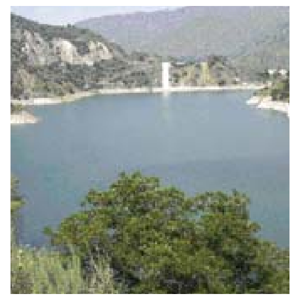
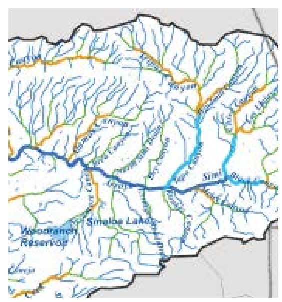
THE GREEN VISIONS PLAN

for 21st century southern california





16. Watershed Assets Assessment Report

Jingfen Sheng
John P. Wilson

Acknowledgements: Financial support for this work was provided by the San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy and the County of Los Angeles, as part of the “Green Visions Plan for 21st Century Southern California” Project. The authors thank Jennifer Wolch for her comments and edits on this report. The authors would also like to thank Frank Simpson for his input on this report.

Prepared for: San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy 900 South Fremont Avenue, Alhambra, California 91802-1460

Photography: Cover, left to right: Arroyo Simi within the city of Moorpark (Jaime Sayre/Jingfen Sheng); eastern Calleguas Creek Watershed tributaries, classified by Strahler stream order (Jingfen Sheng); Morris Dam (Jaime Sayre/Jingfen Sheng). All in-text photos are credited to Jaime Sayre/ Jingfen Sheng, with the exceptions of Photo 4.6 (http://www.you-are-here.com/location/la_river.html) and Photo 4.7 (digital-library.csun.edu/cdm4/browse.php?...).

Preferred Citation: Sheng, J. and Wilson, J.P. 2008. *The Green Visions Plan for 21st Century Southern California. 16. Watershed Assets Assessment Report.* University of Southern California GIS Research Laboratory and Center for Sustainable Cities, Los Angeles, California.

This report was printed on recycled paper.

USC Center for Sustainable Cities

GIS research laboratory
Department of Geography
College of Letters, Arts, and Sciences
University of Southern California
Los Angeles, CA 90089-0255
www.usc.edu/dept/geography/gislab

USC Viterbi School of Engineering

USC College of Letters, Arts & Sciences

THE GREEN VISIONS PLAN

for 21st century southern california

The mission of the Green Visions Plan for 21st Century Southern California is to offer a guide to habitat conservation, watershed health and recreational open space for the Los Angeles metropolitan region. The Plan will also provide decision support tools to nurture a living green matrix for southern California. Our goals are to protect and restore natural areas, restore natural hydrological function, promote equitable access to open space, and maximize support via multiple-use facilities. The Plan is a joint venture between the University of Southern California and the San Gabriel and lower Los Angeles Rivers and Mountains Conservancy, Santa Monica Mountains Conservancy, Coastal Conservancy, and Baldwin Hills Conservancy.

www.greenvisionsplan.net

TABLE OF CONTENTS



1. BACKGROUND

1.1. Project Context

The Green Visions Plan for 21st Century Southern California is a joint venture by the Lower Los Angeles and San Gabriel Rivers and Mountains Conservancy (RMC), the Santa Monica Mountains Conservancy (SMMC), the Baldwin Hills Conservancy (BHC), and the California Coastal Conservancy (CC) to develop a comprehensive habitat conservation, water protection, and recreational opportunities plan for southern California. This report is intended to support and inform region-wide planning efforts from the perspective of watershed health assessment. Southern California faces numerous challenges in water resource management. The natural hydrologic cycle, in which rainwater infiltrates into the ground, has been replaced by a paved drainage system that quickly carries away most of the water following storm events. In the meanwhile, the increasing discharge of reclaimed wastewater and other surface discharge – including lawn watering overflow and streetside car washing – into the regions' waterways has dramatically altered stream flow regimes and hence the nature and quality of urban habitat.

The need for watershed planning and restoration is now widely recognized as the preferred approach to dealing with these issues. Protecting uplands, implementing stronger source controls, treating runoff prior to discharge, and greening and increasing the permeability of the urbanized portions of the region are steps that will replenish groundwater supplies and improve the quality of the region's waterways and aquatic habitat. As the first part of such a strategic implementation plan, this report documents the geographic location and character of hydrologic features and disturbances that have occurred in the plan area. Over time, the various parts of the natural hydrologic system have been severely disrupted with the construction of flood control systems, concrete channels, reservoirs, dams, debris basins, storm detention basins, and spreading grounds. This report aims to provide a watershed baseline condition assessment that describes the historical and current conditions of the watershed, the human modifications that have been made to the hydrologic system, and to what extent hydrologic characteristics have been altered in terms of flow regimes, flow paths, water quality, and groundwater storage. The hydrologic assets inventory will provide principal information for watershed projects such as prioritization of riparian land acquisition, storm water park sites selection, concrete flood control channel removal, dam removal, underground storm drains daylightening, and riparian habitat restoration.

1.2. Analytical Framework, Data Sources, and Methods

The report is organized by five 8-digit hydrologic cataloging unit (HUC) watersheds indexed by the National Hydrography Dataset (NHD). For each watershed, general characteristics of the watershed are described first. The hydrologic conditions of the watershed follow. A series of hydrologic components that characterize the hydrologic system are as follows:

- Stream network and stream classification
- Watershed classification and attributes
- Hydrologic features: dams, reservoirs, flood control facilities, debris basins, spreading grounds, etc.

- Dynamic flow and flood characteristics over time and across the watershed

- Groundwater characteristics

A number of GIS datasets, aerial images, photographs, historic gauging station data, documents, reports and software were used in producing this hydrologic assessment report. The GIS-relevant operations were conducted using ArcGIS 9.2. Major GIS datasets and gauging station data include:

- USGS topographic quadrangle maps at a 1:24,000 scale

- USGS 10m DEMs

- National Hydrography Datasets (NHD)

- 2001 land use data from Southern California Association of Governments (SCAG)

- California Geological map

- "Dams within the jurisdiction of the State of California" (Bulletin 17-93, California Department of Water Resources (DWR), Division of Safety of Dams, Sacramento).

- Debris basin GIS datasets from Ventura County Flood Control Department and Los Angeles County Department of Public Works

- Streamflow data from USGS and Los Angeles County Department of Public Works (LACDPW)

- Rainfall data from National Climatic Data Center (NCDC) and LACDPW

- Simulated mean annual rainfall surfaces based on rainfall gauge data using ANUSPLIN version 4.3 (Hutchinson, 1995, 2004)

- Groundwater basin data from Department of Water Resources (Bulletin 118).

Various GIS datasets, technical reports and documents were analyzed using different methods in order to describe the characteristics of the abovementioned hydrologic components.

Stream classification

Characteristics of streams in the watershed are described by stream classes. The original NHD datasets for five 8-digit HUC watersheds are enhanced with multiple reference datasets (Sheng et al., 2007). With the enhanced stream network, stream segments are classified into a Strahler stream order system using the Nature Conservancy toolset. Strahler's (1952) stream order system is a simple method of classifying stream segments based on the number of tributaries upstream. A stream with no headwater stream is considered a first order stream. Two first order streams join and form a second order stream. Thus, an n^{th} order stream is always located downstream of the confluence of two $(n-1)^{th}$ order streams. Stream segment length, stream gradient, average stream slope, total length of the upstream tributaries, catchment area and total upstream contributing areas are generated for each stream segment using the Nature Conservancy toolset.

Watershed classification

Watersheds are classified by Strahler stream order into catchment classes. Land use/land cover characteristics are described by the stream order in the catchments. The land use data (2001) from Southern California Association of Governments (SCAG) are aggregated into five land use categories of urban, agriculture, forest, water, and others (e.g. open space and recreation) from the original 103 land use classes.

Dynamic flow and flood characteristics over time and across the watershed

Flow and flood statistics – mean annual daily discharges, coefficient of variance, mean annual flood peak discharge, and their temporal trends – are summarized for the stream gauge stations that have data record longer than 20 years. Annual mean daily discharges are estimated by averaging the daily discharge time series data for each selected station. Flood peak discharge time series are used to determine the annual flood discharges and flood magnitudes with different recurrence intervals.

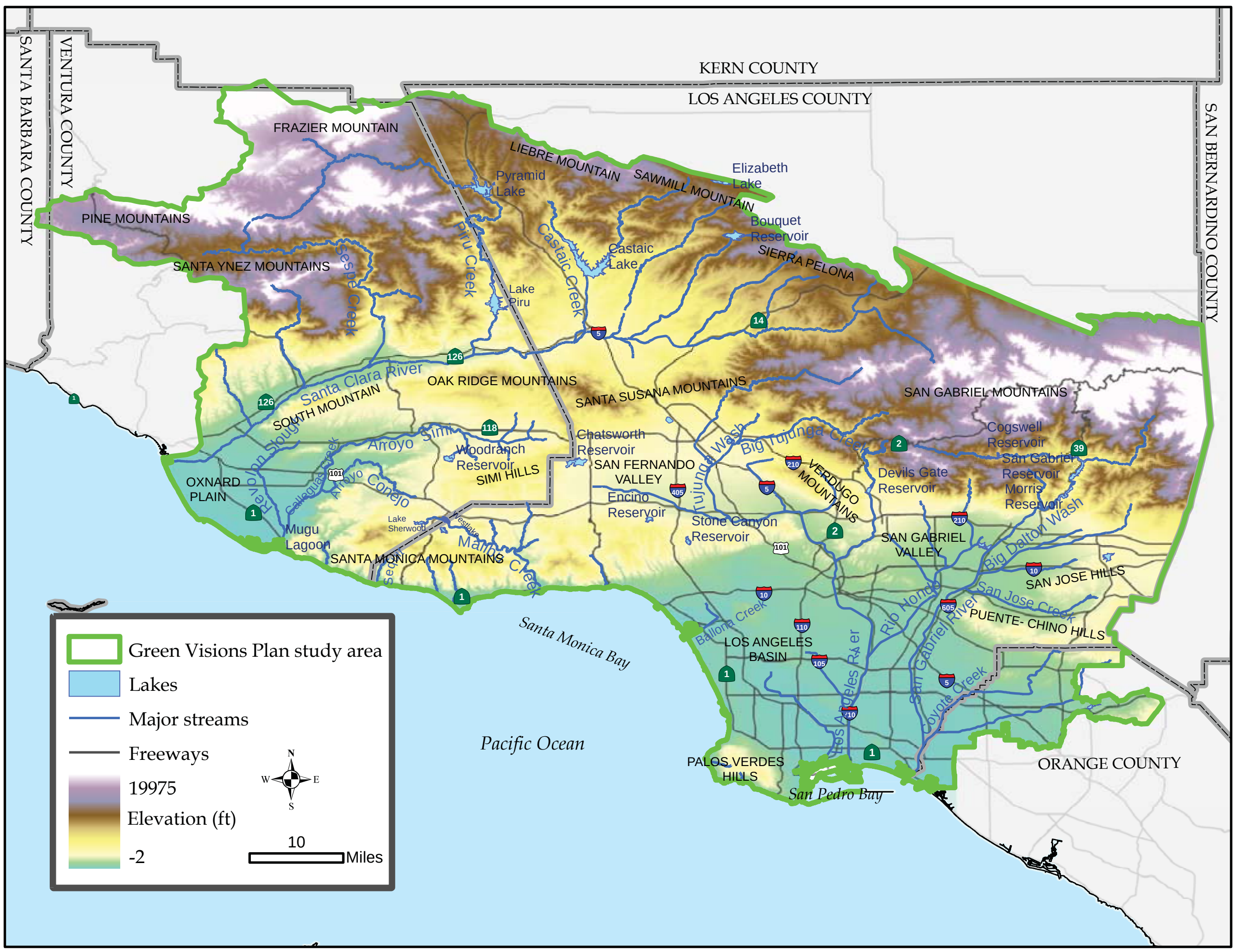
The Kendall non-parametric test is used to identify any significant trend in mean annual daily discharge and annual flood peak discharges. This particular test is designed to detect a monotonically increasing or decreasing trend in the data rather than an episodic or abrupt event (McCuen, 2003). The null hypothesis, which assumed that the tested variables were a sample of n independent and identically distributed random variables, was rejected if the calculated test statistic (Kendall's τ) corresponded to a probability value (*p* value) greater than some critical level of significance, taken here as 5%. The smaller the *p* value, the more convincing is the rejection of the null hypothesis (i.e., that there is no significant trend in the tested time series). Watersheds that are experiencing urbanization or have already become highly urbanized are expected to observe increasing annual flood peaks and maximum daily discharges over time.

The components of dams, lakes, reservoirs, flood control facilities, debris basins, spreading grounds, and groundwater basins are briefly summarized in the report based on the literature and documents reported by the various agencies such as LACDPW and State of California Resources Agency.

2.1 Geology

The study area is bounded to the north by the Frazer, Liebre, Sawmill, Serra Pelona, and San Gabriel Mountains, to the south by the Santa Monica Mountains, the Pacific Ocean, and Palos Verdes Hills, to the west by the Santa Ynez Mountains, and to the east by the San Jose Hills and Puente-Chino Hills (Figure 2.1). The San Gabriel, Santa Susana, Verdugo, and Santa Monica Mountains are part of the Transverse Ranges. The San Gabriel Mountains are generally composed of Mesozoic and older igneous and metamorphic rock. The Santa Susana Mountains are composed mainly of Miocene to Pleistocene marine and non-marine sedimentary rock. The Santa Monica Mountains are composed mainly of Cretaceous to Miocene sedimentary and volcanic rock (USGS 2003). Topography in the Green Visions Plan study area ranges from sea level to over 10,000 ft in the San Gabriel Mountains. Most of the coastal plain is less than 1,000 ft in elevation. The foothills reach 3,000-4,000 feet before rising rapidly into the San Gabriel Mountains, to a height of 10,068 at Mt. San Antonio (Mt. Baldy). The slope of the entire study area averages 30% with mountain slopes as steep as 65.7%, some of the steepest slopes in the world.

Figure 2.1 Topography in the Green Visions Plan study area



Surrounded by mountains, the Los Angeles Basin, San Gabriel Valley, San Fernando Valley, Santa Clara River Valley, Santa Clarita Valley, and Oxnard Plain are situated at the base of and/or on floodplains built from sediments emanating from these mountains. These basins and valleys are filled with alluvial deposits of sand, gravel, clay and silt, which could run thousands of feet thick in the Oxnard coastal plain due in part to the erosive nature of the San Gabriel and Santa Monica Mountains (The California Resources Agency, San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy, Santa Monica Mountains Conservancy, 2001). Up to 10 km of marine to alluvial sediments were deposited in the center of the Los Angeles Basin on a continental margin. Most of the San Gabriel Basin is characterized by interfingering lenses of alluvial deposits of cobbles, gravel, silt, and clay (EPA, 1999).

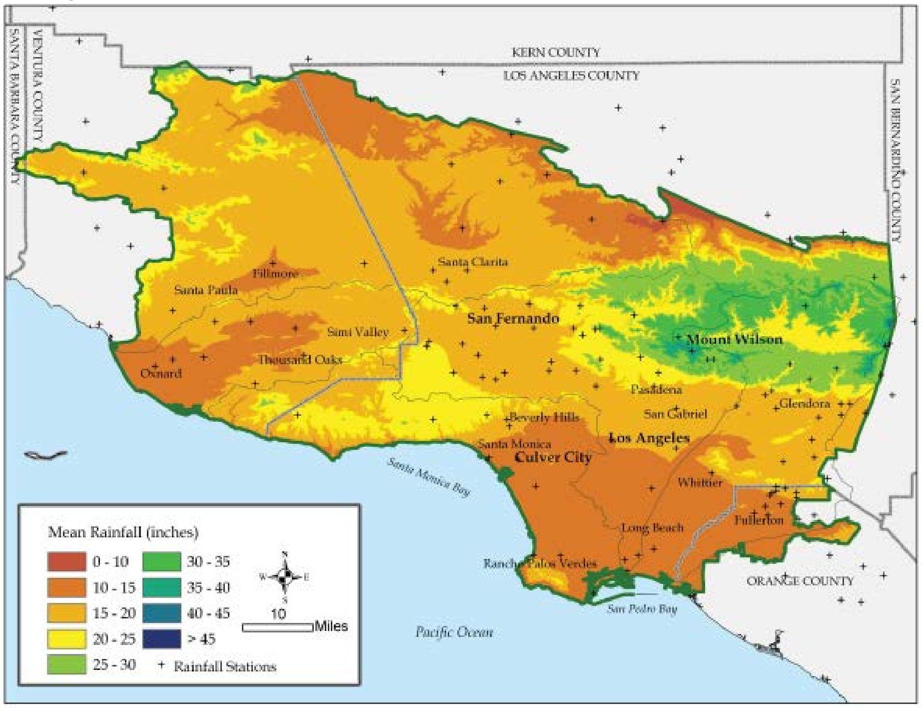
The region is extensively faulted, with the San Andreas Fault running along the north side of the San Gabriel Mountains. The San Andreas Fault is a right-lateral strike-slip fault that runs through the GVP study area and interacts with other faults like the San Jacinto Fault Zone and Pinto Mountain Fault. The second largest fault in terms of length is the San Gabriel Fault. This is also a right-lateral strike-slip fault which runs northwestward subparallel to the San Andreas Fault for a distance of about 140 km (Jennings, 1994; SCEDC, 2006). Throughout the region there are hundreds of lesser fault systems, such as the Newport-Inglewood Fault and the Whittier Fault that are located beneath the Los Angeles Basin, and Malibu Coast Fault and Palos Verdes Fault along the coast (SCEDC, 2006). Several major earthquakes have occurred during the past few decades; these are frequently referenced by the region they struck rather than the name of the fault itself. The best examples are Sylmar in 1971, Whittier Narrows in 1987, and Northridge in 1994 (State of California Resources Agency, 2001).

2.2. Climate

The climate of the study area is a combination of maritime and Mediterranean climates that are determined by cold ocean water and latitude. A consistent temperature inversion layer is usually formed by the maritime climate and causes foggy, hazy and smoggy weather, and during summer a high pressure zone generally prevents precipitation. In the winter, storms bring heavy precipitation over periods of one or two days and this is the primary growing season for vegetation. Spring is known for its fog, and summer for its haze and smog. In the autumn Santa Ana winds blowing from the Mojave desert to the ocean push maritime moisture out to sea and the vegetation becomes particularly dry (Lebow, 1998).

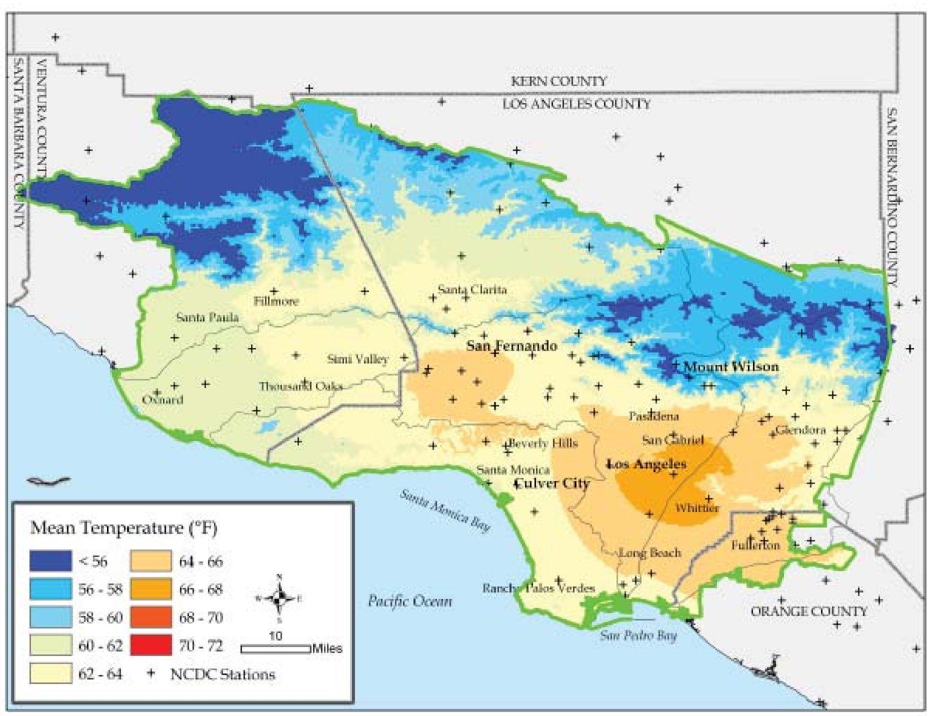
The spatial variation in local climate is largely a result of the topography of the region. Figures 2.2 and 2.3 show the spatial distribution of the mean annual rainfall and temperature across the GVP study area for the period of 1931-2000. The south side of the Santa Monica Mountains benefits from the marine climate and the moisture-laden breezes that blow in from the ocean. The rise of the San Gabriel Mountains along with a series of mountains in the northern part of the GVP study area creates a barrier that traps moist ocean air against the mountain slopes and partially blocks summer heat from the desert and winter cold from the interior northeast.

Figure 2.2 Spatial variation of mean annual rainfall across the GVP study area



From coast to mountains, mean annual rainfall varies from 10-15 inches along the coast to 15-20 inches in downtown Los Angeles to 25-30 inches in the mountains (Figure 2.2). For any given storm event, rainfall totals vary significantly across watersheds. Moisture-laden air from the ocean moves up the mountain slopes, expanding and cooling as it rises. Cooler air holds less moisture, and therefore produces more precipitation on the windward side and warm and dry air on the lee side of the mountains. Along the same profile from coast to mountain, the mean annual temperature changes from 63.1°F at the Culver City station, to 65.8°F at the Los Angeles Downtown station, to 55.7°F at the Mt. Wilson station. The maximum long term temperature observed at the three stations changes from 72.4°F at the Culver City station, to 74.3°F at the Los Angeles Downtown station, to 65.0°F at the Mt. Wilson station. The long term mean temperature of the GVP study area is 61.7°F. The San Fernando Valley and the Los Angeles Basin are two

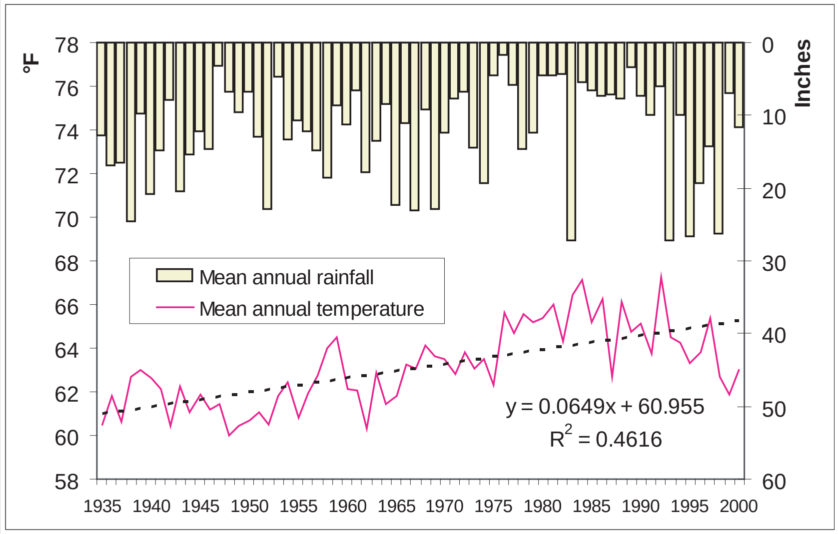
Figure 2.3 Spatial variation of mean annual temperature across the GVP study area



warm spots with higher mean temperatures than the surrounding area.

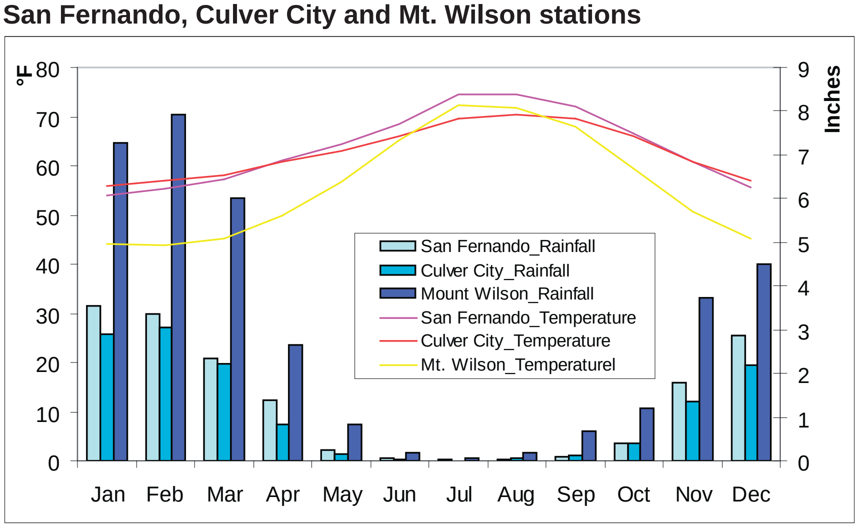
The inter-annual variability of the climate is associated with larger events such as El Niño - Southern Oscillation (ENSO). It is usually characterized by the periodic variation of the dry-wet and warm-cold years. But there is generally no long-term temporal trend in annual total rainfall across the GVP study area according to the rainfall gauge station records except some stations located in the Santa Ynez Mountains (Sheng et al., 2007). Some weather stations have recorded increasing mean annual temperatures over the last several decades. Figure 2.4, for example, shows the inter-annual variation in temperature and rainfall at the Culver City station from 1935 to 2000. It shows periodic changes in both temperature and rainfall with a gradual increase in temperature over the period of records.

Figure 2.4 Annual rainfall and temperature in Culver City station from 1935 to 2000



The seasonal variability in temperature and rainfall is much greater than the annual variability. Figure 2.5 shows the seasonal variations in monthly temperature and rainfall at the San Fernando, Culver City and Mt. Wilson stations from 1930 to 2000. The greatest seasonal temperature and rainfall variations were recorded at the Mt. Wilson station, followed by the San Fernando and Culver City stations. The graph also shows that most of the rainfall occurs in the winter between November and March with very little rainfall received in the summer.

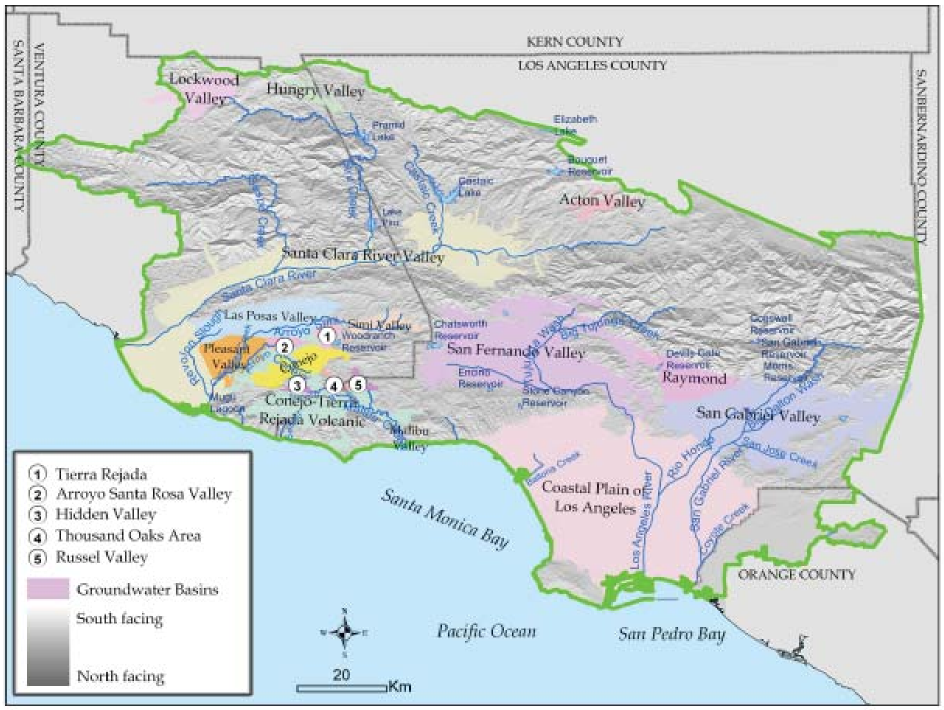
Figure 2.5 Seasonal variations in temperature and rainfall at the San Fernando, Culver City and Mt. Wilson stations



Most winter storms come from the northwest and deliver up to 0.75 inches of rainfall. Storms from the south or southwest are less common, but they may bring 3 to 6 inches of rain over the coastal watersheds if they stall off the coast. Storms from the west are least common but last the longest and are characterized by a series of rain events each bringing 1-2 inches of rain over a period of three to four days. Summer rains are rare, but when they occur they are a result of tropical thunderstorms originating in the Gulf of Mexico or late summer hurricanes off the West Coast of Mexico (State of California Resources Agency, 2001).

2.3. Watershed Hydrology

Figure 2.6 The five 8-digit HUC watersheds and distribution of major groundwater basins in the GVP study area



The Green Visions Plan study area covers five watersheds in southern California indexed by 8-digit HUCs, namely the Calleguas Creek, Los Angeles River, Santa Clara River, San Gabriel River, and Santa Monica Bay watersheds (Figure 2.6). The five watersheds drain 10,637 km^2 and the elevation varies from sea level to 3,060 m. South Mountain, the Oak Ridge Mountains, and the Santa Susana Mountains form the southern boundary of the Santa Clara River watershed and separate the Calleguas Creek watershed from the Santa Clara River watershed. The Simi Hills constitute the southern boundary of Calleguas Creek and separate this watershed from the Santa Monica Bay watershed. The Santa Susana and Santa Monica Mountains separate the Los Angeles River watershed from the Santa Clara River and Calleguas Creek watersheds. The Los Angeles River and San Gabriel River watersheds form an intertwining double watershed system connected through the Rio Hondo River.

The major characteristics of the surface water features in each watershed are summarized in Table 2.1. The five major streams are the Calleguas Creek, the Los Angeles River, the Santa Clara River, the San Gabriel River, and Santa Monica Creek. There are 8,269.4 miles of streams in the Green Visions Plan study area with the average drainage density of 2.0 mi/mi^2. Most of these major surface waters originate from pristine mountains flowing through urbanized foothills and valleys and high density residential and industrial coastal plains, and eventually empty into the ocean at heavily utilized recreational beaches and harbors. The unique surface waterscape of each watershed is therefore formed by its natural topographic setting, underlying geologic structure, climate, and human modifications of the natural system.

Table 2.1 Major characteristics of surface water features in each watershed

Characteristics	Five 8-digit HUC watersheds					The entire GVP
	Calleguas Creek	Los Angeles River	San Gabriel River	Santa Clara River	Santa Monica Bay	
Area (mi^2)	377.5	835.3	712.9	1613.6	571.3	4110.6
Relief (ft)	3655.6	7102.5	10054.2	8798.9	3079.9	6538.4
Mean elevation (ft)	748.8	1588.8	1820.7	3086.8	671.4	1583.3
Lakes/reservoirs (#)	320	394	341	464	301	1820
Lakes/reservoirs area (acre)	1136.7	2273.3	2223.9	6572.9	1284.9	13491.7
Rivers and streams length (mi)	802.5	1394.3	1221.9	3966.9	883.7	8269.4
Drainage density (mi/mi^2)	2.1	1.7	1.7	2.5	1.5	2.0

Alluvial fans in lowlying areas such as the San Fernando Valley, San Gabriel Valley, Oxnard Plain, and Los Angeles Coastal Plain consist of thousands of vertical feet of sediments. These sediments contain fine-grained materials that can restrict the movement of groundwater and coarse-grained materials that constitute aquifers if located in saturation zones. In most of the region, groundwater is found in unconfined alluvial aquifers. In some places underlying the coastal plain, groundwater occurs in multiple aquifers separated by aquitards that create confined groundwater conditions (State of California Resources Agency, 2003). Well yields vary depending on aquifer characteristics and well location, size, and use. Some aquifers are capable of yielding thousands of gallons per minute to municipal wells.

The entire study area contains 18 groundwater basins (Figure 2.6). Some groundwater basins are as large as several hundred square miles and have a capacity exceeding 10 million acre-feet (AF) like the San Gabriel Valley aquifer. Overall, the 18 groundwater basins cover 993,932 acres of surface area (State of California Resources Agency, 2003), and they provide 105,761,570 AF of ground water storage capacity. Recharge of the basin is mainly from the direct percolation of precipitation and percolation of stream flow. Stream flow is a combination of natural runoff from the surrounding mountains, imported water, reclaimed wastewater, and industrial discharges.

Groundwater contributes approximately 30% of the water supply in southern California during a normal year, according to Los Angeles County Department of Public Works. In drought years, when surface supplies are reduced, groundwater provides up to 60% of supplied water (DWR, 1994). These groundwater supplies have dispersed locations across the Green Visions study area. For example, groundwater provides the City of Los Angeles with a reliable, steady source of water supply. Since 1990, the City has extracted an average of 92,400 AF per year, or 15 % of the total City supply, from its groundwater basins that are located within the GVP study area, namely, San Fernando Basin and Coastal Plain of Los Angeles Basin (the Department of City Planning, 2002). Approximately 80% of the City's groundwater supply is extracted from San Fernando Basin.

