 8 - Off-stream Recharge within the Buttes and Lancaster Basins (West of Littlerock Creek between Avenues P and O)		
Criteria	Score	Weighted Score	Comment	Score	Weighted Score	Comment
Capital Cost	4.95	0.7	$267,880,000	5.00	0.8	$265,460,000
Unit Water Cost	4.95	0.7	$996	5.00	0.8	$987
Recharge and Recovery Capacity	4.18	0.4	Lancaster and Buttes Basins	4.18	0.4	Lancaster and Buttes Basins
Recovery Water Quality	3	0.3	Impact from Plume	3	0.3	Impact from Plume
Environmental Impact	2	0.2	Relatively high biological constraints, moderate to high cultural constraints	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints
Implementation Risk and Uncertainty	2	0.2	Least known about Buttes basin - portion within, Impact from Plume	2	0.2	Least known about Buttes basin - portion within, Impact from Plume
Institutional and Private Entity Issues	1	0.1	LAWA, Air Force buffer zone	1	0.1	LAWA, Air Force buffer zone
Recycled Water Recharge Compatibility	5	0.5	RW compatible	5	0.5	RW compatible
Regulatory and Permitting Issues	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH
Public Acceptance	3	0.2	RW, recharge near creek	3	0.2	RW, recharge near creek
Total		**3.40**			**3.52**	
Rank		**8**			**6**	

	Alternative 9 - Off-stream Recharge within the Buttes and Lancaster Basins (East of Littlerock Creek between Avenues N and O)			Alternative 10 - Off-stream Recharge within the Lancaster Basin (Within LACSD Effluent Management Site North of Avenue M)		
Criteria	Score	Weighted Score	Comment	Score	Weighted Score	Comment
Capital Cost	4.90	0.7	$270,840,000	4.85	0.7	$273,880,000
Unit Water Cost	4.90	0.7	$1,007	4.85	0.7	$1,018
Recharge and Recovery Capacity	4.18	0.4	Lancaster and Buttes Basins	5.00	0.5	Lancaster Basin
Recovery Water Quality	5	0.5		4	0.4	Impact from Plume
Environmental Impact	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints	4	0.4	Relatively low biological constraints, moderate to high cultural constraints
Implementation Risk and Uncertainty	3	0.3	Least known about Buttes basin - portion within	4	0.4	Impact from Plume
Institutional and Private Entity Issues	1	0.1	LAWA, Air Force buffer zone	3	0.3	Outside LAWA, LACSD land acquisition, Air Force buffer zone
Recycled Water Recharge Compatibility	5	0.5	RW compatible	5	0.5	RW compatible
Regulatory and Permitting Issues	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH
Public Acceptance	3.5	0.2	RW, recharge near creek	4	0.2	RW, recharge near creek, recharge where RW is already spread
Total		**3.81**			**4.20**	
Rank		**2**			**1**	

Refined Alternatives

The four refined alternatives – 9R, 10A, 10B, and 10C – were developed based on the preliminary alternatives evaluation presented in the preceding section and are shown in Figure ES-4. A summary of why these four refined alternatives were selected is provided below:

- All refined alternatives allow for recycled water to be utilized in groundwater recharge.
- Alternative 9R straddles the Buttes and Lancaster sub-basins with approximately half its recharge area in each sub-basin, which provides flexibility.
- Alternatives 10A, 10B, and 10C are located in the Lancaster Sub-basin, which has the highest specific capacity; roughly double the Pearland and Buttes sub-basins. This reduces the number of recovery wells required.
- Alternative 9R is located east of Littlerock Creek, and LAWA has indicated that if an airport is built in the future, then it will most likely be west of Littlerock Creek.
- Alternatives 10A, 10B, and 10C are located outside (to the north) of LAWA property.
- Alternatives 9R and 10A are located outside of a 10,000-foot buffer zone of the flight path of the Palmdale Air Force Base 42, but within the five-mile buffer zone. The proposed recharge basins of Alternative 10B are located outside of the five-mile buffer zone, and Alternative 10C is completely outside the five-mile buffer zone.

All four refined alternatives have certain characteristics in common. A summary of these characteristics is provided below:

- All four alternatives have been re-designed and modeled with recovery wells placed in a circumferential pattern, instead of the initial linear pattern in order to mitigate potential land subsidence.
- All alternatives have been designed in such a way as to meet the ultimate facility sizing needs of the District, allowing the District to only require a single recharge project for its supply needs.
- The number of recovery wells specified for each alternative provides the recovery capacity necessary for PWD's projected ultimate build-out water demand. For PWD's potable supply needs, the recovery wells can be phased over time as water demand increases. Early construction of recovery wells beyond the needs of PWD would make recovery available for any water banking partners. Maximum extraction rates for dry year supply for partners may require additional wells.
- All alternatives include a distribution system, including a 1-million gallon head tank, distribution system pump station, a chlorination building, and an optional raw water sump and raw water pump station. The head tank and chlorination building are designed for ultimate demands, whereas the pump stations are designed to be implemented through phasing.

- The distribution pump station is proposed to be implemented in multiple phases, each accommodating an increase in demands. The pump station's transmission line is designed to provide ultimate demands through a 30-inch pipeline to the existing 20-inch pipeline at the corner of Palmdale Boulevard and 60th Street, which serves a hydraulic grade line of 2,800 feet. For the first phase, the pumps are designed to be of a 3+1 spare configuration, providing 3,000 gpm at 400 hp, each.

- The raw water pump station is comprised of a 6+1 configuration of 600 hp, 3,000 gpm pumps. The station is designed with suction from a 50,000 gallon sump to supply raw water back to the East Branch canal utilizing the 30-inch raw water pipeline normally used to deliver recharge. In the event that the District creates this system for a water banking partnership, the phasing and number of pumps may be adapted in order to meet the partner's needs.

The weighted scoring matrix for the final four alternatives is provided in Table ES-4.

Recommendation

Based on the screening of the original preliminary 10 alternatives, the best two preliminary alternatives (Alternatives 9 and 10) were identified. In turn, Alternative 9 was refined and Alternative 10 was expanded to include three different options (A, B, and C), resulting in the final four refined alternatives: 9R, 10A, 10B, and 10C. Evaluation of the four refined alternatives resulted in the identification of the best two alternatives for further consideration, which are Alternative 10B and Alternative 10C.

The net present cost estimates for Alternatives 10B and 10C are presented as Table ES-5 and Table ES-6, respectively. The initial capital investment for both alternatives is approximately $85 million.

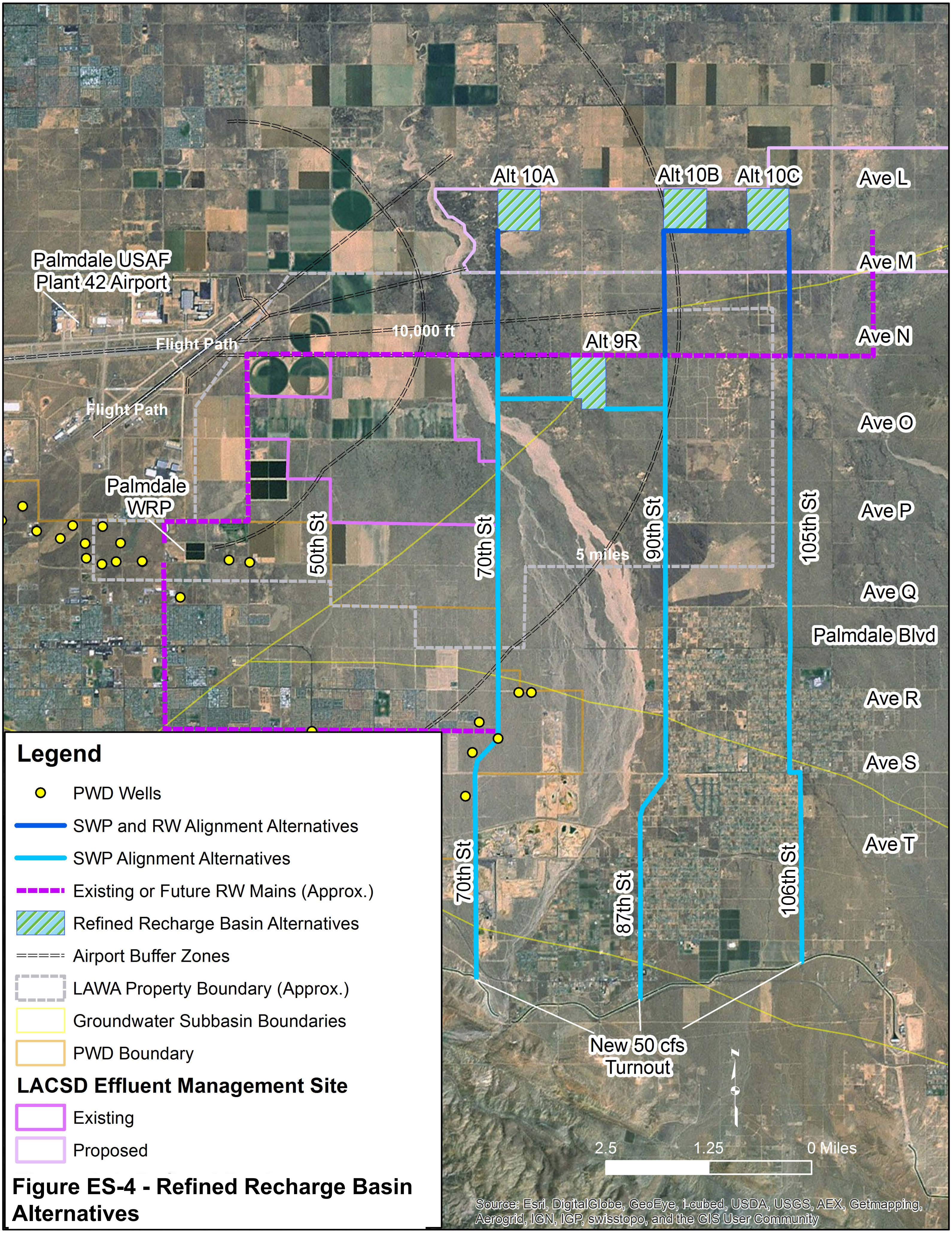


Figure ES-4 - Refined Recharge Basin Alternatives

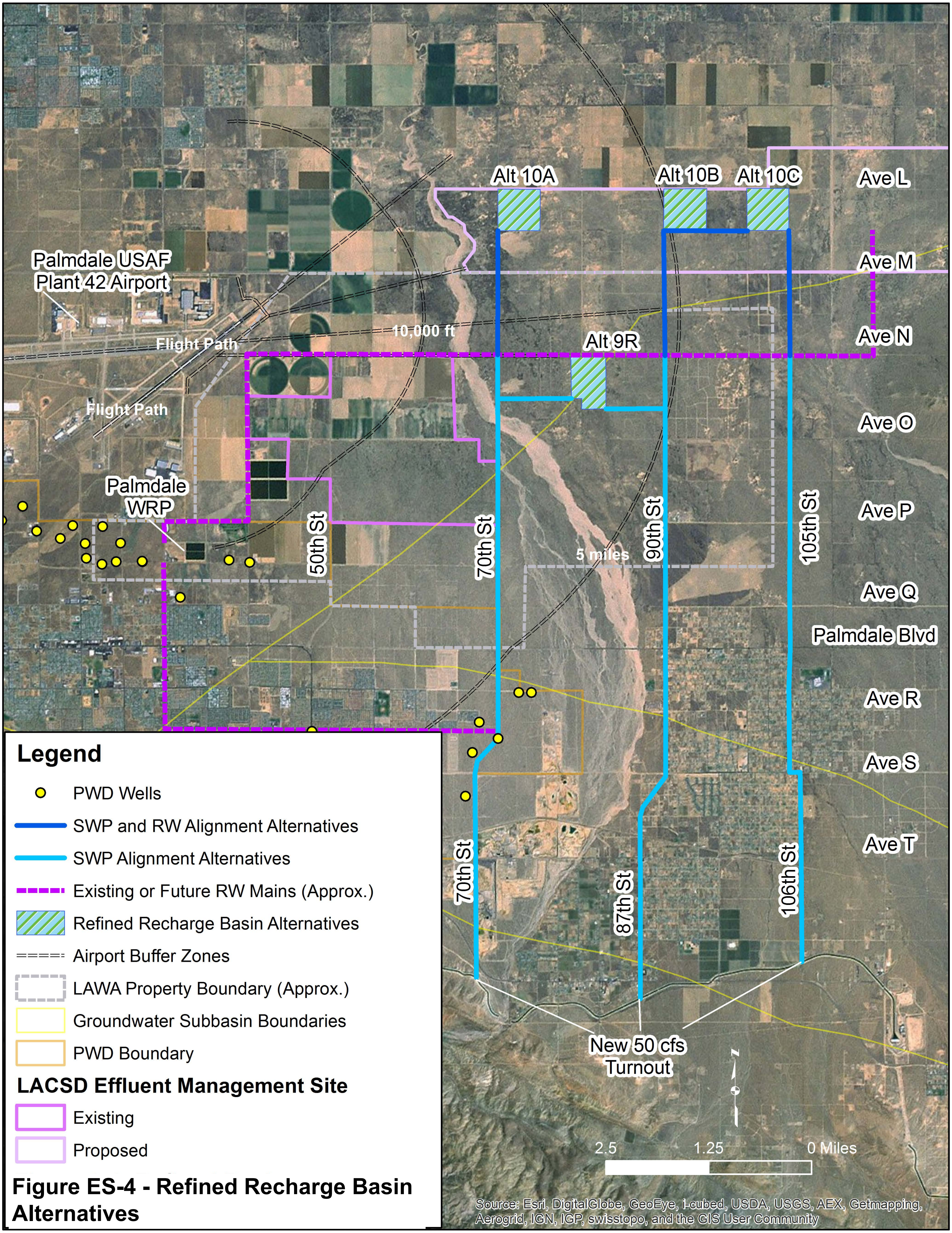


Figure ES-4 - Refined Recharge Basin Alternatives

Table ES-4: Littlerock Creek Groundwater Recharge and Recovery Project Final Four Alternatives Scoring and Ranking

			Alternative 9R			Alternative 10A			Alternative 10B			Alternative 10C		
Criteria	**Weight**	**Scoring Description**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**
Total Cost	15%	1 - 5 (Best)	4.91	0.7	$298,510,000	5.00	0.8	$293,040,000	4.90	0.7	$299,260,000	4.89	0.7	$299,780,000
Unit Water Cost	15%	1 - 5 (Best)	4.91	0.7	$1,110	5.00	0.8	$1,090	4.90	0.7	$1,113	4.89	0.7	$1,115
Recharge and Recovery Capacity	15%	1 - 5 (Best)	3.75	0.6	Buttes and Lancaster Basin	5.00	0.8	Lancaster Basin	5.00	0.8	Lancaster Basin	5.00	0.8	Lancaster Basin
Recovery Water Quality	10%	1 - 5 (Best)	2	0.2	Moderate Proximity to Nitrate Plume	0	0.0	Expected Contact to Nitrate Plume	5	0.5	No Contact with Nitrate Plume	5	0.5	No Contact with Nitrate Plume
Environmental Impact	10%	1 - 5 (Best)	3	0.3	Largely unconstrained - contains suitable habitat and cultural resource	4	0.4	Least Consrained	3	0.3	Largely Unconstrained - Contains Suitable Habitat for MGS	5	0.5	Least Constrained
Implementation Risk and Uncertainty	10%	1 - 5 (Best)	1	0.1	Least Known about Buttes Basin, proximity to Plume	2	0.2	Proximity to Plume	2	0.2	MGS Possibility	4	0.4	
Property Acquisition	10%	1 - 5 (Best)	1	0.1	Lease or MOU	2	0.2	Property ownership, two homes on site	4	0.4	Property ownership, very little LACSD Effluent Management	5	0.5	Property ownership, 35% LACSD Effluent Management
Institutional Issues	10%	1 - 5 (Best)	1	0.1	Airport Proximity	1	0.1	Airport Proximity	5	0.5	Outside FAA Zone	5	0.5	Outside FAA Zone
Public Acceptance	5%	1 - 5 (Best)	5	0.3	LAWA property	1	0.1	All Private Property, Presence of Homes	3	0.2	Mostly Private Property, Little LACSD	4	0.2	65% Private Property, 35% LACSD, within Effluent Management
Total	**100%**	**5**		**3.09**			**3.20**			**4.27**			**4.82**	
Rank				**4**			**3**			**2**			**1**	

Table ES-5: Alternative 10B Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$24,160,000	$24,160,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,480,000	$1,480,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$8,130,000	$8,760,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$18,940,000	$18,940,000
Facilities Subtotal	***$84,220,000***	***$96,970,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$25,790,000	$54,660,000
O&M Costs	$5,360,000	$11,880,000
O&M Subtotal	***$31,150,000***	***$66,540,000***
Grand Total	**$171,770,000**	**$299,260,000**
Unit Water Cost ($/AF)	**$1,071**	**$1,113**

Table ES-6: Alternative 10C Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$23,130,000	$23,130,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,100,000	$1,100,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$8,130,000	$8,760,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$21,440,000	$21,440,000
Facilities Subtotal	***$85,310,000***	***$98,060,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$25,400,000	$54,090,000
O&M Costs	$5,360,000	$11,880,000
O&M Subtotal	***$30,760,000***	***$65,970,000***
Grand Total	**$172,470,000**	**$299,780,000**
Unit Water Cost ($/AF)	**$1,075**	**$1,115**

Implementation Plan

Alternative 10B and Alternative 10C have been sized according to a phasing plan. The preliminary phase is intended to meet the District's water demands for the first 22 years of the project's life, providing a water supply of 14,125 AF/yr. The second phase is sized to meet the District's water demand through the 50-year project evaluation period (through 2067), as well as ultimate buildout, providing a water supply of up to 24,250 AF/yr. An outline of the aspects of this plan for each facet of the alternatives is presented below:

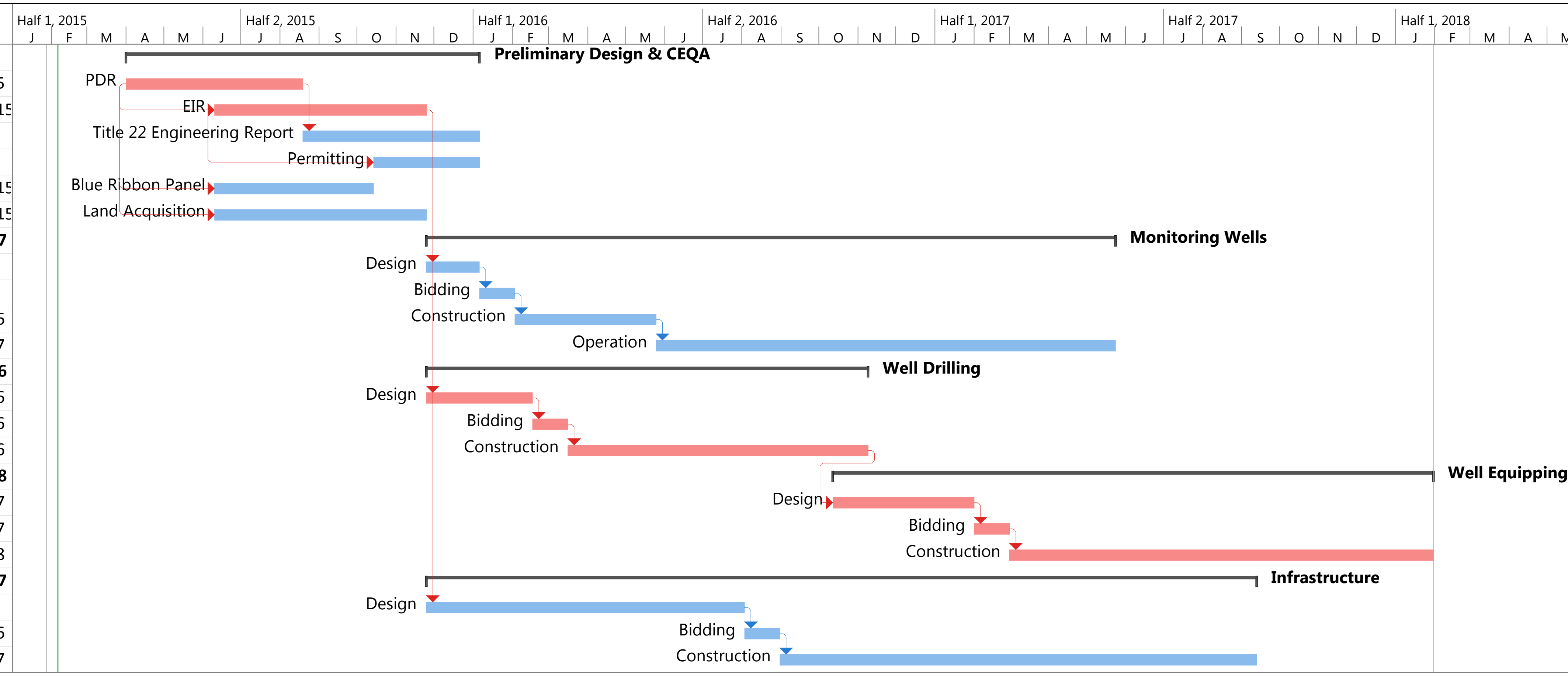
- **SWP Turnout:** The new 50-cfs turnout has been designed to accommodate the ultimate demand.
- **Recharge Site:** The recharge site is intended to accommodate the ultimate demand.
- **Raw Water Conveyance:** The raw water conveyance pipeline is intended to accommodate the ultimate demand.
- **Recycled Water Conveyance:** The recycled water conveyance pipeline is designed to accommodate both current and expected future flows through ultimate buildout.
- **Recovery Wells:** The recovery wells are intended to be phased one half at a time with 8 wells during phase 1 and the additional 8 wells through phase 2.
- **Distribution Site:** The 1-million gallon head tank, pump headers, and chlorination building are intended to accommodate the ultimate demand.
- **Distribution Pump Station:** The distribution system pipeline is intended to accommodate the ultimate demand. However, the pumps themselves are to be phased, meaning the first 3,000 gpm, 400 hp pumps are intended to accommodate the 14,125 AF/yr demand through a 3+1 configuration, and the ultimate demand will be supplied through an additional 3 pumps sized at 2,500 gpm and 400 hp. Although most phasing is intended to be within two parts, this pump station is capable of being implemented through multiple phases as demand increases.
- **Raw Water Pump Station:** The raw water pump station is optional and designed to accommodate a water banking partner or partners in order to pump back to the East Branch canal. As such, it is not required for this pump station to be implemented until a water banking partnership is achieved. However, the system has been sized in order to provide ultimate demand to the aqueduct through the 6+1 configuration of 3,000 gpm, 600 hp pumps. If it is desired to pump back more than 24,250 AF/yr, then the raw water pipeline should be up-sized to 36-inch diameter initially.

Project Schedule

Figure ES-5 presents a preliminary implementation schedule for the initial capital investment of the recommended project. It is anticipated that preliminary design and CEQA tasks will be completed in 2015, with design and construction of facilities to follow in 2016 and 2017. The schedule critical path will consist of the well drilling and equipping tasks, while other infrastructure design and construction will occur in parallel. Under this schedule, the project can begin operation by early 2018.

Figure ES-5: Project Implementation Schedule

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Preliminary Design & CEQA**	**200 days**	**Wed 4/1/15**	**Tue 1/5/16**
2		PDR	100 days	Wed 4/1/15	Tue 8/18/15
3		EIR	120 days	Wed 6/10/15	Tue 11/24/15
4		Title 22 Engineering Repor	100 days	Wed 8/19/15	Tue 1/5/16
5		Permitting	60 days	Wed 10/14/1	Tue 1/5/16
6		Blue Ribbon Panel	90 days	Wed 6/10/15	Tue 10/13/15
7		Land Acquisition	120 days	Wed 6/10/15	Tue 11/24/15
8		**Monitoring Wells**	**390 days**	**Wed 11/25/1**	**Tue 5/23/17**
9		Design	30 days	Wed 11/25/1	Tue 1/5/16
10		Bidding	20 days	Wed 1/6/16	Tue 2/2/16
11		Construction	80 days	Wed 2/3/16	Tue 5/24/16
12		Operation	260 days	Wed 5/25/16	Tue 5/23/17
13		**Well Drilling**	**250 days**	**Wed 11/25/1**	**Tue 11/8/16**
14		Design	60 days	Wed 11/25/1	Tue 2/16/16
15		Bidding	20 days	Wed 2/17/16	Tue 3/15/16
16		Construction	170 days	Wed 3/16/16	Tue 11/8/16
17		**Well Equipping**	**340 days**	**Wed 10/12/1**	**Tue 1/30/18**
18		Design	80 days	Wed 10/12/1	Tue 1/31/17
19		Bidding	20 days	Wed 2/1/17	Tue 2/28/17
20		Construction	240 days	Wed 3/1/17	Tue 1/30/18
21		**Infrastructure**	**470 days**	**Wed 11/25/1**	**Tue 9/12/17**
22		Design	180 days	Wed 11/25/1	Tue 8/2/16
23		Bidding	20 days	Wed 8/3/16	Tue 8/30/16
24		Construction	270 days	Wed 8/31/16	Tue 9/12/17



Project: Schedule_v0

Task	Project Summary	Manual Task	Start-only	Deadline	Manual Progress
Split	Inactive Task	Duration-only	Finish-only	Critical	
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Critical Split	
Summary	Inactive Summary	Manual Summary	External Milestone	Progress	

Economic Analysis

The recommended project alternative not only provides PWD with a reliable water supply solution for the foreseeable future, but also provides the most cost-effective solution when analyzed over a long-term basis. Given PWD's heavy dependence on SWP water for supply, water banking allows the District to maximize its SWP Table A allocations and minimize purchase of Table A water in order to meet dry-year hydrological conditions. Additionally, the project's utilization of recycled water for recharge further offsets the need for SWP water. In order to demonstrate the cost benefits of the recommended project, this section provides a cost analysis of the recommended project versus two alternative water supply strategies: (1) water banking without recycled water and (2) no water banking.

The first alternative for comparison is a water banking project without recycled water recharge (No Recycled Water Alternative). Since recycled water recharge is not utilized, additional SWP water is required, which would necessitate a 36-inch pipeline, rather than the 30-inch pipeline provided for Alternatives 10B or 10C. Additionally, more Table A water is required in order to obtain the additional required SWP water. As shown in Figure ES-6, the No Recycled Water Alternative requires 20,000 AF/yr more Table A Amount than the recommended project.

As shown in Figure ES-7, the overall net present cost of this alternative is approximately $104 million greater than the recommended project. The main differentiator is the required Table A Amounts. The total net present cost of Table A purchase is $109 million for the No Recycled Water Alternative, which is considerably greater than the $26 million required for Table A purchase under the recommended project.

The second alternative for comparison is a water supply strategy that does not utilize any water banking and builds upon the existing water supply system consisting of treated surface water and groundwater (No Water Banking Alternative). Under this alternative, PWD would meet future supply needs by purchasing additional Table A Amounts and expanding the capacity of the LOCWTP, along with the associated East Branch turnout and pipelines. Without water banking to supplement dry-year SWP allocations, PWD would need to purchase Table A water such that it can reliably provide water under a 31 percent Table A allocation year, which is defined by the California Department of Water Resources (DWR) as the allocation percentage for a multi-year drought condition.

The alternative is approximately $309 million greater than the recommended project due to the large amount of Table A purchase required for this alternative. As shown in Figure ES-6, approximately 52,000 AF/yr more Table A Amount is required for the No Water Banking Alternative compared to the recommended project, resulting in $221 million in additional cost for Table A purchase.

In summary, the recommended project has a projected cost savings of $106 million over the 50-year study period in comparison to the No Recycled Water Alternative and a projected cost savings of $309 million when compared to the No Water Banking Alternative, as shown in Figure ES-7.

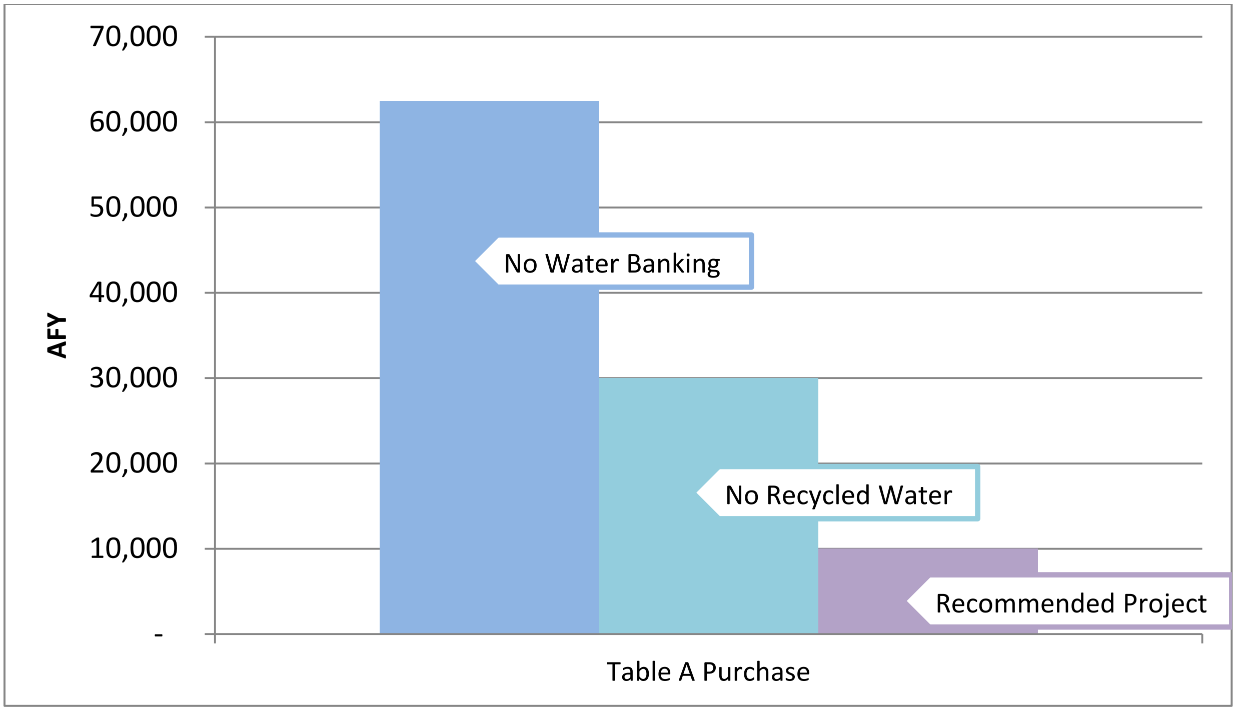


Figure ES-6: Table A Purchase Comparison for 50-Year Study Period

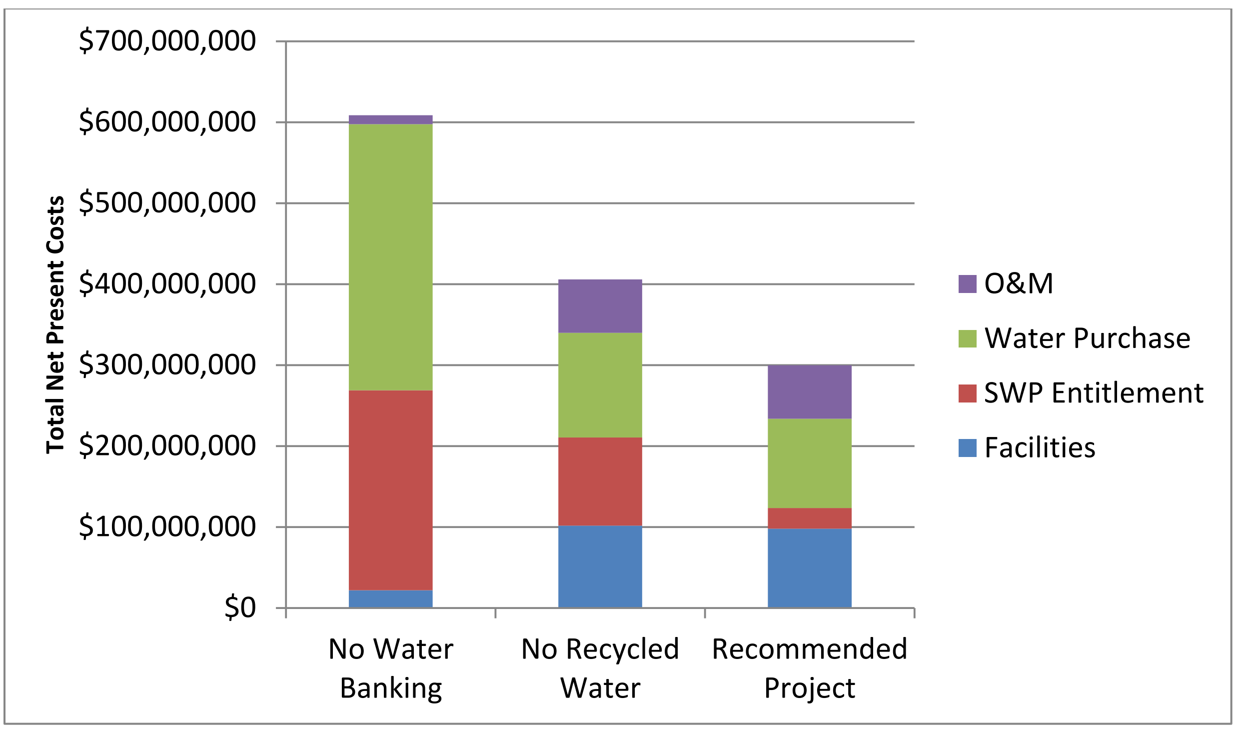


Figure ES-7: Total Net Present Cost Comparison

Mini-Hydro Evaluation

An analysis was conducted to estimate energy generation and greenhouse gas (GHG) reduction potential from the development of a hydropower project as part of the LCGRRP Alternative 10C. Specifically, Kennedy/Jenks assessed the electric generating capabilities at a site located near Avenue N, approximately 7.5 miles along a 30-inch pipeline alignment leading from the East Branch Canal to the Alternative 10C East recharge location. Costs and net savings associated with installation of a mini-hydro turbine at this location were evaluated.

Based on varying hydrological conditions over the 50-year study period, the potential annual electricity production is shown in Table ES-7. Flow throw the recharge pipeline would only occur during normal or wet hydrological conditions.

