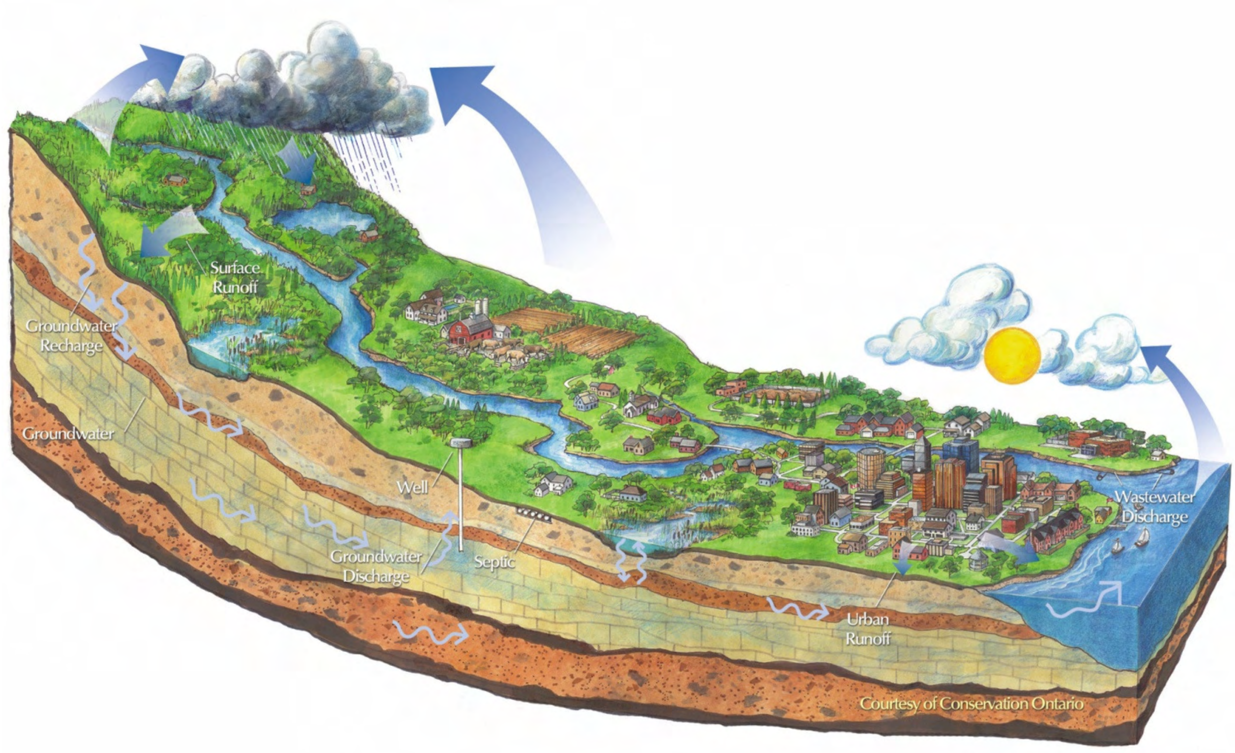
A Water Budget



For the Arroyo Seco Watershed

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April 22, 2010

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Executive Summary

A Water Budget for the Arroyo Seco Watershed has been developed to provide a better understanding of how water is used in our region and what can be done to promote conservation and better management of this invaluable resource. The original version of this document was prepared as a key component of the Arroyo Seco Watershed Management Plan & Education Program in 2003 to evaluate the Arroyo Seco Watershed, part of the Los Angeles River system in Los Angeles County, California. This version updates the 2003 report with new data and evaluation.

This watershed budget should not be viewed as a static analysis, but rather as a tool and a framework for determining how we can better manage local water resources. It illuminates many of the key water issues that face local residents and decision-makers:

- The need to protect our watershed and its precious environment;
- The critical importance of water quality to our region; and
- The need for comprehensive conservation and water management programs to reduce per capita consumption and water imports.

This study is particularly relevant because Pasadena is now developing a Water Integrated Resource Plan to plan its water future. The *Water Budget* provides critical data for that plan. We urge policy-makers and residents of the Arroyo Seco Watershed to utilize this watershed budget as a tool to ensure that water is used wisely now and in the future.

Background

Introduction

Water has always been a vital key to the environmental health and quality of life in our region. From the first settlers who established villages on the rim of the Arroyo Seco and called our region "Hahamongna – Flowing Waters, Fruitful Valley" until today, the significance of water to the health, economy and lifestyle or our region has not diminished.

This purpose of "*A Water Budget for the Arroyo Seco Watershed*" is to analyze the factors that influence water use in the Arroyo Seco Watershed in order to develop a program that will ensure wise use of local water resources and a reduction of our reliance on imported water sources such as the State Water Project and the Colorado River.

First we will examine local climatic and geographic conditions. We will summarize the relevant data and the findings of the studies that have dealt with water use, storage and conservation in the Arroyo Seco Watershed. Then we will attempt to answer some key questions, such as:

- Is there currently balance in the Arroyo Seco Watershed and the related Raymond groundwater basin?
- How much potential is there for increased groundwater storage?
- How can local reliance on imported water supplies be reduced?
- What steps can be taken to augment local conservation and storage?

The essential purpose of this report is to develop a tool to use to promote more efficient management and conservation of local water resources.

California's Water Picture

This water budget has been supported by the California Department of Water Resources and the Bay-Delta Program because the water use of residents in the Arroyo Seco Watershed affects not only our local environment but also distant regions of California and the West. Last November Governor Schwarzenegger and California legislators approved a comprehensive package of water reform measures to fix the critical Bay-Delta system, the hub of California's water system. This inland estuary serves water to twenty-five million Californians including the residents of the Arroyo Seco Watershed. A Bay Delta Stewardship Council has been formed and a long-term Bay Delta Conservation Plan is being drafted to restore ecological health and improve water reliability for the Bay-Delta System. Education, careful planning and environmental sensitivity will be necessary to restore the Bay-Delta system. It is important that all Californians develop a better understanding of their local water system as well as the statewide situation so that all those who touch or are touched by the Bay-Delta can participate in saving it.

The Hydrologic Cycle

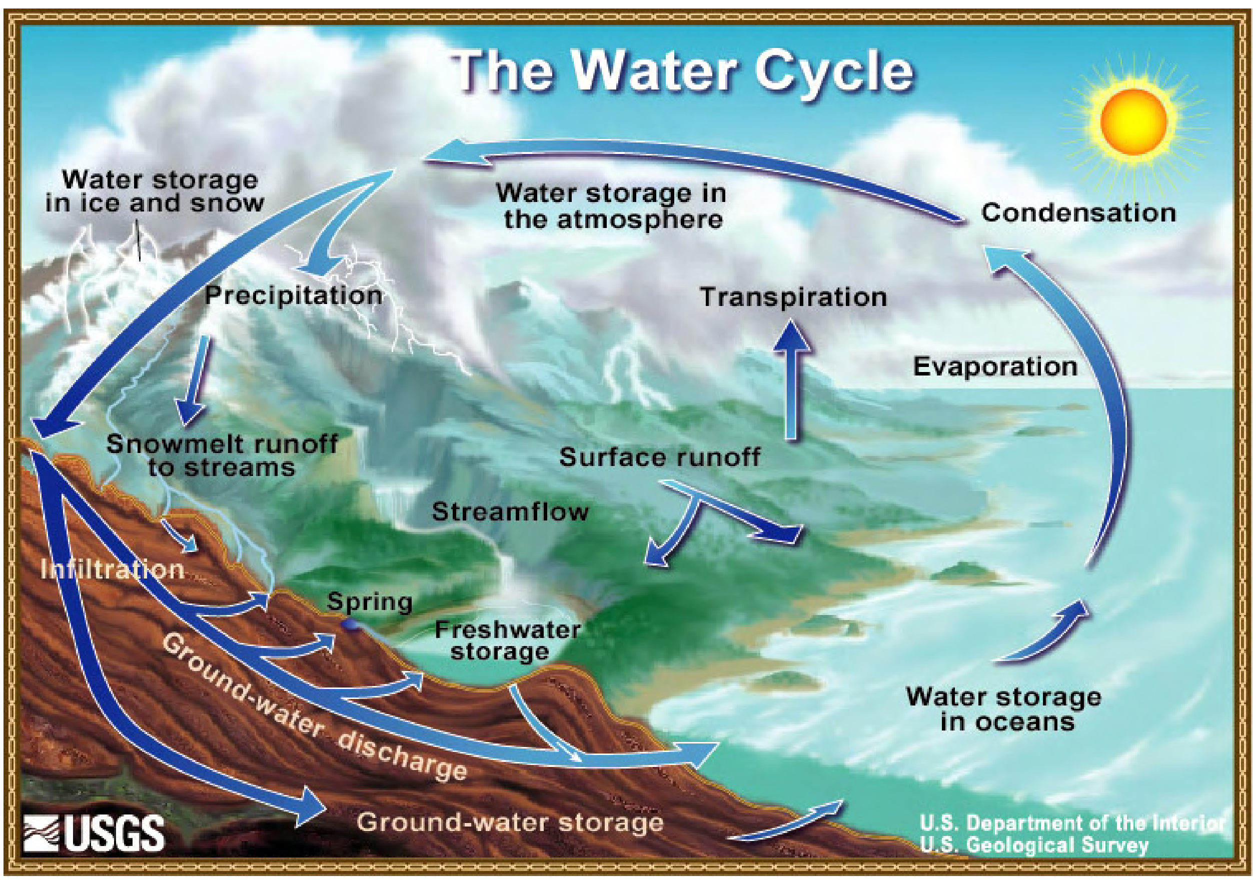


Figure 1 - The Water Cycle

A water budget measures the hydrologic cycle, or water cycle, the process through which water moves through the earth and its atmosphere.

Vapor condenses in the atmosphere until it reaches the size of drops and falls to the ground. Through infiltration some water then soaks into the soil where it increases soil moisture and can percolate down to the groundwater zone. Some rainfall will flow across the earth's surface as runoff. Through transpiration from plants and evaporation, water changes from the liquid to the gaseous state and passes into the atmosphere to complete the cycle.

Land use and vegetation affect the water cycle. Buildings, roads, paving and flood channels block infiltration and accelerate storm runoff. Trees and vegetation can facilitate infiltration and slow soil erosion and storm flow.

Types of Water Budgets

"Water Budget" is a term that can have a variety of meanings. The US Geological Survey defines a water budget as an "Estimate of the size of future water resources in an aquifer, catchment area, or geographical region, which involves an evaluation of all the sources of supply or recharge in comparison with all known discharges or extractions." This kind of water budget is sometimes also referred to as a *water balance*.

The California Urban Water Conservation Council (CUWCC) now mandates the development of a "water budget" for all major landscape sites as part of Best Management Practice 5 -- Large Landscape Conservation Programs and Incentives. Separately metered landscapes (parks, schools, greenbelts, commercial landscapes, agricultural acreage, etc.) are allocated water based on the square footage of the site served and the actual weather conditions including rainfall and evapotranspiration (ET). Some water districts charge irrigation accounts increasingly higher rates if that site uses more water than specified by the water budget. The California Model Water Efficient Landscaping Ordinance has developed a similar approach to evaluating efficient water use.

This water budget evaluates the Arroyo Seco Watershed, part of the Los Angeles River system in Los Angeles County. Our approach is similar to a careful study of a financial account in which we study the income and expenses so that we can see how much money is still left in the balance (storage) for future use. Using historic data and estimates, the Arroyo Seco Watershed Budget can be a valuable tool to plan for the best possible use of one of our most precious resources, water.

Related Studies

Water budgets are more precise when they are developed for specific sites or hydrologic features, such as groundwater basins. There have been a series of studies of the Raymond Basin, the groundwater basin that underlies the upper portion of the Arroyo Seco Watershed. These studies have evaluated and modeled the basin, developing complete water budgets for the aquifer. These studies include:

1. Phase I Report – Devil's Gate Multi-Use Project (1990) and Phase II Report – Devil's Gate Multi-Use Project (1991), prepared by CH2M Hill
2. Technical Memorandum on Raymond Basin Groundwater Flow Modeling, Metropolitan Water District, April 17, 1997
3. Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin, prepared for the Raymond Basin Management Board by Geoscience Support Services, July 7, 2003

The Phase I Report on the Devil's Gate Multi-Use Project, prepared by the engineering company CH2M Hill, analyzed the potential for a groundwater storage program in the Raymond Basin. It evaluated impacts associated with four conjunctive use concepts, which ranged from increasing local pumping during period of high water demands to developing a regional water storage program. The Phase II (1991) report concluded that there were substantial benefits to local parties and no major institutional constraints to implementing a conjunctive use program in the Raymond Basin. As part of their analysis, CH2M Hill developed a Coupled Flow, Energy Solute Transport (CFEST) model, which calculated inputs and outputs for the Raymond Basin.

In 1997 Metropolitan Water District staff prepared a "Technical Memorandum on Raymond Basin Groundwater Flow Modeling." This report updated the CFEST model and converted it to USGS Modflow, the most widely used modeling software at that time. This report included a historical water balance for the Raymond Basin and two projected water balances for two alternative storage program being considered as part of the Raymond Basin Conjunctive Use Program (RBCUP).

In 2003-5 Geoscience Support Services developed a baseline groundwater assessment of the Raymond Basin for the Raymond Basin Management Board. The study was intended to resolve key issues about the potential for groundwater storage and the water quality impacts of such a program. The study reviewed past groundwater models and developed a revised model to provide reliable data for better management of the basin. A preliminary report, "Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin" dated July 7, 2003, contains updated water balance data and provides a revised estimate of the storage capacity of the Raymond Basin.

These studies have thoroughly evaluated the groundwater basin and its inputs and outputs to develop water budgets or balances to determine issues such as:

- The level, potential and effects of storage in the basin,
- flow characteristics, and
- water quality impacts of spreading and storage.

The Los Angeles County Department of Public Works (LACDPW) has developed a hydrologic model of the Arroyo Seco Watershed that can be used to perform simulations of peak discharges for various storm events and land use conditions. This model was developed using the Watershed Modeling System (WMS), which has been adopted by LACDPW for future hydrologic analyses. WMS, which uses standard GIS software, can run hydrologic routines similar to the US Army Corps of Engineers HEC-1 program or LACDPW's modified rational method. This model, however, does not use historical data about precipitation, runoff and flow as a water budget model would.

Despite all this work, the California Department of Water Resources in its 2003 report, "California's Groundwater -- Bulletin 118," states in the description of the Raymond Basin: "Not enough data exist to compile a detailed groundwater budget for this basin."

While the Raymond Basin has been studied extensively, developing a water budget for the Arroyo Seco Watershed is challenging because of the geographic, governmental and hydrologic characteristics of the Watershed. The Arroyo Seco Watershed is not a closed system and has a variety of features that make precision difficult. These include:

- The Arroyo Seco Watershed overlies only part of the Raymond Basin groundwater aquifer, which is also replenished by the Rio Hondo Watershed. The Monk Hill Subbasin in the northwest corner of the basin and part of the main basin underlie the Arroyo Seco Watershed, which is bounded on the east by Millard Canyon in the foothills of the San Gabriel Mountains. Canyons further east including Rubio, Las Flores and Eaton also replenish the groundwater basin, but they are part of the Rio Hondo/San Gabriel River watershed. One third of Pasadena, for instance, physically lies within the Arroyo Seco Watershed, but all of Pasadena overlies the Raymond Basin.
- Areas outside the Arroyo Seco Watershed and even outside the Raymond Basin territory receive significant amounts of water from the Raymond Basin. Arcadia, for instance, receives almost 20% of the total production of the basin.
- The portions of South Pasadena and Northeast Los Angeles that lie in the Arroyo Seco Watershed are below the Raymond Dyke and separated from the Raymond Basin. There is no significant groundwater storage in these communities, so runoff and stream flow are captured by the storm channel system or move as unmetered subsurface water flow to the Los Angeles River.
- The usage patterns of Arroyo Seco Watershed residents are not measured as distinct from other residents of Pasadena, Los Angeles or other communities.
- The total outflow of the Arroyo Seco into the Los Angeles River is not metered or measured. The County of Los Angeles maintains a stream flow meter just south of Devil's Gate Dam and another near Debs Park briefly, but there is no historic measurement of the amount of water flowing from the Arroyo Seco Watershed into the Los Angeles River near Elysian Park in Los Angeles.

This water budget for the Arroyo Seco Watershed will use a combination of techniques to evaluate all the sources and losses of water that constitute the hydrologic cycle in the Arroyo Seco Watershed. These methods involve data gathering, analysis and informed estimates where only incomplete data exist.

The Arroyo Seco Watershed

The **Arroyo Seco Watershed Restoration Feasibility Study** describes the Arroyo Seco Watershed in this way:

> "The Arroyo Seco is one of southern California's greatest natural treasures. The Arroyo Seco watershed represents an outstanding opportunity for the region to demonstrate a collaborative, multi-purpose approach to the management of vital natural resources. The 46.6 square mile Arroyo Seco watershed is tributary to the Los Angeles River and spans five jurisdictions, including, from north to south, the Angeles National Forest, the unincorporated community of Altadena, the City of La Cañada Flintridge, the City of Pasadena, the City of South Pasadena, and the City of Los Angeles."