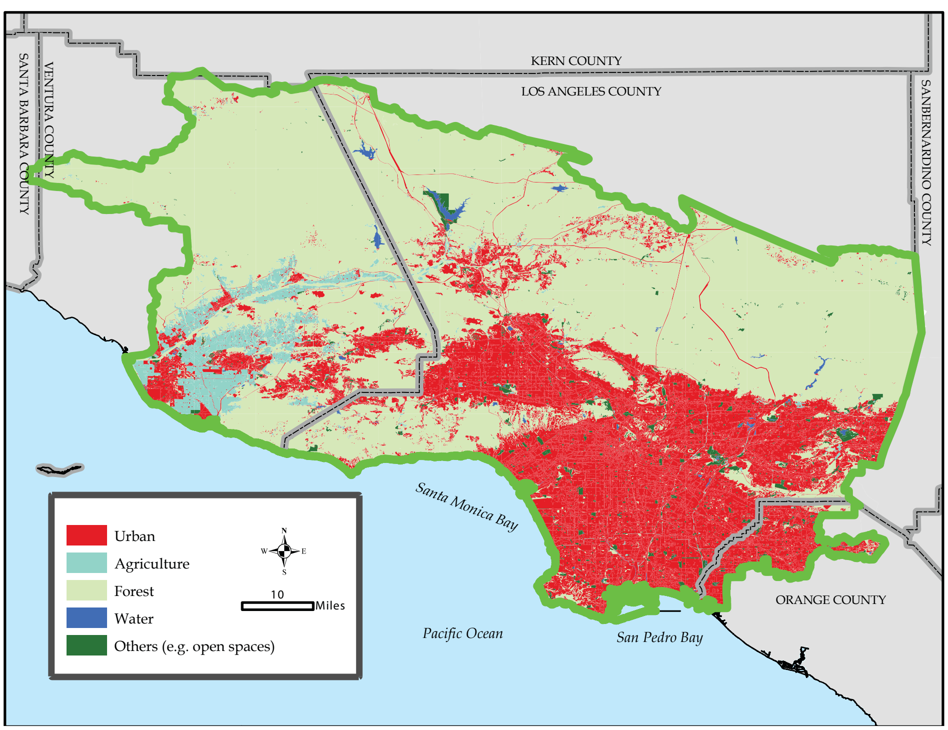
In addition to the reliance on a limited amount of runoff and extensive groundwater supplies, this region has imported water from multiple sources since the turn of the twentieth century to meet the steady expansion of the population and economy (DWR, 1998). In 1913, the Los Angeles Aqueduct (LAA) began importing water from the Owens Valley, and from 1940 additional water was diverted from the Mono Basin through the LAA. The combined carrying capacity of the aqueduct system is about 760 cubic feet per second (cfs), or about 550,000 AF/yr. Between 1970 and 1986, water deliveries through the LAA accounted for more than 75% of the City of Los Angeles's water supply. Deliveries in recent years through the LAA, however, have been significantly reduced because of the extended drought and the legal curtailment of water diversions from the Mono Basin (Department of City Planning, 2002). In 1941, the Colorado River Aqueduct was completed, and this now provides about 25% of the region's supply (DWR, 1998). Some water is also imported from the Sacramento-San Joaquin Delta to this region through the State Water Project that was completed in 1972.

2.4. Urban Growth and Hydrologic System Change

The GVP study area contains nearly 75% of Los Angeles County, which has the largest county population in the United States. In 2005 the U.S. Census Bureau reported an estimated county population of 9,758,886 residents in Los Angeles County. Urban growth has been spectacular in this area. Over the past 20 years about 1.5 million people were added to Los Angeles County (Ethington, 2001), 1.6 times the national average population growth rate (U.S. Census Bureau, 2001). The scarcity of water resources in the Los Angeles metropolitan area is a result of its Mediterranean climate and deterioration in water quality linked to its rapid urban growth.

Forest or open space covers approximately 3,051.5 mi^2 or 65% of the GVP study area with over 95% of this land use type located within the Los Angeles National Forest, Los Padres National Forest and Santa Monica Mountains National Recreation Area (Figure 2.7). The natural land cover has been replaced with buildings, roads, and exotic urban land cover in the remainder of the GVP study area. The Los Angeles watershed, in the early days of the 1800's, offered plentiful land suitable for cultivation that could be irrigated by gravity with a steady, year-round flow of water. By the 1920s, Los Angeles County was one of the most productive agricultural areas in the United States. Bean fields,

Figure 2.7 Land use (2000) (SCAG) across the GVP study area



citrus orchards and dairy farms were scattered across the county. Over time, agriculture has vanished from Los Angeles County, with housing developments, industrial parks, freeways and shopping malls replacing the fertile fields of the past. Today, very little “pristine” landcover remains (Dowling, 2006; The River Project, 2006). Beside forest use, the remaining land uses are agricultural and commercial, industrial, and residential in highly urbanized areas.

As a result of growing water demand from urban development, the hydrologic system has been dramatically modified, starting from the first and most famous water importation project in 1905 when the City of Los Angeles successfully imported water from the Owens Valley, located 200 miles to the northeast of Los Angeles. The imported water source was quickly consumed by sustained urban development in the Los Angeles region. In 1928, the Metropolitan Water District of Southern California (MWD) was created, and sought to obtain additional water from the Colorado River to provide water for southern California (Schwarz, 1991). Many dams, reservoirs and aqueducts were built to facilitate water delivery. MWD also imports water from northern California and the Central Valley (MWD press release, 1991, 1992).

Water shortages and storm flood hazards coexist in the metropolitan hydrologic system. Flood hazard has led to severe alteration of the natural hydrologic system to accommodate urban expansion. The present-day Los Angeles metropolitan region used to be a land of catastrophic floods. The earliest records of massive flooding can be traced back to 1811 (Guinn, 1890). The 1811 flood washed away most of the Pueblo along the Los Angeles River near the confluence with the Arroyo Seco. In 1815, 1822, 1825, 1832, 1842, 1852, 1858 and 1859, large areas in Los Angeles County from the Santa Monica Mountains to the south coast were flooded. Disastrous floods followed in 1861-1862, 1867-1868, 1884, 1886, and 1914. Buildings were ripped up, crops and cattle were swept away, and river courses shifted. After floods in 1884 and 1886, a flood-protection levee was constructed through the center of Los Angeles. From 1921 to 1946 a series of severe storms hit the area and caused big floods such as in 1921, 1927, 1934, 1938, 1940, and 1941-1944. However, from 1946 to 1960 no extreme rainfall events occurred. Since 1962, heavier rainfall events were noted in the basin and caused region-wide floods in 1969 and 1994 and moderate floods in 1978, 1980, 1983, and 1992.

Developments such as railroad levees in riverbeds generated new ways that floods could destroy city infrastructure and disrupt everyday lives at the same time that they stimulated urban growth. In the 1880s, Los Angeles was small enough to escape the catastrophic consequences that follow from building a city on a floodplain. This gradually changed as the urban area expanded and the disaster caused by the 1914 flood caught southern California by surprise (Orsi, 2004). This particular flood was labeled as an unprecedented deluge although it was smaller in terms of the land area that was inundated and total volume of water discharged compared to some earlier floods (Orsi, 2004). However, the disaster brought by this flood was exceptionally severe and was partially attributed to the railroads, pavement, and plowing on the flood plains where willows and grasses used to grow.

Following the 1914 event, flood was handled by the flood-control system built during the first half of the twentieth century. However, storm runoff in rivers surpassed design capacity in parts of the engineered flood system and resulted in increasing peak discharges in major channels (Goodridge, 1997). The response to subsequent floods was to build bigger and better structures - bulldoze additional channels, dam streams, armor the levees with another layer of protection - but each time, another destructive flood followed a few years later (Orsi, 2004). Throughout the twentieth century, flood-control systems were designed by engineers to accommodate floods and predicted future urban growth.

As a result of various water resource projects and flood control systems, the hydrologic regime in the GVP study area is severely altered; streams are riprapped, channelized and covered; riparian habitats are lost; water quality is degraded; and native stream species have diminished or been extirpated. Given the urban growth expected in the region during the next twenty years, it is critical to understand current hydrologic systems and to what extent these systems have been altered. This fundamental knowledge about the hydrologic assets in the GVP study area can inform more sustainable regional development that would maintain the hydrologic functions of the system and restore lost or impaired ecologic and esthetic functions to the extent that we bring some part of nature back to the city.

3. CALLEGUAS CREEK WATERSHED

3.1. Drainage System and Stream Classification

Calleguas Creek watershed drains an area of approximately 377.8 mi^2 of southern Ventura County and outlets into the Pacific Ocean at Mugu Lagoon. The South Mountain, Oak Ridge Mountains and Santa Susana Mountains form the northern boundary of the watershed. The Simi Hills and Santa Monica Mountains distinguish the southern boundary (Figure 3.1). The northern and eastern portions of the watershed are typically rugged and mountainous terrain. The south and west consist of hills, alluvial valleys, and coastal floodplains.

Figure 3.1 Calleguas Watershed topographic map

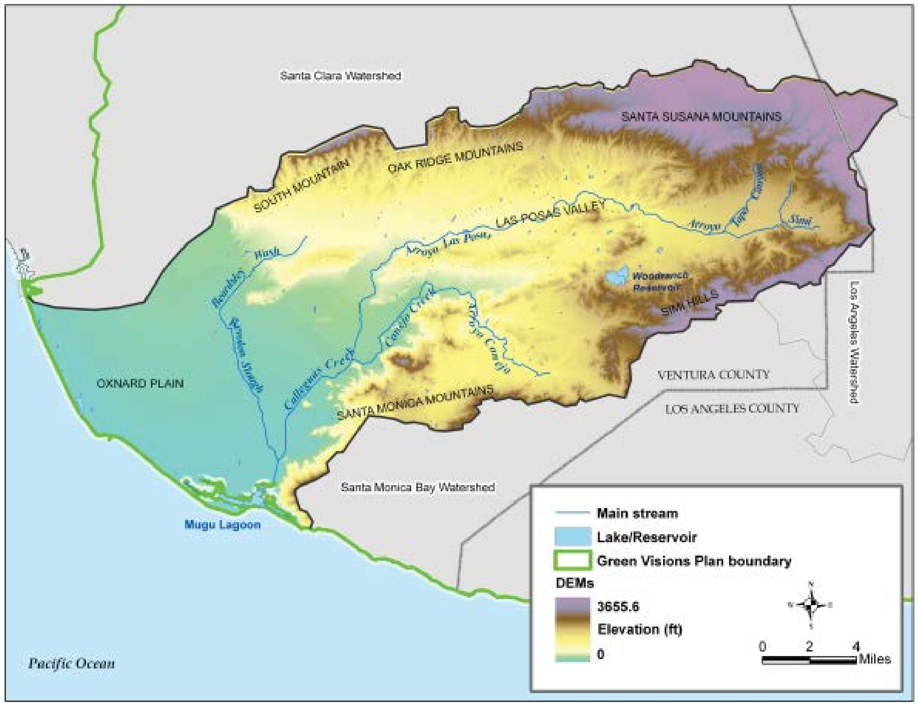
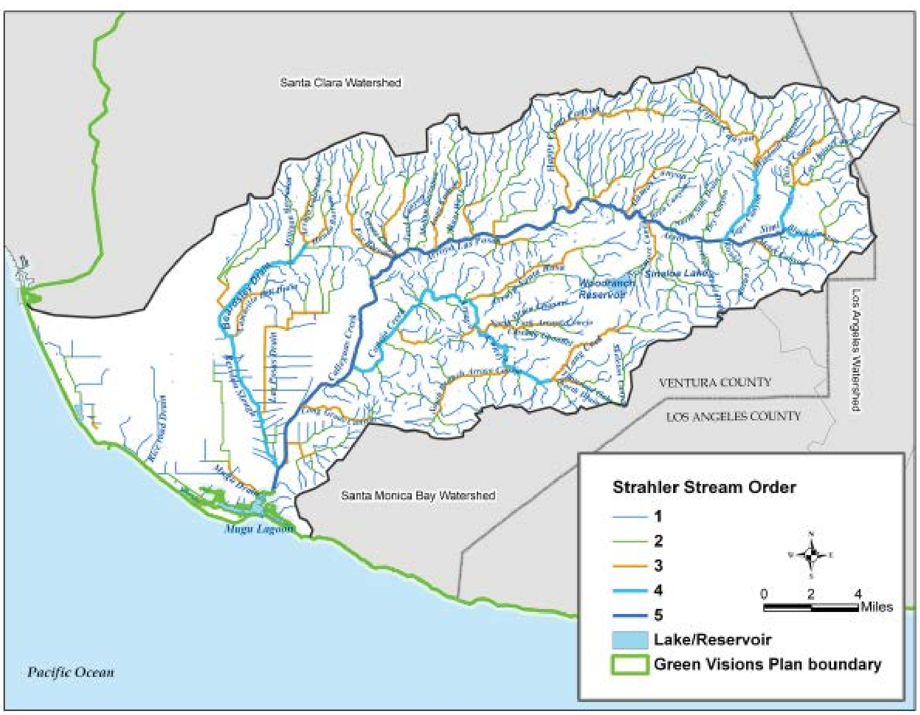


Figure 3.2 Calleguas Creek Watershed tributaries classified by Strahler stream order



From the headwaters of the Arroyo Simi down through the Arroyo Las Posas to Conejo Creek, streams form a trellis pattern with the main channel running along the foothills of the Santa Susana Mountains and tributaries flowing in from north to south. The stream system like Beardsley Wash and its tributaries flowing through the flat and expansive Oxnard Plain follows more of a dendritic

Table 3.1 Basic characteristics of the drainage system in Calleguas Watershed

Strahler stream order	Segments	Bifurcation ratio	Mean channel elevation (ft)	Mean channel slope (%)	Stream length (mi)	Drainage area (mi^2)
1	708	5.1	865.6	7.5	474.2	177.2
2	140	4.2	754.1	3.1	188.2	68.6
3	33	6.6	646.2	1.7	100.1	43.7
4	5	5	343.4	0.7	35.1	16.8
5	1	---	418.2	0.6	34.1	18.9

pattern. The entire drainage system consists of five classes of streams classified by Strahler stream order with a total length of 831.7 mi (Figure 3.2). The main tributaries draining the watershed are Arroyo Conejo, Conejo Creek, Arroyo Las Posas, Arroyo Simi, Beardsley Wash, and Revolon Slough. The longest drain course in the system is the Arroyo Simi / Arroyo Las Posas / Calleguas Creek system along a length of 37.2 mi (Figure 3.2). Table 3.1 describes the major characteristics of the drainage system by Strahler stream order.

Photo 3.1 Mugu Lagoon

The fifth order streams consist of Arroyo Simi, Arroyo Las Posas, and Calleguas Creek originating from the extreme limits of Simi Valley in the east and northeast, then westerly through the urban landscape such as Simi Valley, Las Posas Valley (as Arroyo Las Posas) to Oxnard Plain (as Calleguas Creek) and the Pacific Ocean at Mugu Lagoon (Photo 3.1). Various reaches along the main course are impaired by nonpoint source pollutants and therefore these reaches are listed in California 2002 Clean Water Act Section 303(d) for water quality repairing (California Regional Water Quality Control Board, Los Angeles Region, 2003).

The fourth order streams contain tributaries of Revolon Slough, Conejo Creek, Tapo Canyon and Arroyo Conejo. Arroyo Conejo, formed by South Branch Arroyo Conejo and North Fork Arroyo Conejo, is a major drain course passing through the City of Thousand Oaks from west to east. Portions of the Arroyo Conejo stream channel in the city limits have engineered levees consisting of riprap or concrete sidewalls. Some reaches are entirely lined such as short sections at some of the bridge crossings and at numerous small drop structures (CCWSC, 2006).

The majority of the first and second order streams originate in the mountain hills with a few of them starting from the urban storm drains (e.g., Mugu Drain, Oxnard Industrial Drain). Both drains are threatened by the release of hazardous substances, pollutants, and contaminants from the adjacent area and therefore are on the list of California 2002 Clean Water Act Section 303(d) for water quality enhancement (California Regional Water Quality Control Board, Los

Angeles Region, 2003). A Superfund site was designated by the Federal EPA (EPA, 2002) for the stream cleanup along the Oxnard Industrial Drain.

3.2. Watershed Classification

Calleguas Creek watershed is divided into five watershed classes by Strahler stream order (Figure 3.3). Of all the watershed land area, urbanized industrial and residential land uses constitute 27.6%, agriculture lands constitute 30.8%, open vacant

Figure 3.3 Land uses in Calleguas Creek Watershed

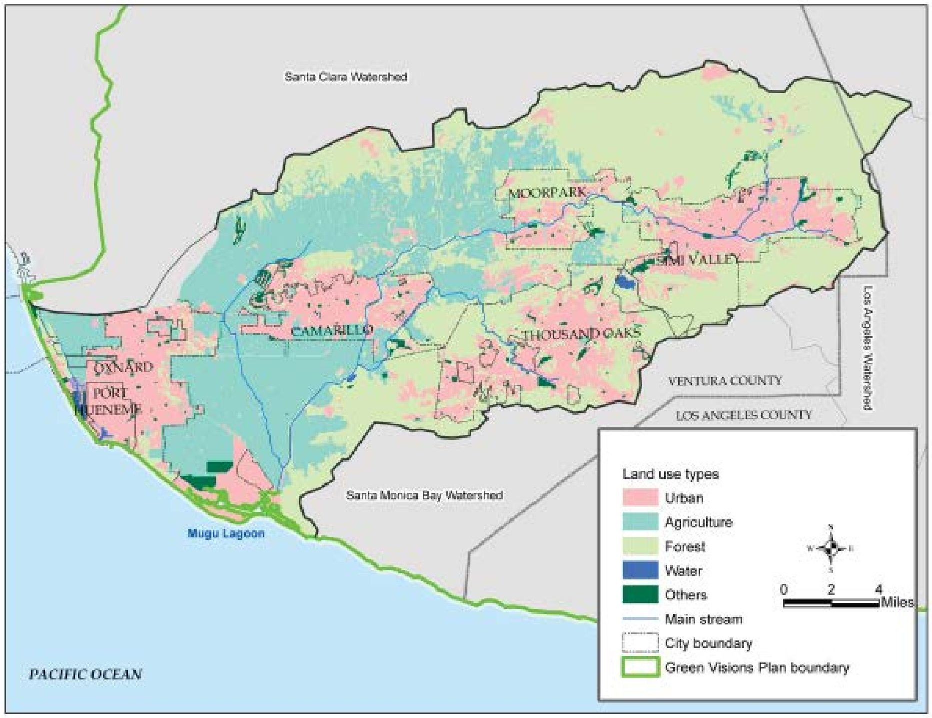
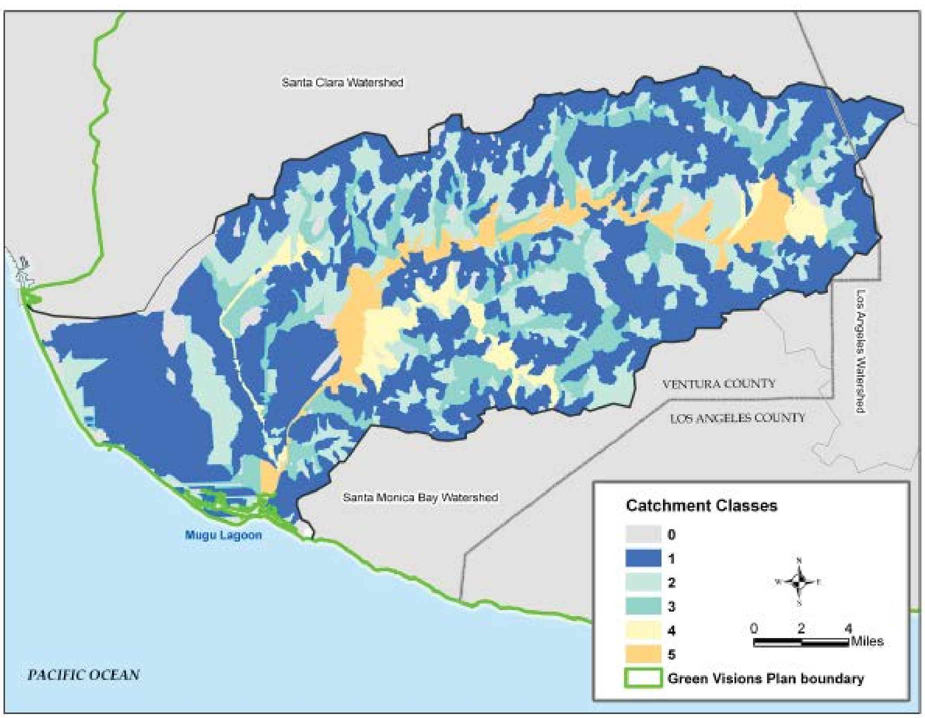


Figure 3.4 Calleguas Creek Watershed classified by Strahler stream order



forest lands occupy the largest share at 39.6%, and the rest of the watershed (2.1%) is used as recreational, open space areas such as parks, golf courses, wetlands, and wildlife preserves (Table 3.2) (Figure 3.4).

Catchments drained by the first order streams are dominated by forest usage (55.6%), which is largely located in the Santa Susana Mountains and Simi Hills (Figure 3.4). The percentage of urban land

Table 3.2 Watershed classification and their major characteristics

Catchment classes	Mean catchment elevation (ft)	Mean catchment slope (%)	Urban (%)	Agriculture (%)	Vacant (Forest) (%)	Water (%)	Others (%)
1	255.5	21.8	18.9	24.1	55.6	0.2	1.2
2	224.9	18.0	23.5	33.4	40.9	0.5	1.7
3	220.7	16.5	25.6	34.8	37.4	0.0	2.1
4	148.6	11.9	30.3	32.6	34.2	0.1	2.8
5	161.2	7.9	50.4	22.2	25.8	0.1	1.5
Average	202.2	15.2	27.6	30.8	39.6	0.2	1.9

use in the catchments increases significantly with catchment order. The percentage of urban land use in the 5th order catchments is the highest among all five classes. Vast areas of nurseries, orchards, vineyards, irrigated cropland, and pasture lands characterize the watershed land use with most of them located on the Oxnard Plain along Revolon Slough, Beardsley Wash and Calleguas Creek (Figure 3.4) (Photo 3.2). Nearly 80% of the area draining Beardsley Wash is occupied by orchards and vineyards. Tributaries wind through the expanse of agricultural land and carry away a high volume of sediments from cleared uplands, which sometimes cause downstream sedimentation after winter storms.

Photo 3.2 Irrigated cropland

3.3. Dams, Lakes, Reservoirs, and Debris Basins

There are six jurisdictional dams within the Calleguas Creek watershed, which are defined as "artificial barriers, together with appurtenant works, which are 25 feet or more in height or have an impounding capacity of 50 acre-feet (AF) or more. Any artificial barrier not in excess of 6 feet in height, regardless of storage capacity, or that has a storage capacity not in excess of 15 acre-feet, regardless of height, is not considered jurisdictional" (DWR, 1994a). They are located, for example, along the upper reaches of Beardsley Wash, Land Creek, Las Llajas Canyon, Runkle Canyon, and Sycamore Canyon. An approximate 6% of the watershed area is regulated by these dams. A number of reservoirs or manmade lakes are formed behind these dams (Figure 3.5). Major features of these named lakes and reservoirs are summarized in Table 3.3.

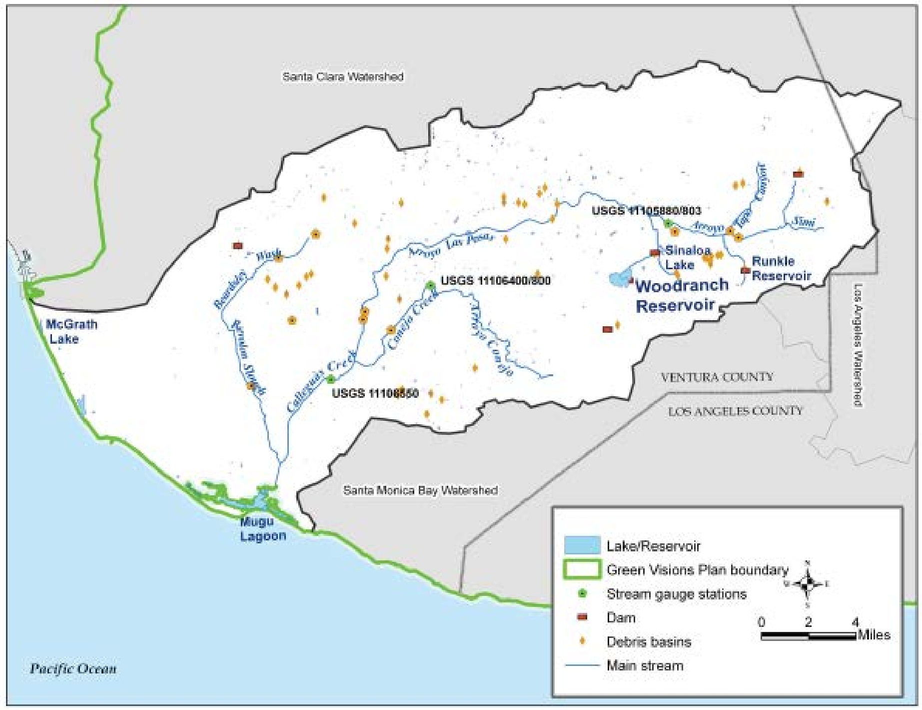
Woodranch Reservoir/Bard Lake – Woodranch Dam

Woodranch Dam at the head of Sycamore Canyon is the largest dam in the Simi Valley area. Completed in 1965, the dam is a 146-foot high earth dam that has a capacity of 11,000 AF impounded by the Bard Reservoir behind it. The reservoir contains only imported, treated water and is used exclusively as a supplemental supply source to maintain peak-hour water pressure in the valley. The reservoir is designed to sustain a 400-year flood event with no impact on the safety of the dam.

McGrath Lake

The lake was part of the historic Santa Clara River Estuary and Delta system (Saint et al., 1993). Now the open water area is reduced to around 10 acres (CERES, 1997a). There is no ocean outlet, although waves occasionally overwash the beach berm. An easement allows the previous, and adjacent, landowner to control the water level of the lake to prevent flooding. A portion of the lake is included in the 2002 list of impaired water bodies. Selected criteria such as Chlordane, DDT, Dieldrin, Fecal Coliform, and Sediment Toxicity are exceeded for sediment contaminants (California Regional Water Quality Control Board, Los Angeles Region, 2003).

Figure 3.5 Dams, debris basins, and lakes/reservoirs



Mugu Lagoon

Mugu Lagoon is one of the few remaining significant saltwater wetland habitats in southern California. Calleguas Creek was channelized and its flows were diverted to the lagoon in 1884 (CERES, 1997b). The creek is leveed with either riprap or earthen banks with a soft bottom through much of the Oxnard Plain. Perennial flows are also from permitted discharges and irrigation return flows (USDA, 1995). A series of seven ditches that drain nearby agricultural fields and parts of the naval station empty into the lagoon (PRC Environmental Management, Inc., 1996). High concentrations of banned pesticides are found in the sediment and biota; the lagoon is included in the 2002 list of impaired water bodies.

Table 3.3 Named lakes/reservoirs in Calleguas Creek Watershed

Name	Contributing steams	NHD Area (acre)	Elevation (ft)	Area (acre)
Wood Ranch Reservoir (Bard Lake)	Las Llajas canyon, Sycamore Canyon and unnamed tributaries	203.5	1009.8	230
Sinaloa Lake	Long Canyon	17.2	0	ND
Runkle Reservoir	Runkle Canyon	3.3	0	ND
Mugu Lagoon	Calleguas Creek and 7 ditches	346.9	4.92	286.5
McGrath Lake	Not applicable	18.27	1.31	10.3

In addition to the six dams listed above, there are 45 district debris basins of varying sizes (Figure 3.5), which have been constructed or are under construction by Ventura County Water Protection District, the Soil Conservation Service, and cities to reduce peak flows. However, watershed development has caused the capacity deficiency of dams or basins designed in its first place, especially of those that were constructed prior to 1970. For instance, Sycamore Debris Basin, situated on Sycamore Canyon, was built in 1981 with the capacity of 15,000 cubic feet and was unable to detain the current 100-year storm events (VCWPD, 2005). The capacity of the Runkle Dam on Runkle Canyon is also exceeded by the current 100-year storm peak flow and fails to provide the necessary protection of the downstream watershed. The Santa Rosa Road Debris Basin constructed in 1957 by the Soil Conservation Service mitigates increased flows due to development to a certain degree; however, the lack of an adequate improved channel downstream of Arroyo Santa Rosa results in the generation of a large floodplain (VCWPD, 2003). VCWPD (2005) evaluated the conditions of dams, detention and debris basins and prioritized a number of structures for retrofitting and upgrading.

3.4. Stream Flow and Annual Flood Dynamics

There are a total of seven USGS gauging stations located in the watershed that monitor the historic or present flow status. The Ventura County Watershed Protection District (VCWPD) operates 15 stream stations (Table 3.4). The stations USGS 11105850 and 11106400 have been installed by the USGS in co-operation with VCWPD. Starting with WY1984, the USGS stopped reviewing and publishing the record for these two sites. VCWPD has continued to provide full records for these two sites to the present (using the numbers of 803 and 800, respectively). The USGS 11106000 station was installed by the USGS in Camarillo in 1928 and discontinued in 1958. A new site 806 was established by VCWPD in 1968 and later was moved downstream to the present location 806A in 1997. VCWPD has continued to provide full records for this site to the present. The site was not working for WY1971. The USGS 11106550 station was installed by the USGS as a co-op site with VCWPD at the Camarillo State Hospital in 1968. USGS continues to review and publish records from this site. Mean annual daily flow, annual peak discharge, temporal trend tests, and flood magnitude estimates for various recurrence events are summarized in Table 3.5 for 13 stations with flow records longer than 20 years.

Mean annual daily discharges and annual flood peak discharges over time are examined at three gauge sites that are located in different places in the watershed (Figure 3.6). They are: (a) Arroyo Simi near the City of Simi at USGS 11105850/VCWPD 803; (b) Conejo Creek Above Highway 101 at USGS 11106400/VCWPD 800; and (c) Calleguas Creek at Camarillo State Hospital at USGS 11106550/VCWPD 805.

Mean Annual Daily Discharge

The surface flow originating from the headwaters of the Santa Susana Mountains is typically not present in certain portions of the channel due to evaporation and groundwater recharge except during and immediately after rainfall. Historically, except for Las Llajas Canyon, Sycamore Canyon and a few more tributaries draining Bard Reservoir, all other tributaries are

Table 3.4 Stream flow stations in Calleguas Creek Watershed

STA_ID	Station name	Drainage (mi^2)	Elevation (ft)	Flow status	Flow records From	Flow records To
11105850/803	Arroyo Simi NR Simi CA	70.6	720	E/P	19331001	To date
11106000/806/806A	Calleguas CA Camarillo	168.7	160	E	19281001	To date [a]
11106400/800	Conejo Creek Above HW 101 CA	64.2	-	P	19721001	To date
11106500	Conejo C NR Camarillo CA	69.8	-		19271001	19310930
11106550/805	Calleguas CA Camarillo State Hospital CA	248	58.4	E/P	19681001	To date
11107000	Honda Barranca NR Somis CA	2.6	350	E	19541001	19630930
11107500	Beardsley Wash NR Somis CA	13.5	-	E	19540701	19580930
700	Arundell Barranca abv Harbor Blvd				19631001	To date
776	Revolon Slough at Laguna Rd	46	11	P	19791001	20050930
780	Beardsley Wash at Central Ave				19940120	To date
782	Las Posas Estates Drain				20000818	20051001
801	Arroyo Simi at Moorpark - Spring St				19331001 [b]	19780322
802	Arroyo Simi At Royal Ave Bridge		875	E	19681001	To date
832	Arroyo Tapo bl Los Angeles Ave	20.2	876	ND	19701001 [c]	20040930
833	Bus Canyon Drain abv Los Angeles Ave	4.9	753	ND	19701001 [c]	20040930
835	Camarillo Hills Drain bl Hwy 101	5.3	84	ND	19861001 [c]	20040930
841/841A [d]	Arroyo Las Posas above Hitch Blvd				19901001	20051001
842	Arroyo Simi below Stow				20020821	To date

Table 3.5 Mean annual daily discharge, temporal trend test, annual peak discharge, temporal trend test, and flood frequency and magnitude estimates

STA_ID	Mean annual daily discharge (cfs)	Sig.(2-tailed)	Coefficient of variation [a]	Average peak discharge (cfs)	Sig.(2-tailed)	Log Pearson Type III predicted peak discharge (cfs) 1.43-yr	2-yr	10-yr	50-yr	100-yr
11105850/803	8.6	0.000**	1.30	2310.3	0.000**	654	1521	5765	8652	9480
11106000/806/806A	11.8	0.032**	1.16	4732.7	0.015**	1513	2741	10317	21083	26740
11106400/800	32.5	0.002**	0.60	4371.9	0.439(-)	2289	3403	8536	14575	17544
11106550/805	51.7	0.070	0.92	8186.4	0.840	3164	5314	17670	35549	45298
11107000	0.1	NA	1.63	184.0	0.028**	164	106	518	1016	1234
700	4.6	0.329	0.71	2370.6	0.053	1462	2000	4132	6302	7295
776	18.9	0.215	0.59	3231.1	0.250	1365	2256	7169	13708	17086
801	3.0	0.022**	1.46	ND	ND	ND	ND	ND	ND	ND
802	5.7	0.820	1.24	1855.9	0.714(-)	794	1220	3845	8230	10906
806	13	0.760	1.16	4670	0.450	1738	2913	10699	24061	32185
832	ND	ND	ND	877.8	0.030**	336	572	1962	4019	5154
833	ND	ND	ND	292.5	0.090	158	223	563	1042	1307
835	ND	ND	ND	1003.5	0.310	629	784	1711	3286	4286

[a] Coefficient of variation is the standard deviation of annual flows divided by the mean annual daily discharge
** Trend is significant at the significance level of 0.05.
NA - Long term trend test are not applied at this site. Daily flow discharges are available only from WY1955 to 1963.
ND - No date

intermittent streams, which run dry in the summer seasons like Meier Canyon in May 2005 (Photo 3.3). Along the main reach of Arroyo Simi near the City of Simi at USGS 11105850/VCWPD 803, ephemeral flow status was recorded until 1975. Since then year-round flows are present in the stream (Photo 3.4). Over time the mean annual flow has significantly increased during the observation period (Table 3.5, Figure 3.6a). In comparison, four miles above along the reach, intermittent flow is recorded at the upstream gauge VCWPD 802 from WY1968 to date and no significant change has detected so far (Table 3.5).

