Appendix E
Options Summary Table and Fact Sheets

Roughly 50 future water supply and demand options were considered to capture wide-ranging possibilities for Pasadena's future water picture. The comprehensive list of options was developed through brainstorming sessions held with the public, the WIRP Advisory Committee, and PWP staff. The full lists of options are summarized in Table E-1 (located at the end of this appendix). The options generally fall under these main categories:

- Local Surface Water/Stormwater Diversions
- Groundwater
- Recycled Water
- Graywater
- On-site stormwater/Urban Runoff
- Imported Water (including transfers/banking opportunities)
- Ocean Desalination
- Conservation

Planning-level analysis was performed to characterize option yields, costs, environmental impacts, and other characteristics relevant to the WIRP objectives and performance measures. It should be noted that although option characterization is based on the best available technical information, more detailed analysis of any of these options will be required prior to implementation.

The following is a brief description of columns in Table E-1 that pertain to yields and costs:

- **Project Yield/Demand – Long-term Average, Before Credits (AFY)**: the total physical water yield of the option
- **PWP Supply Credit (%):** the assumed percentage of the total yield that would be available to PWP as supply, after applying Raymond Basin Management Board spreading credit assumptions, or splitting the yield with other partnering agencies
- **PWP Supply Yield/Demand – Average, After Credits (AFY):** the water supply yield (or demand savings) to PWP, after applying the supply credit percentages to the total yield
- **Total Capital Cost ($, Current):** the total capital cost in 2010 dollars, including cost to customers/develops or other partnering agencies

Maximize Capture of Arroyo Seco Water Rights

Category: Local Surface Water – Arroyo Seco (Table Reference: A)

Brief Description:

Surface runoff from the San Gabriel Mountains that drains to the Arroyo Seco is a water supply source for PWP. PWP owns water rights to divert instantaneous runoff from Arroyo Seco up to 25 cubic feet per second (cfs), a portion of which is currently sent to the Arroyo Seco spreading grounds to recharge the underlying Raymond groundwater basin. Due to recent forest fires that degraded the water quality of the Arroyo Seco, PWP had to reduce spreading operations but water quality levels are anticipated to improve within a few years.

PWP's full water rights are not typically realized due to limitations of PWP's existing facilities as well as discounts in supply credits when applying the Raymond Basin Management Board (RBMB) groundwater spreading credit formulas (PWP can only extract 60-80% of their surface water rights recharged to Raymond Basin). Current operations yield approximately 2,500 AFY of PWP recharge on average, which produces approximately 1,500 acre-feet per year (AFY) of PWP supply yield after RBMB credits are applied. Comparing historical surface runoff to existing spreading indicates that approximately 1,000 AFY of PWP's water rights is underutilized. The WIRP evaluates several options that enhance yield from existing surface runoff water rights.

Concepts:

Several options are available for PWP to maximize its use of water rights in Arroyo Seco, as shown in Figure 1. These options include:

1) Upgrade Behner Water Treatment Plant (WTP) and bring on-line to serve potable demands
2) Expand capacity of diversion structure and existing Arroyo Seco spreading grounds to enhance recharge

PWP's existing diversion structure and pipeline were designed at a capacity to capture the full water rights. However, sedimentation behind the dam that impounds water at the diversion structure has degraded the capacity of the diversion facility – existing diversion capacity is estimated to be approximately 18 cfs. The option to expand spreading and recharge would require improvements to restore the 25 cfs diversion capacity. Diversion structure improvements would not be required for the Behner WTP option, but the improvements would allow for more spreading of water that is not treated at the plant.

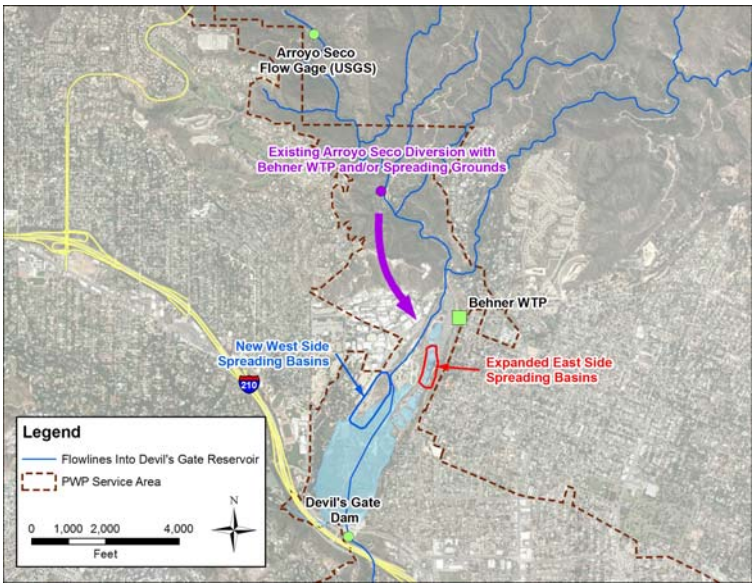

Figure 1. Arroyo Seco Surface Water Options

1) Upgrade existing Behner WTP and bring on-line to serve potable demands

The Behner WTP, owned by PWP, was shut down in 1993 because the existing treatment process (Hardinge Filter) is not capable of producing water that meets more stringent Stage 2 Disinfectants and Disinfection Byproduct Rule (State 2 D/DBPR) and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2 ESWTR). Although the original plant was designed at 10 cfs capacity, upgrading the plant to this capacity is not cost-effective unless the highly variable Arroyo Seco source water is augmented with another source (to avoid having reserve capacity that is not frequently utilized). This option evaluates upgrades for a 2 cfs plant capacity, which will be utilized up to capacity more frequently when treating only Arroyo Seco flows. Any flows exceeding plant capacity that PWP has water rights to capture will be sent to the Arroyo Seco spreading grounds for recharge, which have an existing spreading capacity of 18 cfs.

2) Expanded Arroyo Seco diversions and spreading to enhance recharge

The 2002 Hahamonga Watershed Master Plan includes projects to increase spreading capacity on the east side and west side of Arroyo Seco, as shown in Figure 1. The total spreading capacity would increase from 18 cfs to up to 32 cfs to accommodate

Maximize Capture of Arroyo Seco Water Rights

Category: Local Surface Water – Arroyo Seco (Table Reference: A)

existing diversion water rights of 25 cfs for PWP and 7 cfs for Lincoln Avenue Water Company (LAWC). The expansions will add the following spreading capacity:

- East side basins: Add 6.7 cfs of recharge capacity and 20 acre-feet of storage volume
- West side basins: Add 7.7 cfs of recharge capacity and 32 acre-feet of storage volume

In the existing spreading basins (excluding the former WTP sludge pond), PWP obtains pumping credits for ~60 percent of surface runoff spreading. In new or expanded facilities, PWP would obtain ~80 percent pumping credit for surface runoff spreading. Therefore, the WIRP evaluation incorporates variable pumping credits to compare supply options that increase spreading capacity in Arroyo Seco with the baseline scenario (historical spreading).

Key Assumptions:

- Improvements can be made to restore the diversion capacity to 25 cfs. Potential options include building an inflatable dam that impounds more water during storm events, dredging sediments behind the existing dam, or moving the diversion point to a downstream location (i.e. near existing Behner WTP and spreading grounds). All of these options are technically feasible with varying costs, but coordination with regulatory agencies, such as the Department of Fish and Game, is required to determine which alternative will be permitted. For purposes of the WIRP, analyses of diversion improvements are based on constructing an inflatable dam. Further evaluation of diversion options will be needed if maximizing Arroyo Seco water rights for water supply purposes is a recommended alternative in the WIRP.
- Altering spreading operations will not have any adverse impacts related to the perchlorate plume originating at the Jet Propulsion Laboratory, assuming the depth of the plume is far below any surface spreading operations.
- These options will not impact environmental flows in the Arroyo Seco, since it proposes to enhance capture of flows above 18 cfs (low flows have historically been captured already).
- Additional study will be performed for siting locations of new spreading basins, due to potential sedimentation and habitat issues.

Yield:

- Surface runoff yields for each option are shown in Table 1. Yields show the estimated supply yield before and after the RBMB spreading credit formulas are applied. It is important to recognize that Table 1 shows the yields of option if implemented individually. At later phases of WIRP analysis, multiple options related the Arroyo Seco water and spreading grounds may be combined into one portfolio for evaluation, and the combined yield of the options could be less than summing the individual yields below. Refer to Appendix C for more details on hydrologic analysis of these options.

Table 1
Arroyo Seco Surface Runoff Yields for New Supply Options[1]

Demand Option		Project Yield – Long-term Average, Before Credits (AFY)	PWP Supply Credit (%)	PWP Supply Yield Average, After Credits (AFY)
Expand Arroyo Seco Diversions and Recharge	New Spreading Basins[2]	2,301	80%	1,841
	Existing Spreading Basins	539	60%	323
	Total	2,840	60-80%	2,164
Arroyo Seco Local Treatment Plant	New Treatment Plant[3]	858	100%	858
	Existing Spreading Basins	1,759	60%	1,055
	Total	2,617	60-100%	1,913

[1] Yield shown is PWP's portion of the yield (LAWC yield not included).The yield is dependent on hydrologic conditions and is highly variable on a seasonal and annual basis. Yields could be significantly less in dry years, or more in wet years. Yields shown in the table represent the estimated long-term average yield that could be expected.
[2] Yield assumes surface diversions will first be sent to the new spreading areas (which have a higher credit percentage) before being sent to existing spreading areas.
[3] Yield assumes surface diversions will first be sent to the new treatment plant before being sent to existing spreading areas.

Maximize Capture of Arroyo Seco Water Rights

Category: Local Surface Water – Arroyo Seco (Table Reference: A)

Reliability Considerations:

- Runoff in the Arroyo Seco ranges drastically and is very dependent upon climatic patterns. Annual runoff can range from less than 1,500 AFY in dry years to over 40,000 AFY in wet years. The majority of water in wet years is not captured and flows to the LA River, and ultimately to the Pacific Ocean. In addition to year-to-year variation, runoff in Arroyo Seco is highly seasonal. In the dry season, runoff is typically an order of magnitude below PWP's water rights.
- Water quality in the Arroyo Seco is vulnerable to degradation from forest fires. Local watershed fires result in significant debris and sedimentation that interferes with the diversion intake structure and spreading facilities.

Cost (in 2010 dollars):

Supply Option	Capacity (cfs)	Capital Cost ($)	Operation and Maintenance Cost[A] ($/year)
Upgrade Behner WTP	2.0	$5,900,000	$275,648
New Spreading Grounds	14.4	$440,000	$289,680
Diversion Structure Improvements	Increase to 25	$3,000,000[B]	N/A[C]

Notes:
[A] Includes pumping costs to recover groundwater at $120/AF.
[B] Estimate from Upper Arroyo Seco Stream Sustainability Project.
[C] Assumed to be similar to existing diversions structure maintenance costs (no significant incremental new cost).

- There are potential cost-sharing opportunities with Lincoln Avenue Water Company (LAWC) for the option to expand Arroyo Seco spreading capacity to 32 cfs.

Water Quality:

- Water quality concentrations in Raymond Basin would remain the same or improve with additional spreading of Arroyo Seco water.

Institutional Coordination:

Diversion Structure Improvements:

- Permits from various state and regional agencies, including the Department of Fish and Game
- Coordination with LAWC
- Coordination with Raymond Basin Management Board

Behner WTP Upgrade:

- Permit from California Department of Public Health

Expand existing Arroyo Seco spreading grounds and enhance recharge:

- Coordination with LAWC for the option to expand Arroyo Seco spreading capacity to 32 cfs.
- Coordination with Raymond Basin Management Board.

Environmental Impacts:

- The diversion structure improvements have the most potential for habitat impacts in these option concepts, depending on the design to allow for fish passage and whether dredging is required. Diversion structure improvements may provide environmental benefits, depending upon the type and location of facility.
- Any diversions of water away from the natural stream have potential negative impacts to aquatic life.
- Expanded spreading would increase annual average recharge to the Raymond Basin.

Maximize Capture of Arroyo Seco Water Rights

Category: Local Surface Water – Arroyo Seco (Table Reference: A)

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- **Total Annual Capital Payment ($/year):** the total annual capital payments of the option assuming a payment period of 30 years and a 5.5% interest rate, in 2010 dollars

- **Total Average Annual O&M Cost ($/year):** the total operation and maintenance (O&M) cost for the option, in 2010 dollars

- **Total Average Annual Imported Water Cost ($/year):** the annual cost of MWD import water purchases (if applicable) based on current water rates

- **Unit Cost of Supply Yield ($/AF, current dollars):** the total annual cost (including capital, O&M and imported) for the option divided by the new supply yield, in 2010 dollars

Some of the options in Table E-1 were screened out from further evaluation, as indicated in the notes section. Other options were carried forward for further analysis in this study. Fact sheets (or summary sheets) were developed for several options, many of which were carried forward for portfolio analyses. The fact sheets provide more detailed information for each option including key assumptions, environmental considerations, institutional coordination, etc. The options in Table E-1 that have fact sheets are indicated with a letter reference in the far right column of the table. Fact sheets were developed for the following options, and are included in this appendix.

A. Maximize Capture of Arroyo Seco Water Rights
B. Devil's Gate Storage to Eaton Canyon Spreading Basins
C. Tunnel Water to Brookside Golf Course
D. Arroyo Seco Diversions to Brookside Golf Course
E. Pasadena Groundwater Well Summary
F. Eastside Well Collector Pipeline Option
G. Satellite MBR Plant for On-site Non-Potable Demands
H. Recycled Water (Indirect Potable Reuse)
I. Recycled Water (Non-Potable Demands)
J. Graywater Reuse (Decentralized On-site Systems)
K. Centralized Stormwater Capture to Recharge
L. Rain Barrel, Rain Garden and Bioretention Swale Options
M. Permeable Pavement Option
N. Additional MWD Treated Imported Water Purchases
O. Water Transfers Option
P. Water Banking
Q. Pasadena Groundwater Storage Program Option
R. Ocean Desalination

Devil's Gate Storage to Eaton Canyon Spreading Basins

Category: Local Surface Water – Arroyo Seco (Table Reference: B)

Brief Description:

Most of the stormwater runoff from the City of La Canada Flintridge is routed to Flint Wash, which flows eastward to Devil's Gate Reservoir. In addition, any Arroyo Seco runoff that is not diverted upstream for recharge in the Arroyo Seco spreading basins (under PWP and Lincoln Avenue Water Company water rights) also flows to Devil's Gate Reservoir. There are no existing facilities to divert the water reaching Devil's Gate Reservoir to designated groundwater replenishment areas. Under current operating conditions, this runoff flows through Devil's Gate Dam to the Los Angeles River and ultimately to the Pacific Ocean. The Los Angeles County Water Department of Public Works (LACDPW) Conservation Planning Section is currently designing a conservation project to store and divert water from Devil's Gate Reservoir to the Eaton Wash spreading ground (which are owned and operated by LACDPW) for groundwater replenishment. Under this option, PWP would participate in the project funding and receive credit for a portion of the water recharged.

The decision to transfer stored water from Devil's Gate Reservoir (Arroyo Seco watershed) to the eastern side of Raymond Basin is driven by two key factors. First, recharge capacity within the Arroyo Seco spreading grounds may not allow for the volume of water stored in the Devil's Gate Reservoir to drawdown within a sufficient timeframe to allow for detention storage in the event of a back to back storm event scenario. Secondly, groundwater level decline is more severe in the eastern portion of the Raymond groundwater basin.

Water from Devil's Gate Reservoir would be pumped via a new 30-inch pipeline to Eaton Wash spreading grounds. The LACDPW is also evaluating the feasibility of using of an existing storm drain pipe along a portion of the conveyance route.

A sub-option is also considered in which additional urban stormwater would be captured by reconnecting storm drains that intersect the proposed pipeline to Eaton Canyon, capturing stormwater from areas north of the conveyance pipeline. A map showing the approximate capture area is shown in Figure 1, along with the conceptual pipeline alignment from Devil's Gate Reservoir to Eaton Wash spreading grounds.

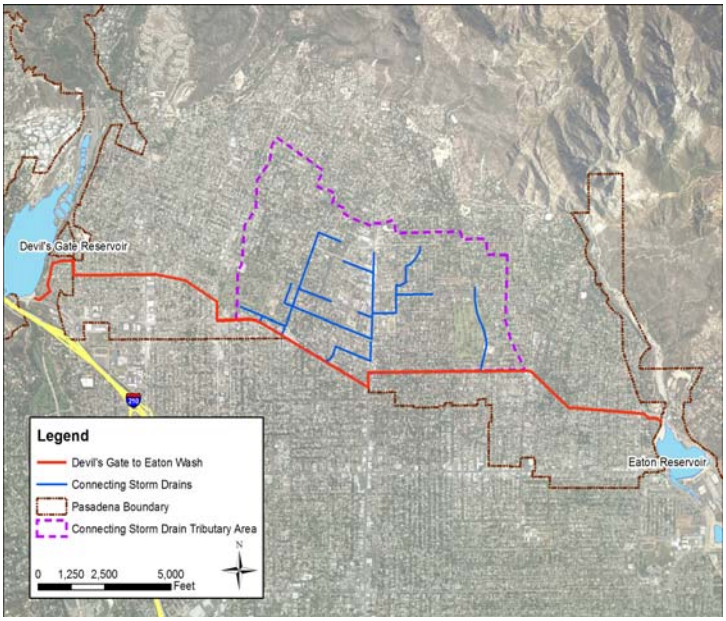

Figure 1. Devil's Gate to Eaton Wash Option

Facilities Required:

- Pumping from Devil's Gate Reservoir to Eaton Wash would require the following:
  - 30,000 linear feet (LF) of 30-inch pipeline
  - New 1,700 horsepower (HP) pump station

Key Assumptions:

- Recharge of stored water behind the dam occurs at a rate similar to infiltration rates of the existing Arroyo Seco spreading ponds. The yield available for diversion from Devil's Gate is the amount of water in storage after accounting for recharge behind the dam.
- Environmental demands in the Arroyo Seco exist downstream of the dam. The environmental flow requirements have yet to be determined, but are assumed to be 3-5 cubic feet per second (cfs) for the WIRP analysis. The yield available for diversion from Devil's Gate is the amount of water in storage after accounting for environmental releases.
- Half of the total water recharged would go toward the long-term health of the basin (and half of cost would be covered by LACDPW). The other half of the water would be available for Raymond Basin Management Board (RBMB) members. Assuming PWP would receive credit proportional to their water rights in the Pasadena subarea (47 percent of total water rights), PWP would pay for 23.5 percent of total project cost (0.50 x 0.47 = 0.235).
- Water that is replenished for the long-term health of the basin would benefit PWP in long-term recovery of the currently reduced groundwater rights. For planning purposes, it is assumed that half of water going toward the health of the basin would be recoverable in the long-term.