Table ES-7: Estimated Electricity Production

Year	Average Flow (GPM)	Available Head (feet)	Annual Generation (kWh/Year)	Year	Average Flow (GPM)	Available Head (feet)	Annual Generation (kWh/Year)
2018	8,332	305	3,188,345	**2043**	0	--	0
2019	8,298	305	3,179,721	**2044**	0	--	0
2020	9,689	287	3,487,627	**2045**	0	--	0
2021	8,224	306	3,160,886	**2046**	0	--	0
2022	8,184	307	3,150,656	**2047**	9,461	290	3,443,453
2023	0	--	0	**2048**	9,417	291	3,434,653
2024	0	--	0	**2049**	9,372	291	3,425,631
2025	0	--	0	**2050**	11,088	266	3,697,983
2026	0	--	0	**2051**	9,283	292	3,407,292
2027	7,982	309	3,097,481	**2052**	9,237	293	3,397,846
2028	7,942	310	3,086,667	**2053**	0	--	0
2029	7,901	310	3,075,783	**2054**	0	--	0
2030	9,286	292	3,408,064	**2055**	0	--	0
2031	7,821	311	3,053,808	**2056**	0	--	0
2032	7,781	312	3,042,718	**2057**	9,004	296	3,347,619
2033	0	--	0	**2058**	8,957	297	3,337,011
2034	0	--	0	**2059**	8,908	297	3,326,155
2035	0	--	0	**2060**	13,255	228	3,799,306
2036	0	--	0	**2061**	11,110	265	3,700,398
2037	7,579	314	2,986,244	**2062**	11,061	266	3,694,909
2038	7,539	314	2,974,747	**2063**	0	--	0
2039	7,499	315	2,963,183	**2064**	0	--	0
2040	8,883	298	3,320,545	**2065**	0	--	0
2041	7,416	316	2,939,317	**2066**	0	--	0
2042	7,375	316	2,927,189	**2067**	10,807	270	3,664,246

Table ES-8 provides an estimate of potential greenhouse gas (GHG) emissions reduction associated with the project. To calculate the GHG emissions associated with this renewable energy project the Southern California Edison (SCE) GHG emissions factor was used. The project results in a net average reduction of nearly 650 metric tons of CO_2 per year.

Table ES-8: Project GHG Reductions

Analysis Time Frame	Average Electricity Generation (kWh/Year)	SCE GHG Emissions Factor (Lbs. of CO_2/MWh)	Average Annual GHG Reduction (MT CO_2)
20 Years	3,159,800	453	649
50 Years	3,210,900	453	660

A hydropower project is eligible for the Self-Generation Incentive Program (SGIP), which provides incentives to entities that produce electricity from renewables. The total SGIP incentive for this project is estimated to be $449,400.

Table ES-9 provides the summary of costs for the project based on the 20-year and 50-year analyses. The table shows the estimated capital costs in 2018 to build the project, and capital cost for just replacement of the turbine package in 2038 and 2058. This project creates a net present value (NPV) savings of $1.4 million over 20 years and nearly $4.7 million over 50 years. The nominal cumulative savings over 20 years is over $1.7 million.

Table ES-9: Hydropower Economic Analysis

Analysis Time Frame	Value of Electricity Generation ($/1st Yr)	Capital Cost (2018 $)	Incentive Amount ($)	Average Annual Net Savings ($/Yr)	NPV of Cumulative Net Savings ($)	Return On Investment (ROI %)
20 Years	$443,500	$3,456,300	$449,400	$88,250	$1,409,900	8.8%
50 Years	$443,500	$3,456,300	$449,400	$253,900	$4,689,700	10.1%
2038 Capital Cost		$3,170,000	$0			
2058 Capital Cost		$8,921,600	$0			

While this project does create overall financial savings over 20 and 50 years for PWD, it does present a cash flow anomaly. Because of the nature of the deliveries (six years of significant flow and four years of no flow) the project creates substantial benefits or savings during the period during deliveries but creates a cost in years with no deliveries due to debt service for the capital cost of the project.

Based on this analysis, installation of a turbine will have a capital cost of approximately $3.5 million, and is cost effective with a NPV savings of $1.4 million over 20 years and nearly $4.7 million over 50 years.

Section 1: Introduction

1.1 Purpose and Scope

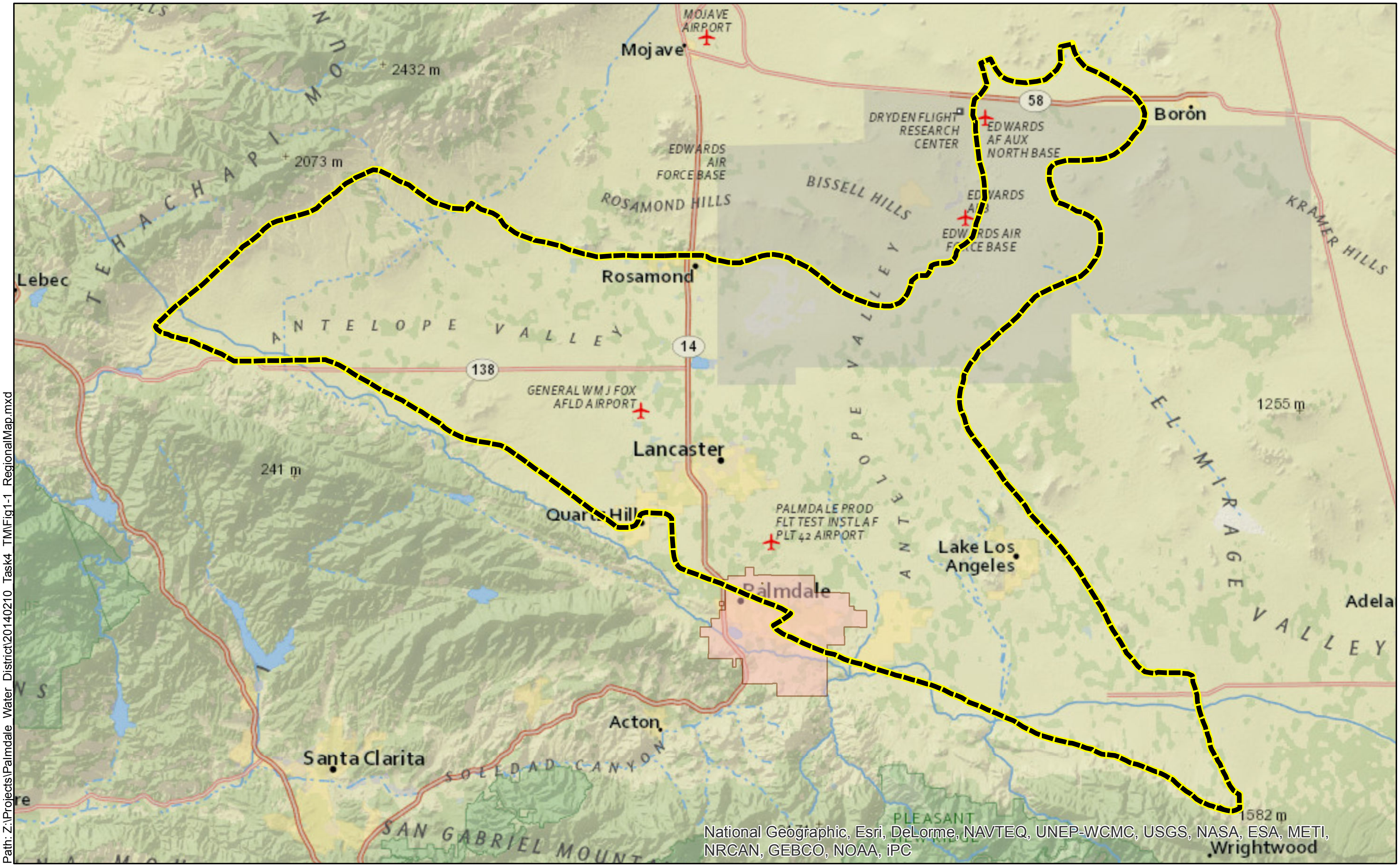
The purpose of this Final Report is to describe the investigations and evaluations conducted as part of the Littlerock Creek Groundwater Recharge and Recovery Project (LCGRRP) Feasibility Study. The overarching goal of the LCGRRP Feasibility Study is to investigate the feasibility of a groundwater banking, storage, and extraction program on behalf of the Palmdale Water District (PWD or District). The selected project alternative will help meet future water demands and improve water supply reliability. New facilities will be constructed to recharge and recover State Water Project (SWP) water as well as recycled water. Infrastructure will include new spreading grounds to recharge water as well as recovery facilities. Surplus SWP water and recycled water will be stored during wet years and recovered during dry years, providing more complete utilization of SWP water and recycled water production.

1.2 Study Area

Located within the Antelope Valley and Antelope Valley Groundwater Basin (AVGB or Basin), east of the City of Palmdale, California, the LCGRRP location is shown on Figure 1-1. The study area traverses three groundwater sub-basins of interest: Pearland, Buttes, and Lancaster. The AVGB is situated between the Central Valley, Sierra Nevada, Transverse Ranges, and Mojave Desert. Located west of the Mojave Desert, the Basin is a topographically closed groundwater basin that has primarily been used for agricultural purposes. It is fed by runoff from the surrounding mountains, which run over the many sub-basins via three main creeks, including Littlerock Creek, which provides the majority of recharge to the Antelope Valley and runs through much of the service area.

Due to the extensive agricultural use over the past century, the Basin has been in an overdraft condition (i.e., pumping greater than natural recharge) since about 1930, leading to rapidly declining groundwater head that caused land subsidence. In 1999, the process to adjudicate groundwater production rights in the Basin was initiated. In 2011, the adjudication court ruled that the safe yield (equivalent to natural recharge plus return flows) of the Basin is 110,000 acre-feet per year (AF/yr or AFY). Although groundwater production has declined significantly from its peak in the 1950s – 60s, it remains above the safe yield of the Basin. The adjudication process seeks to allocate the declared safe yield to the various groundwater producers in the Basin. This process will result in groundwater producers having diminished access to groundwater resources in the future.

Although the results of the adjudication process are not yet known, it is likely that the District will start banking imported water from the SWP and other sources when it is in surplus, recovering the banked water later when imported water is more limited. The LGCRRP water bank may also be used to store tertiary treated recycled water in combination with SWP water for later recovery and use.



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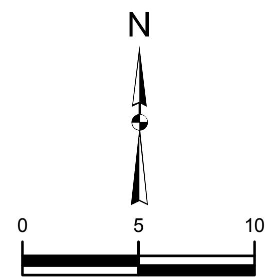
Legend

Palmdale Water District

Antelope Valley Groundwater Basin (from Leighton and Phillips, 2003)



Kennedy/Jenks Consultants

Preliminary LCGRRP Alternatives Report
Kern and Los Angeles Counties, California

Regional Map

K/J 1344505*00
February 2014

Figure 1-1

1.3 Background

PWD provides service to an area of approximately 40 square miles, including the majority of the City of Palmdale as well as substantial adjacent areas outside the City limits. Currently, the District's water needs are met through three sources:

- Imported water from the SWP via the East Branch of the California Aqueduct and treated at the Leslie O. Carter Water Treatment Plant (LOCWTP);
- Surface water from Littlerock Dam Reservoir treated at the LOCWTP; and
- Groundwater from 22 active wells located in the Lancaster and Pearland sub-basins.

The District is investigating reliable methods of water storage due to increasing water demand. Initially, the LCGRRP was envisioned as the largest of four recharge and recovery projects being considered to meet the future needs of the District; however, detailed analysis of water demands and supply indicates that the LCGRRP alone (in combination with incremental increases in SWP Table A water) can meet all of the District's future water supply needs.

For the magnitude of recharge proposed under this project, SWP water will need to be recharged nearly year round. Additional sources may be available during times when there is excess capacity available in the East Branch to transport water to the LCGRRP. The proposed LCGRRP will deliver raw imported water from the East Branch of the California Aqueduct to new spreading basins in or adjacent to Littlerock Creek. Littlerock Creek may be used as a "run of the river" delivery and recharge system that relies on the existing natural channel and some recharge basins in the adjacent floodplain, or a new pipeline may be constructed to convey water to one or more recharge locations. Off-stream recharge basins may be used to supplement or replace in-stream recharge, and will be required for recycled water recharge.

Recycled water may also be included in the project for groundwater recharge (compliant with applicable recycled water regulations). Recycled water from the Los Angeles County Sanitation District (LACSD) Palmdale Water Reclamation Plant (WRP) is available as a source. PWD currently has a small recycled water program that only serves one customer (McAdam Park). Therefore, after the available amount of recycled water is allocated to McAdam Park, the proposed City of Palmdale Hybrid Power Plant (PHPP), and a proposed irrigation supply to east Palmdale, there is a substantial surplus available for groundwater replenishment. This source is anticipated to be available at an approximately constant rate year-round.

1.3.1 Other Facilities

There are other facilities in the study area that influence development of the project alternatives. These features are introduced herein for background purposes as they are discussed later in the report.

- **LACSD Palmdale WRP**. The LACSD operates the Palmdale WRP, located at 39300 30^{th} Street East in the City of Palmdale. The WRP currently occupies 286 acres east of the Antelope Valley (14) Freeway. The Palmdale WRP is a tertiary treatment plant with solids processing facilities, providing primary, secondary, and tertiary treatment for a design capacity of 12 million gallons of wastewater per day (mgd). Effluent is reused for irrigation of trees and fodder crops on City of Los Angeles Department of Airports

(LAWA) property and also for parks in the City of Palmdale. Historically, this site has discharged secondary effluent by land spreading, allowing it to percolate and evaporate, causing adverse impacts to groundwater quality (i.e., elevated nitrate levels), and creating a nitrate plume. This area, shown in Figure 1-2, is referred to as the Effluent Management Site. LACSD also has recycled water seasonal storage ponds located on 120th Street, between Avenue L and Avenue M. Recycled water is conveyed to the storage ponds via a transmission main along Avenue N that could also be utilized to convey recycled water to recharge basin alternatives.

- **Los Angeles World Airports**. LAWA owns the property on both sides of Littlerock Creek, roughly between Palmdale Boulevard and Avenue M. As such, alternatives in this location would be situated within the LAWA property boundary. Alternatives that are located within the property owned by LAWA would require easement or land acquisition. The approval process could be complex and pose several challenges.

- **Air Force Plant 42**. Air Force Plant 42 is a U.S. Government aircraft industrial facility, with a runway that is shared with the Palmdale Regional Airport. This facility will be concerned with wildlife attraction (potential hazardous bird strikes to aircraft) to ponding of water in recharge basins, requiring set-back distances to be considered for categorizing alternatives. Based on Federal Aviation Administration (FAA) guidelines contained in its Wildlife Attractants Advisory Circular (WAAC), a 10,000-foot buffer zone around runways is required, precluding hazardous wildlife attraction, which can be associated with recharge basins. A supplemental zone from 10,000 feet to 5 miles requires appropriate wildlife hazard mitigation techniques.

- **Quarries**. There are rock quarries located adjacent to and west of Littlerock Creek, producing sources of commercial rock. Therefore, an alternative's proximity to the quarries needs to be considered along with the potential for lateral seepage into quarry pits, which could adversely influence quarry operations. In the future, quarry operations may expand northward along the creek.

1.3.2 Recycled Water Regulations

Alternatives with recycled water recharge would require permitting through the Regional Water Quality Control Board (RWQCB) and coordination with the extraction for potable use requirements from the California State Water Quality Control Board Division of Drinking Water (DDW) (formerly California Department of Public Health [CDPH]). The recycled water replenishment regulations adopted on June 18, 2014 identify the requirements and approval process, which can be lengthy and complex. Regulations require that any recycled water recharged be blended with a diluent source of supply. While blending does not have to physically occur at the time of recharge, the replenishment area must be essentially the same for both recycled water and diluent supply for proper blending. It is anticipated that the initial blending requirement will be 80 percent diluent with 20 percent recycled water. With successful water quality testing and monitoring, it is anticipated that the blending requirement will gradually be decreased to 50 percent diluent water within 11 years.

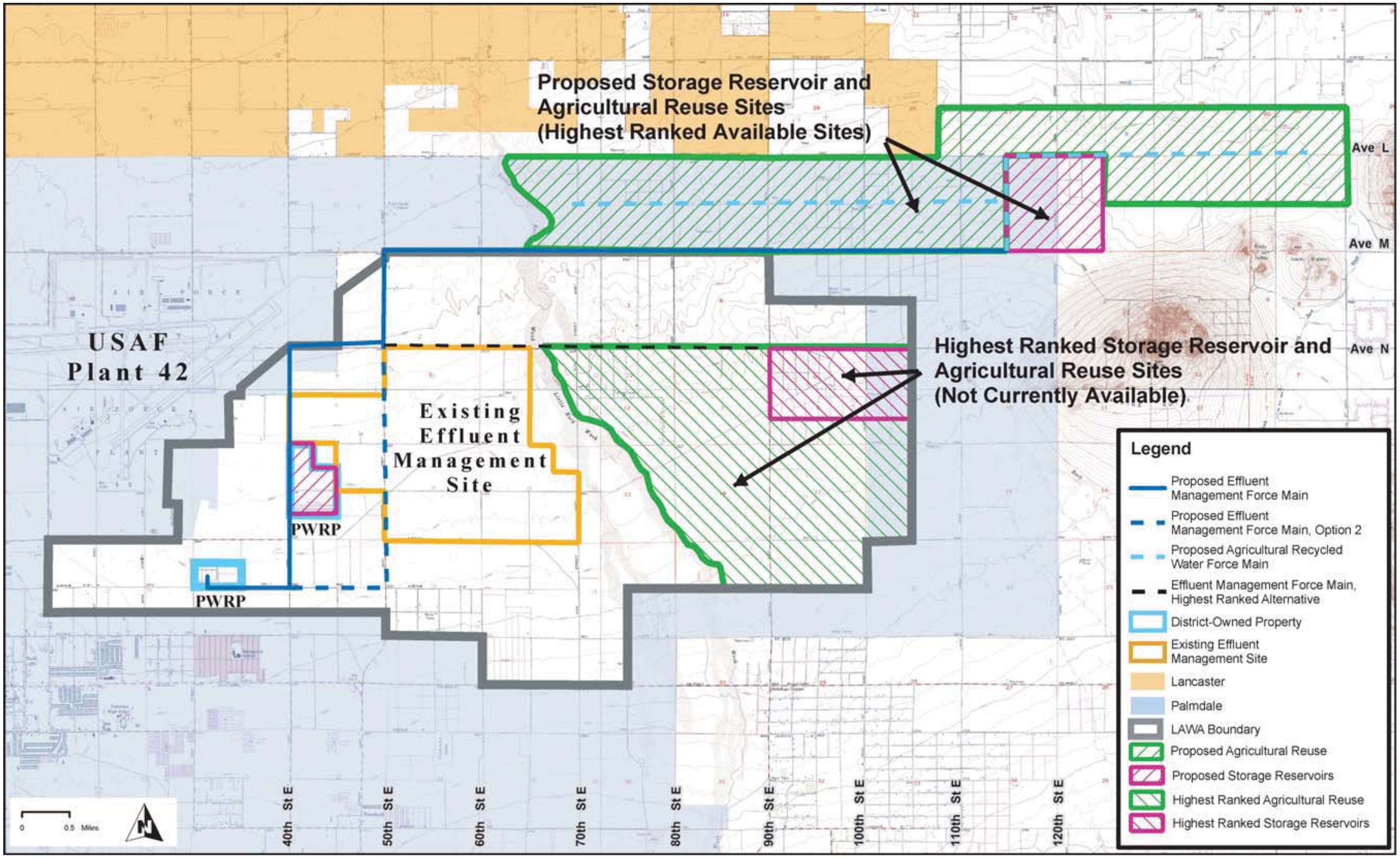


Figure 1-2: Palmdale WRP Existing and Proposed Effluent Management Sites

Source: LACSD, Final PWRP 2025 Facilities Plan and EIR, September 2005

1.4 Approach

This feasibility study consisted of multiple tasks with key technical memoranda (TM) and reports recording findings at the conclusion of specific tasks.

- Task 2, *Regional Water Banking Needs in the Antelope Valley Technical Memorandum (Kennedy/Jenks, 2015a)*, (Appendix A) updated the valley-wide water demands and supply plans and the development of an Integrated Groundwater Banking Plan.

- Task 3, *Source Water Opportunities for LCGRRP Technical Memorandum (Kennedy/Jenks, 2015b)*, (Appendix B) evaluated the availability and timing of recharge supplies in the East Branch of the California Aqueduct.

- In Task 4, Kennedy/Jenks reviewed the hydrogeology of the study area and utilized information from preceding tasks to identify 10 preliminary alternatives for the design and layout of the proposed LCGRRP, wherein alternatives were designated as Alternative 1 – Alternative 10. In addition, this work identified different operational scenarios for the alternatives. These alternatives include locations for recharge basins within the study area, along with different extraction well network configurations.

- Task 5 identified potential environmental constraints for alternative sites. Two reports documented these findings:

    - *Biological Constraints Associated with the Palmdale Water District's Littlerock Creek Groundwater Recharge and Recovery Project (Helix Environmental Planning, 2014)* (Appendix C)

    - *Phase I Cultural Resources Assessment for the Littlerock Creek Groundwater Recharge and Recovery Project (Applied Earthworks, Inc., 2014)* (Appendix D)

- Task 6, *Groundwater Modeling Report (Kennedy/Jenks, 2015c),* (Appendix E), evaluated the use of a numerical groundwater flow model to simulate the impacts of the alternatives, including subsidence and water quality.

- Task 7, Kennedy/Jenks evaluated the 10 alternatives developed in Task 4 based on a set of evaluation criteria; shortlisted the most beneficial alternatives; refined the alternatives to a set of the "final four" alternatives; and further evaluated these "final four" alternatives in order to identify the best two alternatives to pursue. Results of this work are presented in this Final Report.

1.5 Organization of Report

This Final Report is organized as follows:

- Section 1: Introduction - introduces the LCGRRP, provides key background information, and orients the reader to work conducted and deliverables produced under the LCGRRP Feasibility Study.

- Section 2: Physical Characteristics of the Study Area – describes the physical characteristics of the study area, including a discussion of hydrogeology, water quality, and subsidence.

- Section 3: Projected Demands and Facility Sizing Summary – presents the projected water demands, operational scenarios, facility sizing, and unit costs.

- Section 4: Summary of Source Water Opportunities – describes sources water opportunities, including SWP water, recycled water, as well as transfers and exchanges.

- Section 5: Summary of Environmental Constraints – presents the biological and cultural project constraints.

- Section 6: Groundwater Model Development – provides an overview of groundwater model development for the feasibility study.

- Section 7: Description of Preliminary Alternatives – provides a detailed description of the preliminary alternatives (1 -10), along with a discussion of groundwater modeling performed.

- Section 8: Preliminary Alternatives Evaluation – describes the evaluation of the preliminary alternatives.

- Section 9: Description of Refined Alternatives – provides a detailed description of the refined alternatives, along with a discussion of groundwater modeling and infiltration testing.

- Section 10: Refined Alternatives Evaluation – describes the evaluation of the refined alternatives.

- Section 11: Recommendation – provides an economic analysis of the project against two alternative water supply strategies, recommendations, as well as an implementation plan and schedule for future work. Additionally, an evaluation of hydropower generation at the recharge pipeline discharge is provided.

Section 2: Physical Characteristics of the Study Area

This section describes the physical characteristics of the study area, beginning with a presentation of the Basin's hydrogeology, followed by a review of water quality and subsidence issues.

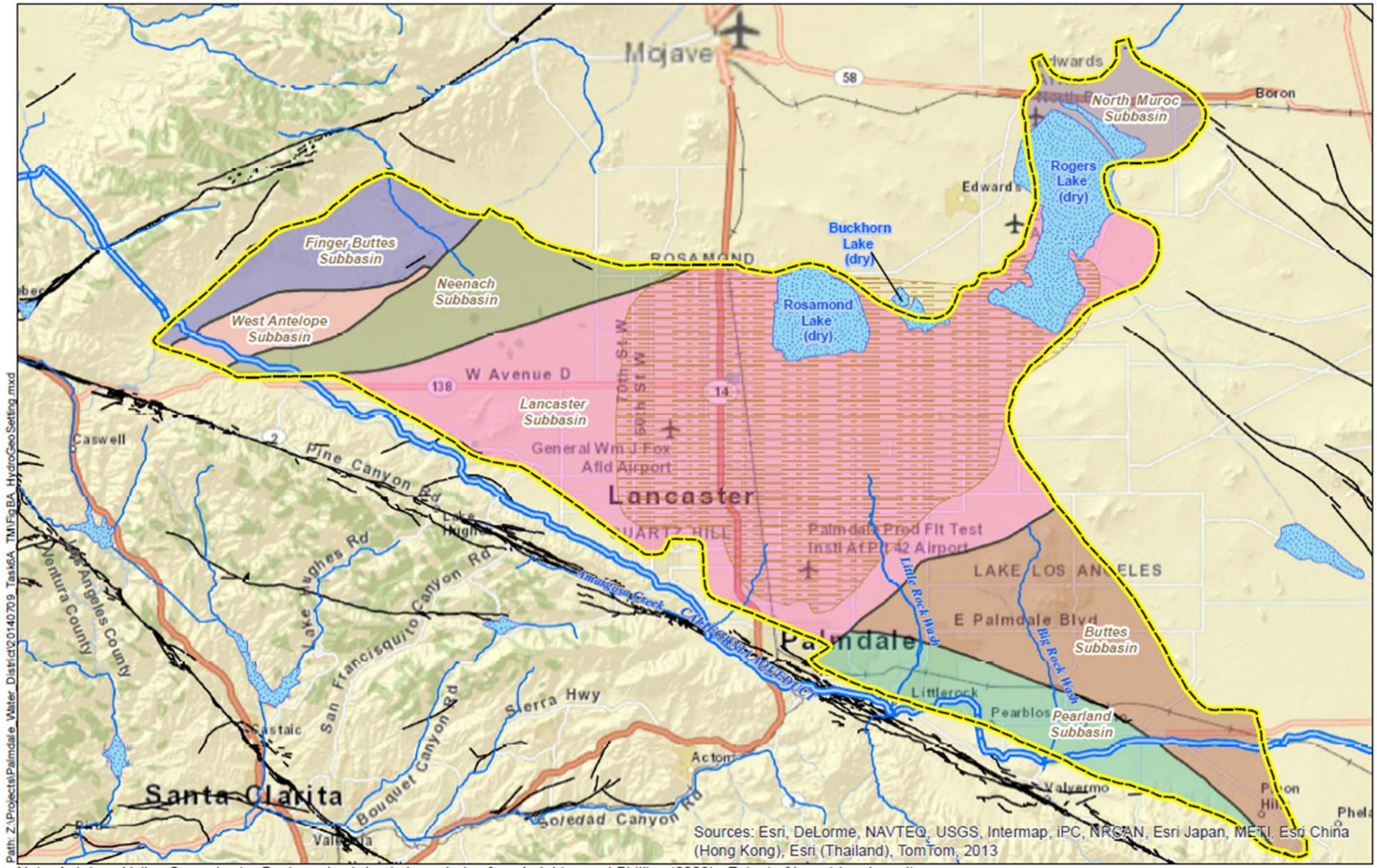
2.1 Hydrogeology

A detailed description of the Basin's hydrogeology can be found in the *Groundwater Modeling Report* (Kennedy/Jenks, 2015c; Appendix E), with a summary of the hydrogeology provided herein. The AVGB is located at the western end of the Mojave Desert in southern California, covering parts of Kern, Los Angeles, and San Bernardino Counties (Figure 1-1). The hydrogeologic setting of the AVGB is shown on Figure 2-1.

The Basin is topographically closed with respect to surface outlets, and was formed by alluvial deposits filling a structural depression resulting from tectonic activity in the area (Leighton and Phillips, 2003). The Basin is bounded on the northwest by the Tehachapi Mountains and the Garlock Fault Zone on the north and east by a series of low hills, ridges, and buttes, and on the south by the San Gabriel Mountains and the San Andreas Fault Zone. Groundwater flow is confined to the Basin, except at the far northeastern end, where a small amount of groundwater flows into the Fremont Valley Basin (Bloyd, 1967).

The basin sediments are made up of alluvium comprising poorly-sorted gravels, sands, silts, and clays that are unconsolidated to moderately indurated, with consolidation increasing with depth, and lacustrine deposits that are finer-grained than the alluvium. The alluvium was deposited in fans shedding from the uplifting San Gabriel and Tehachapi Mountains, while the lacustrine deposits were deposited in an ancient lake that slowly migrated northward over time (Durbin, 1978).

Durbin (1978) divided the Basin sediments into two aquifers separated by a confining unit, the lacustrine deposits. The primary aquifer is located above the lacustrine deposits, stretching to the ground surface; it is assumed to be unconfined everywhere. The primary aquifer is not present in the Rogers Lake area. The deep aquifer is largely located below the lacustrine deposits; it is confined where the lacustrine deposits lie above it, and unconfined where the primary aquifer and lacustrine deposits are absent in the Rogers Lake area. Leighton and Phillips (2003) defined an aquifer structure in the Basin that divided the sediments into three aquifers based on a chronostratigraphic approach and an assumption that the layer boundaries are horizontal everywhere (except the ground surface and the layer bottoms where they overlie bedrock). They utilized lithologic and geophysical logs collected from boreholes in the Lancaster area to define layer boundaries at 1,950 feet above mean sea level (ft msl) and 1,550 ft msl, with each boundary representing locations where the deposits become less permeable and more indurated. The upper aquifer stretches from the ground surface to 1,950 ft msl, the middle aquifer from 1,950 to 1,550 ft msl, and the lower aquifer from 1,550 to 1,000 ft msl, except where the bedrock is above these bottom depths. Below 1,000 ft msl, the sediments were assumed to not be a significant part of the aquifer system.



Note: Antelope Valley Groundwater Basin and sub-basin boundaries from Leighton and Phillips (2003). Extent of lacustrine deposits modified from Leighton and Phillips (2003).

Legend

- Antelope Valley Groundwater Basin Boundary
- Faults Mapped by USGS
- Lacustrine Deposits
- Groundwater Subbasin Boundary

N

0 4 8

Scale: Miles

Kennedy/Jenks Consultants

Palmdale Water District
Palmdale, California

Hydrogeologic Setting of the Antelope Valley Groundwater Basin
K/J 1344505*00
February 2015

Figure 2-1

In this tectonically-active region, faults are common and frequently act as barriers to groundwater flow. The Basin was divided into seven sub-basins largely due to the presence of these faults (see, for example, Bloyd, 1967). Of these seven sub-basins, the LCGRRP study area is confined to the Lancaster, Buttes, and Pearland sub-basins (Figure 2-1). Leighton and Phillips (2003) assumed the fault between the Pearland and Buttes sub-basins as a partial groundwater flow barrier, but did not consider the inferred fault between the Pearland and Buttes sub-basins and the Lancaster sub-basin to be a barrier.

Relative to the hydrogeology of the study area, key findings that influence the LCGRRP include:

- Releasing water from the East Branch of the California Aqueduct directly into the creek would result in a substantial volume of recharge immediately into the Pearland Sub-basin and may result in high water levels in the adjacent quarries.

- The boundary between the Pearland and Buttes sub-basins is considered to be a partial barrier to groundwater flow, while the boundary between the Buttes and the Lancaster sub-basins allows for the free flow of groundwater from the Buttes to the Lancaster sub-basin.

- The Lancaster sub-basin has the highest specific capacity; roughly double the Pearland and Buttes sub-basins. Furthermore, it is the most widely used for groundwater production and is deeper than Buttes or Pearland sub-basins.

- The Buttes sub-basin is shallower than the Lancaster sub-basin and has a lower hydraulic conductivity that could contribute to excessive mounding under the recharge basins.

- Because there are very few existing wells in the Buttes sub-basin, there is little available information to characterize the hydrogeology (i.e., aquifer transmissivity). Such unknowns result in a level of uncertainty associated with this sub-basin.

2.2 Water Quality

Groundwater within the study area is reported as a calcium bicarbonate type, suitable for domestic, irrigation, and most industrial uses (Duell, 1987; Wildermuth, 2007). Historic total dissolved solids (TDS) concentrations for the Basin have generally ranged between 200 to 400 milligrams per liter (mg/L) in the vicinity of Palmdale, but exceeding 1,000 mg/L in the vicinity of the playas (Duell, 1987). The Buttes sub-basin has a lack of adequate water quality (and hydrogeological data) compared to the Pearland and Lancaster sub-basins.

Much of the natural groundwater recharge to the Basin originates as precipitation initially contacting granitic rocks in the mountains to the south of the Antelope Valley. General ionic compositional differences between this water and local ambient groundwater in the Basin (previously subject to water-rock interactions, evapo-concentration, and other processes) provides a means of potential areas of recharge and/or preferential subsurface flow of natural recharge in the study area. Specifically, the distribution of cation ratios (e.g., calcium + magnesium versus sodium + potassium) across the Basin can be indicative of the provenance of local groundwater and the extent to which cation exchange and localized evapo-concentration processes have influenced water chemistry.

Recent water quality data sets from area wells are available from the State Water Resources Control Board (SWRCB) Groundwater Ambient Monitoring and Assessment Program (GAMA) database, which includes water quality parameter data maintained by the U.S. Geological Survey and the California Department of Water Resources (DWR). The GAMA data set was used to access ambient conditions and to identify possible groundwater chemistry responses to the introduction of recharge water of differing composition. In addition, historic water quality data for water supply wells operated by PWD exists. Both datasets illustrate a large degree of compositional overlap, indicating the extent of water quality variability in the groundwater banking area (ranging from calcium-rich to sodium-rich). The distribution of the divalent: monovalent cation ratio in wells across the alluvial fans associated with the Littlerock Creek and Big Rock Creek indicates that comparatively calcium- and magnesium-rich groundwater trends northward into the Antelope Valley from the mountain fronts, generally following both the Littlerock Creek and Big Rock Creek washes.

Among key individual water quality parameters of environmental concern, the median and average nitrate concentrations (based on historical averages of GAMA wells) are 1.8 and 3.8 mg/L NO_3 as nitrate, respectively. However, a subset of wells in the data set are characterized by higher historic average concentrations (between 30 and 45 mg/L), approaching the state maximum contaminant level (MCL) of 45 mg/L.

Historically, LACSD's Effluent Management Site discharged wastewater effluent to the ground surface. As a result, groundwater in this area has become elevated in nitrate and other constituents, creating a nitrate plume with concentrations above the MCL.

The median and average arsenic concentrations (based on historical averages of GAMA wells) are both less than 0.001 mg/L (which is less than the MCL for arsenic of 0.01 mg/L).

Water quality modeling was conducted to model water quality impacts from the alternatives, and these results are discussed in Section 6.