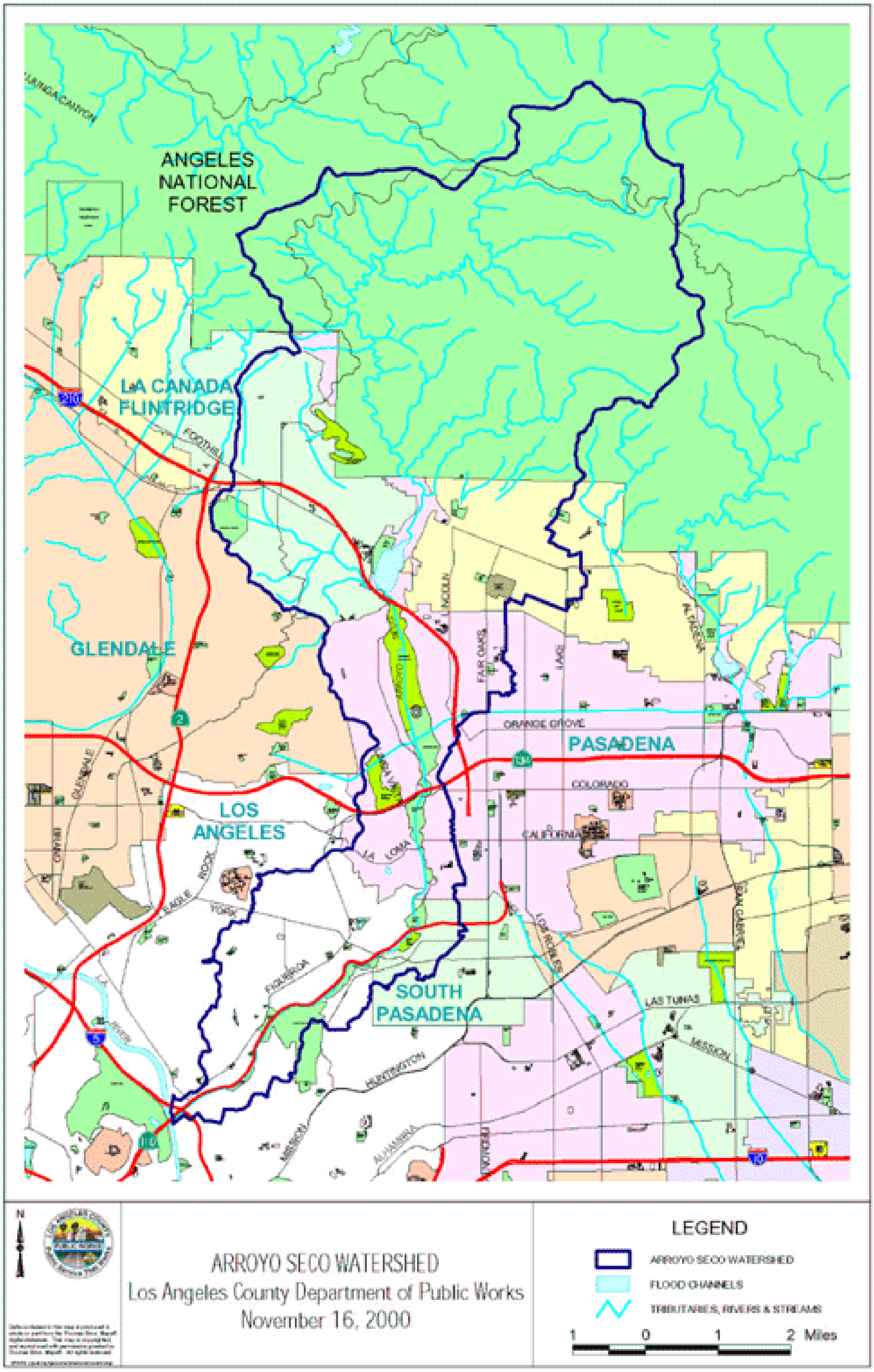


Figure 2 - The Arroyo Seco Watershed

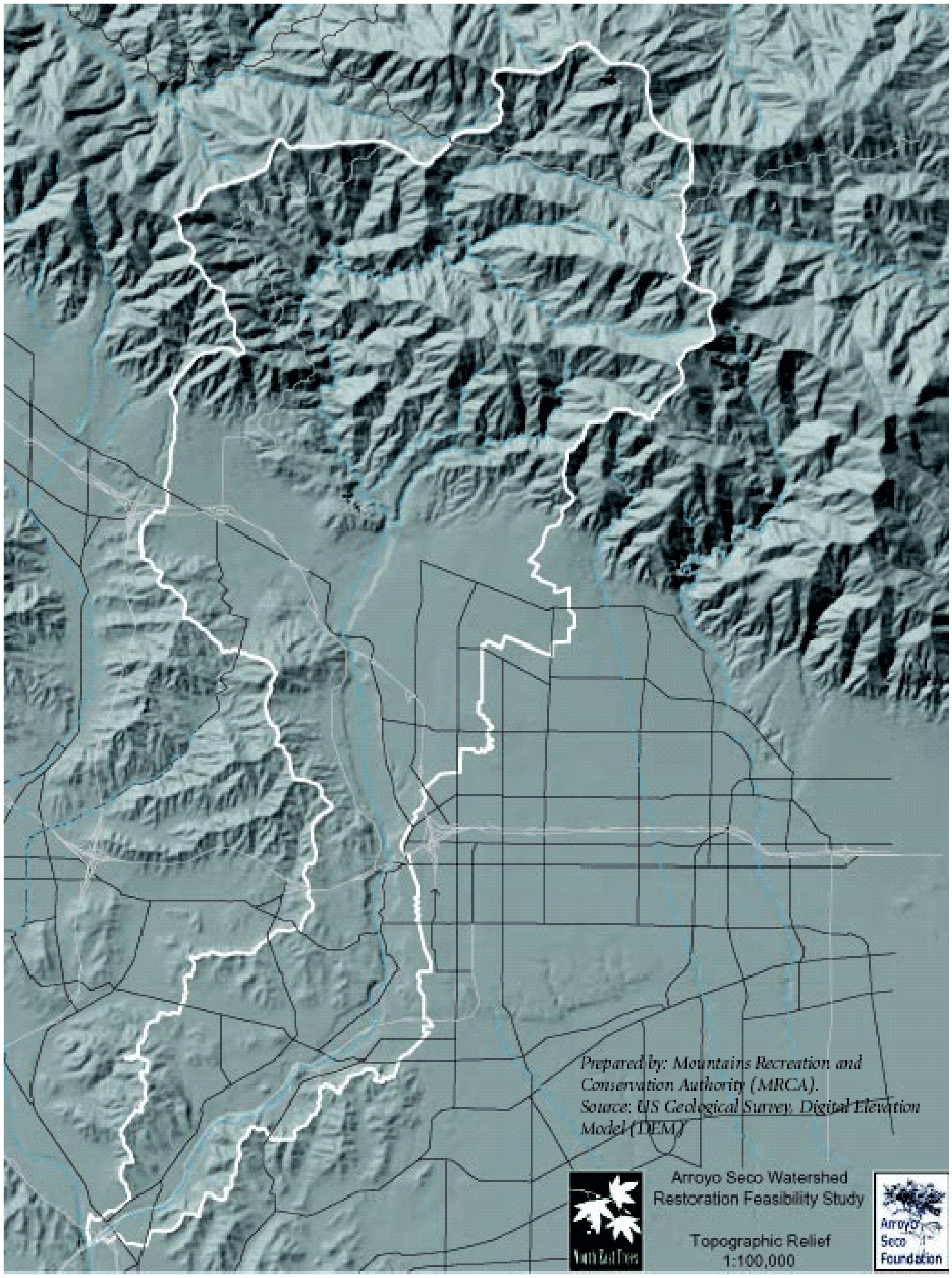


Figure 3 - Topographic Relief of the Arroyo Weco Watershed

The Watershed Budget

The Arroyo Seco Watershed is a relatively small but diverse watershed, composed of mountainous upper watershed and urbanized foothills and plain. This water budget will quantify precipitation, runoff, recharge, evaporation, transpiration and human uses of water within the watershed. This will help those interested in the Arroyo Seco to understand how water arrives, flows through and leaves the watershed, and how human activities modify the natural flow of water.

Precipitation is the sole natural source of water in the Arroyo Seco. Some of the rain that falls on the terrain of the Arroyo Seco evaporates from the land or water surfaces or transpires from vegetation. These two processes are referred to as "evapotranspiration." The remainder of the rainfall either infiltrates into the aquifer beneath part of the watershed or flows off the land surfaces into storm channels that empty into the Arroyo Seco. This runoff flows to the Los Angeles River and eventually into the Pacific Ocean at Long Beach. Groundwater can become stream flow, contributing to the flow of springs or streams during both wet and dry periods, or can be pumped by local water utilities. Some groundwater also seeps over the lower boundary of the Raymond Basin and enters the Main San Gabriel Basin to the south and east.

More than half of the water used locally is imported from distant sources, including the Eastern Sierra Nevada Mountains (Owens Valley), the Colorado River and the Sacramento and San Joaquin Rivers, although a substantial amount of water for human consumption and use is pumped from the Raymond Basin.

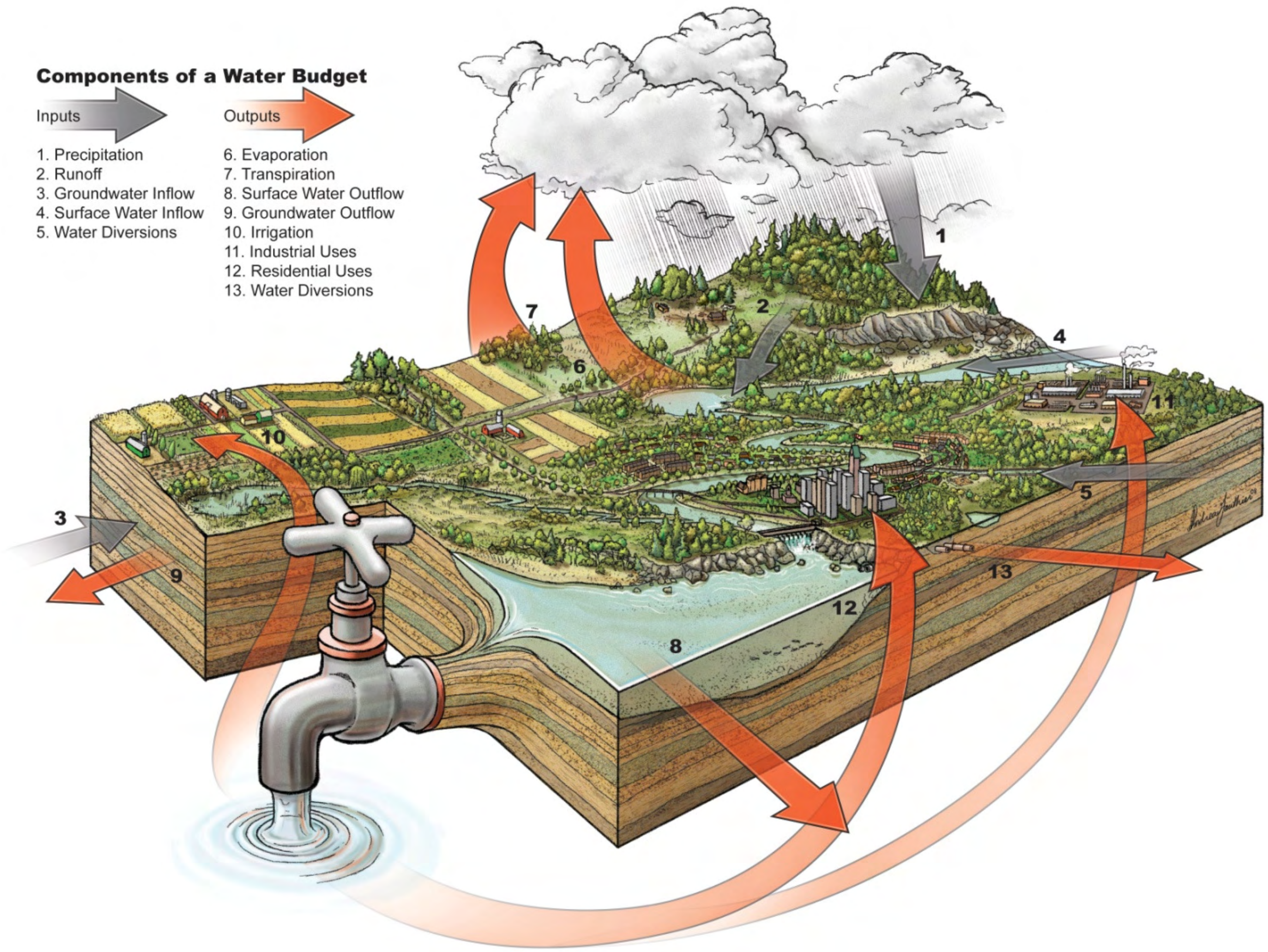


Figure 4 - Conceptual Water Budget

The water budget presented in this report is based on water use figures for 2009 and long-term averages. Some of the data comes from precise measurements, but much of it can best be described as general estimates. Detailed water budgets can be developed for the Arroyo Seco watershed or parts of it through use of hydrologic modeling and geographic information systems, but such models are costly and well beyond the scope of this project.

A more detailed hydrologic model would be beneficial for conservation planning, such as for evaluating the feasibility of water percolation enhancements or best management practices for the retention of rainwater. For the purposes of this project, a generalized spreadsheet model was developed, using estimates of precipitation, infiltration and runoff based on readily available information. This report draws heavily from water supply studies and plans of the US Geological Survey, the Western Climate Data Center, the County of Los Angeles Department of Public Works, the Raymond Basin Management Board, the City of Pasadena Water & Power Department, the Los Angeles Department of Water and Power, Foothill Municipal Water District and the Metropolitan Water District of Southern California.

Impact of Development

Development in the last two hundred years has altered the natural water cycle throughout the Arroyo Seco watershed. The most significant change is that there is no longer a balance in the water budget. While early pioneers relied in the flow from the Arroyo Seco stream, today we depend on a mix of groundwater and imported supplies from northern California and states as far away as Wyoming and Colorado for local use.

The first imported water used to supplement local sources came to the Los Angeles section of the Arroyo Seco when that city began distributing water from the Owens Valley in the Eastern Sierra Nevada Mountains in 1913. In the northern regions of the Arroyo Seco, imported water from the Colorado River first arrived in Pasadena in 1941. Then in the early 1970s the Metropolitan Water District of Southern California began supplying water from the State Water Project to its member agencies, including Los Angeles, Pasadena, Upper San Gabriel Valley Municipal Water District (South Pasadena) and Foothill Municipal Water District (La Cañada Flintridge and Altadena).

Today the neighborhoods of Los Angeles that lie within the Arroyo Seco are totally dependent on imported water sources. The Los Angeles Department of Water Power supplies water to these communities from the San Fernando Valley Basin, the Owens Valley in the Eastern Sierra Nevadas, the Colorado River and the Sacramento/San Joaquin Rivers in Northern California.

As the table below shows, local water agencies in the upper portion of the Arroyo Seco watershed are now dependent on imported supplies for almost two-thirds of their supplies.

Agency	Groundwater	Diversions	MWD	Total Water Use	Imported
La Cañada Irrigation	36.7	73.9	2,791.6	3,077	90.7%
Lincoln Avenue	2,542.3	114.5	856.5	3,513	24.4%
Pasadena	11,867.4	0.0	22,626.6	34,494	65.6%
Valley Water	1,146.2	0.0	2,783.9	3,930	70.8%
Total	15,592.6	188.4	29,058.6	45,014	64.6%

Table 1 - Raymond Basin Agencies Water Use in 2008-2009

It is noteworthy that while water use fell 7% since the previous version of the Watershed Budget, the percentage of imports stayed basically the same (64.6% compared to 64.3%). Pasadena's reduced use of groundwater due to contamination was the most significant change, increasing that city's reliance on imports from 60.7% to 65.6%.

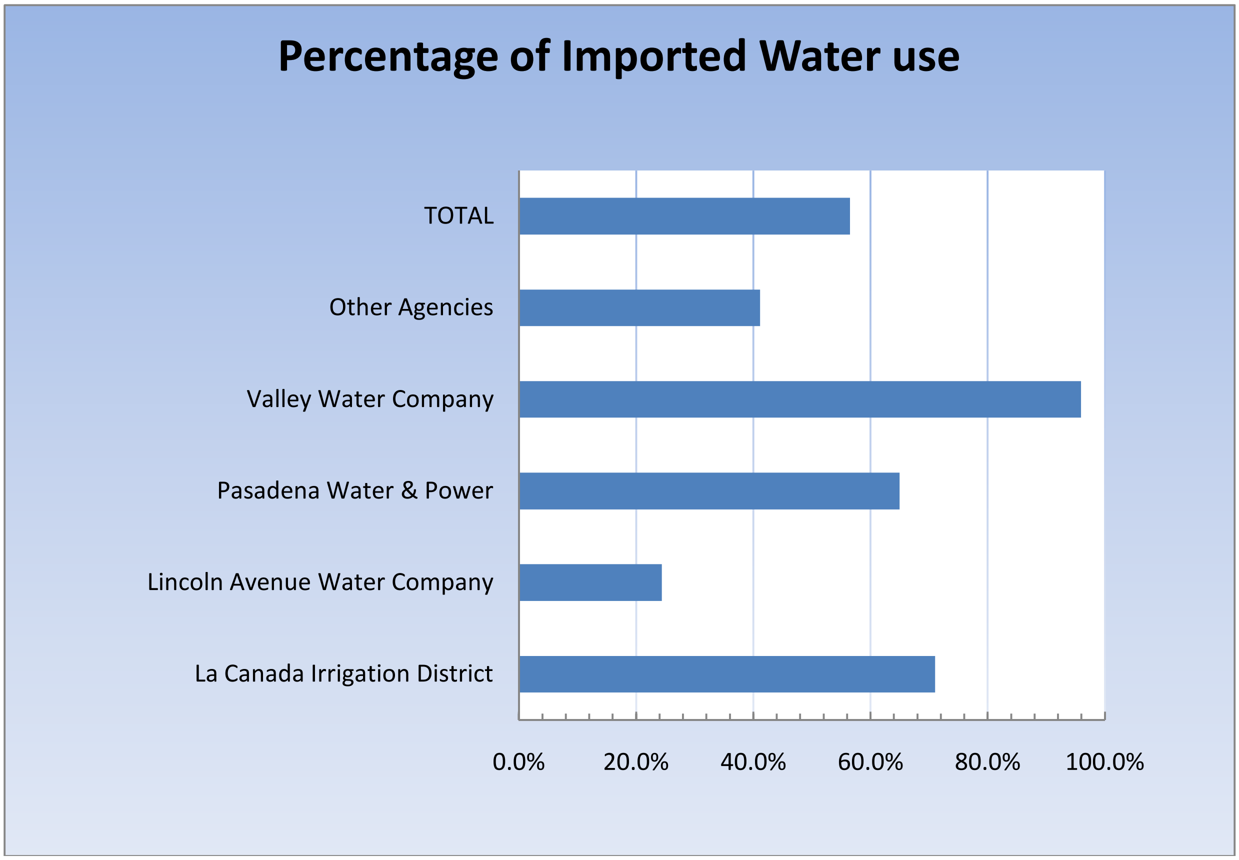


Figure 5 – Percentage of Imported Water Use of Raymond Basin Agencies- 2009

The following chart shows the relative use of groundwater pumping and imported water by Raymond Basin agencies for the last thirteen years. It demonstrates the decline of the direct use of surface water during that period as well as a clear pattern of increasing reliance by Raymond Basin agencies on imported water. This pattern has remained consistent for fifty years.

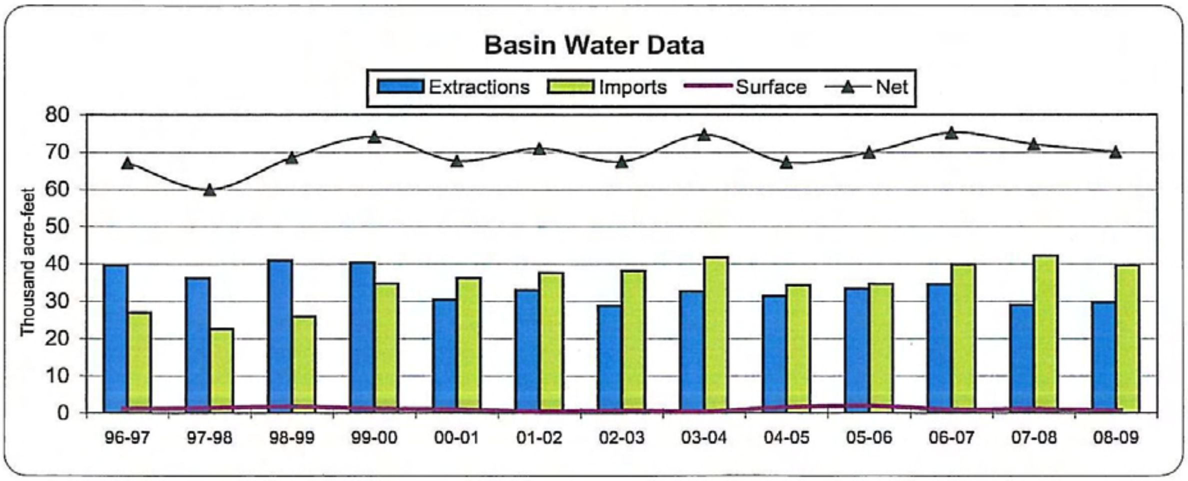


Figure 6 - Raymond Basin Water Use Historic Pattern

Groundwater Recharge

Natural groundwater recharge in the Arroyo Seco Watershed occurs through infiltration and percolation of rainfall and surface runoff as well as subsurface inflow from the San Gabriel Mountains. Average annual precipitation across the watershed ranges from approximately 15 to 24 inches (see Figure 15). Direct percolation of precipitation principally occurs through the watershed's intermittent streams: Arroyo Seco, Millard Canyon and Flint Canyon Wash. Some of the stream flow is diverted to spreading grounds or is retained behind debris structures, enhancing percolation.

Spreading basins in the Hahamongna area at the mouth of the Arroyo Seco as it emerges from the San Gabriel Mountains are used to enhance groundwater recharge by allowing diverted stream flow and storm runoff to percolate into the aquifer below. Injection wells are also used to replenish the groundwater basin. Since 1977 more than one hundred thousand acre-feet have percolated into the groundwater basin through the spreading programs.

The Raymond Basin

The Raymond Basin is the groundwater aquifer that underlies the cities of Pasadena, Sierra Madre, Arcadia, Altadena, San Marino, and La Cañada-Flintridge. Bound by the San Gabriel Mountains to the north, the San Rafael Hills to the west and the Raymond Fault on the south and the east, the forty square mile basin supplies about 40% of the water in these communities. The basin slopes to the south, with elevations from 1,500 feet above sea level at the toe of the San Gabriel Mountains to 500 to 700 feet at the Raymond Fault. Local rainfall, the Arroyo Seco, Eaton Canyon and the foothills of the San Gabriel Mountains feed the Raymond Basin. Groundwater is stored in thick alluvial deposits that have washed down from the mountains to cover the irregular bedrock topography. The Raymond Basin is much like a bowl of sand and gravel filled with water. The bowl tilts to the southeast where some water spills into the Main San Gabriel Basin. Groundwater levels on the north side of Raymond Fault are 200 to 300 feet higher than on the south side of the fault.