Devil's Gate Storage to Eaton Canyon Spreading Basins

Category: Local Surface Water – Arroyo Seco (Table Reference: B)

Yield:

- Devil's Gate Reservoir to Eaton Wash Yield: 1,249 acre-feet per year (AFY)
- Additional Yield from Stormwater Capture Sub-option Yield: 518 AFY
- The yield for this option is dependent on hydrologic conditions and is highly variable on a seasonal and annual basis. Yields could be significantly less in dry years, or more in wet years. Yields shown above represent the estimated long-term average yield that could be expected.
- Values above represent total water spread. PWP credit is assumed to be only a portion of total water spread:
  - PWP Near-term Yield: 23.5 percent of total water spread
  - PWP Long-term Yield: 35.3 percent of total water spread

Cost (in 2010 dollars):

- Devil's Gate Reservoir to Eaton Wash
  - Capital: $11,000,000 (assumes storm drain reconnection costs are negligible compared to total project costs)
  - Operation and maintenance: $439,030
  - Unit cost of supply yield: $674/AF
- Costs above are the total project cost. It is assumed that PWP will fund the capital cost proportional to long-term pumping credits received (35.5 percent of project cost).
- Operation and maintenance costs assume $120/AF groundwater pumping costs to recover supply yield

Water Quality:

- The urban stormwater capture sub-option would reduce pollutant loading to receiving waters or streams.
- Water quality concentrations in Raymond Basin would remain the same or improve with additional spreading of Arroyo Seco water.

Institutional Coordination:

This option would require coordination with Los Angeles County, and Raymond Basin Management Board (RBMB). PWP is a potential partner for this project, and could receive pumping credits for a portion of the water recharged at the spreading grounds.

This option would require several regulatory permits from agencies such as U.S. Army Corps of Engineers, State Water Resources Control Board, U.S. Forest Service, U.S.Fish and Wildlife Service, and the California Regional Water Quality Control Board.

Environmental Impacts:

This option has potential to improve habitat conditions for aquatic life if implemented in an environmentally friendly manner through restoration efforts in the project area, and with more sustained environmental flows downstream of the dam.

Tunnel Water to Brookside Golf Course

Category: Groundwater (Table Reference: C)

Brief Description:

This option proposes to utilize existing Devil's Gate groundwater tunnels that were constructed for water supply purposes in the early 1900's and have been used on and off over time, but have been out of service since 1999. Groundwater seeps into the tunnels and flows toward the Arroyo Seco. The City of Pasadena has water rights to capture and divert some of the tunnel flows, which were used to meet irrigation demands at Brookside Golf course when tunnel diversions were operational. Figure 1 shows the location of the tunnel outlet.

The tunnels were originally constructed to collect water percolating from the water-bearing layers of soil just above the bedrock. Degradation of water quality due to the watershed fires in 1934 and 1935 halted usage of the tunnels. In 1969, water quality of the tunnels improved enough to allow non-potable use. Water was transported to the nearby Brookside Golf Course for use in ponds. In 1971 the Brookside Booster Pump Station was constructed to allow the tunnel water to be used for irrigation, but it had to be discontinued in 1999 when PWP shut down the pump station because high delivery pressure was damaging on-site irrigation piping. Since then, the golf courses' irrigation system lateral piping and 25% of the main lines have been replaced with stronger material, and the Brookside staff has expressed interest in resuming tunnel water usage.

Figure 1. Devil's Gate Tunnel Water to Brookside Golf Course

Facilities Required:

- New booster pump station
- 230 linear feet of 12-inch pipeline
- Disinfection is required to treat surface runoff
- Storage, such as tank or pond

Tunnel Water to Brookside Golf Course

Category: Groundwater (Table Reference: C)

Key Assumptions:

- PWP has water rights of 238 acre-feet per year (AFY) based on Permit 3454 from the State Water Resources Control Board (SWRCB).
- Tunnel water currently flowing to the Arroyo Seco may contribute to meeting some environmental demands.
- Assumes water is utilized once it reaches Brookside Golf Course.
- This option would be designed with potential to connect the tunnel source water to the proposed Phase 1 recycled water system (a separate option evaluated in this study).

Yield:

- Normal Year: 436 AFY
- The yield for this option is dependent on hydrologic conditions could vary on a seasonal and annual basis. Yield shown above represents the estimated long-term average yield that could be expected.
- Reliability of tunnel water is uncertain. Groundwater pumping will increase in the Monk Hill subarea of the Raymond Basin when the new perchlorate treatment plant is online (expected to be complete in December 2010). The increased pumping will likely lower the groundwater levels and reduce flows to the tunnel system. However, groundwater levels and tunnel supply would be replenished with implementation of the LA County Devil's Gate Dam to Eaton Canyon option (a separate option evaluated in this study), which provides some recharge within Devil's Gate Reservoir and provides controlled environmental releases from the dam.
- Brookside Golf Course irrigation demands are estimated to be 550 AFY. A supplemental water source will be required to meet demands – particularly during dry periods.

Cost (in 2010 dollars):

- Capital: $947,071
- Operation and Maintenance Cost: $26,064/year
- Unit cost of supply yield: $209/AF
- Potential cost-sharing with Brookside Golf Course

Water Quality:

Deliveries may be interrupted depending on water quality conditions of Devil's Gate tunnel water (i.e. impaired water quality due to watershed fires).

Institutional Coordination:

This would be a joint project with Brookside Golf Course to provide irrigation water.
Requires coordination with the SWRCP to file a "Statement of Water Diversion and Use" every three years.

Environmental Impacts:

Assuming the tunnel water currently contributes to environmental flows in the Arroyo Seco, portfolios that include this option would need to be paired with another resource option that meets environmental demands.

References:

Hawes, C. S. (April 2010). *Preliminary Design Report for the Devil's Gate and Richardson Tunnel Water Storage and Pumping Facility Project – DRAFT*. CivilTec Engineering, Inc.

Propersi, M., Bichette, R. (April 2008). *Technical Memorandum: Pasadena Tunnel Water Plan.* RMC Water and Environment.

Arroyo Seco Diversions to Brookside Golf Course

Category: Local Surface Water – Arroyo Seco (Table Reference: D)

Brief Description:

This option proposes to capture surface runoff from the Arroyo Seco and store it in a large cistern under Brookside Golf Course, for use in meeting non-potable demand (i.e. irrigation). Water would be collected at Behner Water Treatment Plant (WTP) and flow through gravity to a cistern located under Brookside Golf Course. A general representation of the option is shown in Figure 1.

Figure 1. Arroyo Seco Diversions to Brookside Golf Course

Facilities Required:

- New 8-inch, 10,000-foot pipeline [4.1 million gallons per day (MGD) capacity] from Behner WTP to Brookside Golf Course
- New 4.0 million gallon (MG) cistern at Brookside Golf Course
- Disinfection is required to treat surface runoff

Key Assumptions:

- Yields assume this option is stand-alone (combining this option with other options that divert water from the Arroyo Seco, such as the Behner WTP, would reduce the amount of water yield to the cistern).
- Assumes water is utilized once it reaches Brookside Golf Course

Yield:

- Average Year: 771 acre feet per year (AFY)
- The yield for this option is dependent on hydrologic conditions and is highly variable on a seasonal and annual basis. Yields could be significantly less in dry years, or more in wet years. Yields shown above represent the estimated long-term average yield that could be expected.

During dry periods, demands are not satisfied by the Arroyo and will require augmentation with another source. Average annual irrigation demands for the Golf Course are estimated to be approximately 550 AFY. Therefore, excess water is available during wet periods that could serve other customers along the way.

Arroyo Seco Diversions to Brookside Golf Course

Category: Local Surface Water – Arroyo Seco (Table Reference: D)

Cost (in 2010 dollars):

- Capital: $5,090,000
- Operation and Maintenance: $161,800 / year
- Unit cost of supply yield: $664/AF
- Potential cost-sharing with Brookside Golf Course

Water Quality:

Deliveries may be interrupted depending on water quality conditions in the Arroyo Seco

Institutional Coordination:

This would be a joint project with Brookside Golf Course to provide irrigation water.

Environmental Impacts:

Any diversions from the natural stream have potential negative impacts to aquatic life.

Pasadena Groundwater Well Summary

Category: Groundwater (Table Reference: E)

Raymond Basin Description

Raymond Basin is an alluvial valley approximately 40 square miles in area underlain by deposits of gravel, sand, silt, and clay. The basin located in the northwest portion of the San Gabriel Valley in Los Angeles County, California, and bounded by the San Gabriel Mountains to the north, the San Rafael Hills to the west, and the Raymond Fault to the south/southeast. Raymond Basin is divided into three subareas: the Monk Hill subarea in the northwest, the Pasadena subarea in the central portion of the basin, and the Santa Anita subarea in the east.

The base of the water-bearing strata of the Raymond Basin is defined by bedrock material that is not considered to yield significant quantities of water. Overlying the bedrock are more than 1,200 feet (ft) of unconsolidated alluvial materials consisting of boulders, gravel, sand, silt, and clay. Alluvium is the principal water-bearing unit in the Raymond Basin. This unit readily yields water to wells. Well yields in the alluvium range from a few hundred to several thousand gallons per minute (gpm). The alluvial aquifer system in the Raymond Basin consists of many individual interconnected water-bearing zones.

Specific yield values in the Raymond Basin are typical of alluvial sediments and range from approximately 5 to 18 percent. Groundwater generally flows southerly from areas of recharge at the base of the San Gabriel Mountains to areas of discharge along Raymond Fault at hydraulic gradients ranging from approximately 0.040 to 0.090 ft/ft. The Raymond Fault acts as a leaky hydrologic barrier and defines the boundary between the Raymond Groundwater Basin and the main San Gabriel Valley Groundwater Basin to the south. In general, groundwater levels are relatively higher in the northern half of the basin and lower in the southern half than they were historically.

Groundwater discharge in the Raymond Basin occurs through pumping and subsurface outflow across the Raymond Fault. Current sources of groundwater recharge to the Raymond Basin include:

- Natural infiltration and percolation of rainfall and surface water
- Percolation of applied water from irrigation, other return flows, and cesspools
- Subsurface inflow from adjacent groundwater basins, bedrock areas, and the San Gabriel Mountains
- Artificial recharge through surface water spreading
- Percolation of water from septic tanks.

Raymond Basin Judgment

Pasadena Water and Power (PWP) currently utilizes two local water supplies within the Raymond Basin: groundwater, which is pumped directly into the distribution system; and surface water, which is diverted and spread for groundwater pumping credits. The Raymond Basin Judgment details PWP's groundwater extraction and surface water diversion rights.

In order to alleviate overdraft conditions in the Raymond Basin, the Raymond Basin Judgment was signed on December 23, 1944. The Judgment assigns each pumper a "present unadjusted right" corresponding to the average amount of water that they pumped in the five years prior to 1937. Pasadena's present unadjusted right was 12,946 acre-ft/year. Each pumper's present unadjusted right was scaled down to create the "decreed right" such that the sum of all pumpers' decreed rights is equal to the estimated safe yield of the basin. In the original Judgment, the safe yield was determined to be 21,900 AFY for the entire Raymond Basin. However, according to the first modification of the Judgment in 1955, the safe yield was increased to 5,290 AFY in the Eastern Unit and 25,480 AFY in the Western Unit. This resulted in a total safe yield of 30,770 AFY in the Raymond Basin. Therefore, the sum of all water that is pumped—excluding water pumped from individual storage accounts or as a result of spreading or injection credits—is regulated so as not to exceed the total safe yield of the basin. Based on the new safe yield, PWP's decreed right was calculated to be 12,807 AFY from the Western Unit (Monk Hill and Pasadena subareas); PWP has no water right in the Eastern Unit (Santa Anita subarea).

Pasadena Groundwater Well Summary

Category: Groundwater (Table Reference: E)

Source of Water and Rights

Based on the 1955 modification of the Raymond Basin Judgment, PWP's decreed right was calculated to be 12,807 AFY pumped from the Monk Hill and Pasadena subareas. In addition, based on the 1974 modification to the Raymond Basin Judgment, each pumper diverting water for spreading has the right to pump 80% of the water diverted (less any losses) from any well. PWP may divert a maximum instantaneous amount of 25.0 cfs from the Arroyo Seco to the Arroyo Seco Spreading Basins, as well as 8.9 cfs from Eaton Wash to the Eaton Canyon Spreading basins. However, historic pumping credits from either spreading basins have been less than 80% due to different methodology required by the Raymond Basin Management Board (RBMB). Credits have ranged from 47% to 67% instead. Historically, the average pumped credit from both basins is 2,160 AFY (based on 1999-2009, which is the hydrologic period for the WIRP analysis). Therefore, PWP's total pumping right within the Raymond Basin is an average of approximately 14,967 AFY.

Groundwater supply reliability is further increased by PWP's long term storage accounts within the Raymond Basin. In 1992 and 1993, long term storage policies were adopted within the Raymond Basin, and the basin storage capacity was determined and a storage volume of 96,500 AF was allocated to the Raymond Basin pumpers. PWP's share of the storage volume is 38,500 acre-ft. Additionally, PWP leases storage volume from other cities/agencies within the Raymond Basin.

In 2009, the RBMB implemented a resolution to the 1955 decreed rights to slow declining water levels in the Western Unit of Raymond Basin. This resolution called for a cooperative pumping reduction for parties with water rights in the Pasadena subarea effective July 1, 2009, where RBMB seeks to reduce water production incrementally over five years until a 30% reduction is achieved. Hence, PWP's water right in the Pasadena subarea will be decreased by 2,503 AF over the next 5 years to a final right of 10,304 AFY. As this resolution does not affect pumping credits from spreading diverted surface water, PWP's total pumping right within the Raymond Basin is an average of approximately 12,464 AFY.

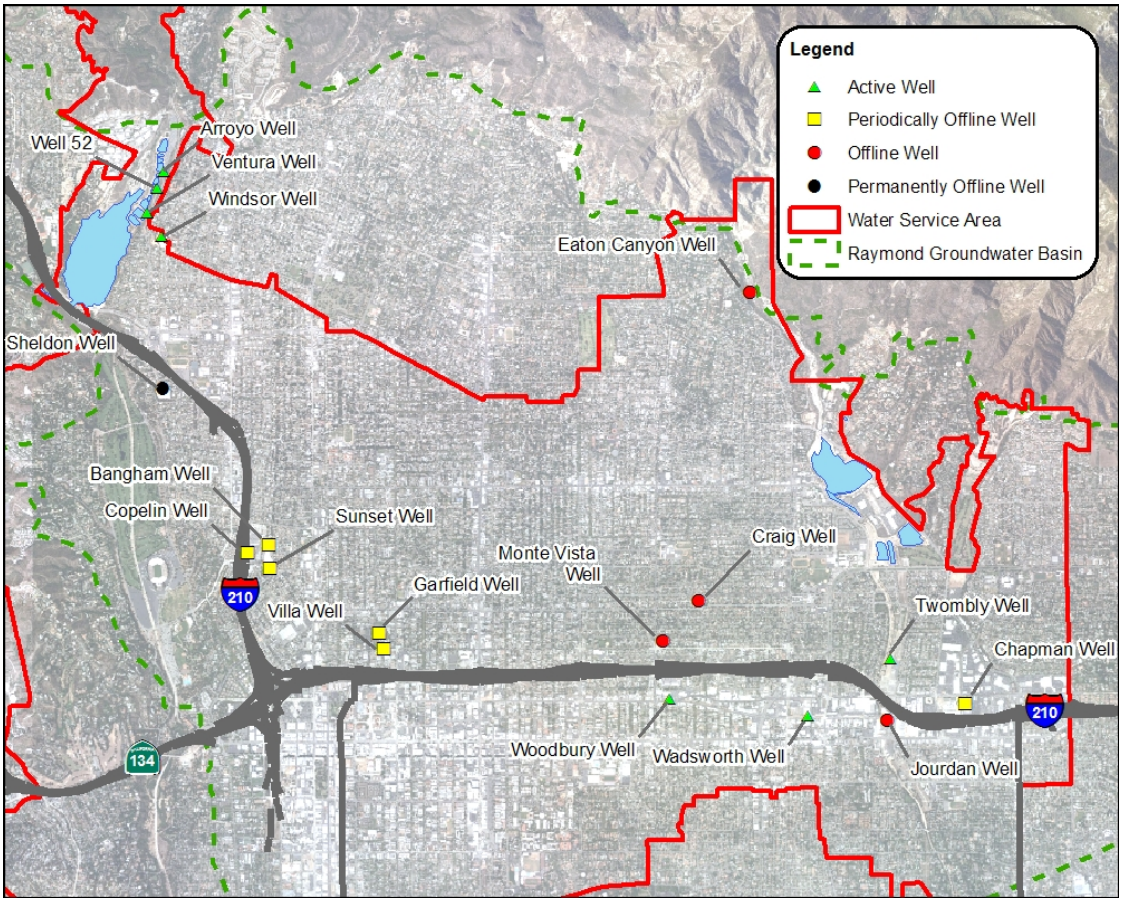

Figure 1: PWP Well Location Map

Pasadena Groundwater Well Summary

Category: Groundwater (Table Reference: E)

Summary of Existing Wells

There are 18 groundwater production wells (see Figure 1) that can pump water into the PWP distribution system. Table 1 lists these wells along with their status, capacity, and water quality issues.

Table 1: PWP Well Status and Capacity

Well Name	Installation Year [2]	Last Year Rehabilitated [4]	Status	Extraction Capacity [4] (cfs)	Maximum Annual Production [4] (AFY)	Injection Capacity [3] (AFY)
Baseline Active Wells						
Arroyo	1930	2010	Standby [5]	4.9	3,547	-
Ventura	1924	2010	Standby [5]	3.3	2,389	-
Well 52	1977	2010	Standby [5]	4.0	2,896	-
Wadsworth (#59 [4])	1998	-	Online	3.1	2,244	1,376
Twombly (#58 [4])	1999	-	Online	4.5	3,258	1,701
Windsor	1969	2010	Standby [5]	3.1	2,244	-
Woodbury	1930	-	Online	3.3	2,389	-
			Subtotal	**26.2**	**18,967**	**3,077**
Offline/Periodic Wells						
Bangham	1993	-	Offline/Blending [6]	3.3	2,389	1,530
Copelin	1921	2008	Offline/Blending [6]	2.5	1,810	-
Villa	1925	2008	Offline/Blending [4,6]	5.1	3,692	-
Chapman	1967	2003	Offline/Intermittent [7]	2.2	1,593	-
Garfield	1921	2007	Offline/Blending [4,]	3.1 [3]	2,244 [3]	1,155
Sunset	1924	-	Offline/Blending [4, 6]	2.9	2,100	-
			Subtotal	**19.1**	**13,828**	**2,685**
Offline Wells						
Craig	1924	2004	Offline [9,13]	1.6	1,158	-
Eaton Canyon [1]	-	-	Seasonal [8]	0.7	507	-
Jourdan	1926	-	Offline [10]	3.6	2,606	3,805
Monte Vista	1925	2006	Offline	2.7	1,955	-
			Subtotal	**8.6**	**6,226**	**3,805**
Permanently Offline Wells						
Sheldon	1921	-	Not active [11]	0.2	145	-
TOTAL [11]				**53.9**	**39,022**	**9,567**

Notes:

1. Source: 2003 Water Master Plan (MWH)
2. Source: 2004 Baseline Groundwater Assessment of the Raymond Basin (Geoscience)
3. Source: 2007 Pasadena Groundwater Storage Program Conceptual Design Report (RMC)
4. Source: PWP Staff, June 2010
5. Perchlorate treatment system in construction, expected completion December 2010
6. Blended with imported water to reduce perchlorate levels
7. Entrained air, in operation during summers (peak water demand)
8. Requires chlorination, which is currently offline
9. Too much vibration
10. Entrained air
11. Well has been offline for a long time
12. Assuming continuous year-round operation of all wells
13. Perchlorate highest at 5.8 parts per billion

Pasadena Groundwater Well Summary

Category: Groundwater (Table Reference: E)

As shown on Figure 2, PWP's groundwater yield in recent history (2004—2008) has been consistently below the amount allocated by the Raymond Basin Judgment, including both groundwater and surface water spreading rights.