The increase in the impervious surface and rising water imports explain the change in flow conditions from ephemeral to perennial and the increased flow volume at USGS 11105850/VCWPD 803. Many local wells were no longer pumped for water supply, as imported water was used instead (VCWPD, 2003). Due to a relatively short period of average to above average water years, a rising ground water problem impacted the western end of the City of Simi Valley. A number of dewatering wells were drilled to pump rising groundwater directly into Arroyo Simi, which consequently turned Arroyo Simi from an ephemeral to a perennial stream. In addition, discharges of treated wastewater effluent, stormwater and landscape irrigation runoff into the stream have increased as residential and commercial developments have expanded throughout the watershed over the past two decades. Those urban drains deliver increasing discharge as well as trash and impaired water to the downstream drains (Photo 3.5).

A changing flow status is also observed in Conejo Creek, above Highway 101 at USGS 11106400/VCWPD 800 (Figure 3.6b), where Arroyo Conejo and Arroyo Santa Rosa join into Conejo Creek. Historically, these two tributaries have ephemerally flowing surface water with the exception of the portion of the north and south branch of Arroyo Conejo, where perennial flow is probably sustained by the City of

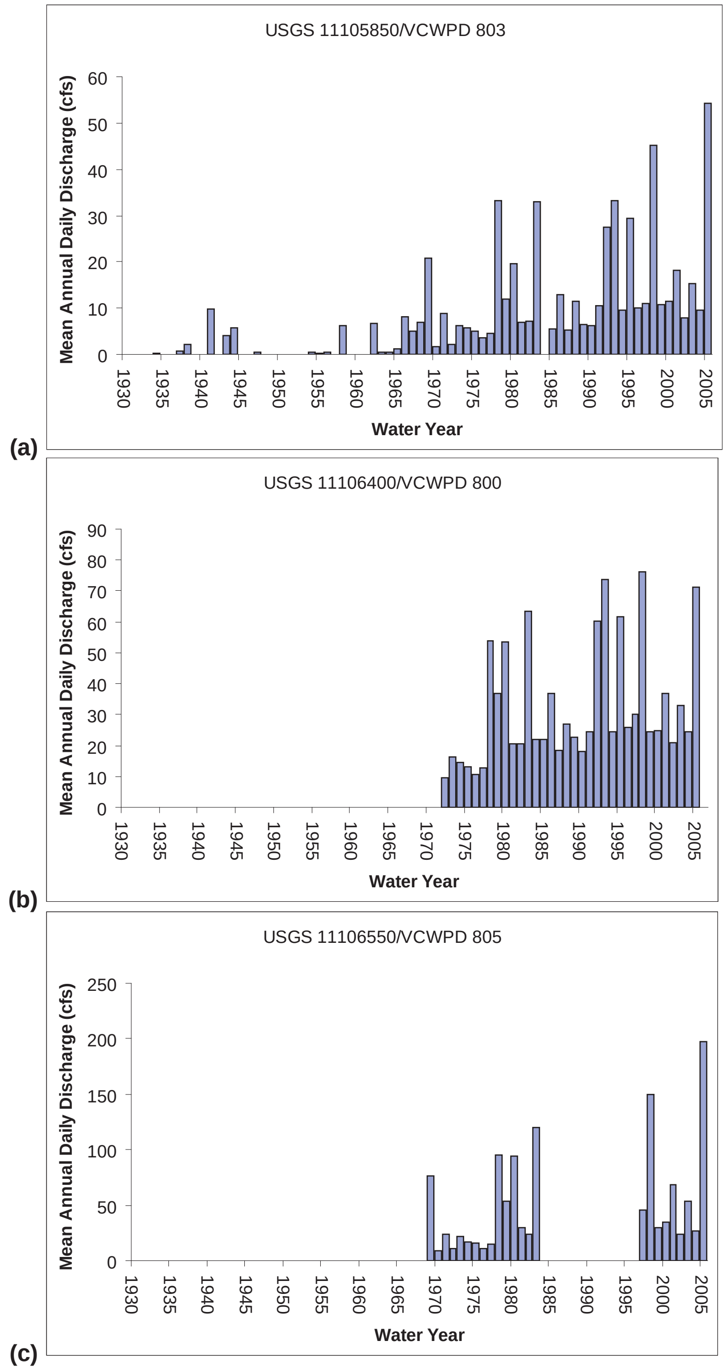


Figure 3.6 Mean annual daily flows in (a) Arroyo Simi near the City of Simi at USGS 11105850/VCWPD 803; (b) in Conejo Creek Above Highway 101 at USGS 11106400/VCWPD 800; and (c) in Calleguas Creek at Camarillo State Hospital at USGS 11106550

Thousand Oaks. Two miles downstream of the junction of Arroyo Santa Rosa with Arroyo Conejo, perennial stream flows have appeared in the stream since the 1970s, as a result of the increasing release of municipal wastewater and urban nonstormwater discharges. Two

Photo 3.3 Meier Canyon in May 2005

Photo 3.4 Arroyo Simi in Moorpark

Photo 3.5 Erringer Road Drain

wastewater treatment plants operated by the City of Thousand Oaks, the Olsen Road Wastewater Treatment Plant (ORWWTP), and the Hill Canyon Wastewater Treatment Plant (HCWWTP), discharge into Arroyo Santa Rosa and Arroyo Conejo (City of Thousand Oaks, 2003).

Near the Calleguas Watershed outlet, Calleguas Creek used to be an ephemeral creek flowing only during the wet season. During the storm seasons the flow course could change freely across the Oxnard Plain without direct discharge into the Mugu Lagoon, with such changes in course recorded as early as 1884. Because Arroyo Las Posas does not generally provide surface flow to Calleguas Creek during dry periods, Conejo Creek provides the majority of the flow in Calleguas Creek and affects flow conditions in Calleguas Creek. Arroyo Conejo received increasing agricultural discharge and wastewater discharges from upland area and became perennial in the early 1970s, which consequently led to the increasing flow in the portion of Calleguas Creek near the junction with Conejo Creek. Calleguas Creek at Camarillo State Hospital (USGS 11106550) has recorded increasing mean annual flows from 41.2 cfs (WY1969 - 1983) to 69.9 cfs (WY 1997-2005) (Figure 3.6c). Water quality impairment is accompanied by increasing agricultural wastewater discharge, which has caused excessive sediment and elevated levels of pesticides and fertilizers carried with sediment from farmland to streams (SSWSC, 2006).

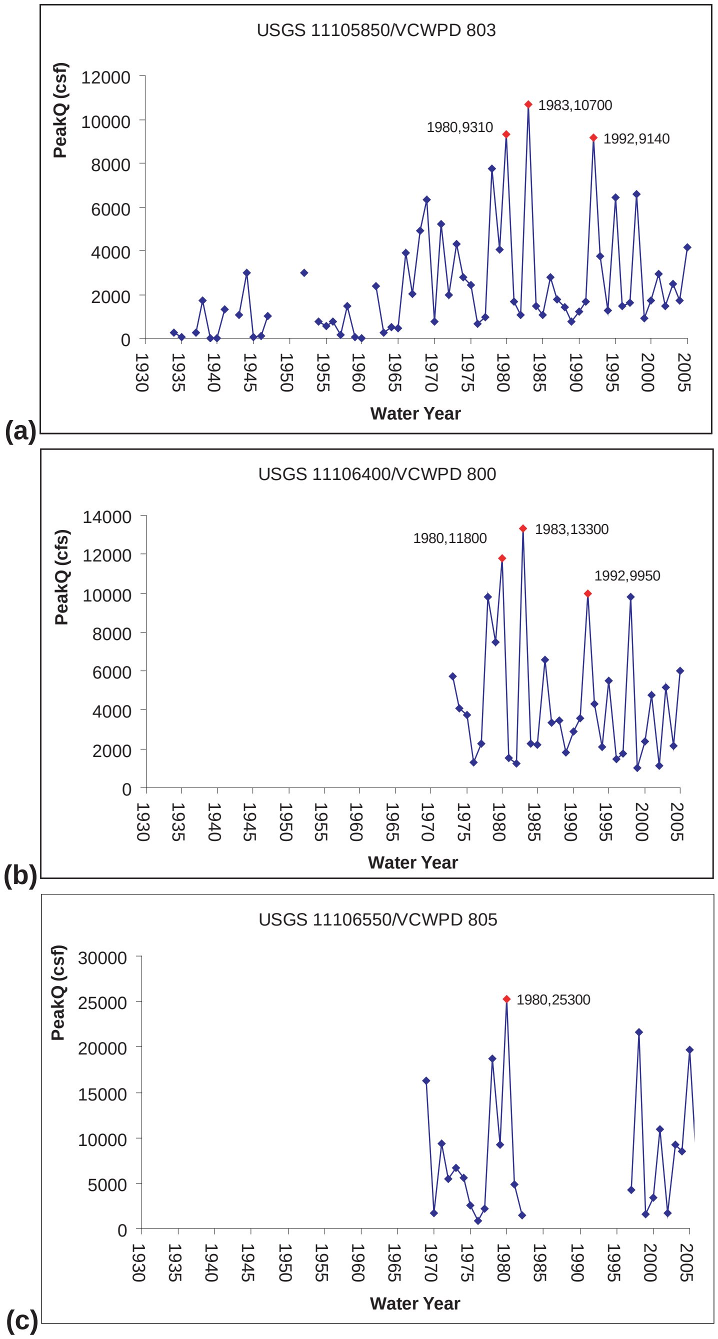


Figure 3.7 Mean annual daily flows in (a) Arroyo Simi near the City of Simi at USGS 11105850/VCWPD 803; (b) in Conejo Creek Above Highway 101at USGS 11106400/VCWPD 800; and (c) in Calleguas Creek at Camarillo State Hospital at USGS 11106550

Flood Dynamics

Accompanying the increasing mean annual daily flow, the annual flood peak discharge observed in Arroyo Simi near the City of Simi at USGS 11105850/VCWPD 803 has significantly increased sixfold from 589 cfs in WY1943 to 2,733 cfs in WY 2005 on a 10-year moving average (Figure 3.7a). In 1983, a disastrous event with an approximate 50-year to 100-year recurrence interval was observed at this site (Figure 3.7a). A federal disaster was declared because of storm damage. Various sites along the channel in Moorpark and Simi Valley suffered severe damage from erosion during this event. Repairs to flood control facilities were estimated to cost $15,000,000 (URS cooperation, 2004).

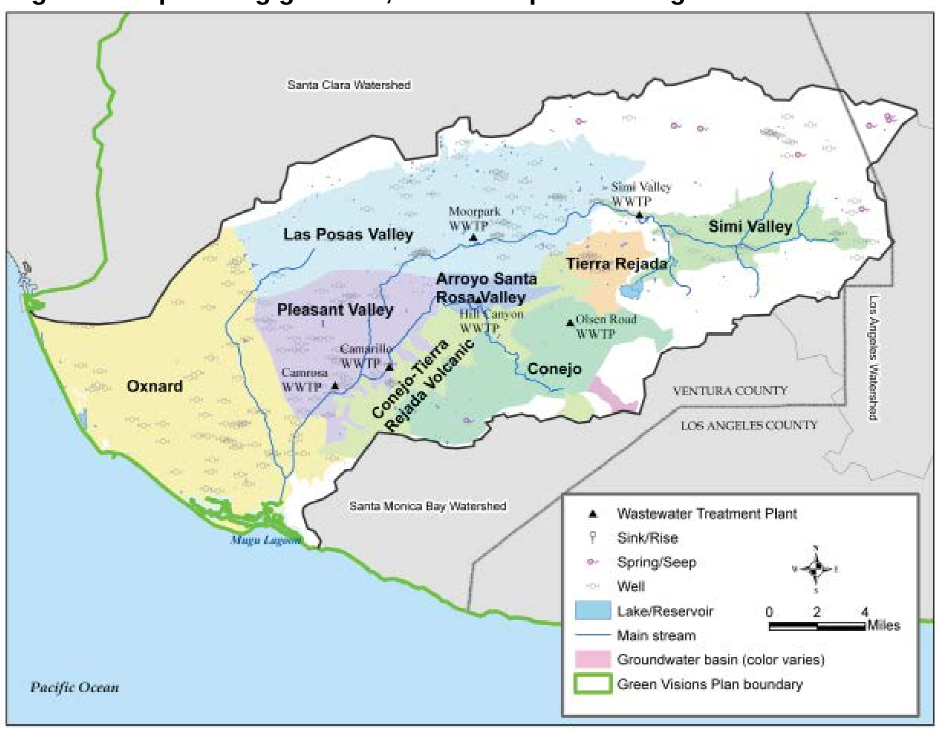
Historically, flood flows in the Calleguas Creek portion of the Oxnard Plain were able to freely spread across the floodplain and deposit their sediment on the Oxnard Plain, which consequently once was valued farmland. This stretch of Calleguas Creek was channelized through the construction of levees; however, the channel capacity was exceeded by 50- and 100-year flows, leading to levee breaks and extensive storm damage of year-round agricultural crops on the Oxnard floodplain (URS cooperation, 2004). In 1980, an approximately 50-year flow event hit the watershed causing Calleguas Creek to breach its levee in the Oxnard Plain and approximately $9,000,000 in damage to the Point Mugu Naval Base due to flooding and sediment deposition (URS cooperation, 2004). Two years later, the downstream Calleguas Creek experienced record flooding during a watershed-wide large event on March 1, 1983. Damage to other public and private facilities was estimated to be approximately $39,000,000. More than half of the total damage estimate was due to damage to agricultural lands (URS Cooperation, 2004).

Many structural modifications for the purposes of flood and sediment control have been installed by local agencies along Calleguas Creek and Revolon Slough including reinforced concrete channels, rock riprap along the stream banks of soft bottom channels and debris basins for sediment control. A series of debris basins exists along the foothill of Camarillo Hills (west portion of the South Mountain) (Figure 3.5). But the existing structures are not adequate to capture and store the accelerated sediment yield. Increasing annual floods recorded in Calleguas Creek near Camarillo at USGS 11106000 (Table 3.5) and along Revolon Slough at gauge 776 and accelerated sediment yield (CCWSC, 2006) indicate the need for flood control improvements, bank stabilization and more structural basins in accommodating encroachment of agricultural and urban land development into places that used to be floodplains.

3.5. Groundwater Recharge and Extraction

There are eight groundwater basins and one Oxnard subbasin located in the watershed (Figure 3.8). Table 3.6 summarizes the major features of these groundwater basins.

Figure 3.8 Spreading grounds, treatment plants and ground water basins



Oxnard Plain

The Oxnard Plain groundwater basin is a major basin that stored an estimated 5,380,000 AF of groundwater in 1999, putting it at approximately 75% capacity (Panaro, 2000). The primary recharge to the Oxnard Plain basin is from underflow from the Oxnard Plain Forebay rather than the deep percolation of water from surface sources on the plain. Recharge to the forebay basin comes from a combination of percolation of Santa Clara River flows (see Chapter 6), artificial recharge from spreading grounds at Saticoy and El Rio (see Chapter 6), agricultural, household and irrigation return flows, percolation of rainfall, and lesser amounts of subsurface flow from adjacent groundwater basins such as Santa Paula Subbasin (see Chapter 6) and Las Posas Basins. The re-

Table 3.6 Groundwater basin data summary

Groundwater Basin/Subbasin Name	Area (acre)	Average well yield (gpm)	Groundwater storage capacity (af)[a]	Groundwater in storage (af)[a]	Ground-water recharge (af)	Average annual extraction	Average TDS (mg/L)
Oxnard Plain	58,000	900	10,500,000	5,380,000	10,200	65,000	1,102
Tierra Rejada	4,390	172	39,320	29,490	1,300	1,500	774
Pleasant Valley	21,600	1000	1,886,000	18,500	8,100	18,500	1,110
Arroyo Santa Rosa Valley	3,740	900-1000	94,000-103,600	70,500	1,200-2,900	< 5,000	1,006
Las Posas Valley	42,200	400	345,000	173,000-224,000	18,266	30,567	742
Simi Valley	12,100	394	180,000	172,000	4,700-5,400	< 5,500	1,580
Conejo Valley	28,900	100	7,106	5,330	300	< 100	631

[a] Values are estimated using the Panaro (2000) method

charged water is the pumped through a pipeline and supplies various users such as agriculture in the Oxnard Plain and surrounding communities (UWCD, 2001).

When groundwater levels are below sea level along the coastline, there may also be significant recharge by seawater flowing into the aquifers and therefore caused local seawater intrusion. Intrusion of seawater has occurred near Pt. Mugu and the City of Port Hueneme (UWCD, 1999). Nitrate concentrations can exceed the state Maximum Contaminant Level (MCL) of 45mg/l. The U.S. Geological Survey also identified another type of saline intrusion – salts moving from the surrounding marine clays and older geologic units as pressure in the aquifers is reduced from overpumping.

Tierra Rejada

Tierra Rejada Basin is currently unmanaged. Annual production from wells is generally used for irrigation. Tierra Rejada Groundwater Basin is replenished by percolation of rainfall to the valley floor, stream flow, and irrigation return. Percolation of effluent from septic systems and a wastewater treatment plant add a minor amount of water to the basin (DWR, 2004). Most hydrographs of wells monitored in the Tierra Rejada Basin show a marked rise in groundwater levels since the 1970s, with some hydrographs indicating more than 100 feet of rise. High nitrate concentrations occur locally in the basin (Panaro, 2000).

Pleasant Valley

Recharge to Pleasant Valley is provided by percolation of surface flow from the Santa Clara River. Precipitation and floodwater from the Calleguas Creek drainage percolate into the unconfined gravels near Mugu Lagoon. Subsurface flows through canyon gravels from the Arroyo Santa Rosa Valley Basin and through fractures in the volcanic rocks recharge Pleasant Valley Basin as well. Irrigation and septic system effluent also contribute a modest amount of recharge to the Valley. In Pleasant Valley, groundwater is being over-drafted and as a result the valley has experienced subsidence (CCWSC, 2006). Recharges from outside the basin reduce groundwater overdraft on the Valley and are preventing further subsidence in the basin (UWCD, 2001). Various diversions and spreading grounds in the Santa Clara River watershed are operated to strategically recharge basins in critical condition such as the Freeman diversion facilities, the Saticoy spreading grounds, and the El Rio spreading ground (see Chapter 6) (Fox Canyon Groundwater Management Agency United Water Conservation District, Calleguas Municipal Water District, 2006). The increased flows in Arroyo Las Posas have raised groundwater levels in the northern area of the City of Camarillo to historic highs. Coincident with this, water quality is degraded, especially for the constituents sulfate, chloride, iron, and manganese (Fox Canyon Groundwater Management Agency United Water Conservation District, Calleguas Municipal Water District, 2006). The potential for seawater intrusion exists in the depressed groundwater elevations in the Valley basin.

Arroyo Santa Rosa Valley

The Santa Rosa basin is a small basin that has an area of 3,730 acres. Groundwater levels are heavily influenced by flows in Conejo Creek. Discharges from wastewater treatment plant, dewatering wells in Thousand Oaks, and irrigation return flows have considerably increased year-round flows in the creek (Fox Canyon Groundwater Management Agency United Water Conservation District, Calleguas Municipal Water District, 2006). Elevated nitrate and sulfate have been a problem (DWR, 2004).

Las Posas Valley

Arroyo Las Posas and its tributaries recharge the Las Posas Valley basin to the valley floor. Some injection of imported water and some amount of irrigation and septic system return flows occur in the eastern portion of the basin (Panaro, 2000). There has been a significant change in average groundwater levels over the past 40 years in the south Las Posas basin, with groundwater levels rising more than 100 ft during this period (Fox Canyon Groundwater Management Agency United Water Conservation District, Calleguas Municipal Water District, 2006). This increase is due to an overall decrease in agricultural use of groundwater and is attributable to increasing discharges from the Moorpark and Simi Valley wastewater treatment plants and dewatering wells in the Simi Valley. Chloride has also become a problem in some portions of the basin, where groundwater must be blended with lower-chloride water to meet irrigation suitability. This problem appears to have migrated downstream, with some of the City of Camarillo's wells now affected.

Simi Valley

Groundwater in the basin generally moves westward through the basin following the course of Arroyo Simi. It sometimes moves in a reversed direction on the condition when groundwater is over-drafted at some key places. Percolation of direct precipitation, inflow of small streams, minor subsurface inflow from surrounding semi-permeable formations, and irrigation return provide recharge to the basin (Panaro, 2000). Hydrographs of wells in the basin show that water levels have typically remained the same or risen since 1980 (DWR, 2004). Currently the City of Simi Valley operates a series of dewatering wells that mitigate the rising water conditions. The groundwater pumped is then discharged into a concrete-lined section of Arroyo Simi, where perennial flows have been recorded since the 1970s. Groundwater from the Simi

Valley Basin is generally not utilized for municipal supply.

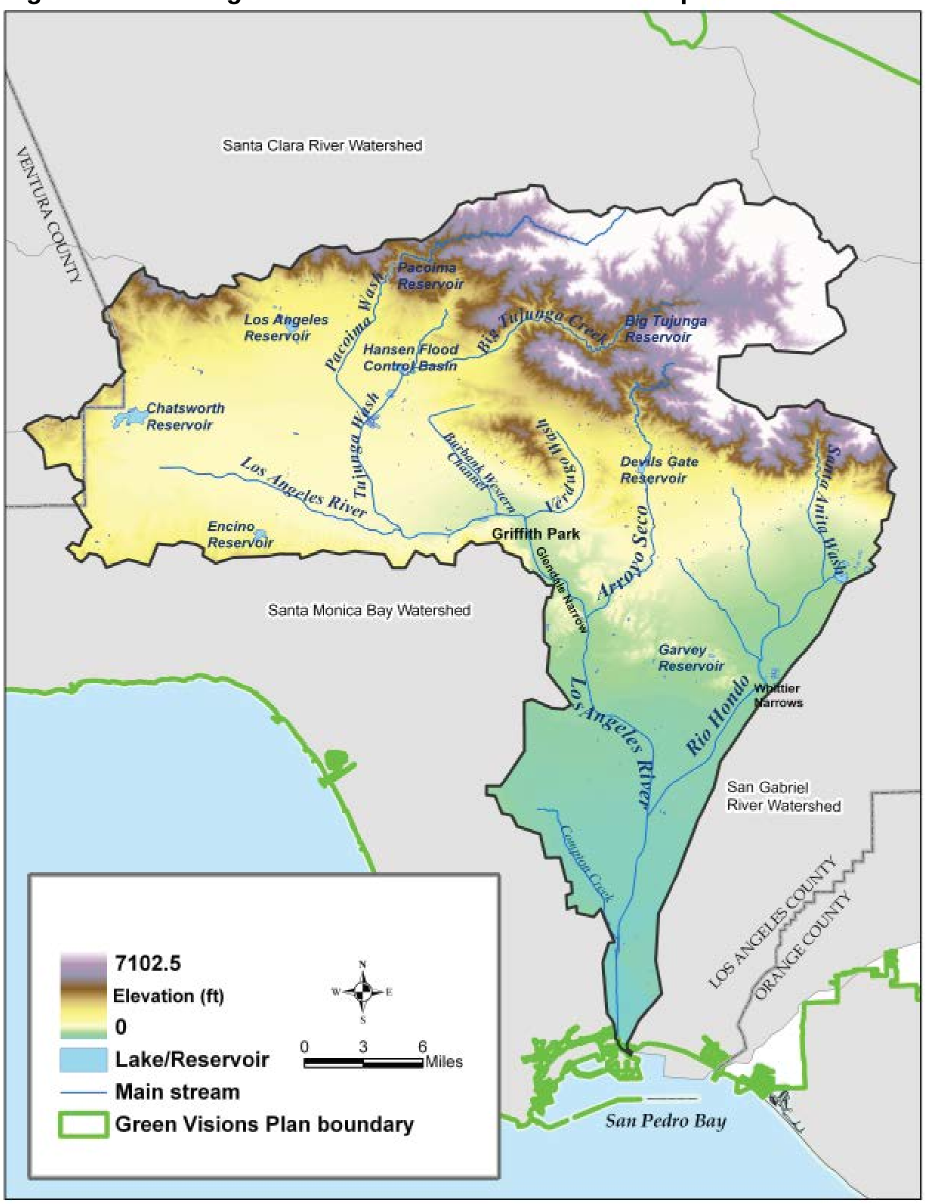
Conejo Valley and Conejo-Tierra Rejada Volcanic Basin

Conejo Valley Basin is the major groundwater basin, and is replenished by percolation of rainfall to the valley floor, stream flow, and irrigation return. Percolation of effluent from septic systems and Olsen Road Wastewater Treatment Plant and Hill Canyon Wastewater Treatment Plant add a minor amount of water to the basin. The quality of water produced from the sedimentary and volcanic units is generally poor in the Thousand Oaks Area and Conejo-Tierra Rejada Volcanic Basin (DWR, 2004). High nitrate concentrations above the MCL occur locally the basin (Panaro, 2000).

4.1. Drainage System and Stream Classification

The Los Angeles River watershed covers a land area of 773.5 mi^2, bordered by the San Gabriel River watershed to the east, and forms a "double watershed" hydrologic system through the Whittier Narrows Dam on the Rio Hondo channel (Figure 4.1). The watershed is shaped by the path of the Los Angeles River, which flows from its headwaters in the Simi Hills and Santa Susana Mountains eastward to the northeastern corner of the Griffith Park, where the channel turns southward through the Glendale Narrows before flowing across the coastal plain and into San Pedro Bay near Long Beach. Major tributaries to the river include Burbank Western Channel, Pacoima Wash, Tujunga Wash, Verdugo Wash, Arroyo Seco, and Rio Hondo Channel at the south of the Glendale Narrows (Figure 4.1).

Figure 4.1 Los Angeles River Watershed elevation map



From the headwaters originating in mountainous hills to the coastal outlet streams, the channel elevation drops from 7,117.6 ft down to sea level with the average channel elevation of 1,597.4 ft. Using the Strahler stream order system, the entire drainage system is composed of six stream orders (Figure 4.2). The basic topographic characteristics of the drainage system by Strahler stream order are summarized in Table 4.1.

Many of the high order streams including 6th, 5th and 4th order streams exist largely as urban streams, which collect storm water and funnel it downstream quickly in concrete channels with very limited open grounds for flowing surface waters. For example, Tujunga Wash (6th order) starts flowing freely through flat valley areas with a mean channel elevation of 852.8 ft and flows to Tujunga Wash Channel in a reinforced concrete box-type channel (Photo 4.1), which was built in 1952, extending approximately 9.5 mi from Hansen Dam to the confluence with the Los Angeles River. Below the confluence with Tujunga Wash, the Los Angeles River (6th order) is a section of the river that remains in a semi-natural condition, also known as the hybrid river. The area supports a variety of low-density uses and is periodically inundated, which allows the growth of willows, reeds and other vegetation, and attracts wildlife. The reach of Glendale Narrows has a rocky, unlined bottom with concrete-lined sides (Photo 4.2). South of Glendale Narrows, the river is contained in a concrete-lined channel down to Long Beach (Photo 4.3).

Most of the Rio Hondo Channel (5th order) is a concrete-lined channel designed to serve primary flood control and water conservation functions. It once was the main bed of the San

Figure 4.2 Los Angeles River tributaries classified by Strahler stream order

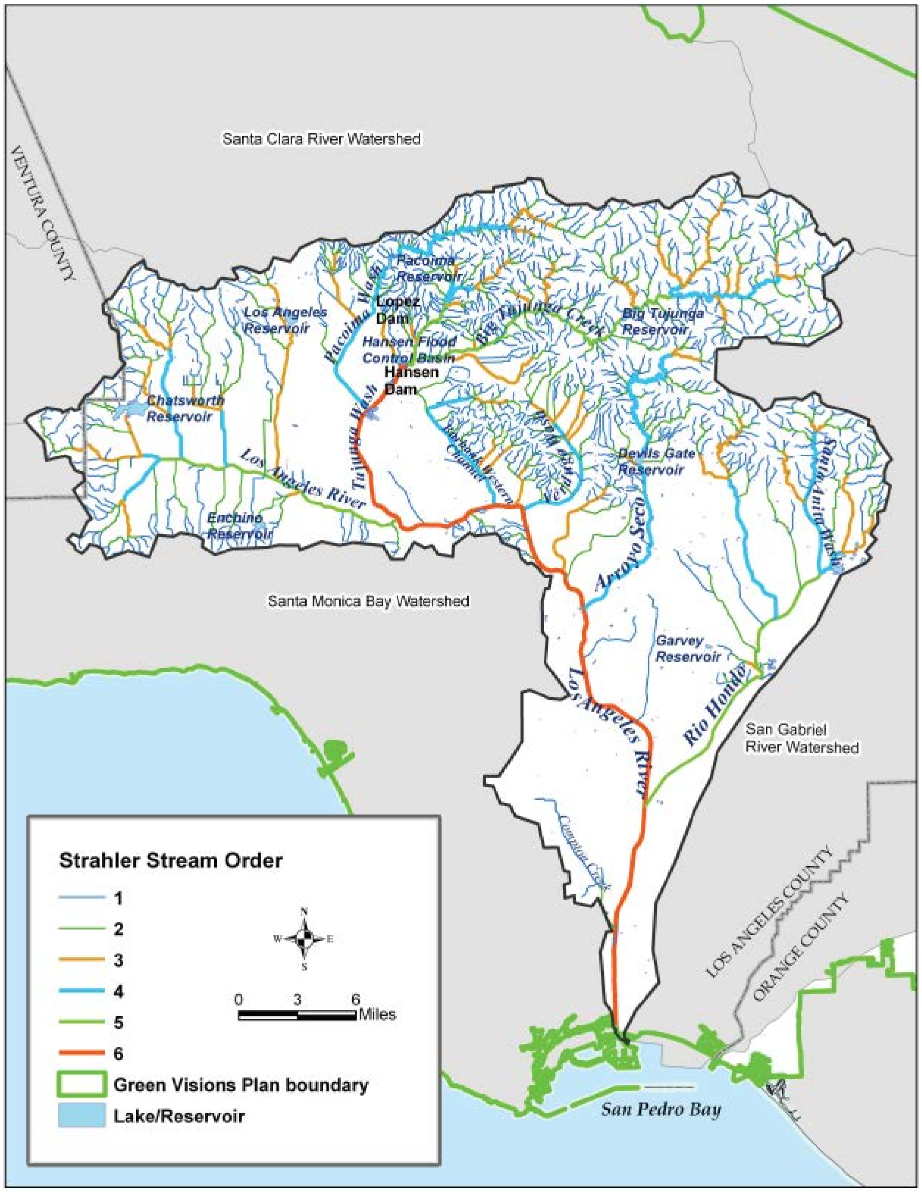


Table 4.1 Basic characteristics of the drainage system in Los Angeles River Watershed

Strahler stream order	Segments	Bifurcation ratio	Mean channel elevation (ft)	Mean channel slope (%)	Stream length (mi)	Drainage area (mi^2)
1	1050	4.4	2525.3	20.5	767.9	334.7
2	238	4.6	2111.0	8.9	305.7	133.0
3	52	3.7	2018.8	5.5	131.9	61.7
4	14	3.5	1677.7	3.0	104.4	68.9
5	4	4.0	1221.5	1.4	53.4	75.8
6	1	NA	453.0	0.6	48.4	82.4
Others	54	NA	19284.5	4.9	30.4	17.0

NA: Not applicable

Photo 4.1 Tujunga Wash Channel

Photo 4.2 Glendale Narrows along the Los Angeles River

Photo 4.3 Concrete-lined channel along the Los Angeles River

Gabriel River. Flood control channelization of Rio Hondo captured tributaries that once formed the western tributaries of the San Gabriel River (MIG and CDM, 2005). After the flood control channelization, Rio Hondo became a tributary of the San Gabriel River, branching from San Gabriel River just below Santa Fe Dam (see Chapter 5) and flowing southwestward to the Los Angeles River.