2.3 Subsidence

Subsidence is the process of compaction of aquifer sediments resulting from the withdrawal of groundwater from storage and lowering of groundwater head elevations (although effects involving a rise in the water table as well as mineral dissolution and precipitation processes can also occur). This happens because the lowered groundwater head reduces fluid pressure within the aquifer, allowing for the materials of the aquifer skeleton to settle under the weight of the overbearing sediments. The mechanics of subsidence are discussed in the *Groundwater Modeling Report* (Kennedy/Jenks, 2015c; Appendix E).

Leighton and Phillips (2003) summarized the historical occurrence of subsidence in the Basin due to groundwater withdrawal. Since groundwater development started in the 1920s, groundwater pumping has outpaced natural recharge, leading to declining storage and dropping groundwater head. Over that time, groundwater head has dropped at least 100 feet across most of the Basin, and more than 200 feet in parts of the Basin. This has led to subsidence of as much as 6.6 feet between 1930 and 1992 near Lancaster and about 10 miles east of Lancaster. Subsidence progressed at a relatively slow rate through about 1960, and then increased markedly as Basin-wide pumping increased. The rate of subsidence decreased through the latter third of the 20th century, but has not stopped. The temporal evolution of the subsidence rate tracks with the evolution of groundwater head elevations in the Basin.

The subsidence has been confined to the Lancaster sub-basin, plus a very small area of the Neenach sub-basin. Although subsidence has been greatest in the central part of the Basin (around and east of Lancaster), the area of historical subsidence is centered more to the north, reaching all the way to the northern Basin boundary. In contrast, historical measured subsidence in the portions of the Lancaster sub-basin closest to the southern Basin boundary has not exceeded 1 foot.

Section 3: Projected Demands and Facility Sizing Summary

The District's current system consists of 24 water production wells (with 22 operational), providing a total well capacity of 11,400 gallons per minute (gpm), with annual groundwater production in the range of 11,000 to 12,000 AF/yr. The Leslie O. Carter Water Treatment Plant has a capacity of 35 mgd and currently operates at about 13,000 AF/yr. The distribution system has a total storage capacity of 52.5 million gallons for operational, emergency, and fire flow storage. Water demands are projected to increase alongside development of the District's service area as described below.

3.1 Projected Water Demands

PWD serves a combination of residential, commercial, and industrial users, with essentially no agriculture. Their current system provided approximately 23,000 AF/yr in 2013 and 2014. Table 3-1 provides a water demand projection for PWD's service area, based on a preliminary draft version of PWD's Water Master Plan, which is currently being updated. A land use analysis indicates that demand will be 44,600 AF/yr under buildout conditions. By 2040, demand is projected to be 31,100 AF/yr. For the 50-year financial analysis of the LCGRRP from 2018 through 2067, the demand in 2067 is projected to be 39,160 AF/yr.

Table 3-1: Projected Retail Demands

Year	Annual Average Demand (AF/yr)
2015	24,809
2020	25,900
2025	27,200
2030	28,500
2035	29,800
2040	31,100
2045	32,457
2050	33,873
2055	35,350
2060	36,892
2065	38,502
2070	40,181
2075	41,934
2080	43,764
Buildout	*44,600*

Existing supply is acquired from SWP allocation, local surface water, and groundwater. However, the Basin has been in an overdraft condition (i.e., pumping greater than natural recharge) since approximately 1930. As a result, groundwater sources are in the midst of an adjudication process as previously described in Section 1. Based on feedback from District staff, it is assumed that the District will receive a groundwater right of 7,200 AF/yr effective in 2022, with a four-year tapering period prior to this year. Assuming the District receives 58% of its Table A water from the SWP (12,354 AF/yr) and 4,000 AF/yr of local surface water, then it will begin to face a deficit by 2021. By 2040, it is estimated that the deficit will reach approximately 7,500 AF/yr. By 2067, this deficit would reach approximately 15,600 AF/yr, and at buildout this deficit would reach 21,000 AF/yr. In dry years when the SWP allocation is less than 58%, these deficits would be much larger.

3.2 Operational Scenarios

In order to ensure the most effective ratio of recycled water and diluent water for the size of the water bank, four operational scenarios (1, 2A, 2B, and 3) were defined. Scenarios 1 and 3 apply to all the alternatives; Scenario 2A is applicable to Alternatives 3 through 10; and Scenario 2B is applicable to Alternatives 1 and 2. Each scenario is described below:

- Scenario 1 – Low Water Treatment Plant (WTP) Utilization: This scenario assumes minimal surface water allocation for treatment at the LOCWTP, with surface water treatment remaining constant at about 4,000 AF/yr over the project's life cycle. This minimal flow is intended to maintain granular activated carbon (GAC) filters at the treatment plant. The remaining surface water would be stored in the water bank through surface spreading and recovered using new wells.

- Scenario 2A – Moderate WTP Utilization with Recycled Water for Groundwater Recharge: This scenario assumes that the treatment plant would serve only 25 percent of the total retail demands every year. The remaining available surface water would be delivered to the water bank for both recovery and banking, with banked water available in dry years. Scenario 2A assumes groundwater recharge through a combination of surface and recycled water.

- Scenario 2B – Moderate WTP Utilization without Recycled Water for Groundwater Recharge: This scenario is the same as 2A, but assumes local surface water supply only for recharge.

- Scenario 3 – High WTP utilization: This scenario assumes that the majority of surface water would be treated at the LOCWTP. It also assumes that the water treatment plant's utilization will grow from about 25 percent of total retail demands in the beginning of project's life cycle (2018) to about 65 percent by the end of project's 50-year financial evaluation (2067). The remaining surface water and available recycled water would be stored in the water bank and recovered using new wells.

With an initial recycled water contribution (RWC) of 20%, increasing to 30% after 5 years, 40% after 8 years, and 50% after 11 years, Kennedy/Jenks has concluded that Scenario 2A defines an optimum utilization of recycled water and project capacity. Through this scenario, the WTP serves 25 percent of demands with the water bank serving 45.4%, 51.5%, and 54.4% of the water demand in 2040, 2067, and at buildout, respectively. Figure 3-1 presents the projected annual water supplies and demand under long-term average hydrological conditions.

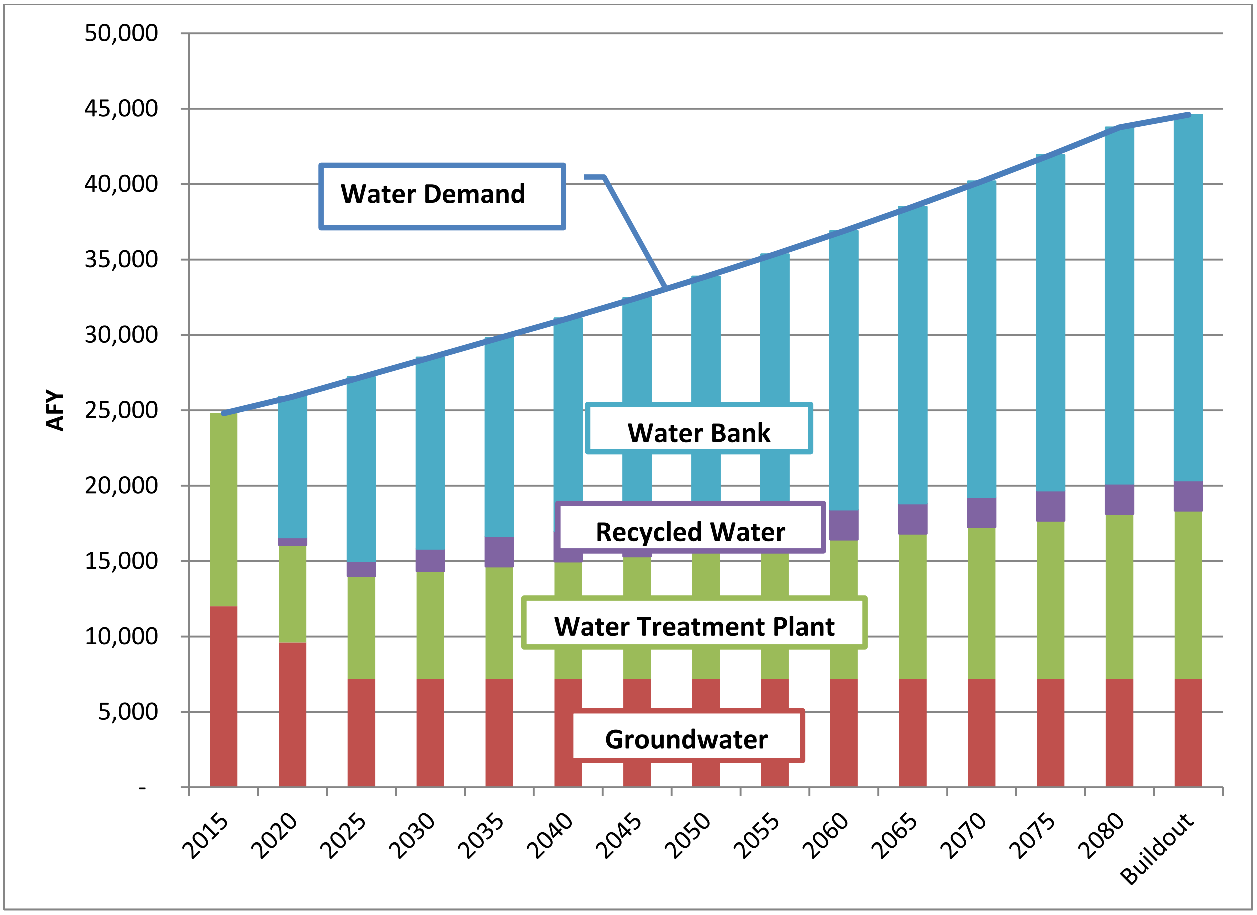


Figure 3-1: Projected Annual Water Supplies & Demand

3.3 Facility Sizing

Scenarios 2A and 2B offer an optimization by providing sufficient diluent supply to maximize the recycled water content after the first five years of the project and utilizing existing supply facilities for average base supply as well as maximum day demand (MDD) peaking, without over-sizing the LCGRRP extraction wells, collection pipelines, distribution pump station, and distribution transmission pipeline. Under Scenario 2, the recovery wells are sized to meet annual average demand and not MDD. Preliminary sizing for LCGRRP facilities was developed based on Scenario 2. The design criteria and accompanying assumptions are as follows:

- Turnout Capacity for Recharge: 50 cubic feet per second (cfs)
- Diluent Pipe Size: 30-inch
    - Assumes a maximum allowed velocity (by gravity) of 10 feet per second (fps)
- Recycled Water Turnout: 20-inch
    - Assumes a maximum velocity 8 fps.
- Combined Raw/Recycled Pipeline, where applicable: 36-inch

- Based on maximum velocity of 8 fps

- Net Recharge Area: 60 acres
  - Assumes an average long-term percolation rate of 3 feet per day (fpd) and includes 75 percent spare basin capacity for wet-dry rotation and maintenance.

- Gross Recharge Site: 160 acres minimum (175 acres for Alternatives 6, 7, 8, and 9)
  - Includes 50 percent more surface area to account for access roads and berms and a 300-ft setback all around the recharge basins.
  - Alternatives 6, 7, 8, and 9 straddle the Buttes and Lancaster sub-basins, and require additional land to separate the two sets of recharge basins.

- Number of Recovery Wells by Buildout:
  - 33 for Alternative 1
  - 32 for Alternative 2
  - 29 for Alternatives 3, 4, 5
  - 22 for Alternative 6
  - 21 for Alternatives 7, 8, 9
  - 16 for Alternative 10
  - Assumes summer peaking is met through 22 currently active groundwater wells and supply from the LOCWTP

- Recovery Well Capacity:
  - 500 gpm for Pearland sub-basin
  - 600 gpm for Buttes sub-basin
  - 1,200 gpm for Lancaster sub-basin

3.4 Costs Assumptions

For each alternative described in this technical memorandum, facility, water purchase, and operation & maintenance (O&M) costs will be provided. The costs are developed based on the cost assumptions presented in Table 3-2. The cost estimates for the preliminary alternatives do not include capital costs for the distribution system pump station, reservoir, or disinfection facilities. These facilities are included in the cost estimates for the four refined alternatives described in Sections 9 and 10.

Table 3-2: Cost Assumptions

Item	Value	Unit
50-cfs turnout	$500,000	$/ea
Pipelines	$10	$/in/LF
Recharge Basins	$100,000	$/acre
Recharge Basin Land Acquisition	$8,000	$/acre

Item	Value	Unit
Recovery Wells	$1,200,000	$/well
Pump Stations	$2,000	$/hp
Reservoir (Steel Tank)	$0.75	$/gal
Chlorination Facility	$250,000	ea
Chemical Cost	$0.88	$/AF
Power	$0.12	$/kWh
O&M Cost - Wells (% of Construction Cost)	1%	%
O&M Cost - Pumps/Tanks/Chemicals (% of Construction Cost)	2%	%
O&M Cost - Recharge Basins (% of Construction Cost)	1%	%
SWP Water	$4,500	$/AF/yr
SWP Purchase Cost	$250	$/AF/yr
Recycled Water Purchase Cost	$100	$/AF/yr
Water Delivery/Purchase Cost Escalation	3%	%
Phase I Planning Horizon	2018 – 2040	years
Total Project Planning Horizon	2018 – 2067	years
Discount Rate	5%	%
Inflation Rate	3%	%
Contingency (% of Construction Cost)	20%	%
Engineering & Admin Cost (% of Construction Cost + Contingency)	20%	%

Notes:
All costs are shown in 2015 dollars.
ea = each; LF = linear foot; hp = horsepower; gal = gallons; kWh = kilowatt hour

Section 4: Summary of Source Water Opportunities

The objective of this section is to identify types of SWP and non-SWP water that could be made available to PWD for the LCGRRP, and to provide estimates of the available quantities and their probability of occurrence. This assessment of SWP water types is largely based on the information presented in the California Department of Water Resources' (DWR) *The SWP Draft Delivery Reliability Report 2013* (DWR, 2013), hereinafter referred to as DWR report. Results of this work are detailed in the *Source Water Opportunities* TM (Kennedy/Jenks, 2015b; Appendix B).

Under the terms of their long-term water supply contracts with DWR, the 29 SWP contractors receive a percentage of their specified Table A Amounts each year, known as "annual allocations." In addition to Table A Amount allocations, each long-term water contract describes several types of SWP water that are available to SWP contractors to supplement Table A water. These types of water include "Article 21" water, carryover water, and turnback pool water.

The DWR report updates the estimated water delivery capability of the SWP for current conditions (2013) and two decades from now (2033). The estimates include the best-known potential future effects of climate change and the anticipated changes in Sacramento River basin land uses. Climate change will alter the timing and magnitude of inflows to upstream storage facilities including Shasta, Folsom, and Oroville reservoirs. In addition, rising sea levels will pose operational challenges to maintaining suitable salinity levels in San Francisco Bay and the Sacramento–San Joaquin Delta (Delta) (DWR, 2013).

Other factors in the analysis of SWP reliability in the DWR report were assumed to not change over time since they were determined to be too uncertain to incorporate into the analysis. For example, regulatory restrictions issued by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) in biological opinions (BOs) were assumed to remain unchanged. The BOs dictate the timing and amounts of SWP Delta exports. These restrictions are undergoing further review and analysis under a federal court order. Also, the Delta water quality and flow requirements contained in the SWRCB water quality control plan for the Delta were assumed to remain unchanged. However, the SWRCB is revising its water quality control plan. Future revisions to the plan and their subsequent inclusion into DWR water rights for the SWP could have a significant effect on SWP deliveries (DWR, 2013).

Other sources of water not related to the SWP may also be considered for the LCGRRP. The primary sources of such water include recycled water from the LACSD Palmdale WRP and water transferred from and/or exchanged with non-SWP entities, such as Los Angeles Department of Water and Power (LADWP). LADWP owns and operates the Los Angeles Aqueduct system, which delivers water from the eastern Sierra Nevada. The assessment of these sources, including estimated available quantities and costs, is summarized in this section, and it is based on information from other SWP contractors, recent water market in California, and initial discussions with potential project partners.

The potential constraints for acquiring additional water supplies and using SWP facilities are also summarized in this section. To determine whether and to what extent the SWP conveyance facilities could be utilized to convey water from project partners to and from the LCGRRP, estimates of seasonal available capacities in select reaches of the California

Aqueduct in recent years are presented. The use of the California Aqueduct as conveyance must be requested from and confirmed by DWR through modeling and is subject to availability of capacity at differing times of the year. The information presented in this section is intended to provide only a "ballpark estimate" of available capacities in the recent past.

4.1 State Water Project

This section describes types of SWP water, including Table A Amount allocations, Article 21, Table A Amount increase opportunities, as well as other SWP opportunities (Carryover, Turnback Pool, and Multi-year Pool). This section also describes the reliability and availability of SWP for the LCGRRP.

4.1.1 Table A Amount Allocations

The maximum Table A Amount is the basis for apportioning water supply and costs to the SWP contractors. Once the total amount of water to be delivered is determined for the year, based on hydrologic conditions, water remaining in SWP storage, and other factors, then all available water is allocated in proportion to each contractor's annual maximum SWP Table A Amount. The established maximum Table A Amounts for the 29 SWP contractors varies widely; the Table A Amount for PWD is currently 21,300 AF/yr.

DWR calculates the water delivery reliability of the SWP using a computer model, which simulates existing and future operations of the SWP by using a system of probability as estimated by DWR. The long-term average allocation is forecasted to decline from 63 percent (or 13,400 AF/yr) under existing conditions to 59 percent (or 12,600 AF/yr) under future conditions.

Figure 4-1 shows that the annual delivery probability curves (i.e., exceedance plots), which provide the estimated percentage of years in which a given annual delivery is equaled or exceeded. For example, it can be concluded from this graph that there is 77 percent probability that the Table A allocation exceeds 50 percent under existing (2013) conditions, and that this probability is expected to decline to about 65 percent under future (2033) conditions.

4.1.2 Article 21 Water

Article 21 water (defined in Article 21 of the water supply contracts, formerly called "Interruptible Water") is offered only periodically, usually in wet hydrologic years, when excess flows are available in the Delta. The estimated range of monthly Article 21 water availability for PWD is a relatively small amount of about 300 to 430 AF/yr over the next 20 years on an average basis.

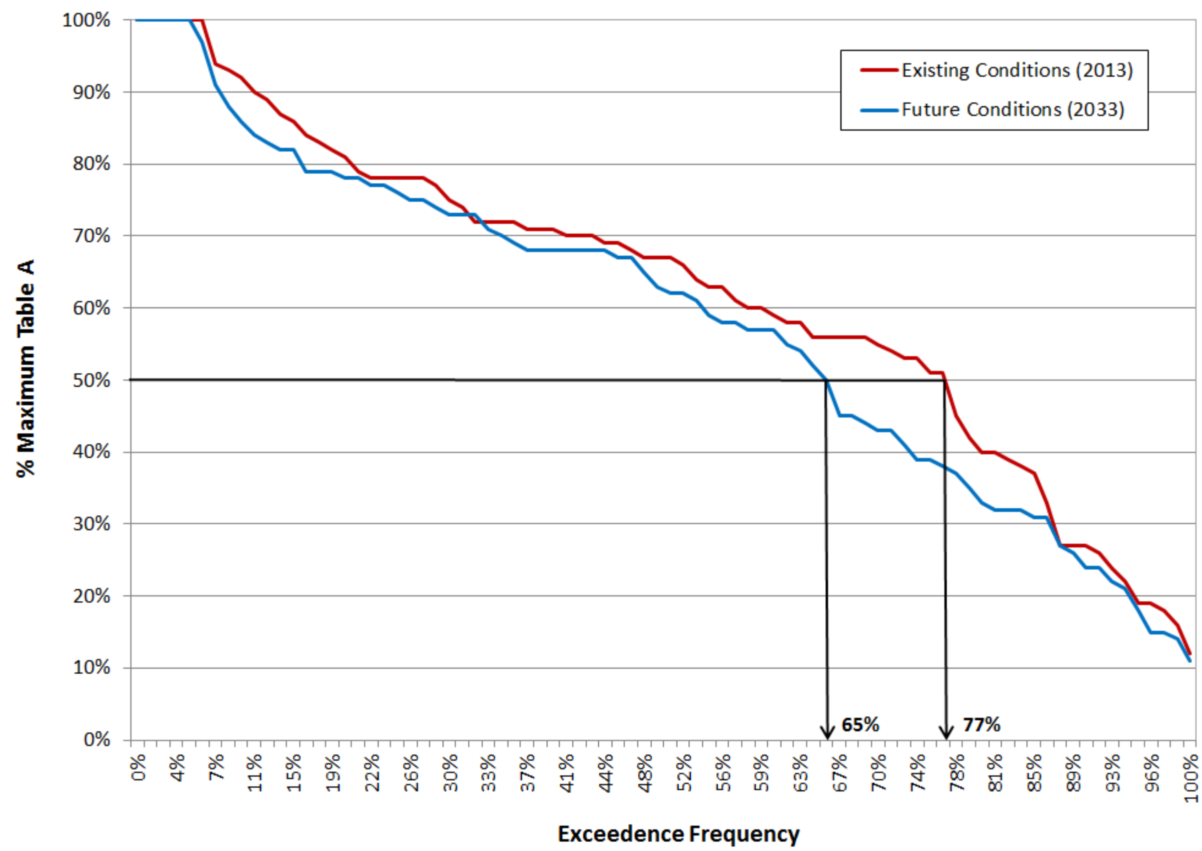


Figure 4-1: Exceedance Frequencies of Palmdale Water District Table A Allocations

4.1.3 Table A Amount Increase Opportunities

PWD may increase its current Table A Amount through either short-term or permanent transfer of a portion of some other contractors' Table A Amounts. Selected contractors may have Table A Amounts in excess of their service area demands for a time, but may not wish to permanently transfer portions of that Table A Amount. In these cases, arrangement can be made for purchase of the excess for a predetermined time as agreed upon.

PWD has entered into a long-term purchase of the Table A allocations with the County of Butte, another SWP contactor. The term of the agreement is ten years, and PWD pays all SWP costs, including capital and O&M, as well as the variable power costs to deliver the water to its service area.

Contractors (or their member agencies) may hold contractual SWP Table A in excess of their demands. Due to the high annual fixed costs of SWP Table A, these agencies may wish to sell this excess to another contractor. As such, Table A would be subject to the SWP annual allocation and SWP delivery and reliability constraints.

4.1.4 Other SWP Water Opportunities

SWP contractors have several options for water that is allocated to them: use it, store it for later use, or transfer it to another contractor. Each long-term water contract describes several types of SWP water that are available to SWP contractors to supplement Table A allocations and Article 21 water: carryover water, turnback pool water, multi-year pool water, and SWP exchanges. Regardless of hydrologic conditions, Table A allocation water is given first priority for delivery over other types of SWP water. Historically, SWP water deliveries to PWD since 1996 have ranged from approximately 9,000 AFY to 21,500 AFY, with an average value of approximately 12,500 AFY.

- **Carryover Water** is Table A water that is allocated to a contractor and approved for delivery to that contractor in a given year, but is not used by the end of the year. Since 1996, PWD has recalled up to 5,300 AF/yr of its carryover water. However, once implemented, the LCGRRP will act as a water savings account for PWD, and it is anticipated that PWD will no longer need to use SWP facilities to store its excess Table A allocated water.

- **Turnback Pools** are a mechanism by which contractors with excess Table A allocations in a given hydrologic year may sell that excess water to other contractors. Since 1996, PWD has only purchased a total of about 750 AF from turnback pools in order to supplement its water supplies, mostly during peak demand months of summer. However, upon implementation of the LCGRRP, PWD should purchase and store this type of water (prior to April 1) if and when the water is offered at a lower price than Table A Amount, particularly during wet years when supply to the pools is high and retail demands are lower than normal.

- **Multi-Year Pool** is a new program, which has been proposed by the SWP contractors and initiated by DWR, to improve management of limited SWP Table A supplies. The initial term of a demonstration multi-year pool will be two years (to distinguish it from the turnback pool and to not conflict with SWP water supply contract terms).

- **SWP Exchanges** are included in provisions of the water supply contracts, providing for exchanges of SWP water (as well as non-SWP water). PWD has entered into annual exchanges with one or more other SWP contractors as needed to bolster its annual Table A allocation in a given water year. These exchanges are highly dependent on hydrology, contractor demands, and the availability of Table A water. Exchanges can be “balanced” (i.e., one acre-foot to the buyer, exchanged for one acre-foot payable to the seller in a future year), or “unbalanced” (in which the buyer receives one acre-foot but agrees to pay a higher amount of water to the seller in a future year, often 1.5 to 2 acre-feet). Because exchanges have flexible terms and can be affected quickly, they are becoming more common among SWP contractors.

4.2 Recycled Water

PWD currently has a small recycled water program that only serves one customer (McAdam Park). PWD is taking proactive steps towards expanding the use of non-potable water to meet a variety of non-potable and indirect potable uses through the formation of a Joint Powers Authority (JPA) with City of Palmdale. One of the PWD goals is to utilize any available recycled water for groundwater recharge as part of the optimal blend of supply alternatives to address future needs. The recycled water can be supplied to PWD from the LACSD Palmdale WRP, which currently produces about 10,000 AF/yr of Title 22 recycled water.

To project future supplies, it was assumed that recycled water from Palmdale WRP would grow linearly at the same rate as potable demands; approximately 0.9 percent per annum on an average basis in the 2015-2040 period. This projection results in an estimated recycled water supply of about 12,500 AF/yr by 2040, which is a lower number than the projections presented in the *Palmdale Water District Recycled Water Facilities Master Plan* (RMC, 2010). An initial 3.5 percent annual growth rate of potable water demands was estimated assuming that 2010 Urban Water Management Plan projections would delay by five years in order to account for slow economic recovery. The annual growth rate of potable water demands has since been revised and estimated to be 0.9 percent.

Based on these assumptions, it is estimated that the total recycled water supply from Palmdale WRP will grow to about 12,500 AF/yr by 2040 and 18,100 AF/yr by buildout. It is anticipated that the recycled water use for landscape irrigation will not exceed 2,000 AF/yr at buildout. In addition, approximately 4,000 AF/yr of recycled water is planned for use at a nearby power plant. Figure 4-2 presents projections of recycled water supply availability for the Project through 2040.

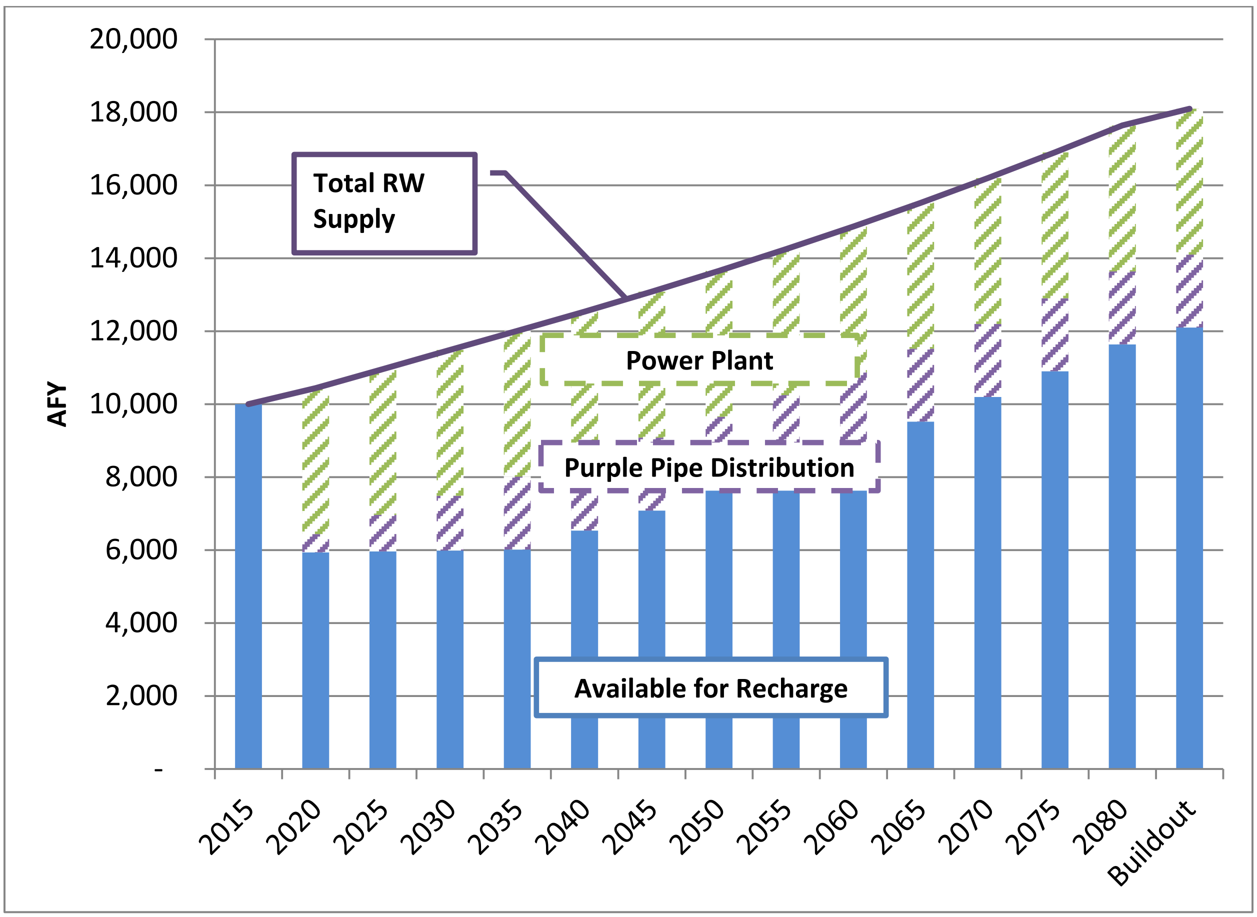


Figure 4-2: Projections of Recycled Water Supply Availability for Groundwater Recharge

4.3 Transfers and Exchanges

Pursuant to provisions of Article 55 of water supply contracts, contractors have the right to receive non-SWP water using SWP transportation facilities. For any non-SWP water delivered, contractors must pay the same power costs as Table A water as well as all incremental costs. A use of facilities charge must also be paid for conveying non-SWP water if a contractor is not participating in the repayment of a reach.

Because non-SWP water generally has a lower priority than SWP water, particularly if the water to be delivered is in excess of the contractors' annual Table A Amounts, delivery of this water is less certain pending capacity availability in SWP transportation facilities. Transfer/exchange opportunities include:

- **Transfer or Exchange with LADWP** – LADWP is a local water agency with significant demands and a diverse water supply portfolio that has expressed interest in participating in the Project. LADWP owns and operates the Los Angeles Aqueduct system that delivers water from the eastern Sierra Nevada – a region with hydrologic characteristics similar to but slightly different from those of the northern Sierra Nevada where the SWP supply originates. The Los Angeles Aqueduct system creates a unique opportunity to divert water from the Los Angeles Aqueduct system and transfer it to the PWD water bank via the East Branch of the California Aqueduct. The pump back and/or exchange mechanism to return the transferred water back to LADWP is yet to be developed.

- **Transfer or Exchange with Central/Northern California Water Rights Holder** - Several water districts and private entities have water for sale, both on a long-term and short-term basis. Depending on water rights or contract terms, geographic location, and access to infrastructure, water can be delivered directly or may require an exchange agreement.

4.4 Potential Water Transfer Constraints

A significant constraint to water transfers is available reach capacities in the California Aqueduct. The excess conveyance capacities of select reaches of the California Aqueduct in the past ten years are discussed in the *Source Water Opportunities* TM (Appendix B). To determine whether and to what extent the SWP conveyance facilities could be utilized to transfer non-SWP water to the Project and potentially from the Project through pump back, average available capacities in the last ten years (2004-13) were estimated for each month of the year. This period included three dry, four normal, and three wet hydrologic years. The information presented in Section 4 of the *Source Water Opportunities* TM 3 (Appendix B) only intended to provide a "ballpark estimate" of available capacities in the recent past. DWR will have to evaluate any future transfer through modeling to ensure adequate capacity exists at the time of transfer.

Based on records of SWP storage and deliveries along the East Branch reaches of the California Aqueduct (including East Branch Extension), it appears that there has been about 850 cfs of available capacities in East Branch reaches upstream of PWD's turnout (on a 10-year average annual basis). However, the availability and amount of available capacity varies both seasonally in a given year and from year to year depending on hydrologic conditions and Table A annual allocations, as detailed below:

- There is a strong inverse correlation between available reach capacities and the level of wetness of a given year. This is evident from higher total deliveries to all SWP contractors in years with higher annual allocations. For example, the highest total delivery in the past ten years occurred in 2006 when annual allocation was 100 percent (75-80 percent of total deliveries in 2006 were Table A water).

- In general, higher capacities were available in dry years and in March and April of wet years. On a ten-year average basis, there had been considerable amount of capacities available in all months (500-1,200 cfs).

- The lowest available capacities typically occurred in the high demand month of August. In August 2006, the available capacity in Reach 20A was as low as 50 cfs.

The results of the analysis conducted by Kennedy/Jenks indicates that there is substantial excess capacity, far in excess of the proposed LCGRRP turnout capacity, in the East Branch reaches of the California Aqueduct in all years and months except potentially July and August of a very wet year, on the order of 1 in 10 years.

Section 5: Summary of Environmental Constraints

Task 5 of the LCGRRP Feasibility Study identified potential environmental constraints for alternative sites. Two reports documented these findings, both of which are provided as appendices:

- *Biological Constraints Associated with the Palmdale Water District's Littlerock Creek Groundwater Recharge and Recovery Project (Helix Environmental Planning, 2014)* (Appendix C)
- *Phase I Cultural Resources Assessment for the Littlerock Creek Groundwater Recharge and Recovery Project (Applied Earthworks, Inc., 2014)* (Appendix D)

Key findings from these two reports are presented herein.

5.1 Biological Constraints

Helix's review was based on a literature review and reconnaissance survey of the preliminary alternative sites. The survey included mapping vegetation communities, developing comprehensive lists of plant and animal species observed, conducting habitat assessments for listed and sensitive species, and identifying areas or features potentially under the jurisdiction of federal and/or state resource agencies. The biological reconnaissance surveys were conducted on June 18 and 19, and November 18, 2014.