In 2011, the baseline well capacity is anticipated to be 18,967 AFY after the completion of the perchlorate treatment facility. This capacity is higher than PWP's present groundwater pumping rights of 14,967 AFY and future rights of 12,464 AFY. The capacity of the baseline active wells exceeds PWP's pumping rights by 4,000 AFY (present) and 6,503 AFY (post-2014). Additional groundwater replenishment would be required before PWP could utilize this excess capacity.

For planning purposes, it is assumed that the useful life of a groundwater well is approximately 45 years after first installation or last rehabilitation year. After 45 years, the well would require an overall rehabilitation to bring the pump back into service. In 2035, it is anticipated that the baseline well capacity will be 16,575 AFY after one well (Woodbury) reaches the end of its useful service life. This future capacity would still be higher than PWP's future groundwater pumping rights of 12,464 AFY.

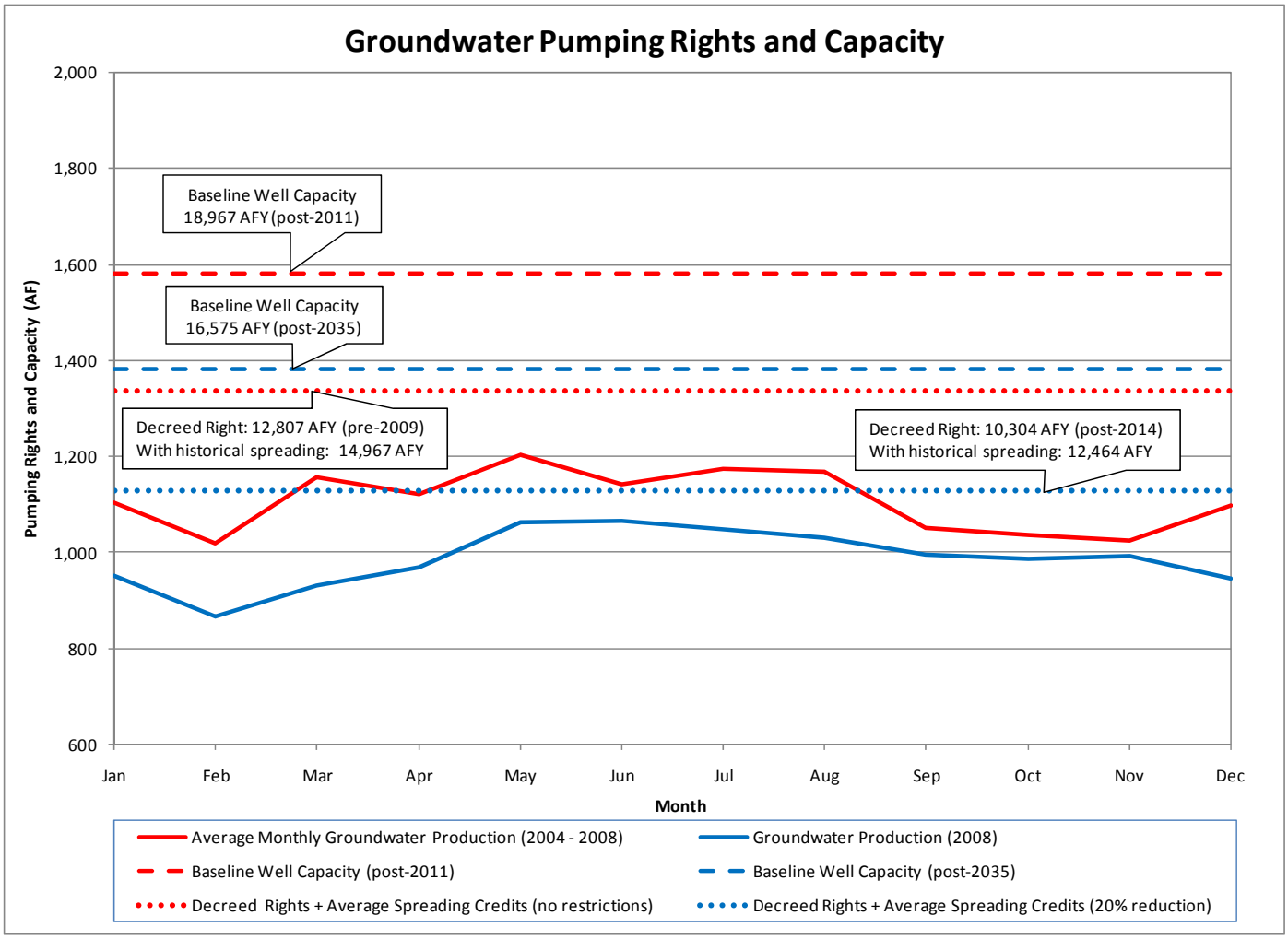

Figure 2: PWP Groundwater Baseline Well Capacity

Eastside Well Collector Pipeline Option

Category: Groundwater (Table Reference: F)

Brief Description:

The Eastside Well Collector option aims to connect seven Eastside wells (Chapman, Craig, Jourdan, Monte Vista, Well No. 58, Well No. 59, and Woodbury) to feed into the existing Jones Reservoir. A new chloramination facility at Jones Reservoir will provide centralized groundwater disinfection prior to introduction into the distribution system. See Figure 1 for an overall recommended alignment for the Eastside Well Collector.

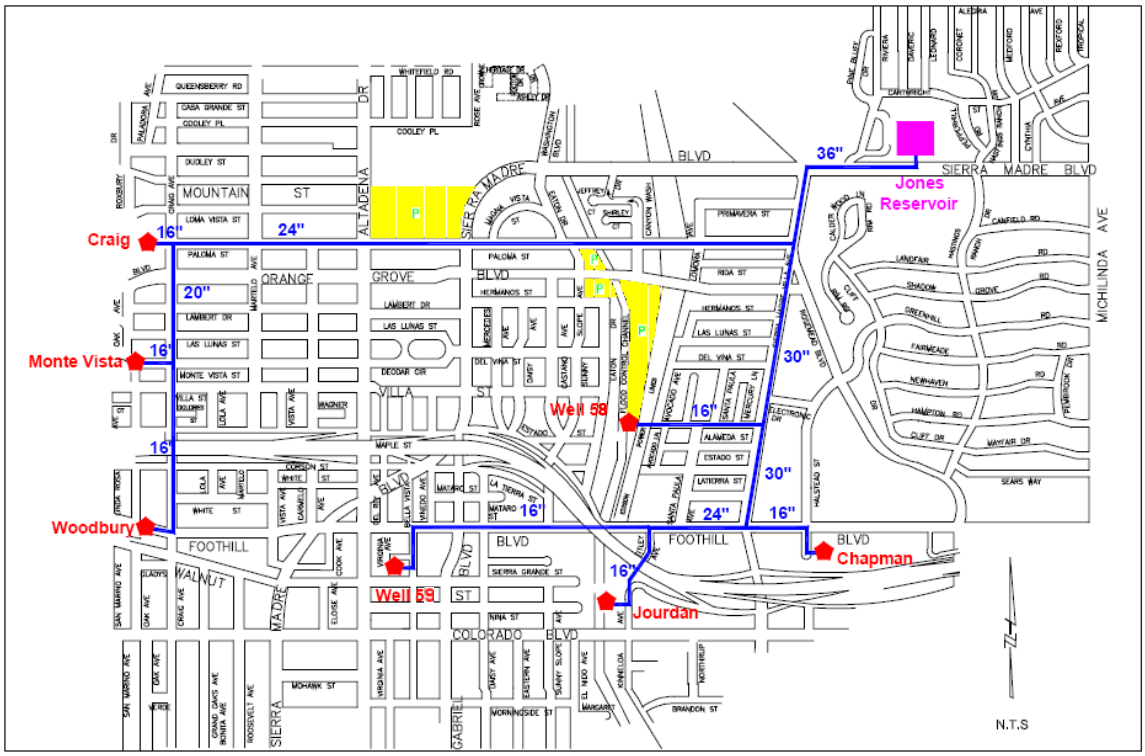

Figure 1. Eastside Well Collector Alternative
(Source: 2003 Water Master Plan)

Facilities Required:

- New 16-inch to 36-inch, 30,000-foot pipeline
- New centralized chloramination facility at Jones Reservoir

Key Assumptions:

- All seven Eastside wells (Chapman, Craig, Jourdan, Monte Vista, Well No. 58, Well No. 59, and Woodbury) are operable.
- The existing Jourdan well pump and motor will be replaced to meet updated hydraulic conditions of the collector system.
- The collector pipeline will permit the operation of the Jourdan well by providing air release capability and allow air to escape at the discharge into the Jones Reservoir.
- Centralized treatment at Jones Reservoir will include chlorine as well as ammonia addition to aid the conversion of disinfectants from chlorine to chloramines.

Eastside Well Collector Pipeline Option

Category: Groundwater (Table Reference: F)

Yield:

- Annual pumping capacity would increase by 11,747 AFY
- This additional well capacity would allow flexibility in PWP operations but would not provide new water supply yield unless paired with an option that replenishes the groundwater basin, or agreement is reached with Raymond Basin Management Board to activate use of storage accounts in the Pasadena subarea.

Cost (in 2010 dollars):

- Capital cost: $12,631,300
  - Includes Jourdan well pump and motor replacement
  - Excludes centralized treatment at Jones reservoir
- Operation & Maintenance (O&M) cost: Assume same as existing wells ($120/AF)

Water Quality:

- Product water would be disinfected at the central treatment facility at Jones Reservoir prior to distribution.

Institutional Coordination:

- Coordination with Raymond Basin Management Board. This option has the potential to increase supply yields in the future if use of storage accounts are activated in the Pasadena subarea.

Environmental Impacts:

- Temporary environmental impacts are associated with the well collector pipeline to be installed under existing city streets to connect to Jones Reservoir. No significant long-term impacts are expected.

Satellite MBR Plant for On-site Non-Potable Demands

Category: Recycled Water Source (Table Reference: G)

Brief Description:

A satellite Membrane Bioreactor (MBR) plant is a packaged water treatment system capable of treating wastewater for non-potable reuse. Advantages include reduced flows to centralized wastewater treatment plants, and offsets to potable system demands. This option proposes constructing a new satellite MBR plant to treat sewer flows from customers with typical non-potable demands, such as irrigation or cooling towers. Screening and pre-treatment would precede the MBR process. MBR effluent would be used for on-site non-potable demands. Brine and sludge from the treatment plants would be discharged into the wastewater collection system.

This option proposes construction of a joint satellite plant to serve CalTech and Pasadena City College (PCC).

Facilities Required:

- New 0.4 million gallons per day (MGD) Advanced Treatment MBR Plant

Key Assumptions:

- Onsite wastewater can be captured to produce supply for on-site non-potable demands.
- Sludge/biosolids from the advanced treatment process can be returned to the sewer system.
- This option assumes there is adequate land available for construction of the satellite plant.
- Onsite non-potable demands are assumed to be:
  - Caltech: 551 acre feet per year (AFY)
  - Pasadena City College: 194 AFY

Yield:

- Total Yield: 410 AFY
- Supply yield is limited by indoor wastewater available for treatment.

Cost (in 2010 dollars):

Capital Cost per Satellite MBR Plant: $11,577,000
O&M: $117,000/year
Unit Cost of Supply Yield: $2,228/AF

Costs do not include piping between Caltech and PCC that would be required for the joint satellite system. This option is assumed to be paired with the build-out recycled water distribution system option, in which piping conveyance of product water could be shared.

Project would eligible for State and Federal grant funding.

Institutional Coordination:

The construction and operation of a satellite plant would require:

- Construction permits from City of Pasadena.
- A Water Reclamation Requirements (WRR) permit from Regional Water Quality Control Board.
- A permit from California Department of Public Health for a new recycled water source.
- A permit from Los Angeles County Sanitation Districts (LACSD) for disposing of sludge from the MBR process to the sewer.

Environmental Impacts:

No significant long-term impacts.

Satellite MBR Plant for On-site Non-Potable Demands

Category: Recycled Water Source (Table Reference: G)

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Recycled Water (Indirect Potable Reuse)

Category: Recycled Water Demand (Table Reference: H)

Brief Description

Recycled water is wastewater that has undergone treatment and purification in order for it to be suitable for a range of beneficial uses depending on different levels of treatment. Indirect potable reuse involves using recycled water to recharge the groundwater aquifer and subsequently recover the water via extraction wells to serve potable demands.

The City of Pasadena's Water and Power Department (PWP) has an existing agreement to purchase tertiary-treated recycled water from the Los Angeles - Glendale water reclamation plant (LAG WRP). In parallel to the Water Integrated Resources Plan (WIRP), PWP has been developing a Recycled Water Master Plan, which is evaluating alternatives to utilize recycled water. Information for the indirect potable reuse (IPR) options was provided by the Recycled Water Master Plan (RWMP) team. Two representative indirect potable reuse options are evaluated in the WIRP:

- **Tertiary Treatment:** This option proposes to use the tertiary treated from LA-Glendale for recharge with no additional treatment. This option would be less expensive, but would face more regulatory constraints. Blending requirements for tertiary-treated replenishment require a larger ratio of diluent (surface runoff) to recycled water. Therefore, the yield for tertiary-treated IPR is less due to the availability of surface runoff. This option represents Alternative EW2 in the RWMP.
- **Advanced Treatment:** This option proposes to construct an advanced recycled water treatment plan within the City of Pasadena, which will add capital expenses to the indirect potable reuse concept but is typically has less regulatory challenges. The advanced treatment plant would require brine disposal facilities. This option represents Alternative EW4 in the RWMP.

For both options, recycled water would be blended with natural surface runoff from Eaton Wash and the Arroyo Seco diversions via the proposed Los Angeles (LA) County's Devil's Gate storage to Eaton Wash project (which is a separate option evaluated in the WIRP).

Required Facilities

See Figure 1 for a map of the conveyance system alignment. Recycled water purchased for groundwater replenishment will be routed through the Phase 1 Non-Potable Recycled Water System (yellow and dark purple piping) and the LA County's Devil's Gate storage to Eaton Wash project (two proposed alignments shown in green and red). A relatively small pipe segment is needed to connect the Phase 1 system to the Devil's Gate storage to Eaton Canyon conveyance. For the advanced treatment option, the new plant would be located along the Phase 1 recycled system alignment. Note that this figure was provided by the RWMP team, and details of the figure are subject to change since the study is currently underway.

Tertiary Treatment

- Conveyance pipeline: 1,100 LF of 10-inch pipeline connection between Phase 1 system to LA County Devil's Gate project
- Operational storage facility: 1.0 MG of storage located at Scholl Canyon Landfill.

Advanced Treatment

- Advanced water treatment facility (AWTF): A new AWTF located in Pasadena to further treat source water from the LAG WRP. Processes include microfiltration, reverse osmosis, and advanced oxidation using ultraviolet (UV) light with hydrogen peroxide (H_2O_2), as well as a pump station for brine disposal.
- Conveyance pipeline:
    - 11,000 LF upsize of Phase 1 system pipelines.
    - 5,300 LF of 12-inch diameter pipeline from AWTF to Arroyo Seco Diversion Project.
    - 27,000 LF to 55,000 LF of 6-inch brine disposal pipeline.
- Operational storage facility – 2.3 MG of storage located at Scholl Canyon Landfill.

Yield

- Tertiary Treatment: 921 AFY
- Advanced Treatment: 2,610 AFY

Supply yields assume 99% of the replenishment water can be recovered via extraction wells. This would require agreement with the Raymond Basin Management Board (RBMB).

Recycled Water (Indirect Potable Reuse)

Category: Recycled Water Demand (Table Reference: H)

Cost (in 2010 dollars)

Assumptions

- Purchase cost of recycled water from LA-Glendale is $253/AF.
- Average O&M costs of groundwater pumping to recover supply yield are same as existing operations ($120/AF).
- Project would eligible for State and Federal grant funding.

Total Capital Cost

- Tertiary Treatment: $4,011,000
- Advanced Treatment: $55,111,000

Annual O&M Cost

- Tertiary Treatment: $362,500/year
- Advanced Treatment: $3,705,000/year

Annual Purchase Cost

- Tertiary Treatment: $235,366/year
- Advanced Treatment: $667,920/year

Permitting/Licensing

Regulatory requirements for indirect potable reuse projects are administered by State agencies, namely the California State Water Resources Control Board (SWRCB), Los Angeles Regional Water Quality Control Board (RWQCB), and California Department of Public Health (CDPH). The provisions of California Environmental Quality Act (CEQA) also apply. The RWQCB issues permits in conjunction with the CDPH, which then requires each County Health Department (CHD) to conduct its own project inspections prior to approvals. For the advanced treatment option, permitting would have to be coordinated with LA County for brine disposal into the sewer system.

Water Quality

Table 1 compares the primary water quality objectives for Raymond Basin along with constituent concentrations from tertiary and advanced treated recycled water supply for groundwater recharge. The tertiary treatment option appears to not meet the water quality objectives; however, when blended with Arroyo Seco diversions from LA County's Devil's Gate Dam to Eaton Canyon project, it is anticipated that the blend product quality would be comparable to the water quality objectives. The advanced treatment option would likely meet all objectives.