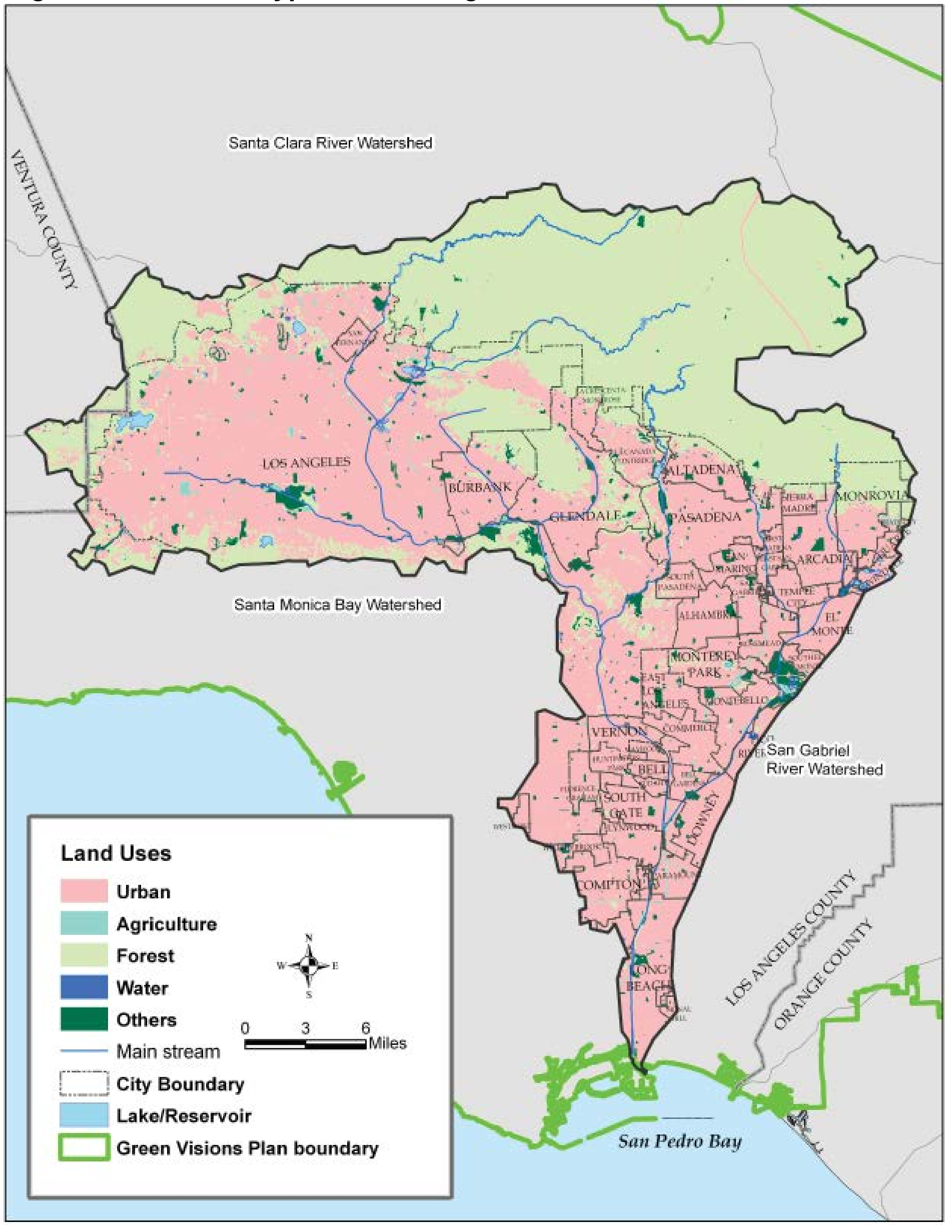
Arroyo Seco, one of the 14 4^{th} order streams, runs in a deeply incised canyon, with the upper Arroyo Seco above the Devil's Gate Reservoir kept in natural channels, and most of the lower course channelized for flood control, and bordered by parks, golf courses, parking lots and residential areas. Pacoima Wash (4th order) is a natural stream from its headwaters to Lopez Dam. Below the dam Pacoima Wash is a concrete channel that provides flow to spreading grounds. The 2nd and 1st order streams are mainly located in headwaters originating the San Gabriel Mountains, San Jose Hills, and Puente-Chino Hills. These streams pass through steep vegetated canyons and carry large amounts of eroded debris off the mountains.

Quite a few of these stream reaches join the main course with impaired waters caused by point and/or point pollution sources. Some are listed in California 2002 Clean Water Act Section 303(d) for the TMDL water quality enhancement (California Regional Water Quality Control Board, Los Angeles Region, 2003) including the Los Angeles River starting seven miles above Sepulveda Flood Control Basin (56.7 mi); Arroyo Seco (10 mi); Burbank Western Channel (13 mi); Rio Hondo (4.6 mi); Verdugo Wash (9.8 mi); and Compton Creek (8.5 mi).

4.2. Watershed Classification

The Los Angeles River watershed is one of the most diverse watersheds in terms of land use patterns. Forest, surface water, and recreational open spaces (e.g., parks, wildlife preserves, and zoos) constitute 35.9 % of the watershed area (SCAG, 2001). Agriculture uses are only 0.7% of the area. The rest of the watershed is composed of heavily urban land uses, and completely or partially encompasses 36 cities and 14 Census-Designated Places (CDP) completely (Figure 4.3).

Figure 4.3 Land use types in Los Angeles River Watershed



The Los Angeles River watershed is divided into six classes by Strahler stream order (Figure 4.4). Catchments drained by the first order streams are dominated by vacant forest usages at 53.5% (Table 4.2). The percentage of urban land use is higher in the 2nd order catchments than the 1st order catchments by 8.8%. The vacant, undeveloped or developed recreational open spaces are largely located within the San Gabriel Mountains (Figure 4.3). Catchments of 4th, 5th and 6th classes are largely urban. Very few agricultural lands are to be found around Rio Hondo, Tujunga Wash and the upper Los Angeles River catchments.

Figure 4.4 Los Angeles River catchments classified by Strahler stream order

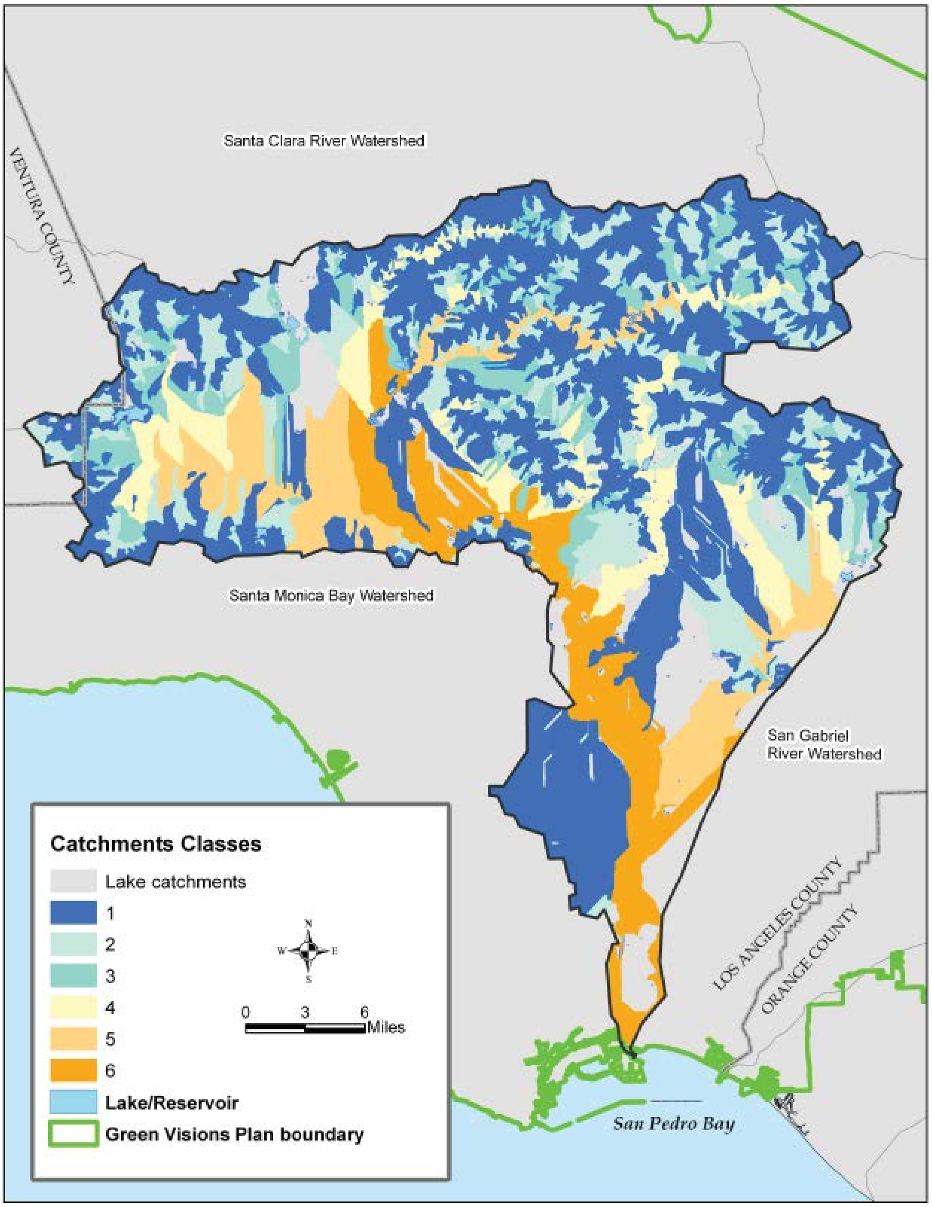


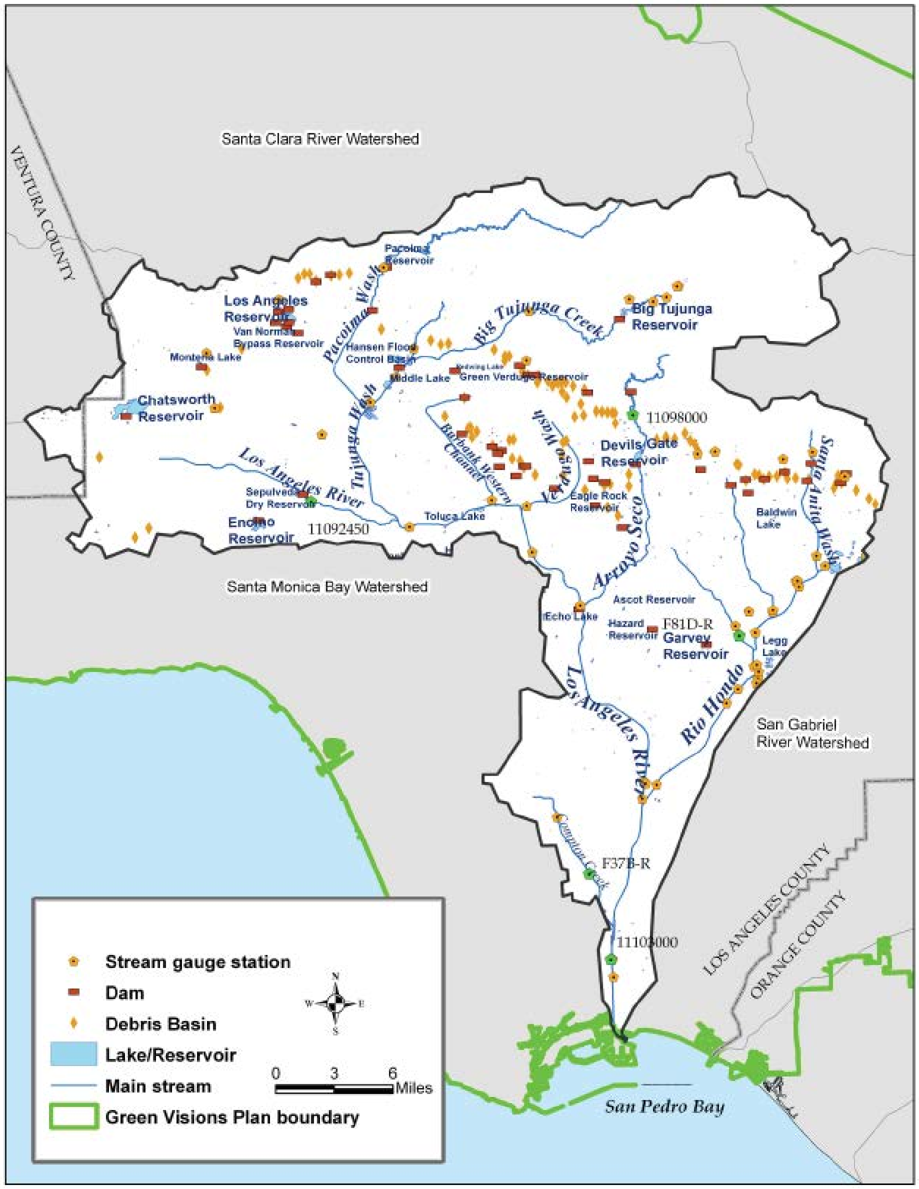
Table 4.2 Watershed classification and their major characteristics

Catchment classes	Mean catchment elevation (ft)	Mean catchment slope (%)	Urban (%)	Agriculture (%)	Vacant (Forest) (%)	Water (%)	Others (%)
1	2174.3	26.8	42.8	0.5	53.5	0.2	3.1
2	2013.6	7.0	51.6	0.8	45.5	0.1	2.1
3	1802.0	21.9	71.7	0.5	24.6	0.2	3.0
4	1162.4	14.3	81.0	1.3	13.7	0.4	3.6
5	756.7	7.3	91.8	0.7	4.1	0.5	2.9
6	389.3	3.2	41.7	0.4	55.7	0.1	2.1
Others	600.9	28.6	41.7	0.4	55.7	0.1	2.1
Average	1271.3	15.6	63.4	0.7	32.8	0.2	2.8

4.3. Dams, Lakes, Reservoirs, and Debris Basins

Historically, flooding in the valleys and periodic droughts made permanent settlements difficult during the late 18th and 19th centuries. To accommodate urban development the hydrologic system of the watershed has been altered, resulting in a sophisticated drainage system that integrates the natural drainage system with heavily engineered hydrologic components. According to NHD documents, the Los Angeles River watershed contains 385 lakes and water body features including Chatsworth Reservoir, Encino Reservoir, Hansen Flood Control Basin, Devil's Gate Reservoir, and Big Tujunga Reservoir (Figure 4.5). Major features of these named lakes and reservoirs are summarized in Table 4.3.

Figure 4.5 Lakes, reservoirs, dams and debris basins



Sepulveda flood control basin – Sepulveda Dam

Sepulveda Dam was built in 1941 and is operated and maintained by the U.S. Army Corps of Engineers for winter flood control along the Los Angeles River. Sepulveda Basin is a dry reservoir with an inundation basin located behind the dam for attenuating flood runoff (Photo 4.4). It collects flood runoff from the upstream uncontrolled drainage areas, stores it temporarily, and releases it to the Los Angeles River at a rate that does not exceed the downstream channel capacity. Although much of this basin is used for recreation, with soccer, baseball, and playing fields, the soft bottom channel of the river near the basin allows the growth of sagebrush, willow, and reeds along the bank.

Chatsworth Reservoir - Encino Reservoir - Los Angeles Reservoir- Van Norman Dams

Table 4.3 Named lakes/reservoirs in the Los Angeles River watershed

Name	Contributing streams	NHD Area (acre)	Elevation (ft) [a]	Area (acres)[a]
Chatsworth Reservoir	Chatsworth Creek, Box Canyon, Woolsely Canyon	559.5	889	607
Encino Reservoir	Unnamed tributaries	134.8	1075	158
Hansen Flood Control Basin	Lopez canyon	123.4	497	
Devil's Gate Reservoir	Arroyo Seco	120.1	1054	110
Big Tujunga Reservoir	Fox creek, White Oak Canyon, Big Tujunga Creek, Josephine Creek	89.3		83
Pacoima Reservoir	Pacoima Wash, Cougar canyon	61.1	2000	68
Garvey Reservoir	No tributaries	31.7	573	38
Legg Lake	Alhambra Wash, Rio Hondo and tributaries	27.8		
Echo lake	No tributaries	13.9		12
Van Norman Bypass Reservoir	No tributaries	10.1	365	12
Eagle Rock Reservoir	No tributaries	7.5		7
Ascot Reservoir	No tributaries	7.1	620	
Toluca lake	No tributaries	4.3	778	
Monteria Lake	No tributaries	4.2		
Green Verdugo Reservoir	No tributaries	3.4		3
Middle Lake	Little Tujunga, Tujunga Wash	3.2		
Baldwin Lake	Unnamed tributaries	2.5		
Hazard Reservoir	No tributaries	0.7	476	1

a Documented data from various sources other than NHD.

Chatsworth Reservoir is an unused reservoir that used to serve as a water-storage facility for the Los Angeles Department of Water and Power, but due to dam safety concern, no longer does. Encino Reservoir is another small water supply reservoir. It used to receive its water from the Los Angeles Reservoir via pipeline and provide drinking water to the local community. As of January 1, 2003, Encino Reservoir was taken out of service. It will continue to distribute a small amount of water, while serving primarily as a storage reservoir for emergency use (LADPW, 2002). Although it is filled by imported water, it does not have a regular outlet or path of spillway flow, thus any breach would flood a residential area. Los Angeles Reservoir began storing water in August 1977. Both the Upper and Lower Van Norman Dams behind Los Angeles River Reservoir have been reconstructed to modern safety standards to serve as emergency flood control storage. They are now known as the San Fernando Storm Water Detention Basins.

Photo 4.4 Sepulveda Basin

Big Tujunga Reservoir - Big Tujunga Dam - Hansen flood control basin - Redwing Lake - Hansen Dam

Big Tujunga Dam, with Big Tujunga Reservoir behind it, was built in 1931 for flood control and water conservation by LADPW. In the winter of 2004-2005, the reservoir filled with sediment-rich water and debris from the upper watershed and eventually spilled water to the Big Tujunga mainstream. The storms resulted in some of the highest flows for the Big Tujunga ever recorded. Little Tujunga Canyon and Big Tujunga Creek enter the Hansen Dam flood control basins right above Tujunga Wash. Hansen Dam was constructed by the U.S. Army Corps of Engineers, Los Angeles District in 1939 and 1940 following damaging flood events in 1914 and 1938 (USACE, 1990). In conjunction with Sepulveda Dam and Lopez Dam, Hansen Dam provides flood control protection for the lower portions of the San Fernando Valley and the City of Los Angeles.

Pacoima Reservoir - Pacoima Dam

The Pacoima Dam was built in 1929 in order to provide flood control and water conservation. It is at an elevation of 1,950 feet and has a capacity of 6,060 AF.

Garvey Reservoir

Garvey Reservoir, built in 1954, is a municipal surface water reservoir that provides water to the eastern portion of Los Angeles.

Echo Lake - Legg Lake

Certain portions of Echo Lake (13 acres) and Legg Lake (25 acres) are listed in California 2002 Clean Water Act Section 303(d) for water quality enhancement (California Regional Water Quality Control Board, Los Angeles Region, 2003) due to nonpoint/point source pollutants.

4.4. Stream Flow and Annual Flood Dynamics

There are a total of 38 USGS gauging stations located in the watershed that monitor flow status. The County of Los Angeles Department of Public Works operates 20 stream stations (Table 4.4). Five stations are co-operated by USGS and LADPW. Mean annual daily flow, annual peak discharge, temporal trend tests, and flood magnitude estimates for various recurrence events are summarized in Table 4.5 for 37 stations that have flow records longer than 20 years.

Mean annual daily discharges and annual flood peak discharge dynamics are examined at four stream gauge sites that are located in different landscapes of the watershed (Figure 4.6). These four sites are: (a) upper Los Angeles River at Sepulveda Dam at USGS 11092450; (b) Arroyo Seco near Pasadena at USGS 11098000; (c) Compton Creek at F37B-R; and (d) Los Angeles River at Long Beach near the outlet to the ocean USGS 11103000/F319-R.

Mean Annual Daily Discharge

Flow in the Upper Los Angeles River at USGS 11092450 has been regulated since WY1941. Water runs year-round in the stream with evident seasonal variations. The maximum annual

Table 4.4 Stream flow stations in Los Angeles River Watershed.

Station Name	Area (mi²)	Eleva-tion (ft)	Upstream Regulation	Flow Status	Flow Records From	Flow Records To
BURBANK WESTERN STORM DRAIN at Riverside Dr.	25		Non		1949	date
MONTEBELLO STORM DRAIN above Rio Hondo	10		Y		1932	date
RIO HONDO below Lower Azusa Avenue	41		Y	E	1932	date
SANTA ANITA WASH at Longden Avenue	19	360	Y	E	1932	date
SAWPIT WASH below Live Oak Avenue	16	323	Y	P	1932	date
VERDUGO WASH at Estelle Avenue	27	470	Y		1935	date
SANTA FE DIVERSION CHANNEL below Santa Fe Dam			Y	E	1942	date
LOS ANGELES RIVER at Tujunga Avenue	401		Y		1950	date
ARCADIA WASH below Grand Avenue	9	298	Y		1955	date
EATON WASH at Loftus Drive	23	260	Y		1956	date
RUBIO DIVERSION CHANNEL below Gooseberry Inlet	2	1,399	Y		1959	date
BRANFORD STREET CHANNELbelow Sharp Avenue	5	846	Y		1962	date
COMPTON CREEK near Greenleaf Drive	23	65	Non		1928	date
RIO HONDO above Stuart and Gray Road	140		Y		1928	date
LOS ANGELES RIVER above Arroyo Seco	511		Y		1929	date
LOS ANGELES AQUED at outlet at San Fernando CA					1966	1976
PROJECT 85 A SPRR BL HDWKS CA	ND	ND	ND	ND	ND	ND
SANTA FE DIV CHANNEL CA		420	Y		1973	1974
RIO HONDO FLD FLOW CHAN CA					1965	1970
LIMEKILN CYN WASH NR CHATSWORTH CA	3				1960	1973
LIMEKILN C AB ALISO C NR CHATSWORTH CA	10	835	Y		1973	1974
LOS ANGELES R A SEPULVEDA DAM CA	158	663	Non		1930	2006
PACOIMA C NR SAN FERNANDO CA	28	1,650	Non		1914	1979
NF MILL C NR LA CANADA CA	6		Non		1960	1973
MILL C NR COLBY RANCH CA	6		Non		1930	1934
TUJUNGA C BL MILL C NR COLBY RANCH CA	65	2,650	Non		1948	1971
TUJUNGA C NR COLBY RANCH CA	68	2,410	Y		1931	1950
FOX C NR COLBY RANCH CA	9		Non		1930	1937
BIG TUJUNGA C NR SUNLAND CA	106	1,572	Y		1916	1977
HAINES C NR TUJUNGA CA	1	2,430	Non		1914	1961
LITTLE TUJUNGA C NR SAN FERNANDO CA	21	1,068	Non		1914	1973
BIG TUJUNGA C BL HANSEN DAM CA	153		Y		1932	2007
LOS ANGELES R A FELIZ BLVD AT LOS ANGELES CA			Y		1973	1977
LOS ANGELES R A LOS ANGELES CA	514	293	Y		1929	1979
ARROYO SECO NR PASADENA CA	16	1,398	Non		1910	2007
LOS ANGELES R NR DOWNEY CA	599	96	Y		1928	date
SAWPIT C NR MONROVIA CA	5	1,100	Non		1916	1961
SANTA ANITA C NR SIERRA MADRE CA	10	1,475	Non		1916	1971
LITTLE SANTA ANITA C NR SIERRA MADRE CA	2	2,200	Non		1916	1979
ARCADIA WASH A GRAND AVE A ARCADIA CA	9	310	Non		1974	1975
EATON C NR PASADENA CA	6	1,230	Non		1966	1966
EATON WASH A LOFTAS DRIVE EL MONTE CA	20	260	Y		1973	1975
RUBIO WASH A GLENDON WAY NR EL MONTE CA	11	285	Non/Y		1949	date
RIO HONDO AB WHITTIER NARROWS DAM CA	91		Y		1956	2007
MONTEBELLO CA	15		Non		1930	date
RIO HONDO NR MONTEBELLO CA	116	191	Y		1928	date
MISSION C NR MONTEBELLO CA	4		Non		1929	1977
MISSION C BL WHITTIER NARROWS DAM CA			Y		1956	1970
RIO HONDO BL WHITTIER NARROWS DAM CA	124		Y		1966	2006
RIO HONDO NR DOWNEY CA	143	91	Y		1928	1979
COMPTON C A 120TH ST NR COMPTON CA	15	90	Non		1974	1975
LOS ANGELES R A LONG BEACH CA	827	11.9	Y		1929	date
CA	831		Y		1973 [a]	1980

a : No flow data available at the site. Water quality was sampled between WY1973 and 1980.

mean discharge was 292.1 cfs recorded in WY2005, and the lowest was 7.1 cfs recorded in WY1950 (Figure 4.6a). Significant increasing trends were detected during the period of WY1943-2006 in mean annual daily discharge (Table 4.5).

Before passing the Devil's Gate Dam, flows at USGS 11098000 run freely without regulation or significant diversion and most of the tributaries that feed Arroyo Seco are kept in natural channels since little to no development has occurred in this portion of the watershed. Over the years, mean annual flows have varied with the climate but no significant changes occurred from WY1915 to 2005 (Figure 4.6b).

Table 4.5 Mean annual daily discharge, temporal trend significance test, annual peak discharge, temporal trend significance test, and flood

STA_ID	Mean annual daily discharge (cfs)	Sig.(2-tailed)	Coefficient of variation	Average peak discharge (cfs)	PQ Sig.(2-tailed)
E285-R	15.3	0.000**	0.70	3293.7	0.000**
F181-R	2.3	0.066 (-)	0.80	719.3	0.007(-)**
F192B-R	19.3	0.962	1.88	1781.2	0.320(-)
F193B-R	10.9	0.260	1.67	1069.7	0.472(-)
F194B-R	15.7	0.357	1.06	1697.0	0.152
F252-R	10.1	0.000**	1.07	2425.4	0.000**
F280-R	13.4	0.068	1.20	259.5	0.413
F300-R	130.0	0.000**	0.99	15540.4	0.001**
F317-R	5.6	0.000**	0.67	1907.2	0.004**
F318-R	1.4	0.374	4.21	2757.4	0.058
F338-R	1.4	0.036**	1.36	159.4	0.081
F342-R	1.4	0.179	0.69	769.1	0.006**
F37B-R	10.1	0.039**	0.65	3148.1	0.000**
F45B-R	53.6	0.002**	1.83	12104.5	0.000**
F57C-R	135.4	0.000**	1.09	20295.9	0.000**
11092450	53.4	0.000**	1.02	6347.5	0.000**
11093000	9.9	0.649(-)	1.39	424.6	0.831(-)
11094000	12.3	0.086	1.71	1742.3	0.002**
11095500	28.0	0.444(-)	1.37	2652.4	0.162(-)
11096000	0.1	0.018(-)**	1.67	22.8	0.589
11096500	2.5	0.906	1.65	887.0	0.940
11097000	25.7	0.000**	2.13	2509.5	0.258
11097500	70.9	0.035**	1.11	16589.6	0.000**
11098000	9.8	0.620	1.23	1114.5	0.904
11098500/F34D-R	181.1	0.000**	1.00	26569.6	0.000**
11099500	1.1	0.739	1.34	181.6	0.584(-)
11100000	6.7	0.492	1.24	669.6	0.283
11100500	0.9	0.828(-)	1.15	66.3	0.677
11101000	2.1	0.147(-)	1.61	356.2	0.061(-)
11101180/F82C-R	4.9	0.020**	0.59	2219.0	0.001**
11101250	50.6	0.017**	1.15	8532.4	0.009**
11101380/F81D-R	7.5	0.000**	0.63	3529.8	0.000**
11101500/F64-R	85.6	0.172	1.91	6780.3	0.002**
11102000	174.7	0.000(-)**	0.86	16.2	0.272(-)
11102300	174.7	0.991	0.86	17039.0	0.762
11102500	36.1	0.372	2.10	8912.2	0.000**
11103000/F319-R	295.9	0.000**	1.24	35892.2	0.000**

** Trend is significant at the 0.01 level (2-tailed).

A significant increase in the mean annual flow can be detected at the site F37B-R in Compton Creek during the period of WY1930 to 2005 (Figure 4.6c). Much of the open land in the watershed was developed in the last 70 years, and it is likely that this increase in runoff is a result of the large increase of impervious cover. An estimated 65% of the drainage area is now covered by impervious surfaces (SCAG, 2001).

Similar hydrologic changes have affected the other urban streams, such as Alhambra Wash at the site F81D-R and Rubio Wash near El Monte at F82C-R (Table 4.5). All these streams run through the urban landscape free of dam regulation or diversions while subject to the impacts of land use change. Flow status at these sites changed from ephemeral to perennial around the 1940's due to the contribution of urban storm drain runoff to the stream outflow.

Mean annual daily discharge observed near the Los Angeles River outlet at USGS 11103000/F319-R also shows a long term increasing trend with the average discharge of 223.2 cfs from WY1928 to 2005 (Figure 4.6d). The lower Los Angeles River used to flow freely, shifting back and forth across the coastal plain before it was controlled in the 1950s in order to control runoff and reduce the impacts of major flood events. It once took the course where Ballona Creek runs today and discharged to the Santa Monica Bay during the early 1800s, until a major storm event caused it to shift course south to San Pedro.

Increasing change in the mean annual daily discharge also occurs in the Verdugo Wash at F252-R, Burbank Western Channel at E285-R, and many reaches along the Los Angeles River (Table 4.5). Increasing release of tertiary treated reclaimed waste water from Los Angeles-Glendale Water Reclamation plant affects hydrologic conditions in streams. In WY2005, at the confluence with Verdugo Wash, recyled water contributes 14% of the total outflow in the Los Angeles River stream channel.

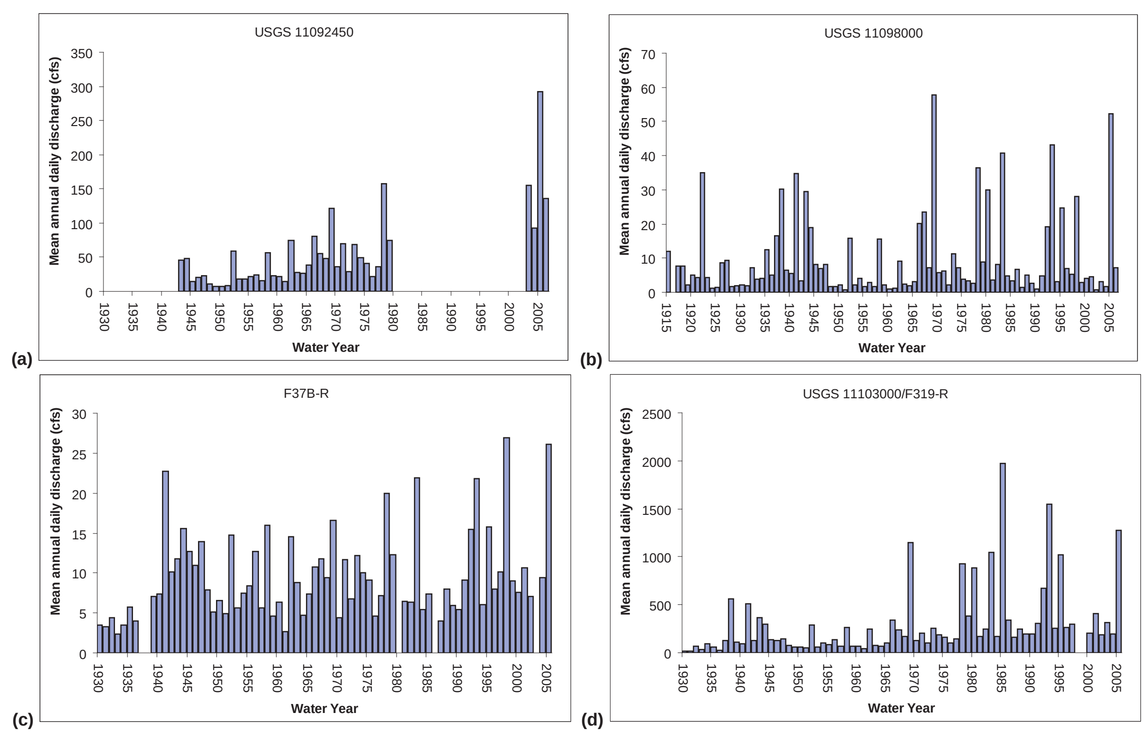


Figure 4.6 Mean annual daily discharges in: (a) upper Los Angeles River at Sepulveda Dam at USGS 11092450; (b) Arroyo Seco near Pasadena at USGS 11098000; (c) Compton Creek at F37B-R; and (d) Los Angeles River near the outlet site USGS 11103000/F319-R.