Initially, Helix conducted a thorough review of relevant maps, databases, and literature pertaining to biological resources known to occur within the study area. This literature review also served to place the project within a regulatory context, accounting for related and applicable federal and state regulations. Recent aerial imagery, topographic maps, and soils maps were acquired and reviewed to obtain updated information on the study area's biological setting. In addition, sensitive species and habitat databases were reviewed, including the California Department of Fish and Wildlife (CDFW), California Natural Diversity Database, the California Native Plant Society Electronic Inventory, and regional lists produced by the USFWS. The pre-survey investigation also included a verification of whether or not the project site falls within areas designated as final or proposed USFWS Critical Habitat for any federally-threatened or endangered species.

Based on the results of the biological reconnaissance, habitat assessments, and the project's regulatory context, the least-biologically constrained area within the Project site is Alternative site 10. Except for several areas of active desert dunes and rabbitbrush scrub, Alternative site 10 is entirely disturbed, upland habitat dominated by Russian thistle. Except for the extreme western end, Alternative Site 3 is entirely fallow, agricultural uplands with low potential to support sensitive species, and therefore also has relatively low constraints. Alternative sites 8, 9, 10A, and 10C are largely unconstrained, but support more extensive areas of native scrub vegetation, and thus are more likely to provide habitat for sensitive species. Note that Alternatives 10A and 10C are refined alternatives and are described in Section 9.

The most constrained locations are Alternative sites 1 and 2 (within Littlerock Creek), which are under CDFW jurisdiction and have high potential to support sensitive species such as Mohave ground squirrel. Also, the U.S. Army Corps of Engineers (USACE) could also assert jurisdiction over activities within this area. However, based on a preliminary assessment, Helix would not expect them to do so. Alternative Site 10B is unconstrained except in the southern end, where there is suitable habitat for Mohave ground squirrel and a historical record of its presence.

Alternative sites 6 and 7 are also relatively constrained, as they contain large numbers of Joshua trees and also include alluvial terrace and wash habitats at the edge of Littlerock Creek that are the most likely types of habitat for sensitive species.

Based on the potential constraints identified, Helix recommended a suite of studies to fully disclose potential impacts and permitting requirements:

- Rare plant survey, specifically targeting sagebrush loeflingia;
- Protocol-level surveys for burrowing owl;
- Protocol-level surveys for desert tortoise;
- Protocol-level trapping for Mohave ground squirrel, especially in Alternative Site 10B;
- Formal jurisdictional delineation; and
- Biological resources technical report to support California Environmental Quality Act (CEQA) documentation.

Under a worse-case scenario and assuming impacts to resources could not be avoided, the following agency permits could be required:

- Federal Endangered Species Act (FESA) Section 7 Biological Opinion and Incidental Take Statement or Section 10(a) HCP and Incidental Take Permit from the USFWS for impacts on desert tortoise;
- California Endangered Species Act (CESA) Section 2080.1 Consistency Determination from CDFW for impacts on desert tortoise;
- CESA Section 2081 Memorandum of Agreement and Incidental Take Permit from CDFW for impacts on Mohave ground squirrel;
- Clean Water Act (CWA) Section 404 Individual Permit or Nationwide Permit from USACE for impacts on waters of the U.S. (if Littlerock Creek, including paleochannels and tributaries, is considered jurisdictional);
- CWA Section 401 Water Quality Certification from SWRCB or RWQCB for impacts on waters of the U.S./waters of the State (if Littlerock Creek, including paleochannels and tributaries, is considered jurisdictional);
- State Porter-Cologne Water Quality Control Act Waste Discharge Requirements from the SWRCB or Regional Water Quality Control Board (RWQCB) for impacts on isolated waters of the State; and/or

- Fish and Game Code Section 1602 Streambed Alteration Agreement from CDFW for impacts on jurisdictional streambed or riparian habitat.

To summarize, Helix's analysis of the alternatives for the LCGRRP found no major biological resources constraints on any alternative site outside of Littlerock Creek based on the information available. Alternative Site 10B is potentially constrained by the historic record of Mohave ground squirrel in the southern end. A single low-sensitivity species was observed (loggerhead shrike), and the site was assessed as having high potential for only one listed species potentially requiring consultation and permitting with CDFW (Mohave ground squirrel). No sensitive plant species were observed, and the project site has low potential for any to occur. The LCGRRP is not expected to require federal permits from USFWS or the USACE, unless desert tortoise is determined to occupy impact areas, which is unlikely, and the USACE takes jurisdiction over Littlerock Creek, which based on preliminary assessment is unlikely. Alternative Sites 3, 10, 10A, and 10C are considered the least-constrained, respectively. Impacts to Littlerock Creek would require a Section 1602 Streambed Alteration Agreement from CDFW.

5.2 Cultural Constraints

Applied Earthworks, Inc. (AE) cultural resources investigation was conducted in accordance with CEQA. An archaeological literature and records search, a search of the Sacred Lands File from the Native American Heritage Commission, and a reconnaissance level archaeological survey of 10 percent of the LCGRRP area was performed. Native American individuals and organizations were also contacted to obtain additional information and/or concerns regarding cultural resource issues related to the LCGRRP.

The archaeological literature and records search indicated that 45 cultural resources are present within a 1-mile radius of the project area. A search of the Sacred Lands File from the Native American Heritage Commission indicated that no Native American cultural resources are known to exist within the immediate study area. Native American individuals and organizations were contacted to elicit information and/or concerns regarding cultural resource issues related to the proposed Project. Comments received stated that Littlerock was a drawing area for Native American people. As such, it was suggested that an archaeological and Native American monitor be present for new development in undisturbed areas. It was also noted that the study area has been occupied continuously by Native American ancestors, and it was recommended that a culturally-affiliated Native American monitor to be present during all ground-disturbing activities. The Tribal Historic and Cultural Preservation Representative for the Fernandeño Tataviam Band of Mission Indians indicated that the study area is located in a culturally sensitive area.

A reconnaissance level archaeological survey of 10 percent of project area (approximately 382 acres) was performed by AE on June 17–20, 2014 and November 17– 18, 2014. As a result, 17 archaeological resources were identified, 16 historic archaeological sites, and one prehistoric isolated artifact, indicating the archaeological sensitivity of the study area to be moderate to high. Once the project alternative and design are finalized, an intensive Phase I pedestrian survey of the direct impact areas is recommended by AE. After a complete inventory of cultural resources within the impact areas has been compiled, AE also recommended that an evaluation program be developed to assess the significance of these cultural resources as historical resources under CEQA. This recommended evaluation program will determine whether the

LCGRRP will impact any significant cultural resources, at which time further management recommendations can be made.

Section 6: Groundwater Model Development

A number of previous groundwater modeling studies have been performed in and around the study area. These studies are summarized in detail in the *Groundwater Modeling Report* (Kennedy/Jenks, 2015c; Appendix E). Durbin (1978) developed the first numerical groundwater flow model of the Basin for the U.S. Geological Survey (USGS). The purpose of the Durbin model was to develop a tool that could be used to predict the effect of various management alternatives on the groundwater flow system. The Durbin model was an early numerical groundwater model constructed prior to the introduction of the modular finite-difference flow model (MODFLOW) software system; it was accomplished using a computer program created specifically for the study. The model was constructed as a two-aquifer system, an upper aquifer and a lower aquifer, separated by a confining unit representing the lacustrine deposits. The model included streamflow infiltration, subsurface outflow (to other neighboring basins), evapotranspiration, pumping, and irrigation return flow.

Leighton and Phillips (2003) used numerous USGS reports published after development of the Durbin model to produce a finite-difference model using MODFLOW, the industry-standard modular groundwater flow modeling software package (McDonald and Harbaugh, 1988). The MODFLOW model grid is made up of a regular array of rows and columns with a one-mile resolution. This updated model simulated a three-layer aquifer system based on a chronostratigraphic approach, with the lacustrine deposits included as low-transmissivity area of the three layers. Thickness-integrated aquifer parameters (such as transmissivity) are allowed to vary depending on changes in head. Faults are simulated using the Horizontal Flow Barrier (HFB) package (Hsieh and Freckleton, 1993), which imposes a decreased conductance between cells on opposite sides of the fault. One of the most important upgrades affected in the Leighton and Phillips model was the inclusion of land subsidence resulting from the large declines in groundwater head over time, which was accomplished using the Interbed Storage (IBS) package (Leake and Prudic, 1991). This allowed for the prediction of the effect of groundwater management strategies on the future occurrence of land subsidence.

The USGS MODFLOW model, which covers the entire AVGB, is characterized by a resolution too coarse to simulate site-specific conditions over the project area. Therefore, several modifications were made to the regional model to enable its use for project simulations. In particular, the Telescopic Mesh Refinement (TMR) tool (Leake and Claar, 1999) was used to extract a portion of the existing regional model, which, in turn, was used to create a subregional model. The TMR tool creates a model grid from a subset of the grid cells in an existing model; the grid of the subregional model can then be set to a finer resolution. In addition, the TMR tool automatically generates boundary conditions for the TMR model.

For the LCGRRP, a TMR area was chosen within the existing regional model that covers the project area and a distance of several miles in each direction to prevent the specified head boundaries from significantly impacting onsite conditions. The TMR area includes the entirety of the Buttes and Pearland sub-basins and part of the Lancaster sub-basin. The resolution of the subregional TMR model was chosen to be 330 feet in both the east-west and north-south directions. The three-layer structure of the regional model was preserved. The subregional model includes no-flow boundaries along the southern and eastern boundaries, as in the regional model. Specified-head boundaries were introduced along the northern and western boundaries by the TMR tool, with the specified heads determined using the simulated head in the corresponding cells of the transient regional model. In order to facilitate application of the regional model to the LCGRRP area, other modifications were made, including:

- Changes to spatial and temporal distribution of groundwater pumping,
- Modifications of boundary conditions, and
- Improved delineation of faults within the subregional model domain.

For the refined alternatives presented in Section 9, numerical modeling was used to address potential water quality impacts – direct or indirect – stemming from groundwater banking operations. Direct impacts could include the introduction and mechanical spreading of constituents of the recharge water present in different concentrations than encountered in ambient groundwater. Indirect effects entail potential water-aquifer mineralogy interactions in response to changed aquifer geochemical conditions; an example of concern would include the mobilization of naturally-occurring adsorbed trace elements in response to shifting pH. To address both possibilities, the USGS reactive transport model PHAST (Parkhurst et al., 2004) was used to simulate the evolution of aquifer chemistry in response to artificial recharge. PHAST is a finite-differenced-based numerical groundwater flow and transport model that is linked with the USGS geochemical modeling code PHREEQC (Parkhurst and Appelo, 1999). PHREEQC models water-rock interactions, including mineral precipitation and dissolution, ion exchange, surface complexation with hydrous ferric oxide mineral phases, and aqueous speciation, assuming chemical equilibrium.

To summarize, the groundwater modeling simulation approach included:

- Analytic element modeling to screen preliminary alternatives (Section 7). For each simulation, the analytic element model addressed larger-scale controls on flow, including not only the recharge basins and extraction wells themselves, but also nearby faults as well as the transmissivity contrast between the Lancaster and Buttes sub-basins.
- Use of the subregional MODFLOW model was used to simulate refined alternative banking scenarios (see Section 9), including assessing possible land subsidence impacts.
- Use of the U.S. Geological Survey's PHAST model to develop a screening-level assessment of chemical reactive mixing associated with recharge.

Section 7: Description of Preliminary Alternatives

This section describes the 10 preliminary alternatives. As previously mentioned, water supply scenario 2A is utilized for sizing infrastructure. To recapitulate, water supply scenario 2A assumes that the Leslie O. Carter WTP would serve 25 percent of the total retail demands every year. The remaining available surface water would be stored in the water bank. Scenario 2A also assumes groundwater recharge through a combination of surface and recycled water.

Table 7-1 provides a summary of the preliminary facility sizing for the major recharge and conveyance components based on water supply scenario 2A. The proposed recharge locations and conveyance alignments are shown on Figure 7-1.

Table 7-1: Summary of Preliminary Facility Sizing

	Scenario 2A
Turnout Capacity[a] (cfs)	50
Raw Water Pipe Size[b] (inch)	30
Recycled Water Pipe Size[c] (inch)	20
Combined Raw/Recycled Water Pipe Size[c] (inch)	36
Net Recharge Area[d] (acre)	60
Gross Recharge Site[e] (acre)	160 - 175
Number of Recovery Wells at Buildout[f]	16 - 33

Notes:

(a) The proposed turnout capacity is sized to accommodate 100% surface water allotment under buildout conditions.
(b) The raw water pipeline was sized assuming a maximum allowed velocity of 10 ft/s.
(c) The recycled water and combined pipelines were sized assuming a maximum allowed velocity of 8 ft/s.
(d) The net recharge areas were estimated assuming an average long-term percolation rate of 3 fpd and includes 75 percent redundancy.
(e) The gross recharge areas include 50 percent more surface area to account for access roads and berms and a 300-ft setback all around the recharge basins.
(f) The number of recovery wells is based on the assumed well capacities for each sub-basin, as discussed in the previous section.

A description of each of the ten alternatives and their infrastructure needs is presented in this section. The location of proposed recharge sites and pipelines for each alternative is shown on Figure 7-1. Generalizations regarding the alternatives include:

- Alternatives 1 and 2 assume run-of the river for recharge, with Alternative 1 delivering imported water directly from the East Branch. Alternative 2 would utilize a pipeline to deliver from the East Branch to a point in the Creek about half-way to Palmdale Boulevard; thus, avoiding most of the quarries.

- Alternatives 3 through 10 assume pipeline delivery of imported water from the East Branch directly to constructed recharge basins, with no water in or from the creek.

- The recharge basins for Alternatives 3 and 9 are proposed on the east side of the creek, and would be served from a new turnout along 87th Street and pipeline continuing north in 90th Street.

- The recharge basins for Alternatives 4, 5, 6, 7, 8 are proposed on the west side of the creek, and would be served from a new turnout (and pipeline) along 70th Street.

- The recharge basin for Alternative 10 is proposed east of the creek, but unlike Alternatives 3 and 9, would be served from 70th Street due to the northwesterly alignment of the creek.

- Alternatives 7, 8, and 9 are within the limits of the Los Angeles World Airport 17,000-acre property that was acquired in the 1960s for a regional airport that was never constructed. Alternative 6 is mostly within LAWA property. Alternatives 3, 4, and 5 are south of the LAWA property, and Alternative 10 is north of the LAWA property. Alternative 10 is located within an area designated by LACSD for a future Effluent Management Site.

- Two of the ten alternatives (Alternatives 1 and 2) do not utilize recycled water.

- Seven of the eight alternatives designed to receive recycled water would be supplied from LACSD's existing 48-inch diameter transmission pipeline along Avenue N.

- One alternative (Alternative 5) was designated to receive recycled water from a proposed 24-inch pressurized recycled water distribution system water main along Avenue R.

- The eight alternatives with constructed recharge basins were first evaluated with linear rows of extraction wells on the down gradient side: west, north, or a combination of west and north. Section 9 includes extraction wells in a radial pattern around the recharge basins for the final four refined alternatives. A well-to-basin setback distance of 2,500 feet was modeled to achieve a minimum groundwater travel time of 12 months for groundwater replenishment with recycled water.

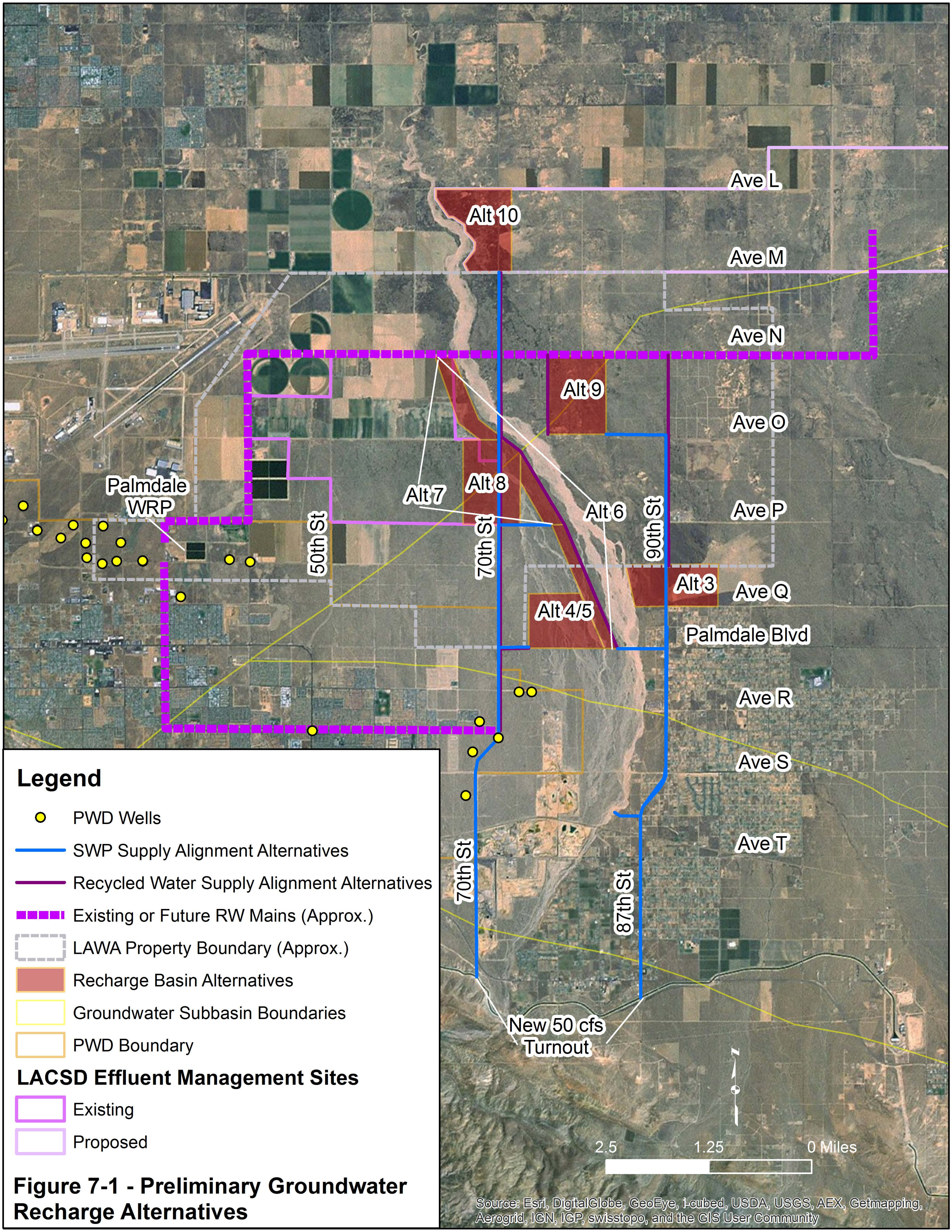


Figure 7-1 - Preliminary Groundwater Recharge Alternatives

7.1 Alternative 1 – Run-of-River Recharge within Pearland Sub-basin

Alternative 1 assumes that surface water from the East Branch of the California Aqueduct would be released directly in the creek for groundwater recharge. This alternative is not intended to change the contribution of local surface runoff. Characteristics, constraints, or benefits are described below.

- **SWP Turnout:** A new 50-cfs turnout to supply the water bank would be constructed near 72nd Street where Littlerock Creek meets the California Aqueduct.
- **Groundwater Basin(s):** The majority of the released water would be recharged initially within the Pearland sub-basin due to the porous nature of the creek bed. However, it is anticipated that with continued recharge, the upper creek bed would become saturated, and the released water would enter the Buttes sub-basin.
- **Recharge Site:** This alternative assumes in-stream recharge. Therefore, no recharge basins would need to be constructed.
- **Raw Water Conveyance:** Because the creek bed is used to convey water, no raw water pipeline would be required.
- **Recycled Water Conveyance:** Recycled water could not be recharged in this alternative because regulations require that recycled and diluent water recharge must occur in the same area for proper blending. This requirement could not be met in this alternative because the extent of recharge within the creek cannot be controlled.
- **Recovery Wells:** To meet buildout demands, 33 wells (22 wells in the Pearland sub-basin and 11 wells in the Buttes sub-basin) would need to be constructed.
- **Land Acquisition:** Land acquisition would not be required for recharge basins.
- **Other Project Constraints:** No encroachment into LAWA property is anticipated. However, the proximity of the creek to local quarries and the potential for lateral seepage into quarry pits, which could adversely influence quarry operations, could pose an implementation hurdle.
- **Other Project Benefits:** Due to minimal construction requirements and lack of recycled water recharge, the implementation timeframe for this alternative would be relatively short with minimal capital costs.
- **Costs:** Table 7-2 presents the cost estimate for Alternative 1. Net present costs are the sum of the present value of all costs over a select period of interest and time. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-2: Alternative 1 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$0	$0
Recharge Basin Construction	$0	$0
Recharge Basin Land Acquisition	$0	$0
Recovery Wells	$35,880,000	$52,860,000
Well Collection Pipelines	$7,130,000	$7,130,000
Distribution Pipelines	$9,120,000	$9,120,000
Facilities Subtotal	***$52,920,000***	***$69,900,000***
SWP Table A Water Purchase	***$65,050,000***	***$104,910,000***
SWP Water Purchase	$62,920,000	$129,270,000
Recycled Water Purchase	$0	$0
Water Purchase Subtotal	***$62,920,000***	***$129,270,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$5,160,000	$11,910,000
O&M Subtotal	***$28,350,000***	***$59,550,000***
Grand Total	**$209,240,000**	**$363,630,000**
Unit Water Cost ($/AF)	**$1,304**	**$1,352**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.2 Alternative 2 – Run-of-River Recharge within Pearland and Buttes Sub-basins (Run-of-river and Pipeline Conveyance Combination)

To avoid interference with quarry operations, an alternative was developed to introduce the SWP water into the creek at a location downstream of the quarries. The water would be conveyed from a new aqueduct turnout via 2.5 miles of 36-inch diameter pipeline along 87th Street with an outlet along East Avenue S-8. This alternative assumes a combination of pipeline and run-of river conveyance. Characteristics, constraints, or benefits are described below. This alternative is not intended to change the contribution of local surface runoff.

- **SWP Turnout:** A new 50-cfs turnout to supply the water bank would be constructed at 87th Street.

- **Groundwater Basin(s):** This alternative bypasses approximately half of the Pearland sub-basin. Therefore, the likelihood of recharging the Buttes sub-basin in addition to the

Pearland sub-basin would be higher compared to Alternative 1. It is still unlikely that the released water would reach as far as the Lancaster sub-basin.

- **Recharge Site:** This alternative also assumes in-stream recharge; therefore, no recharge basin would need to be constructed.

- **Raw Water Conveyance:** Approximately 2.5 miles of 36-inch diameter pipeline would be constructed from the turnout and along 87th Street to the creek via East Avenue S-8.

- **Recycled Water Conveyance:** Same as Alternative 1.

- **Recovery Wells:** To meet future demands at buildout, 32 wells (12 wells in the Pearland sub-basin and 20 wells in the Buttes sub-basin) would need to be constructed.

- **Land Acquisition:** Because recharge basins are not needed, land acquisition would not be required.

- **Other Project Constraints:** This alternative minimizes interference with the existing quarries. However, if the quarries are further expanded along the creek to the north, then the potential for lateral seepage may still pose a challenge.

- **Other Project Benefits:** Due to minimal construction requirements and the absence of recycled water recharge, the implementation timeframe for this alternative would be relatively short with minimal capital costs.

- **Costs:** Table 7-3 presents the cost estimate for Alternative 2. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-3: Alternative 2 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$5,660,000	$5,660,000
Recharge Basin Construction	$0	$0
Recharge Basin Land Acquisition	$0	$0
Recovery Wells	$33,990,000	$50,970,000
Well Collection Pipelines	$6,910,000	$6,910,000
Distribution Pipelines	$9,120,000	$9,120,000
Facilities Subtotal	***$56,470,000***	***$73,450,000***
SWP Table A Water Purchase	***$65,050,000***	***$104,910,000***
SWP Water Purchase	$62,920,000	$129,270,000
Recycled Water Purchase	$0	$0
Water Purchase Subtotal	***$62,920,000***	***$129,270,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$4,890,000	$11,430,000
O&M Subtotal	***$28,080,000***	***$59,070,000***
Grand Total	**$212,520,000**	**$366,700,000**
Unit Water Cost ($/AF)	**$1,325**	**$1,364**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.3 Alternative 3 – Off-stream Recharge within the Buttes Sub-basin Only (East of Littlerock Creek)

This alternative assumes recharge within constructed basins outside the creek. The net or effective recharge area is estimated at 60-acres with redundancy. The gross recharge area, inclusive of berms, streets, and 300-feet of setback all around the basins, is 160 acres. The recharge site is located adjacent to and east of the creek just outside LAWA property. The recycled water would be supplied from the north via LACSD's existing 48-inch diameter pipeline along Avenue N, and the raw water supply would be conveyed to the basins from the south along 87th and 90th Streets. Characteristics, constraints, or benefits are described below.

- **SWP Turnout:** A new 50-cfs SWP turnout to supply the water bank would be constructed at 87th Street.

- **Groundwater Basin(s):** The recharge basins are entirely located within Buttes sub-basin.

- **Recharge Site:** The site is located adjacent to and east of the creek, just south of LAWA property.
- **Raw Water Conveyance:** Approximately 4.7 miles of 30-inch diameter pipeline would be constructed from the turnout and along 87th and 90th Streets to the recharge site, just north of Palmdale Boulevard.
- **Recycled Water Conveyance:** Approximately 2.5 miles of 24-inch diameter pipeline would be constructed from LACSD's existing recycled water pipeline in Avenue N to the recharge site along 90th Street.
- **Recovery Wells:** To meet future demands at buildout, an additional 29 wells would need to be constructed within the Buttes sub-basin.
- **Land Acquisition:** The proposed recharge site is located outside LAWA, and land acquisition would be required.
- **Other Project Constraints:** This alternative has several technical, institutional, and private entity related implementation hurdles. Proximity of the proposed recharge site to the existing developments south of Avenue Q and the need to tie-in to the existing recycled water pipeline owned and operated by LACSD are among those hurdles. Moreover, the proposed recharge basins are entirely located within the Buttes sub-basin, which has the least amount of readily-available information on aquifer transmissivity and hydrogeologic characteristics.
- **Other Project Benefits:** Unlike Alternatives 1 and 2, this alternative allows for recycled water recharge.
- **Costs:** Table 7-4 presents the cost estimate for Alternative 3. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-4: Alternative 3 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$15,340,000	$15,340,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$30,210,000	$45,980,000
Well Collection Pipelines	$6,260,000	$6,260,000
Distribution Pipelines	$5,560,000	$5,560,000
Facilities Subtotal	***$68,710,000***	***$84,480,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$5,640,000	$12,560,000
O&M Subtotal	***$28,830,000***	***$60,200,000***
Grand Total	**$153,940,000**	**$280,430,000**
Unit Water Cost ($/AF)	**$960**	**$1,043**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.4 Alternatives 4/5 – Off-stream Recharge within the Buttes Sub-basin Only (West of Littlerock Creek)

Similar to Alternative 3, Alternatives 4 and 5 assume recharge within constructed recharge basins located outside the creek channel. The recharge site is located adjacent to and west of the creek just south of LAWA property and has the same size as Alternative 3. For Alternative 4, the recycled water would be supplied from the north via LACSD's existing 48-inch diameter pipeline along Avenue N; whereas for Alternative 5, the recycled water would be supplied from a future 24-inch diameter recycled water distribution pipeline that is currently being planned along East Avenue R-8 south of the proposed recharge site. The raw water supply would be conveyed from the south along 87th and 90th Streets, and a short distance along Palmdale Boulevard. Characteristics, constraints, or benefits are described below.

- **SWP Turnout:** Same as Alternative 3.

- **Groundwater Basin(s):** The recharge basins are entirely located within Buttes sub-basin.

- **Recharge Site:** The 160-acre site is generally located adjacent to and west of the creek, north of Palmdale Boulevard and just outside LAWA property.
- **Raw Water Conveyance:** Approximately 4.5 miles of 30-inch diameter pipeline would be constructed from the turnout, and then along 70^{th} Street and Palmdale Boulevard to the proposed recharge site.
- **Recycled Water Conveyance:** For Alternative 4, approximately 4 miles of 24-inch diameter pipeline would be constructed from LACSD's existing recycled water pipeline in Avenue N along 70^{th} Street and the western edge of the creek to the south end of the proposed recharge site on Palmdale Boulevard. For Alternative 5, the recycled water would be diverted from the future recycled water transmission main along East Avenue R-8. Approximately 1.25 miles of 24-inch diameter pipeline would be constructed along 70^{th} Street and Palmdale Boulevard.
- **Recovery Wells:** Same as Alternative 3.
- **Land Acquisition:** Similar to Alternative 3, the proposed recharge site is located outside LAWA, and land acquisition would be required.
- **Other Project Constraints:** For Alternative 4, agreement with LACSD for recycled water conveyance may be an implementation constraint. The proposed recharge basins are entirely located within Buttes sub-basin, where limited information on aquifer transmissivity and hydrogeologic characteristics is available.
- **Other Project Benefits:** Unlike Alternatives 1 and 2 and similar to Alternative 3, these alternatives allow for recycled water recharge.
- **Costs:** Table 7-5 and Table 7-6 present the cost estimates for Alternatives 4 and 5, respectively. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-5: Alternative 4 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$17,230,000	$17,230,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$30,210,000	$45,980,000
Well Collection Pipelines	$6,260,000	$6,260,000
Pump Station	$0	$0
Reservoir	$0	$0
Chlorination Facilities	$0	$0
Distribution Pipelines	$5,560,000	$5,560,000
Facilities Subtotal	***$70,600,000***	***$86,370,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$5,640,000	$12,560,000
O&M Subtotal	***$28,830,000***	***$60,200,000***
Grand Total	**$155,830,000**	**$282,320,000**
Unit Water Cost ($/AF)	**$971**	**$1,050**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

Table 7-6: Alternative 5 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$12,700,000	$12,700,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$30,210,000	$45,980,000
Well Collection Pipelines	$6,260,000	$6,260,000
Distribution Pipelines	$5,560,000	$5,560,000
Facilities Subtotal	***$66,070,000***	***$81,840,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$54,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$5,640,000	$12,560,000
O&M Subtotal	***$28,830,000***	***$60,200,000***
Grand Total	**$151,300,000**	**$277,790,000**
Unit Water Cost ($/AF)	**$943**	**$1,033**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.5 Alternatives 6/7 – Off-stream Recharge within the Buttes and Lancaster Sub-basins (Along the Western Edge of Littlerock Creek)

The proposed recharged sites for Alternatives 6 and 7 are stretched alongside of the creek. For Alternative 6, the proposed recharge site extends for 4.25 miles along the western edge of the creek from Ave N to Palmdale Boulevard. Per this configuration, approximately half of the recharge site would be located in the Buttes sub-basin with the remaining half of the recharge area located within the Lancaster sub-basin. The proposed recharge site for Alternative 7 is shorter in length, extending for 2.5 miles along the western edge of the creek between Avenue N and Avenue P. Approximately one-third of the recharge area in this alternative is located in the Buttes sub-basin with the remaining two-thirds of the recharge area located within the Lancaster sub-basin. Both alternatives allow recycled water recharge from LACSD's existing 48-inch diameter pipeline along Avenue N. Characteristics, constraints, or benefits are described below.

- **SWP Turnout:** A new 50-cfs turnout is proposed at the intersection of California Aqueduct and 87th Street for Alternative 6 and 70th Street for Alternative 7.

- **Groundwater Basin(s):** For Alternative 6, two-thirds of the recharge site is located in Buttes sub-basin with the remaining one-third in Lancaster sub-basin. For Alternative 7, the recharge site is equally divided between the Buttes and Lancaster sub-basins.

- **Recharge Site:** The proposed recharge sites are located along the western edge of the creek between Avenue N and Palmdale Boulevard (Alternative 6) and Avenue P (Alternative 7). The majority of recharge site for Alternative 6, and the entire site for Alternative 7, are within the LAWA property. Because of the inefficient shape and the need for a gap at the sub-basin boundary, the area required is estimated to be 175 acres compared to 160 acres for Alternatives 3, 4, 5, and 10.

- **Raw Water Conveyance:** For Alternative 6, approximately 5 miles of 30-inch diameter pipeline would be constructed along 87th and 90th Streets from the new turnout location to the south end of the proposed recharge (north of Palmdale Boulevard). For Alternative 7, approx. 6.3 miles of 30-inch pipeline would be constructed along 70th Street and Avenue P. The pipeline would extend from the new turnout location on 70th Street to the south end of the proposed recharge site (north of Avenue P).

- **Recycled Water Conveyance:** Both alternatives would receive recycled water from LACSD's existing transmission main along Avenue N. For Alternative 6, the 24-inch diameter recycled water pipeline would extend for about 4 miles from Avenue N south along 90th Street all the way to the south end of the proposed recharge site north of Palmdale Boulevard to allow gravity distribution to all recharge basins. The recycled water pipeline for Alternative 7 would extend 2.3 miles from Avenue N south along 90th Street to Avenue P.

- **Recovery Wells:** For Alternative 6, at buildout 22 wells would be required (14 wells in Buttes sub-basin and 8 wells in Lancaster sub-basin). For Alternative 7, at buildout 21 well would be required (10 wells in Buttes sub-basin and 11 wells in Lancaster sub-basin).

- **Land Acquisition:** Approximately three-quarters of the recharge site in Alternative 6 and the entire recharge site for Alternative 7 are within LAWA property and must be leased or its use established through other contracting means. The portion of Alternative 6 would require land acquisition. For both alternatives the lease or other contractual arrangement for long-term use of the LAWA property is estimated in this study to be equal to the 160 ac property acquisition for the non-LAWA alternatives.

- **Other Project Constraints:** For both alternatives, agreements with LAWA and LACSD would be required. Furthermore, both recharge sites are within close proximity of the existing nitrate plume, which was created by the groundwater recharge of the secondary effluent from LACSD's Palmdale WRP without diluent and prior to the plant upgrade to tertiary treatment and nitrification/de-nitrification for nitrate reduction. Also, two-thirds of the proposed recharge site in Alternative 6, and half of the recharge site in Alternative 7, are located within Buttes sub-basin (sub-basin has little information on aquifer transmissivity and geologic characteristics).