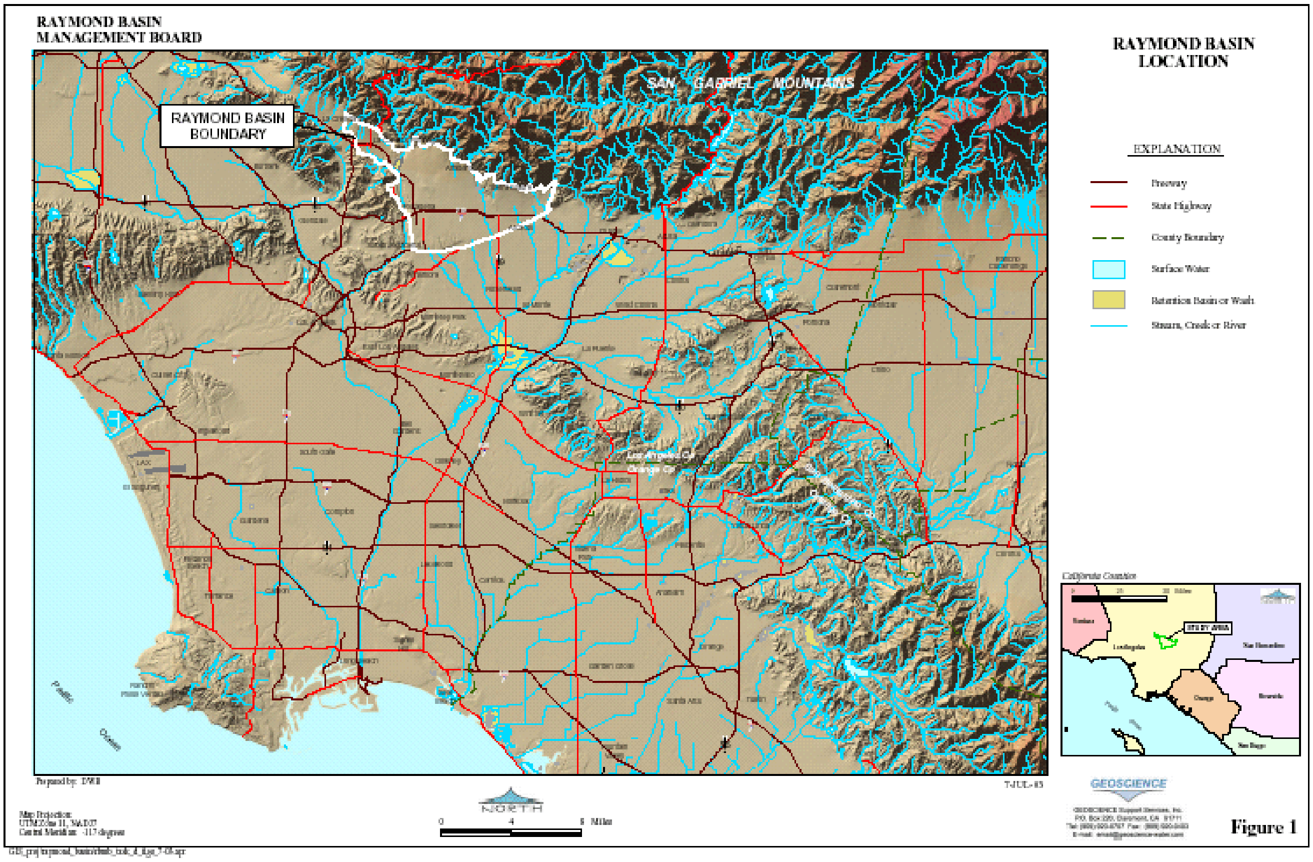


Figure 7 - Raymond Basin Location Map

The Raymond Basin is divided into three sub-areas. The northwest of the basin is the Monk Hill Subarea which includes La Cañada-Flintridge, Altadena and northwest Pasadena down to Monk Hill (just north of Washington Boulevard). The main basin is the Pasadena Subarea found beneath Pasadena. The Santa Anita Subarea makes up the northeastern corner of the basin and includes portions of Arcadia and Sierra Madre.

The water budget for a groundwater basin is balanced if the amount of water entering the aquifer matches the amount of water extracted. When outputs exceed inputs, the aquifer is overdrawn or overdrafted. The Raymond Basin has been overdrawn for more than one hundred years. The addition of imported water has relieved but not eliminated the draw down. Even with imports, though, the Raymond Basin today is still suffering a significant annual overdraft that has recently lead to a reduction in pumping rights for Raymond Basin water rights holders.

Inputs or recharge sources to the water budget for the Raymond Basin include boundary inflow from the mountain watershed and surface flow. There are five components of surface flow:

- natural recharge from precipitation,
- stream flow,
- recharge from applied water such as landscaping,

- recharge from septic flows, and
- percolation from spreading operations.

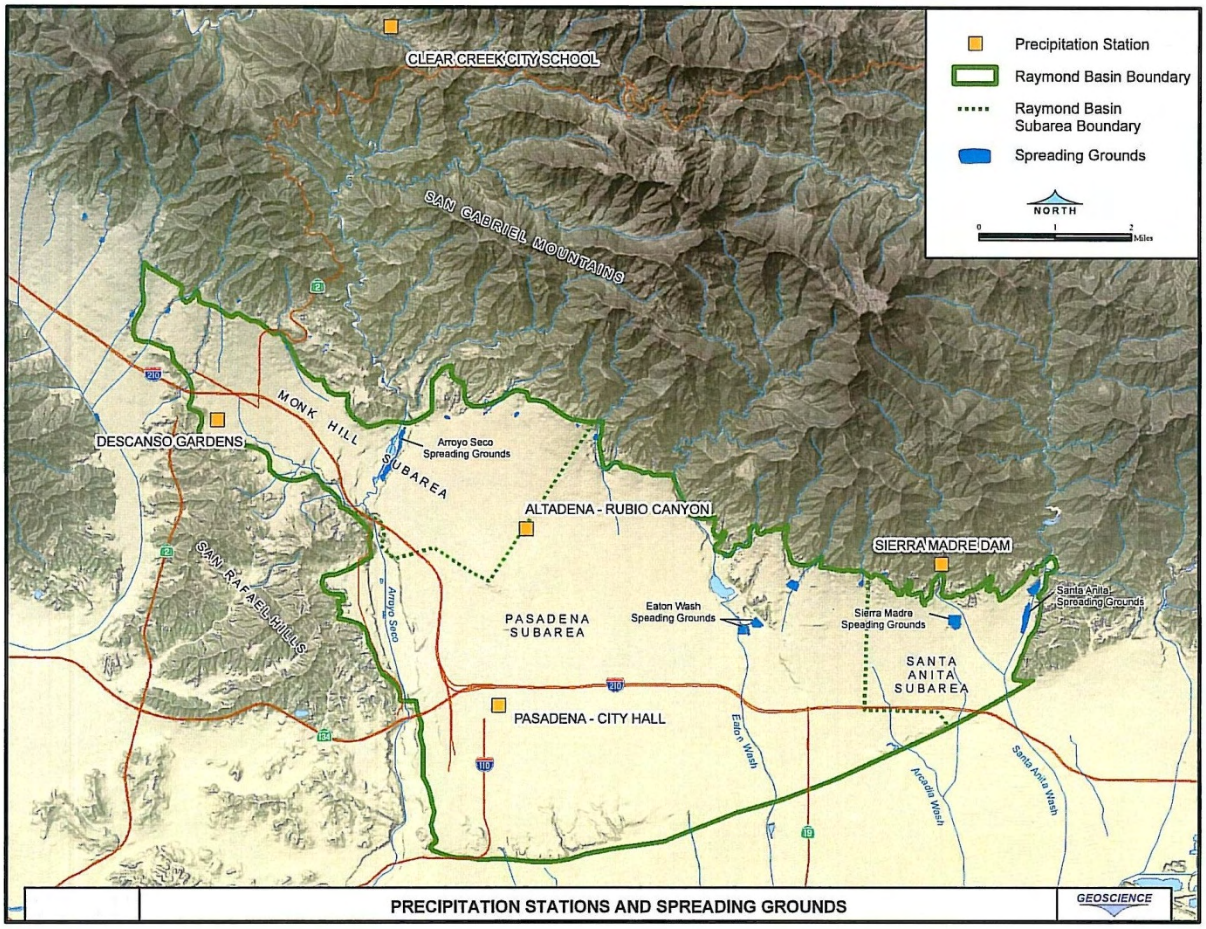


Figure 8 – Location of Precipitation Stations and Spreading Grounds

Outputs include surface diversions and groundwater extractions for urban and industrial use, transpiration by riparian vegetation, and subsurface seepage from the Raymond Basin to the Man San Gabriel Basin, the aquifer below the Raymond Fault. The California Department of Water Resources estimated the subsurface outflow across the Raymond Fault in 1969 to be 6,360 acre-ft per year. CH2M Hill in 1992 estimated that in some years the flow is as much as 10,564 acre-ft.

In the 1940s the Raymond Basin was the subject of an adjudication, a legal agreement or decision that defines the rights of water rights holder in a basin. The intent of the Raymond Basin adjudication and subsequent management efforts has been to develop a sustained yield program that would balance extractions from the basin with natural replenishment supplemented by imported supplies.

The 2003 Geoscience technical report found that the management program is not reaching its goal. "Despite increases in spreading, the volume of ground water in storage within the Raymond Ground Water Basin has decreased by 112,600 acre-ft from 1983 to 2002, although the decrease was less pronounced during the period from 1991 to 2002. Between 1991 and 2002, the volume of ground water in storage decreased by approximately 46,100 acre-ft while it decreased by approximately 66,500 acre-ft from 1983 to 1991." This overdraft of about 5,600 acre feet per year, in a basin with a capacity of 1.45 million acre feet, has occurred during the same period of time as local water agencies have established storage accounts in the basin.

Overdrafting of groundwater can cause environmental problems, including land subsidence, habitat reduction, and adverse groundwater quality impacts. It also generall leads to further reliance on imported supplies.

Water Budget Factors

Climatic Conditions – Precipitation and Temperature

The climate of the Arroyo Seco Watershed is subtropical to semiarid with hot dry summers and mild, moist winters occasionally punctuated by intense storm events. It is classified as Mediterranean, a distinction that only five regions of the world enjoy. The watershed begins in the San Gabriel Mountains, part of the Transverse Range of Southern California, where the rainfall is significantly higher than at lower elevations. Storms are particularly intense. In the report "*Climate of California*," the Western Regional Climate Center states: "The maximum intensity of precipitation for periods of 12 hours or longer which might be expected at intervals of 10 to 100 years is greater in portions of the San Gabriel and San Bernardino Mountains in southern California than anywhere else in the continental United States." The upper watershed of the Arroyo Seco is one of those fierce portions. More than 11 inches of rain has fallen in a twenty-four period in the upper watershed, while the maximum in the lower reaches was 7.7 inches recorded on March 2, 1938.

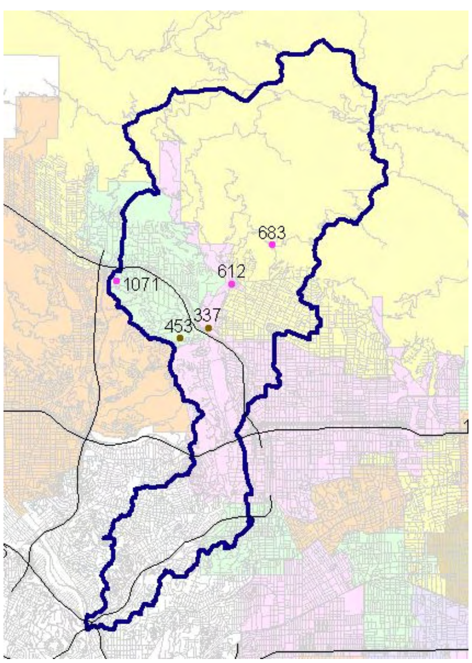


Figure 9 – Los Angeles County Rainfall Gages in the Arroyo Seco

Rainfall generally declines as elevation falls in the watershed. At Mount Wilson, just outside the upper limit of the watershed, the mean annual rainfall is 35.47 inches. The average at Oakwilde, five miles into the mountains, is 28.19 inches. At County Weather Station 683, a few miles south, the mean rainfall for the period from 1981 to 2003 was 23.5 inches, while at the Pasadena City Hall weather station, average annual precipitation from 1931 to 2009 was 20.32 inches. In Highland Park the historic mean rainfall has been 18.56 inches. The average precipitation at Los Angeles Civic Center, 2 miles south of the lower limits of the Arroyo Seco watershed is 14.7 inches. The highest annual rainfall occurred in 1983 at 48.47; the lowest year was in 1945 which there were only 5.37 inches.

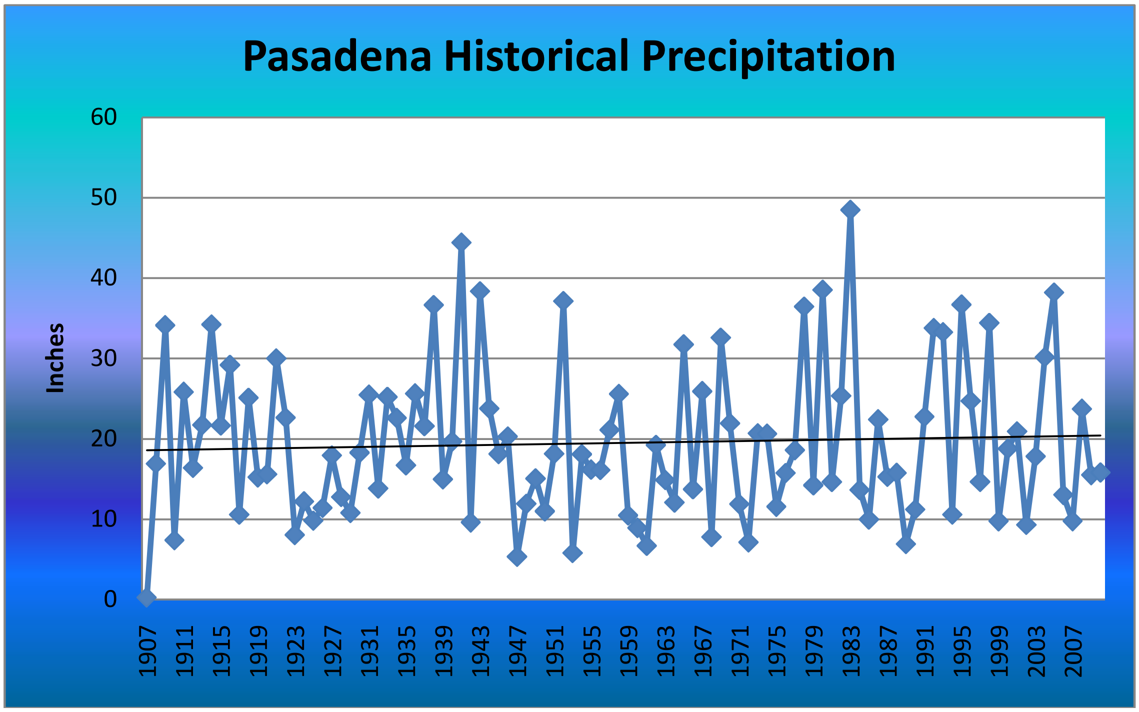


Figure 10 – Pasadena Historical Precipitation

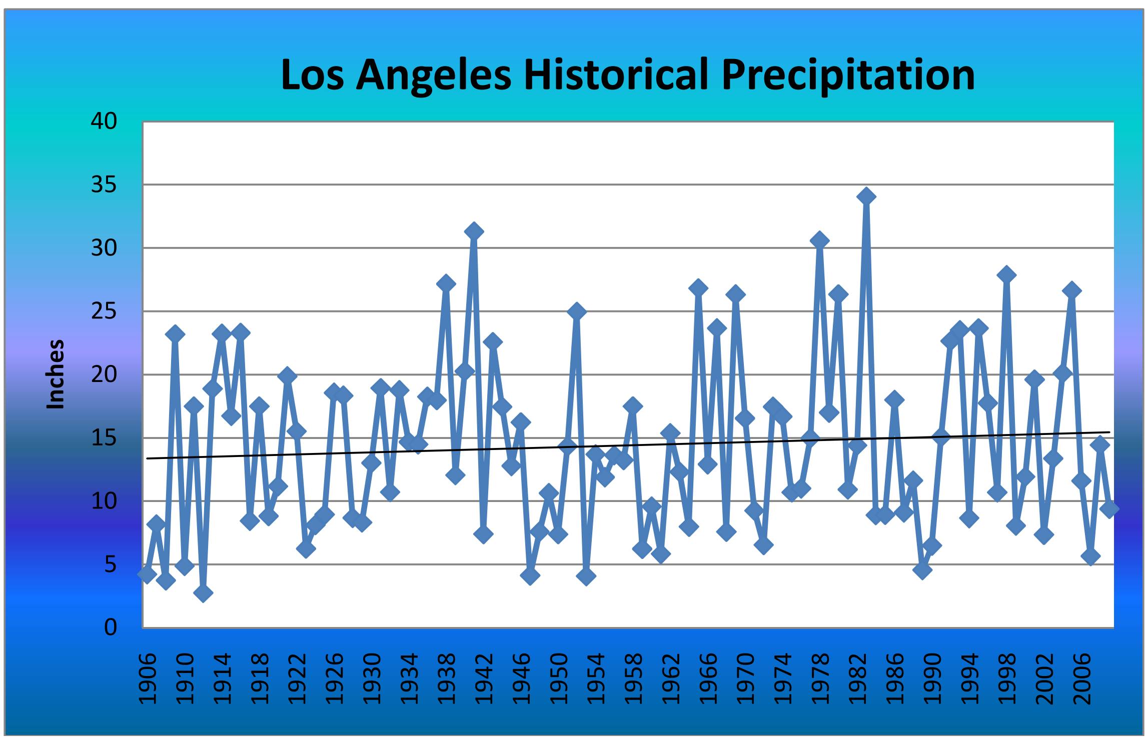


Figure 11 – Los Angeles Historical Precipitation

Local Rainfall Pattern

Most of the precipitation in the Arroyo Seco watershed occurs during the winter months of December through March, following the pattern of monthly precipitation recorded at the Pasadena weather station.

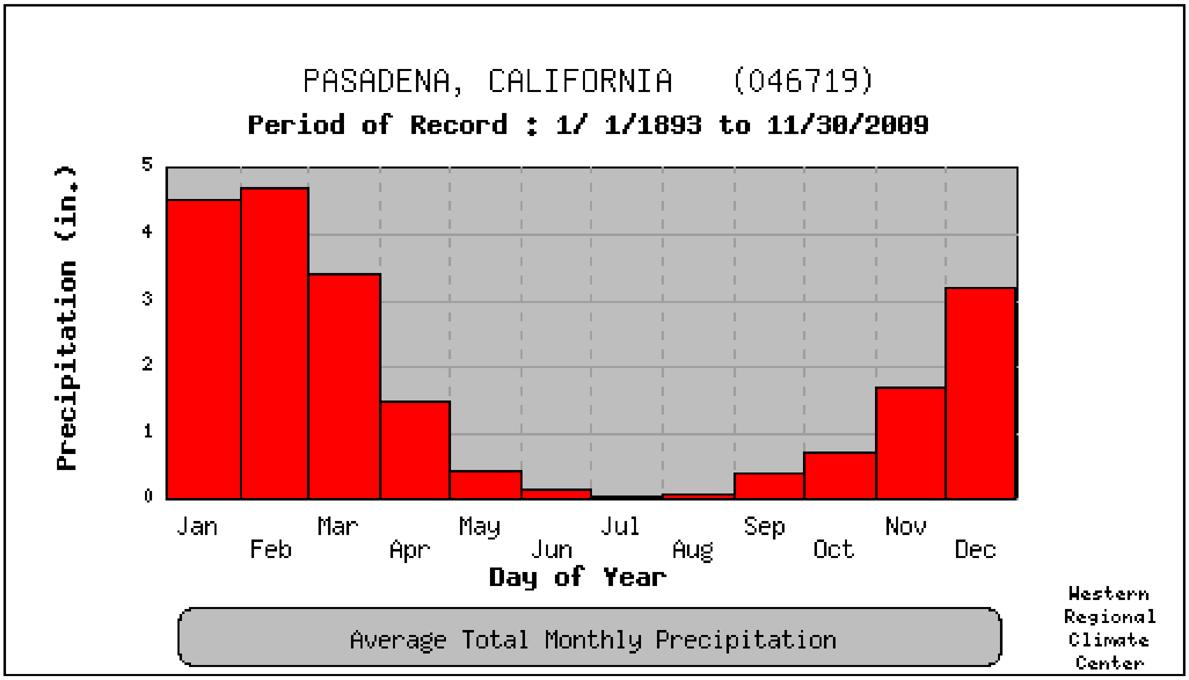


Figure 12 - Pasadena Monthly Precipitation

The charts below illustrate the rainfall and precipitation patterns of the Arroyo Seco, including the average, minimum, maximum and total figures for Pasadena and Los Angeles.

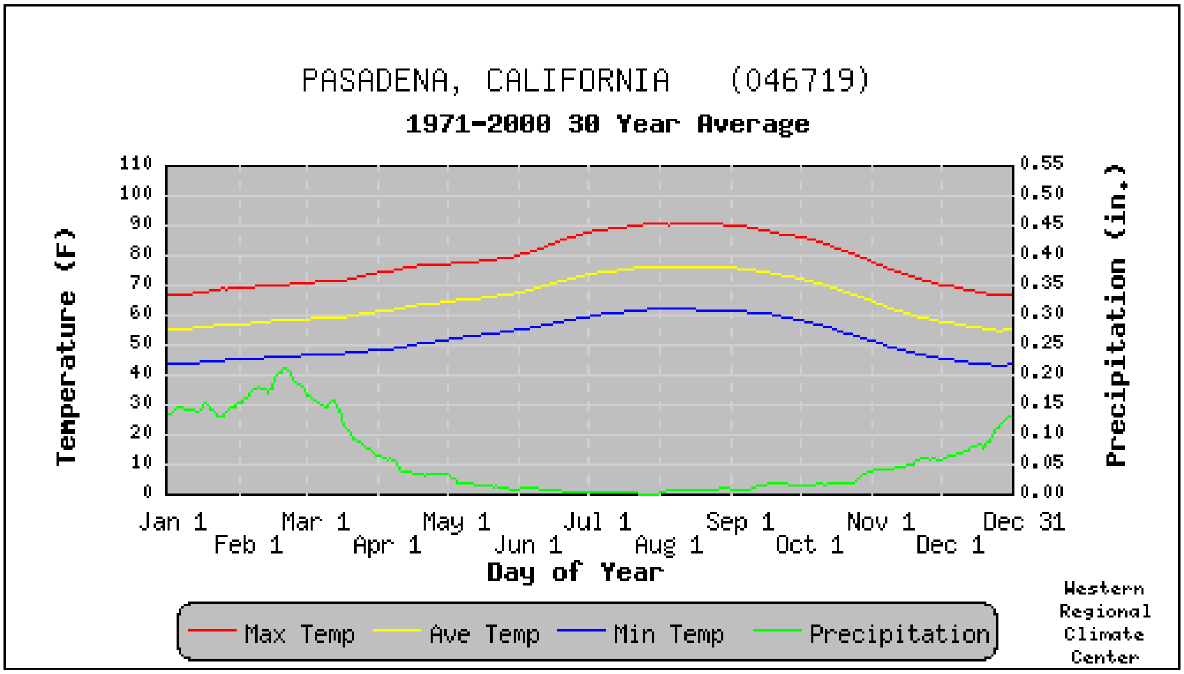


Figure 13 - Pasadena Climate

- Max. Temp. is the average of all daily maximum temperatures recorded for the day of the year between the years 1971 and 2000.