Flood Dynamics

The record peak flood discharge at USGS 11092450 was observed during the December 28, 2004 storm event (Figure 4.7a). The storm produced 3.5 inches of rainfall in San Fernando Valley and caused severe flooding at various locations (Photo 4.5). The 2004 flood exceeded the high peak discharge during the deadly 1938 flood, during which 3.1 inches of rainfall was brought to the upper San Fernando Valley and caused massive inundation in low-lying areas (Photo 4.6), prompting the construction of Hansen Dam and Sepulveda Dam. After years and

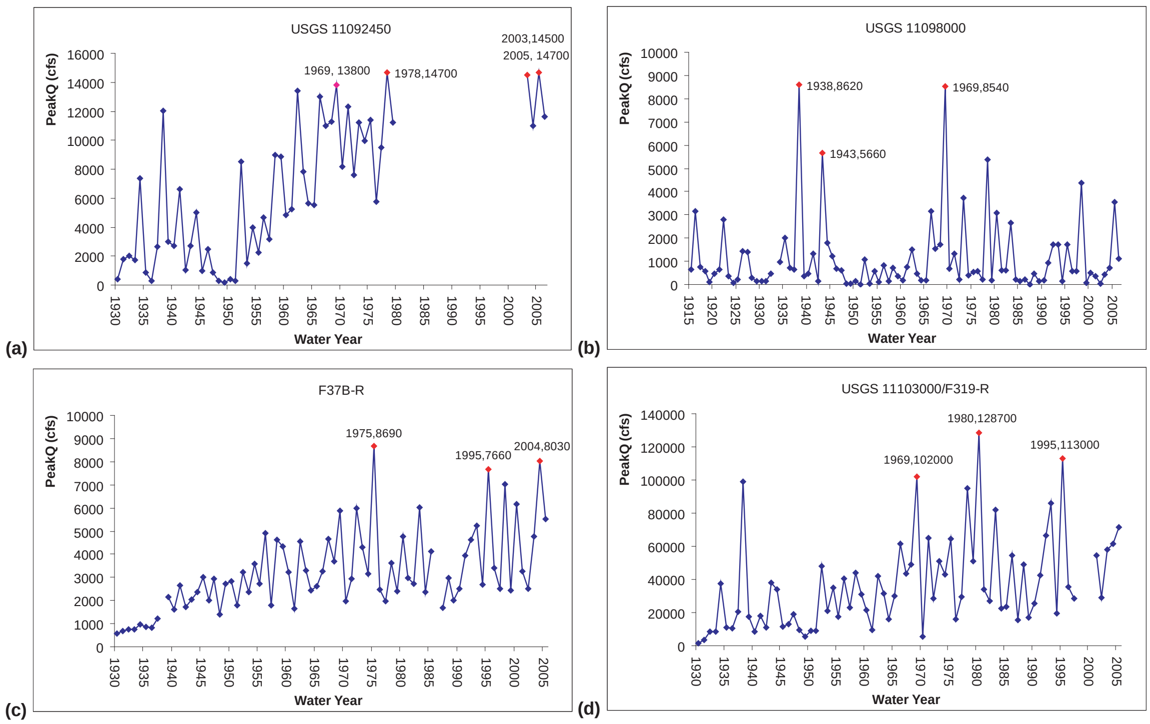


Figure 4.7 Annual flood peak discharges in: (a) upper Los Angeles River at Sepulveda Dam at USGS 11092450; (b) Arroyo Seco near Pasadena at USGS 11098000; (c) Compton Creek at F37B-R; and (d) Los Angeles River near the outlet site USGS 11103000/F319-R.

Photo 4.5 Dec 28, 2004 storm flooding

Photo 4.6 Canoga Park, March 2, 1938

years of upstream development and flood control infrastructure construction, a significant increase is still detected in the annual flood peak discharges (Table 4.5).

The flood regime in Arroyo Seco above the site USGS 11098000 is natural and no increasing trend is found in annual flood peak discharges (Figure 4.7b). This site experienced the record flood events of 1938 and 1969, which were also observed at other sites that have natural flood regimes (see Chapter 5).

An increasing trend in annual flood peak discharges is found in Compton Creek at F37B-R (Figure 4.7c). Associated with this increasing flood risk, flood protection has traditionally been a high priority within the watershed (Los Angeles and San Gabriel Rivers Watershed Council et al., 2005). When first constructed, flood control projects were designed to accommodate a 100-year flood. Since that time, the volume of storm water has increased due to the increasing extent of impervious surfaces. Flooding occurs locally in the watershed where local drainage system capacity is exceeded by storms larger than a 25-year event. On November 12, 2003, rainfall intensities exceeding a 500-year event, with over five inches of rainfall and over one foot of hail in some locations, caused significant localized flooding that damaged over 250 structures and resulted in the reported abandonment of over 100 vehicles along flooded streets and intersections (Los Angeles and San Gabriel Rivers Watershed Council et al., 2005).

Significant increases in flood peak discharges are also detected at various sites along many urban streams and highly altered streams reaches. The urban stream Alhambra Wash, at F81D-R, has experienced increasing change since the 1930s, largely attributed to rapid population growth and the urban expansion in the Alhambra Wash watershed and adjacent cities in the San Gabriel Valley. This also has occurred in Verdugo Wash at F252-R, and Burbank Western Channel at E285-R. The drainage areas along these reaches are highly urbanized with more than 80% of the land converted to impervious surfaces.

As a consequence, the magnitude of annual floods in the lower Los Angeles River at USGS 11103000/F319-R increases after receiving flows augmented at various parts of the watershed. Although up to 74% of the watershed area is regulated by dams, reservoirs, detention basins, and spreading grounds, most structures were constructed on the low order streams (i.e., 1st and 2nd order). The influence of impervious urban surfaces and effluents of urban water on hydrologic processes is substantial. Over time the capability of flood protection structures built on low order streams in prior periods is exceeded by the increasing flood peaks and loss of the natural ability of the watershed to contend with flood risks.

4.5. Groundwater Recharge and Extraction

Three groundwater basins – San Fernando Valley, San Gabriel Valley, and Raymond – and one Central subbasin underlie the watershed (Table 4.6). The Central subbasin, also know as the “Central Basin,” belongs to the Coastal Plain of the Los Angeles groundwater basin. San Gabriel Valley Basin underlies both the Los Angeles River and San Gabriel River watersheds (Figure 4.8). It will be discussed in Chapter 6. Central Basin will be discussed along with other subbasins in Chapter 7. Table 4.6 summarizes the major features of these groundwater basins.

San Fernando Valley

Recharge of the basin comes from a variety of sources. Water flowing in the adjacent Tujunga Wash, Verdugo Wash and Arroyo Seco infiltrates the eastern portion of the groundwater basin. Precipitation falling on impervious surfaces, streamflow from the surrounding mountains, and reclaimed, industrial discharges replenish the western portion of the San Fernando Valley Basin (ULARAW, 1999). Spreading of imported water and runoff occurs in the Pacoima, Tujunga, and Hansen Spreading Grounds (ULARAW, 1999) (Figure 4.8). Rising ground water appears in many locations along the foothills. In the Verdugo Wash, sometimes the concrete floor is broken by the force of groundwater as the water table reaches above the

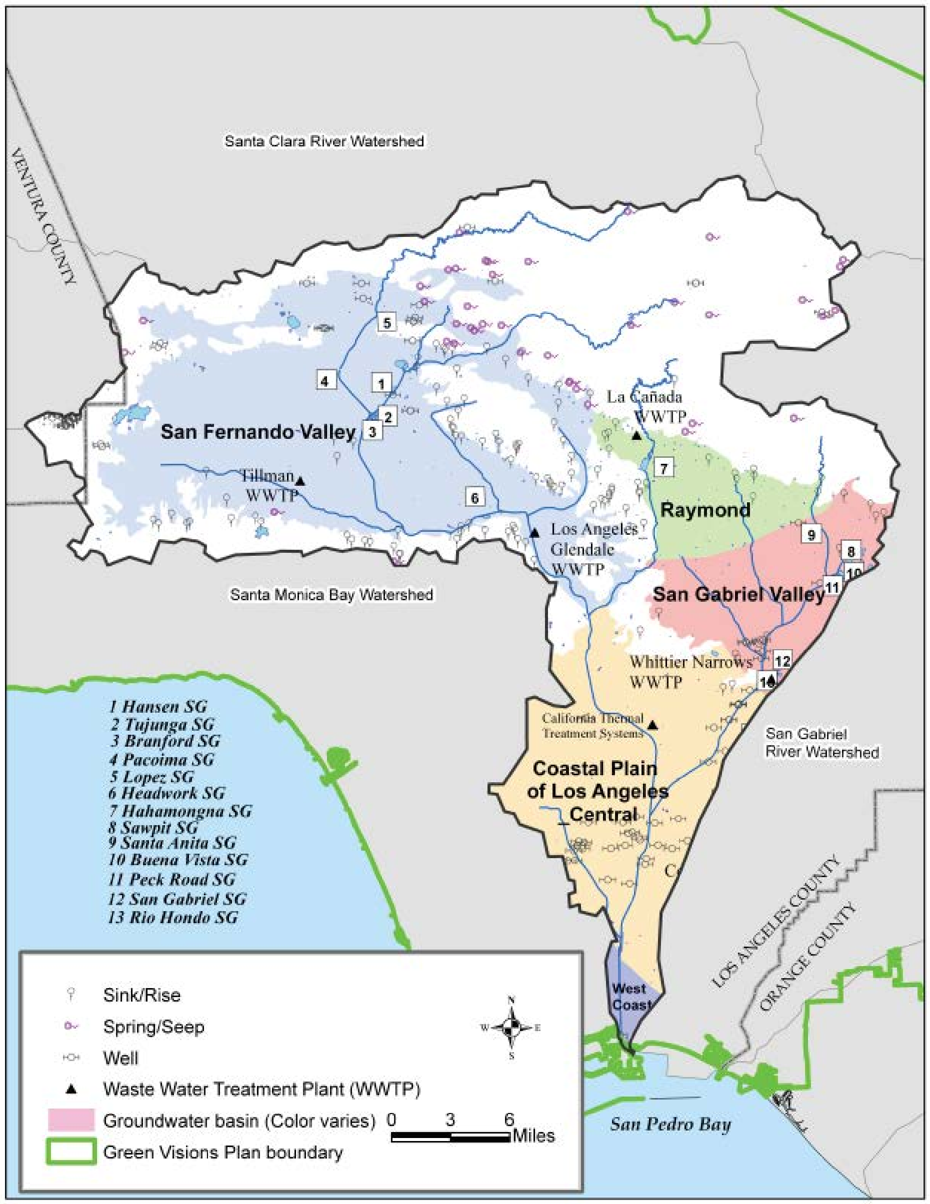
Table 4.6 Groundwater basin data summary

Groundwater Basin/Subbasin Name	Area (acres)	Average well yield (gpm)	Groundwater storage capacity (af)[a]	Groundwater in storage (af)[a]	Ground-water recharge (af)	Average annual extraction (af)	Average TDS (mg/L)
San Fernando Valley	145,000	1,220	3,670,000[i]	3,049,000[i]	108,500[i]	220,000	499
Raymond	26,200	1,880	1,450,000	1,000,000	7,500	6,400	346

a Values are estimated using the Panaro (2000) method

i: Value are estimated using the ULARAW (1999) method

Figure 4.8 Groundwater basins, springs, wells and spreading grounds



level of the river floor. At the outlet of the Verdugo Wash more and more rising groundwater is recharged to the downstream together with the storm runoff collected from the upstream (ULARAW, 2006). Groundwater at various sites is affected by contamination of volatile organic compounds such as trichloroethylene (TCE), perchloroethylene (PCE), petroleum compounds, chloroform, nitrate, sulfate, and heavy metals (Setmire, 1985; ULARAW, 1999). Four Superfund sites were placed on the Federal EPA's list, located in the vicinity of the North Hollywood section of the City of Los Angeles Services, the Crystal Springs Well Field in the Cities of Los Angeles and Glendale, the Glorietta Well Field in the City of Glendale, and the Pollock Well Field area in the City of Los Angeles. To alleviate the contamination, wells are either taken out of service or blended with water from clean sources to ensure that the public receives water with TCE/PCE concentrations below the State's guidelines (U.S. EPA, 2002).

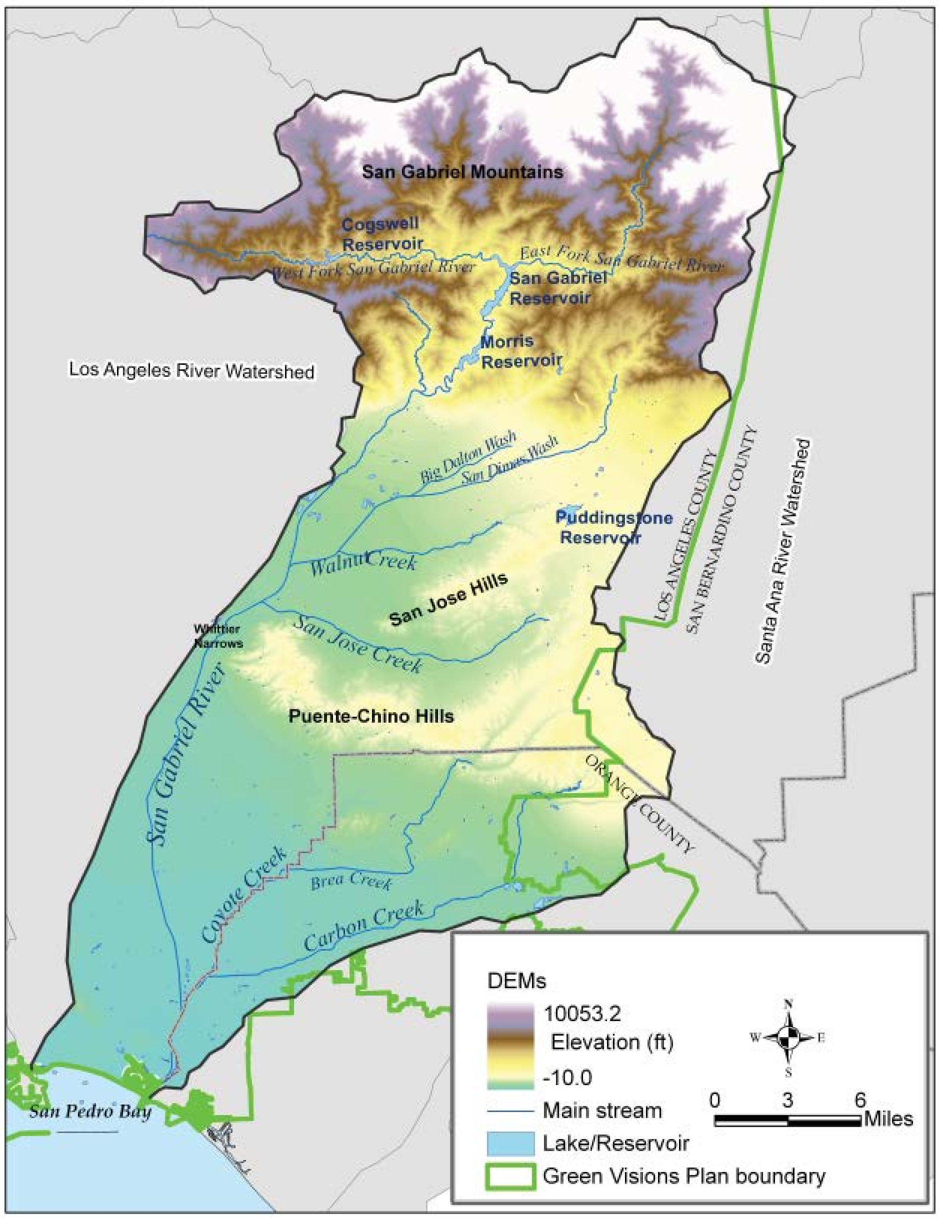
Raymond

Raymond is recharged through infiltration and percolation of rainfall and surface runoff as well as subsurface inflow from the San Gabriel Mountains. The addition of imported water to the watershed has relieved the overdraft flow from Raymond in the last century or so (Brick, 2003). Even with extra imports, Raymond Basin today is still suffering a significant annual overdraft that may pose a threat in terms of land subsidence, habitat reduction, and adverse groundwater quality impacts. Spreading basins in the Hahamongna area at the mouth of the Arroyo Seco are used to enhance groundwater recharge by allowing diverted stream flow and storm runoff to percolate into the aquifer beneath. Injection wells are also used to replenish the groundwater basin (Brick, 2003). The groundwater on the west edge of the basin may be affected by the pollutants discharged from the nearby Jet Propulsion Laboratory (NASA). In 1990, significantly elevated levels of carbon tetrachloride, trichloroethene, tetrachloroethene, and other volatile organic compounds (VOCs) were detected in groundwater both under and downgradient the JPL site. In 1992, this site was placed on the Federal EPA's Superfund list for pollution remediation (U.S.EPA, 2002).

5.1. Drainage System and Stream Classification

The San Gabriel River watershed is the largest watershed in the San Gabriel Mountains drainage system of southern California, encompassing a total land area of 690.7 mi^2. The watershed is bordered by the San Gabriel Mountains to the north, the Santa Ana River watershed to the east, the Los Angeles River watershed to the west and discharges southward to the Pacific Ocean through the coastal plain of the Los Angeles Basin. The San Gabriel River begins in the Angeles National Forest and consists of three major upper forks (the North, West, and East forks) within the San Gabriel Canyon and a number of significant tributary streams join in along the main course, namely, San Jose Creek, Walnut Creek, and Coyote Creek (Figure 5.1). A relatively unusual flow pattern has developed. The main path of the San Gabriel River winds along the extreme western boundary of the watershed for most of its length, as a result of the underlying geology of the region and hydrologic engineering structures that have shaped its course. In particular, flood control channelization of the Rio Hondo captured tributaries that once formed the western tributaries of the San Gabriel River (MIG and CDM, 2005).

Figure 5.1 San Gabriel River Watershed elevation map



The entire stream drainage system is classified into six orders in the Strahler stream order system (Figure 5.2). Table 5.1 summarizes the basic physio-topographic characteristics of streams by Strahler order. The watershed contains a total length

Figure 5.2 San Gabriel River tributaries classified by Strahler stream order

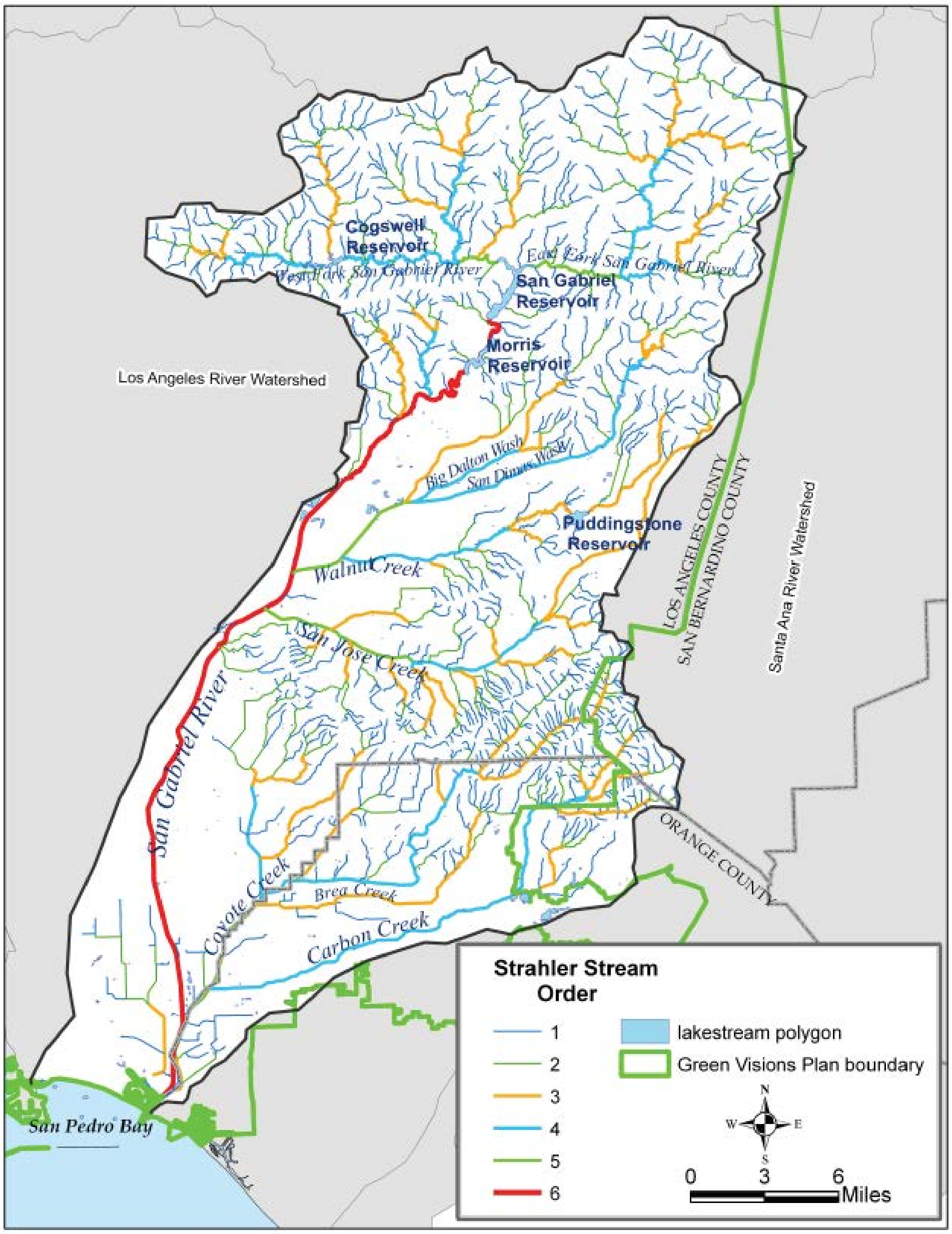


Table 5.1 Basic characteristics of the drainage system in the San Gabriel River Watershed

Strahler stream order	Segments	Bifurcation ratio	Mean channel slope (%)	Mean channel elevation (ft)	Stream length (mi)	Drainage area (mi^2)
1	890	4.7	16.4	2062.8	680.8	323.3
2	191	3.8	7.5	1777.1	235.1	103.1
3	50	4.2	3.2	1350.4	172.3	105.0
4	12	2.4	2.4	1382.2	106.3	87.9
5	5	5.0	0.9	723.9	27.0	24.7
6	1	-	2.2	558.3	44.0	46.0

of 1,298 mi streams (NHD, 1999) with an average channel elevation of 1,245.7 ft. The sixth order streams include the San Gabriel River below San Gabriel Reservoir. A large portion of the reach passing through the San Gabriel Valley has been engineered for flood control purposes. However, unlike the Los Angeles River, this reach of the San Gabriel River is an earthen-bottomed channel between raised levees, which therefore retains the infiltration of water into underlying groundwater basins (MIG and CDM, 2005). Beginning seven miles below the Whittier Narrows Dam, the earthen-bottom of the river is replaced by a concrete channel for about 10 miles. After the confluence with Coyote Creek, the river returns to an earthen bottom, and flows another 3.5 miles through a natural estuary to the Pacific Ocean (MIG and CDM, 2005).

The 5th Strahler order streams consist of the East Fork and West Fork of the San Gabriel

River, Walnut Creek, San Jose Creek, and Coyote Creek from north to south. The East Fork and West Fork of the San Gabriel River are located within the Angeles National Forest and the other three are urban streams that are surrounded by a number of cities. The 4th and 3rd order streams are also characteristic of urban hybrid streams with parts of their stream reaches passing through urban landscapes and parts through wildlands. Quite a few of these urban reaches join the main San Gabriel River with impaired water quality, caused by point and/or nonpoint pollution sources. Some are listed in the California 2002 Clean Water Act Section 303(d) for TMDL water quality enhancement (California Regional Water Quality Control Board, Los Angeles Region, 2003) including the San Gabriel River starting at Ramona downstream (29 mi); San Jose Creek (19.7 mi); Walnut Creek Wash below Puddingstone Reservoir (12 mi) and Coyote Creek (13 mi).

Photo 5.1 San Gabriel River passing through San Gabriel Canyon

The 2nd and 1st order streams are mainly located in headwaters originating in the San Gabriel Mountains, San Jose Hills, and Puente–Chino hills. These streams pass through steep vegetated canyons and carry large amounts of eroded debris off the mountains (Photo 5.1).

5.2. Watershed Classification

The human settlement of the watershed started as early as 500 B.C. As of today, land uses within the uppermost portion of the watershed are dominated by forest, recreation and natural open space, and they remain in a relatively natural state and are ecologically intact (Figure 5.3). From the foothills of the San Gabriel Mountains to the outlet to the Pacific Ocean, the drainage is surrounded by dense urban development. Within the San Gabriel River valley, the majority of land has been converted to residential and commercial uses. Overall, land uses within the watershed include 47.0% urban or build-up area, 0.8% agriculture, 51.2% open space and forest, and 1.0% water (SCAG, 2001).

The entire watershed is divided into six classes of catchments by Strahler stream order (Figure 5.4). The sixth order catchments are along the San Gabriel River below San Gabriel Reservoir. The majority of the catchment area is covered by urban land uses (67.1%). The percentage of urban land use (78.1%) in the fifth order catchments is the highest among all the classes. Only 17.6 percent of the drainage basin is covered by forests, riparian vegetation or open land. The second and first order catchments are headwater catchments in which vegetated or forest land covers most area of the catchment (Table 5.2).

Figure 5.3 Land use types in the San Gabriel River Watershed

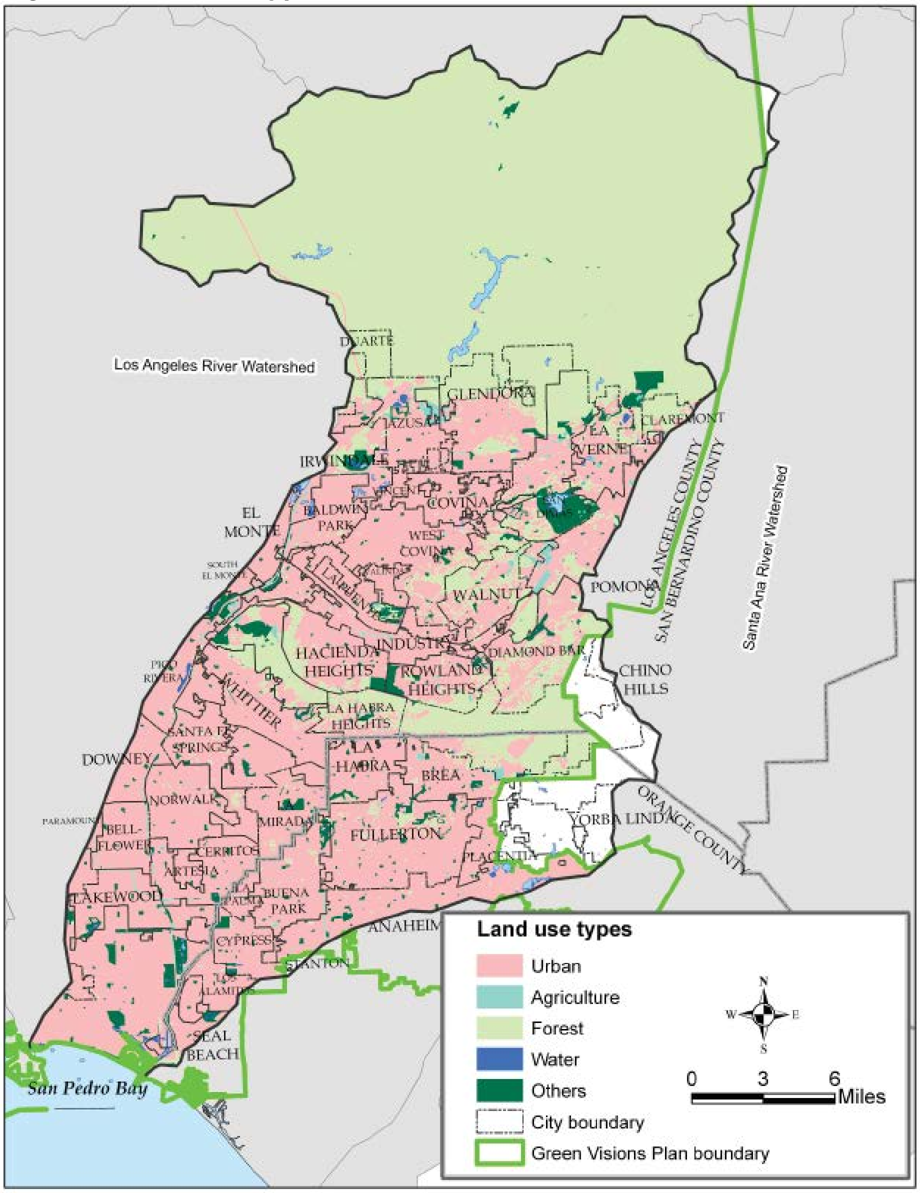
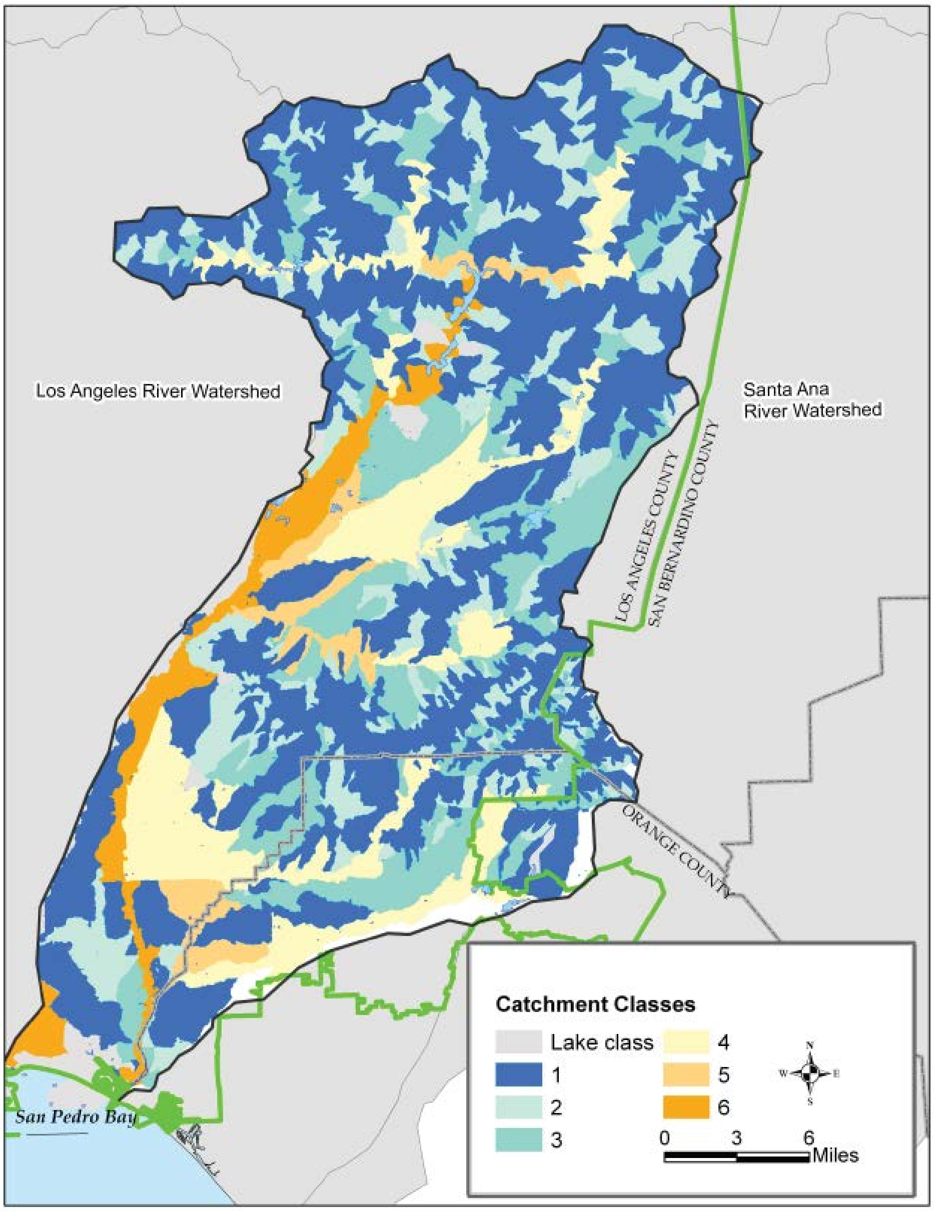


Table 5.2 Watershed classifications and their major characteristics

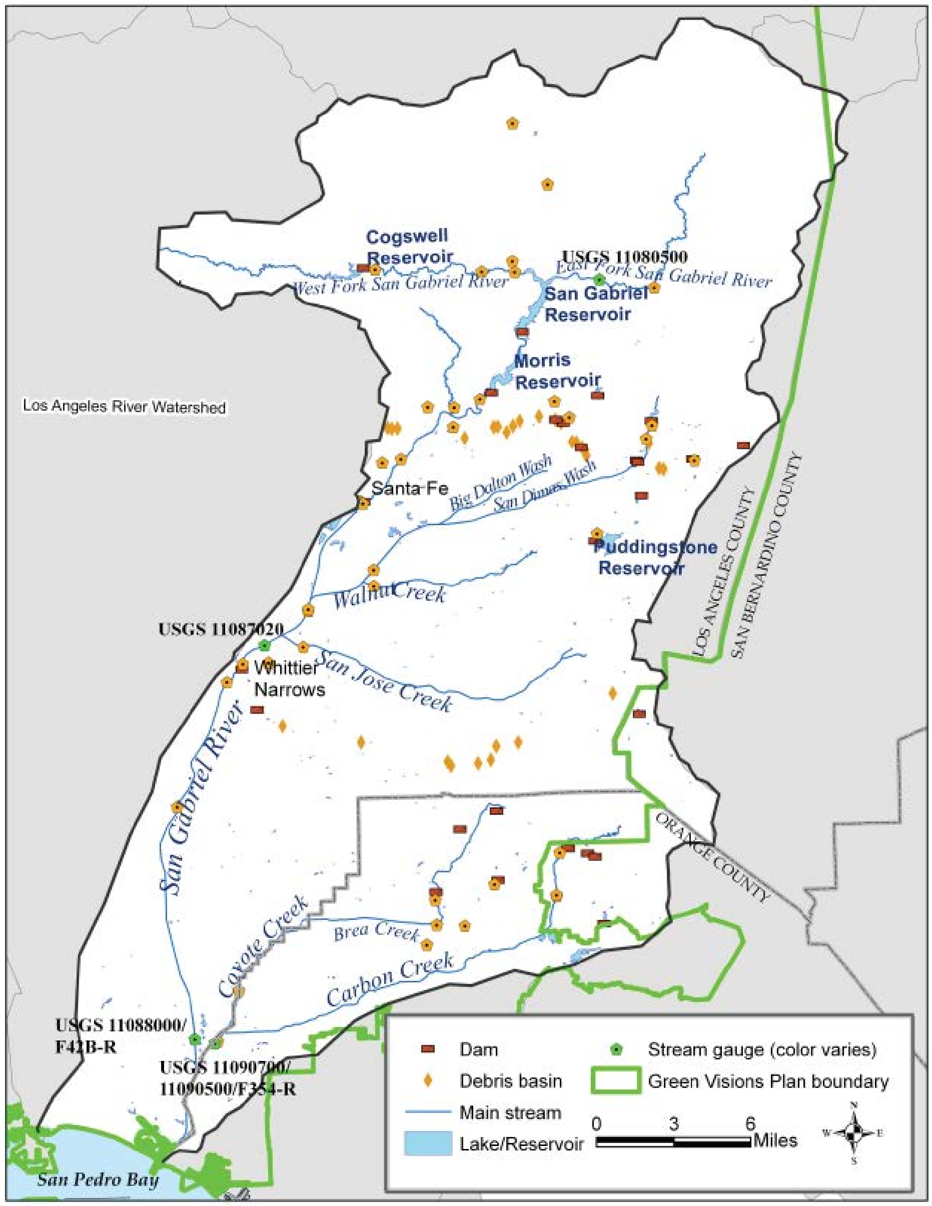
Catchment classes	Mean catchment elevation (ft)	Mean catchment slope (%)	Urban (%)	Agriculture (%)	Forest (%)	Water (%)	Others (%)
1	766.3	36.5	34.4	0.5	61.6	0.2	3.3
2	695.7	35.0	37.6	0.7	59.0	0.2	2.5
3	373.6	21.0	60.7	0.9	33.8	0.4	4.2
4	238.9	15.1	71.9	0.6	24.3	0.4	2.8
5	160.2	11.2	78.1	0.8	17.6	1.0	2.5
6	142.6	10.5	67.1	3.3	17.9	5.2	6.6
Others	297.1	16.5	42.2	4.1	23.6	22.5	7.8
Average	382.1	20.8	56.0	1.6	34.0	4.3	4.2

Figure 5.4 San Gabriel River catchments classified by Strahler stream order



5.3. Dams, Lakes, Reservoirs, and Debris Basins

Figure 5.5 Lakes, reservoirs, dams and debris basins



For centuries, flood water has periodically swept out of the San Gabriel Mountains causing extensive damages and loss of life. The disastrous flood of 1914, which caused over $10 million in property damage, led to the creation of the Los Angeles County Flood Control District and the construction of a series of dams to impound San Gabriel Mountains storm waters until they could be released in a controlled way. Many of these dams are now also operated for water conservation in conjunction with spreading grounds located along the water courses (Figure 5.5). Debris basins were constructed to capture eroded materials from steep canyons which had caused severe damage in the past. These structures have effectively prevented disastrous damages to the watershed since their construction.