- **Other Project Benefits:** Both alternatives allow recharging of both the Buttes and Lancaster sub-basins.
- **Costs:** Table 7-7 and Table 7-8 present the cost estimates for Alternatives 6 and 7, respectively. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-7: Alternative 6 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$19,070,000	$19,070,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$22,660,000	$34,790,000
Well Collection Pipelines	$4,750,000	$4,750,000
Distribution Pipelines	$4,610,000	$4,610,000
Facilities Subtotal	***$62,430,000***	***$74,560,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$4,550,000	$10,040,000
O&M Subtotal	***$27,740,000***	***$57,680,000***
Grand Total	**$146,570,000**	**$267,990,000**
Unit Water Cost ($/AF)	**$914**	**$996**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

Table 7-8: Alternative 7 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$19,450,000	$19,450,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$22,660,000	$33,580,000
Well Collection Pipelines	$5,670,000	$5,670,000
Distribution Pipelines	$4,610,000	$4,610,000
Facilities Subtotal	***$63,730,000***	***$74,650,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$4,550,000	$9,840,000
O&M Subtotal	***$27,740,000***	***$57,480,000***
Grand Total	**$147,870,000**	**$267,880,000**
Unit Water Cost ($/AF)	**$922**	**$996**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.6 Alternative 8 – Off-stream Recharge within the Buttes and Lancaster Sub-basins (West of Littlerock Creek between Avenue P and Avenue O)

Similar to Alternative 7, this Alternative 8 has one-third of the recharge area located in the Buttes sub-basin and two-thirds of the recharge area located in the Lancaster sub-basin west of Littlerock Creek. The proposed recharge site is located within LAWA property south of Avenue O, north of Avenue P, and east of 65th Street East. The diluent supply would be conveyed from a new turnout through 5.5 miles of 30-inch diameter pipeline along 70th Street. The recycled water would be supplied from LACSD's existing 48-inch diameter pipeline along Avenue N through 2 miles of 24-inch diameter pipeline along 70th Street. Characteristics, constraints, or benefits are described below.

- **SWP Turnout:** A new 50-cfs turnout would need to be constructed at the intersection of California Aqueduct and 70th Street.

- **Groundwater Basin(s):** This alternative recharges both the Lancaster and Buttes sub-basins equally.

- **Recharge Site:** The proposed recharge site is located within LAWA property south of Avenue O, north of Avenue P, and east of 65th Street East.

- **Raw Water Conveyance:** The raw water supply is proposed to be conveyed from the new turnout through 5.5 miles of 30-inch diameter pipeline along 70th Street.

- **Recycled Water Conveyance:** The recycled water is proposed to be supplied from LACSD's existing pipeline along Avenue N through 2 miles of 24-inch diameter pipeline along 70th Street.

- **Recovery Wells:** Same as Alternative 7.

- **Land Acquisition:** The entire 175-acre recharge site is located within LAWA property and must be leased or otherwise be acquired. The long-term use of the LAWA property is estimated in this study to be equal to the 160-acre property acquisition for the non-LAWA alternatives.

- **Other Project Constraints:** Same as Alternatives 6 and 7.

- **Other Project Benefits:** Same as Alternatives 6 and 7.

- **Costs:** Table 7-9 presents the cost estimate for Alternative 8. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-9: Alternative 8 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$17,030,000	$17,030,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$22,660,000	$33,580,000
Well Collection Pipelines	$5,670,000	$5,670,000
Distribution Pipelines	$4,610,000	$4,610,000
Facilities Subtotal	***$61,310,000***	***$72,230,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$4,550,000	$9,840,000
O&M Subtotal	***$27,740,000***	***$57,480,000***
Grand Total	**$145,450,000**	**$265,460,000**
Unit Water Cost ($/AF)	**$907**	**$987**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.7 Alternative 9 – Off-stream Recharge within the Buttes and Lancaster Sub-basins (East of Littlerock Creek between Avenue N and Avenue O)

Similar to Alternatives 7 and 8, Alternative 9 has one-third of the recharge area located in the Buttes sub-basin and two-thirds of the recharge area located in the Lancaster sub-basin, but to the east of Littlerock Creek. The proposed recharge site is located within LAWA property south of Avenue N, north of Avenue O, and to the east of the creek. The raw water supply would be conveyed from a new turnout through 7.7 miles of 30-inch diameter pipeline along 87th and 90th Streets. The recycled water would be supplied from LACSD's existing 48-inch diameter pipeline in Avenue N. Even though the proposed recharge site is located just south of Avenue N, approximately 1.0 mile of recycled water pipeline would be needed to distribute recycled water to the southern portion of the site. Characteristics, constraints, or benefits are described below.

- **SWP Turnout:** A new 50-cfs turnout would need to be constructed at the intersection of California Aqueduct and 87th Street.

- **Groundwater Basin(s):** This alternative recharges both the Lancaster and Buttes sub-basins equally.

- **Recharge Site:** The proposed recharge site is located within LAWA property south of Avenue N, north of Avenue O, and to the east of Littlerock Creek.

- **Raw Water Conveyance:** The raw water supply is proposed to be conveyed from the new turnout through 7.7 miles of 30-inch diameter pipeline along 87th Street, 90th Street, and Avenue O.

- **Recycled Water Conveyance:** The recycled water is proposed to be supplied from LACSD's existing pipeline along Avenue N through 1.0 mile of 24-inch diameter pipeline along either the western or eastern edge of the recharge site.

- **Recovery Wells:** Same as Alternatives 7 and 8.

- **Land Acquisition:** The entire 175-acre recharge site is located within LAWA property and must be leased or otherwise be acquired. The long-term use of the LAWA property is estimated in this study to be equal to the 160-acre property acquisition for the non-LAWA alternatives.

- **Other Project Constraints:** Agreements with LAWA and LACSD must be achieved. Moreover, half of the recharge site is located within Buttes sub-basin (sub-basin has little information on aquifer transmissivity and hydrogeologic characteristics).

- **Other Project Benefits:** Same as Alternatives 6, 7, and 8.

- **Costs:** Table 7-10 presents the cost estimate for Alternative 9. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-10: Alternative 9 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$19,120,000	$19,120,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$22,660,000	$33,580,000
Well Collection Pipelines	$5,670,000	$5,670,000
Distribution Pipelines	$7,900,000	$7,900,000
Facilities Subtotal	***$66,690,000***	***$77,610,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$4,550,000	$9,840,000
O&M Subtotal	***$27,740,000***	***$57,480,000***
Grand Total	**$150,830,000**	**$270,840,000**
Unit Water Cost ($/AF)	**$940**	**$1,007**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.8 Alternative 10 – Off-stream Recharge within the Lancaster Sub-basin (Within LACSD Effluent Management Site North of Avenue M)

The proposed recharge site in Alternative 10 is located entirely in Lancaster sub-basin, outside LAWA property and within LACSD's Effluent Management Site, just east of Littlerock Creek between Avenue M and Avenue L. The raw water supply would be conveyed from a new turnout through 8.7 miles of 30-inch diameter pipeline along 70th Street. The recycled water would be supplied from LACSD's existing pipeline along Avenue N through 1.0 mile of 24-inch diameter pipeline along 70th Street to the north. Characteristics, constraints, or benefits are described below.

- **SWP Turnout:** A new 50-cfs turnout would need to be constructed at the intersection of the California Aqueduct and 70th Street.

- **Groundwater Basin(s):** This alternative recharges the Lancaster sub-basin only.

- **Recharge Site:** The proposed recharge site is located outside LAWA property, within LACSD's Effluent Management Site, north of Avenue M, south of Avenue L, and just east of Littlerock Creek.

- **Raw Water Conveyance:** The raw water supply would be conveyed from a new turnout through 8.7 miles of 30-inch diameter pipeline along 70^{th} Street.

- **Recycled Water Conveyance:** The recycled water would be supplied from LACSD's existing pipeline in Avenue N through 1.0 mile of 24-inch diameter pipeline along 70^{th} Street to the north.

- **Recovery Wells:** To meet future demands at buildout, 16 wells in Lancaster sub-basin would need to be constructed. The recovery wells for this alternative are much further away from PWD's distribution system than the recovery wells for the other alternatives.

- **Land Acquisition:** The proposed recharge site is located within LACSD's future Effluent Management Site. Currently, LACSD disposes of the majority of its recycled water through leased agricultural property not exceeding agronomic irrigation rates. As of 2014, LACSD has only acquired about 1 percent of the land within the proposed Alternative 10 site. The cost for the 160-acre property acquisition is estimated using the assumed unit cost presented in Section 3. LACSD currently disposes of water to an individual land owner.

- **Other Project Constraints:** The alternative does not provide an opportunity to recharge the Buttes or Pearland sub-basins. Agreement with LACSD must be achieved for both recycled water use and land acquisition. Furthermore, the site with a linear row of wells on the west and north could pull in elevated nitrate levels from the existing nitrate plume; model results indicate at extraction levels exceeding the direct needs of PWD may see interference from the nitrate plume.

- **Other Project Benefits:** The Lancaster sub-basin is best understood, and has the highest aquifer transmissivity and best hydrogeologic characteristics for recharge and recovery when compared to Buttes or Pearland sub-basins. As such, Alternative 10 requires the fewest wells to meet PWD's water demands.

- **Costs:** Table 7-11 presents the cost estimate for Alternative 10. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 7-11: Alternative 10 Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$23,580,000	$23,580,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$5,180,000	$5,180,000
Distribution Pipelines	$17,860,000	$17,860,000
Facilities Subtotal	***$73,070,000***	***$82,760,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$23,190,000	$47,640,000
O&M Costs	$3,460,000	$7,720,000
O&M Subtotal	***$26,650,000***	***$55,360,000***
Grand Total	**$156,120,000**	**$273,880,000**
Unit Water Cost ($/AF)	**$973**	**$1,018**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.
(d) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

7.9 Groundwater Modeling of Preliminary Alternatives

Eight of the 10 alternatives are designed to include the replenishment of recycled water but not local storm water, and two of the alternatives are designed to accept local storm water (with recharge in the creek bed) but not the replenishment of recycled water. The modeling approach addressed key technical issues concerning response of the aquifer system to the preliminary alternatives. The sizes of the proposed recharge basins, recharge rates, well field configurations, and proposed withdrawal rates are subject to a series of criteria. Technical issues and criteria considered by groundwater modeling included:

- Groundwater elevation changes associated with operation of recharge basins and extraction wells, wherein shallow groundwater cannot mound to within 50 feet of the ground surface.

- Travel times between recharge basins and extraction wells, wherein recharged water travel times in groundwater cannot be less than one year between the recharge basin and associated extraction well network.

- Land subsidence and dewatering, wherein extraction well field(s) cannot generate groundwater drawdowns that would locally dewater the shallow aquifer and/or lead to appreciable land subsidence.

- Water quality changes, wherein no adverse water quality impacts (e.g., mobilization of trace metals following recharge) can occur.

Groundwater modeling was conducted to help support the selection of the refined alternatives. The preliminary alternatives were assessed using an analytic element groundwater modeling approach to address groundwater flow impacts associated with the:

- Respective recharge basin configurations,

- Posited linear extraction well networks consisting of arrays of 15 wells, aligned in rows to the west or north (i.e., down gradient flow direction) from the respective recharge basin, and

- The proposed recharge and withdrawal schedule listed.

For each alternative, a well-to-basin-edge distance offset of approximately 2,500 feet was posited to provide ample trample distance so that recharged water, including reclaimed water, maintained a residence period of at least one year in the aquifer.

Modeled differences between ambient groundwater elevations and those perturbed by recharge and extraction indicate that average drawdowns on the order of tens of feet could be expected within the extraction well fields, and groundwater mounding on the order of 100 feet beneath the recharge basins could occur for selected alternatives (e.g., Alternatives 3 and 8), particularly when groundwater banking occurs within the Buttes sub-basin. The large drawdowns associated with the extraction well fields would raise concerns about land subsidence, although this topic was not explored further for these non-preferred scenarios. Reverse particle tracking with respect to the proposed extraction well locations for each alternative indicate, that in all cases, the 2,500 foot well-to-basin offset does appear to offer sufficient residence time for buffering for reclaimed water.

Section 8: Preliminary Alternatives Evaluation

This section evaluates the feasibility of the alternatives using ten economic and non-economic criteria. The preliminary alternatives were scored and ranked based on these criteria to determine which alternatives are the most favorable. Criteria used included:

- Total Cost
- Unit Water Cost
- Recharge and Recovery Capacity
- Recovery Water Quality
- Environmental Impact
- Implementation Risk and Uncertainty
- Institutional and Private Entity Issues
- Recycled Water Recharge Compatibility
- Regulatory and Permitting Issues
- Public Acceptance

8.1 Evaluation Criteria Description

A definition of each criteria and how it applies to the project alternatives is presented herein.

8.1.1 Total Cost

Total cost is the present and future funding requirement for the implementation of an alternative. It is estimated as the sum of construction, property acquisition, construction contingency (twenty percent), and other soft costs such as engineering, management, legal, and environmental. In addition, since the LCGRRP is being used to meet all of PWD's future water supply needs, the future costs of purchasing additional SWP Table A water rights is included in the net present costs of the total costs.

8.1.2 Unit Water Cost

Unit water cost is an estimate of the cost of the projected water resource developed through each alternative compared to the total costs of the alternative over the life of the project. The total costs include capital and annual O&M costs. The unit water cost of an alternative is measured as the ratio of combined amortized capital cost and annual O&M costs in dollars per year ($/yr) over the estimated yield of the alternative in acre-feet per year (AF/yr). The unit water cost is therefore identified in dollars per acre-foot ($/AF).

8.1.3 Recharge and Recovery Capacity

Recharge and Recovery Capacity considers the geology and aquifer properties in two ways:

- The recharge rate at which a basin is able to infiltrate water on average over a long period, and
- The capacity of existing and planned recovery wells.

The recharge rate can be measured through standard infiltration tests, and both the recharge rate and recovery capacity are estimated in the groundwater model.

8.1.4 Recovery Water Quality

Recovery Water Quality relates to the ability of an alternative to meet existing and anticipated water quality standards in the future. Introduction of recharge water to the aquifer system may impact the groundwater composition through: (1) simple mixing and (2) reactions involving aquifer minerals in response to changing water chemistry. The California GAMA data set was used to access ambient conditions and to identify possible groundwater chemistry responses to the introduction of recharge water of differing composition. The preliminary groundwater quality modeling described in Section 7 and the *Groundwater Modeling Report* (Appendix E), did not indicate an expectation for mobilization of trace metals following recharge.

Potential influence from the existing LACSD Palmdale WRP nitrate plume for elevated TDS or nitrate was modeled for both of the proposed extraction rates to meet PWD's water demands and for higher rates that may be required to export water for potential water banking partners. At the lower PWD rates, nitrate from the plume was not shown to impact the nearby alternatives; however, at the higher extraction rates modeled, the nitrate plume could reach several of the alternative sites.

8.1.5 Environmental Impact

Environmental Impact criterion seeks to differentiate among alternatives with varying impacts on existing biological and cultural resources in the project area. The criterion was measured by conducting a site specific constraints study performed by Helix and AE, as described in Section 5. The Helix biological constraints report (Appendix C) identifies the biological resources and constraints in the project area. This report provides information regarding biological resources and constraints for the ten preliminary alternatives. Helix's review was based on a literature review and field reconnaissance survey of the preliminary alternative sites. The survey included mapping vegetation communities, developing comprehensive lists of plant and animal species observed, conducting habitat assessments for listed and sensitive species, and identifying areas or features potentially under the jurisdiction of federal and/or state resource agencies.

The AE cultural resources report (Appendix D) identifies the cultural resources and constraints in the project area. AE's cultural resources investigation was conducted in accordance with CEQA. An archaeological literature and records search, a search of the Sacred Lands File from the Native American Heritage Commission, and a reconnaissance level archaeological survey of 10 percent of the LCGRRP area was performed. Native American individuals and organizations were also contacted to obtain additional information and/or concerns regarding cultural resource issues related to the LCGRRP.

8.1.6 Implementation Risk and Uncertainty

Implementation Risk and Uncertainty relates to the unintended consequences of implementation of various alternatives. One main design consideration that factors into the risk and uncertainty for an alternative is the amount of available water quality and/or hydrogeological data. A lack of adequate water quality or hydrogeological data could result in less accurate recovery water quality and recharge and recovery projections. The Buttes sub-basin has a lack of adequate water quality and hydrogeological data compared to the Pearland and Lancaster sub-basins. Another design consideration is uncertainty regarding the impact of groundwater recharge on adjacent residential developments, current or planned quarry operations, and the nearby existing LACSD Palmdale WRP nitrate plume.

8.1.7 Institutional and Private Entity Issues

The Institutional and Private Entity Issues criterion considers the complexity of obtaining project support of public agencies and/or private entities, either directly or indirectly involved with the project, and the consequences on the project's implementation and/or schedule. Examples of institutional complexity affecting the project are LACSD, LAWA, and Air Force Plant 42 coordination and support. LACSD owns and operates an existing recycled water transmission main along Avenue N being considered as the conveyance for the majority of alternatives that use recycled water as a source. LAWA owns the property on both sides of the creek roughly between Palmdale Boulevard and Avenue M. The proposed recharge basins for several alternatives are within the LAWA property boundary, and given the extreme difficulty and resistance to acquiring LAWA property (much of which was purchased using federal airport funding), these sites would require long-term agreements or lease terms. Air Force Plant 42 will be concerned over wildlife attractions (potential hazardous bird strikes to aircraft) due to ponding of water in the recharge basins and set-back distances used to categorize the alternatives. Examples of private entities affecting the project are quarry operations adjacent to and west of Littlerock Creek. Alternatives with in-stream recharge may adversely impact the operation of active and planned quarries through the lateral seepage of water into the pits.

8.1.8 Recycled Water Recharge Compatibility

Recycled Water Recharge Compatibility considers whether an alternative provides the opportunity for recycled water recharge in addition to recharge using imported water. Draft recycled water recharge regulations require that any recycled water recharged be blended with a diluent source of supply. While blending does not have to physically occur at the time of recharge, the replenishment area must be essentially the same for both recycled water and diluent supply. This requirement excludes recycled water recharge opportunities within the in-stream recharge alternatives. Therefore, alternatives with in-stream recharge will not utilize recycled water recharge since the exact recharge location within Littlerock Creek will not be able to be controlled. For alternatives with no in-stream recharge, the recharge area can be controlled, and recycled water can be utilized.

8.1.9 Regulatory and Permitting Issues

Regulatory and Permitting Issues pertains to the level of efforts and challenges required to secure required permits for various alternatives. The process of obtaining permits is often lengthy and complex. For example, in-stream recharge alternatives would require permitting through the USACE and CDFW that would impact the implementation of these alternatives.

Similarly, alternatives with recycled water recharge would require permitting through the RWQCB and coordination with the extraction for potable use requirements from the California DDW. The recycled water replenishment regulations adopted in June 2014 identify the requirements and approval process, which can be lengthy and complex.

8.1.10 Public Acceptance

Public Acceptance relates to the likely support versus opposition of the public associated with each alternative. The ability and the ease with which an alternative will be understood and receive favorable public support and acceptance will be based on a vetting process to be developed with the District. Issues such as the public perception of using recycled water recharge as a planned water supply (Indirect Potable Reuse [IPR]) are anticipated to be more challenging from the public acceptance standpoint compared to an alternative using only imported water for recharge. An additional public acceptance issue is the proximity of the project to an existing development.

8.2 Alternatives Scoring

The ten economic and non-economic criteria were used to score and rank the ten preliminary alternatives. All of the alternatives were given a score for each of the evaluation criteria. Scoring was done on a scale of 1 to 5, where 1 was the lowest (minimum) score and 5 was the highest (maximum) score that could be given. However, it was not required that a score of 1 or 5 was given to at least one alternative for each evaluation criteria.

An important aspect of the scoring that needed to be reflected was that each of the ten evaluation criteria does not have equal importance (weight) in the overall scoring of an alternative. As a result, each evaluation criteria was given a weight that reflects how important they are in relation to each other and the overall scoring of an alternative. The weight of each evaluation criteria was assigned as a percentage, reviewed with the District, and applied with the total weight adding up to 100 percent.

The scores that were given to an alternative for each evaluation criteria were multiplied by the weight of the evaluation criteria to calculate a weighted score. The weighted scores (for each alternative) were added together to determine the total weighted scores for the alternatives. The total scores were used to rank the alternatives and determine which were the most favorable.

Descriptions of how each evaluation criteria were scored are presented below.

8.2.1 Total Cost

Table 8-1 provides a summary of the preliminary estimates for the total costs that reflect the 2014 Water Master Plan Update water demands. Alternatives with lower total costs were scored higher, and alternatives with higher total costs were scored lower.

Table 8-1: Preliminary Cost Estimates

Alternative	Facility Costs ($)	SWP Table A Water Costs ($)	Water Purchase Costs ($)	O&M Costs ($)	Total Costs ($)	Unit Cost ($/AF)
1	$69,900,000	$104,910,000	$129,270,000	$59,550,000	$363,630,000	$1,352
2	$73,450,000	$104,910,000	$129,270,000	$59,070,000	$366,700,000	$1,364
3	$84,480,000	$25,590,000	$110,160,000	$60,200,000	$280,430,000	$1,043
4	$86,370,000	$25,590,000	$110,160,000	$60,200,000	$282,320,000	$1,050
5	$81,840,000	$25,590,000	$110,160,000	$60,200,000	$277,790,000	$1,033
6	$74,560,000	$25,590,000	$110,160,000	$57,680,000	$267,990,000	$996
7	$74,650,000	$25,590,000	$110,160,000	$57,480,000	$267,880,000	$996
8	$72,230,000	$25,590,000	$110,160,000	$57,480,000	$265,460,000	$987
9	$77,610,000	$25,590,000	$110,160,000	$57,480,000	$270,840,000	$1,007
10	$82,770,000	$25,590,000	$110,160,000	$55,360,000	$273,880,000	$1,018

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) The cost estimate does not include costs for the distribution system pump station, reservoir, or disinfection facilities.

The score for each alternative was calculated from multiplying the maximum score of 5 by the ratio of the minimum total cost of any alternative to the total cost of the alternative being scored. This calculation resulted in the alternative with the minimum total cost receiving the maximum possible score of 5, and the other alternatives receiving lower scores based on the linear relationship of the minimum total cost to their total costs.

For total costs, Alternative 8 received the highest score of 5 and Alternative 1 and 2 received the lowest scores of 3.65 and 3.62, respectively. The total costs for Alternatives 3 through 10 only varied by about +/- 3% of the average across all eight alternatives. The weight for total cost in the overall scoring was 15%.

8.2.2 Unit Water Cost

Table 8-1 provides a summary of the preliminary estimates for the unit water costs that reflect the 2014 Water Master Plan Update water demands. Alternatives with lower unit water costs were scored higher, and alternatives with higher unit water costs were scored lower.
The score for each alternative was calculated from multiplying the maximum score of 5 by the ratio of the minimum unit water cost of any alternative to the unit water cost of the alternative being scored. This calculation resulted in the alternative with the minimum unit water cost receiving the maximum possible score of 5, and the other alternatives receiving lower scores based on the linear relationship of the minimum unit water cost to their unit water costs.

Alternatives 8 received the highest score of 5 and Alternatives 1 and 2 received the lowest scores of 3.65 and 3.62, respectively. The unit water costs for Alternatives 3 through 10 only varied by about +/- 3% of the average across all eight alternatives. The weight for unit water cost in the overall scoring was 15%.

8.2.3 Recharge and Recovery Capacity

The recovery capacity of the alternatives was utilized to score the alternatives. Table 8-2 provides a summary of the preliminary distribution for the wells required in each sub-basin. Alternatives with a greater average recovery capacity were scored higher and alternatives with a lesser average recovery capacity were scored lower.

Table 8-2: Distribution of Recovery Wells

Alternative	Pearland Sub-basin	Buttes Sub-basin	Lancaster Sub-basin
1	67%	33%	--
2	33%	67%	--
3, 4, 5	--	100%	--
6	--	50%	50%
7, 8, 9	--	33%	67%
10	--	--	100%

It was assumed that the recovery capacity for extraction wells in the Pearland, Buttes, and Lancaster sub-basins were 500 gpm, 600 gpm, and 1,200 gpm, respectively. For alternatives where all the wells are located in the same sub-basin, the average recovery capacity was equal to the recovery capacity of a well in that sub-basin. For alternatives where wells are located in different sub-basins, the average recovery capacity was equal to the sum of the percentage of wells in a basin multiplied by the recovery capacity of that basin. Table 8-3 provides a summary of the preliminary estimates for the recovery capacities.

Table 8-3: Preliminary Recovery Capacities

Alternative	Recovery Capacity
1	533
2	567
3,4,5	600
6	900
7,8,9	1,000
10	1,200

The score for each alternative was calculated from multiplying the maximum score of 5 by the ratio of the recovery capacity of the alternative being scored to the maximum recovery capacity of any alternative. This calculation resulted in the alternative with the maximum recovery capacity receiving the maximum possible score of 5, and the other alternatives receiving lower scores based on the linear relationship of their recovery capacities to the maximum recovery capacity.

Alternative 10 received the highest score of 5, and Alternative 1 received the lowest score of 2.22. The weight for recharge and recovery capacity in the overall scoring was 10%.

8.2.4 Recovery Water Quality

The introduction of recharge water to the aquifer system may impact groundwater composition and quality through mixing and/or reactions involving aquifer minerals in response to changing water chemistry. Recovery water quality indicates the ability of an alternative to meet existing and future anticipated water quality standards. At this point, the recovery water quality for all of the alternatives is expected to meet all federal and state maximum contaminant levels.

There are several alternatives where the recovery water quality could be impacted by the existing LACSD Palmdale WRP nitrate plume for elevated TDS and/or nitrate. Alternatives 6, 7, 8, and 10 have the potential to pull in some of the nitrate plume after approximately 20 years of operation due to their relative close proximity to the nitrate plume. This potential is exacerbated if extraction is increased to supply water to potential partners beyond the extraction rates needed to supply PWD's water demands.

Alternatives modeled and projected to have better water quality were ranked higher, and alternatives that were modeled and projected to have poorer water quality were ranked lower.

Alternatives 3, 4, 5, and 9 received the highest score of 5; Alternative 10 was assigned a score of 4; Alternatives 1 and 2 a score of 3.5; and Alternatives 6, 7, and 8 received the lowest score of 3. The weight for recovery water quality in the overall scoring was 10%.

8.2.5 Environmental Impact

Based on the biological constraints identified by Helix, each preliminary alternative was categorized into one of three levels of constraints (relatively high constraints, largely unconstrained and relatively low constraints) as summarized in Table 8-4.

Table 8-4: Biological Constraints

Alternative	Level of Constraint
1	Relatively high
2	Relatively high
3	Relatively low
4	Largely unconstrained
5	Largely unconstrained
6	Relatively high
7	Relatively high
8	Largely unconstrained
9	Largely unconstrained
10	Relatively low

Based on the cultural resources investigation, AE concluded that the archaeological sensitivity of the LCGRRP area is considered to be moderate to high.

Alternatives with lower environmental impacts were scored higher and alternatives with higher environmental impacts were scored lower. The score for each preliminary alternative was determined based on the results of Helix's biological review and AE's cultural resources investigation. Because the whole LCGRRP area was determined to have moderate to high archaeological sensitivity, no alternative received the maximum score of 5. Alternatives were given scores of 2 (relatively high), 3 (largely unconstrained), or 4 (relatively low) based on their level of biological constraints.

Alternatives 3 and 10 received the highest score of 4; and Alternatives 1, 2, 6, and 7 received the lowest score of 2. The weight for environmental impact in the overall scoring was 10%.

8.2.6 Implementation Risk and Uncertainty

The two design considerations that factored into the risk and uncertainty for an alternative were (1) availability of water quality and/or hydrogeological data, and (2) uncertainty regarding the impact of groundwater recharge on adjacent residential developments, current or planned quarry operations, and the nearby existing LACSD Palmdale WRP nitrate plume. Alternatives with higher risks and levels of uncertainty were scored lower, and alternatives with lower risks and levels of uncertainty were scored higher.

Alternatives located in Buttes sub-basin were scored lower than alternatives located in either the Pearland or Lancaster sub-basins due to a lack of adequate water quality and hydrogeological data. Alternatives that are entirely located in the Buttes sub-basin were also scored lower than alternatives that are only partially located in the Buttes sub-basin and partially located in the Pearland or Lancaster sub-basins.

Alternatives that are located adjacent to either residential developments or current or planned quarry operations were scored lower than alternatives that are not since it is not known exactly how the groundwater recharge will impact these developments and operations.

Alternatives that are located in a relative close proximity to the existing LACSD Palmdale WRP nitrate plume were scored lower than alternatives that are not since it is not known what impact the nitrate plume will have on the recovery water quality.

With the implementation of any alternative there is risk and uncertainty, and as a result no alternative received the maximum score of 5. Alternative 10 received the highest score of 4; Alternative 9 received a 3; and Alternatives 2, 3, 4, 5, 6, 7, and 8 received the lowest score of 2. The weight for implementation risk and uncertainty in the overall scoring was 10%.

8.2.7 Institutional and Private Entity Issues

This criterion factors in the potential consequences on an alternative’s implementation and/or scheduling as a result of the complexity of obtaining support of public agencies and/or private entities. Alternatives with significant complexity received a lower score, and those with less complexity received higher scores.

Alternatives that are located within the property owned by LAWA would require easement or land acquisition. The approval process could be complex and pose several challenges. No inference is made either directly or implied, relative to interaction with LAWA; per se. Seeking permission for an encroachment onto any large landowner has uncertainty. As a result, alternatives that are located within LAWA property received the lowest scores. Alternatives that are entirely located in LAWA property were scored lower than alternatives that are only partially located in LAWA property.

Alternatives that utilize in-stream recharge could affect the quarry operations that are adjacent and to the west of Littlerock Creek. These alternatives could impact the operation of quarries through the lateral seepage of water into the pits. This consideration resulted in alternatives with in-stream recharge receiving lower scores.

LACSD owns and operates recycled water transmission mains that would be utilized to convey recycled water for alternatives with recycled water as a source. Coordination with LACSD to connect to their recycled water transmission mains would need to occur. Recycled water is a positive aspect for the alternatives that use it. One alternative, Alternative 10, is located within LACSD's Effluent Management Site and land acquisition would be required. However, it is anticipated that this land acquisition would not be as complex as land acquisition from LAWA. Alternatives that require coordination and support from LACSD for recycled water and/or land acquisition received higher scores.

Air Force Plant 42 is generally located to the west of all ten alternatives. Based on FAA guidelines, a 10,000-foot buffer zone is required around the runways to protect turbine powered aircraft, because recharge basins will attract wildlife. For recharge basins greater than 10,000 feet but within 5 miles from airport operations, appropriate wildlife hazard mitigation techniques would need to be followed. None of the alternatives are within 10,000 feet of Air Force Plant 42; however, many of the alternatives are within 10,000 feet to 5 miles. Alternatives that are located within these buffer zones received lower scores than alternatives that have their recharge basins outside the 5-mile limit.

The implementation of any alternative will have some complexity with regard to obtaining support of public agencies and/or private entities. As a result, no alternative received the maximum score of 5. Alternatives 2, 3, 4, 5 and 10 received the highest score of 3; and Alternatives 7, 8 and 9 received the lowest score of 1. The weight for institutional and private entity issues in the overall scoring was 10%.

8.2.8 Recycled Water Recharge Compatibility

Alternatives that allow for recycled water to be recharged were scored high, and those that do not allow for recycled water to be recharged were scored low.

Alternatives that allow for recycled water recharge (Alternatives 3, 4, 5, 6, 7, 8, 9, and 10) received the maximum score of 5; and alternatives that do not allow for recycled water recharge (Alternatives 1 and 2) received the minimum score of 1. The weight for recycled water recharge compatibility in the overall scoring was 10%.

8.2.9 Regulatory and Permitting Issues

The permitting process for alternatives with recycled water recharge is expected to be more lengthy and complex than the permitting process for Alternatives 1 and 2 with in-stream recharge and no recycled water. Alternatives with more permitting complexity were scored lower, and those with less permitting complexity were scored higher.

Alternatives with in-stream recharge (Alternatives 1 and 2) received the highest score of 2. Alternatives with recycled water recharge (Alternatives 3, 4, 5, 6, 7, 8, 9, and 10) received the lowest score of 1. The weight for regulatory and permitting issues in the overall scoring was 5%.

8.2.10 Public Acceptance

Public perception of indirect potable reuse is anticipated to be the most difficult issue in obtaining public acceptance and support. As a result, alternatives that utilize recycled water were scored lower than alternatives that do not use recycled water. However, Alternative 10, which has recycled water recharge, was scored higher than other alternatives with recycled water recharge since it is located in LACSD's Effluent Management site where recycled water is already spread.

The proximity of the project to existing development is another issue in obtaining public acceptance and support. Alternatives that are located near existing development were scored lower than alternatives that are not located near existing development.

With the implementation of any alternative, the process of obtaining public acceptance and support is a challenge, and as a result no alternative received the maximum score of 5. Alternatives 1, 2, and 10 received the highest score of 4; and Alternative 3 received the lowest score of 2. The weight for public acceptance in the overall scoring was 5%.

8.3 Ranking Matrix

The scoring and ranking of the ten preliminary alternatives was performed in a matrix. This matrix includes a list of the ten economic and non-economic criteria, weight of each criteria, scores for each alternative, weighted scores for each alternative, total weighted score for each alternative, rank of each alternative, and comments on the scoring.

The ten preliminary alternatives were ranked from the most favorable to the least favorable based on the total weighted score of each alternative. A higher total weighted score indicated the alternative was more favorable, and a lower total weighted score indicated the alternative was less favorable. The greater the total weighted score, the more favorable an alternative was deemed. The most favorable alternative received a ranking of 1 and the least favorable alternative received a ranking of 10. The alternatives ranking matrix is presented in Table 8-5 and summarized in Table 8-6. Alternative 10 is the most favorable alternative, followed by Alternative 9, then a group of near-equal scores for Alternatives 3, 4, and 5; then a second group of near-equal scores for Alternatives 6, 7, and 8; with Alternatives 1 and 2 the least favorable alternatives.