- Ave. Temp. is the average of all daily average temperatures recorded for the day of the year between the years 1971 and 2000.

- Min. Temp. is the average of all daily minimum temperatures recorded for the day of the year between the years 1971 and 2000.

- Precipitation is the average of all daily total precipitation recorded for the day of the year between the years 1971 and 2000.

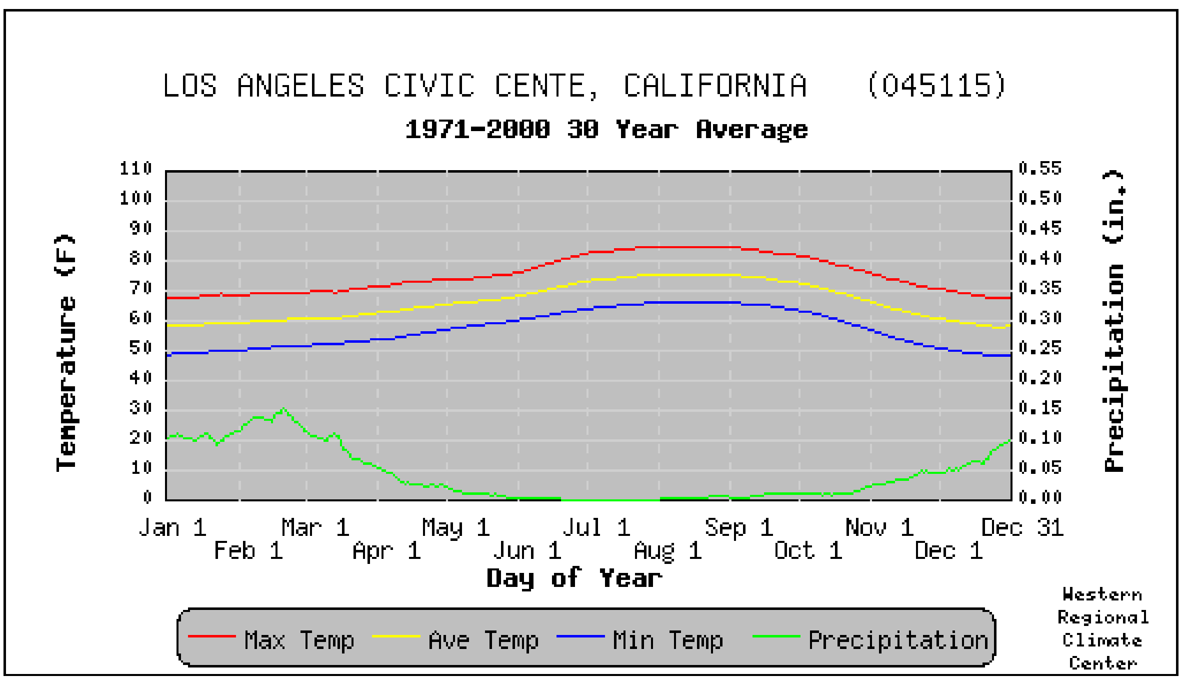


Figure 54- Los Angeles Climate

Month	High Temp	Average Temp	Low Temp	CDD *	HDD *	Rain (Inches)
January	**67.8**	**56.1**	**44.3**	**0.3**	**28.1**	**4.5**
February	**70.3**	**58.1**	**45.9**	**1.1**	**20.5**	**5.0**
March	**71.3**	**59.3**	**47.2**	**2.2**	**20.0**	**4.4**
April	**76.0**	**63.0**	**50.0**	**6.9**	**12.9**	**1.2**
May	**78.2**	**65.9**	**53.5**	**10.6**	**8.0**	**0.5**
June	**84.0**	**70.7**	**57.4**	**19.1**	**2.0**	**0.2**
July	**89.4**	**75.3**	**61.1**	**31.8**	**0.0**	**0.1**
August	**90.6**	**76.3**	**62.0**	**35.2**	**0.2**	**0.2**
September	**88.5**	**74.6**	**60.6**	**29.4**	**0.8**	**0.5**
October	**82.5**	**68.9**	**55.2**	**15.3**	**3.4**	**0.7**
November	**73.8**	**61.0**	**48.1**	**3.3**	**15.6**	**1.5**
December	**68.0**	**56.1**	**44.1**	**0.6**	**28.3**	**2.5**

Heating Degree Days relate a day's temperatures to the demand for fuel to heat a building. When the temperature is above 65 degrees, there are no heating degree days. If the temperature is less than 65, subtract it from 65 to find the number of heating degree days.

Cooling Degree Days are also based on the temperature minus 65. It relates the temperature to the energy demands of air conditioning.

Heating and cooling degree days can be used to estimate how much is spent on heating or air conditioning in a particular region.

Table 2 – Temperature and Degree Days in the Arroyo Seco Watershed

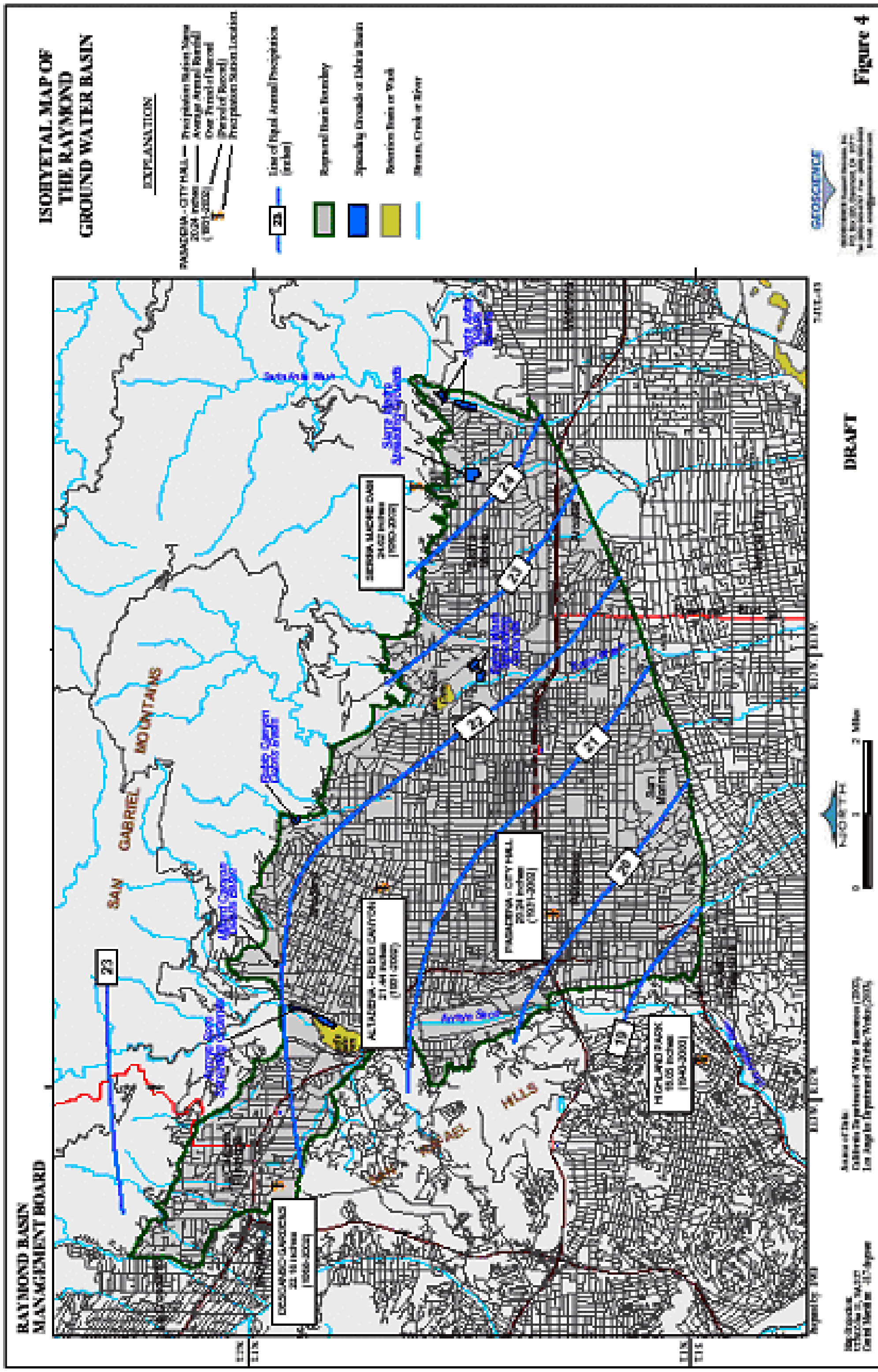


Figure 15 - Isohyetal Map of the Raymond Basin

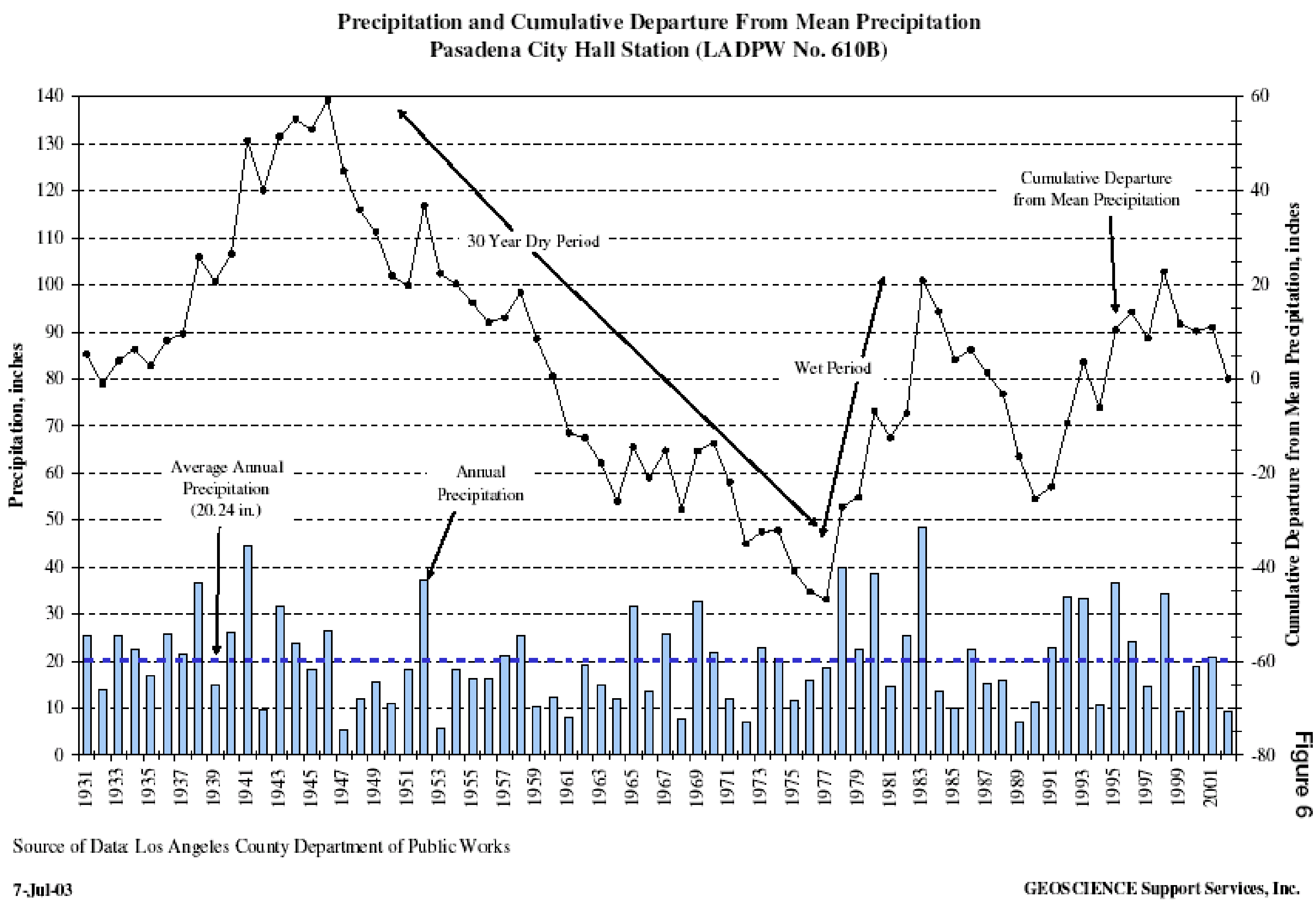


Figure 16 - Pasadena Precipitation

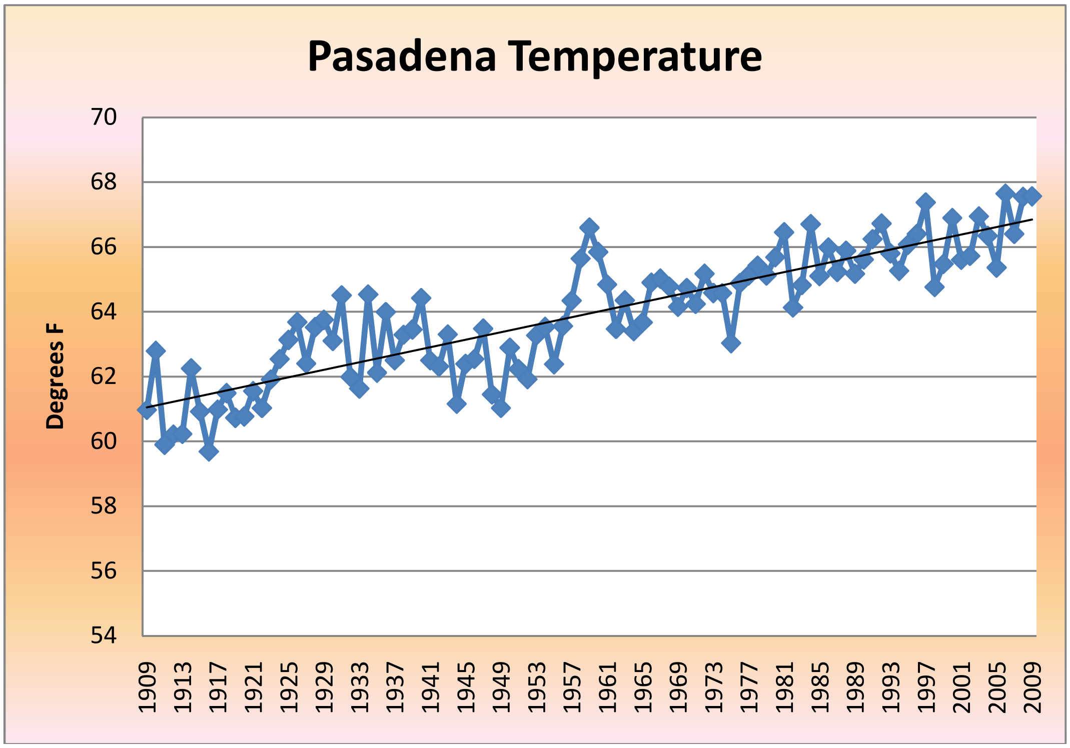


Figure 17 - Pasadena Average Temperature

The mean annual temperature in Pasadena is 67.56 degrees Fahrenheit, almost 5 degrees higher than the temperature one hundred years ago. At the Los Angeles Civic Center, the mean temperate, now 66.18 degrees, has also climbed almost 5 degrees since 1910.

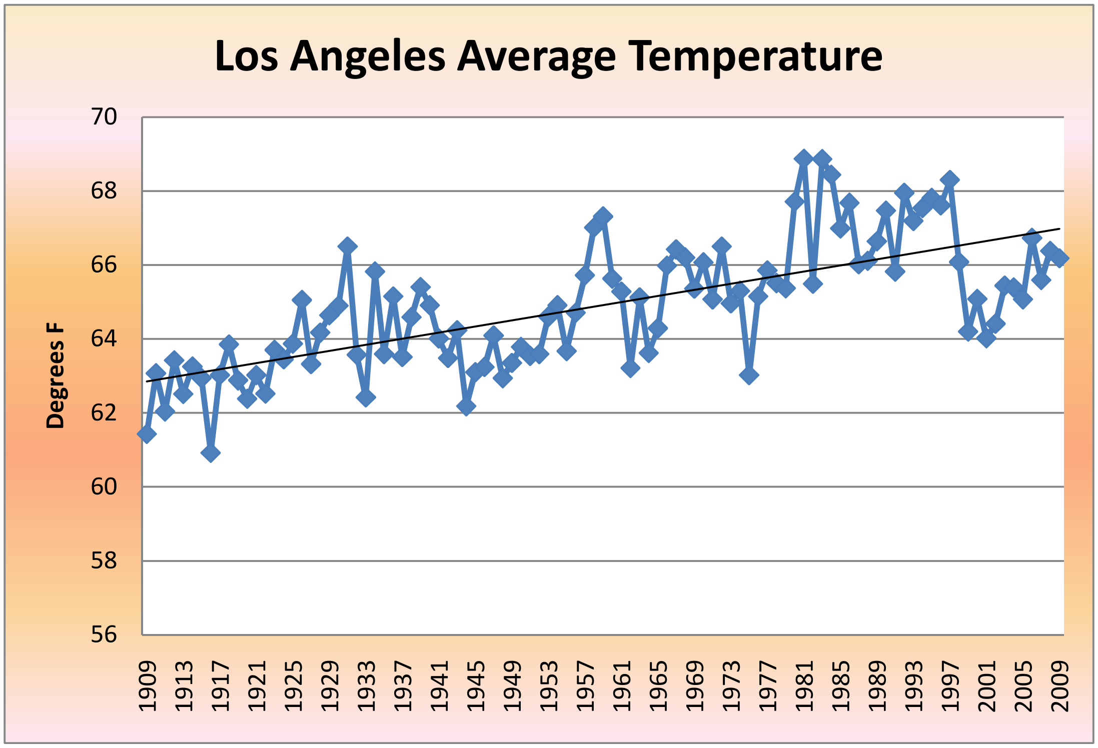


Figure 18 - Los Angeles Average Temperature

Streamflow

Figure 19 - Location of USGS Stream Gage

The County of Los Angeles Department of Public Works and the United States Geologic Survey monitor streamflow in the Arroyo Seco Watershed. The USGS gage station (USGS Gage #11098000) is located about 0.7 miles east of the Angeles Crest Highway and 5.5 miles northwest of Pasadena. The USGS gage provides continuous data going back to December 1, 1910. It can be viewed in real-time at:
http://waterdata.usgs.gov/ca/nwis/discharge?site_no=11098000.

Figure 20 indicates the sharp variation in daily mean streamflow in the Arroyo Seco. Figure 21 portrays the peak stream flow in cubic feet per second since 1914.

Complete data and documentation can be found at the USGS website. The USGS now provides a real-time video cam view of the Arroyo Seco stream at its gage above JPL.
http://ca.water.usgs.gov/webcams/jpl/ You can also find a an easy-to-understand graphical presentation of the steamflow data on the Arroyo Seco website:
http://www.arroyoseco.org/streamflow.htm

This chart indicates the variability of the flow in the Arroyo Seco stream for the 94 years of record on the USGS gage. This measurement records the stream flow in the 16.0 square miles of the upper mountain watershed above the gage.