A majority of the watershed area (87%) is dammed and under flood control regulation by these facilities, mostly (80%) as a result of the Whittier Narrows Dam. Table 5.3 shows natural and man-made lakes with or without dams behind.

Cogswell Reservoir - Cogswell Dam

The construction of Cogswell Dam began in 1932 and was completed in April 1934. It is a rock-filled structure with a concrete cutoff wall and rises 255 ft above the original stream bottom (USACE, 1991). This facility is owned by the Los Angeles County Flood Control District and operated and maintained by the LADPW.

Table 5.3 Named lakes/reservoirs in San Gabriel River Watershed

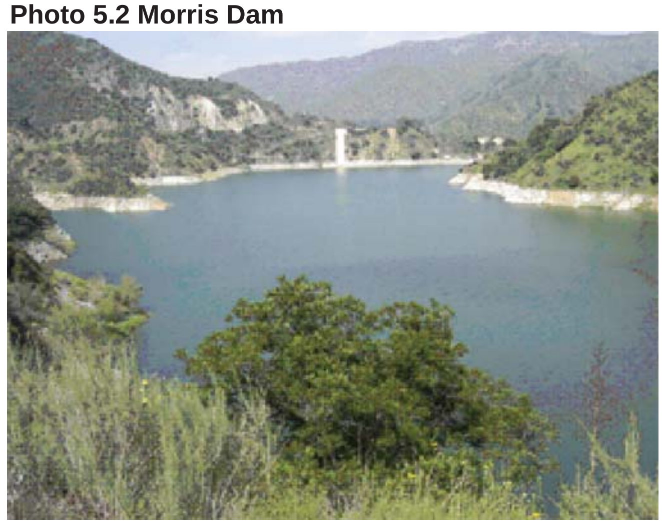
Name	NHD Area (Acres)	NHD Perimeter (mi)	Elevation (ft)	Area (Acres)
Yorba Linda Reservoir	33.4	1.97	270	321
Santa Fe Reservoir	ND	ND	ND	1059[a]
San Gabriel Reservoir	524.8	11.2	1453	560
San Dimas Reservoir	35.4	1.6	1463	36
Puddingstone Reservoir	243.8	5.0	939	253
Pacific Crest Reservoir	2.41	0.2	7898	
Morris Reservoir	283.4	6.7	1152	420
Laguna Lake	5.2	0.7		
Humble Reservoir	5.6	0.3		
Hoover Reservoir	1.7	0.1		1
Crystal Lake	6.7	0.4		
Colorado Lagoon	13.8	1.1		
Cogswell Reservoir	144.8	7.0	2385	146
Bouton Lake	9.9	1.2		
Big Dalton Reservoir	21.4	1.5	1706	26
Arnold Reservoir	10.3	0.6		
Anaheim Union Reservoir	9.2	0.6	346	
Anaheim Lake	72.1	2.0		

a : Area at top of the flood control pool

San Gabriel Reservoir - San Gabriel Dam - Morris Reservoir - Morris Dam

San Gabriel Dam (San Gabriel No.1 Dam), located within San Gabriel Canyon, drains an area of 202.7 mi^2 sitting behind San Gabriel Reservoir. It is operated as a combined unit with downstream Morris Dam, and all dam operations here have a direct impact on the condition and capabilities of Morris Reservoir. Right below the San Gabriel Dam, the Azusa Conduit (known formerly as the Southern California Edison Conduit) begins and delivers water to downstream users (CDM, 2005). Morris Dam, draining an area of 212 mi^2, is a concrete, partially-arched, gravity structure rising 245 ft above the original streambed (USACE, 1991) (Photo 5.2). Water flows below Morris Dam are highly variable, depending on season and scheduled water releases from San Gabriel Reservoir, Morris Dam and Upper San Gabriel No. 3 Reservoir. In addition, a MWD water discharge outlet located below Morris Dam delivers untreated, imported water from the California Aqueduct and Colorado River to downstream water users, including spreading and water reclamation facilities.

Photo 5.2 Morris Dam



Santa Fe Reservoir - Santa Fe Dam

Santa Fe Dam and Reservoir is a major flood control project constructed and operated by the U.S. Army Corps of Engineers, Los Angeles District. Construction of the project started in August 1941, but it was temporarily interrupted in 1943 in deference to military work. It provides flood protection for the densely populated area between the dam and Whittier Narrows Reservoir. Although it has no authorized storage allocation for water supply, its flood control operation provides incidental water conservation benefits to the San Gabriel Valley and other parts of the Los Angeles Basin (USACE, 1997). Flow from Santa Fe Dam does not, however, normally enter the Rio Hondo, except during spillway flow conditions, or by diversion through the Santa Fe Diversion Channel into the Buena Vista Channel, and then into the LACDPW Buena Vista or Peck Road spreading basins (See Chapter 4).

Whittier Narrows Dam - Whittier Narrows Basin

Whittier Narrows is a natural gap in the hills along the southern boundary of the San Gabriel Valley. The Whittier Narrows Dam was built in 1957 together with upstream flood control basins to provide water conservation and storage functions. The Rio Hondo (see Chapter 4) and San Gabriel Rivers flow through the Narrows and are impounded by the dam. It collects upstream runoff and releases from Santa Fe Dam. If the inflow to the reservoir exceeds the groundwater recharge capacity of the spreading grounds or the storage capacity of the water conservation or flood control pools, water is released into the San Gabriel River.

Puddingstone Reservoir – Puddingstone Dam

Puddingstone Dam was built in 1928 as a flood control reservoir for the Los Angeles basin, holding about 253 surface acres of water. It is located on Walnut Creek and owned by the Los Angeles County Department of Public Works. Currently it is used for flood control and water conservation purposes. It is also used for a wide variety of recreational purposes including fishing, boat races, summer swimming, and other aquatic activities.

Various water usages in the watershed have caused impairment of water quality listed in California 2002 Clean Water Act Section 303(d). The bodies affected include: Puddingstone Reservoir (243 acres); Santa Fe Dam Lake (20 acres); and Crystal Lake (3.7 acres) (California Regional Water Quality Control Board, Los Angeles Region, 2003).

5.4. Stream Flow and Annual Flood Dynamics

There are a total of 36 USGS gauging stations located in the watershed that monitor flow status. The County of Los Angeles Department of Public Works operates 16 stream stations (Table 5.4). Five stations are co-operated by USGS and LADPW. Mean annual daily flow, annual peak discharge, temporal trend significance tests, and flood magnitude estimates for various recurrence events are summarized in Table 5.5 for 31 stations that have flow records longer than 20 years. Mean annual daily discharges and annual flood peak discharges dynamics are examined at four stream gauge sites that are located in different land-

Table 5.4 Stream flow stations in San Gabriel River Watershed.

Station ID	Station Name	Drainage Area (mi²)	Elevation (ft)	Upstream Regulation	Flow Status	Flow Records From	To
Z7110090	SAN GABRIEL R A WHIT		235	Y		1998	2001
Z7192710	SAN GABRIEL R A AZUS		760			1998	2001
F190-R	SAN GABRIEL R at Foothill Blvd	230		Y		1932	To date
F250-R	AZUSA CONDUIT	203		Y		1933	To date
F261C-R	SAN GABRIEL R below Valley Blvd.	118		Y		1937	To date
F262C-R	SAN GABRIEL R above Florence Avenue	216		Y		1937	To date
F263C-R	SAN GABRIEL R below San Gabriel River Pkwy	206		Y		1937	To date
F274B-R	DALTON WASH at Merced Avenue	36	348	Y		1949	1995
F280-R	SANTA FE DIVERSION CHAN below Santa Fe Dam			Y		1942	To date
F304-R	WALNUT CREEK above Puente Avenue	58	340	Y		1952	To date
F329-R	BRADBURY CHANNEL below Central Avenue	3	515	Y		1957	To date
11075720	CARBON C BL CARBON CYN DAM CA	19.5				1961	To date
11075730	CARBON C A OLINDA CA	19.7				1930	1938
11075740	CARBON C NR YORBA LINDA CA	20.1	288.6			1950	1961
11078160	LIVE OAK C BL LIVE OAK DAM CA	ND	ND	ND	ND	ND	ND
11080000	EF SAN GABRIEL R A CAMP BONITA CA	58		Non		1927	1932
11080500	EF SAN GABRIEL R NR CAMP BONITA CA	85	1,567	Y		1932	1979
11080880	WF SAN GABRIEL R BL COGSWELL DAM CA	41	2,140	Y		1974	1975
11081000	BEAR C NR CAMP RINCON CA	28		Y		1929	1936
11081200	NF SAN GABRIEL R A COLDBROOK GUARD STATION	7		Non		1960	1973
11081500	NF SAN GABRIEL R A CAMP RINCON CA	19		Y		1929	1936
11082000	WF SAN GABRIEL R A CAMP RINCON CA	104	1,475	Y		1927	1978
11082800 a	SAN GABRIEL R A AZUSA PH CA					1906	1981
11083500/U8-R	SAN GABRIEL R NR AZUSA CA	214	868	Y		1893	To date
11084000	ROGERS C NR AZUSA CA	7	800	Non		1917	1962
11084500/U7-R	FISH C NR DUARTE CA	6	906	Non		1916	1979
11084950	SANTA FE DIV CHANNEL CA		420	Y		1973	1974
11085000	SAN GABRIEL R BL SANTA FE DAM NR BALDWIN PK	236	400	Y		1942	2006
11085019	SAN GABRIEL R BL VALLEY BLVD CA	ND	ND	ND	ND	ND	ND
11085560	PUDDINGSTONE C BL PUDDINGSTONE DAM NR SAN	32	830	Y		1974	1974
11086000	DALTON C NR GLENDORA CA	7	1,170	Non		1919	1962
11086300	SAN DIMAS C BL SAN DIMAS DAM CA	16		Non		1952	1978
11086400	SAN DIMAS C NR SAN DIMAS CA	18	1,240	Regulated		1916	1956
11086500	LITTLE DALTON C NR GLENDORA CA	3	1,334	Non		1914	1971
11086990/F312B-R	SAN JOSE C NR EL MONTE CA	88		Non		1955	To date
11087020	SAN GABRIEL R AB WHITTIER NARROWS DAM CA	442		Y		1955	2007
11087040	SAN GABRIEL R A WHITTIER NARROWS CA			Y		1966	1981
11087195/F312B-R 1.9 mil apart	SAN JOSE C NR WHITTIER CA	89	215	Non		1929	1964
11087500	SAN GABRIEL R A PICO CA	447	180	Y		1928	1978
11088000/F42B-R	SAN GABRIEL R A SPRING ST NR LOS ALAMITOS CA	472		Y		1928	To date
11088500	BREA C BL BREA DAM NR FULLERTON CA	22		Non		1942	2006
11089000	BREA C A FULLERTON CA	24	160	Y		1930	1969
11089500	FULLERTON C BL FULLERTON DAM NR BREA CA	5		Non		1941	2006
11090000	FULLERTON C A FULLERTON CA	8		Y		1935	1964
11090200	FULLERTON C A RICHMAN AVE AT FULLERTON CA	12		Y		1959	1981
11090500	COYOTE C A LOS ALAMITOS CA	120	20.2	N		1931	To date
11090700/F354-R	COYOTE C NR ARTESIA CA	150	ND	N		1963	1979

a : No flow data available at the site.

scapes of the watershed (Figure 5.6). These four sites are: (a) East Fork San Gabriel River near Camp Bonita at USGS 11080500; (b) San Gabriel River above Whittier Narrows Dam at USGS 11087020; (c) Coyote Creek at Los Alamitos at USGS 11090500/F354-R; and (d) San Gabriel River at Spring Street near the outlet at USGS 11088000/F42B-R.

Mean Annual Daily Discharge

Flow in the headwaters on the upstream of the East Fork of the San Gabriel River was free of regulation during the observation period from WY1935-1979 at the USGS 11080500 site. Over the gauging period, water ran year-round in the canyon creek and the annual mean daily discharge fluctuated (Figure 5.6a) with the precipitation regime. But no long term trend was observed at this site (Table 5.5).

Table 5.5 Mean annual daily discharge, temporal trend significance test, annual peak discharge, temporal trend significance test, and flood frequency and magnitude estimates.

STA_ID	Mean annual daily discharge (cfs)	Sig.(2-tailed)	Coefficient of variation	Avg. peak discharge (cfs)	PQ Sig.(2-tailed)
F190-R	126.7	0.003**	1.52	3879	0.865(-)
F250-R	40.5	0.935	0.482	91.1	0.646
F261C-R	98.3	0.293	1.33	7175.7	0.076
F262C-R	36.9	0.165(-)	1.954	4066.1	0.463(-)
F263C-R	75.1	0.002**	1.158	4715.7	0.823
F274B-R	28.5	0.000**	0.986	3146.9	0.000**
F280-R	13.4	0.068	1.2	259.5	0.618
F304-R	19.2	0.752	1.076	3006.5	0.001**
F329-R	1.2	0.000**	1.145	289.5	0.42
11075720	1.1	0.001**	1.766	184.3	0.045**
11080500	72	0.309(-)	0.966	3875.8	0.614(-)
11082000	70.4	0.994	1.146	4328.8	0.865
11083500/U8-R	117	0.099	1.407	4777	0.179(-)
11084000	2.8	0.291(-)	1.168	437.7	0.837(-)
11084500/U7-R	5.4	0.59	1.424	666	0.686
11085000	65.4	0.879	1.894	3053.6	0.685
11086000	1.1	0.551(-)	1.515	202.5	0.467(-)
11086300	6.3	0.248	1.51	350.8	0.982(-)
11086400	4.3	0.439(-)	1.109	391.6	0.157(-)
11086500	0.7	0.721(-)	1.274	143.7	0.61
11086990/F312B-R	43.8	0.000**	0.685	7145.5	0.000**
11087020	194.6	0.029**	1.026	17757.8	0.003**
11087195	8.6	0.371	0.97	2570.2	0.966(-)
11087500	68.2	0.000**	1.181	5307.5	0.128
11088000/F42B-R	70.3	0.000**	1.261	5047.7	0.056
11088500	4.7	0.000**	1.308	562.1	0.000**
11089000	1.4	0.681	1.467	473	0.183(-)
11089500	1.4	0.000**	1.077	179.6	0.000**
11090000	0.6	0.937	1.213	244.2	0.388(-)
11090200	2.9	0.000**	1.065	740	0.000**
11090500/F354-R [a]	37	0.000**	1.59	6295.6	0.000**

** Trend is significant at the 0.01 level (2-tailed).

Flow at site USGS 11087020 above the Whittier Dam is dominated by treated effluent from two nearby treatment plants, the San Jose WWTP and the Pomona WWTP.

Increasing effluent, derived from both reclaimed water and imported water, has caused the increasing stream flow discharge to the San Gabriel River (Sanitation Districts of Los Angeles County, 2006). The annual mean flow and the base flow have significantly increased over time, in particular, since the 1990s (Figure 5.6b).

Three gauging stations are located near the mouth of Coyote Creek to monitor the flow

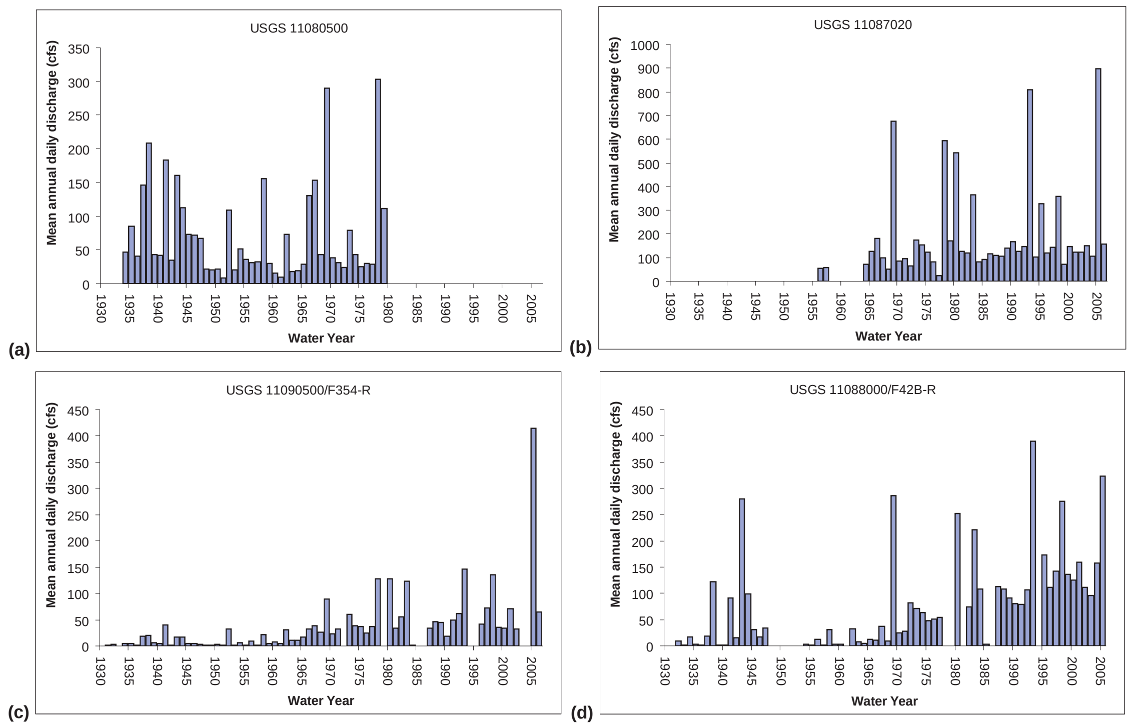


Figure 5.6 Mean annual daily discharges in: (a) East Fork San Gabriel River near Camp Bonita at USGS 11080500; (b) San Gabriel River above Whittier Narrows Dam at USGS 11087020; (c) Coyote Creek at Los Alamitos at USGS 11090500/F354-R; and (d) San Gabriel River at Spring Street near the outlet at USGS 11088000/F42B-R.

dynamics in this urban creek, F354-R, USGS 11090700, and 11090500. F354-R and USGS 11090700 gauged the flow status at the same site and the recorded data for WY1963-1979 were identical. USGS 11090500, located about 2.5 mi upstream from F354-R, measured historical flows during WY1931-63 for the same reach of the creek. The data from both sites are consolidated to form a single series to examine temporal variation.

Coyote Creek passes through a flat coastal alluvial plain with the entire drainage area dominated by residential and commercial development. Over the last several decades, the mean annual daily flow (Figure 5.6c) and the base flow in the tributaries of Coyote Creek have also significantly increased in response to the increasing percentage of impervious cover as documented in the literature (USACE, 1990b). Near the outlet of the San Gabriel River at USGS 11088000/F42B-R, the mean annual daily flow is 161.5 cfs (Figure 5.6d), doubling the mean flow in the headwater at USGS 11080500 after the river flows downstream about 50 miles in length.

Flood Dynamics

The gauge site USGS 11080500 at the headwater of the East Fork of the San Gabriel River

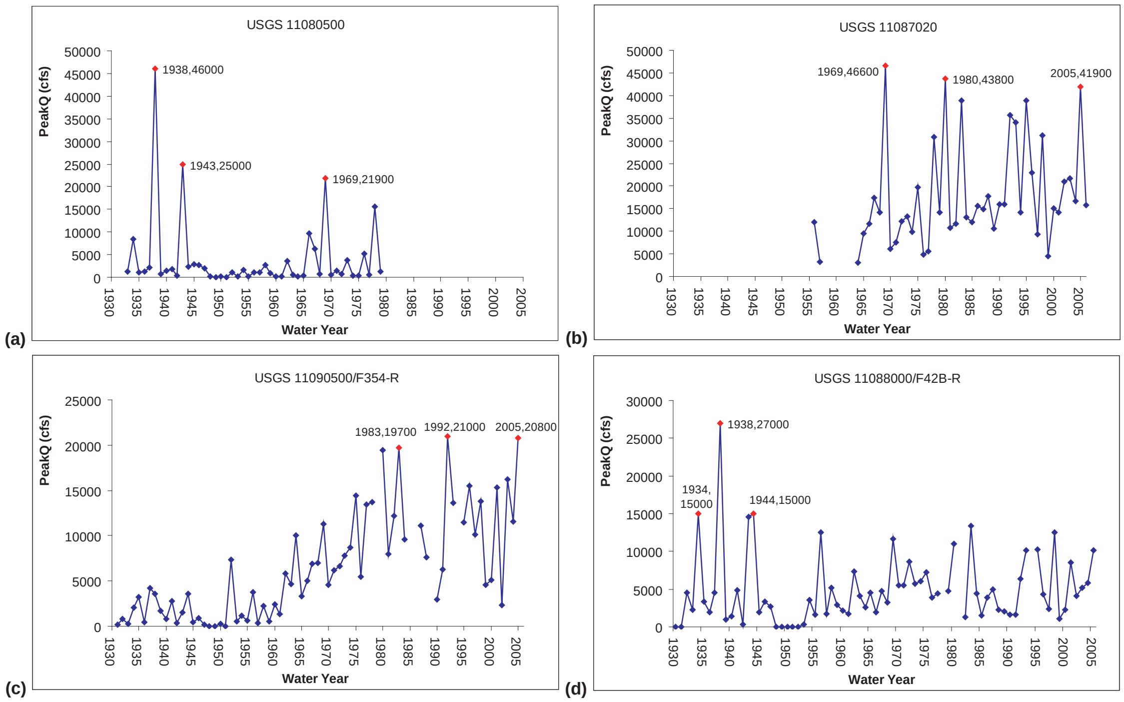


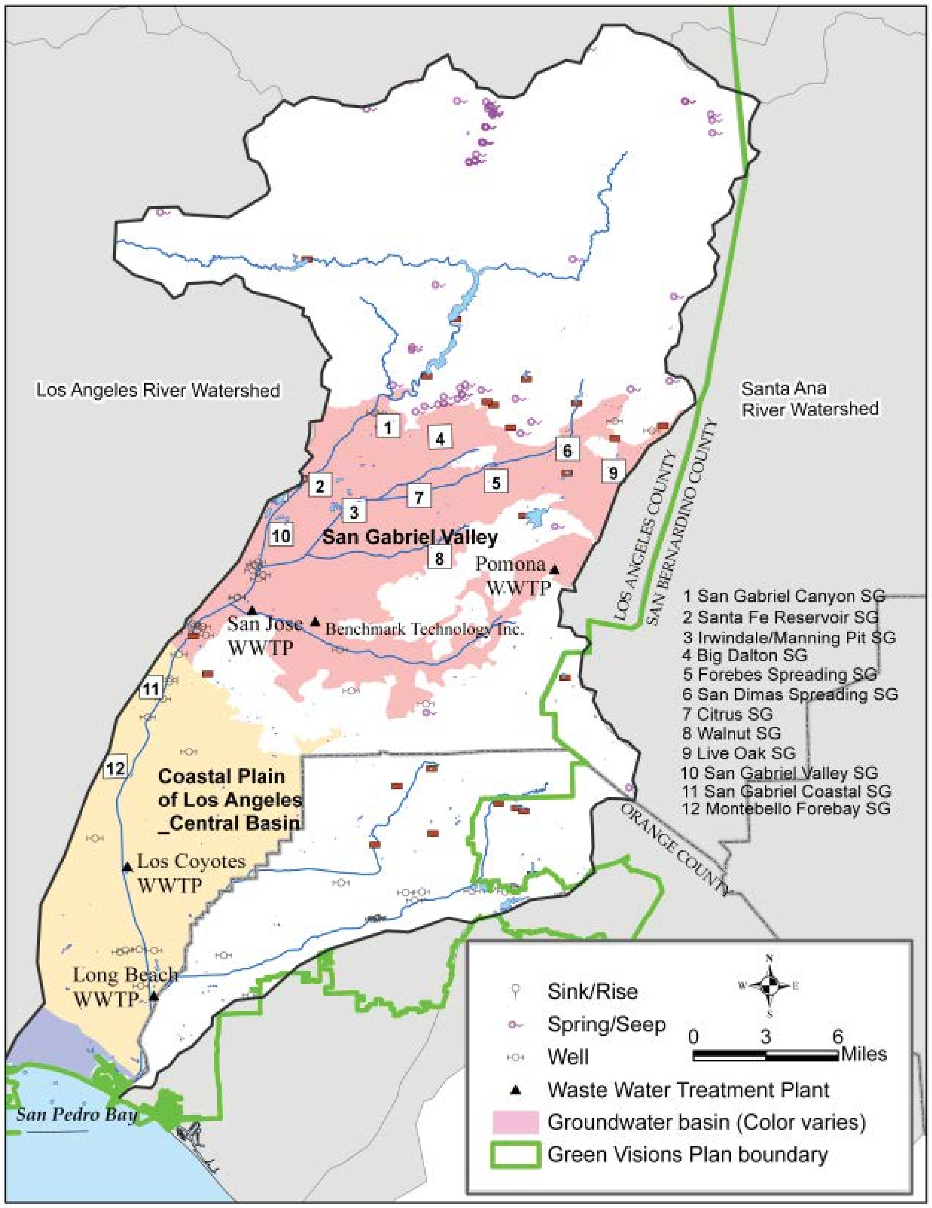
Figure 5.7 Mean annual daily discharges in: (a) East Fork San Gabriel River near Camp Bonita at USGS 11080500; (b) San Gabriel River above Whittier Narrows Dam at USGS 11087020; (c) Coyote Creek at Los Alamitos at USGS 11090500/F354-R; and (d) San Gabriel River at Spring Street near the outlet at USGS 11088000/F42B-R.

observed the largest recorded flood peak discharge of 46,000 cfs on March 02, 1938 after a four day storm (Figure 5.7a). During the event, a total amount of 15.6 inches of rainfall was recorded at the foothills of the San Gabriel Mountains by the headwaters of Big Dalton Wash. On the same day, the river near the outlet at USGS 11088000/F42B-R also recorded the largest recorded flood peak discharge of 27,000 cfs (Figure 5.7d). However, at the site of Coyote Creek at USGS 11090500/F354-R, the 1938 event turned out to be a relatively small event, ranked as a biannual flood event.

On January 25, 1969, the other massive flood hit the headwater site after a six day storm with a total of 32.5 inches rainfall recorded at Mt. Baldy and 23.2 inches along the foothills. On the same day, the largest recorded peak flood was reached at the site USGS 11087020 along the middle reach of the San Gabriel River (Figure 5.7b). However, the 1969 event was not recorded as one of the top three largest events at the downstream site USGS 11088000/F42B-R due to the dam regulation and water storage facilities constructed along the river (Figure 5.7d). Since then, no events larger than the 1938 flood were recorded at the outlet site. Due to the influence of urban development, the 1969 flood peak discharges were easily exceeded at the urban stream site USGS 11090500/F354-R, which has experienced significant increases in flood peak discharges in the past (Table 5.5). Treated water effluent to the middle reach of the San Gabriel River has also augmented flood peak discharge at the site USGS 11087020 and an increasing trend is shown in Figure 5.7c.

There are six more sites that have experienced increases in flood peak discharge other than the aforementioned two sites (Table 5.5). All of these gage sites are located in urban landscapes along Dalton Wash, Walnut Creek, Carbon Creek below Carbon Canyon, San Jose Creek, Brea Creek, and Fullerton Creek. For example, USGS 11088500 monitors the Brea Creek, which passes through a highly urbanized watershed and drains mostly densely urbanized residential, commercial and industrial lands. Research by USACE (1990b) showed an increase in peak annual discharge with increases of percent impervious cover the past 40 years.