Table 1: Water Quality Objectives vs Treated Water Quality

Constituent (mg/L)	Raymond Basin [1] Groundwater Objectives	LAG WRP [1, 2] (Tertiary Treatment)	Pasadena AWTF [2] (Advanced Treatment*)
Total Dissolved Solids (TDS)	450	639 – 832	10
Chloride	100	146 – 187	3.6
Boron	0.5	0.1 – 0.5	0.01
Nitrate (N)	10	4.4 – 6.7	0.2
Sulfate	100	127 – 293	2.8
Total Nitrogen	10	6.1	1.0

Sources:
1 – RBMB Draft Criteria for Delivery of Supplemental Water (Stetson, 2006)
2 – LAG WRP 2008 Annual Monitoring Report
* Estimated values

Environmental Impacts

Potential minor environmental impacts associated with construction of AWTF. No long-term environmental impacts expected associated with project construction. The continuous groundwater replenishment occurring throughout the year may provide some habitat benefits in spreading areas.

Institutional Coordination

This option would require coordination with Raymond Basin Management Board for groundwater recharge, Glendale Water and Power for recycled water purchases, and Los Angeles County for spreading operations, conveyance facilities. The advanced treatment plant option would also require coordination with LA County for brine disposal to the sewer system.

Recycled Water (Indirect Potable Reuse)

Category: Recycled Water Demand (Table Reference: H)

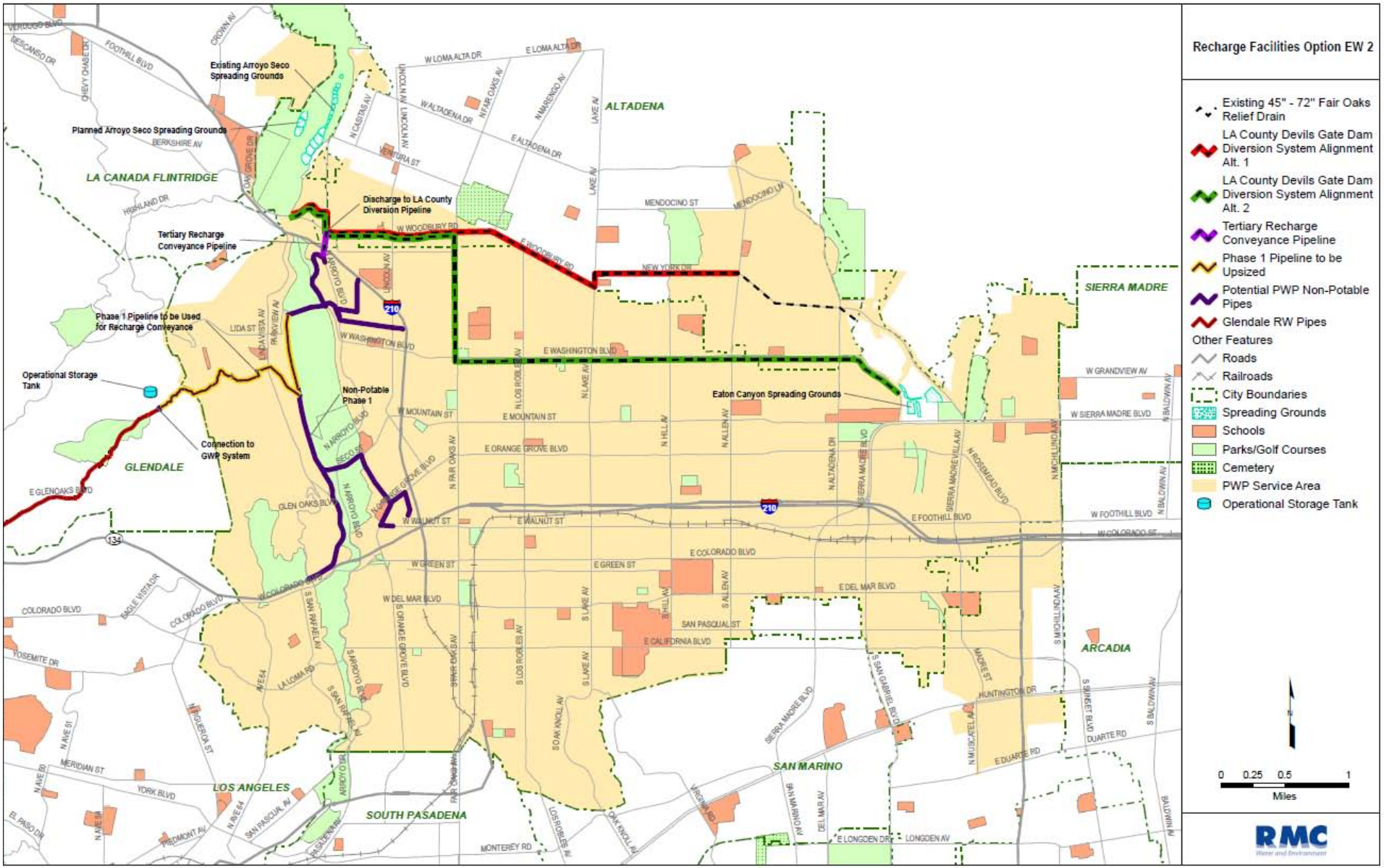

Figure 1: Recycled Water Indirect Potable Reuse Option

Recycled Water (Indirect Potable Reuse)

Category: Recycled Water Demand (Table Reference: H)

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Recycled Water (Non-Potable Demands)

Category: Recycled Water Demand (Table Reference: I)

Brief Description

Recycled water is wastewater that has undergone treatment and purification in order for it to be suitable for a range of beneficial uses. Recycled water that has undergone tertiary treatment can be safely used for many non-potable applications, including landscape irrigation (e.g., golf course, parks, roadway medians, and cemeteries), industrial cooling towers, toilet flushing, and wetlands restoration. Tertiary-treated recycled water is also known as Title 22 water as defined by the California Title 22 Standards (Title 22, Division, 4, Chapter 3, 4 of the California Code of Regulations), regulated by the California Department of Public Health.

The City of Pasadena Water and Power Department (PWP) has an existing agreement to purchase tertiary-treated recycled water from the Los Angeles - Glendale water reclamation plant (LAG WRP). In parallel to the Water Integrated Resources Plan (WIRP), PWP has been developing a Recycled Water Master Plan, which is evaluating alternatives to utilize recycled water. Information for the non-potable reuse (NPR) options was provided by the Recycled Water Master Plan (RWMP) team. Two representative recycled water distribution system options to deliver water for non-potable reuse are evaluated in the WIRP:

- **Phase 1:** This option is a smaller distribution system that primarily serves Brookside Golf Course and Brookside Park, as well as nearby customers.
- **Maximum Build-Out (RWMP Alternative 3):** This option maximizes the use of recycled water for non-potable reuse applications.

Required Facilities

The recycled water distribution system to non-potable demands requires the construction of pipelines that are separate and distinguishable from both existing potable water and sewer lines. See Figure 1 for a map of the proposed recycled water distribution system build-out. Conveyance from the LAG WRP to the vicinity of the PWP service area is already in place (see red piping). Phase 1 piping is represented by the green piping, and all other distribution mains represent the non-potable reuse build-out system. Note that this figure was provided by the RWMP team, and details of the figure are subject to change since the study is currently underway.

Both NPR options are compatible with the indirect potable reuse options for tertiary-treated groundwater replenishment at Eaton Canyon. However, only Phase 1 would be compatible with the advanced-treated indirect potable reuse option.

Yield

- Phase 1: 1,130 AFY
- Maximum Build-Out: 3,000 AFY

Cost (in 2010 dollars)

Assumptions

- Capital costs below represent the total cost to PWP and customer/developers. Although the cost to customer/developer will vary widely on a case by case basis depending on site conditions, an average capital retrofit cost of $2000/AFY was assumed for purposes of the WIRP.
- Purchase cost of recycled water from LA-Glendale is $253/AF. Note purchase costs could be reduced of the recycled system was augmented with the tunnel water option.
- Project would eligible for State and Federal grant funding.

Total Capital Cost (including customer/developer costs)

- Phase 1: $15,260,000
- Maximum Build-Out: $38,600,000

Annual O&M Cost

- Phase 1: $80,000/year

Recycled Water (Non-Potable Demands)

Category: Recycled Water Demand (Table Reference: I)

- Maximum Build-Out: $140,000/year

Annual Purchase Cost

- Phase 1: $285,890/year recycled supply only; $175,582/year with tunnel augmentation
- Maximum Build-Out: $759,000/year recycled supply only; $648,692/year with tunnel augmentation

Permitting/Licensing

Regulatory requirements for non-potable reuse projects are administered by State agencies, namely the California State Water Resources Control Board (SWRCB), Los Angeles Regional Water Quality Control Board (RWQCB), and California Department of Public Health (CDPH).

Water Quality

Table 1 summarizes the water quality parameters for recycled water produced at LAG WRP, which meets Title 22 requirements for tertiary-treated recycled water and includes nitrification/denitrification.

Table 1: Bacteria Concentration in Water

Constituent	Water Quality
Total Dissolved Solids (TDS)	639 - 832 mg/L
pH	7.2 - 7.6
ECW (TDS/640)	1.0 – 1.3 mmho/cm
Chloride	146 – 187 mg/L
Boron	0.1 – 0.5 mg/L
Nitrate	4.4 – 6.7 mg/L as N
Sulfate	127 – 293 mg/L
Total Suspended Solids (TSS)	<1.0 – 2.1 mg/L
Source: LAG WRP 2008 Annual Monitoring Report	

Environmental Impacts

Temporary environmental impacts can be potentially associated with the construction of the non-potable recycled water distribution system pipelines. Pipeline alignments will mostly be constructed under existing city streets. No significant long-term environmental impacts are expected.

Recycled Water (Non-Potable Demands)

Category: Recycled Water Demand (Table Reference: I)

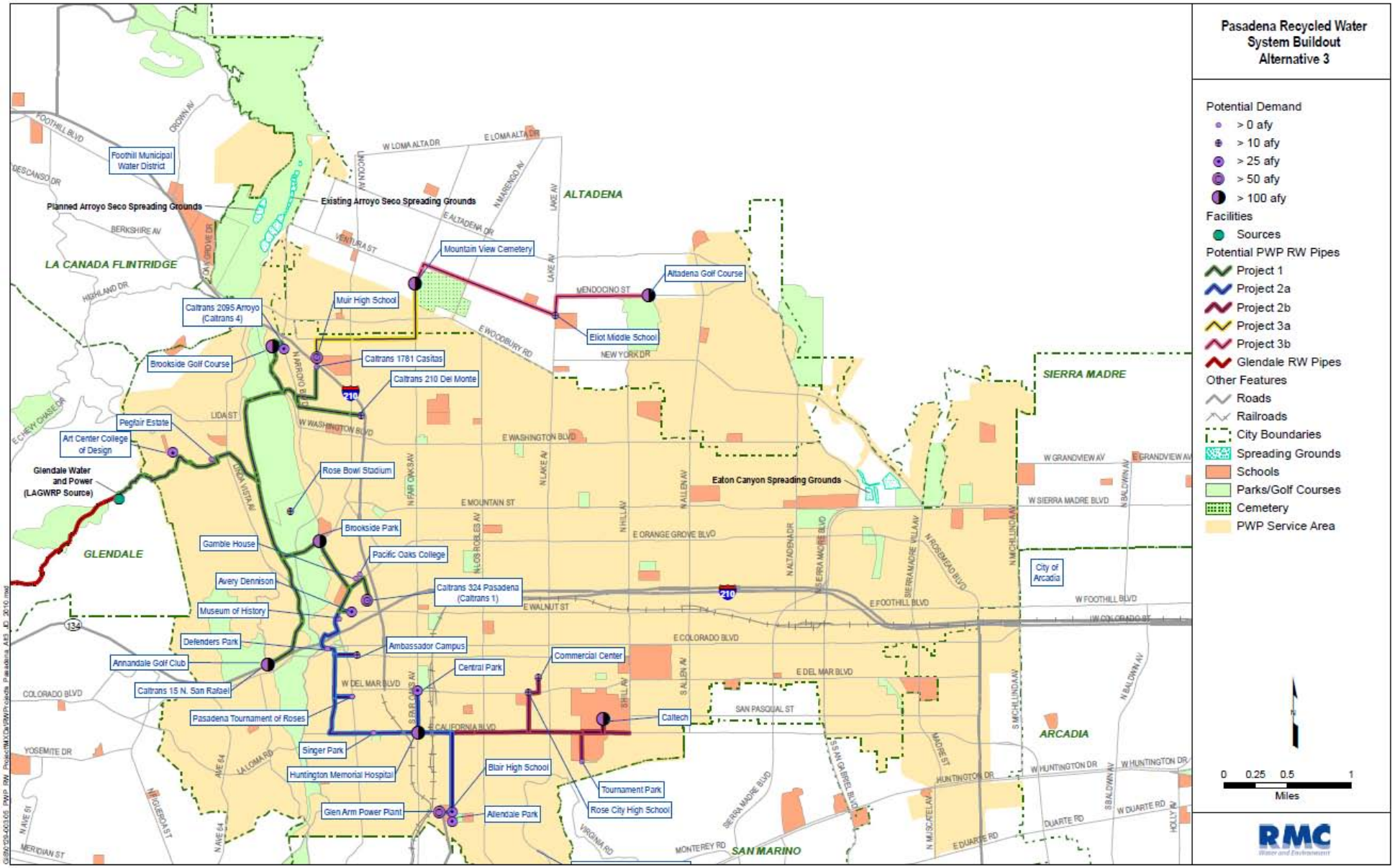

Figure 1: Pasadena Recycled Water Build-Out for Non-Potable

Recycled Water (Non-Potable Demands)

Category: Recycled Water Demand (Table Reference: I)

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Graywater Reuse (Decentralized On-site Systems)

Category: Graywater (Table Reference: J)

Brief Description

Graywater is wastewater that originates from household fixtures such as showers, bathtubs, clothes washing machines, and bathroom sinks; graywater excludes wastewater from toilets, dishwashers, and kitchen sinks. Graywater is typically recycled for reuse in non-potable applications, i.e. landscape irrigation. This option would provide retrofits to existing homes to enable on-site graywater recycling. For this option, a "Simple System" graywater collection system was evaluated, where wastewater from the laundry, bath, and shower are combined and reused for landscape irrigation. See Figure 1 for a schematic of a Simple System.

Required Facilities

All graywater systems are required to meet the acceptable design criteria outlined in *California Graywater Regulations Chapter 16A " Nonpotable Water Reuse Systems."*

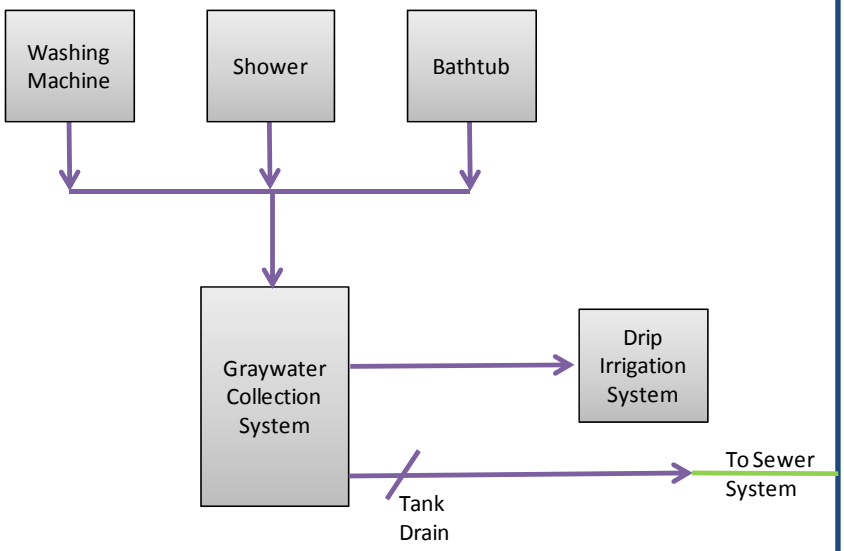

Figure 1: Simple System (Laundry + Bath + Shower)

- **Irrigation field:** All graywater systems used for landscape irrigation require a designated destination for graywater within the receiving landscape. The irrigation field may include a drip irrigation system, a mulch basin, or any other approved method for dispersal of graywater. The primary purpose of the irrigation field is to ensure that the dispersed graywater does not stagnate.
- **Piping/plumbing:** The Uniform Plumbing Code (UPC) regulates the graywater piping installation requirements to deliver graywater to the irrigation field. For health reasons, graywater must have separate piping, valves, and other system components from potable water systems. Provisions should also be provided for disposal of excess/unused graywater into the sewer system. Because graywater has not been widely used previously, code standards are still evolving to reduce potential health risks.
- **Drip irrigation system:** In order to mitigate human contact to microbial content of graywater, regulations require that graywater systems be designed to avoid reaching land surface or becoming airborne. Thus, graywater is currently restricted to subsurface applications through drip irrigation emitters and non-clogging nozzles or in mulch basins.
- **Storage Tank (optional):** As the timing of graywater production and usage are typically not synchronized, a storage tank helps to store graywater to be used at a later time. If storage is provided, regulations require that the graywater is not stored for more than 24 hours. Storage tanks should be marked with large clear warning signs to indicate that the water is non-potable. Storage tank design should also ensure zero spills or overflows. If graywater is only used for irrigation, storage may be eliminated.

Key Assumptions

- Approximately 25% participation of single family homes by 2035 (about 10,000 homes).
- Approximately 40% of total indoor water use becomes available as graywater supply (via clothes washing, shower, bathtub wastewater).
- On-site outdoor demands are sufficient to utilize graywater supply via drip irrigation.

Yield

- Assuming 10,000 homes participate, annual yield would be: 807 AFY

Graywater Reuse (Decentralized On-site Systems)

Category: Graywater (Table Reference: J)

Cost (in 2010 dollars)

Total Capital Cost: $54,000,000 for 10,000 homes ($5,400 per home)
Annual O&M Cost: $1,620,000/year for 10,000 homes ($162/year per home)
Unit Cost: $6615/AF

Because wastewater is used on-site, savings could be expected from reduced sewer fees. Assuming an average sewer bill of $11.2/month for a single-family home and a 40% reduction in wastewater, savings of $54/year per household could be expected (or $540,000 for 10,000 homes).

Net Annual O&M Cost (with sewer fee savings): $1,080,000/year for 10,000 homes
Net Unit Cost (with sewer fee savings): Approximately $5,950/AF

Projects would eligible for State grant funding.

Permitting/Licensing

A Simple System requires construction permits unless exempted by the enforcing agency (City of Pasadena). A Simple System should comply with the guidelines outlined in *California Graywater Regulation Chapter 16A (Section 1603A.1.2 Simple System - System requirements).*

Water Quality

Graywater reused for outdoor non-potable applications is typically untreated wastewater with a lower concentration of bacteria than most other raw wastewater sources. Although no technology is potentially risk-free, the public health risk associated with graywater is a lot higher than municipally treated recycled water since water quality of graywater is seldom monitored. There is no documentation to prove substantial risk associated with graywater reuse, but there is little data available of applications in California. Table 1 summarizes the typical bacteria concentration of different water treatment levels.