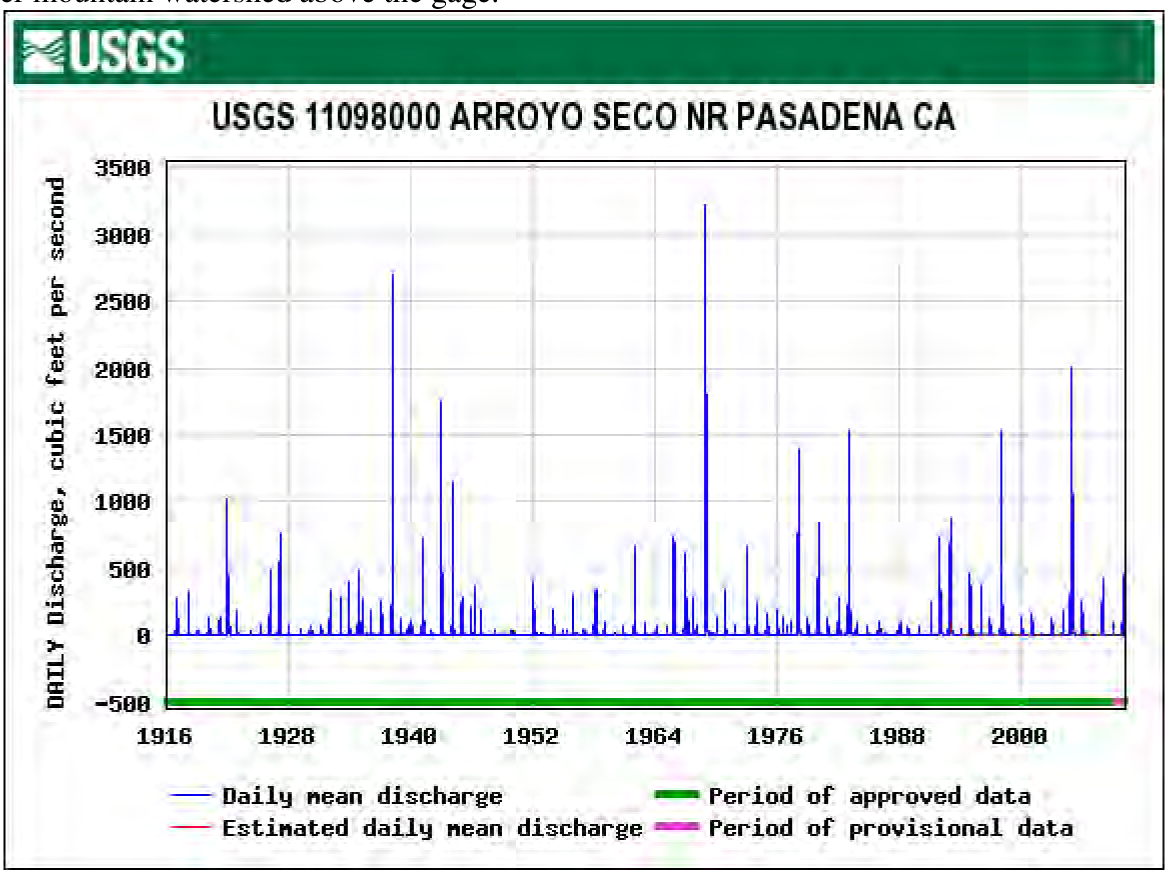


Figure 20 - Arroyo Seco Daily Mean Streamflow - 1916-2010

The peak streamflow was recorded on Mar. 02, 1938 at 8,620 cubic feet per second (cfs). The flood of 1969 trailed closely with a flow of 8,540 cfs on Jan. 25, 1969. The flood of 1914, which was so destructive in the Los Angeles section of the Arroyo Seco, had a peak of 5,800. The largest streamflow in the last 25 years occurred on February 23, 1998 with a flow of 4,380 cfs.

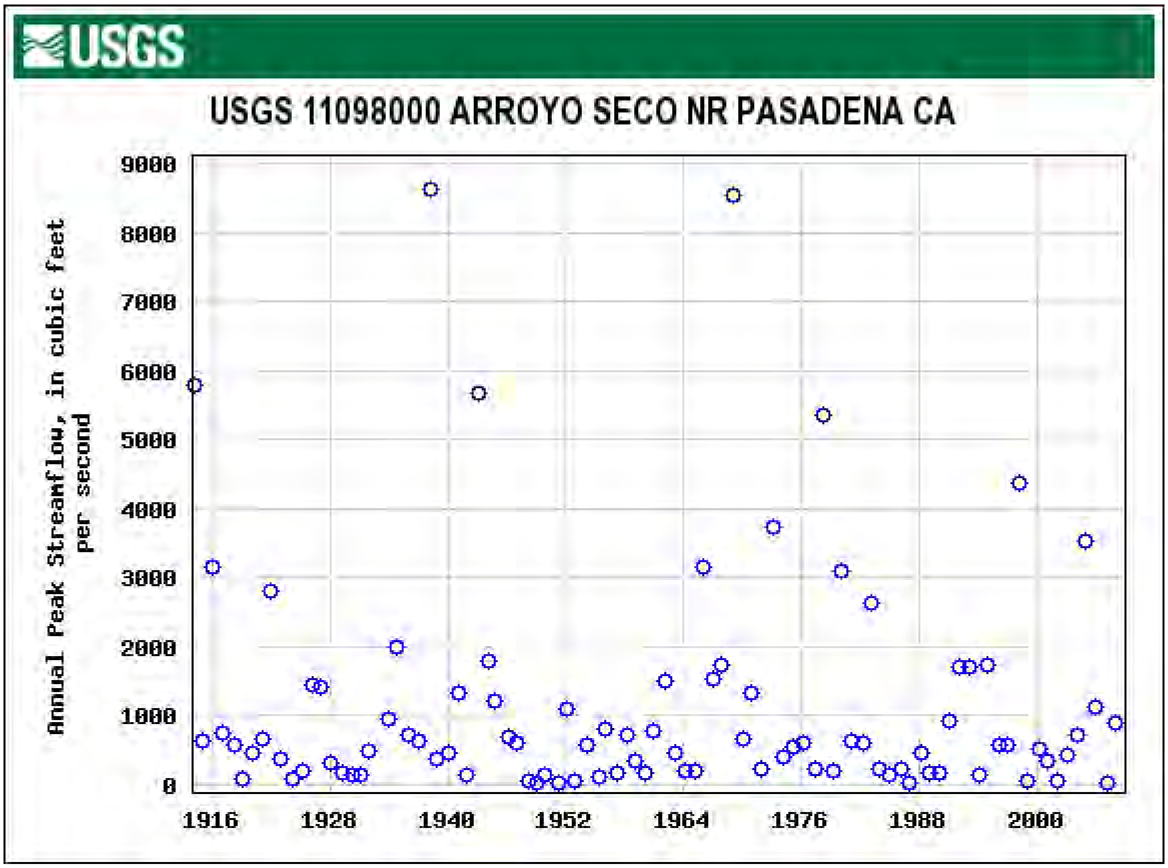


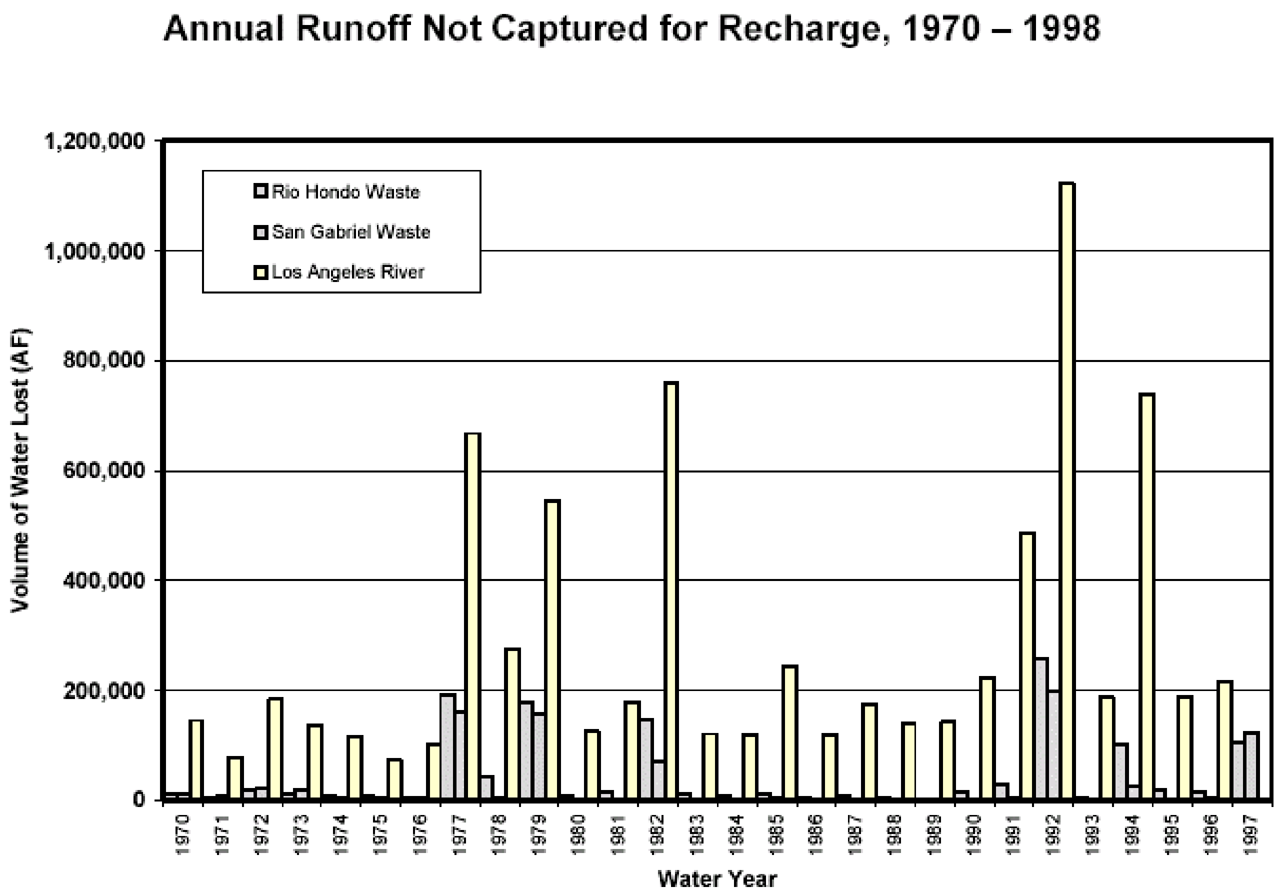
Figure 21 - Peak Streamflow in the Arroyo Seco - 1914-2001

Figure 22: Arroyo Stream in Flood

These figures record the streamflow from the upper mountain watershed of the Arroyo Seco. The LA County gage below Devil's Gate Dam records the mountain watershed as well as the flow from La Cañada and from Millard Canyon, a total of 32 square miles. In 2001 LA County installed a gage on the lower Arroyo Seco near Debs Park, but it only maintained the gage for two years, so there is no accurate historic measure of the runoff from the 15 square miles of the urbanized watershed below Devil's Gate Dam. Based on modeling and calculations contained in the *Technical Report On Hydrology, Hydraulics And Geomorphology* prepared by Montgomery Watson Harza for the *Arroyo Seco Watershed Restoration Feasibility Study* in 2002, the average annual flow of the Arroyo Seco into the Los Angeles River is 10,620 acre feet.

The amount of runoff in the lower urbanized section of the watershed, averaging approximately 3,300 acre feet per year, indicates the potential savings that can be achieved by local rainfall retention programs. Because 75% of all rainfall in the watershed occurs in storms of ¾ inch or less, it is clear that the amount of runoff has a significant water supply impact in the Arroyo Seco Watershed.

Figure 23 demonstrates the large amount of runoff from the major rivers of Los Angeles County that now reaches the ocean, sometimes more than 400,000 acre feet per year. Runoff from the Arroyo Seco, a major tributary of the Los Angeles River, contributes to this flow.

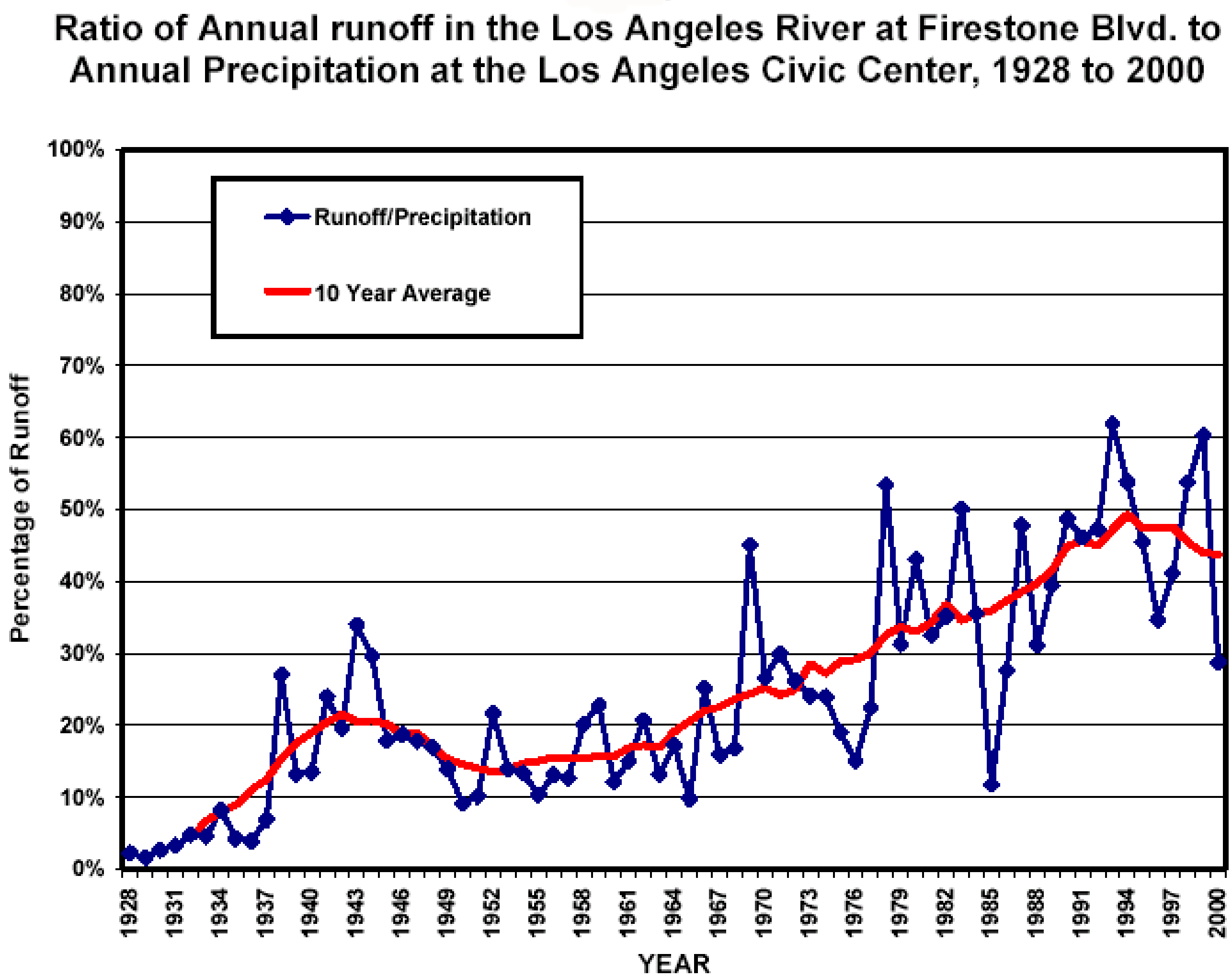


Source: LACDPW Water Resources Division
Note: in the years 1970-1998, records indicate that significant spreading did occur, but runoff exceeded the spreading capacity.

Figure 23 - Annual Runoff Not Captured for Recharge, 1970 - 1998

Land Use

Land use changes in the last one hundred and twenty fives years have had a profound impact on natural hydrologic processes in the Arroyo Seco. First agriculture and then urbanization altered the stream courses, water storage, pollutant levels, evapotranspiration, infiltration, and surface runoff in the watershed. The amount of rainfall converted to runoff has significantly increased with urbanization. The same forces of urbanization that have occurred in the Arroyo Seco Watershed have transformed the Los Angeles River. Figure ???, taken from the Water Augmentation Study Pilot Program Report, prepared by the Los Angeles and San Gabriel Rivers Watershed Council, illustrates the ratio of annual runoff in the Los Angeles River to annual precipitation from 1928 to 1998. Before the late 1930s, less than 10 percent of Los Angeles basin rainfall was converted to runoff and entered the Los Angeles River. The rest either evaporated or infiltrated into the ground. Now 40-50% of rainfall becomes runoff (Figure 20).



Source: Los Angeles County Department of Public Works and Western Regional Climate Data Center

Figure 24 - Ratio of Annual Runoff - Los Angeles River

Urban development has also altered the timing and extent of flooding, the sediment yield of rivers, and the health of aquatic habitats. Roads, buildings, parking lots, and other impermeable surfaces, have replaced the natural terrain of the Arroyo Seco, preventing rainfall from infiltrating into the ground. In the 1930s and 1940s, a concrete-lined flood control channel, designed to efficiently convey water out of the area during storms, replaced the natural Arroyo Seco stream. Pipes and culverts captured the other springs and streams in the watershed, funneling their flow directly into the flood channel system and eventually to the Pacific Ocean.

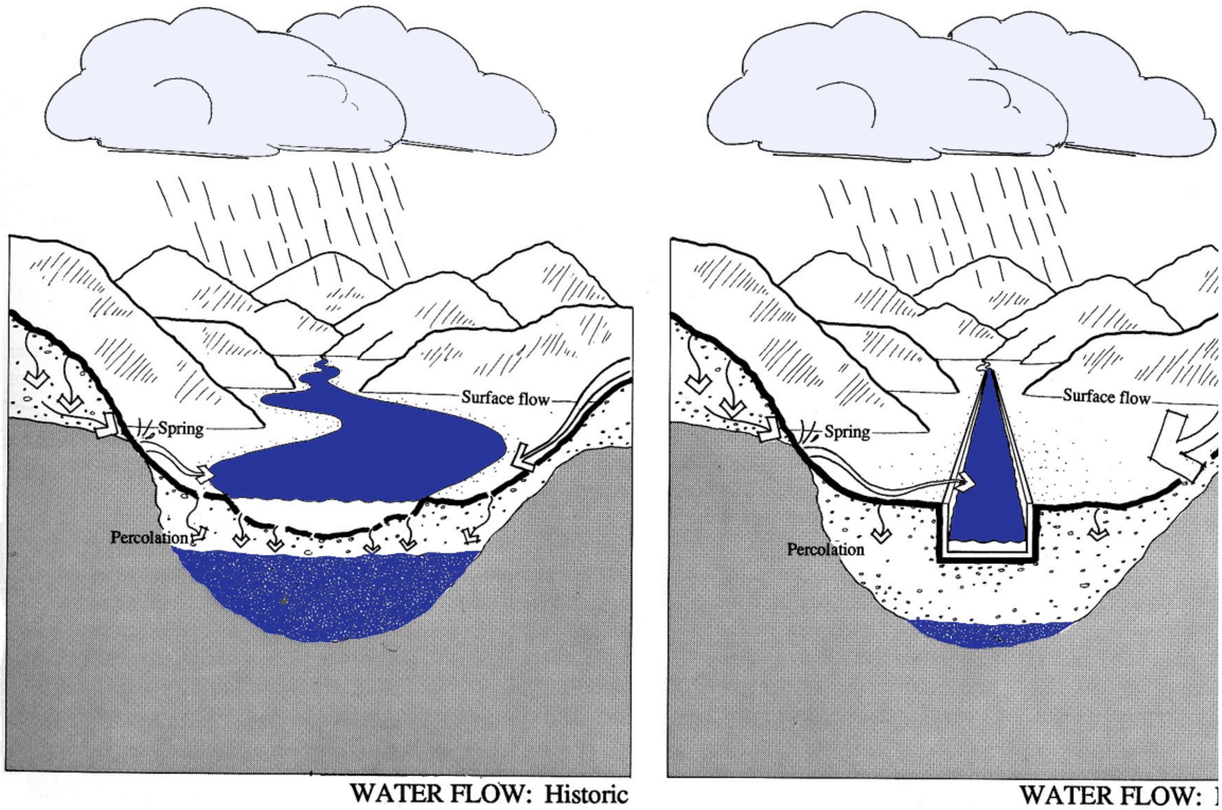
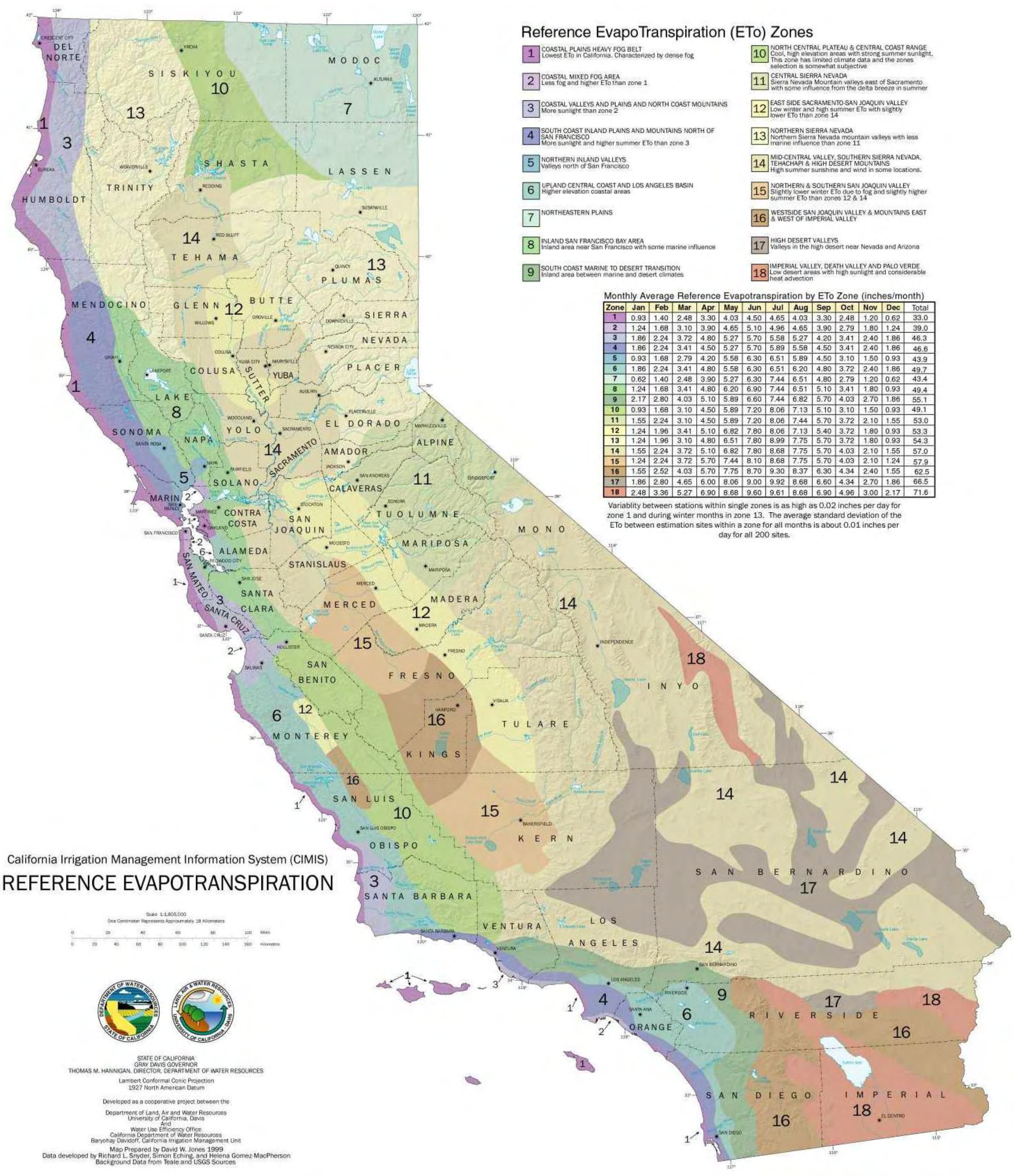


Figure 25 - The Effect of Channelization on Infilitration



Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

Figure 26 - California Irrigation Management Information System (CIMIS)

Evapotranspiration in the Arroyo Seco Watershed

Evapotranspiration (ET) is the combination of soil evaporation and plant transpiration. These two processes represent the water loss from the plant-soil system due to evaporative demand of the atmosphere.