Figure 5.8 Groundwater basins, waste water treatment plants, and spreading grounds



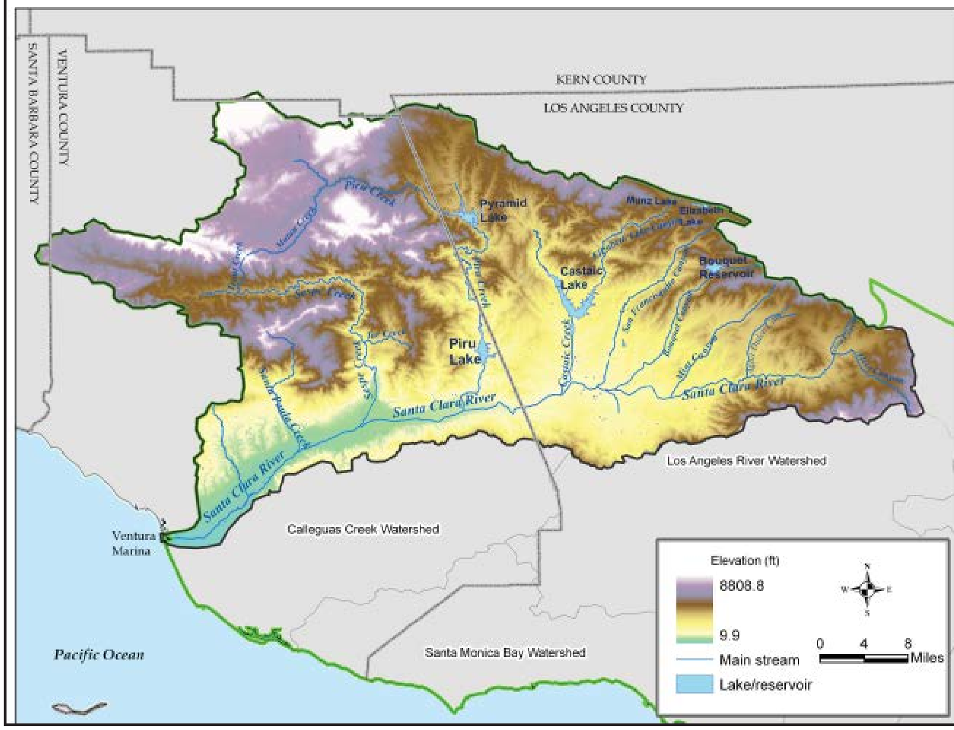
5.5. Groundwater Recharge and Extraction

Two groundwater basins - San Gabriel Valley and "Central Basin" - underlie Los Angeles River and San Gabriel River Watershed (Figure 5.8). Groundwater is recharged and extracted bythe "double" watershed hydrologic system. "Central Basin" was described in Chapter 4 and this chapter will discuss San Gabriel Groundwater Basin since a larger portion of San Gabriel Groundwater Basin is contained in the San Gabriel River watershed. The storage capacity of the basin was estimated to be 10,438,000 af by DWR (1975) and the usable storage within the operation range is 8,600,000 af. Recharge of the basin is mainly from direct percolation of precipitation and percolation of stream flow. Stream flow is a combination of runoff from the surrounding mountains, imported water conveyed in the San Gabriel River to spreading grounds, and treated sewage effluent (DWR, 2004). Various spreading grounds operated by LADPW along the Rio Hondo and San Gabriel River and its tributaries are key resources for groundwater recharge activities (with tributaries including namely Rio Hondo, Peck Road, Buena Vista, Sawpit Santa Anita as discussed in Chapter 4, Figure 4.8; and Forbes, San Gabriel Coastal, San Dimas, Santa Fe, and Walnut, shown in Figure 5.8). The Rio Hondo spreading grounds are located south of the Whittier Narrows, the largest and most productive spreading grounds in Los Angeles County. Flow from the Rio Hondo is kept at a minimum due to its recharge purpose and is only expected to reach the Los Angeles River during rain events when the spreading facilities are bypassed or when flows exceed recharge capacities.

Most notably, the San Gabriel Basin contains substantial contaminated plumes of volatile organic compounds (VOCs) due to past disposal of industrial solvents related to the aerospace and other manufacturing uses, as well as other pollutants resulting from past agricultural land use practices (MIG and CDM, 2005). Primary contaminants in the basin are trichloroethylene, perchloroethylene, and carbon tetrachloride, with the plume mainly running along the axis of the Rio Hondo Wash (4 miles) in El Monte, San Gabriel River (7.5 mi) in Baldwin Park, Alhambra Creek (2 mi) in Alhambra, and San Jose Creek (1 mi) in La Puente. Four Superfund sites were designated by the Federal EPA in these places. At these sites, contaminated groundwater is being treated to remove the contaminants to prevent the polluted water from migrating southward to the Central Basin. Due to various contaminations, ability to store and extract water is limited to the basin (MWD, 2007).

6.1. Drainage System and Stream Classification

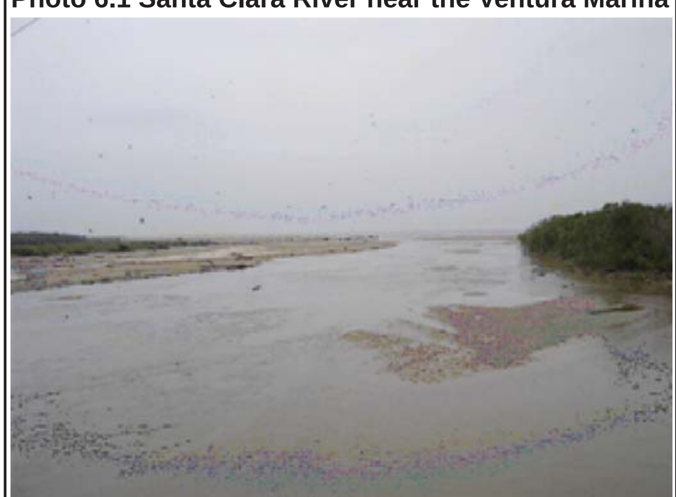
Figure 6.1 Santa Clara River Watershed topographic map



The Santa Clara River watershed is the largest watershed in southern California remaining in a relatively pristine state. The Santa Clara River and its tributaries drain an area of 1,617 mi^2 (NHD, 1999). Approximately 40% of the watershed is located in Los Angeles County and 60% in Ventura County. The Santa Clara River headwaters are located in the Angeles National Forest southeast of the community of Acton. The highest elevation in the headwaters reaches 6,600 ft in the rugged mountains of Los Padres National Forest (Figure 6.1). The river flows in a westerly direction for approximately 84 mi and discharges to the Pacific Ocean near the Ventura Marina (Photo 6.1).

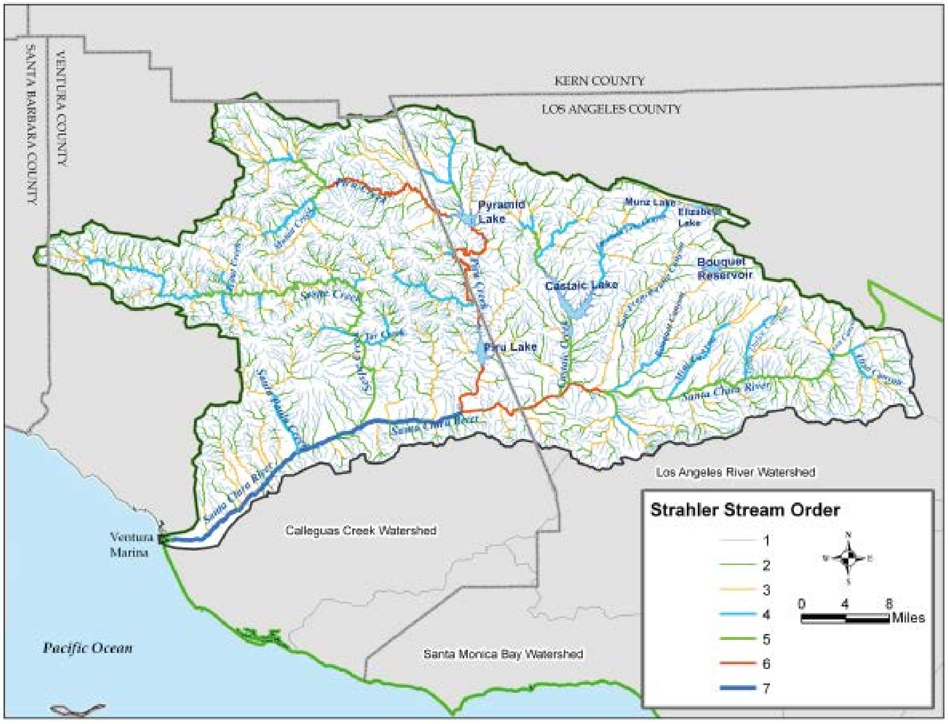
The major tributaries include Castaic Creek and San Francisquito Creek in Los Angeles County, and Sespe Creek, Piru Creek, and Santa Paula Creek in Ventura County. A total length of 4,024.5 miles of stream network wass reported in 1999 NHD. The average channel elevation of the drainage system is 2,311 ft, much higher than those of the other four HUC watersheds. The entire channel system consists of seven classes of streams according to the Strahler stream order classification system (Figure 6.2).

Photo 6.1 Santa Clara River near the Ventura Marina



Topographic relief in the 1st order headwaters is significant, with the majority of headwaters covered by steep sided canyons and ridges with a mean channel gradient of 17.3%, much steeper than the average of 5.1% (Table 6.1). A dense stream system develops along the 1st and 2nd stream

Figure 6.2 Santa Clara River tributaries classified by Strahler stream order



catchment with a density of 2.7 mi/mi^2, which signifies a quick hydrologic response of the surface runoff to rainfall in the headwaters.

Castaic Creek, Sespe Creek and the Upper Santa Clara River mainly constitute the 5th order streams. Most of Castaic Creek has been cut off by the construction of Castaic Dam. Flows run in a natural undisturbed creek. Sespe Creek, starting from its confluence with Rock Creek downstream to its confluence with the Santa Clara River, is classified as a 5th order stream. Sespe Creek is the only stream in southern California designated as a California Wild and Scenic River (67 Federal Register 43: 9953, 2002). A length of four miles along the reach between the confluences of Sespe Creek with Rock Creek and Trout Creek is administered by the California Secretary of Agriculture as a scenic river; and the 27.4-mile segment downstream to the confluence with Santa Clara River is designated as a Wild River (Photo 6.2). It supports many riparian dependent species that are not found in abundance elsewhere on the southern or central coast of California (USDA, 2003). Piru Creek (6th order) and the lower portion of the Santa Clara River (7th order) consist of a relatively low-gradient, broad alluvial valley surrounded by agricultural land use (Photo 6.3).

Even though a majority of the streams remain natural and intact, quite a few are impaired by various sources of urban runoff, and nonpoint agricultural discharge, especially the major stream reaches near the cities joining the Santa Clara River's main course. Some stream reaches are listed in California 2002 Clean Water Act Section 303(d) for TMDL water quality enhancement, including Aliso Canyon (10 mi), Mint Canyon

Table 6.1 Basic characteristics of drainage system in Santa Clara River watershed

Strahler stream order	Segments	Bifurcation ratio	channel elevation	Mean channel slope (%)	Stream length (mi)	Drainage area (mi^2)
1	2981	5.2	3294.7	17.3	2490.3	916.7
2	576	4.1	3050.4	7.8	771	299.3
3	139	4.3	2774.8	4	418.8	179.8
4	32	4.6	2783.4	2.9	147.8	76
5	7	3.5	2134.6	1.6	98.5	74.9
6	2	2	1835.8	1.5	65.4	43.3
7	1	-	305	0.4	32.7	27

Photo 6.2 Sespe Creek near Grand Ave, Ventura County

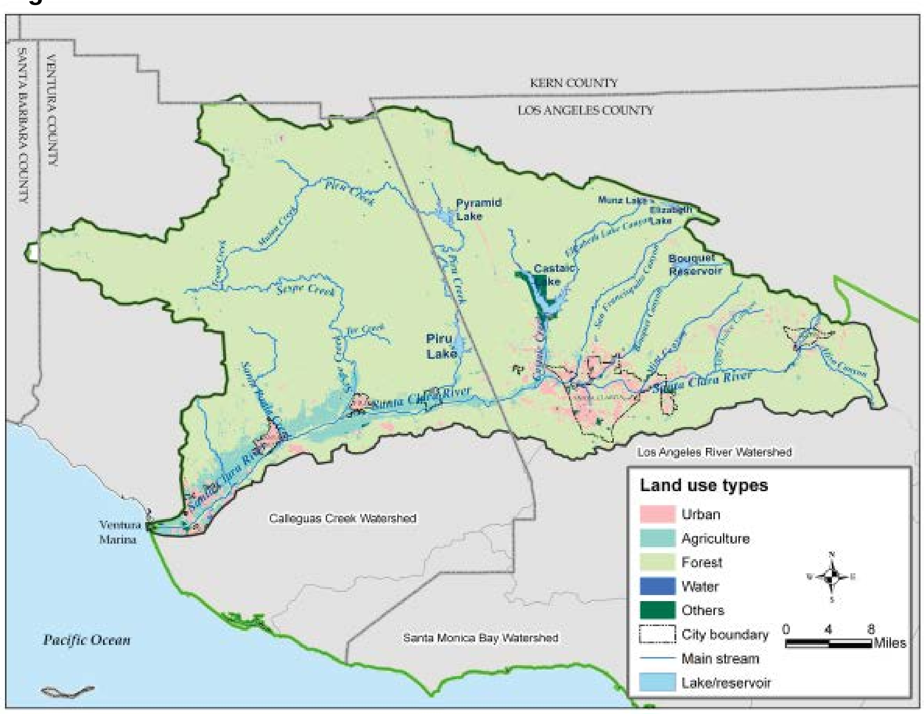
Photo 6.3 Santa Clara River near the Los Angeles-Ventura County line

(8.1 mi), Long Canyon (2.6 mi), Hopper Creek (13 mi), Piru Creek (63 mi), Sespe Creek (63 mi) and Santa Clara River (66.5 mi)(California Regional Water Quality Control Board, 2003).

6.2. Watershed Classification

The Santa Clara River watershed is largely intact and unaffected by development. Agriculture – farming and raising livestock – did not start until 1870s (AMEC Earth & Environmental, 2005). Euro-American immigrants arrived, established large-scale agriculture, and began controlling the river, tributary streams, and groundwater. From 1920 to the present day, as the population of Ventura and Los Angeles Counties has expanded numerically and geographically, urban development has encroached upon the floodplain (AMEC Earth & Environmental, 2005). As of 2001, however, developed and/or urbanized areas made up only 10.1% of the total watershed area, mainly along the Santa Clarita Valley and the floors of the upper Santa Clara

Figure 6.3 Land uses in Santa Clara River Watershed



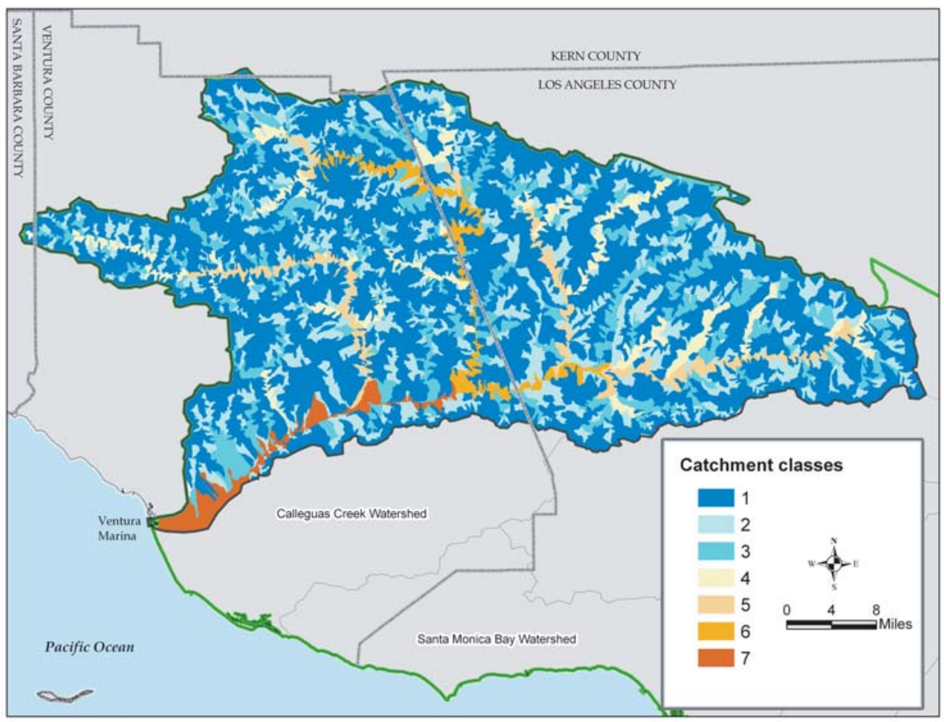
River Valley (Figure 6.3). The most prevalent land use is forest and open space covering 78.4% of the watershed (Table 6.2). Agriculture comprises 8.7% of the land use in the watershed.

The watershed is classified into seven classes indexed by the Strahler stream order of each catchment (Figure 6.4). The catchments along the main river support a number of cities and communities. In past years, the floodplain has been constrained and degraded by private levees, mining, and water facilities, reduced from its former vast extent. Some large, rustic rural estates together with abundant trees and surviving native vegetation, protected from grading, are located along the upper reach of the Santa Clara River and 4th order streams like Aliso Canyon, Acton Canyon and Agua Dulce Canyon.

Table 6.2 Watershed classifications and their major characteristics

Catchment classes	Mean catchment elevation (ft)	Mean catchment slope (%)	Urban (%)	Agriculture (%)	Vacant (Forest) (%)	Water (%)	Others
1	3379.1	37.2	4.8	2.6	92	0.2	0.4
2	3030.1	34.4	6.1	3.5	89.6	0.3	0.6
3	2708.6	31	7.6	6.8	84.2	0.9	0.6
4	2776.5	31	10.6	3.4	83.3	1.6	1
5	2174.3	29.5	8.8	3.6	80.5	3.4	3.8
6	2139.2	35.4	8.6	7.6	80.3	3	0.5
7	275.8	4.9	24.3	33.6	38.9	0.7	2.4
Average	2354.8	29.1	10.1	8.7	78.4	1.5	1.3

Figure 6.4 Santa Clara River Watershed classified by Strahler stream order



6.3. Dams, Lakes, Reservoirs, and Debris Basins

Although the Santa Clara River remains primarily in a natural physical state, the flow regime within the watershed is highly engineered to optimize delivery schedules and aquifer recharge. There are four major lakes/reservoirs within the system, namely Castaic Lake, Lake Piru, Pyramid Lake, and Bouquet Reservoir (Figure 6.5). Table 6.3 lists all lakes/reservoirs labeled in the NHD datasets.

Bouquet Reservoir

The reservoir was completed in 1934, and has a storage capacity of approximately 36,500 acre-feet with a drainage area of 13.6 mi^2. It is owned by the Los Angeles City Department of Water and Power (LADWP) and is primarily used to provide storage for the water transported from the San Andreas Fault through the Los Angeles Aqueduct as well as water from peak hydroelectric power generation at San Francisquito Power Plants.

Figure 6.5 Dams, debris basins, and lakes/reservoirs

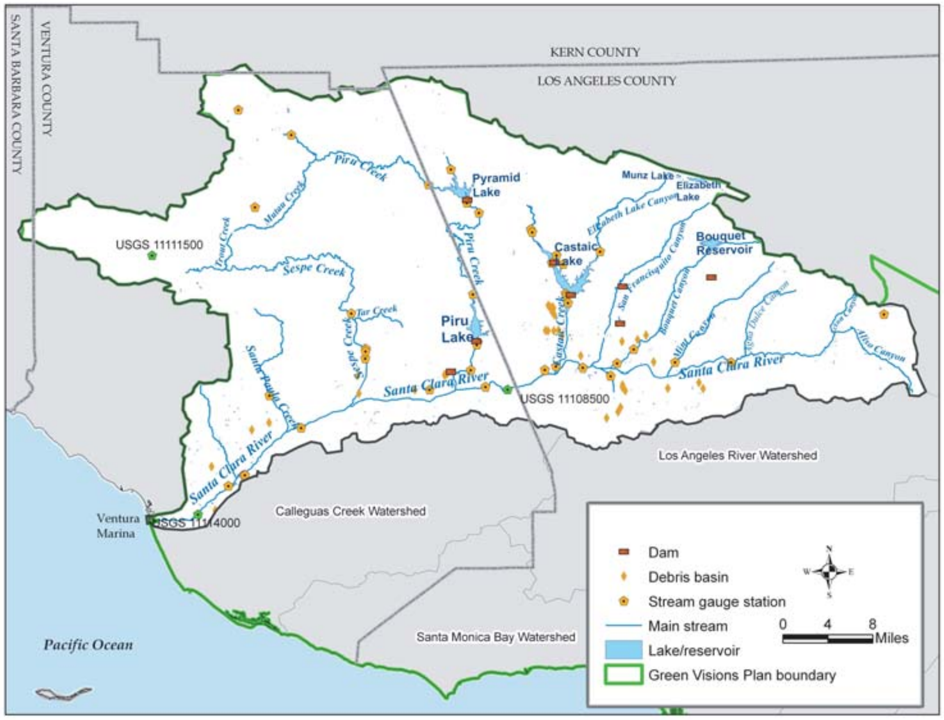


Table 6.3 Named lakes/reservoirs in Santa Clara River watershed

Name	Contributing streams	Area (acres)
Bouquet Reservoir	Bouquet Canyon, Martindale Canyon, Spunky Canyon and 3 unnamed streams	590.1
Elizabeth Lake	Unnamed tributaries and 2 unnamed streams	220.6
Castaic Lagoon	Castaic Creek and 3 unnamed streams	189.5
Castaic Lake	Elizabeth Lake Canyon, Castaic Creek, Elderberry Canyon, Necktie Canyon, Dry Gulch and 8 unnamed streams	2,230.5
Dry Canyon Reservoir	Dry Canyon	46.4
Drinkwater Reservoir	Drinkwater Canyon	3.0
Elderberry Forebay	Elderberry Canyon, Castaic Creek and 7 unnamed streams	381.9
Hughes Lake	Unnamed tributaries	21.8
Lake Piru	Reasoner Canyon, Piru Creek, Canton Canyon, Devil Canyon, Santa Felicia Canyon, Oak Canyon, and 15 unnamed streams	1,220.6
Lower Rose lake	Rose Valley Creek	6.4
Munz Lakes (3 parts)	Munz Canyon and 2 unnamed streams	11.0
Pyramid Lake	Piru Creek, Beartrap Canyon, Posey Canyon, Apple Canyon, Gorman Creek, West Fork Liebre Gulch and 7 unnamed streams	1,177.0
Upper Rose lake	Rose Valley Creek streams	1.8

Castaic Lake - Castaic Lagoon - Elderberry Forebay - Castaic Dam

Castaic Lake is the largest lake that has two bodies of water and provides opportunities for recreation such as sailing, water skiing, power boating, and fishing. The lake is created by an earthfill dam across Castaic Creek. The reservoir also serves as the West Branch Terminus of the California Aqueduct. In addition to water storage functions, storm flows are regulated so that the lake is operated to conserve local storm water that would otherwise be discharged into the Pacific Ocean. This is accomplished by limiting flows to levels where instream flows can be readily percolated into the underlying groundwater basins (EIP Associates, 2004). Castaic Lagoon (Photo 6.4) is located directly south and downstream of Castaic Dam. The lagoon provides recreational opportunities. The Elderberry

Photo 6.4 Castaic Reservoir, Ventura County

Forebay is part of the Castaic Reservoir System. It is an enclosed section of the northwest arm of Castaic Lake.

Pyramid Lake - Pyramid Dam - Lake Piru - Santa Felicia Dam

Pyramid Lake is located on Piru Creek. It stores winter runoff from the upper reaches of Piru Creek. Pyramid Lake/ Pyramid Dam and Castaic Reservoir are part of the State Water Project (SWP) system and are operated by the California Department of Water Resources. The two lakes are hydraulically connected. State water is sent through the William E. Warne Power plant into Pyramid Lake, through the Angeles Tunnel into the Castaic Power Plant, and then into Castaic Lake. Since the construction of Santa Felicia Dam in 1955, water from Pyramid Lake and upper reaches of Piru Creek has been captured and stored in Lake Piru. These controlled seasonal releases from Lake Piru provide percolation into downstream groundwater basins of the Santa Clara River and Coastal Plain.

Various patterns of water usages in the watershed have impaired the water quality of particular bodies, including Elizabeth Lake (123 acres), Lake Hughes (21 acres), and Munz Lake (6.6 acres) (California Regional Water Quality Control Board, Los Angeles Region, 2003).

6.4. Stream Flow and Annual Flood Dynamics

There are a total of 59 stream gauge stations located within the watershed that record historic and/or current stream flow data, of which 15 stations are co-op sites by USGS and Ventura County Watershed Protection District (VCWPD) (Table 6.4). Most of these stations were installed by the USGS. At various junctures, the USGS stopped reviewing and publishing the record for these sites. The VCWPD took over operation and continued to publish the records.

Some sites were removed and re-estimated in the adjacent area. The site names were changed accordingly by adding suffix of A, B, C or D to the site name. The hydrologic conditions monitored at the relocated sites were not necessary the same depending on the location along the reach. The Los Angeles County Department of Public Works (LADPW) operated three sites in the watershed (Table 6.4). Mean annual daily flow, annual peak discharge, temporal trend tests, and flood magnitude estimates for various recurrence events are summarized in Table 6.5 for 17 stations that have flow records longer than 20 years.

Mean annual daily flow and annual peak flood flow variations over time are shown in Figures 6.6 and 6.7 for the stations that are located at different landscapes of the watershed: (1) in the

Table 6.4 Stream gauge stations in Santa Clara River Watershed

Station ID	Station Name	Drainage Area (mi²)	Elevation (ft)	Upstream Regulation	Flow Status	Flow Records From	To
CA002000	CA002000		1515	Y		1997	To date
PY003000	PY003000		2578	Y		1998	1998
Z2130000	SANTA PAULA C NR SAN		440	Non		1998	2000
Z2136010	SANTA CLARA R NR SAN		270	Y		1998	2000
Z2170200	SANTA CLARA R A HWY		1050	Y		1998	2000
Z2215000	SESPE C NR FILLMORE		570	Y		1998	2000
Z2324000	PIRU C BL SANTA FELI		870	Y		1998	2000
LADPW F328-R	MINT CANYON CREEK AT FITCH AVENUE	27		Non	E	1956	To date
LADPW F377-R	BOUQUET CANYON CREEK at Urbandale Avenue	52		Non		1967	To date
VCWPD664	Station Canyon Creek abv Lake Casitas	ND	ND	ND	ND	1979	1990
VCWPD720	Santa Clara River at 12th Street	ND	ND	ND	ND	2004	2006
VCWPD781	Santa Clara Drain	ND	ND	ND	ND	1995	2005
11107700	SOLEDAD CYN TRIB NR ACTON CA	4		Non		1960	1973
11107745	SANTA CLARA R AB RR STATION NR LANG CA	157	1790	Non	P/E	1949	2005
11107770	MINT CYN C A SIERRA HWY NR SAUGUS CA	28	1540	Y		2001	2005
11107860	BOUQUET C NR SAUGUS CA	52	1305	Non		1970	2003 e
11107870	BOUQUET C BL HASKELL CYN C NR SAUGUS CA	61	1185	Y		2003	2005
11107922	SF SANTA CLARA R A SAUGUS CA	43		Non		1975	1977
11108000/F92-R	SANTA CLARA R NR SAUGUS CA	411	1046	Non	E/P	1929	2005 [a]
11108075	CASTAIC C AB FISH C NR CASTAIC CA	37	1640	Non		1976	1993 d
11108080	FISH C AB CASTAIC C NR CASTAIC CA	27		Non		1965	1993 f
11108090	ELDERBERRY CYN C AB CASTAIC C NR CASTAIC CA	3		Non		1977	1993 f
11108092	ELDERBERRY FOREBAY NR CASTAIC CA	76	1400	Y		2004	2005
11108095	NECKTIE CYN C AB CASTAIC C NR CASTAIC CA	2		Non		1976	1993 f
11108130	ELIZABETH LK CYN C ab Castaic Lk nr Castaic, CA	44		Non		1976	1993 g
11108133	CASTAIC LK NR CASTAIC CA	137	1520	Y	ND	ND	ND
11108134	CASTAIC C BLW MWD DIV blw Castaic Lk nr Castaic	138	1240	Y		1994	2006
11108135	CASTAIC LAGOON PARSHALL FL NR CASTAIC CA	138		Y		1976	1996 h
11108145	CASTAIC C NR SAUGUS CA	184	952		E	1946	1976
11108200	SANTA CLARA TRIB NR VAL VERDE CA	1		Non		1960	1973
11108500/707	SANTA CLARA RIVER AT L.A.-VENTURA CO. LINE CA	625	795	N/Y	E/P	1952	1997
11109000/707A	SANTA CLARA R NR PIRU CA	645	710	Y		1927	2006 [b]
11109100/704	PIRU C BL THORN MEADOWS NR STAUFFER CA	23		Non		1971	1978
11109200/703	MF LOCKWOOD C NR STAUFFER CA	6		Non		1971	1978
11109250/702	LOCKWOOD C A GORGE NR STAUFFER CA	59		Non		1971	1981
11109375/716	PIRU C BL BUCK C NR PYRAMID LK CA	198		Non	P	1976	2003 [c]
11109398	WB CA AQUADUCT A William Warne PP nr Gorman, CA		2582	Non		1995	2006
11109520	PYRAMID LK NR GORMAN CA	295	2200	Non			
11109525	PIRU C BL PYRAMID LK NR GORMAN CA	295	2200	Y		1988	To date i
11109550	PIRU C AB FRENCHMANS FLAT CA	308	2140	Y		1976	1977 j
11109600/705/705A	PIRU CREEK ABOVE LAKE PIRU CA	372	1059	Y	E/P	1955	To date
11109700	LK PIRU NR PIRU CA	425		Y			
11109800/714	PIRU CREEK BELOW SANTA FELICIA DAM CA	425		Y	E	1955	To date
11109801	COMBINED FLOW PIRU C bl Santa Felicia Dam + Spill			Y		1997	1998
11110000/706	PIRU C NR PIRU CA	437		Non	E/P	1912	1974
11110500/701	HOPPER CREEK NEAR PIRU CA	24	590	Non	E	1930	To date
11111500/711	SESPE CREEK NEAR WHEELER SPRINGS CA	50	3501	Non	P	1947	To date
11112000	SESPE C NR SESPE CA	210	1350	Non		1916	1926
11112500	FILLMORE IRR CO CN NR FILLMORE CA		680	Y		1939	1993 j
11113000/710A,B,C, D	SESPE C NR FILLMORE	251	565	Non	E/P	1911	To date
11113001	SESPE C + FILLMORE IRR CO CN NR FILLMORE CA	251		Non	P	1939	1993 j
11113300	SANTA CLARA R NR SANTA PAULA CA			Y		1966	1996 k
11113500/709/709A	SANTA PAULA C NR SANTA PAULA	38	619	Non	P	1927	To date
11113900	SATICOY DIV NR SATICOY			Y		1969	1987
11113910/724	SANTA CLARA R A DIV NR SATICOY CA	ND	ND	ND	Nd	2005	2005
11113920	SANTA CLARA R A SATICOY CA	1577	120	Y		1995	1999
11114000/708/708A	SANTA CLARA RIVER AT MONTALVO CA	1594		Y	E	1927	2004
11117000	SAN ANTONIO C NR OJAI CA	34		Non		1927	1932

headwater at the Sespe Creek near Wheeler Springs station (USGS 11111500/711), (2) the Santa Clara River at LA-Ventura County station where Mint Canyon joins the Santa Clara River's middle reach (USGS 11108500/707), and (3) near the watershed outlet at the Montalvo station (USGS 11114000708/708A).

Table 6.5 Mean annual daily discharge statistics, annual flood peaks, and flood frequency and magnitudes for selected gauge stations

Station ID	Mean annual daily discharge (cfs)	Sig.(2-tailed)	Coefficient of variation	Average peak discharge (cfs)	Sig.(2-tailed)
F328-R	0.5	0.062	1.69	318.2	0.064(-)
F377-R	1.3	0.454(-)	1.36	456.0	0.225(-)
11107745	3.9	0.063(-)	1.48	868.2	0.043**
11108000/F92-R	16.2	0.019**	1.56	4293.6	0.147
11108145	11.5	0.049**	2.28	1869.8	0.309
11108500/707	54.7	0.000**	1.21	7639.8	0.009**
11109375	52.5	0.680(-)	1.11	NA	NA
11109600/705/705A	64.3	0.082	1.04	6222.2	0.575(-)
11109800/714	51.0	0.058	0.69	360.6	0.004**
11110000/706	63.2	0.816	1.11	4969.3	0.002(-)**
11110500/701	6.2	0.586	1.31	1712.0	0.736
11111500/711	17.4	0.003**	1.45	2094.4	0.213
11112500	4.9	0.001(-)**	0.33	ND	ND
11113000/710A,B,C, D	134.2	0.168	1.23	18951.0	0.482
11113001	122.4	0.542	1.23	ND	ND
11113500/709/709A	25.9	0.344	1.27	3384.7	0.831
11114000/708/708A	176.9	0.058	1.69	29217.7	0.623

Mean annual daily discharge

The Sespe Creek headwaters have been monitored by USGS 11111500/711 since WY1947 until the present date. Flows in the entire creek are undisturbed, free-flowing, and year-round without diversions or impoundments. A significant increasing trend is detected with the annual flow and the base flow in the creek (Figure 6.6a); however, a significant decrease in precipitation has occurred during the observation period in the adjacent weather stations. The water balance in this portion of the watershed must have experienced a large change, a situation that requires addition research. At the confluence of the middle Santa Clara River with Mint Canyon at the LA-Ventura County Line station, an increasing trend is also detected from WY1953 to 1996 due to the discharge of effluent from the Saugus Water Reclamation Plant (SWRP) and Valencia Water Reclamation Plant (VWRP) (Los Angeles County Sanitation Districts, 1997). These two water plants account for up to 40% of total stream flow during the winter and 90% during summer months (EIP Associates, 2004). As of 2000, the permitted treatment capacity for these two plants is 100 million AF per day. There are planned expansions for local sewer treatment plants due to the increased demands from the adjacent communities.