Table 1: Bacteria Concentration in Water

Type of Water	Coliforms/100 ml
Drinking water	<1
Disinfected Tertiary Recycled water	<2.2
Disinfected Secondary Reclaimed water	<23
Undisinfected Reclaimed water	20 to 2000
Graywater	100 to 100 million
Raw Wastewater	Millions to billions

* Source: White paper on Graywater by Bahman Sheikh

Environmental Impacts

According to regulations, the absence of groundwater in a test hole 3 feet (ft) below the deepest irrigation or disposal point is sufficient to satisfy the use of graywater systems, unless seasonal high groundwater levels have been documented. Historic records of the Raymond Groundwater Basin during 1991 and 1983 show that the groundwater elevations varied from 100 ft to 300 ft below surface. Thus, all graywater reuse systems within the City should have no adverse impacts on the underlying groundwater basin. However, this assumption is uncertain due to limited data.

References

- California Graywater Regulations. 2009. Chapter 16A " Nonpotable Water Reuse Systems".
- B Sheikh, PhD, PE. 2010. White Paper on Graywater
- Grey is Green. 2010. Greywater Recycling for the DIYer. Accessed at: <http://www.grey-is-green.com/details.htm>
- Oasis Design. 2009. Monitoring Graywater Use: Three Case Studies in California (Reprint). Accessed at: <http://oasisdesign.net/greywater/SBebmudGWstudy.htm>

Centralized Stormwater Capture to Recharge

Category: Stormwater/Urban Runoff (Table Reference: K)

Brief Description:

This option is to capture a portion of stormwater from an existing storm drain pipe and pump to existing Eaton spreading grounds. The Eaton spreading grounds recharge the underlying Raymond groundwater basin, which have been experiencing water level declines. The centralized stormwater option would involve installation of a pump station and possible storage to divert water from an existing storm drain or channel. Figure 1 shows the potential location identified in Rubio Wash where runoff from a large portion of Pasadena can be diverted.

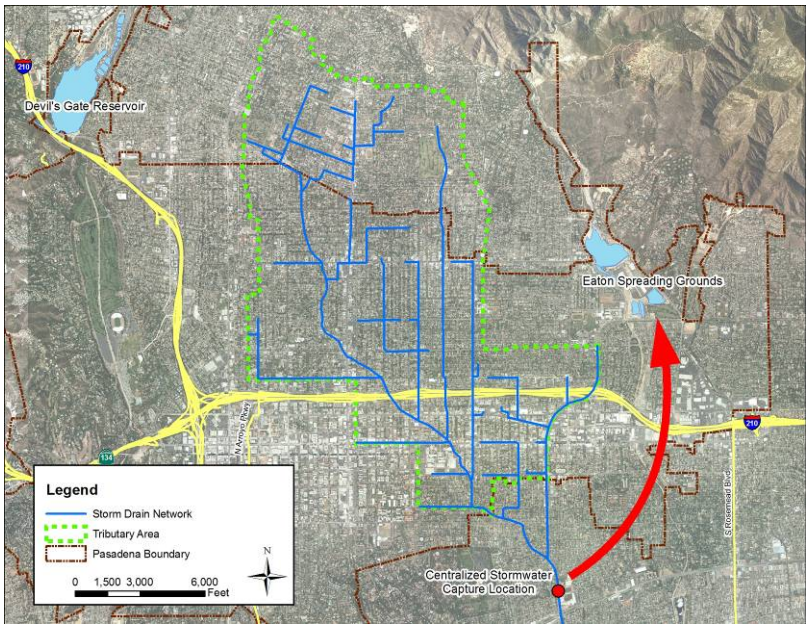

Figure 1. Centralized stormwater location and tributary area

Multiple scenarios were simulated using flow gage data from Rubio Wash to determine the appropriate storage size and pump capacity for this option.

Figure 2 shows yields calculated using different combinations of storage and pumping capacity, and Figure 3 shows the cost per acre foot (AF) for the different options. The option selected to carry forward for further evaluation in the WIRP is the 100 horsepower (HP), 0.5 AF storage option because it has the lowest annual cost per AF out of all of the available options. This option is ideal for capturing primarily dry weather flow, although other options may be selected to capture more water during storm events.

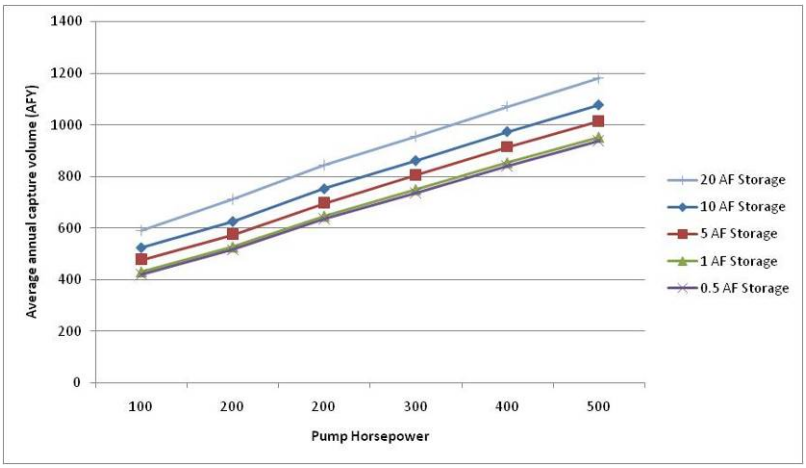

Figure 2. Centralized stormwater average annual stormwater capture volumes

Facilities Required:

- 16,000 linear feet (LF) of 8-inch pipe
- 100 HP, 2 cubic feet per second (cfs) pump station

Key Assumptions:

- Assumes Eaton spreading grounds will have sufficient capacity for additional replenishment water.
- PWP supply credit (amount of water recharged that can be recovered as supply) from Raymond Basin is 10.5%. The recharge from this option will be used to improve the long-term safe yield of the basin.

Centralized Stormwater Capture to Recharge

Category: Stormwater/Urban Runoff (Table Reference: K)

Yield:

- Average Year: 421 acre feet per year (AFY)
- Average Year after assumed PWP Supply Credit (10.5%): 44 AFY
- The yield for this option is dependent on hydrologic conditions and is highly variable on a seasonal and annual basis. Yields shown above represent the estimated long-term average yield that could be expected. Refer to Appendix C for more details regarding hydrologic analysis.

Cost (in 2010 dollars):

- Capital: $2,600,000
- Operation and Maintenance: $ 38,305/year
- Unit Cost of Supply Yield: $4,914/AF (after supply credits)

Water Quality:

- Implementation would reduce urban stormwater volume from Pasadena, and reduce pollutant loading by 421 AFY (0.38 million gallons per day [MGD])

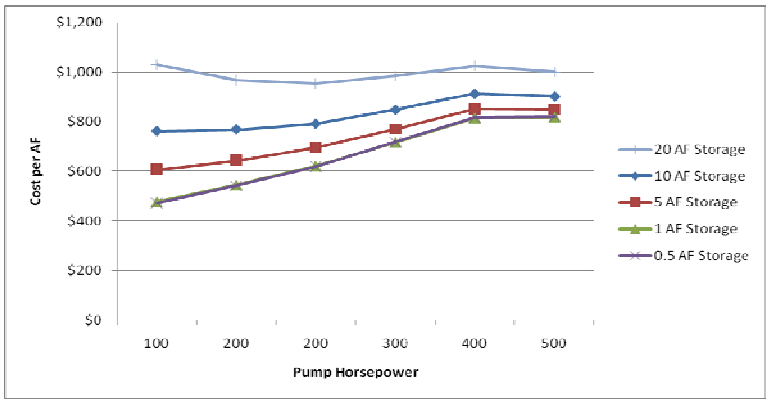

Figure 3. Centralized stormwater annual cost per AF

Institutional Coordination:

- The centralized stormwater capture point is located in San Marino High School, and Rubio Wash is managed by LA County. This project would require coordination with both entities.
- Requires coordination with San Marino High School and LA County could be reduced if the stormwater capture location were moved upstream within the City limits. However, the annual capture volume would be less.
- Coordinate with the Raymond Basin Management Board regarding supply credits.
- Coordinate with Los Angeles County for use of Eaton Canyon spreading grounds.
- Coordinate with the City of Pasadena Public Works Department for potential benefits associated with total maximum daily load (TMDL) regulatory compliance.

Environmental Impacts:

- Increase recharge to the Raymond Basin by 421 AFY (0.38 MGD).
- Implementation would reduce urban stormwater pollutant loading to receiving waters (Rubio Wash).
- No long-term habitat impacts associated with construction of project

Rain Barrel, Rain Garden and Infiltration Strip/Bioswale Options

Category: Stormwater/Urban Runoff (Table Reference: L)

Brief Description:

This option proposes to provide incentives for homeowners and businesses to install or construct rainwater collection systems on their properties. By reducing runoff from properties, the water can be utilized for non-potable water demand or increase recharge to Raymond Basin. For stormwater capture devices were considered:

- **Residential rain barrel:** Rain barrels are installed to capture runoff from rooftops for use in non-potable water demands, such as irrigation. Residential properties tend to install rain barrels at the end of downspouts.
- **Residential rain gardens:** For residential rain gardens, rooftop runoff is routed through downspouts into gardens designed to infiltrate the water. These gardens have the benefits of reducing off-site runoff and provide aesthetic benefits to the property, and water is recharged to the ground providing benefits to the underlying aquifer.
- **Residential infiltration strips/bioswales:** Biorentention strips on single family residential lots collect not only rooftop runoff, but also any drainage from the property and overwatering. This type of option would be implemented on a neighborhood scale, usually constructed between the road and the residential properties.
- **Commercial infiltration strips/bioswales:** Bioretention strips for commercial properties would collect runoff from parking lot areas and other available open spaces.

Facilities:

- Residential rain barrel option assumes a downspout disconnection and 100 gallon rain barrel.
- Residential rain garden option includes a downspout and rain garden designed with ability to store up to approximately 375 gallons through ponding and porous media.
- Residential infiltration strips/bioswales includes a downspout disconnection and an infiltration strip with capacity to store up to 1,260 gallons though ponding and porous media.
- Commercial infiltration strips/bioswales includes a downspout disconnections and an infiltration strip with capacity to store up to 8,000 gallons though ponding and porous media

Source of photos:
California Sea Grant
Green Sheet #3
Surfrider Foundation
Ocean Friendly Gardens

Key Assumptions:

- For each single-family residential option (rain barrels, rain gardens, and infiltration strip/bioswales), the yield for this analysis assumes 25 percent participation (roughly 9,000 homes).
- For the commercial infiltration strip/bioswale options, the yield assumes 30 percent participation (or roughly 1,500 parcels).
- For options that provide replenishment to the groundwater basin (all options except rain barrels), it is assumed that the recharge will be used to improve the long-term safe yield of the basin (no immediate supply credits). In the long-term, assume approximately 10.5 percent (0.25*0.42=.105) of water recharged could be recovered by PWP.

Yield:

- Residential Rain Barrels: 32 AFY
- Residential Rain Gardens: 106 AFY, 11 AFY after supply credits (10.5 percent)
- Residential Infiltration Strip/Bioswale: 256 AFY, 27 AFY after supply credits (10.5 percent)
- Commercial Parking Lot Swales: 321 AFY, 34 AFY after supply credits (10.5 percent)

The yields are dependent on hydrologic conditions and are highly variable on a seasonal and annual basis. Yields could be significantly less in dry years, or more in wet years. Yields shown above represent the estimated long-term average yield that could be expected. Refer to Appendix C for more information on yield analyses of these options.

Rain Barrel, Rain Garden and Infiltration Strip/Bioswale Options

Category: Stormwater/Urban Runoff (Table Reference: L)

Cost (in 2010 dollars):

Total costs of options are summarized below. Projects would eligible for State grant funding.

	Residential Rain Barrels	Residential Rain gardens	Residential Infiltration Strip/Bioswale	Commercial Infiltration Strip/Bioswale
Per Unit Capital Costs, $/each	$200	$368	$1182	$7354
Total Capital Costs, $	$1,759,000	$3,235,500	$10,397,500	$10,147,920
Annual Operation and Maintenance (O&M) Cost[1], $/year	$88,000	$222,600	$715,400	$523,226

Notes:

1. Annual O&M costs are assumed to be 5 percent of capital cost.
2. For all options except rain barrels, annual O&M costs include $120/AF to recover supply yield from the ground.

References:

1. http://www.eco-gardening.com/
2. www.watertanks.com
3. http://www.millcreekwatershed.org/assets/files/howto.pdf
4. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Filtering%20Practice/Bioretention.htm

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Institutional Coordination:

- Partner with the City of Pasadena Public Works Department for total maximum daily load (TMDL) benefits.
- Coordinate with the Los Angeles Integrated Regional Water Management Plan to promote grand funding.

Environmental Impacts:

- Rain gardens and infiltration strips/bioswales can increase recharge to the Raymond Basin.
- All stormwater options reduce stormwater runoff from properties, and in turn reduce pollutant loading to receiving waters (streams). These water quality benefits potentially help with total maximum daily load (TMDL) compliance.
- Considered a “green” alternative, with very little energy use.

Permeable Pavement Option

Category: Stormwater/Urban Runoff (Table Reference: M)

Brief Description:

Permeable pavement refers to pavement with infiltration capabilities to allow water to seep into the ground instead of being routed to storm drains, and ultimately to the Pacific Ocean. Permeable pavement would reduce runoff volume into the storm drains and provide some recharge benefits to the Raymond Groundwater Basin. Samples of constructed permeable pavement are shown in Figure 1 and Figure 2.

Figure 1. Example permeable pavement

Figure 2. Example permeable pavement

Permeable pavement has many of the same properties as traditional pavement in that it has sufficient structural strength to support most large vehicles, and requires little maintenance. Permeable pavement is designed for rapid infiltration and does not significantly impede infiltration of the underlying soil. Typically, the soil infiltration rate is less than that of permeable pavement, and controls the rate of recharge. A cross-section showing the different infiltration rates is shown in Figure 3. Maintenance involves washing debris away using a high pressurized water jet, and when completed can restore from 80-90% of the pavement's original capacity. Note that most clogging occurs in isolated areas. The typical design life for permeable pavement is 20 years.

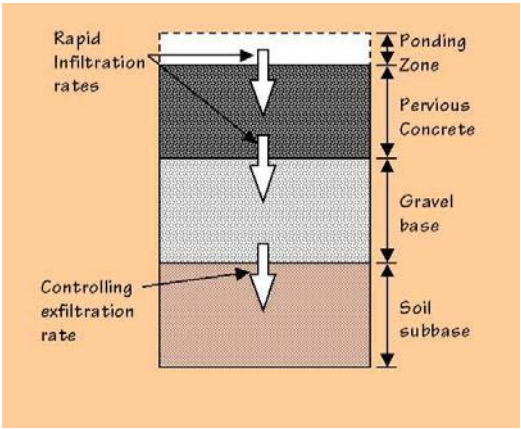

Figure 3. Permeable pavement cross section showing infiltration rates

Facilities Required:

Permeable pavement for constructed roads, sidewalks, and parking lots.

Permeable Pavement Option

Category: Stormwater/Urban Runoff (Table Reference: M)

Key Assumptions:

- Four acres of impervious surface are routed to every one acre of permeable pavement
- Pervious pavement infiltration rate is significantly greater than soil infiltration rate
- Permeable pavement would be installed in place of new pavement or for replacing roads in need of repair. In analysis of this option, the cost for permeable pavement reflects the incremental new cost for permeable pavement compared to traditional pavement.
- The cost for permeable pavement is 40% greater than traditional pavement.
- Approximately 20% of all parking lots (21 acres) and 2% of all roads (60 acres) will be constructed with permeable pavement within the planning horizon (2035).
- Assumes permeable pavement represents 25% of entire drainage area.
- PWP supply credit (amount of water recharged that can be recovered as supply) from Raymond Basin is 10.5%. The recharge from this option will be used to improve the long-term safe yield of the basin (no immediate supply credits). In the long-term, assume 25% of 42% (0.25*0.42=.105) of water recharged could be recovered by PWP.

Yield:

- Recharge per acre of pavement: 4 acre feet per year (AFY)
- Total yield for 81 acres: 324 AFY
- Total yield after assumed PWP supply credit (10.5%): 34 AFY
- Groundwater replenishment occurring from this option is dependent on hydrologic conditions and is highly variable on a seasonal and annual basis.

Cost (in 2010 dollars):

- Capital Cost for 81 acres of porous Pavement: $21,122,571, which is approximately $6,035,020 more than traditional pavement
- Unit Cost of Supply Yield: $12,325/AF (based on supply yield of 34 AFY)
- Projects would eligible for State grant funding.

Water Quality:

- Improved water quality in creeks, rivers and ocean due to reduced storm drain discharges.
- No adverse water quality impacts to underlying aquifer since porous pavement and soil act as treatment systems.

Institutional Coordination:

- Coordinate with the City of Pasadena Public Works Department for potential total maximum daily load (TMDL) regulatory benefits. Coordinate with the Raymond Basins Management Board on location of porous pavement facilities and monitoring of aquifer response.

Environmental Impacts:

- Adds recharge to the Raymond Basin.
- Reduces stormwater pollutant discharges to creeks and rivers.

References:

Sean Van Delist, Cement Council of Texas
www.perviouspavement.org/

Additional MWD Treated Imported Water Purchases

Category: Imported Water (Table Reference: N)

Brief Description:

Pasadena Water and Power (PWP) purchases imported water from the Metropolitan Water District of Southern California (MWD), which is one of the largest water purveyors in the country. On average, approximately 1.7 billion gallons per day moves through MWD's delivery system to its 26 member agencies, serving over 19 million people. The City of Pasadena was one of the original, founding member agencies of MWD. Imported water is conveyed from the Sacramento-San Joaquin River Delta (Delta) in Northern California via the State Water Project (SWP) and from the Colorado River via the Colorado River Aqueduct (CRA). While MWD owns and operates the CRA, the SWP is managed by the State of California Department of Water Resources (DWR). Both sources require significant pumping to reach Southern California. Water from the Delta requires a lift of over 2,000 feet to cross the Tehachapi Mountains, and the CRA requires a lift of over 1,500 feet across the Mojave Desert.

Figure 1
Major California Water Systems

MWD has a basic apportionment of Colorado River water of 550,000 acre-feet. However, due to surplus conditions and unused apportionments from other Colorado River Basin states, MWD has historically delivered 1.2 million acre-feet until 2003, when the Secretary of Interior forced the State of California to live within its basic apportionment of 4.4 million acre-feet. MWD and the San Diego County Water Authority have implemented a variety of water conservation and transfer programs with Imperial Valley Irrigation District and Palos Verdes Irrigation District to augment basic apportionment. Currently, MWD receives an average of about 750,000 acre-feet from the CRA, with the long-term goal to develop supplemental supplies to deliver 1.2 million acre-feet again.