The ET rate (Eto) is a reference number which represents an estimate of evapotranspiration from an extended surface of three to six inch tall green grass cover of uniform height, actively growing, completely shading the ground, and not short on water. Throughout the state of California, a series of weather stations that form the California Irrigation Management Information System (CIMIS) are located within a small grass field that is optimally irrigated. Instruments attached to the weather station datalogger measure weather parameters that would directly affect ETo estimates such as solar radiation, air temperature, humidity, wind and rain. This data is captured by the weather station's database and produces a reference evapotranspiration (ETo) rate every hour.

CIMIS helps agricultural growers and turf managers administering parks, golf courses and other landscapes to develop water budgets for determining when to irrigate and how much water to apply, but it also supplies a key factor for our water budget calculation of the Arroyo Seco Watershed.

The two closest CIMIS weather stations to the Arroyo Seco Watershed are in Glendale and Monrovia. The California Department of Water Resource Model Landscape Ordinance Program lists a reference ETo value for Pasadena of 52.3 and for Los Angeles of 50.1. This table lists the amount of ET that is likely to occur from a well-water field each month during the year.

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
Pasadena	2.1	2.7	3.7	4.7	5.1	6.0	7.1	6.7	5.6	4.2	2.6	2.0	52.3
Los Angeles	2.2	2.7	3.7	4.7	5.5	5.8	6.2	5.9	5.0	3.9	2.6	1.9	50.1

Table 3: Monthly Average Reference Evapotranspiration

Water Balance

A helpful way of looking at local weather conditions compares precipitation to potential evapotranspiration. The chart below, sometimes referred to as a water budget, is a direct comparison of supply of water and the natural demand for water. It illustrates the months when there is plenty of precipitation and when there is very little or none. Here are some useful terms:

- **Potential Evapotranspiration (PE)**: This is a measure of the ability of the atmosphere to remove water from the surface through the processes of **evaporation** and **transpiration** assuming no control on water supply.

- **Actual evapotranspiration** (**AE)** is the quantity of water that is actually removed from a surface due to the processes of **evaporation** and **transpiration**.
- **Precipitation (P)**: All moisture from the atmosphere, rain, snow, hail and sleet.
- **Surplus**: Water above what is lost naturally from the soil (when P is greater than PE)
- **Deficit**: Water that would be lost above what is in the soil if it were present (when P is less than PE)

The chart shows the water balance for our region based on average monthly rainfall rates and evapotranspiration patterns. The seasonal variability in evapotranspiration mirrors the seasonal trend in air temperature. In this watershed measurable evapotranspiration occurs all year long but reaches a maximum in July and decreases in October.

The interaction of these climate factors dramatically affects water consumption. This pattern can be a handy water conservation tool for landscape irrigators who often fail to adjust automatic sprinkler systems according to ET conditions. Irrigation rates should be set to meet but not exceed evapotranspiration. Any excess is wasted.

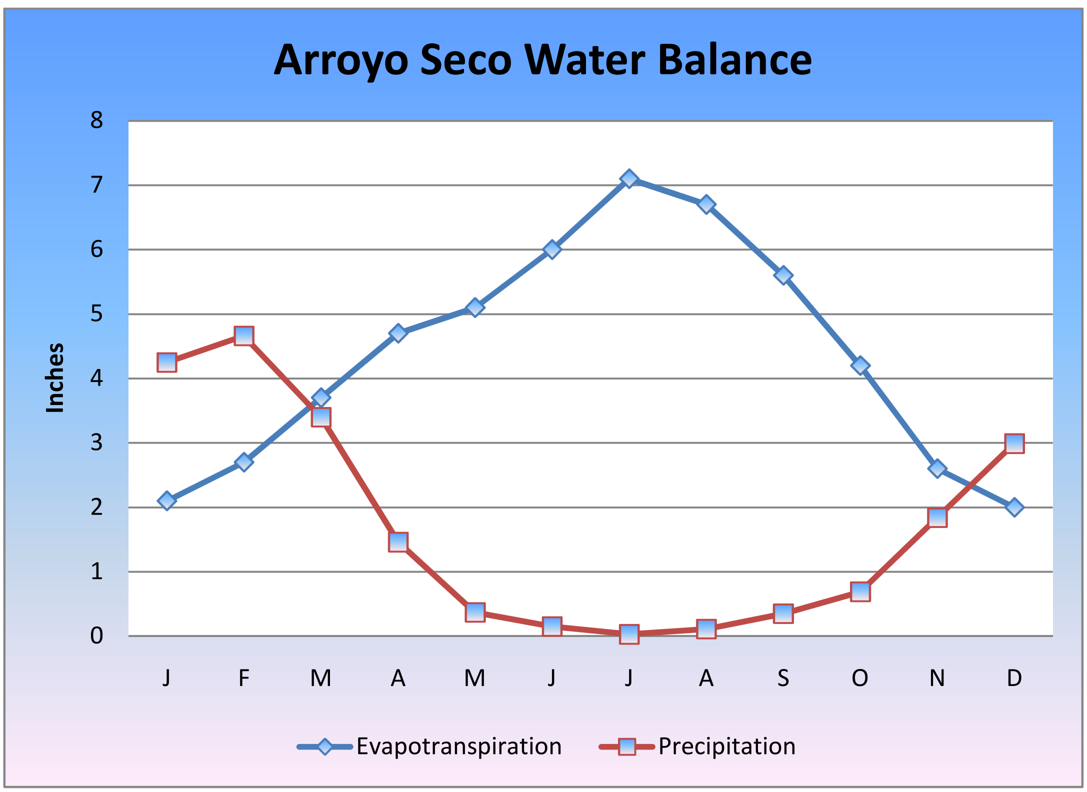


Figure 27 - Water Balance

Water Use in the Arroyo Seco Watershed

Supply

The communities of the Arroyo Seco rely heavily on imported water to supply local needs. Almost two-thirds of the water used in the Arroyo Seco is imported from sources outside of the watershed. The remainder comes from groundwater pumping from the Raymond Basin in the upper part of the watershed and a small amount of surface water. In this tabulation, we include only those portions of the communities that overlie within the Raymond Basin.

Agency	Groundwater	Diversions	MWD	Total Water Use	Imported
La Cañada Irrigation	36.7	73.9	2,791.6	3,077	90.7%
Lincoln Avenue	2,542.3	114.5	856.5	3,513	24.4%
Pasadena	11,867.4	0.0	22,626.6	34,494	65.6%
Valley Water	1,146.2	0.0	2,783.9	3,930	70.8%
Total	15,592.6	188.4	29,058.6	45,014	64.6%

Table 4 – Local Water Usage

LOS ANGELES

Northeast Los Angeles is entirely dependent on imported water. The Los Angeles Department of Water and Power provides supplies from the San Fernando groundwater basin and the Owens Valley, as well as water from the State Water Project and the Colorado River that it obtains from the Metropolitan Water District.

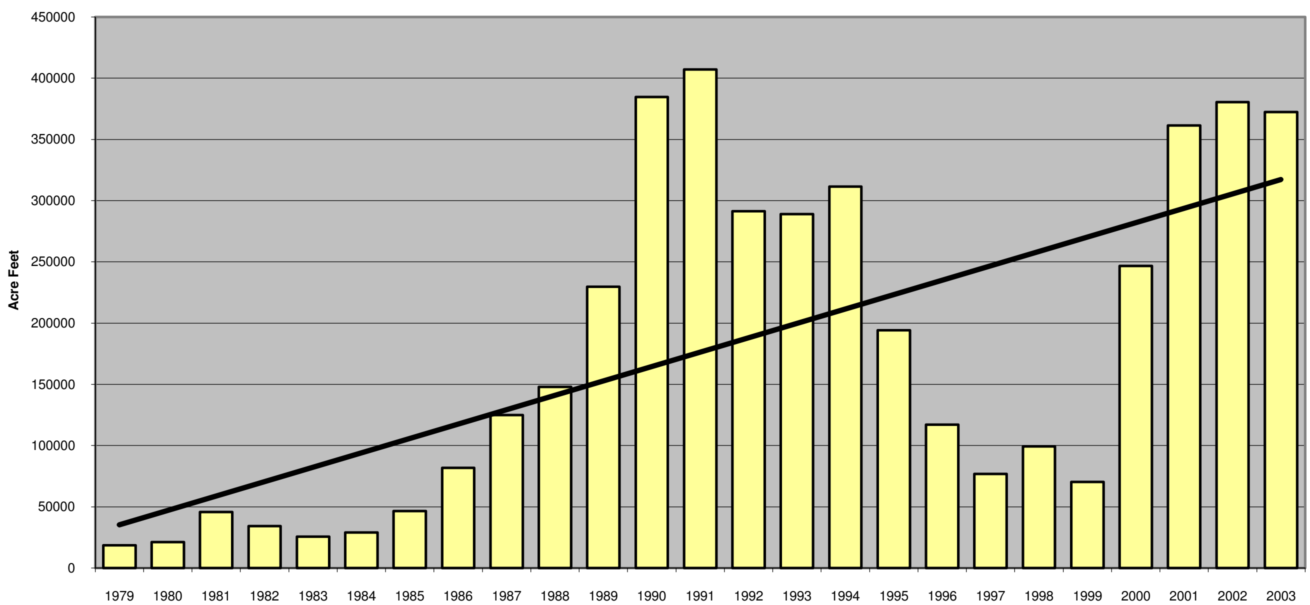


Figure 28 - Los Angeless Purchases from MWD 1979-2003

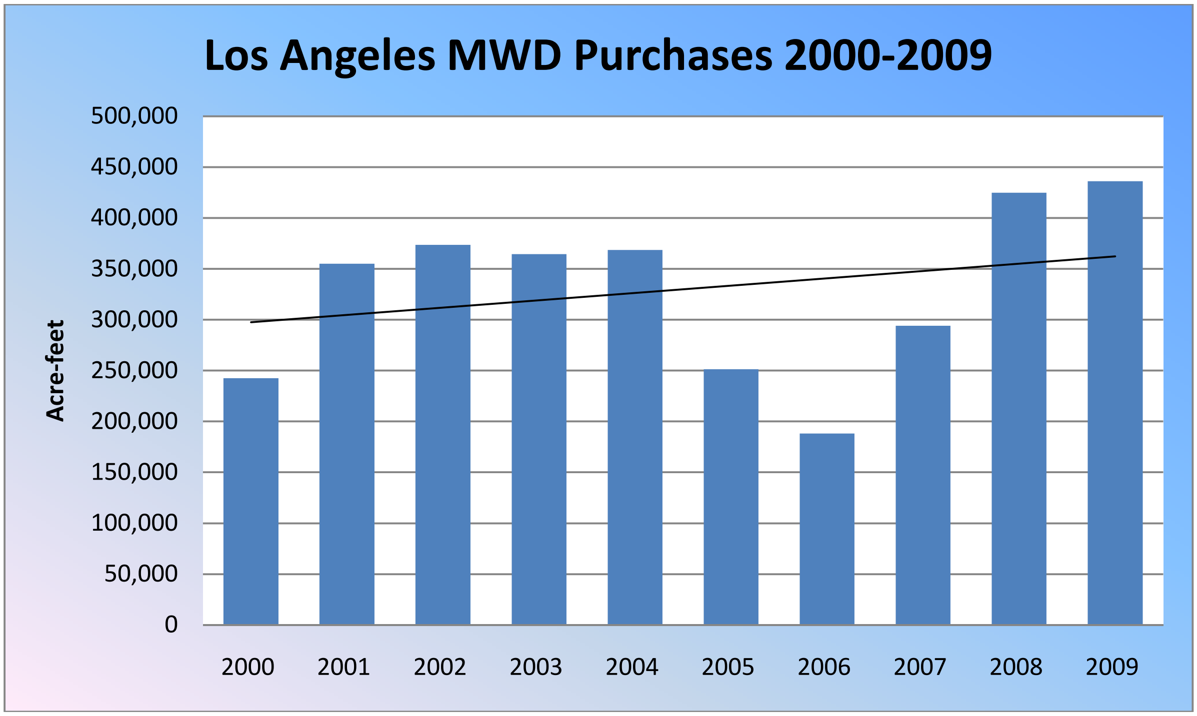


Figure 29 - Los Angeles Purchases from MWD 2000-2009

Note the steady increase in imported water purchases in the last thirty years. In recent years Los Angeles has come to increasingly rely on water imported from the Metropolitan Water District due to court-imposed limits on exports from the Owens Valley. MWD receives water from the State Water Project and from the Colorado River

SOUTH PASADENA

There are no local sources of supply in South Pasadena. That community receives water from groundwater pumping in the nearby Main San Gabriel Basin as well as from the State Water Project and the Colorado River, supplied by Upper San Gabriel Municipal Water District, an MWD member agency.

LA CAÑADA FLINTRIDGE

The City of La Cañada Flintridge is supplied primarily (+/- 80%) by imported water delivered by Foothill Municipal Water District, a member agency of the Metropolitan Water District of Southern California. Local groundwater is pumped by La Cañada Irrigation District. Foothill MWD estimates that of the water served 90% is used for residential purposes, 5% goes to light commercial, and 5% government.

In recent years water consumption has grown significantly in La Cañada Flintridge. During the 1990s per capita consumption grew by 40%. These increases are all the more alarming because La Cañada Flintridge experienced an 11% decline in population during the 1990s. Sales for the major water companies serving the community have grown in proportion. Consumption has recently declined by a few percent, but this community is a the high end of water consumption throughout Southern California.

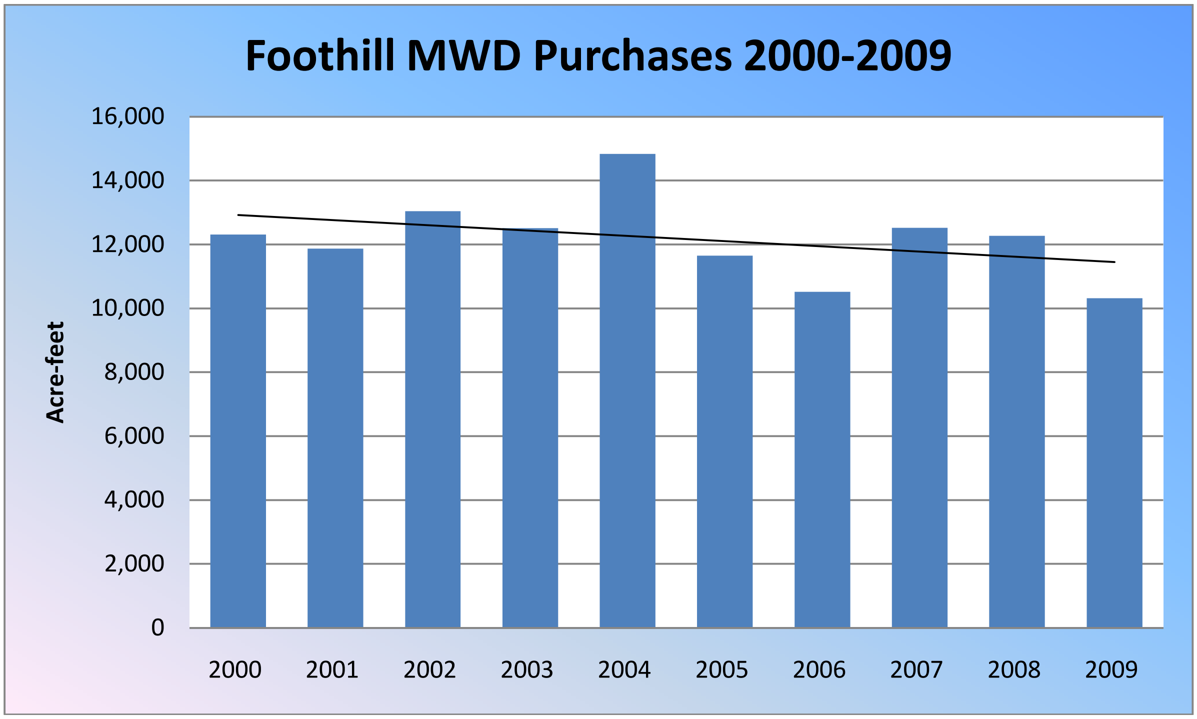


Figure 30 – Foothill Municipal Water District Purchases from MWD

PASADENA

Twenty years ago Pasadena received 60% of its water locally. Today it receives 65% of its water from the Metropolitan Water District's State Water Project and Colorado River supplies. Pasadena also has the right to pump 41% of the supplies of the Raymond Basin. In the last few years Pasadena has had to close ten of its wells due to perchlorate contamination, forcing that city to rely more heavily on imported water supplies.

In 1993 Pasadena discontinued its use of the Behmer Treatment Plant at the mouth of the Arroyo Seco to treat surface water from the Arroyo Seco due to new water quality requirements.

Figure 30 shows imported water purchases for the Foothill Municipal Water District and Figure 31 shows the totals for Pasadena from 1975 through June 2001. The purchase data mirrors weather patterns slowing or declining during wet periods, but there was a clear growth trend that significantly exceeded population growth. In Pasadena the growth amounted to 42%, while population growth during the period was only 13%. In the Foothill MWD territory, which includes Altadena, La Cañada and La Crescenta, the growth in imported water purchases was 63% during that period. In the last ten years, these communities have been able to reduce per capita consumption, but it is not clear whether this is a long-term trend or a drought response.