Table 8-5: Littlerock Creek Groundwater Recharge and Recovery Project
Ten Preliminary Alternatives Scoring and Ranking

			Alternative 1 - Run-of-River Recharge within Pearland Basin			Alternative 2 - Run-of-River Recharge within Pearland and Buttes Basins			Alternative 3 - Off-stream Recharge within the Buttes Basin (East of Littlerock Creek)			Alternative 4 - Off-stream Recharge within the Buttes Basin (West of Littlerock Creek)			Alternative 5 - Off-stream Recharge within the Buttes Basin (West of Littlerock Creek)		
Criteria	**Weight**	**Scoring**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**
Capital Cost	15%	1 - 5 (Best)	3.65	0.5	$363,630,000	3.62	0.5	$366,700,000	4.73	0.7	$280,430,000	4.70	0.7	$282,320,000	4.78	0.7	$277,790,000
Unit Water Cost	15%	1 - 5 (Best)	3.65	0.5	$1,352	3.62	0.5	$1,364	4.73	0.7	$1,043	4.70	0.7	$1,050	4.78	0.7	$1,033
Recharge and Recovery Capacity	10%	1 - 5 (Best)	2.22	0.2	Pearland and Buttes Basin	2.36	0.2	Buttes and Pearland Basin	2.50	0.3	Buttes Basin	2.50	0.3	Buttes Basin	2.50	0.3	Buttes Basin
Recovery Water Quality	10%	1 - 5 (Best)	3.5	0.4		3.5	0.4		5	0.5		5	0.5		5	0.5	
Environmental Impact	10%	1 - 5 (Best)	2	0.2	Relatively high biological constraints, moderate to high cultural constraints	2	0.2	Relatively high biological constraints, moderate to high cultural constraints	4	0.4	Relatively low biological constraints, moderate to high cultural constraints	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints
Implementation Risk and Uncertainty	10%	1 - 5 (Best)	2	0.2	Near existing creek/quarry operations	2	0.2	Least known about Buttes basin, potential to be near future creek/quarry operations	2	0.2	Least known about Buttes basin, adjacent to existing development	2	0.2	Least known about Buttes basin	2	0.2	Least known about Buttes basin
Institutional and Private Entity Issues	10%	1 - 5 (Best)	2	0.2	Outside LAWA, quarry operations	3	0.3	Outside LAWA, potential future quarry operations	3	0.3	Outside LAWA, proximity to existing development	3	0.3	Outside LAWA, Air Force buffer zone	3	0.3	Outside LAWA, Air Force buffer zone
Recycled Water Recharge Compatibility	10%	1 - 5 (Best)	1	0.1	Not RW compatible	1	0.1	Not RW compatible	5	0.5	RW compatible	5	0.5	RW compatible	5	0.5	RW compatible
Regulatory and Permitting Issues	5%	1 - 5 (Best)	2	0.1	USACE and CDFW	2	0.1	USACE and CDFW	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH
Public Acceptance	5%	1 - 5 (Best)	4	0.2	No RW, recharge in creek	4	0.2	No RW, recharge in creek	2	0.1	RW, recharge near creek, near existing development	3	0.2	RW, recharge near creek	3	0.2	RW, recharge near creek
Total	**100%**	**5**		**2.67**			**2.77**			**3.72**			**3.66**			**3.68**	
Rank				**10**			**9**			**3**			**5**			**4**	

	Alternative 6 - Off-stream Recharge within the Buttes and Lancaster Basins (Along the Western Edge of Littlerock Creek)			Alternative 7 - Off-stream Recharge within the Buttes and Lancaster Basins (Along the Western Edge of Littlerock Creek)			Alternative 8 - Off-stream Recharge within the Buttes and Lancaster Basins (West of Littlerock Creek between Avenues P and O)			Alternative 9 - Off-stream Recharge within the Buttes and Lancaster Basins (East of Littlerock Creek between Avenues N and O)			Alternative 10 - Off-stream Recharge within the Lancaster Basin (Within LACSD Effluent Management Site North of Avenue M)		
Criteria	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**
Capital Cost	4.95	0.7	$267,990,000	4.95	0.7	$267,880,000	5.00	0.8	$265,460,000	4.90	0.7	$270,840,000	4.85	0.7	$273,880,000
Unit Water Cost	4.95	0.7	$996	4.95	0.7	$996	5.00	0.8	$987	4.90	0.7	$1,007	4.85	0.7	$1,018
Recharge and Recovery Capacity	3.75	0.4	Buttes and Lancaster Basins	4.18	0.4	Lancaster and Buttes Basins	4.18	0.4	Lancaster and Buttes Basins	4.18	0.4	Lancaster and Buttes Basins	5.00	0.5	Lancaster Basin
Recovery Water Quality	3	0.3	Impact from Plume	3	0.3	Impact from Plume	3	0.3	Impact from Plume	5	0.5		4	0.4	Impact from Plume
Environmental Impact	2	0.2	Relatively high biological constraints, moderate to high cultural constraints	2	0.2	Relatively high biological constraints, moderate to high cultural constraints	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints	3	0.3	Largely unconstrained biologically, moderate to high cultural constraints	4	0.4	Relatively low biological constraints, moderate to high cultural constraints
Implementation Risk and Uncertainty	2	0.2	Least known about Buttes basin - portion within, Impact from Plume	2	0.2	Least known about Buttes basin - portion within, Impact from Plume	2	0.2	Least known about Buttes basin - portion within, Impact from Plume	3	0.3	Least known about Buttes basin - portion within	4	0.4	Impact from Plume
Institutional and Private Entity Issues	2	0.2	Portion in LAWA, Air Force buffer zone	1	0.1	LAWA, Air Force buffer zone	1	0.1	LAWA, Air Force buffer zone	1	0.1	LAWA, Air Force buffer zone	3	0.3	Outside LAWA, LACSD land acquisition, Air Force buffer zone
Recycled Water Recharge Compatibility	5	0.5	RW compatible	5	0.5	RW compatible	5	0.5	RW compatible	5	0.5	RW compatible	5	0.5	RW compatible
Regulatory and Permitting Issues	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH	1	0.1	RWQCB and CDPH
Public Acceptance	3	0.2	RW, recharge near creek	3	0.2	RW, recharge near creek	3	0.2	RW, recharge near creek	3.5	0.2	RW, recharge near creek	4	0.2	RW, recharge near creek, recharge where RW is already spread
Total		**3.46**			**3.40**			**3.52**			**3.81**			**4.20**	
Rank		**7**			**8**			**6**			**2**			**1**	

Table 8-6: Ranking Matrix Summary

Alternative	Total Weighted Score	Ranking
1	2.67	10
2	2.77	9
3	3.72	3
4	3.66	5
5	3.68	4
6	3.46	7
7	3.40	8
8	3.52	6
9	3.81	2
10	4.20	1

After reviewing and analyzing the results of the scoring and ranking matrix, the next step was to refine the most favorable alternatives. Based on the screening of the 10 alternatives, alternatives 9 and 10 were found to be more favorable than the other alternatives. In turn, these two alternatives were refined to generate four refined alternatives - Alternatives 9R, 10A, 10B, and 10C.

Section 9: Description of Refined Alternatives

This section describes the refined recharge basin alternatives considered for further analysis and design. There are four alternatives considered:

- Alternative 9R
- Alternative 10A
- Alternative 10B
- Alternative 10C

These alternatives were chosen based on the preliminary alternatives evaluation presented in the preceding section. A summary of why these four refined alternatives were selected is provided below:

- All refined alternatives allow for recycled water to be utilized in groundwater recharge.
- Alternative 9R straddles the Buttes and Lancaster sub-basins with approximately half its recharge area in each sub-basin. This design allows flexibility as to which sub-basin receives recharge: Buttes, Lancaster, or both.
- Alternatives 10A, 10B, and 10C are located in the Lancaster Sub-basin, which has the highest specific capacity; roughly double the Pearland and Buttes sub-basins. This reduces the number of recovery wells required.
- Alternative 9R is located east of Littlerock Creek, and LAWA has indicated that if an airport is built in the future, then it will most likely be west of Littlerock Creek.
- Alternatives 10A, 10B, and 10C are located outside (to the north) of LAWA property.
- Alternatives 9R and 10A are located outside of a 10,000-foot buffer zone of the flight path of the Palmdale Air Force Plant 42, but within the five-mile buffer zone. The proposed recharge basins of Alternative 10B are located outside of the five-mile buffer zone, and Alternative 10C is completely outside the five-mile buffer zone.

All four refined alternatives have certain characteristics in common. A summary of these characteristics is provided below:

- All four alternatives have been re-designed and modeled with recovery wells placed in a circumferential pattern, instead of the initial linear pattern. In initial modeling, it was found that a linear pattern around the recharge area would cause excessive drawdown and potentially cause up to 1 foot of subsidence over a 20-year period in the four preferred alternatives. Consequently, a second extraction well placement scheme, based on spacing the extraction wells in a radial pattern, spaced 4,500 feet from the center of the recharge basin, was also evaluated. This scheme appears to largely mitigate the modeled land subsidence, reducing the areal impact and the magnitude of subsidence after 20 years to just 0.1 foot for the area around some of the extraction wells and less than 0.1 foot around the majority of the extraction wells. While 1 foot of subsidence in 20 years could be considered significant, model estimates of 0.1 foot of subsidence after 20 years are considered to be negligible.

- All alternatives have been designed in such a way as to meet the ultimate facility sizing needs of the District, allowing the District to only require a single recharge project for its supply needs.

- The number of recovery wells specified for each alternative provides the recovery capacity necessary for PWD's projected ultimate build-out water demand. For PWD's potable supply needs, the recovery wells can be phased over time as water demand increases. Early construction of recovery wells beyond the needs of PWD would make recovery available for any water banking partners. Maximum extraction rates for dry year supply for partners may require additional wells.

- All alternatives include a distribution system, including a 1-million gallon head tank, distribution system pump station, a chlorination building, and an optional raw water sump and raw water pump station. The head tank and chlorination building are designed for ultimate demands, whereas the pump stations are designed to be implemented through phasing. The design characteristics of each facet listed are described in the subsections that follow.

- The proposed chlorination building is designed to house an on-site hypochlorite (hypo) generator and its appurtenances to feed approximately 125 pounds of chlorine per day at a dosing rate of 0.8 mg/L. Such criteria would utilize a 200 lb/day system. The chlorine generation system consists of a salt truck delivery/fill station, skid-mounted hypo generation unit, feed water softening system, salt/brine storage tank, brine pump, hypo storage tank, hydrogen blower and vent system, chemical metering pumps, piping, and a chemical injector at the point of chlorine application. At 0.8% hypo, double-wall containment is not required and the dilute hypo (bleach) is much less corrosive to pumps and piping. The units have a built-in PLC control system and operate with a constant current and variable brine feed to compensate for any scaling of the electrodes over time. For example, for a system that generates hypo at a rate of 200 ppd of chlorine equivalent with a demand of only 120 ppd would operate for 14.4 hours a day. This system is intended to treat the raw water from the recovery wells either before it enters the head tank or after the tank before the distribution pump station at the District's discretion.

- The distribution pump station is proposed to be implemented in multiple phases, each accommodating an increase in demands. The pump station's transmission line is designed to provide ultimate demands through a 30-inch pipeline to the existing 20-inch pipeline at the corner of Palmdale Boulevard and 60th Street, which serves a hydraulic grade line of 2,800 feet. For the first phase, the pumps are designed to be of a 3+1 spare configuration, providing 3,000 gpm at 400 hp, each. The tables regarding the specific characteristics of each pump station are provided in the alternative subsections that follow. In most cases, the pump horsepower has been slightly oversized in order to accommodate the higher transmission head loss in phase 2. Once the District's demands rise to approximately 14,125 AF/yr, additional pumps may be implemented, which are projected to include 3 additional 2,500 gpm pumps at 400 hp. The lower second phase pump capacity is based on the assumption that, as the demand grows, the system will be required to run more water through the pipeline. The greater flow in the pipeline will increase the dynamic head loss experienced by the system, lowering the existing pump's capacity to approximately 2,500 gpm under ultimate build-out. With possible remediation to the existing pumps, such as the installation of larger impellers, the combined old 3,000 gpm pumps and new 2,500 gpm pumps will accommodate the complete 24,250 AF/yr (approximately 15,000 gpm) ultimate demand with the final 6+1 configuration.

- The raw water pump station is comprised of a 6+1 configuration of 600 hp, 3,000 gpm pumps. The station is designed with suction from a 50,000 gallon sump to supply raw water back to the East Branch canal utilizing the 30-inch raw water pipeline normally used to deliver recharge. Based on the District's discretion, this pump station may also be phased, beginning with a 3+1 configuration in phase 1 and constructing the final two pumps in phase 2. However, in the event that the District creates this system for a water banking partnership, the phasing and number of pumps may be adapted in order to meet the partner's needs. Under the circumstance that the chlorination building is used to chlorinate the water within the head tank, the raw water pump station will be designed with a de-chlorination chemical feed system.

Discussion regarding each alternative constraints and benefits is provided in Section 10.2.

9.1 Alternative 9R

Alternative 9R is a revision of Preliminary Alternative 9.

- **SWP Turnout:** A new 50-cfs turnout would be constructed at the intersection of the aqueduct and 70th Street or 87th Street.

- **Groundwater Basin(s):** The alternative is capable of recharging both the Lancaster and Buttes sub-basins.

- **Recharge Site:** The proposed 175-acre recharge site is located within the LAWA property and is bounded by Avenue N to the north, Avenue N-8 to the south, and 78th Street to the west. A property line approximately 0.6 mile west of 90th Street defines the eastern border. The layouts of the site and conveyance alignments are shown on Figure 9-1.

- **Raw Water Conveyance:** The raw water supply is proposed to be conveyed from the new turnout north along 70th Street or 87th Street/90th Street. The pipeline length varies for the two alignments. The 70th Street alignment would be a 30-inch diameter raw water pipeline running 7.6 miles north to East Avenue N, east approximately 0.9 miles to a point that aligns with a future 79th Street, then south 0.5 miles as a combined 36-inch diameter raw water and recycled water pipeline to the recharge basin diversion structure. The 90th Street alignment would be a 30-inch diameter raw water pipeline running 7.9 miles north to East Avenue N, then west 1.1 miles to the same point described for the 70th Street alignment and south in a combined pipeline.

- **Recycled Water Conveyance:** The recycled water is proposed to be supplied from LACSD's existing pipeline along Avenue N through a 24-inch turn-out. For either the 70th or 90th Street raw water supply alignment, a common 36-inch pipeline would run south 0.5 miles to the recharge site diversion structure.

- **Recovery Wells:** This alternative requires 21 wells at buildout, 10 wells with a capacity of 600 gpm in the Buttes sub-basin, and 11 wells with a capacity of 1,200 gpm in the Lancaster sub-basin. One well in the Lancaster sub-basin is a spare. The wells in each sub-basin are located 4,500 feet from the center of the recharge site in a radial pattern. The first phase of the project requires 6 wells in the Buttes sub-basin and 6 wells in the Lancaster sub-basin. The remaining 4 wells in the Buttes sub-basin and 5 wells in the Lancaster sub-basin would be constructed in the second phase of the project. The piping for the first phase is sized, and upsized where necessary to deliver water from the wells in both phases to the storage reservoir. The well layout and piping system is shown in Figure 9-2. The approximate length of each pipeline required by diameter and phase of the project is shown in Table 9-1.

Table 9-1: Alternative 9R Recovery Wells Piping Requirements

Pipe Diameter (in)	Phase 1 Pipe Length (ft)	Phase 2 Pipe Length (ft)
8	4,400	2,700
10	6,900	2,400
12	7,300	0
16	6,800	0
20	4,500	0
24	3,800	0

- **Land Acquisition:** The entire 175-acre recharge site is located within LAWA property and must be leased or secured through a long-term memorandum of understanding (MOU).

- **Distribution System Location:** The 1 million-gallon head tank and pump stations are proposed to be located at the northern center of the project site along East Avenue N, which lies at 2,540 feet (MSL) in elevation.

- **Potable Water Distribution Pump Station:** The transmission system pipeline is proposed to be a 30-inch alignment running 1.3 miles west on East Avenue N, 3.5 miles south down 70th Street, then 1 mile west via Palmdale Boulevard. The specific characteristics of this station, including ultimate demand, are located on Table 9-2.

- **Raw Water Pump Station:** The optional raw water pump station for pumping back to the East Branch would be located adjacent to the distribution system head tank and discharge back into the 30-inch diameter raw water pipeline. A set of valves on the raw water pipeline would allow recharge or pump-back. The specific characteristics of this pump station are also located on Table 9-2.

- **Costs:** Table 9-3 presents the cost estimate for Alternative 9R. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 9-2: Alternative 9R Pump Station Characteristics

	Phase I Distribution System	Ultimate Distribution System	Raw Water System
Demand (AF/yr)	14,125	24,250	24,250
Flow (gpm)	8,758	15,035	15,035
Diameter (in)	30	30	30
Full Flow Velocity, (fps)	4.0	6.8	6.8
Length (mi)	5.8	5.8	8.8
Pump Station Elevation (ft)	2,540	2,540	2,540
Static HGL (ft)	2,800	2,800	2,940
Static Head (ft)	260	260	400
Head Loss[a] (ft)	47	129	195
TDH (ft)	307	389	595
Pump Capacity (gpm)	3,000	2,500	3,000
Required HP	291	307	564
Motor Size (HP)	400[b]	400	600
Number of Pumps	3+1	6+1	5+1

Notes:
(a) Hazen-Williams roughness constant estimated to be 135.
(b) Motor oversized in phase 1 in order to accommodate future demands on system and modifications to the pumps in order to obtain ultimate demand flows.

Table 9-3: Alternative 9R Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$19,720,000	$19,720,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,550,000	$1,550,000
Recovery Wells	$22,660,000	$33,580,000
Well Collection Pipelines	$7,580,000	$8,040,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$14,460,000	$14,460,000
Facilities Subtotal	***$82,370,000***	***$96,170,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$24,970,000	$52,590,000
O&M Costs	$6,450,000	$14,000,000
O&M Subtotal	***$31,420,000***	***$66,590,000***
Grand Total	**$170,190,000**	**$298,510,000**
Unit Water Cost ($/AF)	**$1,061**	**$1,110**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.

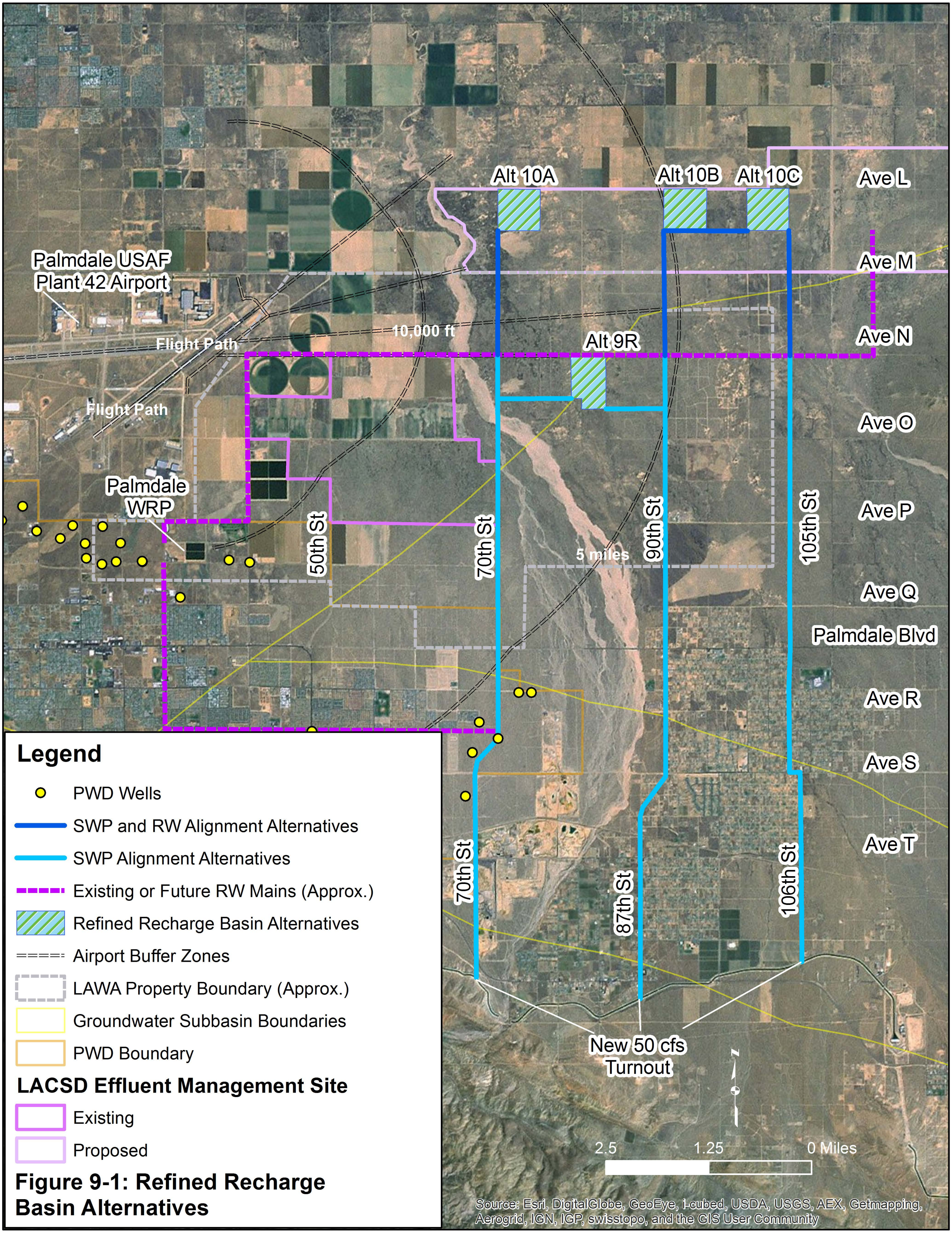
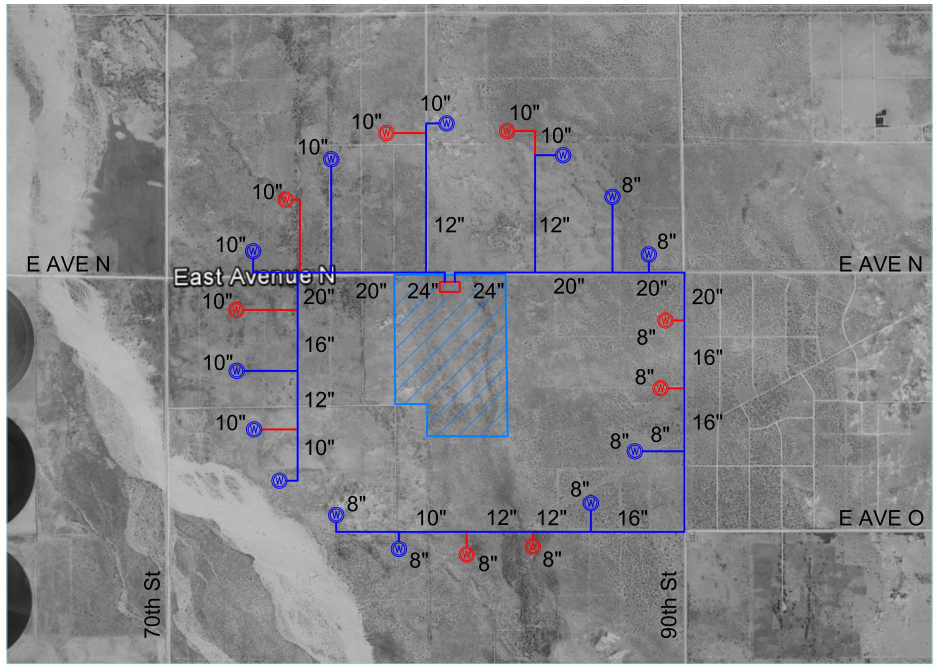
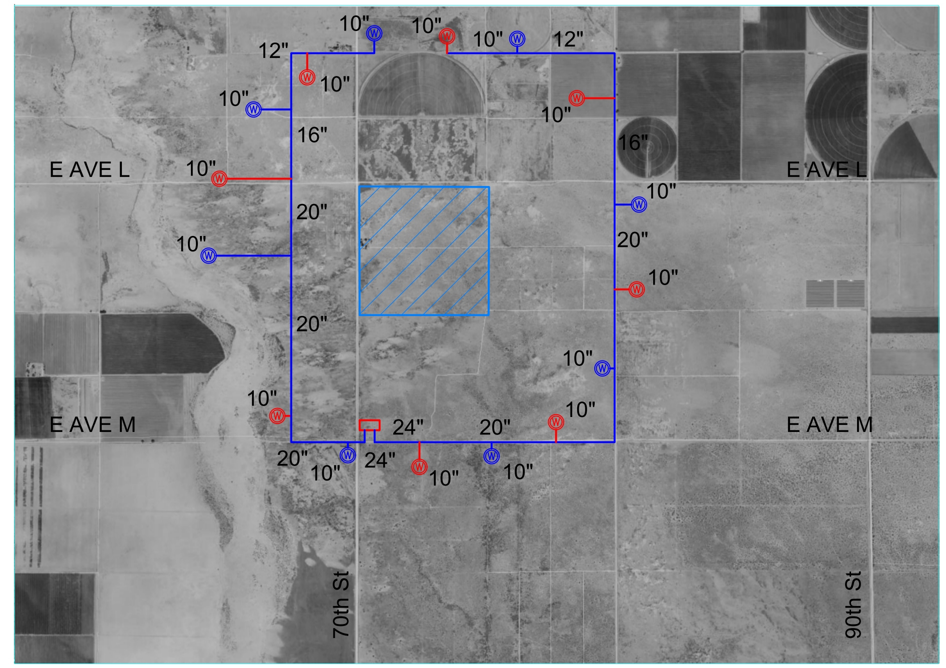


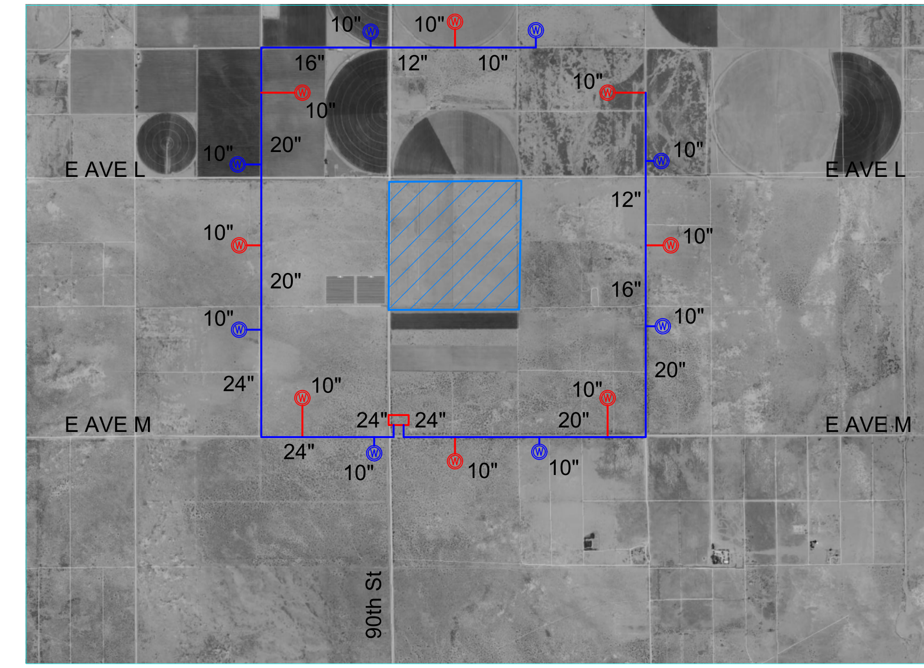
Figure 9-1: Refined Recharge Basin Alternatives



ALTERNATIVE 9 R



ALTERNATIVE 10 A



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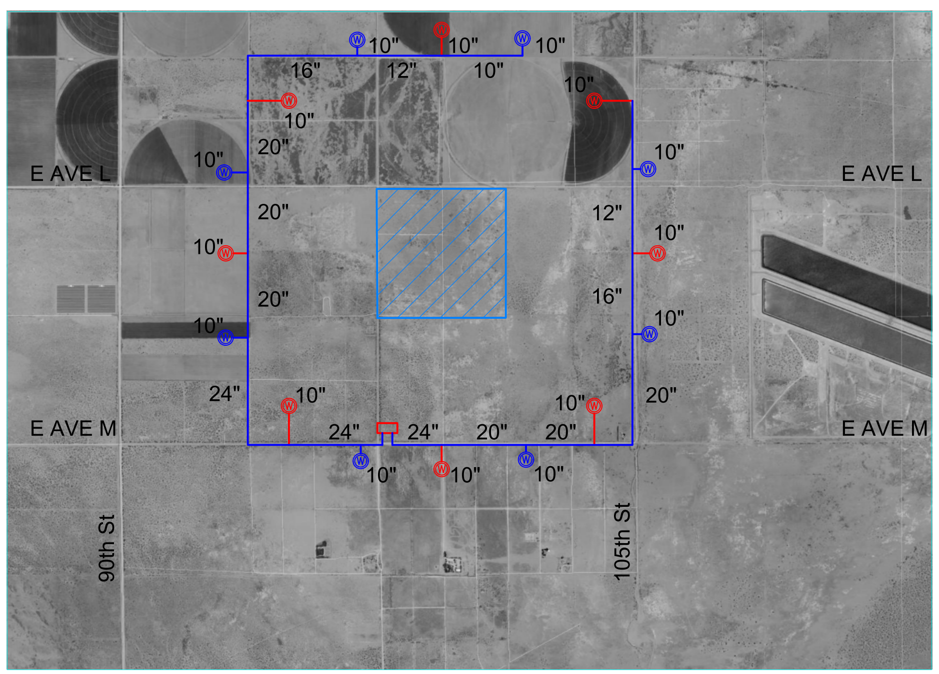
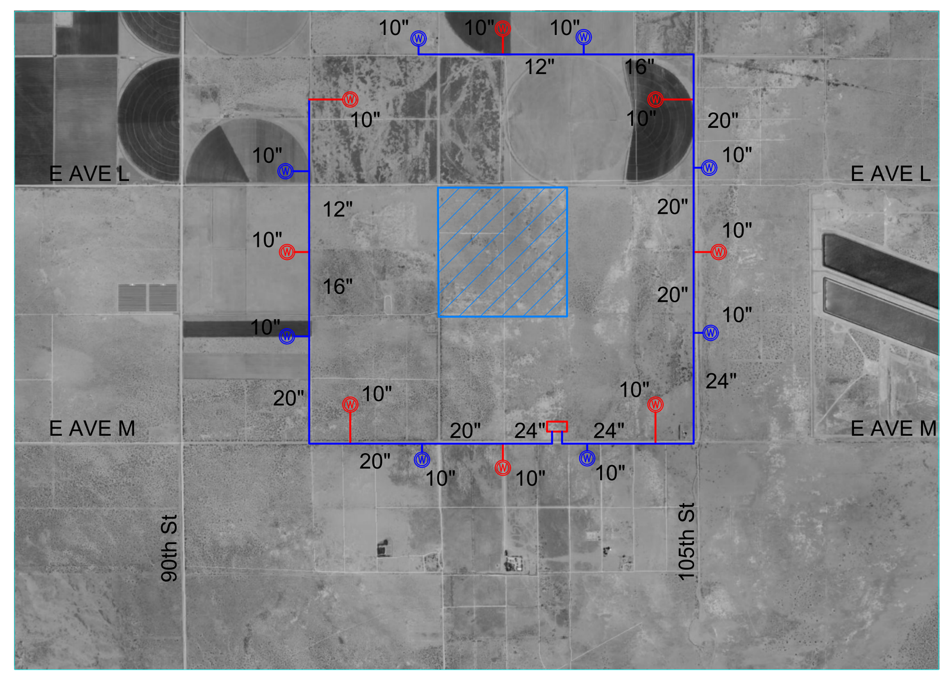


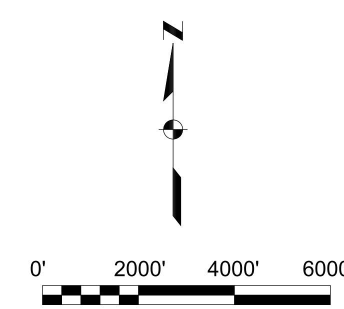
ALTERNATIVE 10 C (WEST)



ALTERNATIVE 10 C (EAST)

LEGEND

- PHASE 1 RECOVERY WELL
- PHASE 1 PIPELINE
- PHASE 2 RECOVERY WELL
- PHASE 2 PIPELINE
- 1 ACRE PUMP STATION AND STORAGE TANK SITE
- SITE ALTERNATIVE FOR RECHARGE BASINS



Kennedy/Jenks Consultants

RECOVERY WELL LAYOUTS AND PIPE SIZING

Figure 9-2

9.2 Alternative 10A

Alternative 10A is the first of three adaptations of preliminary Alternative 10.

- **SWP Turnout:** A new 50-cfs turnout would be constructed at the intersection of the aqueduct and 70th Street.
- **Groundwater Basin(s):** The alternative recharges the Lancaster sub-basin.
- **Recharge Site:** The project area's perimeter is comprised of East Avenue L to the north, 75th Street to the east, and 70th Street to the west. The site extends approximately 0.5 miles south of East Avenue L (halfway to East Avenue M). The eight recharge basins are designed to be 750 x 435 feet in a 2 x 4 arrangement. The complete area of the basins, including roads and separations, is approximately 1,730 x 2,060 feet. The layout of the site and conveyance alignments is shown on Figure 9-1.
- **Raw Water Conveyance:** The raw water supply is proposed to be conveyed from the new turnout through 9.2 miles of pipeline along 70th Street, with 7.7 miles of 30-inch diameter raw water pipeline to East Avenue N, and 1.5 miles of 36-inch diameter combined raw water and recycled water pipeline from East Avenue N to the recharge site.
- **Recycled Water Conveyance:** The recycled water is proposed to be supplied from LACSD's existing pipeline along Avenue N with a turnout delivering recycled water to the combined raw water and recycled water pipeline on 70th Street described above.
- **Recovery Wells:** This alternative requires 16 recovery wells at buildout, all with a capacity of 1,200 gpm in the Lancaster sub-basin. Two of the wells are spares. The wells are located 4,500 feet from the center of the recharge site in a generally radial pattern. Wells are not able to be constructed in the southwest side of the alternative due to the creek. As a result, the location of the wells forms a horseshoe pattern and they are located in closer proximity to each other than the full-radial Alternatives 10B and 10C. The first phase of the project requires 8 wells in the Lancaster sub-basin. The remaining 8 wells would be constructed in the second phase of the project. The piping for the first phase is sized, and upsized where necessary, to deliver water from the wells in both phases to the head tank. The well layout and piping system is shown in Figure 9-2. The approximate length of pipe required by diameter and phase of the project is shown in Table 9-4.

Table 9-4: Alternative 10A Recovery Wells Piping Requirements

Pipe Diameter (in)	Phase 1 Pipe Length (ft)	Phase 2 Pipe Length (ft)
10	5,100	5,400
12	4,700	0
16	3,100	0
20	12,400	0
24	4,500	0

- **Land Acquisition:** The entire 160-acre recharge site is located north of LAWA property and must be purchased from private property owners.