MWD is the largest contractor for SWP supplies, with a delivery contract of 2.01 million acre-feet. However, past historical average deliveries from the SWP to MWD have only been 1.0 million acre-feet. In drought years, MWD may only receive a fraction of its contract (200,000 to 400,000 acre-feet). But because of MWD's surface storage and groundwater banking programs, it can store surplus SWP supplies to be used during droughts. MWD has also implemented a number of water transfers in the Central Valley to further augment its SWP supplies during droughts. Figure 1 shows the major water systems within California that MWD relies on for imported water and related water transfers and groundwater banking programs.

PWP receives treated imported water through five turnouts from MWD's Upper Feeder (see Table 1). Currently this imported water is treated at MWD's Weymouth water treatment plant (WTP). In the event that Weymouth WTP is offline, three turnouts (P-1, 3 , and 5) are backed up by MWD's Jensen WTP.

Table 1. PWP's Treated Water Connection Capacity to MWD's System

Turnout	Capacity (cubic feet per second, cfs)
P-1	50
P-2	30
P-3	7.5
P-4	50
P-5	7.5

Facilities Required:

There is sufficient MWD connection capacity in existing turnouts to meet all of Pasadena's current and projected water demands. However, there may be future capital investments that need to be made by MWD for retrofitting treatment plants and for other infrastructure related to maintaining the imported water system. In addition, there will likely be improvements to the SWP system to improve reliability of the Delta water supplies.

Additional MWD Treated Imported Water Purchases

Category: Imported Water (Table Reference: N)

Reliability Issues:

Although PWP's connection capacity to MWD's system is sufficient to meet future water demands, there are significant issues associated with the reliability and costs of imported water. Imported water supply from MWD is very vulnerable to ongoing droughts, environmental restrictions, seismic events and climate change. In August of 2007, U.S. District Court Judge Oliver Wanger ruled to restrict water deliveries from the Delta in order to protect the Delta smelt under the Endangered Species Act. This action, coupled with a three year drought in California, resulted in MWD reducing its imported water allocation in the summer of 2009, the first time a regional mandatory water use restriction has been imposed since 1991. And even with massive rainfall and snowfall in the winter of 2009/2010, MWD issued that imported water restrictions would continue for the summer of 2010. This is the first time that MWD had to restrict its imported water supplies for two consecutive years. DWR has estimated that potential climate change could reduce SWP water supplies by as much as 15 percent by 2030.

Both the state and MWD have taken actions to improve water reliability. In November of 2009, several important bills were signed into law to improve water supply reliability for California. Senate Bill (SB) 1 established a framework for solving the problems in the Delta, establishing the co-equal goals of restoration and supply reliability and a new governance structure to develop a comprehensive Delta Plan to be developed by 2012. SB 6 requires statewide groundwater monitoring to help better manage this important resource for normal and drought-year operations. And SB 7 requires an aggressive statewide requirement of 20 percent urban conservation by 2020. In addition, an $11 billion bond measure will be before voters in November of 2010 to help pay for Delta restoration; local recycling, desalination and groundwater projects statewide; and for regional and state storage and supply programs. MWD continues to seek water transfers and storage programs in order to supplement its imported water and has a goal of being able to deliver full reliability of imported water deliveries by 2020 (MWD IRP Update, 2004). However, even if long-term solutions are found for the Delta, it could take decades for the needed facilities to be constructed.

Cost (in 2010 dollars):

Capital: None.

Tier 1 Treated Water Rate:	2010 = $701/acre-foot	2012 = $794/acre-foot
Tier 2 Treated Water Rate:	2010 = $811/acre-foot	2012 = $920/acre-foot

In 2009, MWD's full service water rates for Tier 1 water increased almost 15 percent (almost 3 times the previous year's increase). And in 2010, MWD's Tier 1 water rates increase by over 20 percent. Given the improvements that are needed in the Delta, it is almost certain that continued significant rate increases for MWD will occur for some time into the future.

Water Quality:

Product water quality from MWD's Weymouth WTP meets all primary drinking water standards.
Total dissolved solids (TDS) ranges from 487-678 ppm, with the highest running annual average of 565 ppm.

Weymouth WTP historically received a blend of SWP water and CRA water until 2008, when MWD's operations changed resulting from the environmental restrictions in the Delta. Since 2008, Weymouth WTP has been treating only CRA water which does not meet Raymond Basin water quality objectives for TDS.

Institutional Coordination:

Requires coordination with MWD.

Environmental Impacts:

- Until a long-term solution to the Delta is implemented, use of MWD water will continue to have impacts on the Delta habitat.
- Significant energy requirements to pump and convey imported water releases substantial greenhouse gases.

Water Transfers Option

Category: Imported Water (Table Reference: O)

Brief Description:

PWP could engage in water transfers to increase their water supply. Water transfers can be short-term or long-term. Short-term water transfers are typically a one-time purchase of water, usually on an as-needed basis to offset the effects of drought. Long-term transfers are those that take place over a period of more than 1 year. Long-term transfers can be made through an options agreement, where buyers have the "option" to purchase a certain amount of water any time during the life of the agreement. An "option" payment would be made each and every year to secure the right to transfer the water. When the water is called, then the buyer would pay the water transfer cost for that amount of supply needed in that year. In the past years, most water transfers have occurred between sellers from north of the Delta to buyers south of the Delta. Water transfers from the Central Valley or Colorado River Region have been limited because the lack of available water supplies. PWP would have to find a seller, negotiate a price, transfer amount, and delivery schedule. Water transfers can occur through various mechanisms including stored water purchases, groundwater substitution, or crop idling agreements.

North to south water transfers require approval from the California Department of Water Resources (DWR) or U.S. Bureau of Reclamation (Reclamation), depending on the sellers' contract supplies (Central Valley Project (CVP) or State Water Project (SWP)) and the pumping facility used for transfer through the Delta (SWP's Harvey O. Banks Pumping Plant or CVP's C.W. "Bill" Jones Pumping Plant). DWR and Reclamation closely coordinate transfers and have similar approval requirements. California Water Code Section 1810 and the Central Valley Project Implementation Act protect against injury to third parties as a result of water transfers. Three fundamental principles include that use of a water conveyance facility is to be made with (1) no injury to other legal users of water; (2) no unreasonable effects on fish, wildlife or other in-stream beneficial uses of water; and (3) no unreasonable effects on the overall economy or the environment in the counties from which the water is transferred. DWR and Reclamation have defined the approval requirements of water transfers in "Draft Technical Information for Water Transfers in 2010", which the agencies update as needed before the transfer season.

In addition to the approval requirements, DWR and Reclamation must also implement water transfers within the operating parameters of the Biological Opinions on the Continued Long-term Operations of the CVP/SWP to protect sensitive fish species in the Delta. The Opinions' provisions applicable to conveyance of transfer water include:

- The maximum amount of water transfers covered in the Opinions is 600,000 acre feet per year (AFY); and
- Transfer water will be conveyed through the Banks Pumping Plant and Jones Pumping Plant during July through September only.

A major concern for water transfers is the ability to move the purchased water through the Delta. Export of the transfer water is dependent on availability of capacity at the SWP or CVP pumping facilities and subject to other operational requirements. Available capacity is severely limited due to operational and regulatory restrictions. The current pumping window for transfers through Banks and Jones Pumping Plants is July through September. Pumping within this window can be further reduced based on specific hydrologic conditions and regulatory compliance or water quality issues. DWR and Reclamation determine the availability of pumping capacity during the transfer period.

Facilities Required:

- Existing conveyance facilities would be used, including Banks or Jones Pumping Plants, California Aqueduct and Metropolitan Water District (MWD) conveyance facilities

Key Assumptions:

- DWR or Reclamation approve water transfer
- Pumping capacity would be available to move transfer water through the Delta

Water Transfers Option

Category: Imported Water (Table Reference: O)

Yield:

- 5,000 AFY max delivery
- 3,000 AFY long-term average
- Transfers are more likely to occur in dry years because pumping capacity would be available. In wet years, capacity may not be available because Banks and Jones Pumping Plants are pumping SWP and CVP water to meet contract demands.

Cost (in 2010 dollars):

No capital costs associated with water transfers. PWP would need to pay the costs of the water, additional costs for carriage water (20% extra water needed to meet Delta water quality standards), and conveyance costs.
$275/AF: Water purchase cost
$490/AF: Wheeling fees (includes SWP and MWD wheeling)
$217/AF: MWD treatment surcharge
$982/AF: Total cost

Water Quality:

Since the transfer water is delivered through MWD's system, the water quality depends on MWD operations. Water quality is expected to be the same as current water quality from Weymouth water treatment plant (WTP) unless MWD operations change, which likely will not occur unless conditions in the Delta are improved over the long-term (at least another ten years).

Product water quality from MWD's Weymouth WTP meets all primary drinking water standards. Total dissolved solids (TDS) ranges from 487-678 ppm, with the highest running annual average of 565 ppm.

Institutional Coordination:

PWP must find a seller north of the Delta with water available for transfer. PWP and the seller would need to negotiate price and develop the transfer approval package for DWR or Reclamation. DWR or Reclamation must approve transfers and facilitate movement of water through the Delta. For 1-year transfers, PWP would also need to file a permit for temporary change in place of use with the State Water Resources Control Board.

Environmental Impacts:

- DWR and Reclamation have mandatory requirements for transfers that reduce potential environmental impacts in the sellers' service area, Delta region, and buyers' service area.
- Significant energy requirements to pump and convey imported water releases substantial greenhouse gases.
- There is no local construction associated with water transfers; therefore, there would be no environmental impacts from construction activities.

Water Banking

Category: Imported Water (Table Reference: P)

Brief Description:

This option is similar to the water transfers option, but PWP would also participate in a water banking agreement. Water banking involves storing water underground for future use, especially during dry periods. Several water agencies have established a formal groundwater bank. Semitropic Water Storage District in Kern County operates a groundwater bank with a storage capacity in excess of 1 million acre-feet (AF). Multiple agencies already participate in the bank, including Metropolitan Water District (MWD) and Santa Clara Valley Water District. Semitropic Water Storage District is currently constructing the Stored Water Recovery Unit, which increases their banking operation and has storage and pump back capacity available for new banking partners.

PWP can purchase "shares" in the bank, which entitles them to storage and pump back. As currently planned, shares operate on a 3:1 storage to pump back ratio and a partner can only store 0.33 AF/share/per year. PWP could purchase 5,000 shares and be eligible to store 15,000 AF of water in the bank and pump out 5,000 AF during dry years. It would take 9 years to store the entire 15,000 AF, the first 5,000 AF could be extracted after 3 years. PWP would purchase high priority shares to be guaranteed extraction capacity during dry years.

For this analysis, it was assumed that a yield of up to 15,000 AF would be purchased throughout the planning horizon and used in dry years. The Central Valley groundwater banking opportunities appear attractive due to reliability in drought conditions, but they are generally more expensive than other transfer opportunities.

Key Assumptions:

- Groundwater bank has available capacity for recovery during dry years

Yield:

- 5,000 AFY max
- 2,000 AFY long-term average

Cost (in 2010 dollars):

The Stored Water Recovery Unit is developed so there would be no capital costs associated with the banking option. PWP would need to pay an initial investment for shares in the bank and annual fees for water and put and take operations of the bank.

Capital: $10,000,000
Based on initial share investment of $2000/share

Fixed annual operation and maintenance (O&M): $115,000
Based on maintenance and management fees of $23/share

Variable O&M Costs:
Put operations : $76/AF
Take operations : $76/AF
Purchase cost : $366/AF
MWD wheeling : $314/AF
MWD treatment surcharge : $217/AF
Total variable O&M cost of product water : $1,049/AF

Average Unit Cost of Supply Yield: $1,210/AF (cost fluctuates based on water import)

Water Banking

Category: Imported Water (Table Reference: P)

Water Quality:

Since the banking water is delivered through MWD's system, the water quality depends on MWD operations. Water quality is expected to be the same as current water quality from Weymouth water treatment plant (WTP) unless MWD operations change, which likely will not occur unless conditions in the Delta are improved over the long-term (at least another ten years).

Product water quality from MWD's Weymouth WTP meets all primary drinking water standards. Total dissolved solids (TDS) ranges from 487-678 ppm, with the highest running annual average of 565 ppm.

Institutional Coordination:

Groundwater banking requires coordination with Semitropic Water Storage District and MWD.

Environmental Impacts:

- Semitropic Water Storage District is completing environmental documentation for the Stored Water Recovery Unit and will be required to mitigate environmental impacts associated with constructing and operating the bank.
- Significant energy requirements to pump and convey imported water releases substantial greenhouse gases.
- There is no local construction associated with water transfers; therefore, there would be no environmental impacts from construction activities.

Pasadena Groundwater Storage Program Option

Category: Imported Water (Table Reference: Q)

Brief Description:

The Pasadena Groundwater Storage Program (PGSP) option is a proposed conjunctive use program to improve water supply reliability and flexibility by:

- Storing up additional groundwater reserves when imported water is abundant.
- Reducing dependence on imported water during periods of drought or emergency conditions.
- Elevating groundwater levels through recharging Raymond Basin.

Imported water would be stored by direct injection with Aquifer Storage and Recovery (ASR) wells, spreading at existing Arroyo Seco or Eaton Canyon spreading areas, and through in-lieu recharge (reduced groundwater pumping).

The project could be implemented by PWP, or in partnership with Foothill Municipal Water District (FMWD).

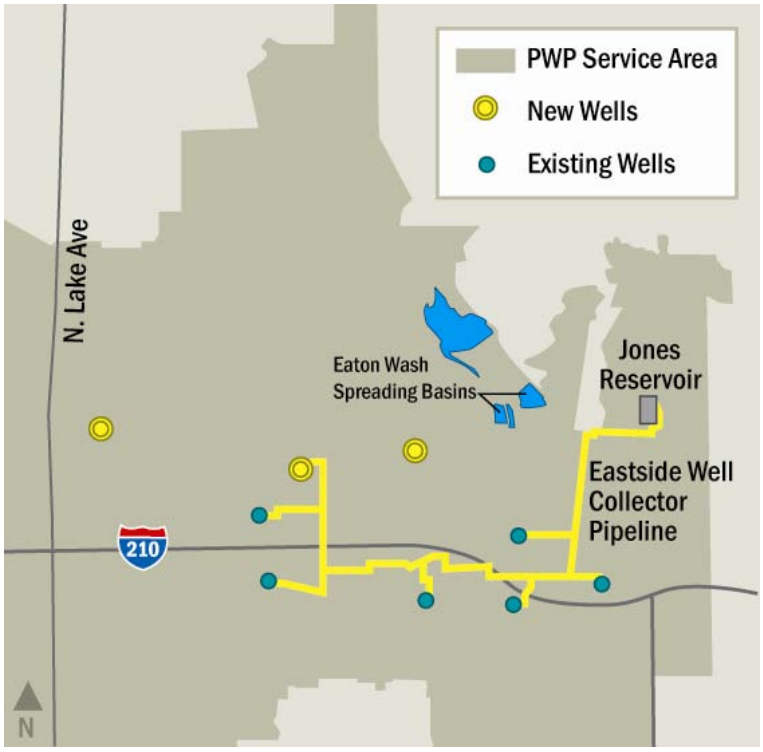

Figure 1. New PGSP Facilities

Facilities Required:

Figure 1 shows the recommended facilities that make up the components of the PGSP:

- Three new ASR wells
- Eastside Well Collector (sub-option)
  - New 16-inch to 36-inch, 30,000-foot pipeline
  - New centralized chloramination facility at Jones Reservoir

Facilities are based on the *2007 Pasadena Groundwater Storage Program Conceptual Design Report* prepared by RMC. If implemented with FMWD, additional facilities would be required.

Key Assumptions:

- PWP currently holds rights to 38,500 acre-feet (AF) of storage capacity (13,400 AF in the Monk Hill Subarea and 25,100 AF in the Pasadena Subarea).
- Water could be recharged when replenishment water is available, and extracted during drought or emergency periods.
- Replenishment water would be available as follows:
  - Between 2011 and 2020, replenishment water will only be available 20 percent of the time.
  - From 2021-2029, replenishment water would be available 50 percent of the time.
  - From 2030-2035, replenishment water would be available 70 percent of the time.
- Replenishment would occur up to 20,000 AFY in a given year, but would average approximately 6,500 AFY over time.

Yield:

- Maximum (net) PWP 'take' during drought year or emergency conditions: 25,000 AFY
- Average new yield over time: 5,000 AFY
- This option would add extraction capacity with the Eastside Well Collector and new ASR wells.

Pasadena Groundwater Storage Program Option

Category: Imported Water (Table Reference: Q)

Cost (in 2010 dollars):

Costs are based on the *2007 Pasadena Groundwater Storage Program Conceptual Design Report* prepared by RMC, and inflated to 2010 dollars:

- Capital cost: $36,145,400
- Operation and maintenance (O&M) Cost: $586,800/year
- Imported Water Cost: $3,789,500/year
- Average Unit Cost of Supply Yield: $1,404/AF

It is assumed that replenishment water purchased from MWD would be a reduced rate (lower than Tier 1 treated water rate).

Funding or Cost-Sharing Opportunities:

- Potential partnerships with neighboring water agencies (i.e. Foothill Municipal Water District)
- Project would eligible for State and Federal grant funding.

Water Quality:

The water quality objectives for Raymond Basin are as follows:

- Boron: 0.5 milligrams per liter (mg/L)
- Chloride: 100 mg/L
- Sulfate: 100 mg/L
- Total Dissolved Solids (TDS): 450 mg/L

Any water recharged to the local groundwater basin should be in compliance with the water quality objectives. Based on MWD's 2008 Water Quality Report, the effluent quality of imported water from the Colorado River treated at Weymouth Treatment Plant do not currently meet the Raymond Basin quality standards for sulfate and TDS. If water quality from Weymouth is not suitable for direct injection, the water could be blended with surface water flows and recharged in spreading areas. Alternatively, water could be stored through reduced groundwater pumping in years when replenishment water is available (known as in-lieu recharge).

Institutional Coordination:

Approval from Raymond Basin Management Board (RBMB). Currently, RBMB does not allow use of storage accounts in the Pasadena subarea due to declining water levels. Therefore, storage accounts are not credited for reduced pumping and recharged imported water cannot be recovered. Further study is needed to negotiate use of storage accounts in the Pasadena subarea, in order to provide more incentive to recharge and build storage.

Storage accounts are active in the Monk Hill subarea, but PWP has not utilized stored water due to capacity limitations which will be resolved once the Monk Hill groundwater treatment plan is online.

The program will also require coordination with MWD to obtain replenishment water at a reduced water rate.

Environmental Impacts:

- Increases replenishment to the Raymond Basin
- Until a long-term solution to the Delta is implemented, use of MWD water will continue to have impacts on the Delta habitat.
- Significant energy requirements to pump and convey imported water releases substantial greenhouse gases.