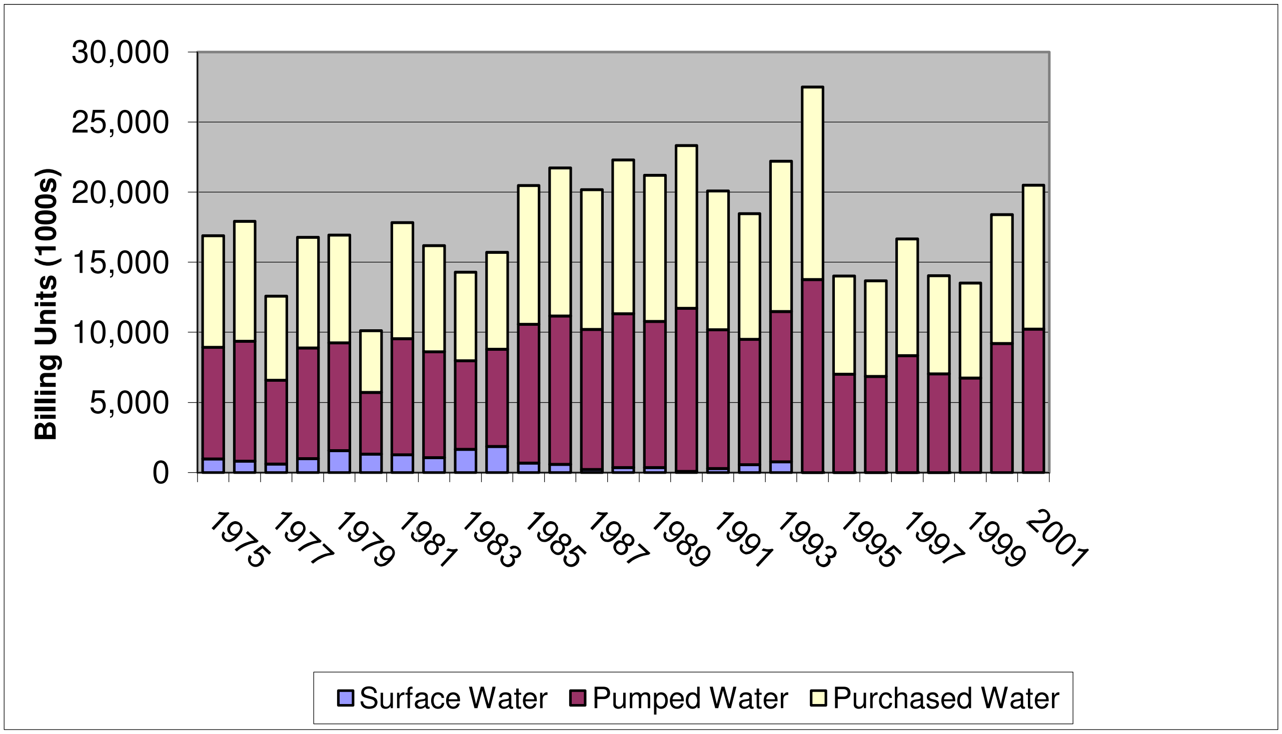


Figure 31 - Pasadena Sources of Water 1975-2001

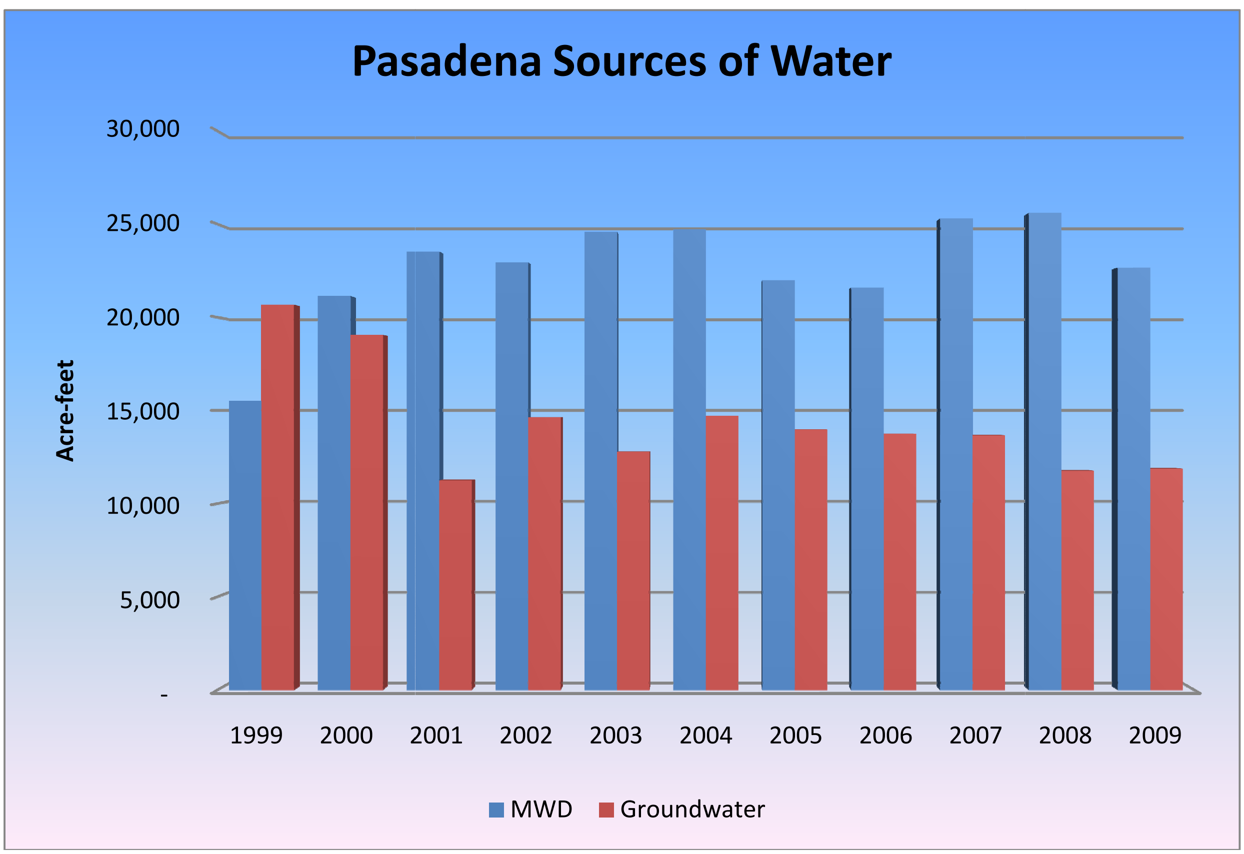


Figure 32 - Pasadena Water Sources 1999-2009

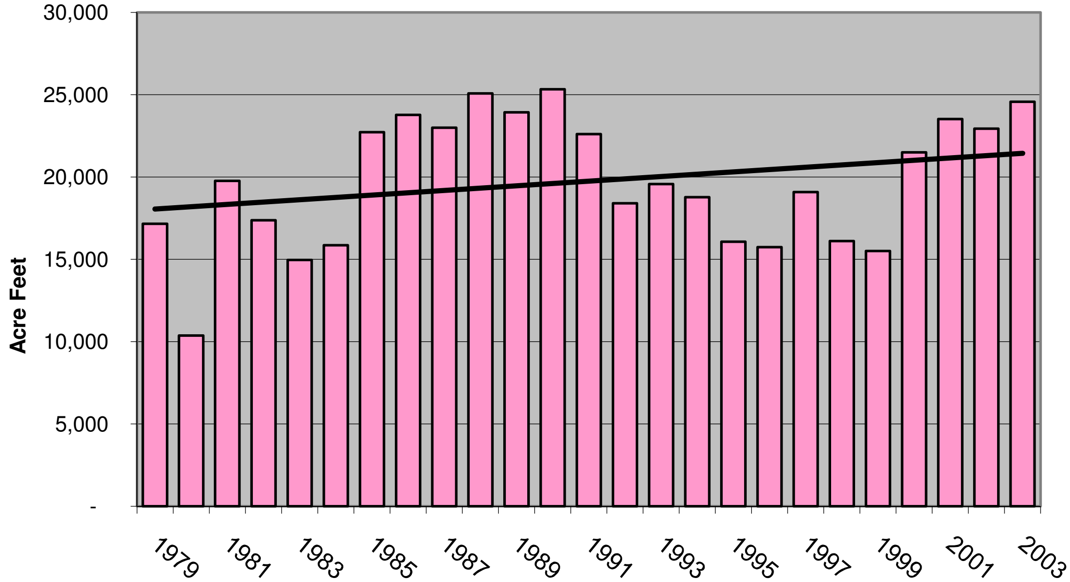


Figure 33 - Pasadena Water Purchases from MWD – 1978-2003

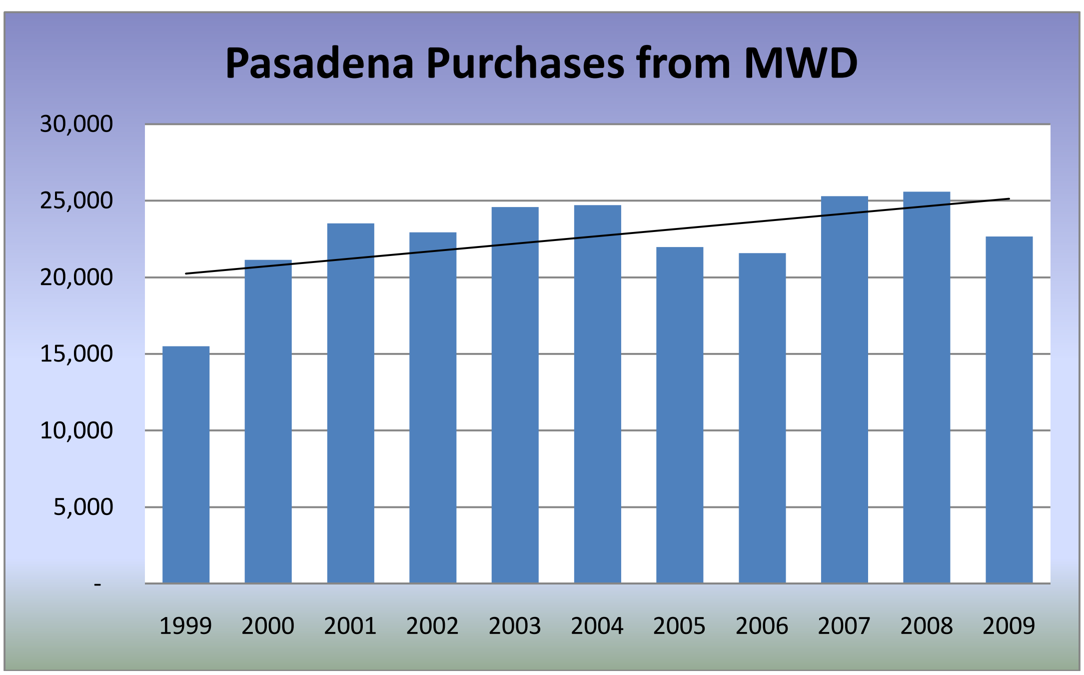
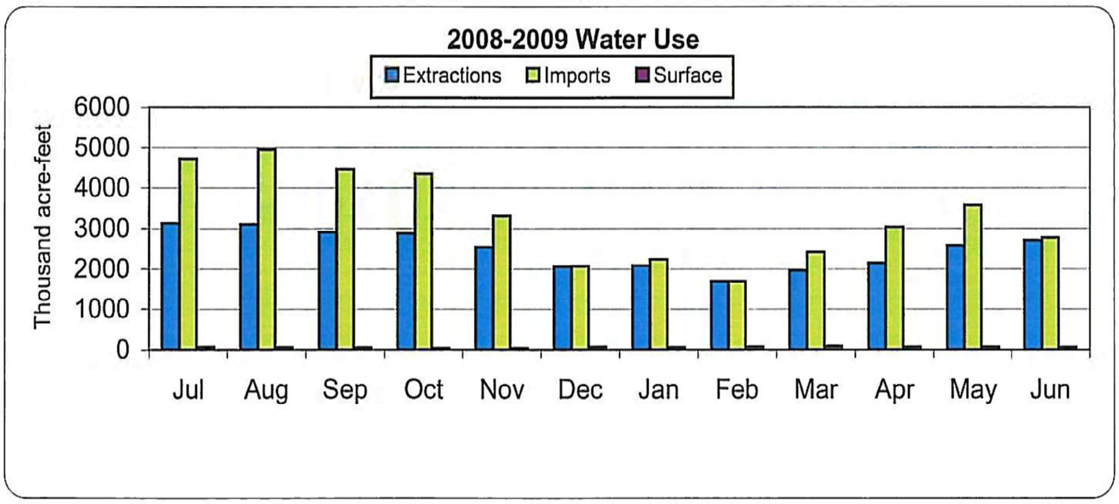


Figure 34 - Pasadena Purchases from MWD – 1999-2009

Altadena

The community of Altadena receives a quarter of its water (25.5%) in 2009 from imported sources delivered by Foothill Municipal Water District. Lincoln Avenue Water Company, Las Flores Water Company and Rubio Cañon Land and Water Association all supply local water as well to the residents of western Altadena.



Water Consumption

Water consumption in the Arroyo Seco Watershed varies dramatically. It ranges from a low of 75 gallons per day per capita in Northeast Los Angeles to a high of 307 gallons per day in La Cañada. Factors that contribute to the disparity include density, lot size and economic status.

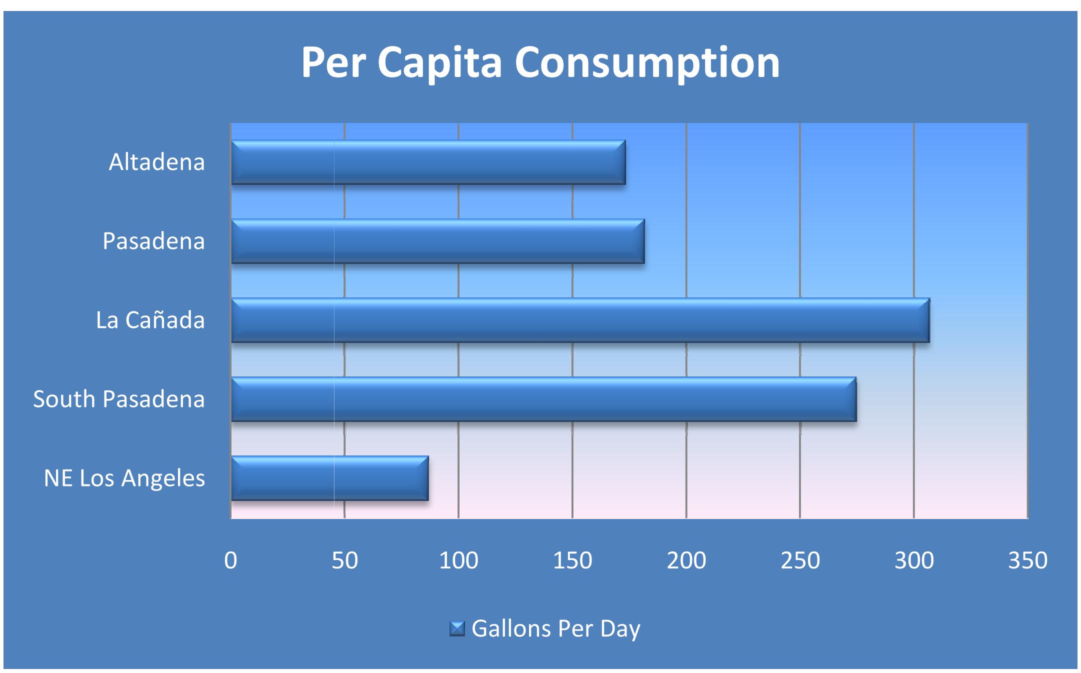


Figure 36 - Per Capita Consumption

Water users in Northeast Los Angeles not only set the conservation standard for the Arroyo Seco Watershed but also for the City of Los Angeles as well, consuming only 74% of the amount per capita as other residents of Los Angeles. Arroyo Seco residents in the Northeast Los Angeles communities consume a remarkable 87 gallons per person per day. Factors that contribute to this remarkably low level of usage include density, lot size, the amount of outside irrigation and income levels.

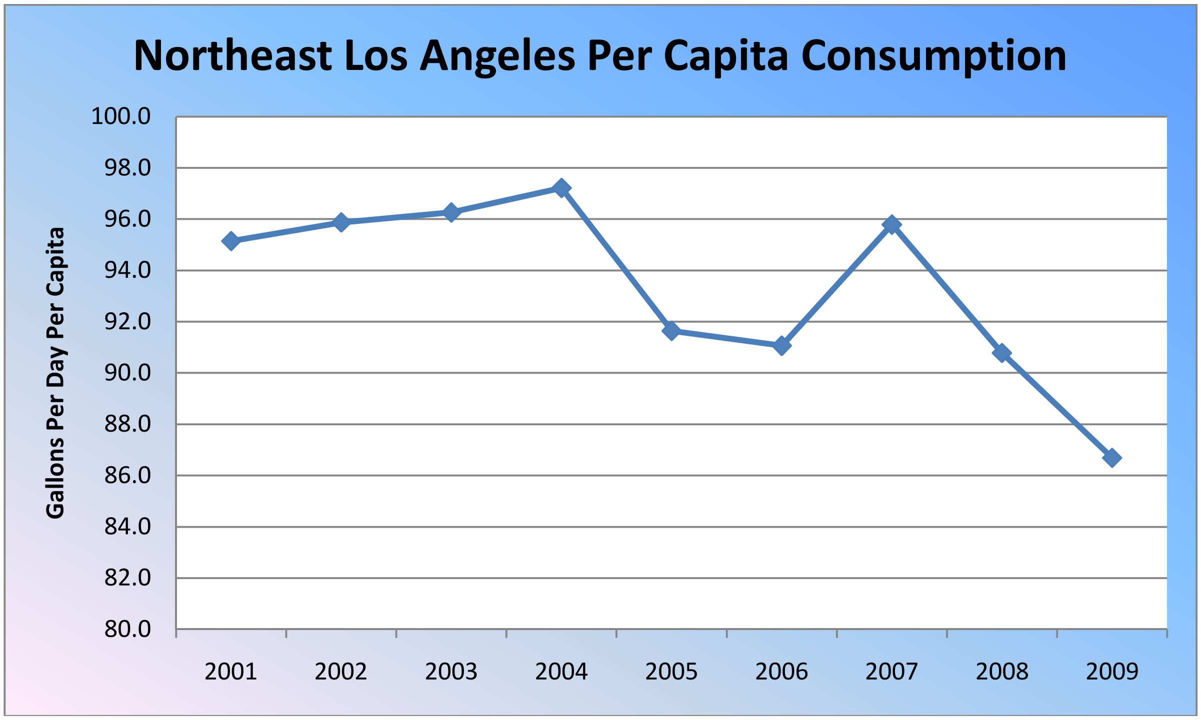


Table 5 – North East Los Angeles Water Consumption

The Water Budget

Now we will examine the inputs and outputs of the Arroyo Seco Watershed to complete the water budget.

Inputs

Rainfall in various forms is the key local input into the watershed budget. Average annual precipitation for the Arroyo Seco Watershed amounted to 41,000 acre-feet in 2009, significantly less than the historical average of 54,400 acre-feet. Some of this rainfall recharges the Raymond Basin directly or through boundary inflow from the San Gabriel Mountains. Water agencies also divert some of the surface flow that results from the precipitation into spreading basins where it percolates into the aquifer beneath the communities of La Cañada, Pasadena and Altadena.

Some water also replenishes the Raymond Basin from septic systems primarily in the La Cañada Flintridge area and from imported water used for landscaping. Most of the septic tank input will be eliminated in the future as sewer systems are extended throughout La Cañada Flintridge.

Imported water is brought into the watershed from a variety of sources:

- The State Water Project and the Bay Delta ecosystem (MWD and its member agencies)
- The Colorado River (MWD and its member agencies)
- The Eastern Sierra Nevadas (Los Angeles)
- The Upper Los Angeles River Area (San Fernando Basin – Los Angeles)
- Central Basin (Los Angeles)
- Main San Gabriel Basin (South Pasadena)

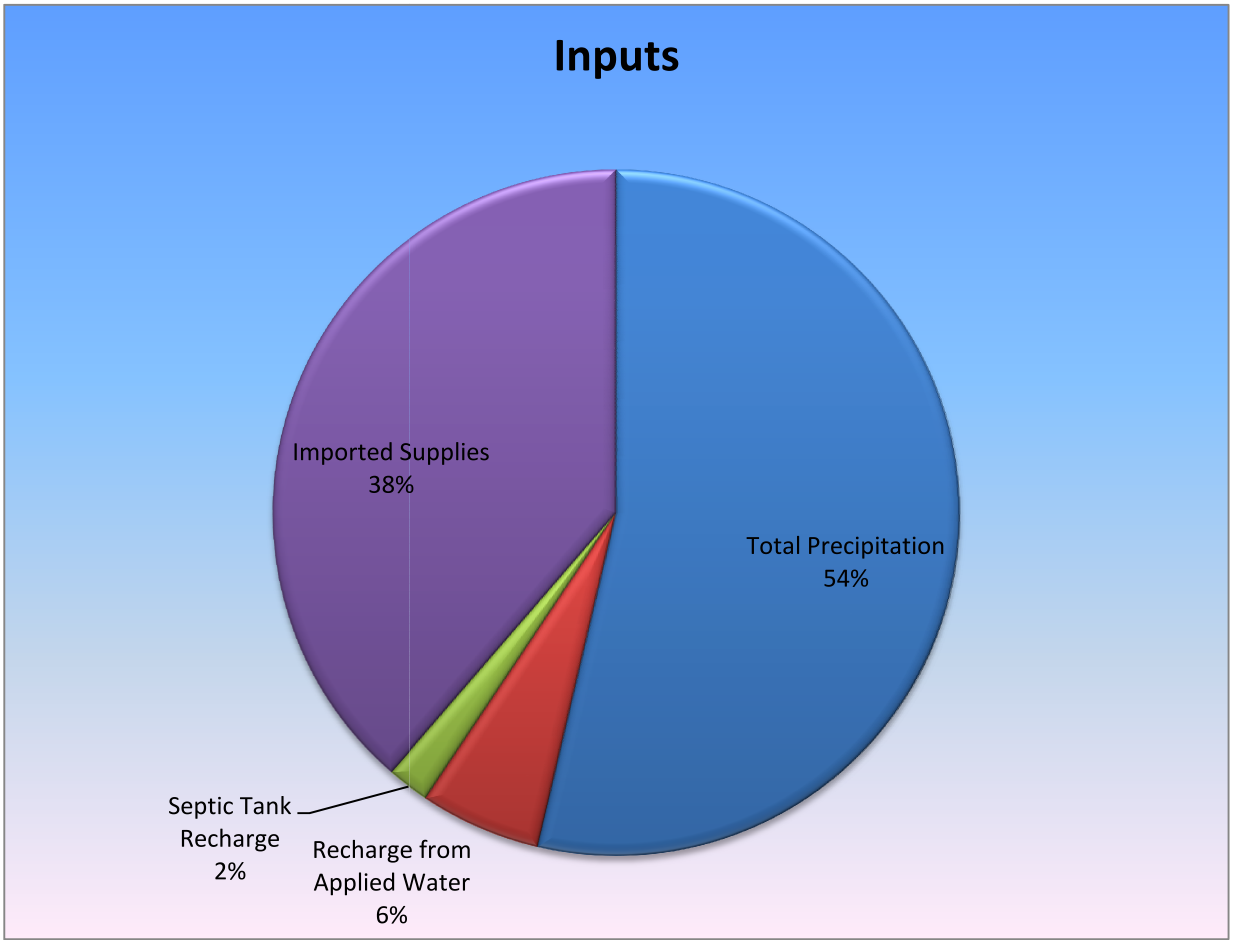


Figure 37 - Inputs to the Water Budget

Outputs

A large part of the water that enters the Arroyo Seco Watershed naturally is consumed by evaporation and transpiration of plants. A small amount is exported outside of the watershed. Approximately 7,000 acre-feet per year seeps over the Raymond Fault into the Main San Gabriel Basin to the south and east. In an average year just over 10,000 acre-feet of water runs off the surface and is discharged into the Los Angeles River. The main consumptive use (+/- 31,000 acre feet annually) is for water production and sales to local water users, primarily residential users.