- **Distribution Site Location:** The 1-million gallon head tank and pump stations are proposed to be located on their own 1-acre parcel at the southwest corner of the project area at the intersection of East Avenue M and 70th Street, which lies at 2,504 feet in elevation. In order to avoid an additional 600 HP pump for the raw water pump station (compared to Alternatives 10B and 10C at slightly higher ground elevations) the head tank for this site is designed with a 40 side wall as opposed to a 24-foot side wall for the other sites, which under normal operating conditions will be assumed to be maintained with a water elevation of 25 to 30 feet.

- **Potable Water Distribution Pump Station:** The transmission system pipeline is proposed to be a 30-inch pipeline running 4.6 miles south from 70th Street, then 1 mile west via Palmdale Boulevard. The specific characteristics of this station, including ultimate demand, are located on Table 9-5.

- **Raw Water Pump Station:** The optional raw water pump station for pumping back to the East Branch would be located adjacent to the distribution system head tank and discharge back into the 30-inch diameter raw water pipeline. A set of valves on the raw water pipeline would allow recharge or pump-back. The specific characteristics of this pump station are also located on Table 9-5.

- **Costs:** Table 9-6 presents the cost estimate for Alternative 10A. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 9-5: Alternative 10A Pump Station Characteristics

	Distribution System	**Distribution System (Ultimate)**	**Raw Water System**
Demand (AF/yr)	14,125	24,250	24,250
Flow (gpm)	8,758	15,035	15,035
Diameter (in)	30	30	30
Full Flow Velocity, (fps)	4.0	6.8	6.8
Length (mi)	5.6	5.6	8.7
Pump Station Elevation (ft)	2,504	2,504	2,504
Static HGL (ft)	2,800	2,800	2,940
Static Head[a] (ft)	281	281	421
Head Loss[b] (ft)	46	124	193
TDH (ft)	327	405	614
Pump Capacity (gpm)	3,000	2,500	3,000
Required HP	309	320	581
Motor Size (HP)	400	400	600
Number of Pumps	3+1	6+1	5+1

Notes:
(a) Static head is calculated to take into account the additional 15 feet of head provided by the modified head tank.
(b) Hazen-Williams roughness constant estimated to be 135.

Table 9-6: Alternative 10A Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$23,580,000	$23,580,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,510,000	$1,510,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$8,070,000	$8,620,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$13,960,000	$13,960,000
Facilities Subtotal	***$78,630,000***	***$91,300,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$25,740,000	$54,110,000
O&M Costs	$5,360,000	$11,880,000
O&M Subtotal	***$31,100,000***	***$65,990,000***
Grand Total	**$166,130,000**	**$293,040,000**
Unit Water Cost ($/AF)	**$1,036**	**$1,090**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.

9.3 Alternative 10B

Alternative 10B is a modification of Alternative 10 that is moved farther east from Littlerock Creek. This additional 2-mile distance from the Alternative 10A location is provided in order to place the recharge area outside of the 5-mile zone from the airport, as well as completely out of the influence of the nitrate plume.

- **SWP Turnout:** A new 50-cfs turnout would be constructed at the intersection of the aqueduct and 87th Street.
- **Groundwater Basin(s):** The alternative recharges the Lancaster sub-basin.
- **Recharge Site:** The project area's perimeter is comprised of 90th Street to the west, East Avenue L to the north, and 95th Street to the east. The area extends approximately 0.5 miles south of East Avenue L (halfway to East Avenue M). The sizing and configuration of the recharge site is the same as Alternative 10A. The layout of the site and conveyance alignments are shown on Figure 9-1.

- **Raw Water Conveyance:** The diluent supply is proposed to be conveyed from the new turnout through 9.4 miles of pipeline along 87th/90th Street, with 7.9 miles of 30-inch diameter raw water pipeline to East Avenue N, then 1.5 miles of 36-inch diameter combined raw water and recycled water pipeline from East Avenue N to the diversion structure.

- **Recycled Water Conveyance:** The recycled water is proposed to be supplied from LACSD's existing pipeline along Avenue N with a turnout delivering recycled water to the combined raw water and recycled water pipeline along 90th Street described above.

- **Recovery Wells:** This alternative requires 16 recovery wells at buildout, all with a capacity of 1,200 gpm in the Lancaster sub-basin. Two of the wells are spares. The wells are located 4,500 feet from the center of the recharge site in a radial pattern. The first phase of the project requires 8 wells in the Lancaster sub-basin. The remaining 8 wells would be constructed in the second phase of the project. The piping for the first phase is sized, and upsized where necessary, to deliver water from the wells in both phases to the storage reservoir. The well layout and piping system is shown in Figure 9-2. The approximate length of pipe required by diameter and phase of the project is shown in Table 9-7.

Table 9-7: Alternative 10B Recovery Wells Piping Requirements

Pipe Diameter (in)	Phase 1 Pipe Length (ft)	Phase 2 Pipe Length (ft)
10	3,400	6,300
12	3,400	0
16	4,400	0
20	11,000	0
24	6,300	0

- **Land Acquisition:** The entire 160-acre recharge site is located north of LAWA property and must be purchased from private property owners. However, a small portion of this area has been acquired by the LACSD for their proposed Effluent Management area, and may be acquisitioned from them.

- **Distribution Site Location:** The 1-million head tank and pump stations are proposed to be located on their own 1-acre parcel at the southwest corner of the project area at the intersection of East Avenue M and 90th Street, which lies at an elevation of 2,530 feet.

- **Potable Water Distribution Pump Station:** The distribution system pipeline is proposed to be a 24-inch alignment running 4.6 miles south from 90th Street, then 3.0 miles west via Palmdale Boulevard. The specific characteristics of this station, including ultimate demand, are located on Table 9-8.

- **Raw Water Pump Station:** The optional raw water pump station for pumping back to the East Branch would be located adjacent to the distribution system head tank and discharge back into the 30-inch diameter raw water pipeline. A set of valves on the raw water pipeline would allow recharge or pump-back. The specific characteristics of this pump station are also located on Table 9-8.

- **Costs:** Table 9-9 presents the cost estimate for Alternative 10B. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 9-8: Alternative 10B Pump Station Characteristics

	Distribution System	Distribution System (Ultimate)	Raw Water System
Demand (AF/yr)	14,125	24,250	24,250
Flow (gpm)	8,758	15,035	15,035
Diameter (in)	30	30	30
Full Flow Velocity, (fps)	4.0	6.8	6.8
Length (mi)	7.6	7.6	8.9
Pump Station Elevation (ft)	2,530	2,530	2,530
Static HGL (ft)	2,800	2,800	2,940
Static Head (ft)	270	270	410
Head Loss[a] (ft)	62	169	197
TDH (ft)	332	439	607
Pump Capacity (gpm)	3,000	2,500	3,000
Required HP	315	346	575
Motor Size (HP)	400	400	600
Number of Pumps	3+1	6+1	5+1

Note:
(a) Hazen-Williams roughness constant estimated to be 135.

Table 9-9: Alternative 10B Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$24,160,000	$24,160,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,480,000	$1,480,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$8,130,000	$8,760,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$18,940,000	$18,940,000
Facilities Subtotal	***$84,220,000***	***$96,970,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***

	Phase I Net Present Costs	Total Net Present Costs
Power Costs	$25,790,000	$54,660,000
O&M Costs	$5,360,000	$11,880,000
O&M Subtotal	***$31,150,000***	***$66,540,000***
Grand Total	**$171,770,000**	**$299,260,000**
Unit Water Cost ($/AF)	**$1,071**	**$1,113**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.

9.4 Alternative 10C

Alternative 10C is located the farthest east from Littlerock Creek. Although no additional distance was required from Air Force Plant 42 and nitrate plume, this alternative was placed farther east in order to utilize a location in which approximately 35% of the land is owned by LACSD for its proposed Effluent Management area.

- **SWP Turnout:** A new 42-cfs turnout would be constructed at the intersection of the aqueduct and 87th Street or 106th Street.

- **Groundwater Basin(s):** The alternative recharges the Lancaster sub-basin.

- **Recharge Site:** The project area's perimeter is comprised of 100th Street to the west, East Avenue L to the north, and 105th Street to the east. The area extends approximately 0.5 miles south of East Avenue L. The sizing and configuration of the recharge site is the same as Alternatives 10A and 10B. The layouts of the site and conveyance alignments are shown on Figure 9-1.

- **Raw Water Conveyance:** The raw water supply is proposed to be conveyed from the new turnout either (1) 7.9 miles north along 87th/90th Street, 1.5 miles east across Avenue N, then 1.5 miles north along 105th Street, or (2) 9.0 miles north along 106th/105th Street. The westerly (90th Street) alignment involves 9.9 miles of 30-inch and 1.5 miles of 36-inch pipeline. The easterly (105th Street) alignment requires 7.5 miles of 30-inch and 1.5 mile of 36-inch pipeline. Although the westerly (90th Street) alignment is 1.9 miles longer, it is also closer the PWD's distribution system for the delivery of potable extraction water.

- **Recycled Water Conveyance:** The recycled water is proposed to be supplied from LACSD's existing pipeline along Avenue N to a turn-out delivering recycled water to the combine raw water and recycled water pipeline along 105th Street described above.

- **Recovery Wells:** This alternative requires 16 recovery wells at buildout, all with a capacity of 1,200 gpm in the Lancaster sub-basin. Two of the wells are spares. The wells are located 4,500 feet from the center of the recharge site in a radial pattern. The first phase of the project requires 8 wells in the Lancaster sub-basin. The remaining 8 wells would be constructed in the second phase of the project. The piping for the first phase is sized, and upsized where necessary, to deliver water from the wells in both phases to the storage reservoir. This alternative has two possible locations for the distribution site, and as a result there are two piping system layouts. The well layout and approximate pipe length for each piping system layout is the same for each location of the distribution site. The well layout and two piping systems are shown in Figure 9-2. The approximate length of pipe required by diameter and phase of the project is shown in Table 9-10.

Table 9-10: Alternative 10C Recovery Wells Piping Requirements

Pipe Diameter (in)	Phase 1 Pipe Length (ft)	Phase 2 Pipe Length (ft)
10	3,400	6,300
12	3,400	0
16	4,400	0
20	11,000	0
24	6,300	0

- **Land Acquisition:** The entire 160-acre recharge site is located north of LAWA property and must be purchased from private property owners. However, approximately 35% of this area has been acquired by the LACSD for its Effluent Management area, and may be acquired from them.

- **Distribution Site Location:** The 1-million gallon head tank and pump stations may be located on their own 1-acre parcel either at the southwest corner of the project area at the intersection of East Avenue M and 100th Street, lying at an elevation of 2,546 feet, or the southeast corner at the intersection of East Avenue M and 105th Street, lying at an elevation of 2,550 feet.

- **Potable Water Distribution Pump Station:** The distribution system pipeline is proposed to be a 30-inch alignment running from either the west alignment of the east alignment. The west alignment requires 1.0 mile west along East Avenue M, 4.6 miles south from 90th Street, then 3.0 miles west via Palmdale Boulevard. The east alignment requires 4.6 miles south along 105th Street then 4.6 miles west along Palmdale Boulevard. The specific characteristics of both alternatives, including ultimate demands, are located on Table 9-11 and Table 9-12.

- **Raw Water Pump Station:** The optional raw water pump station for pumping back to the East Branch would be located adjacent to the distribution system head tank and discharge back into the 30-inch diameter raw water pipeline. A set of valves on the raw water pipeline would allow recharge or pump-back. The specific characteristics of both locations of this pump station are also located on Table 9-11 and Table 9-12.

Costs:

- Table 9-13 presents the cost estimate for Alternative 10C west. Net present costs are provided for Phase I, which is from 2018 to 2040, and the total project planning horizon, which is from 2018 to 2067.

Table 9-11: Alternative 10C West Pump Station Characteristics

	Distribution System	Distribution System (Ultimate)	Raw Water System
Demand (AF/yr)	14,125	24,250	24,250
Flow (gpm)	8,758	15,035	15,035
Diameter (in)	30	30	30
Full Flow Velocity, (fps)	4.0	6.8	6.8
Length (mi)	8.6	8.6	9.9
Pump Station Elevation (ft)	2,546	2,546	2,546
Static HGL (ft)	2,800	2,800	2,940
Static Head (ft)	254	254	394
Head Loss[a] (ft)	70	191	220
TDH (ft)	324	445	614
Pump Capacity (gpm)	3,000	2,500	3,000
Required HP	307	351	581
Motor Size (HP)	400	400	600
Number of Pumps	3+1	6+1	5+1

Note:
(a) Hazen-Williams roughness constant estimated to be 135.

Table 9-12: Alternative 10C East Pump Station Characteristics

	Distribution System	Distribution System (Ultimate)	Raw Water System
Demand (AF/yr)	14,125	24,250	24,250
Flow (gpm)	8,758	15,035	15,035
Diameter (in)	30	30	30
Full Flow Velocity, (fps)	4.0	6.8	6.8
Length (mi)	9.2	9.2	8.5
Pump Station Elevation (ft)	2,550	2,550	2,550
Static HGL (ft)	2,800	2,800	2,940
Static Head (ft)	250	250	390
Head Loss[a] (ft)	75	204	188
TDH (ft)	325	454	578
Pump Capacity (gpm)	3,000	2,500	3,000
Required HP	308	358	548
Motor Size (HP)	400	400	600
Number of Pumps	3+1	6+1	5+1

Note:
(a) Hazen-Williams roughness constant estimated to be 135.

Table 9-13: Alternative 10C West Cost Estimate

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$23,130,000	$23,130,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,100,000	$1,100,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$8,130,000	$8,760,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$21,440,000	$21,440,000
Facilities Subtotal	***$85,310,000***	***$98,060,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$25,400,000	$54,090,000
O&M Costs	$5,360,000	$11,880,000
O&M Subtotal	***$30,760,000***	***$65,970,000***
Grand Total	**$172,470,000**	**$299,780,000**
Unit Water Cost ($/AF)	**$1,075**	**$1,115**

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.
(c) Phase I = 2018 – 2040; Total Project = 2018 – 2067.

Table 9-14 presents a summary of the net present costs for each alternative.

Table 9-14: Alternatives Net Present Cost Summary

Alternative	Facility Costs ($)	SWP Table A Water Costs ($)	Water Purchase Costs ($)	O&M Costs ($)	Total Costs ($)	Unit Cost ($/AF)
9R	$96,170,000	$25,590,000	$110,160,000	$66,590,000	$298,510,000	$1,110
10A	$91,300,000	$25,590,000	$110,160,000	$65,990,000	$293,040,000	$1,090
10B	$96,970,000	$25,590,000	$110,160,000	$66,540,000	$299,260,000	$1,113
10C	$98,060,000	$25,590,000	$110,160,000	$65,970,000	$299,780,000	$1,115

Notes:
(a) Net present costs are shown.
(b) Construction costs are fully burdened with contingency and engineering & administration costs.

9.5 Groundwater Modeling of Refined Alternatives

Alternatives 9R, 10A, 10B, and 10C represent preferred groundwater banking scenarios based on consideration of:

- Recharge and extraction involving the relatively transmissive Lancaster sub-basin aquifer, as compared to those of the Pearland and Buttes sub-basins,
- Engineering considerations, as previously described, and
- Stipulated constraints (i.e., setback distances per the FAA).

This section describes groundwater modeling results for Alternatives 10A, 10B, and 10C. Given that Alternative 9R is approximately in the same location as Alternative 9, the modeling results for Alternative 9 are assumed to be representative for Alternative 9R. Each alternative entails groundwater recharge through rectangular basins of approximately 120 acres, with groundwater withdrawals occurring through matching networks of 16 extraction wells. This number of wells was chosen as a compromise to minimize well construction and connection costs, while avoiding excessive drawdown in individual wells. Two extraction well network designs were investigated: a linear configuration, with wells positioned to the north and west of the recharge basins (analogous to Alternatives 3 through 10), and a radial configuration design to minimize drawdown and – by extension – land subsidence. As in the case of Alternatives 3 through 10, the linear well configurations assume a well-to-basin-edge spacing of 2,500 feet, while the radial configurations for Alternatives 10A through 10C assume that all wells are spaced uniformly along a circle defined by a well-to-basin-center spacing of 4,500 feet.

The linear well configuration scenarios are similar to those of preliminary Alternatives 3 through 10 in that adequate recharge water travel time (i.e., greater than one year) is achieved by the proposed well spacing, although there is significant drawdown predicted (on the order of tens of feet or more). In contrast, the radial well network configurations produce much less drawdown in the vicinity of the extraction wells, which is attributable to increasing the separation distances between individual wells so that superposition of the wells' cones of depression is minimized. Intuitively, the reverse particle tracking from the extraction well network indicates that a travel time exceeding one year exists for all three scenario alternatives under the radial extraction well geometry implementation. Predicted groundwater mounding (with respect to average ambient conditions) remains less than 180 feet, thereby remaining beneath the 50-foot depth below ground surface. Little difference in mounding height is evident between the linear and radial extraction well field configurations.

Estimated spatial distributions of land subsidence for Alternatives 10A, 10B, and 10C were generated using the existing spatial distributions of aquifer elastic and inelastic compaction properties in the USGS MODFLOW model for the Basin (Leighton and Phillips, 2003) without subsequent modification. Because the original MODFLOW model already includes pre-groundwater banking subsidence estimates, the original subsidence estimates were subtracted from the current post-groundwater banking estimates to quantify the differential subsidence that would be expected solely as a result of groundwater banking and withdrawal. The modeled extent of land subsidence differs significantly between the posited linear and radial extraction well configurations, with the former configuration yielding differential subsidence values of up to one foot, while the latter is characterized by much smaller amounts of subsidence (on the order of 0.1 foot or less) over a smaller area.

The PHAST reactive transport model was used to address potential water quality impacts of groundwater banking assuming:

- A simplified, one-layer model of the area surrounding Alternative 10B, a radial extraction well geometry configuration,
- Representative mean water compositions for local groundwater and recharge water (a combination of SWP and recycled water), and
- Adsorbent mineral phase in the aquifer.

Modeled numerical tracer (e.g., chloride) concentrations indicate that the radial extraction well field captures the majority of the recharged water. The modeled concentration of arsenic, a non-conservative constituent subject to adsorption/desorption reactions suggest little potential for mobilization as a result of pH changes and other effects. However, this issue should be further examined through the use of more site-specific groundwater compositional data.

In summary, the proposed radial extraction well configurations for Alternatives 10A, 10B, and 10C adequately address required groundwater banking performance metrics with respect to both groundwater mounding and recharge water residence times and can therefore serve as a basis for subsequent design.

9.6 Infiltration Testing

The recharge rate can be measured through standard infiltration tests, and both the recharge rate and recovery capacity were estimated in the groundwater model. Converse Consultants prepared a *Percolation Test Results Report* (PTRR) (Converse Consultants, 2014) that presents subsurface conditions and recommended design infiltration rates for Alternatives 10A, 10B, and 10C. The PTRR is provided in Appendix F.

A document review of published and unpublished geologic/geotechnical reports pertaining to the project area was performed for appropriate seismic and faulting information, depth to groundwater, and site geology. Field exploration of the project area included site reconnaissance and a subsurface exploration program to obtain subsurface information and perform percolation tests. The field exploration included drilling five exploratory borings to at least 10 feet below the expected bottom of the recharge basins and a maximum depth of 21.5 feet below ground surface (bgs). An additional 15 percolation test borings were drilled to 5 feet bgs in order to perform percolation testing.

The subsurface soils encountered in the exploratory borings consist primarily of loose to medium dense silt and sand mixtures. Lenses of caliche were observed in some boring locations. The presence of caliche along with dry moisture conditions resulted in some soil layers being slightly cemented. Groundwater was not encountered in any of the borings. The document review indicated that historical groundwater depths of 175 feet to 350 feet bgs have been measured at multiple wells located near the project area. As a result, groundwater is not expected to be encountered during construction of any of the alternatives.

Percolation rates describe the movement of water horizontally and downward into soil. Infiltration rates describe the downward movement of water through a horizontal surface. Percolation rates are related to infiltration rates, but are generally higher and require conversion before use in design. The results of the percolation tests, conversion factors, and a factor of safety were used to estimate the infiltration rates for the project area. The recommended design infiltration rates for the project area are presented in Table 9-15.

Table 9-15: Design Infiltration Rates

Project Area	Test Location Description	Recommended Design Infiltration Rate (ft/day)
Alternative 10A	North Side of Alternative 10A, South Side of Avenue L	2.2
Alternative 10A	South Side of Alternative 10A, North Side of Avenue M	6.0
Alternative 10B	North Side of Alternative 10B, South Side of Avenue L	9.4
Alternative 10C	North Side of Alternative 10C, South Side of Avenue L	9.4
Alternative 10C	South Side of Alternative 10C, North Side of Avenue M	12.0

The slopes of the recharge basins are expected to have a 3:1 (horizontal to vertical) gradient. Based on the subsurface conditions, caving of dry cohesionless granular soils may occur during excavation. Unsuitable conditions for a cut slope may include low-density soils, running sands, severe soil fractures, or other conditions. A flatter slope ratio of 4:1 should be considered for slope stability purposes in such dry and cohesionless sandy soils. Adequate surface and top of slope drainage controls should be included in slope designs to mitigate erosion of the slope face. The slopes of the Project's recharge basins should be lined with gunite to protect against erosion.

Section 10: Refined Alternatives Evaluation

This section provides an evaluation of the refined alternatives described in the preceding section.

10.1 Evaluation Criteria Description

Supplementing the evaluation criteria described previously, there are additional pertinent characteristics that must be considered in the evaluation of the refined alternative recommendations. The use of recycled water in all four refined alternatives requires all the alternatives to maintain the same regulations and permitting. As such, it has been removed as an evaluation criteria. The specific attributes are outlined in Table 10-1.

Table 10-1: Evaluation Criteria

Criteria	Description
Total Cost	The total net present cost of an alternative over the study period of 50 years (2018 – 2067)
Unit Water Cost	An estimate of the cost of the projected water resource compared to the total costs of the alternative over the life of the project
Recharge and Recovery Capacity	(1) The recharge rate at which the basin can infiltrate water and (2) the capacity of planned recovery wells
Recovery Water Quality	The ability of an alternative to meet water quality standards, primarily based on the alternative's distance from the existing nitrate plume
Environmental Sensitivity	Potential sensitivity regarding biological and cultural resources in each project area
Implementation Risk and Uncertainty	The unintended consequences of implementation of various alternatives
Property Acquisition[a]	The ease at which property may be acquired, whether by a private or public owner
Institutional Issues[b]	The complexity of obtaining project support of public agencies and/or private entities, either directly or indirectly involved in the project, and the consequences on the project's implementation and/or schedule
Public Acceptance[c]	The likely support versus opposition of the public associated with each alternative

(a) Property acquisitions from public entities such as LACSD's Effluent Management (EM) area (Figure 1-2) are easier to acquire as opposed to a private entity. Furthermore, land ownership is considered more preferable than leasing.

(b) Institutional issues are more likely to occur the closer the proximity to Air Force Plant 42, specifically within a 5-mile radius as according to the provisions described in the FAA's 2007 WAAC.

(c) Due to the use of recycled water in all four alternatives, the public's reaction to recycled water use is not considered a differentiator as with the original alternatives with and without recycled water; however, local resistance to property acquisition and project location may be a differentiator.

10.2 Alternatives Discussion

Included herein are the four most favorable alternatives as recommended by Kennedy/Jenks. Each is described as it relates to the evaluation criteria. The details described for each alternative have been evaluated similarly to Section 8 and ranked accordingly. The results of the evaluations for all four alternatives are discussed in Section 10.3.

10.2.1 Alternative 9R

The original Alternative 9 is within approximately 0.2 miles of Littlerock Creek, limiting the location of the recovery wells that meet the setback distance, required to comply with regulatory travel time requirements. As such, Alternative 9R was shifted slightly to the northeast to increase the distance from the creek while maintaining 50% of its recharge area over each of the Buttes and Lancaster sub-basins. Although moving Alternative 9R further northeast is an option, this would place the recharge area within the flight path of Air Force Plant 42, which is not advisable.

The Buttes sub-basin is shallower than the Lancaster sub-basin and has a lower hydraulic conductivity. As such, recovery wells placed within this sub-basin are estimated to produce half the capacity as wells within the Lancaster sub-basin. According to groundwater modeling performed in Task 6 (presented in the *Groundwater Modeling Report* [Appendix E]), if the site were to be located completely in the Buttes sub-basin, then the recharge basin would be susceptible to mounding. This aspect of the Buttes sub-basin combined with the lessening of possible recovery well capacities requires the alternative to straddle both basins. In addition, because there are very few existing wells in the Buttes sub-basin, there is little available information to characterize the groundwater in the area. Such unknowns produce a level of uncertainty paired with the sub-basin.

The recharge area is characterized by native scrub vegetation and is a more likely habitat for sensitive species. Furthermore, the northern region of the site contains a cultural resource noted as an isolated well cement cover, which provides evidence of possible past agricultural use and cultural significance. The elevations range from a peak elevation of approximately 2,574 feet to 2,529 feet sloping toward the northwest. This range in elevations is amenable to construction of recharge basins using a balanced cut and fill approach.

This alternative lies approximately 2.45 miles from the nitrate plume. Although this site is farther than Alternative 10A, there may be related concerns regarding the possible effect of the nitrate plume on future water quality. Similarly, the site is within the 5-mile buffer consigned by the FAA for the airport. Within this zone, the project would be required to take precautions against attracting any wildlife that could cause a bird strike. Such additional precautions may increase the capital and operating costs of the project.

The project area is contained within LAWA property. Utilizing land that is already owned by another institution may be advantageous because of public acceptance is streamlined as no new parties can acquire land in the area. Conversely, coordination with LAWA for the land would be required. Discussions would most likely conclude in a long-term lease agreement via a memorandum of understanding (MOU) for the property at a rate and time frame to be negotiated, could burden the alternative with additional risk as well as property acquisition issues.

The distribution system for this alternative is expected to be the second smallest of the alternatives. Its southwesterly location proves an advantage with regard to distribution piping, allowing for the total pipe length for both raw water and distribution pumping systems to be a combined 14.6 miles. The advantages and disadvantages of the system are reflected in the alternative's total cost.

Details pertaining to the evaluation criteria are defined below.

1) **Total Cost:** The total net present cost is $170,190,000 for Phase I and $298,510,000 for the total project, which makes Alternative 9R more expensive than Alternative 10A, but less expensive than Alternatives 10B and 10C.

2) **Unit Water Cost:** The unit water cost for this location has been estimated to be $1,110/AF, which is comparable to the other alternatives.

3) **Recharge and Recovery Capacity:** This alternative requires an additional four wells compared to Alternatives 10A through 10C. As such, it has received a lower but moderate score.

4) **Recovery Water Quality:** The proximity to the nitrate plume is greater than Alternatives 10B and 10C, but less than Alternative 10A. As such, Alternative 9R receives a greater score than Alternative 10A but less than the other two.

5) **Environmental Impact:** The environmental concerns and cultural evidences give Alternative 9R a higher risk for environmental and cultural obstacles, granting a lower score for Environmental Sensitivity.

6) **Implementation Risk and Uncertainty:** The placement of the alternative in the Buttes sub-basin casts some uncertainty in its design due to the lack of information available for the sub-basin. Also, the proximity to the nitrate plume creates a level of uncertainty in future water quality, granting it a lower score comparatively.

7) **Property Acquisition:** The location within LAWA property is less preferable than a property the District may own, giving it a lower score.

8) **Institutional Issues:** Projected issues stem from the recharge area's proximity to Air Force Plant 42, creating concerns with the FAA and wildlife entities. As such, this alternative has been given a low score due to higher probability of institutional issues.

9) **Public Acceptance:** This alternative is expected to be more accepted publicly due to the inability of the public to use the land from LAWA, granting it a high score.

10.2.2 Alternative 10A

Alternative 10A is the most similar to the original Alternative 10 in location, but has been moved east away from Littlerock Creek. The close proximity of Alternative 10 to the creek creates a concern with environmental sensitivity. Furthermore, the proximity to the creek also included institutional and permitting issues, specifically with the USACE and CDFW. As such, Alternative 10's location was adjusted to Alternative 10A in order to accommodate the specified concerns as well as provide space to the west for the required groundwater travel time between the recovery wells and the recharge area without placing any wells to the west of the creek. The change in location also increases the distance of the recharge area from the Air Force Plant 42 Airport and nitrate plume.

Alternative 10A is located completely within the Lancaster sub-basin. This sub-basin is the most widely used for groundwater production and is deeper than Buttes or Pearland sub-basins. As such, the recovery wells in this sub-basin are expected to achieve 1,200 gpm, which requires fewer wells to be installed than Alternative 9R, saving the project in capital cost and land acquisition. For the radial well layout, the projected subsidence for Alternative 10A after 20 years is estimated to be 0.10 foot for 10 of the 15 wells, which is essentially negligible.

The recharge area is characterized by scrub vegetation that is not expected to contain sensitive species and is considered one of the least constrained alternatives both environmentally and culturally. The northwestern region of the site contains two locations that are considered developed, which appear to be homes. According to the 2014 PTTR (Converse Consultants, 2014) (Appendix F), the average infiltration rates are 2.2 fpd in the northern region and 6.0 fpd in the southern region. Values of approximately 2 fpd are considered to be good; equal or greater than 4 fpd are considered to be excellent. The elevations range from a peak elevation of approximately 2,501 feet to 2,473 feet sloping toward the northwest. This range in elevations is amenable to construction of recharge basins using a balanced cut and fill approach.

At approximately 1.9 miles, this alternative is farther from the nitrate plume than the Preliminary Alternative 10 but still remains within an area of influence. According to the most recent groundwater modeling performed by Kennedy/Jenks in Task 6 (*Groundwater Modeling Report*; Appendix E), the nitrate plume is estimated to potentially reach the recharge area in 20 years, causing future water quality issues. Its location also lies within the five-mile buffer zone prescribed by the FAA. Like Alternative 9R, being within the buffer zone will force the project to include wildlife precautions which may increase capital and operating costs.

This alternative lies outside of the LAWA property but contains two homes. The area is nearly completely owned by private property owners, which could complicate land acquisition and public acceptance.

The distribution system for this alternative is expected to be the smallest of the three alternatives (10A, 10B, and 10C). Its westerly location and close proximity to 70th Street proves to be an advantage with regard to piping, allowing for the total pipe length for both raw water and distribution systems to be a combined 14.3 miles. However, the requirement of a taller head tank in order to accommodate the low elevation of the site may result in increased expense for the head tank and reduced operational flexibility. The advantages and disadvantages of the system are reflected in the alternative's total cost.

Details as pertaining to the evaluation criteria are defined below.

1) **Total Cost:** The total net present cost is $166,130,000 for Phase I and $293,040,000 for the total project, which is the lowest estimate of the four alternatives.

2) **Unit Water Cost:** The unit water cost for this alternative is $1,090/AF, which is comparable to the other alternatives.

3) **Recharge and Recovery Capacity:** This alternative provides PWD's ultimate water demand with 16 wells compared to the 21 required by Alternative 9R, granting a higher score.

4) **Recovery Water Quality:** Alternative 10A is situated closest to the nitrate plume, giving it the lowest score of the four.

5) **Environmental Impact:** This alternative is considered one of the least constrained with no considerable cultural or biological risks.

6) **Implementation Risk and Uncertainty:** There is a certain level of uncertainty for future water quality due to project's proximity to the nitrate plume. Furthermore, there is a slight risk associated with the amount of subsidence the wells are expected to encounter, albeit only 0.10 feet after 20 years.

7) **Property Acquisition:** Although the project is placed outside of LAWA property, the property in question is owned almost completely by private owners, including two homes. As such, property acquisition is expected to be moderately difficult for this alternative.

8) **Institutional Issues:** The project area lies within the five-mile flight zone prescribed in the Federal Aviation Administration FAA's 2007 WAAC, granting a lower score.

9) **Public Acceptance:** Since this alternative lies within private property, there may be issues with the current property owners.

10.2.3 Alternative 10B

Alternative 10B is a modification of Alternative 10A that has been moved farther east from Littlerock Creek. Although Alternative 10A was placed the required distance away from the creek for the recovery wells to remain east of the creek, it remained within the affected area of the nitrate plume as well as the five mile buffer from the Air Force Plant 42. Alternative 10B resolves these issues over Alternative 10A. This alternative is nearly a duplicate of Alternative 10A with regard to capacity and environmental, but is no longer influenced by the airport or nitrate plume.

Alternative 10B is also located completely within the Lancaster sub-basin. As such, the recovery wells in this sub-basin are expected to achieve 1,200 gpm, which allows for fewer to be installed than Alternative 9R, saving the project in the area of capital cost and land acquisition, while remaining comparable to 10A. For the radial well layout, the projected subsidence for Alternative 10B is estimated to be 0.10 foot for 4 of the 16 wells, which creates less risk than that of 10A.

The recharge area is characterized by scrub vegetation and is considered unconstrained both environmentally and culturally. However, the southern region of the site contains suitable habitat for the Mohave ground squirrel and a historical record of its presence. According to the 2014 PTTR (Converse Consultants, 2014) (Appendix F), the average infiltration rate is 9.4 fpd in the northern region but the southern region has not been measured. The elevations range from a peak elevation of approximately 2,535 feet to 2,501 feet sloping toward the northwest. This range in elevations is amenable to construction of recharge basins using a balanced cut and fill approach.

This alternative lies outside of the LAWA property, lies outside the 5-mile flight zone, and contains only agricultural property. The area is nearly completely owned by private property owners, which could make land acquisition more difficult, although not to the extent as Alternative 10A. Furthermore, the LACSD's proposed future Effluent Management area encompasses the site in question, although few parcels have been purchased to date. Being within areas that the LACSD has already acquired will make land acquisition less difficult as well as bolster public acceptance since the land is already taken and expected to be used for similar purposes as the LCGRRP.

The distribution system for this alternative is larger than Alternatives 9R and 10A, but less than Alternative 10C. Its northeasterly location proves a disadvantage in regard to distribution piping, causing the total pipe length for both raw water and distribution systems to be a combined 16.5 miles. The advantages and disadvantages of the system are reflected in the alternative's total cost.

This alternative's relation to the evaluation criteria is outlined below.

1) **Total Cost:** The total net present cost is $171,770,000 for Phase I and $299,260,000 for the total project, which is higher than Alternatives 9R and 10A, but lower than Alternative 10C.

2) **Unit Water Cost:** The unit water cost for this alternative is $1,113/AF, which is comparable to the other alternatives.