Ocean Desalination

Category: Ocean Desalination (Table Reference: R)

Brief Description:

Desalination is the process whereby dissolved minerals (salts and others) are removed from seawater or brackish groundwater. Desalination offers improved water quality (low salinity), and, as a more local source, can help protect against supply vulnerabilities due to droughts and earthquakes. The cost-efficiency of desalination has improved in the last couple of decades due to advances in treatment technologies, but is still very energy dependent and not seen to reduce carbon emissions compared to traditional water treatment processes.

Desalination facilities are typically built along coastal communities to reduce water conveyance distances. Because Pasadena is not located near a saline body of water, this option will evaluate a potential partnership with a regional agency to construct an ocean desalination facility. There is a possibility to partner with San Diego County Water Authority (SDCWA) on a new 50 million gallon per day (mgd) [or 56,000 acre-feet per year (AFY)] ocean desalination plant near Camp Pendleton, with future expansion up to 150 mgd capacity. PWP would pay a purchase cost for water once the plant is constructed. This would be an exchange agreement, since the desalinated water would physically be delivered to SDCWA member agencies and in return, PWP would receive the water allocation via Metropolitan Water District's (MWD's) facilities. This would require coordination with SDCWA and MWD. A schematic figure showing the relationship between the ocean desalination supply option and PWP water supply system is shown in Figure 1.

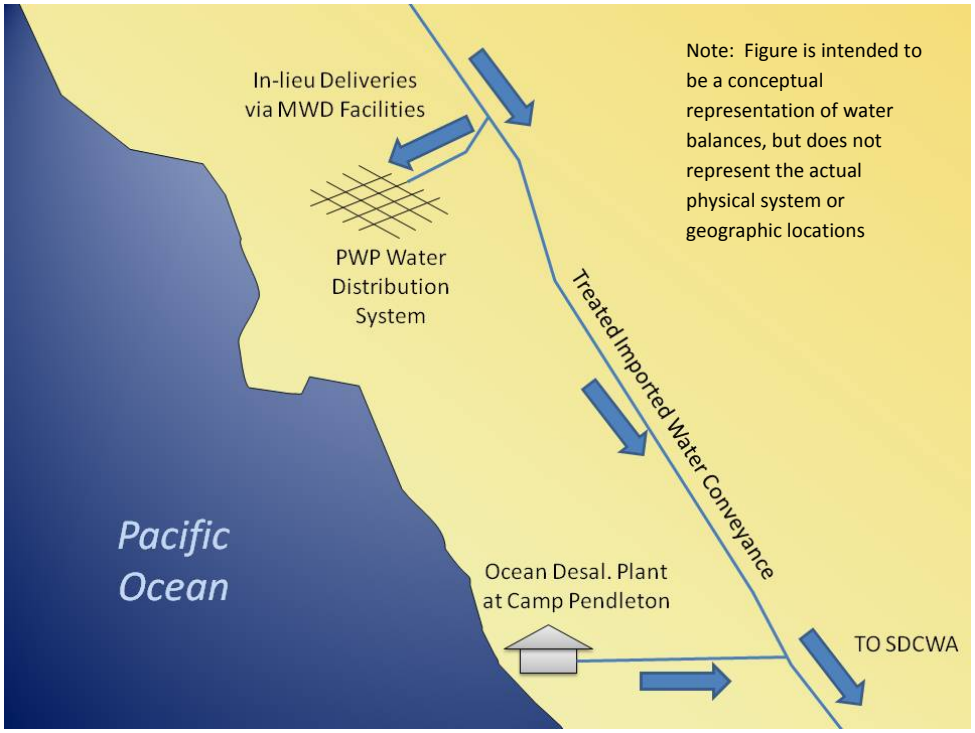

Figure 1. Ocean desalination option representation

Yield:

Assumes 5,000 AFY would be available to PWP.

Cost (in 2010 dollars):

- Purchase cost for water is assumed to be approximately $2,650/AF.
- Assumed purchase cost is based on unit cost to build the project, and an additional $150/AF for agency coordination.

Ocean Desalination

Category: Ocean Desalination (Table Reference: R)

For the 50 mgd plant, capital costs are estimated to be approximately $1.3 billion (including treatment facilities, conveyance, intake facilities, and discharge facilities). Operation and maintenance costs are estimated to be $50 million per year.

- Project would eligible for State and Federal grant funding.

Water Quality:

In lieu water delivered to PWP will be imported water from MWD's Weymouth water treatment plant (WTP). Product water quality from MWD's Weymouth WTP meets all primary drinking water standards. Total dissolved solids (TDS) ranges from 487-678 ppm, with the highest running annual average of 565 ppm.

Weymouth WTP historically received a blend of SWP water and CRA water until 2008, when MWD's operations changed resulting from the environmental restrictions in the Delta. Since 2008, Weymouth WTP has been treating only CRA water which does not meet Raymond Basin water quality objectives for TDS.

Institutional Coordination:

This option would require coordination with SDCWA and MWD.

Environmental Impacts:

Desalination is a locally developed water source and can reduce the environmental impacts associated with imported water. However, because the desalination treatment process is very energy intensive, there would be no significant reduction in the carbon footprint of water production. Environmental review of ocean aquatic habitat impact will be required to determine the impacts of brine discharge and intake facilities.

Pasadena Water and Power (PWP) Water Integrated Resources Plan (WIRP)
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Local Surface Water - Arroyo Seco													
Expanded Arroyo Seco Diversions and Recharge	The City of Pasadena has water rights to divert up to 25 cfs of surface water from the Arroyo Seco for water supply use. This water is currently used for groundwater replenishment at the Arroyo Seco spreading grounds, and is limited to 18 cfs due to diversion and spreading capacity. Current operations yield approximately 2,500 AFY of PWP recharge on average, which produces approximately 1,500 AFY of PWP supply yield after Raymond Basin Management Board (RBMB) credits are applied. This option proposes improvements to the City of Pasadena's diversion structure and expand spreading basins to maximize use of water rights. The total capacity of the spreading basins would be designed to 32 cfs, since facilities would be shared with Lincoln Avenue Water Company which has ~7 cfs of water rights.	New Spreading Basins:	Recharge	2,301	80%	1,841	$3,400,000	$233,900	$289,704	$0	$789	Cost includes diversion improvements and spreading basin expansions, as well as groundwater pumping O&M costs to recover supply yield. Yield shown in table is PWP portion of yield only (LAWC yield not included). Yield assumes surface diversions will first be sent to the new spreading areas (which have a higher credit percentage) before being sent to existing spreading areas. The total average combined yield of existing and new spreading areas is 2,164 AFY after credits, which is 664 AFY of new supply yield over existing operations (which yield 1,500 AFY). Unit cost is based on incremental new yield over existing conditions (664 AFY.)	A
		Existing Spreading Basins:	Recharge	539	60%	323							
		Total:	Recharge	2,840	60-80%	2,164							
Local Treatment Plant (Arroyo Seco)	The City of Pasadena's Behner WTP was shut down in 1993 due to water quality issues. This option proposes treatment process improvements to bring the Behner WTP capacity back online. The proposed Behner WTP capacity is 1.3 MGD (2.0 cfs). However, yield is dependent on surface water availability. Excess water would be sent to the Arroyo Seco spreading basins (yields shown do not assume diversion structure improvements or spreading basin expansions).	New Treatment Plant:	Potable	858	100%	858	$5,900,000	$406,000	$275,648	$0	$1,650	See note 1. Yield assumes surface diversions will first be sent to the new treatment plant before being sent to existing spreading areas. The total combined yield of the treatment plant and existing spreading areas is 1,913 AFY after credits, which is 413 AFY of new supply yield over existing operations (which yield 1,500 AFY). Unit cost is based on incremental new yield over existing conditions (413 AFY). O&M cost includes groundwater pumping to recover supply yield from recharge at existing basins.	A
		Existing Spreading Basins:	Recharge	1,759	60%	1,055							
		Total:	Potable/ Recharge	2,617	60-100%	1,913							
Devil's Gate storage to Eaton Canyon spreading basins	This is a Los Angeles County conservation project. Devil's Gate Reservoir along the Arroyo Seco (downstream of PWP's spreading basins) has potential to capture and store water. This project proposes to move stored water though new pipeline conveyance to Eaton Wash speading basins. PWP is a potential partner for this project, and could receive pumping credits for a portion of the water recharged at the spreading grounds.	Pumping from Devil's Gate Reservoir	Recharge	1,249	Near-term: 23.5% of total water spread Long-term: 35.5% of total water spread	443	$11,000,000	$756,900	$439,030	$0	$674	Conservation of water behind dam may increase natural replenishment to groundwater/tunnels. Need to consider environmental demands downstream of the Devil's Gate dam. Eaton Wash spreading basins have more storage capacity than the Arroyo Seco spreading grounds. Replenishment on the East side of the groundwater basin (near Eaton Wash) is desired since groundwater levels in this area have been experiencing decline. Implementing the stormwater capture sub-option would reduce the yield of the 'Centralized Stormwater Capture' option by approximately 25 percent, due to overlapping drainage areas of the options. O&M costs assume $120/AF groundwater pumping costs to recover supply yield.	B
		Stormwater Capture Sub-option (connect existing storm drain pipes to pipeline routed to Eaton Wash)		518		184							
		Total:		1,767		627							

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Devil's Gate storage to expanded Arroyo Seco spreading basins	Similar to above, but water would first be pumped to the Arroyo Seco spreading basins up to capacity (existing or expanded), and then conveyed to Eaton Wash spreading basins.		Recharge	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** Preliminary hydrologic analysis shows that the occurences when sufficient water is collected at Devil's Gate Reservoir to pump to the Arroyo Seco spreading grounds are during storm events with significant rainfall where the Arroyo Seco spreading grounds have reached capacity and are overflowing into Devil's Gate Reservoir. As a result, this option would not generate additional capacity.	
Tunnel Water to Brookside Golf Course	This option proposes to utilize existing groundwater tunnels that were constructed for water supply purposes in the early 1900's and have been used on and off over time, but have been out of service since 1999. Groundwater seeps into the tunnels and flows toward the Arroyo Seco. The City of Pasadena has water rights to capture and divert some of the tunnel flows, which were used to meet irrigation demands at Brookside Golf course when tunnel diversions were operational. This option would include a new lined storage pond at the golf course.		Non-potable/ Recharge	436	100%	436	$947,071	$65,200	$26,064	$0	$209	If tunnel flows are captured and diverted, need to consider environmental demands for water in the Arroyo Seco.	C
Arroyo Seco Diversions to Brookside Golf Course	This option proposes to capture surface runoff from the Arroyo Seco diversion point and store it in a large cistern under Broodside Golf Course, for use in meeting non-potable demands (i.e. irrigation). Facilities required include a new 8-inch, 10,0000-foot pipeline and 4 million gallon (MG) cistern.		Non-potable	771	100%	771	$5,090,000	$350,200	$161,800	$0	$664	**No further evaluation.** This option is not cost-effective compared with other similar options such as using Tunnel Water to Brookside Golf Course.	D
Arroyo Seco Diversions to non-potable system	This option proposes to utilize up to 25 cfs of Arroyo Seco diverions rights for non-potable use. The surface water diversions would connect to a new non-potable distribution system and augment recycled water supply.		Non-potable	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** This option would be implemented in conjunction with the maximum recycled water distribution system to non-potable reuse. The Arroyo Seco diversions, which are typically not available during peak summer demand months, would augment recycled water supply and reduce the amount of winter-time recycled water purchases from the LA-Glendale WRP. If the maximum non-potable distribution system is pursued at a later time, it is recommended that this option is further studied.	
Local Suface Water - Eaton Wash													
Eaton Wash diversions direct to non-potable demand	The City of Pasadena has water rights to divert up to 8.9 cfs of surface water from the Eaton Wash for water supply use. The water is currently sent to the Eaton Wash spreading basins which are owned and operated by the County. This option proposes to divert Eaton Wash surface water into a future recycled distribution system for non-potable use such as irrigation. This option involves construction of a new 12-inch, 5,000-foot pipeline (3.9 cfs capacity) to convey water to the proposed recycled water system.	Non-potable supply:	Non-potable	148	100%	148	NA	NA	NA	NA	NA	**No futher evaluation.** This option does not produce significant system-wide yield benefits,and the cost savings of recycled water offsets will likely not be significant compared with the capital cost of the project. Current spreading operations yield approximately 880 AFY on average after credits are applied. Any water that does not serve non-potable demands directly would be sent to the spreading basins.	
		Existing Spreading Basins:	Recharge	TBD	80%	NA							
		Total:	Non-potable/ Recharge	TBD	80-100%	NA							
Local Treatment Plant (Eaton Wash)	This option proposes to construct a new water treatment plant to maximize yield of the City's water rights to divert flows from Eaton Wash for water supply. The treatment plant would be designed to produce potable water and connect to the City's existing distribution system. This option would not increase water supply as water rights of Eaton Wash are currently being maximized.		Potable	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation**. Hydrologic analysis of potential yields to not show significant increase in new supply over historical yields from spreading operations; therefore, do not warrant construction of a new water treatment plant. The water losses PWP experiences from the credit formula typically occur in very large storm events that occur infrequently, and it is likely that Eaton Dam provides some benefit to spreading operations.	
Groundwater													
Rehabilitation/Treatment at Existing Wells	Add treatment to or rehabilitate existing wells currently offline or with limited use.		Potable	NA	100%	NA	NA	NA	NA	NA	NA	**No further evaluation.** PWP has already planned to rehabilitate and maintain existing wells that are part of the baseline system through the planning horizon. Given the other groundwater options that add extraction capacity, and the excess capacity of the baseline wells, it is not expected that additional groundwater well capacity options are necessary for this analysis.	E

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Impaired groundwater wells	Evaluate potential of groundwater from existing Sheldon Well and Eaton Canyon Well for non-potable use.	Non-potable	NA	100%	0	$397,000	$27,300	$139,000	$0	NA	Would need to be paired with a groundwater replenishment source option; not a stand-alone option.	E
Eastside Well Collector Pipeline	Would include air release capability to allow operation of existing Jourdan Well, and would replace existing pump and motor at Jourdan well. Would provide a means for centralized treatment at Jones Reservoir for water produced by Eastside wells. Incremental new groundwater capacity of 11,747 AFY over baseline capacity (with addition of Chapman, Craig, Jourdan, and Monte Vista wells).	Potable	NA	100%	0	$12,631,300	$869,100	Assume same as existing wells ($120/AF)	$0	NA	This project is a component of the Pasadena Groundwater Storage Program option. This option would improve reliability of existing wells that currently have water quality issues, and allow more flexibility in operations. This option would need to be paired with a replenishment option to recover any new yield from the groundwater basin.	F
Recycled Water - WRP Source Options												
Purchase water from the Los Angeles-Glendale Water Reclamation Plant (WRP)	The City of Pasadena has an agreement with the City of Glendale to purchase up to 6,000 AFY (9 MGD peak) of recycled water from the Los Angeles-Glendale Water Reclamation Plant (WRP), which consists of a tertiary treatment process. Using the recycled water for indirect potable reuse would require construction of an advanced treatment facility in Pasadena.	NA	6000 AFY (9 MGD peak) contract	100%	6000 AFY (9 MGD peak) contract	$0	$0	$1,518,000	$0	$253	This source would serve recycled water demand options.	
Satellite plants for On-site Non-potable Demands	Potential large customers could construct a satellite treatment plant that would treat on-site sewer flows and produce recycled water that could be used to meet on-site non-potable demands such as irrigation. Sludge/biosolids from the treatment process would be returned to the sewer system. For this option, a joint satellite plant that would serve Caltech and PCC is considered.	Non-potable	410	100%	410	$11,577,000	$796,600	$117,000	$0	$2,228		G
Construct new water reclamation plant in Pasadena	This option involves construction of a new 2-MGD water reclamation plant (WRP) with membrane bioreactor and reverse osmosis treatment in Pasadena.	NA	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** The availability of wastewater in the sewer trunk line for PWP use is uncertain due to other planning efforts (i.e. by the Sanitation Districts of Los Angeles County) proposing to beneficially utilize this water.	
Partner with Foothill MWD to construct a new regional water reclamation plant	The option proposes a partnership with Foothill MWD to construct a new regional WRP in Foothill MWD's service area and transport some of the recycled water to Pasadena. This concept proposes a 4-MGD (4,480 AFY) WRP with membrane bioreactor treatment, and would send approximately 3,360 AFY of recycled water to recharge (assuming the spreading basins are available 25% of the time due to recharge of stormwater runoff, maintenance, etc).	NA	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** Implementation of this option is not within the jurisdiction of PWP. This concept is in very early planning stages and there is not enough information to warrant feasibility for analysis at this time. It is recommended that this option be studied in future updates of the WIRP when more information becomes available.	
Construct a new centralized satellite plant in Pasadena	This option proposes construction of a new 2-MGD satellite membrane bioreactor (MBR) treatment plant in Pasadena. The plant would treat water from the sewer collection system for non-potable reuse, and sludge/biosolids from the treatment process would be returned to the sewer system.	Non-potable	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** The availability of wastewater in the sewer trunk line for PWP use is uncertain due to other planning efforts (i.e. by the Sanitation Districts of Los Angeles County) proposing to beneficially utilize this water.	