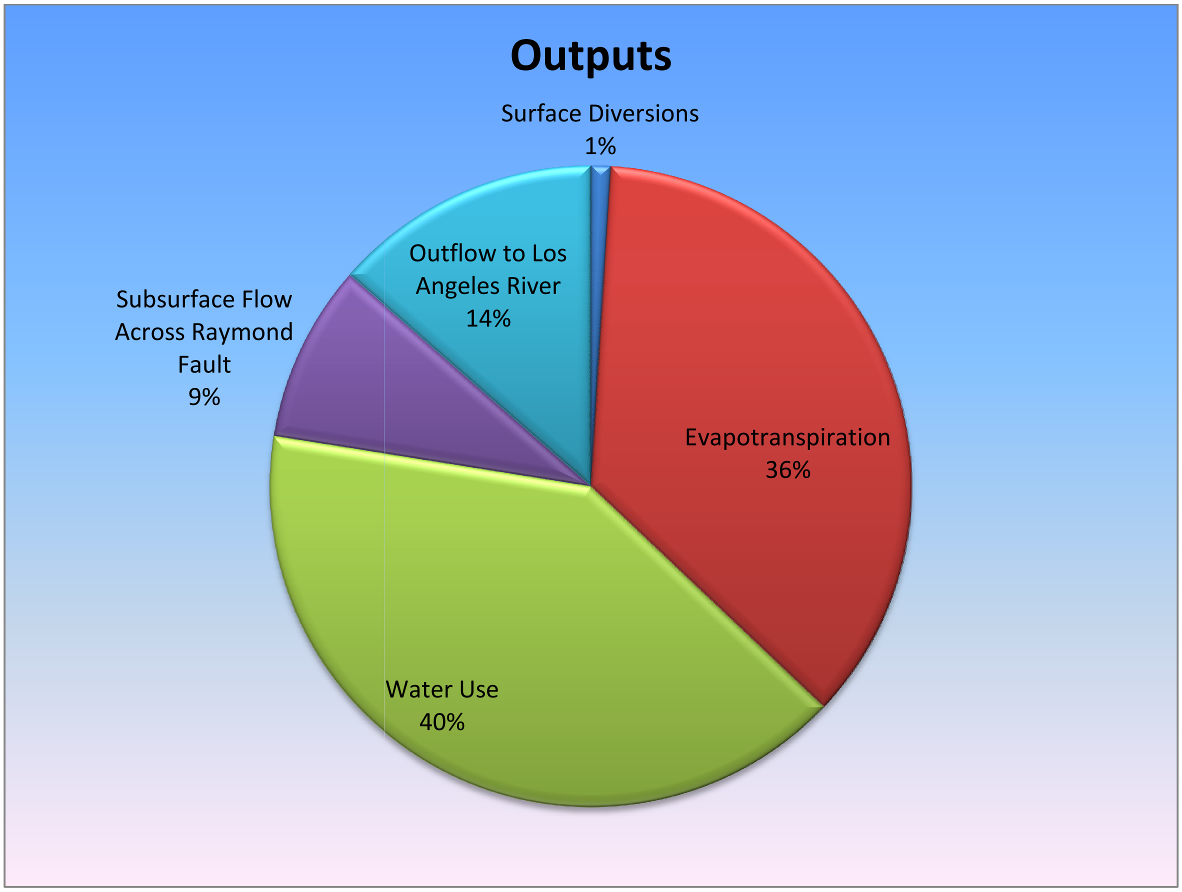


Figure 38 - Outputs from the Water Budget

Arroyo Seco Watershed Budget - 2009			
Inputs			
	Total Precipitation	40,357	
	Precipitation Recharge		6,054
	Boundary Inflow		7,900
	Stream Flow (Spreading)		3,770
	Recharge from Applied Water	4,275	
	Septic Tank Recharge	1,500	
	Imported Supplies	29,057	
	TOTAL INPUTS	75,189	
Outputs			
	Surface Diversions	774	
	Evapotranspiration	28,250	
	Water Use	31,668	
	Subsurface Flow Across Raymond Fault	7,000	
	Outflow to Los Angeles River	10,602	
	TOTAL OUTPUTS	78,294	
Changes in Storage		(3,105)	

Table 6: Arroyo Seco Watershed Budget

Analysis

The water budget for 2009 again indicates a significant overdraft or reduction of storage in the Raymond Basin. Because several of the numbers are estimates based on historical patterns, it is important to consider the pattern that the budget documents rather than the precision of the numbers involved. In early 2009 Raymond Basin agencies in the main part of the basin voluntarily agreed to reduced their pumping incrementally five percent each year until a full thirty percent reduction is achieved. This reduction is a good step, but not a solution. It should reduce the overdraft, but unless consumption is similarly reduced or new sources of water are developed to replenish the basin, the negative picture will continue into the future.

Ways to Improve the Water Budget

People impact the Arroyo Seco Watershed and its water budget in both negative and positive ways. Here are some examples:

- Removing groundwater (e.g. pumping for domestic or commercial use)
- Adding groundwater (e.g. septic systems, irrigation, replenishment)
- Removing surface water (e.g. for municipal and industrial use)
- Adding surface water (e.g. treated wastewater, drains)
- Changing vegetation types (e.g. landscaping)
- Building impervious surfaces (e.g. parking lots, buildings, roads)

Once the water budget is properly understood, the communities of the Arroyo Seco can construct a comprehensive program to protect our watershed and to maximize the value of local water resources.

Problems of Imported Water

In additional to hydrologic variability, the water supply for Southern California and the Arroyo Seco Watershed is linked to critical environmental and political issues that affect not only our region but also most of California and the West. Imported water, once thought to be the solution to future water needs, has not proven to be as reliable as early planners thought. Each of the major sources of imported supply is plagued by persistent problems:

- **The State Water Project** – The SWP cannot deliver enough water to satisfy the contracts that were signed with agencies like MWD in the 1960s. Continuing challenges related to fish and wildlife, water supply reliability, natural disasters, and water quality have beset the project. The Bay-Delta Conservation Plan is now being prepared to bring together federal and state agencies to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses for California’s water system.

- **The Colorado River** – Until 2002 Southern California relied on surplus deliveries of Colorado River water to meet the needs of agriculture and the coastal communities, but that surplus is no longer available. California water agencies that rely on the Colorado River, particularly MWD, have cut their usage of this supply from an average of 5.2 million acre feet per year to 4.4 million acre feet per year. Climate scientists predict a reduced flow in the future of 10-20%.
- **The Owens Valley** – Los Angeles developed this supply of water from the Eastern Sierra Nevadas in 1913 and relied on it for many years, but in the last two decades a series of legal actions and a new environmental stewardship ethic have limited the amount of water that Los Angeles can import from the Owens Valley.

It is clear that the economic and environmental health of our region requires us to decrease our reliance on imported water sources. The solution lies in conservation and better utilization of local water resources. The water budget can be a useful tool to accomplish this goal.

Since precipitation and imports are the only ways to increase the supply or input side of the water budget, there is not much that local residents can do to improve that side of the water budget. More productive energy can be applied to reducing the demand or outputs and to managing local resources more efficiently.

Some Practical Steps

STREAM RESTORATION

The availability of imported water and the threat of floods in our semi-arid region led planners to undervalue the rainfall that falls upon our watershed. Instead of husbanding precious water resources, streams like the Arroyo Seco have been treated as nuisances or threats. More than ten thousand acre-feet a year of runoff that should replenish the ground is efficiently diverted into pipes, culverts, and storm drains where it is whisked away to the ocean. The main Arroyo Seco stream, which transports an average of 7,000 acre-feet per year from the upper mountain watershed and an additional 3,000 acre-feet of runoff, has been transformed into a three-sided concrete box with only limited interaction with the water table. Dozens of smaller streams suffer a similar fate.

RAINWATER RETENTION

Runoff in the lower urbanized section of the watershed amounts to an average of 3,300 acre-feet per year. Local rainfall retention programs, such as the Standard Urban Stormwater Mitigation Plan (SUSMP) program mandated by the Los Angeles Regional Water Quality Control Board, can recover a significant amount of this water. The SUSMP program requires that new developments retain or treat the first ¾-inch of a 24-hour rainfall event in order to reduce pollutants transported to the Pacific Ocean. The SUSMP standards have been developed to improve water quality, but they can also have a significant water supply impact in the Arroyo Seco Watershed because 75% of all rainfall in the watershed occurs in storms of ¾-inch or less.

Yards and gardens can be reconfigured to capture and utilize rainfall. Building permits can reinforce the value of water by providing incentives for rainwater recovery features.

Cleaning Up Contamination

A large number of wells in the Arroyo Seco Watershed have been closed due to contamination, particularly in the critical percolation zone at Hahamongna as the streams descends from the San Gabriel Mountains and enters the urbanized plain of the Arroyo Seco. Volatile organic chemicals, nitrates and perchlorate have knocked the wells out, forcing Pasadena and Lincoln Avenue Water Company to increase their purchase of imported water at considerable expense. Cleaning up this contamination should be the first priority of local water agencies to protect public health and water reliability. A treatment plant is now under construction at Windsor Reservoir, but additional facilities are needed to clean up and restore the Raymond Basin.

Native Landscaping

Landscape irrigation is the major factor that contributes to the wide divergence of per capita water consumption in the Arroyo Seco Watershed. Typically more than half the consumption in a single-family detached house in our region will be for outdoor irrigation, primarily for lawns and exotic plants better suited to other climatic regions. The native plants that once predominated in our region and their Mediterranean cousins have learned to adapt to the natural cycle of wet and dry years, thriving in the heat and dry weather like camels in the desert. They are perfectly suited to our climate, and can be beautiful additions to local landscapes while significantly reducing outdoor water use. Native plants and other Mediterranean-climate plants from similar regions around the world are truly *California-Friendly*.

Recycled Water

Reclaimed wastewater is now being used extensively throughout Southern California primarily for landscape irrigation and industrial applications, but not yet in the Arroyo Seco Watershed.

Wastewater from the upper Arroyo Seco Watershed goes to the facilities of the Los Angeles County Sanitation District near Whittier Narrows where it is treated. Some of it replenishes Central Basin, a groundwater aquifer in southern Los Angeles County. In the Northeast Los Angeles portion of the watershed, wastewater is shipped to the Los Angeles Glendale Water Reclamation Plant near the intersection of the 5 and 135 Freeways.

Pasadena made arrangements fifteen years ago to hook up to recycled water from the LA/Glendale plant, and a pipeline now brings the water as far as Scholl Canyon at the western boundary of Pasadena. The pipes and facilities needed to distribute the water to Brookside Golf Course and other large irrigation users in Pasadena, however, have not been completed. Even a modest reclamation program can increase Pasadena's water supplies by 3%.

Foothill MWD is now developing plans to enhance local resources by the use of conservation and recycling. The agency plans to build "scalping" plants that will treat local wastewater and put it to beneficial use in the neighborhoods of the foothills.

CONJUNCTIVE USE

The next major step in the historical development of water resources in our region is the completion of the long-delayed Raymond Basin Conjunctive Use Program (RBCUP). Conjunctive use, the coordinated use of surface supplies and groundwater resources with imported water, is a water resources management methodology that can optimize water resources while reducing the environmental stress often associated with water importation. The RBCUP, which has been discussed by local water agencies and the Metropolitan Water District for more than twenty years, will upgrade local water facilities and provide MWD with storage capacity of up to 75,000 acre-feet in the Raymond Basin to improve regional water reliability. MWD will replenish the Raymond Basin with water to be stored or replaced. In most years MWD will leave the water in storage, but in dry years it will pump up to 25,000 acre-feet from the aquifer. The Foothill Groundwater Storage was established six years ago as part of this broader Raymond Basin program. It allows for the development of 9,000 acre-feet of storage by Foothill MWD and other foothill agencies. The City of Pasadena completed the environmental impact report for the Pasadena Groundwater Storage Program, the other component of RBCUP, in 2007, but the Pasadena City Council did not finalize the approval of the program, and no action has been taken since then.

CONSUMER EDUCATION

For many decades the residents of our region have taken water for granted, but we now face a mounting water crisis. A growing population is met with diminished imported supplies, contaminated local water sources and an elevated per capita consumption that significantly exceeds much of Southern California. Local water agencies need to step up their water conservation programs by educating the public about the water situation and offering incentives and motivation to use water more wisely.

A key component of an effective consumer education program is to let the residents of the Arroyo Seco Watershed know how their water use affects the local environment as well as distant parts of California and the West. It is important that the residents of our region know of the environmental challenges that face the Sacramento and San Joaquin Rivers and San Francisco Bay because a significant part of our water supplies and that of 25 million other Californians flows through that hub. It is a powerful motivation for local residents to know about the work of the Bay Delta Program to restore the ecological health of those rivers and our state.

Water waste and inefficient use can no longer be tolerated. The residents of the Arroyo Seco must join with their fellow Californian to develop a new ethic and practice of stewardship of water and our precious environmental resources.

Other Steps

The Water Resources technical report of the *Arroyo Seco Watershed Restoration Feasibility Study* includes these recommendations for augmenting or supplementing local water supply:

- Protect and preserve foothill lands to enhance percolation into the groundwater basin and to prevent aggravated runoff.
- Promote comprehensive conservation and implement best management practices throughout the watershed to improve water quality and reduce consumption.
- Expand water conservation and recycling programs through the watershed.
- Create conjunctive use of groundwater basin for enhanced storage during wet periods and for use during dry periods.
- Develop upper watershed reforestation and revegetation programs to reduce sediment flow and improve local retention.
- Naturalize the stream in Hahamongna for greater percolation and habitat benefits and reconsider the use and expansion of the spreading basins.
- Complete a sediment management study for Devil's Gate Dam basin.
- Review the functionality and effects of the upper basin flood control structures such as debris basins and check dams.

These and other approaches should be carefully evaluated and implemented if feasible to enhance and better manage local water supplies.

Conclusion

The Arroyo Seco Watershed Budget is a tool to promote a better understanding of local water use and better management of the water resources of the Arroyo Seco. The approach used here is a relatively simple, straightforward evaluation of all the components of the hydrologic cycle and human interaction with it. More detailed and sophisticated techniques can be used to refine this budget to help the public and planners understand the effects of future management options.

The water budget highlights many of the key water issues that face local decision-makers:

- The need to protect our watershed and its precious environment
- The critical importance of water quality to our region
- The need for comprehensive conservation and water management programs to reduce per capital consumption and reliance water imports.

More sophisticated watershed modeling tools, which include surface water, groundwater and water quality elements, can serve as decision-making tools for watershed management programs involving habitat restoration, water conservation/supply and water quality. These tools can be used to refine, test and assess specific watershed management alternatives. In this way, the water budget and refined models can provide the context for an informed, prescriptive approach to planning and the development of local codes and ordinances to help "balance the budget". Planners and policy makers can determine the relative benefits of conservation standards and programs and even derive an estimate of their economic benefits. Local agencies such as planning departments and water service providers could use these forecasts and estimates to develop incentive programs for voluntary “site improvements” such as California Friendly landscapes and removing impermeable surface.

We urge the residents of the Arroyo Seco and our governmental leaders to redouble their efforts to use water wisely and to restore the natural functioning of the Arroyo Seco, our region’s greatest natural treasure.

Appendix 1 – Water Budget Terminology

Evaporation	The process by which water is changed from the liquid or the solid state into the vapor state. In hydrology, evaporation is vaporization that takes place at a temperature below the boiling point.
Gaging station	A particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or discharge are obtained.
Ground water	Water in the ground that is in the zone of saturation, from which wells, springs, and ground-water runoff are supplied.
Ground-water outflow	That part of the discharge from a drainage basin that occurs through the ground water. The term "underflow" is often used to describe the ground-water outflow that takes place in valley alluvium (instead of the surface channel) and thus is not measured at a gaging station.
Ground-water runoff	That part of the runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.
Hydrologic budget	An accounting of the inflow to, outflow from, and storage in, a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, reservoir, or irrigation project.
Hydrologic cycle	A convenient term to denote the circulation of water from the sea, through the atmosphere, to the land; and thence, with many delays, back to the sea by overland and subterranean routes, and in part by way of the atmosphere; also the many short circuits of the water that is returned to the atmosphere without reaching the sea. (After Meinzer, 1949, p. 1.)
Hydrology	The science encompassing the behavior of water as it occurs in the atmosphere, on the surface of the ground, and underground. (Am. Soc. Civil Engineers, 1949, p. 1.)
Infiltration	The flow of a fluid into a substance through pores or small openings. It connotes flow into a substance in contradistinction to the word percolation, which connotes flow through a porous substance.
Percolation	The movement, under hydrostatic pressure, of water through the interstices of a rock or soil, except the movement through large openings such as caves.
Runoff	That part of the precipitation that appears in surface streams. It is the same as streamflow

	unaffected by artificial diversions, storage, or other works of man in or on the stream channels.
Streamflow	The discharge that occurs in a natural channel. Although the term *discharge* can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than runoff, as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.
Surface water	Water on the surface of the earth.
Transpiration	The quantity of water absorbed and transpired and used directly in the building of plant tissue, in a specified time. It does not include soil evaporation.
Source - Manual of Hydrology: Part 1. General Surface-Water Techniques, GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1541-A, *Methods and practices of the Geological Survey* http://water.usgs.gov/wsc/glossary.html	

Appendix 2 – Water Budget Resources
Important Sources of Local Climate and Water Data

Resource	Information	Location
Pasadena Climate	Precipitation, temperature, historical record for this weather station	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?capasa
Altadena Climate	Precipitation, temperature, historical record for this weather station	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca0144
Mt. Wilson Climate	Precipitation, temperature, historical record for this weather station	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca6006
Arroyo Seco Ranger Station Climate	Precipitation, temperature, historical record for this weather station	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca0327
Los Angeles Civic Center	Precipitation, temperature, historical record for this weather station	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca5115
Arroyo Seco Streamflow (USGS gage)	Current, average, peak streamflow over 94 years	http://www.arroyoseco.org/streamflow.htm
USGS Stream Gage Webcam	Real-time webcam that can be adjusted, streamflow data	http://ca.water.usgs.gov/webcams/jpl/
Current California Drought Conditions	Status, water levels, assistance	http://www.water.ca.gov/drought/
Western Regional Climate Center	Historical and current climate information and education	http://www.wrcc.dri.edu/
Bewaterwise.com	Complete information on conservation programs and landscaping options for a dry region	http://www.bewaterwise.com

Appendix 3 –Table and Figures

Appendix 4 – Credits and Sources

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4	Figure 1 - The Water Cycle	United States Geological Survey (USGS), Illustration by John M. Evans USGS, Colorado District, http://ga.water.usgs.gov/edu/watercyclegraphichi.html
4	Definition of Water Budget	USGS [Adapted from Dictionary of Earth Sciences, Oxford University Press, 1999]
6	California DWR, Bulletin 118	California Department of Water Resources, 2003. California' s Ground Water, Bulletin 118. Draft Individual Basin Descriptions. Raymond Groundwater Basin. Accessed online 4/21/10 at http://www.waterplan.water.ca.gov/groundwater/draftmain2.htm
9	Figure 2 – Arroyo Seco Watershed	Los Angeles County Department of Public Works
10	Figure 3 – Topographic Map	Arroyo Seco Watershed Restoration Feasibility Study, North East Trees and the Arroyo Seco Foundation
12	Figure 4 - Conceptual Water Budget	Conservation Ontario, http://www.conservation-ontario.on.ca/resources/graphics/Water_budjet_Andrea_Gauthier_2009_sm.jpg
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		July 7, 2003
24	Figure 16 – Pasadena Precipitation	Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin, prepared for the Raymond Basin Management Board by Geoscience Support Services, July 7, 2003
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43	Table 5 – North East Los Angeles Water Consumption	Los Angeles Department of Water & Power

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46	Table 6 - Arroyo Seco Watershed Budget	Data provided by Raymond Basin Management Board, City of Los Angeles Department of Water & Power, City of Pasadena Water & Power Department, County of Los Angeles Department of Public Works, US Geologic Survey, Geoscience Draft Technical Memorandum, MWD's, Technical Memorandum on Raymond Basin Groundwater Flow Modeling, CIMIS, and Western Regional Climate Center
52	Appendix 1 – Water Budget Terminology	Manual of Hydrology: Part 1. General Surface-Water Techniques, GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1541-A, *Methods and practices of the Geological Survey* http://water.usgs.gov/wsc/glossary.html)
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