3) **Recharge and Recovery Capacity:** The capacity is the same as Alternative 10B. However, this location is expected to have a higher infiltration rate than Alternative 10A, granting a higher score than both Alternatives 9R and 10A.

4) **Recovery Water Quality:** Alternative 10B lies a considerable distance away from the nitrate plume, which should provide enough of a buffer to no longer be considered a concern.

5) **Environmental Impact:** This alternative is expected to have less of an impact than Alternative 9R, but due to the possible presence of the Mohave ground squirrel, may have a higher environmental impact than Alternative 10A. As such, the scoring for this criterion is between the two.

6) **Implementation Risk and Uncertainty:** A level of uncertainty lies with the environmental impacts due to the MGS. In the case that the squirrel is encountered, there may be some regulatory obstacles to overcome. Also, the lack of percolation information for the southern portion of the project area also provides a level of uncertainty, though not to the extent as the lack of information for the Buttes basin in Alternative 9R.

7) **Property Acquisition:** The location does not contain any homes and lies outside of the LAWA property with some minor land owned by LACSD. As such, property acquisition is expected to be less difficult than Alternatives 9R or 10A.

8) **Institutional Issues:** The recharge basins for the site are located outside of the five-mile flight zone. As such, no institutional issues are expected.

9) **Public Acceptance:** In terms of land acquisition, the project area is located across private property with no homes. Although the alternative lies within the LACSD Effluent Management area, the LACSD has not acquired much land this far west. As such, the scoring for this criterion is similar to Alternative 10A but slightly higher without having to purchase two existing homes.

10.2.4 Alternative 10C

Alternative 10C is located the farthest east from Littlerock Creek. Although Alternative 10B was placed the required distance away from the creek, nitrate plume, and airport, another alternative has been provided in order to utilize the land for the LACSD's Effluent Management area. This alternative is nearly identical to Alternative 10B with regard to capacity and general environment.

Alternative 10C is also located completely within the Lancaster sub-basin. As such, the recovery wells in this sub-basin are expected to achieve 1,200 gpm, which allows for fewer to be installed than Alternative 9R, saving the project in the area of capital cost and land acquisition, while remaining comparable to Alternatives 10A and 10B. For the radial well layout, the projected subsidence for Alternative 10A after 20 years is estimated to be 0.10 foot for 2 of the 16 wells.

With no remarks regarding cultural or environmental impacts, the recharge area is considered one of the least constrained in both aspects. According to the 2014 PTTR (Converse Consultants, 2014) (Appendix F), the average infiltration rate is 9.4 fpd in the northern region and 12 fpd in the southern region. The elevations range from a peak elevation of approximately 2,550 feet to 2,515 feet sloping toward the northwest. This range in elevations is amenable to construction of recharge basins using a balanced cut and fill approach.

This alternative lies completely outside of the LAWA property as well as the FAA five-mile buffer zone and contains only agricultural property. Approximately 65% of the land is owned by private property owners, but approximately 35% of the land has been acquired for the LACSD's Effluent Management area. Being within areas that the LACSD has already acquired will make land acquisition less difficult as well as bolster public acceptance since the land is already taken and expected to be used for similar purposes as the LCGRRP.

Although the distribution system for this alternative has the optimal elevation of all the alternatives, its pipeline is longer than the all the other alternatives. Its northeasterly location proves a disadvantage in regard to distribution piping, causing the total pipe length for both raw water and distribution systems to be a combined 18.5 miles if the western distribution site location is chosen and 17.7 miles if the eastern site is chosen. The advantages and disadvantages of the system are reflected in the alternative's total cost.

This alternative's relation to the evaluation criteria is outlined below.

1) **Total Cost:** The total net present cost is $172,470,000 for Phase I and $299,780,000 for the total project, which is the highest total cost for the four alternatives.

2) **Unit Water Cost:** The unit water cost for this alternative is $1,115/AF, which is comparable to the other alternatives.

3) **Recharge and Recovery Capacity:** The capacity is the same as Alternatives 10A and 10B. This alternative has the most information regarding the percolation rate as well as the highest rate among the four alternatives, granting it the highest score of the four.

4) **Recovery Water Quality:** Alternative 10C lies the farthest from the nitrate plume, eliminating the plume as a concern.

5) **Environmental Impact:** This alternative is considered the least constrained.

6) **Implementation Risk and Uncertainty:** Although there is always some level of uncertainty, the location of this alternative within the LACSD Effluent Management area and distance

from the nitrate plume with no environmental or cultural concerns allows a considerable amount of confidence compared to the other alternatives. In addition, the sub-regional groundwater model showed essentially no subsidence after 20 years, and the lowest values compared to the other alternatives.

7) **Property Acquisition:** This alternative has been placed outside of LAWA property. However, the alternative location lies closer to the LACSD Effluent Management area and 35% of the area is already owned by LACSD, which should lessen the difficulty of land acquisition.

8) **Institutional Issues:** This project area is out of the five-mile flight zone prescribed by the FAA.

9) **Public Acceptance:** Since this alternative lies within the LACSD Effluent Management area, the public is likely to already expect the land to be used by a public entity for similar purposes. As such, this location is likely to have one of the highest public acceptance scores.

10.3 Alternatives Scoring

The weighted scoring matrix for the final four alternatives is provided in Table 10-3.The ranking matrix summary is provided as Table 10-2.

Table 10-2: Ranking Matrix Summary

Alternative	Total Weighted Score	Ranking
9R	3.09	4
10A	3.20	3
10B	4.27	2
10C	4.82	1

Table 10-3: Littlerock Creek Groundwater Recharge and Recovery Project
Final Four Alternatives Scoring and Ranking

			Alternative 9R			Alternative 10A			Alternative 10B			Alternative 10C		
Criteria	**Weight**	**Scoring Description**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**	**Score**	**Weighted Score**	**Comment**
Total Cost	15%	1 - 5 (Best)	4.91	0.7	$298,510,000	5.00	0.8	$293,040,000	4.90	0.7	$299,260,000	4.89	0.7	$299,780,000
Unit Water Cost	15%	1 - 5 (Best)	4.91	0.7	$1,110	5.00	0.8	$1,090	4.90	0.7	$1,113	4.89	0.7	$1,115
Recharge and Recovery Capacity	15%	1 - 5 (Best)	3.75	0.6	Buttes and Lancaster Basin	5.00	0.8	Lancaster Basin	5.00	0.8	Lancaster Basin	5.00	0.8	Lancaster Basin
Recovery Water Quality	10%	1 - 5 (Best)	2	0.2	Moderate Proximity to Nitrate Plume	0	0.0	Expected Contact to Nitrate Plume	5	0.5	No Contact with Nitrate Plume	5	0.5	No Contact with Nitrate Plume
Environmental Impact	10%	1 - 5 (Best)	3	0.3	Largely unconstrained - contains suitable habitat and cultural resource	4	0.4	Least Consrained	3	0.3	Largely Unconstrained - Contains Suitable Habitat for MGS	5	0.5	Least Constrained
Implementation Risk and Uncertainty	10%	1 - 5 (Best)	1	0.1	Least Known about Buttes Basin, proximity to Plume	2	0.2	Proximity to Plume	2	0.2	MGS Possibility	4	0.4	
Property Acquisition	10%	1 - 5 (Best)	1	0.1	Lease or MOU	2	0.2	Property ownership, two homes on site	4	0.4	Property ownership, very little LACSD Effluent Management	5	0.5	Property ownership, 35% LACSD Effluent Management
Institutional Issues	10%	1 - 5 (Best)	1	0.1	Airport Proximity	1	0.1	Airport Proximity	5	0.5	Outside FAA Zone	5	0.5	Outside FAA Zone
Public Acceptance	5%	1 - 5 (Best)	5	0.3	LAWA property	1	0.1	All Private Property, Presence of Homes	3	0.2	Mostly Private Property, Little LACSD	4	0.2	65% Private Property, 35% LACSD, within Effluent Management
Total	**100%**	**5**		**3.09**			**3.20**			**4.27**			**4.82**	
Rank				**4**			**3**			**2**			**1**	

Section 11: Recommendation

Based on the screening of the original preliminary 10 alternatives, the best two preliminary alternatives (Alternatives 9 and 10) were identified. In turn, Alternative 9 was refined and Alternative 10 was expanded to include three different options (A, B, and C), resulting in the final four refined alternatives: 9R, 10A, 10B, and 10C. Evaluation of the four refined alternatives resulted in the identification of the best two alternatives for further consideration, which are Alternative 10B and Alternative 10C.

11.1 Implementation Plan

As discussed in the Section 9, Alternative 10B and Alternative 10C have been sized according to a phasing plan. The preliminary phase is intended to meet the District's demands for the first 22 years of the project's life, accommodating a demand of 14,125 AF/yr. The second phase is intended to meet the ultimate demand of 24,250 AF/yr through 50 years (through 2067). An outline of the aspects of this plan for each facet of the alternatives is presented below:

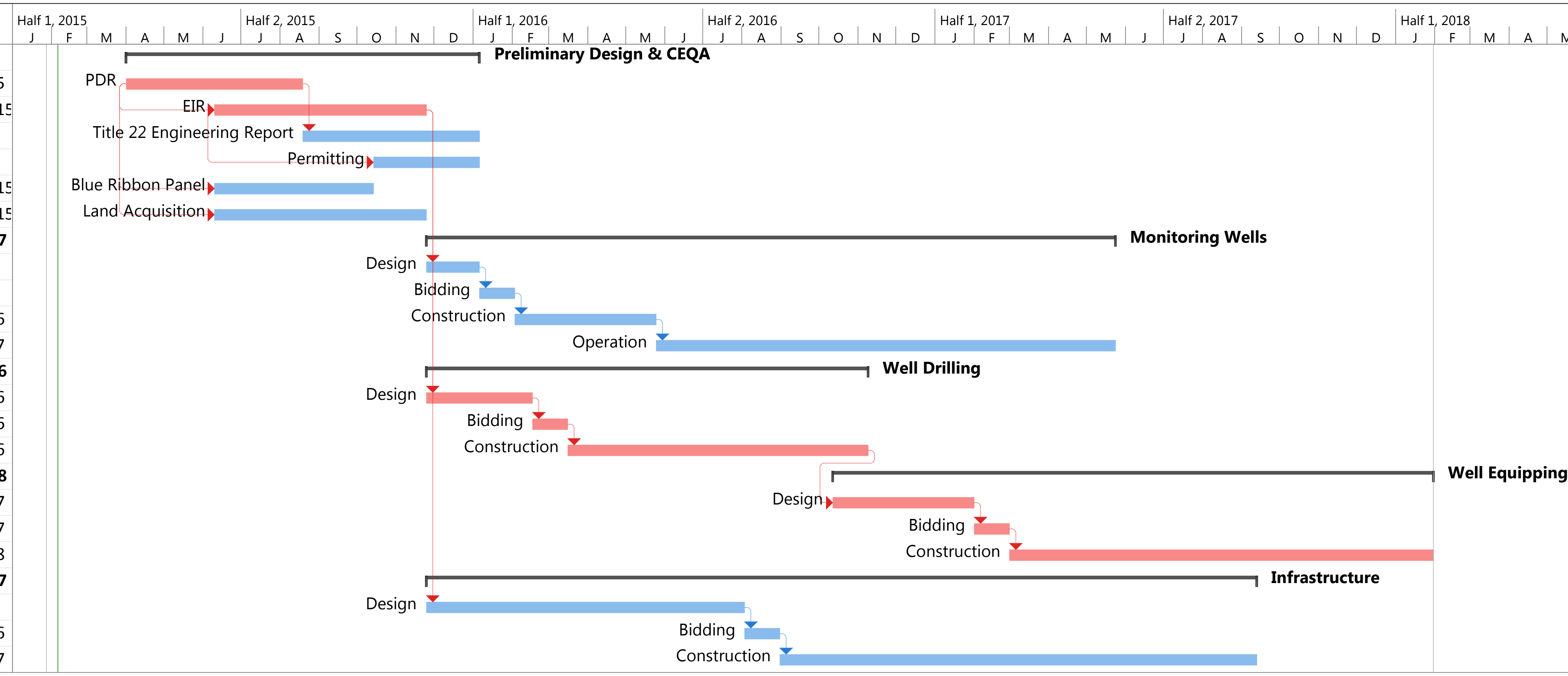
- **SWP Turnout:** The new 50-cfs turnout has been designed to accommodate the ultimate demand.
- **Recharge Site:** The recharge site is intended to accommodate the ultimate demand.
- **Raw Water Conveyance:** The raw water conveyance pipeline is intended to accommodate the ultimate demand.
- **Recycled Water Conveyance:** The recycled water conveyance pipeline is designed to accommodate both current and expected future flows through ultimate buildout.
- **Recovery Wells:** The recovery wells are intended to be phased one half at a time with 8 wells during phase 1 and the additional 8 wells through phase 2.
- **Distribution Site:** The 1-million gallon head tank, pump headers, and chlorination building are intended to accommodate the ultimate demand.
- **Distribution Pump Station:** The distribution system pipeline is intended to accommodate the ultimate demand. However, the pumps themselves are to be phased, meaning the first 3,000 gpm, 400 hp pumps are intended to accommodate the 14,125 AF/yr demand through a 3+1 configuration, and the ultimate demand will be supplied through an additional 3 pumps sized at 2,500 gpm and 400 hp. Although most phasing is intended to be within two parts, this pump station is capable of being implemented through multiple phases as demand increases.
- **Raw Water Pump Station:** The raw water pump station is optional and designed to accommodate a water banking partner or partners in order to pump back to the East Branch canal. As such, it is not required for this pump station to be implemented until a water banking partnership is achieved. However, the system has been sized in order to provide ultimate demand to the aqueduct through the 6+1 configuration of 3,000 gpm, 600 hp pumps. If it is desired to pump back more than 24,250 AF/yr, then the raw water pipeline should be up-sized to 36-inch diameter initially.

11.2 Project Schedule

Figure 11-1 presents a preliminary implementation schedule for the initial capital investment of the recommended project. It is anticipated that preliminary design and CEQA tasks will be completed in 2015, with design and construction of facilities to follow in 2016 and 2017. The schedule critical path will consist of the well drilling and equipping tasks, while other infrastructure design and construction will occur in parallel. Under this schedule, the project can begin operation by early 2018.

Figure 11-1: Project Implementation Schedule

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Preliminary Design & CEQA**	**200 days**	**Wed 4/1/15**	**Tue 1/5/16**
2		PDR	100 days	Wed 4/1/15	Tue 8/18/15
3		EIR	120 days	Wed 6/10/15	Tue 11/24/15
4		Title 22 Engineering Repor	100 days	Wed 8/19/15	Tue 1/5/16
5		Permitting	60 days	Wed 10/14/1	Tue 1/5/16
6		Blue Ribbon Panel	90 days	Wed 6/10/15	Tue 10/13/15
7		Land Acquisition	120 days	Wed 6/10/15	Tue 11/24/15
8		**Monitoring Wells**	**390 days**	**Wed 11/25/1**	**Tue 5/23/17**
9		Design	30 days	Wed 11/25/1	Tue 1/5/16
10		Bidding	20 days	Wed 1/6/16	Tue 2/2/16
11		Construction	80 days	Wed 2/3/16	Tue 5/24/16
12		Operation	260 days	Wed 5/25/16	Tue 5/23/17
13		**Well Drilling**	**250 days**	**Wed 11/25/1**	**Tue 11/8/16**
14		Design	60 days	Wed 11/25/1	Tue 2/16/16
15		Bidding	20 days	Wed 2/17/16	Tue 3/15/16
16		Construction	170 days	Wed 3/16/16	Tue 11/8/16
17		**Well Equipping**	**340 days**	**Wed 10/12/1**	**Tue 1/30/18**
18		Design	80 days	Wed 10/12/1	Tue 1/31/17
19		Bidding	20 days	Wed 2/1/17	Tue 2/28/17
20		Construction	240 days	Wed 3/1/17	Tue 1/30/18
21		**Infrastructure**	**470 days**	**Wed 11/25/1**	**Tue 9/12/17**
22		Design	180 days	Wed 11/25/1	Tue 8/2/16
23		Bidding	20 days	Wed 8/3/16	Tue 8/30/16
24		Construction	270 days	Wed 8/31/16	Tue 9/12/17



Project: Schedule_v0

Task		Project Summary		Manual Task		Start-only		Deadline		Manual Progress	
Split		Inactive Task		Duration-only		Finish-only		Critical			
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Critical Split			
Summary		Inactive Summary		Manual Summary		External Milestone		Progress			

11.3 Economic Analysis

The recommended project alternative not only provides PWD with a reliable water supply solution for the foreseeable future, but also provides the most cost-effective solution when analyzed over a long-term basis. Given PWD's heavy dependence on SWP water for supply, water banking allows the District to maximize its SWP Table A allocations and minimize purchase of Table A water in order to meet dry-year hydrological conditions. Additionally, the project's utilization of recycled water for recharge further offsets the need for SWP water. In order to demonstrate the cost benefits of the recommended project, this section provides a cost analysis of the recommended project versus two alternative water supply strategies: (1) water banking without recycled water and (2) no water banking.

The cost analysis utilizes the same cost assumptions described in Section 3, including a 50-year analysis period (2018 – 2067). For the purposes of this cost analysis, Alternative 10C is utilized to represent the recommended project. Table 11-1 provides a summary of the net presents costs for the recommended project.

Table 11-1: Recommended Project Net Present Cost Summary

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$23,130,000	$23,130,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,100,000	$1,100,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$8,130,000	$8,760,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$21,440,000	$21,440,000
Facilities Subtotal	***$85,310,000***	***$98,060,000***
SWP Table A Water Purchase	***$0***	***$25,590,000***
SWP Water Purchase	$46,840,000	$88,630,000
Recycled Water Purchase	$9,560,000	$21,530,000
Water Purchase Subtotal	***$56,400,000***	***$110,160,000***
Power Costs	$25,400,000	$54,090,000
O&M Costs	$5,360,000	$11,880,000
O&M Subtotal	***$30,760,000***	***$65,970,000***
Grand Total	**$172,470,000**	**$299,780,000**
Unit Water Cost ($/AF)	**$1,075**	**$1,115**

The first alternative for comparison is a water banking project without recycled water recharge (No Recycled Water Alternative). For the purposes of this analysis, facility sizes and locations are identical to the facilities for Alternative 10C, with the exception of the recharge pipeline. Since recycled water recharge is not utilized, additional SWP water is required, which would necessitate a 36-inch pipeline, rather than the 30-inch pipeline provided for Alternative 10C. Additionally, more Table A water is required in order to obtain the additional required SWP water. As shown in Figure 11-2, the No Recycled Water Alternative requires 20,000 AF/yr more Table A Amount than the recommended project.

As shown in the cost summary for the No Recycled Water Alternative, Table 11-2, the overall net present cost of this alternative is approximately $106 million greater than the recommended project. The main differentiator is the required Table A Amounts. The total net present cost of Table A purchase is $109 million for the No Recycled Water Alternative, which is considerably greater than the $26 million required for Table A purchase under the recommended project.

Table 11-2: No Recycled Water Project Net Present Cost Summary

	Phase I Net Present Costs	Total Net Present Costs
Turnout	$790,000	$790,000
Recharge Pipelines	$26,870,000	$26,870,000
Recharge Basin Construction	$9,000,000	$9,000,000
Recharge Basin Land Acquisition	$1,100,000	$1,100,000
Recovery Wells	$15,110,000	$24,810,000
Well Collection Pipelines	$8,130,000	$8,760,000
Pump Station	$5,040,000	$7,460,000
Reservoir	$1,180,000	$1,180,000
Chlorination Facilities	$390,000	$390,000
Distribution Pipelines	$21,440,000	$21,440,000
Facilities Subtotal	***$89,050,000***	***$101,800,000***
SWP Table A Water Purchase	***$65,050,000***	***$108,930,000***
SWP Water Purchase	$62,920,000	$129,270,000
Recycled Water Purchase	$0	$0
Water Purchase Subtotal	***$62,920,000***	***$129,270,000***
Power Costs	$25,400,000	$54,090,000
O&M Costs	$5,360,000	$11,880,000
O&M Subtotal	***$30,760,000***	***$65,970,000***
Grand Total	**$247,780,000**	**$405,970,000**
Unit Water Cost ($/AF)	**$1,545**	**$1,510**

The second alternative for comparison is a water supply strategy that does not utilize any water banking and builds upon the existing water supply system consisting of treated surface water and groundwater (No Water Banking Alternative). It is assumed that PWD will offset a small portion of demand with direct recycled water use, identical to the assumption utilized for the recommended project. Under this alternative, PWD would meet future supply needs by purchasing additional Table A Amounts and expanding the capacity of the LOCWTP, along with the associated East Branch turnout and pipelines. Without water banking to supplement dry-year SWP allocations, PWD would need to purchase Table A water such that it can reliably provide water under a 31 percent Table A allocation year, which is defined as the allocation percentage for a multi-year drought condition. With water banking, the Table A purchase amounts would just have to meet a 58 percent Table A allocation, which is the long-term average allocation.

Table 11-3 provides the net present summary for the No Water Banking Alternative. Even though facility and O&M costs are lower than those for the recommended project, the overall project is approximately $309 million greater than the recommended project due to the large amount of Table A purchase required for this alternative. As shown in Figure 11-2, approximately 52,000 AF/yr more Table A Amount is required for the No Water Banking Alternative compared to the recommended project, resulting in $221 million in additional cost for Table A purchase.

In summary, the recommended project has a projected cost savings of $106 million over the 50-year study period in comparison to the No Recycled Water Alternative and a projected cost savings of $309 million when compared to the No Water Banking Alternative, as shown in Figure 11-3.

Table 11-3: No Water Banking Project Net Present Cost Summary

	Phase I Net Present Costs	Total Net Present Costs
Turnout (Palmdale Lake)	$790,000	$790,000
Pipeline (to Palmdale Lake)	$1,140,000	$1,140,000
WTP Expansion	$0	$20,090,000
Facilities Subtotal	***$1,930,000***	***$22,020,000***
SWP Table A Purchase	***$186,560,000***	***$247,040,000***
SWP Water Purchase	$165,130,000	$328,730,000
Recycled Water Purchase	$0	$0
Water Purchase Subtotal	***$165,130,000***	***$328,730,000***
O&M Costs	$0	$11,060,000
O&M Subtotal	***$0***	***$11,060,000***
Grand Total	**$353,620,000**	**$608,850,000**
Unit Water Cost ($/AF)	**$2,204**	**$2,264**

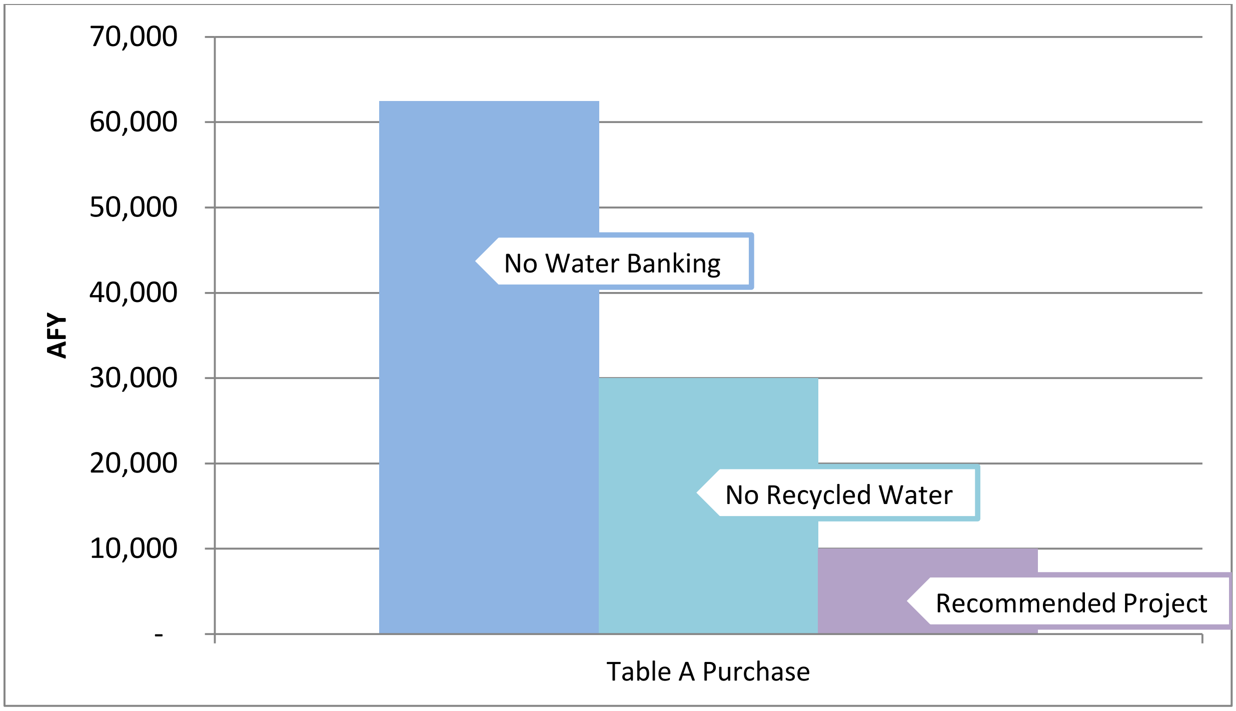


Figure 11-2: Table A Purchase Comparison for 50-Year Study Period

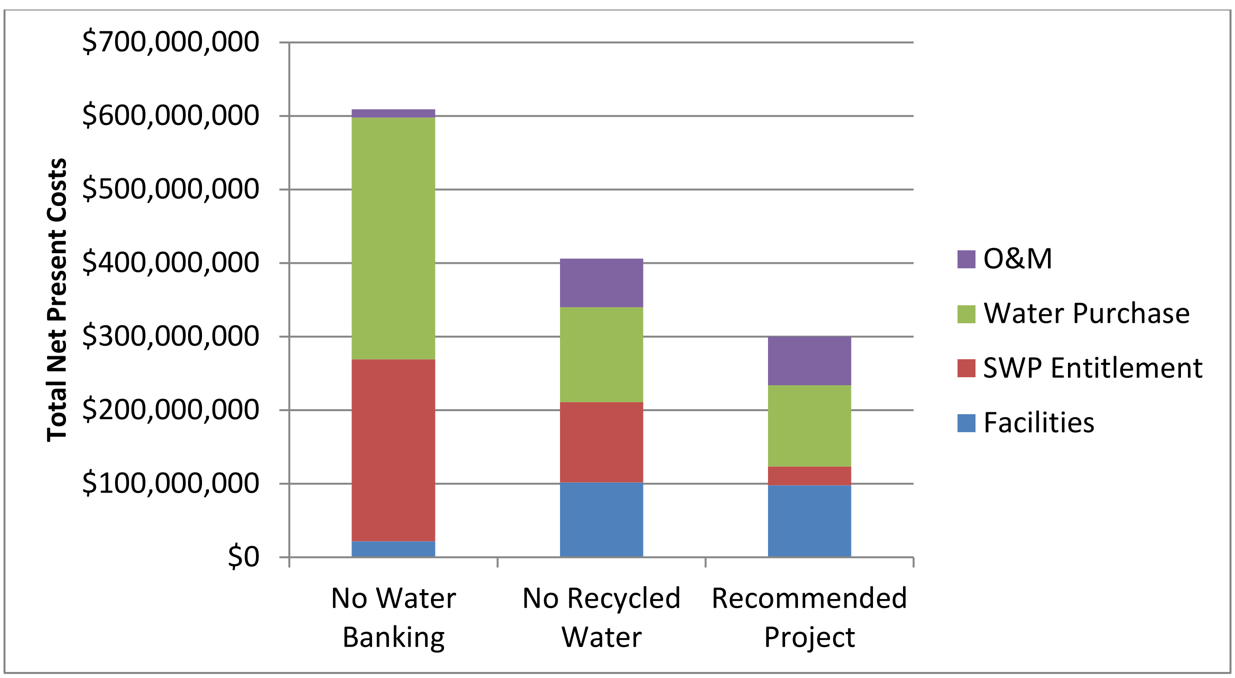


Figure 11-3: Total Net Present Cost Comparison

11.4 Mini-Hydro Evaluation

An analysis was conducted to estimate energy generation and greenhouse gas (GHG) reduction potential from the development of a hydropower project as part of the LCGRRP Alternative 10C. Specifically, Kennedy/Jenks assessed the electric generating capabilities at a site located near Avenue N, approximately 7.5 miles along a 30-inch pipeline alignment leading from the East Branch Canal to the Alternative 10C East recharge location. Costs and net savings associated with installation of a mini-hydro turbine at this location were evaluated. The full analysis and associated TM can be found in Appendix H.

11.4.1 Background Information

Hydroelectric power is created by converting the energy of falling or flowing water to mechanical energy, which in turn, can perform work such as turning an electric generator. To determine the amount of electricity from a particular site, the flow and elevation change, or head, must be calculated, and the pipeline losses must be subtracted. Given the flow and effective head at a site, the potential kilowatts that can be generated at the site can be calculated. Electric generation for the project is estimated to range between 350 and 420 kW.

Water power has been used throughout history as a renewable resource, with hydroelectric turbines being used to provide approximately 8% of the electricity generated in the United States. Many water utilities use hydro turbines to produce energy. Most of the turbines used in potable water systems are similar to centrifugal pumps running backwards. Many hydro turbines are custom built to precisely match the flow and head conditions expected at the site. Turbines are reliable and have O&M requirements similar to pumps.

11.4.2 Project Application

A delivery schedule for the LCGRRP was prepared based on estimated annual SWP Table A Amount allocations and recharge water deliveries from the East Branch Canal. The delivery schedule is based on a 10 year cycle that assumes 5 years of average conditions, 1 "wet" year, and 4 years where virtually zero flow is diverted from the East Branch Canal. This schedule was used to derive the annual electrical generation potential of an in-line hydro turbine. In addition, financial analysis was performed for two time periods: (a) 20-years and (b) 50-years. Based on the assumptions detailed in Appendix H, the potential annual electricity production is shown in Table 11-4.

Table 11-4: Estimated Electricity Production

Year	Average Flow (gpm)	Available Head (feet)	Annual Generation (kWh/Yr)	Year	Average Flow (gpm)	Available Head (feet)	Annual Generation (kWh/Yr)
2018	8,332	305	3,188,345	**2043**	0	--	0
2019	8,298	305	3,179,721	**2044**	0	--	0
2020	9,689	287	3,487,627	**2045**	0	--	0
2021	8,224	306	3,160,886	**2046**	0	--	0
2022	8,184	307	3,150,656	**2047**	9,461	290	3,443,453
2023	0	--	0	**2048**	9,417	291	3,434,653
2024	0	--	0	**2049**	9,372	291	3,425,631
2025	0	--	0	**2050**	11,088	266	3,697,983
2026	0	--	0	**2051**	9,283	292	3,407,292
2027	7,982	309	3,097,481	**2052**	9,237	293	3,397,846
2028	7,942	310	3,086,667	**2053**	0	--	0
2029	7,901	310	3,075,783	**2054**	0	--	0
2030	9,286	292	3,408,064	**2055**	0	--	0
2031	7,821	311	3,053,808	**2056**	0	--	0
2032	7,781	312	3,042,718	**2057**	9,004	296	3,347,619
2033	0	--	0	**2058**	8,957	297	3,337,011
2034	0	--	0	**2059**	8,908	297	3,326,155
2035	0	--	0	**2060**	13,255	228	3,799,306
2036	0	--	0	**2061**	11,110	265	3,700,398
2037	7,579	314	2,986,244	**2062**	11,061	266	3,694,909
2038	7,539	314	2,974,747	**2063**	0	--	0
2039	7,499	315	2,963,183	**2064**	0	--	0
2040	8,883	298	3,320,545	**2065**	0	--	0
2041	7,416	316	2,939,317	**2066**	0	--	0
2042	7,375	316	2,927,189	**2067**	10,807	270	3,664,246

To calculate the GHG emissions associated with this renewable energy project, the Southern California Edison (SCE) GHG emissions factor was used. The project results in a net average reduction of nearly 650 metric tons of CO_2 per year.

Potential environmental impacts (i.e., air, land, water, noise, aesthetics, and waste by-products) were considered, with no significant impacts identified (i.e., turbine noise). In addition, operational impacts were considered, and it was found that installation of a new hydro turbine would have a modest effect on operations. A turbine is expected to require 10% of one employee full-time equivalent (FTE) time for O&M; maintenance is expected to cost $0.005/kWh.

A hydropower project is eligible for the Self-Generation Incentive Program, which provides incentives to entities that produce electricity from renewables. This project would fall under the

“Pressure Reduction Turbines” category, with an SCE incentive of $1.07 per Watt. Currently the SGIP allows incentives to be available through January 1, 2016; however, renewal of the program is anticipated.

A hydropower project has a lifetime of 20 years with proper turbine maintenance. Capital costs were developed using current 2014 dollars and increased by an inflation factor of 3 percent to reflect a 2018 startup year. Table 11-5 provides the summary of costs for the project based on the 20-year and 50-year analyses. The table shows the estimated capital costs in 2018 to build the project, and capital cost for just replacement of the turbine package in 2038 and 2058. The table also shows the NPV of cumulative annual net savings from the project, which takes into account all costs & benefits of the project. This project creates a NPV savings of $1.4 million over 20 years and nearly $4.7 million over 50 years. The nominal cumulative savings over 20 years is over $1.7 million.

While NPV analysis determines whether a project is financially beneficial to PWD, it does not tell how this project compares to other potential projects PWD is considering in its CIP. Return-On-Investment (ROI) allows the District to compare this hydro project against other projects and rank order the projects by ROI percentage. This project creates a fairly robust ROI of nearly 9%.

Table 11-5: Summary of Costs

Analysis Time Frame	Value of Electricity Generation ($/1st Yr)	Capital Cost (2018 $)	Incentive Amount ($)	Average Annual Net Savings ($/Yr)	NPV of Cumulative Net Savings ($)	Return On Investment (ROI %)
20 Years	$443,500	$3,456,300	$449,400	$88,250	$1,409,900	8.8%
50 Years	$443,500	$3,456,300	$449,400	$253,900	$4,689,700	10.1%
2038 Capital Cost		$3,170,000	$0			
2058 Capital Cost		$8,921,600	$0			

While this project does create overall financial savings over 20 and 50 years for PWD, it does present a cash flow anomaly. Because of the nature of the deliveries (six years of significant flow and four years of no flow) the project creates benefits or savings during the period during deliveries, but creates a cost in years with no deliveries. If PWD proceeds with the project it will need to take periods of negative cash flow into account in its financial forecasts and planning.

Section 12: References

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