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Recycled Water Demand Options													
Direct Potable Reuse	This option concept involves advanced treatment of recycled water, which would then serve potable demands directly.		Potable	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** Although there have been significant advances in treatment technology and monitoring methodology that could make direct potable reuse a reasonable option to consider, there are currently no regulations or criteria in California for this type of a project. Direct potable reuse has yet to be applied in California, and has historically been deemed unacceptable by regulatory agencies. It is recommended that Direct Potable Reuse be studied at a later date due to the current regulatory hurdles. Therefore, this option has been screened our from further evaluation in this analysis.	
Indirect Potable Reuse	This option will evaluate using recycled water for an indirect potable reuse project. Recycled water would be sent to the Eaton Canyon groundwater spreading grounds and recovered via extraction wells to serve potable demands. Indirect potable reuse concepts are being considered in the Recycled Water Master Plan (RWMP).	Tertiary-treated recycled water (RWMP Alt EW2)	Recharge	930	99%	921	$4,011,000	$276,000	$362,484	$0	$693	Costs for source water not included here. O&M costs of groundwater pumping to recover supply yield are included ($120/AF).	H
		Advanced-treated recycled water (RWMP Alt EW4)	Recharge	2,636	99%	2,610	$55,111,000	$3,791,900	$3,705,157	$0	$2,873	Costs for source water not included here. O&M costs of groundwater pumping to recover supply yield are included ($120/AF).	H
Non-Potable Demands	This option involves constructing a recycled water distribution system to non-potable demands such as irrigation. Non-potable demand concepts are being considered in the Recycled Water Master Plan (RWMP)	Maximize NPR (RWMP Alt 3): Maximizes the use of recycled water under MDD conditions, and provides flexibility for groundwater replenishment (with tertiary treatment) at Eaton Canyon spreading grounds.	Non-potable	3,000	100%	3,000	$38,600,000	$2,655,900	$140,000	$0	$932	Costs for source water not included here. Capital costs include assumed customer retrofit cost of $2000/AFY. Note that customer retrofits vary on a case by case basis, and this cost is a gross assumption to account for customer costs for purposes of the WIRP. Buildout non-potable reuse alternatvies evaluated in the RWMP have similar yields and costs. Since the WIRP analysis is intended to be strategic-level planning, one representative non-potable reuse buildout alternative (Alternative 3) is evaluated	I
		Smaller Phase 1: This option is a lower level of non-potable reuse demands, and can be combined with a groundwater replenishment options that includes an advanced treatment system.	Non-potable	1,130	100%	1,130	$15,260,000	$1,050,000	$80,000	$0	$1,000	Costs for source water not included here. Capital costs include assumed customer retrofit cost of $2000/AFY. Note that customer retrofits vary on a case by case basis, and this cost is a gross assumption to account for customer costs for purposes of the WIRP.	I
Graywater													
Graywater	Graywater refers to the water from non-sewage household activities (such dishwashing, laundry, and bathing) that can be recycled for non-potable uses. This option would provide retrofits to existing homes to allow on-site graywater recycling, either through irrigation, toilet use, or other similar uses.		Non-potable	807	100%	807	$54,000,000	$3,715,500	$1,084,000	$0	$5,947	Yield assumes water from laundry, bathtub and shower, and is the total yield if 10,000 homes participate.	J

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Stormwater/Urban Runoff												
Centralized Stormwater Capture to Recharge	A diversion system would be constructed in the existing storm drain network to capture stormwater and divert it to the Eaton Spreading Grounds. Facilities required for this option include storage, a new pump, and new pipeline conveyance from the capture point to the spreading grounds. Treatment needs will need to be investigated.	Recharge	421	Near-term: None. Long-term: 10.5% of total water recharged	44	$2,600,000	$178,900	$38,305	$0	$4,914	**No further evaluation.** RBMB may implement this option to improve recharge into the basin, but PWP would not receive significant supply credits. It should be noted that a portion of the drainage area for this option overlaps with the Devil's Gate Storage to Eaton Canyone spreading basins option (urban runoff collected along conveyance pipeline).	K
Residential Rain Barrels (onsite capture)	Residential households will be provided rain barrels to capture storm runoff from rooftops to on-site storage. The water can then be used for non-potable purposes such as irrigation.	Non-potable	32	100%	32	$1,759,000	$121,000	$88,000	$0	$6,531	Yield represents the amount of water that can be captured from rooftop areas and stored in 100 gallon rain barrels. Assumes 25% implementation across service area.	L
Residential Rain Gardens (onsite capture)	Residential households would construct a raingarden to retain water on-site. The option would collect water from rooftops of residential homes. Water would infiltrate into Raymond Basin.	Recharge	106	Near-term: None. Long-term: 10.5% of total water recharged	11	$3,235,500	$222,600	$163,336	$0	$34,675	This option does not produce significant supply yield, but has water quality benefits for the watershed. O&M costs assume $120/AF groundwater pumping costs to recover supply yield. Assumes 25% implementation across service area.	L
Residential infiltration strip/bioswale (onsite capture)	Residential households would construct a swale at the edge of the property to retain water on-site. This option assumes water is collected from rooftops, driveways, and lawn overwatering. Water would infiltrate into Raymond Basin.	Recharge	256	Near-term: None. Long-term: 10.5% of total water recharged	27	$10,397,500	$715,400	$523,226	$0	$46,080	This option does not produce significant supply yield, but has water quality benefits for the watershed. O&M costs assume $120/AF groundwater pumping costs to recover supply yield. Assumes 25% implementation across service area.	L
Commercial Parking Lot Swales (onsite capture)	Commercial businesses would construct a swale to collect stormwater from parking lot drainage areas. Water would infiltrate into Raymond Basin.	Recharge	321	Near-term: None. Long-term: 10.5% of total water recharged	34	$10,147,920	$698,200	$511,045	$0	$35,877	This option does not produce significant supply yield, but has water quality benefits for the watershed. O&M costs assume $120/AF groundwater pumping costs to recover supply yield. Assumes 30% implementation in commercial parking lots across service area.	L

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Permeable pavement (parking lots)	Permeable pavement refers to pavement with infiiltration capabilities to allow water to seep into the ground instead of being routed to storm drains. Permeable pavement would reduce runoff volume into the storm drains and provide some recharge benefits to the Raymond Groundwater Basin.	Recharge	324	Near-term: None. Long-term: 10.5% of total water recharged	34	$21,122,571; Approx. $6,035,000 more than traditional pavement	$415,200	$4,082	$0	$12,325	This option des not produce significant supply yield, but has water quality benefits for the watershed. Unit cost reflects the net capital cost increase over traditional pavement. O&M is assumed to be comparable to asphalt paving. O&M costs assume $120/AF groundwater pumping costs to recover supply yield. Assumes 20% implementation of large designated parking lot areas within service area.	M
Utilize streets as recharge areas	This option proposes to capture larger drainage areas and utilize streets as recharge areas, similar to the Elmer Avenue Neighborhood Retrofit project in Los Angeles.	Recharge	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation**. The Elmer Avenue project resulted in approximatly 16 AFY of recharge. There are several other options on the list that have very similar benefits (increase recharge and reduced pollutant discharges) that are representative of this option. The WIRP evaluation is very high-level strategic analysis. Should similar options be recommended, this type of project would be part of a more detailed feasibility study.	
Imported Water												
MWD Treated Imported Water Purchases	Continue to purchase imported water treated at Weymouth WTP from Metropolitan Water District (MWD). Most of the water treated at Weymouth WTP is from the Colorado River, while some source water is from Northern California via the State Water Project.	Potable	Based on need, as available	100%	Based on need, as available	$0	$0	$0	TBD in Portfolio Analyses	$811	Unit cost expected to increase faster than inflation at least for next 20 years.	N
North of Delta Transfers	Participate in a transfer agreement to receive water from Sacramento Valley area in drought years. Although this source water would not be purchased from MWD, it would be delivered via MWD facilities.	Potable	3,000	100%	3,000	$0	$0	$0	Included in O&M costs	$982	Costs include purchase cost, wheeling, and treatment.	O
Groundwater Banking	Participate in a groundwater banking agreement to store water underground (i.e. in Central Valley) for future use during dry periods. Groundwater extractions would be delivered from the Central Valley to the City of Pasadena via MWD faciliites.	Potable	2,000	100%	2,000	$10,000,000	$688,100	$5,360,000	Included in O&M costs	$1,210	Costs are expected to be higher than the water transfers option, but water banking is more reliable than transfers.	P
Pasadena Groundwater Storage Program (PGSP)	Utilize storage accounts in Raymond Basin and recharge through direct injection of treated water, spreading, or in-lieu (reduced groundwater pumpting), and recover at a maximum rate of 25,000 AFY in drought or emergency periods (average yield over time is roughly 5,000 AFY). Includes construction of the Eastside well collector and three new injection/extraction wells.	Recharge/ Potable	4,890	100%	4,890	$36,145,400	$2,487,000	$586,800	$3,789,500	$1,404	Costs shown are total for project. However, O&M costs do not include operation of the new FMWD nitrate treatment facility.	Q
Raw Imported Water Recharge (put/take)	Partner with Foothill Water Coalition to construct new conveyance of raw imported water to recharge areas in Raymond Basin. This project is known as the San Gabriel/Raymon Basin Feeder, and would extend the existing Devil Canyon Azusa Feeder Pipeline, owned by the San Gabrial Valley Municipal Water District (a State Water Project contractor), to the San Gabriel Basin and Raymond Basin for groundwater replenishment. Phase 1 of this project would extend the raw water pipeline from its current terminus in Azusa to the Santa Anita and Sierra Madre Spreading Grounds. Phase 2 would provide water to the Eaton Wash spreading grounds. Phase 3 would provide water to the Arroyo Seco Spreading Grounds.	Recharge	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** There is not currently adequate information to evaluate the potential yield of this option. However, the Foothill Water Coalition will likely evaluate the feasibility of this option. It is recommended that this option be evaluated in future updates of the Integrated Resources Plan as more information becomes available.	

Pasadena Water and Power (PWP) Water Integrated Resources Plan (WIRP)
Table E-1. List of Potential Water Resource and Conservation Options

Source or Demand Option	Brief Description	Type of Use[2]	Project Yield/Demand - Long-term Average, Before Credits (AFY)	PWP Supply Credit (%)	PWP Supply Yield/Demand - Average, After Credits (AFY)	Total Capital Cost ($, Current)	Total Annual Capital Payment ($/year)	Total Average Annual O&M Cost ($/year)	Total Average Annual Imported Water Cost ($/year)	Unit Cost of Supply Yield ($/AF, current dollars)	Notes	Reference
Raw imported water to non-potable demands	Purchase raw imported water through a new conveyance connection to augment a future recycled water distribution system.	Non-potable	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** This option would be implemented in conjunction with the raw imported water recharge option (above). As such, it is recommended that this option be evaluated in future updates of the IRP as more information becomes available.	
Ocean Desalination												
Ocean Desalination	Evaluate a potential partnership with a regional agency to construct an ocean desalination facility There is a possibility to partner with San Diego County Water Authority (SDCWA) on a new 50-mgd ocean desalination plant (100-mgd ultimate) near Camp Pendleton. PWP would pay a purchase cost for water once the plant is constructed. This would be an exchange agreement, since the desalinated water would physically be delivered to SDCWA member agencies and in return, PWP would recieve the water allocation via MWD's facilities. This would require coordination with SDCWA and MWD.	Potable	5,000	100%	5,000	$0	$0	$0	$0	$2,650		R
Conservation												
Moderate Conservation Program	Includes various conservation options listed below (see notes column)	Potable/Non-potable	6,600	100%	6,600	$0	$0	$2,790,000	$0	$692		
Aggressive Conservation Program	Includes various conservation options listed below (see notes column)	Potable/Non-potable	9,000	100%	9,000	$0	$0	$4,244,000	$0	$724		
Maximum Conservation Program	Includes various conservation options listed below (see notes column)	Potable/Non-potable	12,000	100%	12,000	$0	$0	$6,121,000	$0	$787		
Water Budget Rate Structure	The water budget rate would be modified to encourage conservation with a pricing structure favorable to customers remaining within monthly water allocation, while inefficient users will pay significantly higher rates in excess of monthly allocation. Customer outdoor water requirements will be based on the property type, size, and landscaping needs.	Potable/Non-potable	TBD	100%	TBD	TBD	TBD	TBD	0	TBD	Will be evaluated in the implementation phase.	
Fixture Replacement Ordinance or Expanded Rebates for Residential and Commercial Properties	Replace high water use toilets and urinals with high water efficiency devices. These replacements will be applicable to single and multi-family residential units subject to Quadrennial and Occupancy Ispection Programs, single-family units adding 500 square feet or more, and non-residential buildings built before or on Jan. 1, 1994 seeking a building permit; or through expanded rebates from PWP.	Potable	4,700	100%	4,200	$0	$0	$1,600,000	$0	$560	Partly included in Moderate Conservation Program; fully included in Aggressive & Maximum Conservation Programs.	
New Construction (landscaping)	This option would implement aggressive landscaping requirements for all new construction, essentially replacing turf with combination of drought-tolerant plants and warm season grasses.	Non-potable	2,500	100%	2,000	$0	$0	$1,000,000	$0	$850	Included in Aggressive & Maximum Conservation Programs.	
Power plant conservation	This option would decrease the amount of water used for cooling towers	Potable	NA	100%	NA	NA	NA	NA	NA	NA	This use is better served by recycled water.	
Encourage efficient irrigation	Encouraging efficient irrigation would reduce outdoor water consumption by reducing water losses due to overspray, runoff, and other factors, and replacing existing cool-season turf with warm season turf	Non-potable	1,630	100%	1,630	$0	$0	$904,000	$0	$1,000	Included in Moderate, Aggressive & Maximum Conservation Programs.	
Install individual meters in multi-family residential buildings	This option would result in the installation of individual meters (sub-meters) for new multi-family residential dwelling units or if the entire water system in an existing multi-family residential unit complex are replaced.	Potable	250	100%	250	$0	$0	$130,000	$0	$1,000	Included in Aggressive & Maximum Conservation Programs.	

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Rebates for alternative landscaping (rock gardens)	This option woould provide rebates for removing turf and replacing it with alternative low-water use landscaping materials.	Non-potable	3,000	100%	3,000	$0	$0	$2,170,000	$0	$1,400	Included in Maximum Conservation Program only.	
Real-time metering	Replacing existing manually read meters with real-time metering would allow users and PWP to monitor there water use on a real-time basis. For example, a customer could view their water use before and after outdoor watering and see how much they actually consume for outdoor water use. Data could also be used to assist customers in evaluating water use and developing suggestions for conservation. These meters would also alert customers and PWP if usage appears abnormal, such as if a break in a customer's pipe occurs.	Potable/Non-potable	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** Replacement of meters for existing customers is extremely expensive and there are few studies that indicate that real time metering leads to conservation. As such, this option will not be evaluated in the WIRP at this time.	
Minimize losses through upgraded metering system	Overtime the accuracy of meters declines. This option would result in the replacement of older meters with new meters.	Potable/Non-potable	TBD	100%	TBD	TBD	TBD	TBD	TBD	TBD	Will be evaluated in the implementation phase.	
Minimize PWP and Fire Department's fire hydrant flushing programs	See notes column.		NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** The Pasadena Fire Department requires flow tests to make sure every hydrant is ready in case of emergency and to ensure adequate pressure in building sprinkler systems; and the California Department of Public Health requires water distribution system flushing when nitrite levels exceed 25 parts per billion or when water samples test positive for coliform bacteria. Flushing is also used to release “dead-ends” (stagnant water) from the distribution system, which prevents deterioration of water quality. Flushing is a necessary operational procedure, but PWP and the Fire Department are reviewing the flushing program and intestigating ways to minimize the amount of water being flushed and how to recapture it. Because this is a tactical operational decision, it will not be evaluated as a long-term water resources strategy.	
Other concepts considered in the WIRP												
Re-operate flood control debris basins for storage and recharge	There are a number of existing flood risk management dams and debris basins on the watershed drainage areas north of the Raymond Basin. Under this option, PWP would partner with the Foothill Water Coalition to modify these basins and structures to provide a dual purpose, flood risk management and groundwater recharge, will allow this water to be captured for beneficial use instead of being discharged to the ocean. Potential debris basins for consideration in this option include the Rubio Wash Debris Basin, Pasadena Glen/Hastings Canyon Debris Basin, and Bailey Canyon Debris Basin.	Recharge	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** There is not currently adequate information to evaluate the potential yield of this option. However, the Foothill Water Coalition will likely evaluate the feasibility of this option. It is recommended that this option be evaluated in future updates of the Integrated Resources Plan as more information becomes available. One consideration to be analyzed is the impact of this option to downstream spreading areas.	
District Cooling Plant	See notes column.	Non-potable	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** A district cooling system is typically analyzed in terms of energy resource benefits. If this option is implemented for energy benefits, there is a possibility that the disctrict cooling system could utilize treated recycled water for the cooling system. However, detailed analysis of the treatment needs would be required to determine feasibility. Due to potential treatment needs, this type of use of recycled water could be expensive compared with using recycled water for irrigation or recharge, which have similar benefits of offsetting potable water use. In addition, this type of use provides no benefit to the underlying groundwater basin. Therefore, it has been screened out from further evaluation.	

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Condemn property for recharge areas	See notes column.	Recharge	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** Expansion of the Arroyo Seco spreading grounds is being considered in the WIRP, which determine whether expanded recharge areas are a preferred option. The level of public support for condemning properties for recharge areas is very uncertain, given the various options for water supply. Therefore, this option has been screened out from further evaluation.	
Convert lined ponds at golf courses to unlined ponds for recharge	This option will consider addtitional groundwater replenishment that could occur by converting lined ponds at golf courses to unlined ponds.	Recharge	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation**. After preliminary review of this option, PWP will likely not receive significant supply credit (if any) for recharge through pond losses.	
Educational Opportunities for Conservation and Reuse	See notes column.	N/A	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation**. Education opportunities are encouraged to promote conservation and reuse options, which are being evaluated in the WIRP.	
Water produced from hydrogen-burning cars	See notes column.	N/A	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** Use of water from hydrogen-burning cars is a new technology that is not predominantly used and comes with significant uncertainty as a feasible water supply strategy at this point in time. Therefore, it has been screened out from further evaluation.	
Cloud seeding	Consider a potential partnership with regional agencies for a cloud seeding program to induce rainfall to enhance local surface water supplies.	N/A	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** Effectiveness of cloud seeding is very uncertain due to unpredictable nature of clouds, and the factors needed for cloud seeding to work (i.e. type of cloud, pollution levels, etc). Even if PWP were to partner with other agencies for a regional cloud-seeding program, the benefits to PWP would be very difficult to quantify to determine cost-effectiveness of the program. Additionally, the long-term ecosystem effects are unknown due to potential changes in circlution patterns. Due to the high uncertainty associated with the feasibility and effectiveness of this option, it has been screened out from further evaluation as an integrated water resource strategy.	
De-centralized NASA shuttle systems	This concept proposes to provide self-sustaining water systems to individual residences/buildings, similar to technology used on NASA shuttles. These systems would be capable of treating on-site wastewater to a water quality level suitable for indoor potable uses.	N/A	NA	NA	NA	NA	NA	NA	NA	NA	**No further evaluation.** This option concept is similar to direct potable reuse, although it would be administered with several on site decentralized systems. Although there have been significant advances in treatment technology, there are currently no regulations or criteria in California for this type of a project. This concept has never been applied by a water utility in California, and direct potable reuse has historically been deemed unacceptable by regulatory agencies. Therefore, this option has been screened our from further evaluation in this analysis.	

[1] Any local surface water diversions going to spreading are subject to a credit formula established by the Raymond Basin Management Board, which accounts for basin losses. As a result, pumping credit (or supply yield) is a portion of water recharged. Local surface water used directly (not recharged) is not subject to the credit formula, and maximizes yield of water rights.
[2] All groundwater recharge options will require evaluation of existing recharge capacity and potential new/expanded recharge facilities, as well as evaluation of baseline well extraction capacity and potential new wells if necessary. Groundwater recharge options should also be reviewed with RBMB for general review, and to determine appropriate assumptions for credits to PWP.
[3] Annual capital payments are based on an annual interest rate of 5.5% and a payment period of 30 years
AFY: acre-feet per year
MGD: million gallons per day
cfs: cubic feet per second
WTP: water treatment plant
O&M: operation and maintenance
TBD: to be determined
NPR: non-potable reuse
WRP: Los Angeles-Glendale Water Reclamation Plant
RWMP: Recycled Water Master Plan
PGSP: Pasadena Groundwater Storage Program
NA: Not applicable