The mean annual daily flow reaches 176.9 cfs near the outlet (Figure 6.6c), 11 times larger than observed at USGS 11111500/711. Under the flow regulation of dams and diversion facilities, no long term trend is observed at the outlet station. Significant increases in the mean annual daily flow are also observed at several other stream stations: Castaic Creek near Saugus, CA (USGS 11108145), USGS 11112500 near Fillmore, CA, and Santa Clara River (USGS11108000/F92-R). All these sites are located near cities and the reaches of the streams receive water from urban areas.

Flood Dynamics

Floods along the lower Santa Clara River are potentially severe based on the past records (AMEC Earth & Environmental, 2005). Historically, floods caused bank erosion and damages

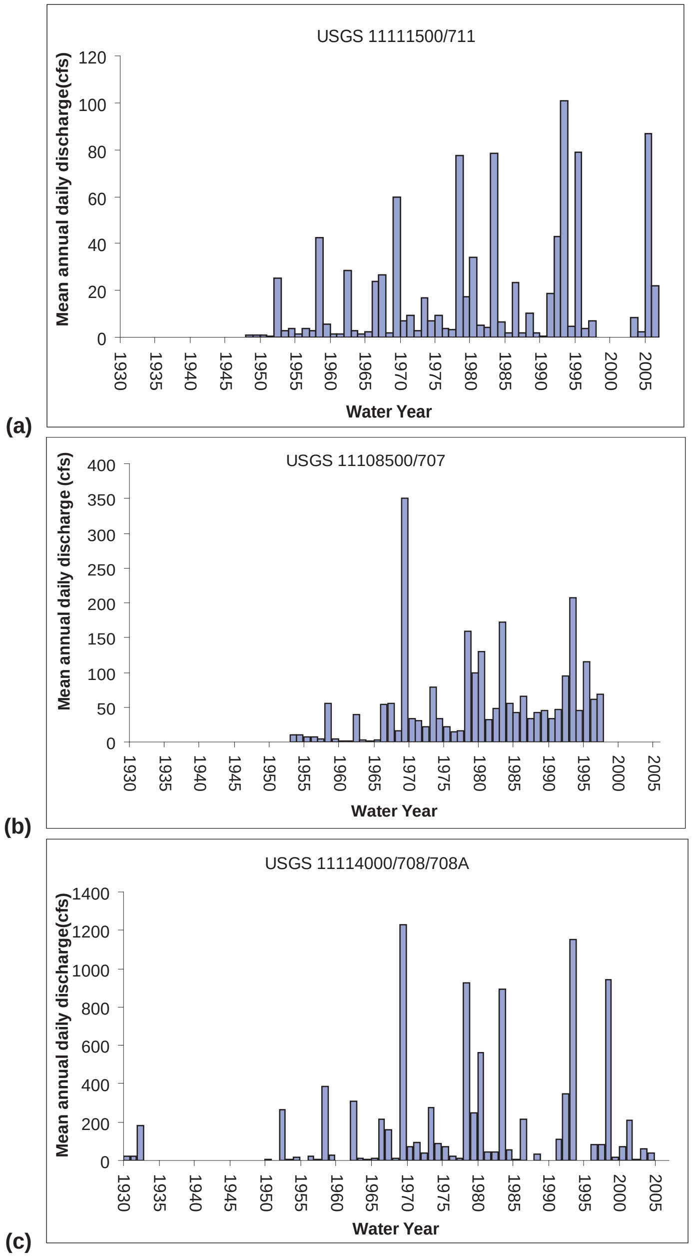


Figure 6.6 Mean annual daily flow: (a) (a) in the headwater at Sespe Creek near Wheeler Springs station (USGS 11111500/717), (b) at the confluence of the Santa Clara River with Mint Canyon at middle at SANTA CLARA RIVER AT L.A.-VENTURA CO. LINE CA station (USGS 11108500/707); and (c) near the outlet at the Montalvo station (USGS 11114000/708/708A).

to railroad bridges along the river, irrigation systems, and other infrastructure. Therefore, the banks are reinforced with groins and levees along much of the lower river located within the Santa Paula and the Oxnard Plain. The first public flood protection levee was constructed by USACE/VCWPD in 1961 (AMEC Earth & Environmental, 2005).

Flood risks caused by extreme events vary over time and across space. The annual flood peak discharge increases 13 times from 2,202 cfs in the Sespe Creek headwaters to 28,241 cfs at the river outlet near the ocean. Unlike the increasing trends in the mean annual flow and baseflow in the Sespe Creek headwaters, flood peak discharges remain stationary over time in the headwaters (Figure 6.7a). But a long term increasing trend is apparent with flood peak discharge at the LA-Ventura County Line station, partially linked to rapid urban growth and land use conversion, as mentioned above (Figure 6.7b).

Near the river outlet, the worst flood event recorded occurred in January and February 1969, producing an estimated peak discharge of 165,000 (estimated 50-year flood) (Figure 6.7c). During the two consecutive floods, multiple sections of freeway were closed for certain days. Bridges were washed out or destroyed and agricultural lands incurred extensive damage. During the peak of the 1969 flood, the Ventura Marina was inundated by a large overflow from the Santa Clara River and this recreational attraction was filled with sand and silt that had washed downstream. As a consequence of the frequent flooding, the banks are now reinforced with groins and levees along much of the lower river (Flood Protection Subcommittee, 1996). Under flow regulation and diversion, flood peak discharges have been stable over the time period for which data

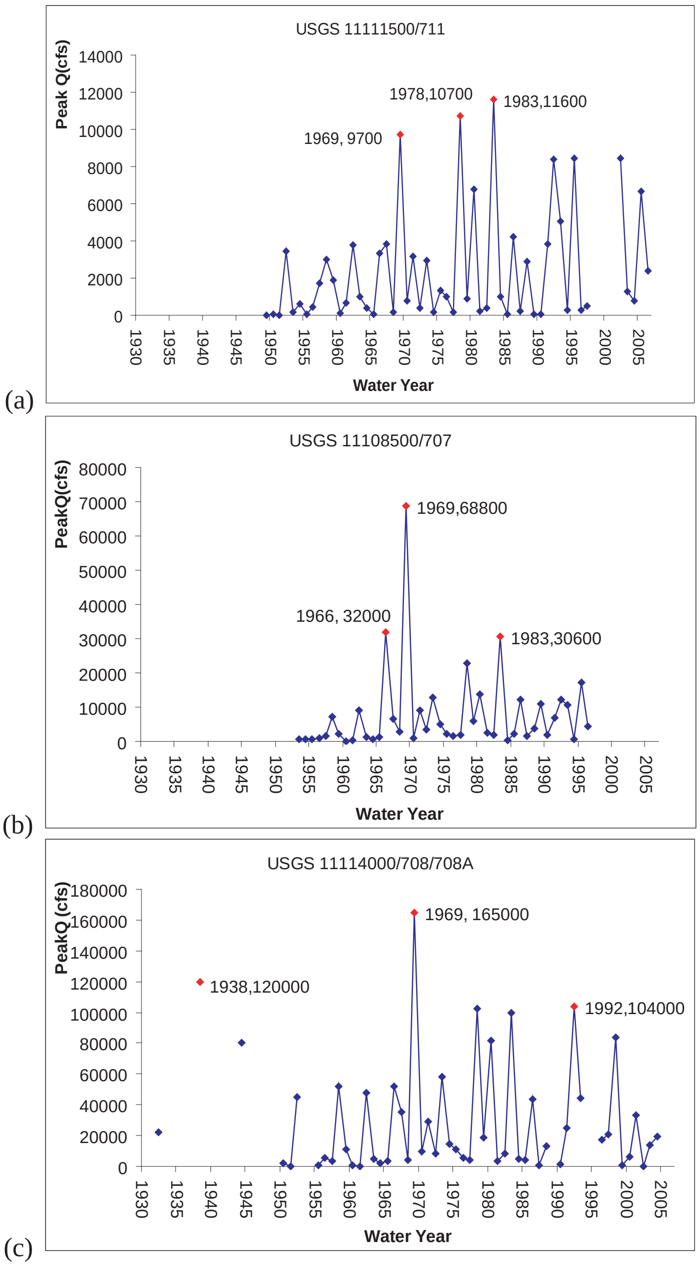


Figure 6.7 Annual flood peak discharges: (a) in the headwater at Sespe Creek near wheeler springs station (USGS 11111500/717), (b) at the confluence of the Santa Clara river with the Mint Canyon at middle at SANTA CLARA RIVER AT L.A.-VENTURA CO. LINE CA station (USGS 11108500/707nd (c) near the outlet at the Montalvo station (USGS 11114000/708/708A).

have been collected.

Significant increases in peak flow discharge are also observed at several other stations, including Piru Creek right below Santa Felicia Dam (USGS 11109800/714), Piru Creek near Piru, CA (USGS 11110000/706), and Santa Clara River near Lang, CA (USGS 11107745). Landmark Village, part of the proposed Newhall Ranch planned community, located along the Santa Clara River near the county line, could have significant impacts on streams and habitats, flow characteristics, and flood risk near the massive project.

6.5. Groundwater Recharge and Extraction

Nine groundwater basins are summarized in Table 6.6 and mapped in Figure 6.8 according to data obtained from the Department of Water Resources (DWR, 2004).

Mound Subbasin

Mound Subbasin underlies the western part of the Santa Clara River Valley Groundwater Basin. It is recharged by the Santa Clara River and its tributary streams. Natural runoff and imported water from Lake Piru could be released to recharge the basin. Subsurface flow from the Santa Paula Subbasin and irrigation and percolation of direct precipitation provide recharge as well. Subsurface water may flow into or out of the basin across the border with the Oxnard Subbasin depending on relative groundwater levels. During prolonged drought conditions, the groundwater table may drop below sea level near the coast (California Regional Water Quality Control Board – Los Angeles Region, 2006). This situation promotes seawater intrusion, though it has not been a problem to date.

Santa Paula Subbasin

Table 6.6 Groundwater basin data

Groundwater Basin/Subbasin Name	Area (acres)	Average well yield (gpm)	Groundwater storage	Groundwater in storage (af)[a]	Ground-water	Average annual	Average TDS (mg/L)
Mound Sub	14,800	700	153,000	110,000	ND	8,000	1640
Santa Paula Sub	22,800	700	754,000	675,000	ND	21,612	1198
Fillmore Sub	20,800	700	7,330,000	6,960,000	ND	42,972	1100
Piru Sub	8,900	800	1,979,000	1,880,000	ND	9,092	1300
Santa Clara River Valley East Sub	66,200	ND	ND	ND	ND	ND	ND
Acton Valley	8,270	140	40,000 [b]	6,000	ND	1,520	ND
Lockwood Valley	21,800	25	49,210	34,44	ND	ND	ND
Hungry Valley	5,310	28	10,937	10,400		-	<350

a Values are estimated using the Panaro (2000) method
b Values are estimated using the DWR (1975) method

The Santa Paula Groundwater Basin is recharged by percolation of the surface flow in the Santa Clara River, Santa Paula Creek, and other minor tributary streams. Subsurface flow from the Fillmore Subbasin, percolation of precipitation, and unused irrigation waters provide recharge as well (DWR, 2004). The water table flattens westward, possibly due to an increase in fine material in the San Pedro Formation that causes a decrease in permeability (California Regional Water Quality Control Board – Los Angeles Region, 2006)

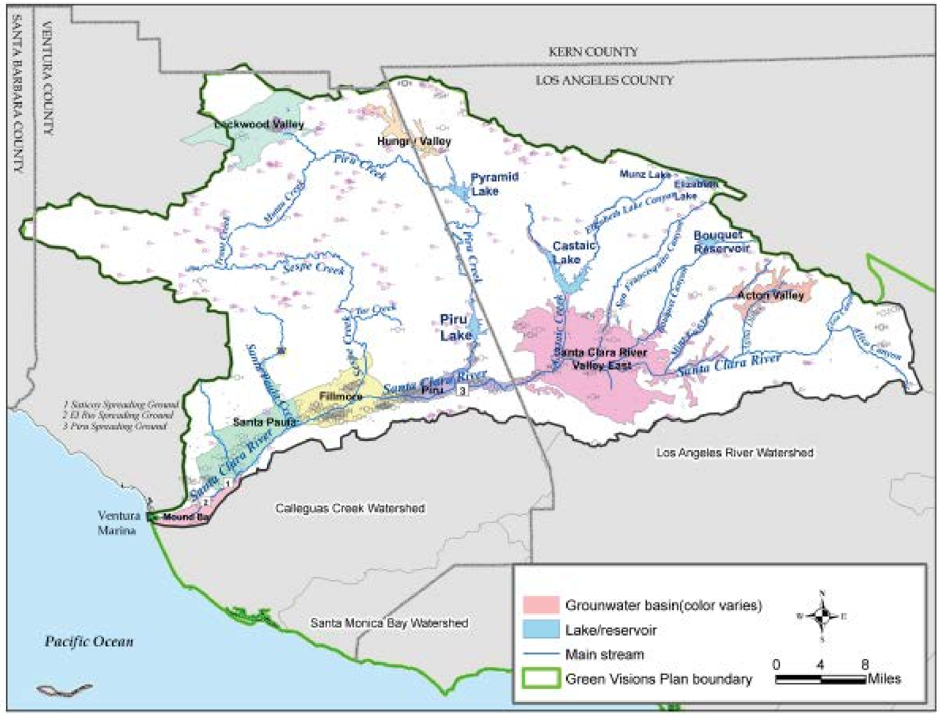
Fillmore Subbasin

The Subbasin is bounded by the municipalities of Fillmore to the east and Santa Paula to the west. The subbasin is considered to be in hydraulic connection with the Santa Paula Subbasin to the west. Recharge to the subbasin is provided by percolation of the surface flow in the Santa Clara River, Sespe Creek, underflow from the Piru Subbasin, direct percolation of precipitation, percolation of irrigation waters, and releases by UWCD from Lake Piru. Water in this subbasin is characterized by calcium sulfate, although some groundwater in the Sespe Creek upstream area is calcium bicarbonate in character. High nitrate concentration was found near Fillmore, CA. High concentrations of TDS (greater than 1,000 mg/l) and sulfate (greater than 800 mg/l) were found in Pole Creek Fan near Fillmore, CA. Recharge within this area is limited due to the poor water quality of Pole Creek and urban runoff associated with Fillmore. Elevated concentrations of nitrate and fluoride may be associated with the native waters of the San Pedro Formation.

Piru Subbasin

The subbasin is recharged by rainfall, irrigation returns, and artificial recharge through spreading grounds and water conservation releases by United Water Conservation District (UWCD) (DWR, 2004). The average annual artificial recharge at the Piru spreading ground is quite variable in dry versus wet years but has been as high as 6,600 acre-feet per year in the late 1990s during a wet year (AMEC Earth & Environmental, 2005). Water quality degradation of the Piru Subbasin has become clear over the past several years. TDS, sulfate, fluoride, and nitrate concentrations are a problem in a few wells. The most prominent natural contaminants in the subbasin are boron and sulfate (UWCD, 1996). Agricultural return flows may lead to high nitrate concentrations particularly during dry periods (UWCD, 1996; Panaro, 2000). High chloride concentration flows that have migrated from the Santa Clara River are an imminent threat to the basin. In fact, higher chloride concentrations have occurred in wells just west of Piru Creek over the past several years, at the same time that recharge water percolating from Piru Creek had much lower chloride concentrations (Bachman, 2006).

Figure 6.8 Santa Clara River Watershed groundwater basins, springs, wells and spreading grounds



Santa Clara River East Valley

The Upper Santa Clara River, Bouquet Creek and Castaic Creek are the main tributaries that drain the surface area of the subbasin. Discharge from the subbasin is through pumping for municipal and irrigation uses, uptake by plants, and outflow to the Santa Clara River in the western part of the subbasin. Perchlorate contamination was found in four Saugus Formation wells operated by retail water purveyors in 1997 in the eastern part of the Subbasin. Since then, the four Saugus municipal supply wells have been out of water supply service as well as two wells that drew water from the Santa Clara River alluvium. Planning for remediation of the perchlorate contamination and restoration of impacted well capacity is underway (Black & Veatch, 2005).

Acton Valley

Groundwater in the basin is found in alluvium and stream terrace deposits (California Regional Water Quality Control Board – Los Angeles Region, 2006). The basin is recharged from deep percolation of precipitation on the valley floor and runoff in the Santa Clara River and its tributaries. The basin is also recharged by subsurface inflow. Water sampled from 75 wells measured during 1989 showed high concentrations of TDS, sulfate, and chloride in the northern part of the basin with some of these concentrations exceeding drinking water standards (Slade 1990; DWR 2004).

Lockwood Valley

This groundwater basin underlies Lockwood Valley in northeastern Ventura County. Groundwater is found primarily in Quaternary alluvium. Recharge is principally provided by percolation of precipitation. Boron and arsenic concentrations locally approach drinking water standards (VCWPD, 1996). High alpha particle counts derived from radioactive uranium have been detected in water from four wells in the basin (VCWPD, 1996).

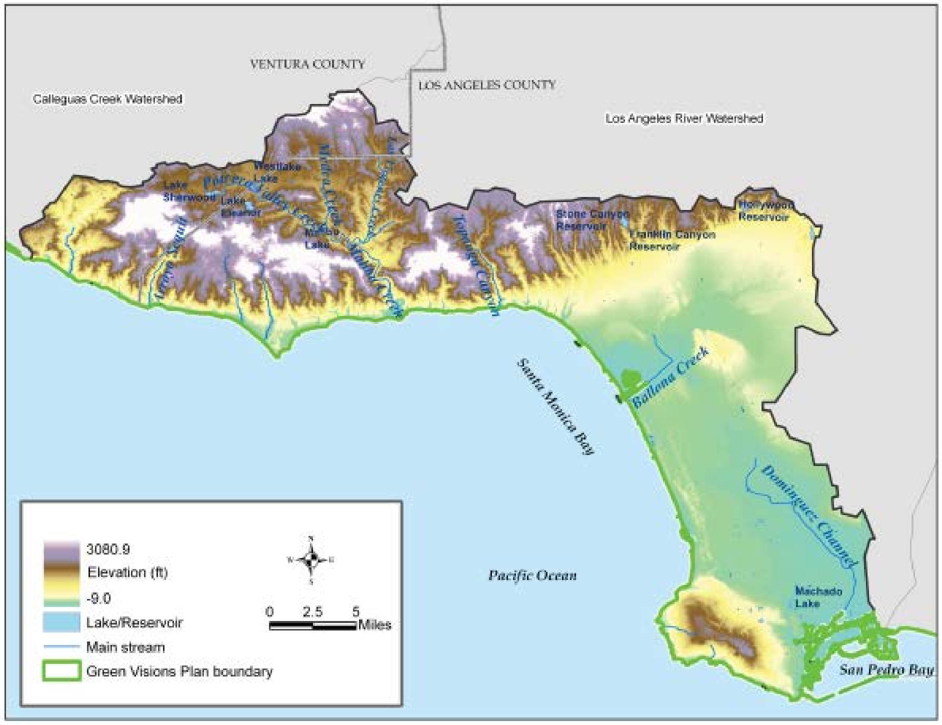
Hungry Valley

Groundwater is found primarily in Quaternary alluvium and some fractures in underlying rocks (Crowell, 1952). Recharge to the basin is chiefly from percolation of rainfall and stream runoff (Panaro 2000). The groundwater has an average pH of 8.1 which is slightly alkaline (VCWPD, 1996). The quality of groundwater and local springs within Hungry Valley is overall very good (CDFFP, 1999). Only one parameter, fluoride, has historically exceeded the state quality standards for Basin Plan beneficial uses.

7.1. Drainage System and Stream Classification

The Santa Monica Bay watershed is a coastal watershed with 165.1 mi shoreline along the Pacific Ocean. The entire watershed encompasses an area of 567.7 mi^2 with most of the watershed (504 mi^2) located in Los Angeles County. Its borders extend from the crest of the Santa Monica Mountains in the north to the Ventura-Los Angeles County line in the west to downtown Los Angeles in the southeast.

Figure 7.1 Santa Monica Bay Watershed elevation map



The highest elevation from which the headwaters originate is up to 3,080.9 ft in the Santa Monica Mountains (Figure 7.1). The average elevation of the channel system is about 623.4 ft, which is far lower than the mean channel elevation in the other four watersheds (e.g., 2,310 ft in the Santa Clara River watershed). The entire drainage system consists of five classes of streams classified by Strahler stream system (Figure 7.2). The basic topographic characteristics of the drainage system by Strahler stream order are summarized in Table 7.1.

The Santa Monica Mountains and Palos Verdes Hills are two headwater areas where many streams originate, including, from north to south, Arroyo Sequit, Trancas Canyon, Zuma Canyon, Malibu Creek, Topanga Creek, Ballona Creek, Agua Amarga Canyon, and Altamira Canyon (Figure 7.2). In the urban area, very few natural drainages except Dominguez Channel and south of Ballona Creek flow through the landscape.

Table 7.1 Basic characteristics of the drainage system in Santa Monica Bay watershed

Strahler stream order	Segments	Bifurcation ratio	Mean channel elevation (ft)	Mean channel slope (%)	Stream length (mi)	Drainage area (mi^2)
1	708	5.2	828.6	13.0	528.0	206.5
2	135	4.4	602.5	5.7	194.1	127.6
3	31	3.9	384.4	2.7	118.0	137.9
4	7	7.0	233.6	1.2	30.7	22.4
5	1	NA	364.6	1.6	10.3	5.6
Others	156	NA	829.5	11.0	79.5	67.7

Malibu Creek begins at Malibu

Figure 7.2 Santa Monica Bay tributaries classified by Strahler stream order

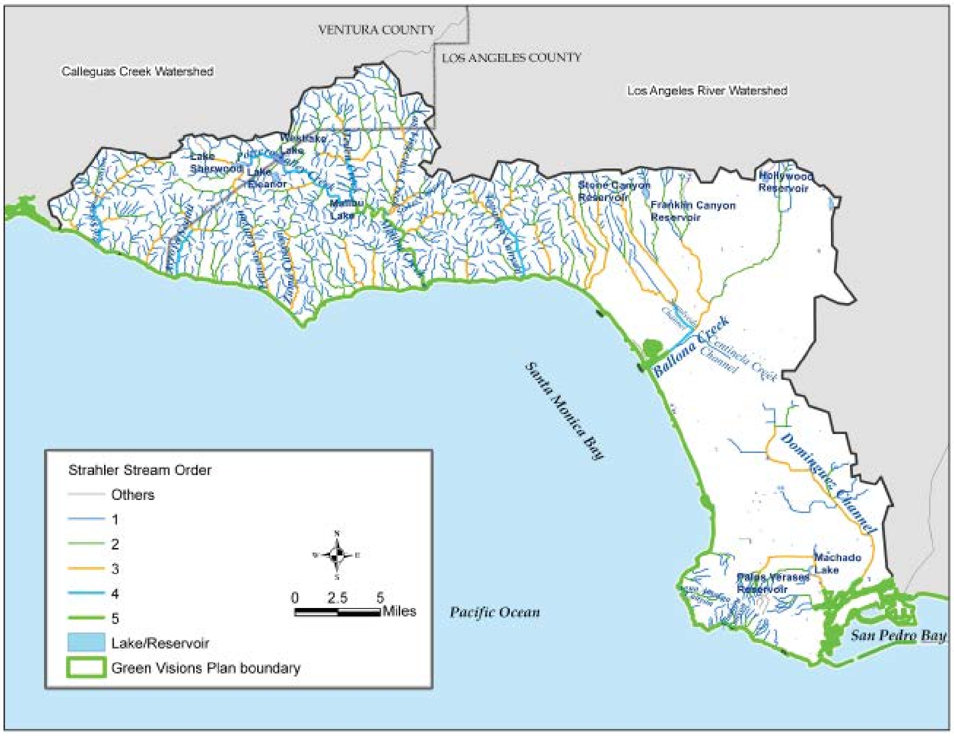
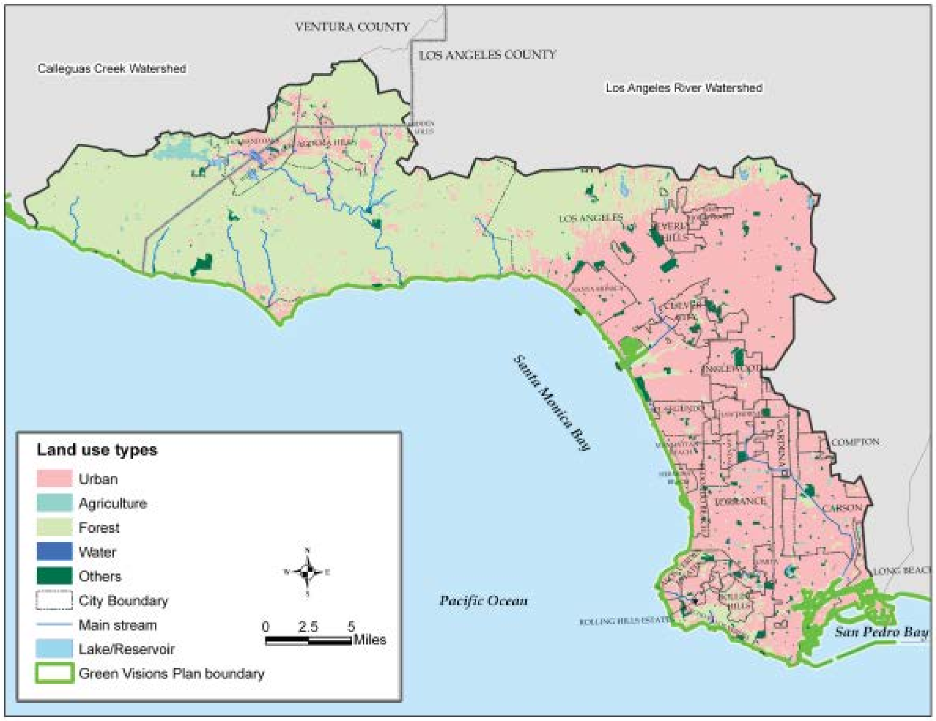


Photo 7.1 A waterfall along the Malibu Creek near the Malibu Lake

Creek Lake and follows a 10.3-mile course to the ocean. It is the only 5th order stream segment in the watershed. It drains the largest watershed area in the Santa Monica Mountains and therefore a substantial stream runs in it through the flat canyon floor. Medea Creek, Las Virgenes Creek, and Stokes Canyon feed the creek along the water course. Flows in tributaries merging into Malibu Creek can be discontinuous during the summer dry season and running during the winter wet season (Photo 7.1).

One of the 4th order streams, Topanga Canyon, merging into Santa Monica Bay through a small estuary, drains 18.0 mi^2 of the watershed. Most of the upper tributaries are natural but the canyon is dotted by development (Figure 7.3). The stream bed along the lower Topanga Canyon has been lined with boulders and concrete, and the banks have been sandbagged due to the frequent flooding in the canyon (Topanga Canyon Floodplain Management Citizens' Advisory Committee, 1996). Ballona Creek, Big Sycamore Canyon and Arroyo Sequit are also 4th order streams. Ballona Creek is an urban stream which has been modified into storm drains, underground culverts, and open concrete channels. Big Sycamore Canyon and Arroyo Sequit Canyon have remained relatively natural, protected within the Santa Monica Mountains National Recreation Area. Riparian environments along these natural streams constitute the best aquatic ecologic resources of all the coastal streams in the Santa Monica Mountains. For example, Arroyo Sequit, draining the tallest peak in the Santa Monica Mountains (3,100 ft), is designated as a "Significant Watershed" on the Sensitive Environmental Resources Map of the 1989 Malibu Local Coastal Program Land Use Plan and is also home to the endangered steelhead trout as well as several other species of plants and animals (National Park Service and Santa Monica Mountains National Recreation Area, 1999).

Figure 7.3 Land use types in Santa Monica Bay watershed



Various reaches of the streams aforementioned are carrying impaired waters into the main channels and eventually discharge to the beaches and ocean. The ones that are listed in California 2002 Clean Water Act Section 303(d) for the TMDL water quality enhancement (California Regional Water Quality Control Board, Los Angeles Region, 2003) include Ballona Creek (9 mi), Dominguez Channel (15 mi), Las Virgenes Creek (12 mi), Lindero Creek (3 mi), Topanga Canyon (8.6 mi) and Malibu Creek (4.7 mi).

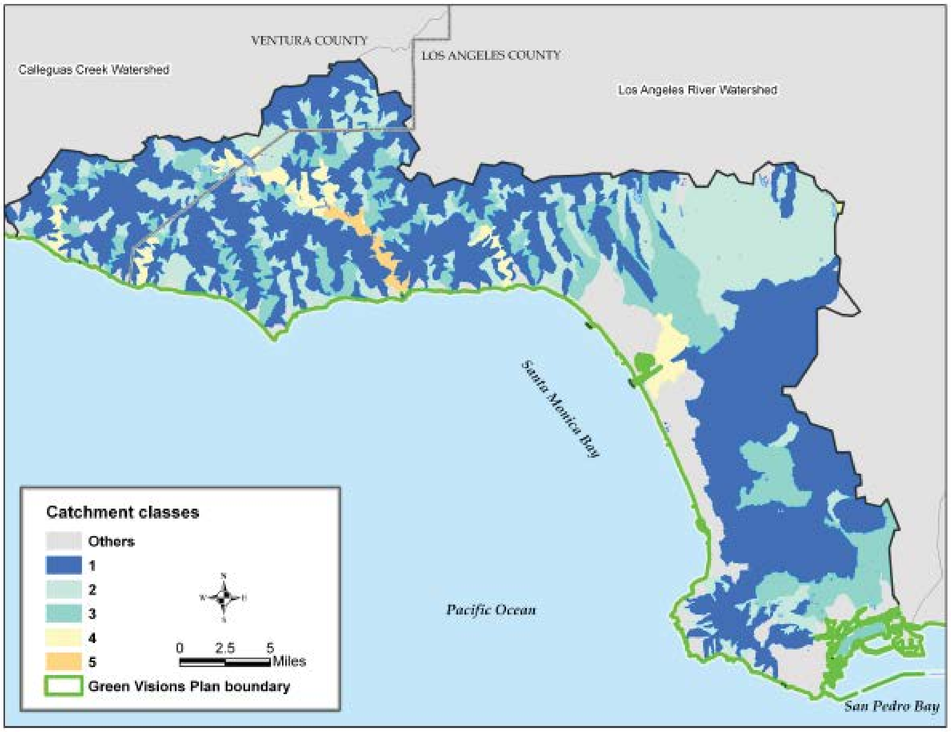
7.2. Watershed Classification

The Santa Monica Bay watershed is divided into five classes by Strahler stream order (Figure 7.4). Catchments drained by the first order streams are dominated by vacant forest usages (50.3%) (Table 7.2). The percentage of urban land use is higher in the 2nd order catchments than the 1st order catchments by 9.8%. The forested, undeveloped or developed recreational open space like parks and wild land

Table 7.2 Watershed classification and their major characteristics

Catchment classes	Mean catchment elevation (ft)	Mean catchment slope (%)	Urban (%)	Agriculture (%)	Forest (%)	Water (%)	Others (%)
Others	70.0	11.2	48.5	2.1	40.7	0.7	8.0
1	246.8	23.9	41.4	0.8	50.3	4.3	3.2
2	221.7	23.9	50.2	0.9	45.6	0.5	2.8
3	142.7	19.2	74.3	1.2	20.7	0.4	3.3
4	179.3	25.8	31.6	0.0	63.2	2.6	2.6
5	198.1	45.9	9.1	0.0	90.9	0.0	0.0
Average	176.4	25.0	42.5	0.8	51.9	1.4	3.3

Figure 7.4 Santa Monica Bay watershed classified by Strahler stream order



preserves are largely situated inside the Santa Monica Mountains National Recreation Area and Palos Verdes Hills (Figure 7.3). The percentage of urban land use in the 3rd order catchments is the highest among all five classes. Some large acreage residential properties lie along the 2nd to 4th order streams, for instances, Ballona Creek, Las Virgenes Creek, Medea Creek, Potrero Valley Creek, and Topanga Creek. Small agricultural lands are scattered around Dominguez Channel, Las Virgenes Creek, and Palos Verdes Hills (Figure 7.3).

7.3. Dams, Lakes, Reservoirs, and Debris Basins

A number of lakes, reservoirs, and dams are situated within the watershed (Figure 7.5). Major features of these named lakes and reservoirs are summarized in Table 7.3.

Several lakes located in the headwaters: Westlake Lake, Lake Sherwood, Lake Eleanor, and Lake Lindero

Westlake Lake is in the upper portion of the Malibu Creek watershed. The lake is under the list of 303(d) (i.e., the Federal Clean Water Act Section 303(d)) for various pollutants of concern related to non-point source pollution (California Regional Water Quality Control Board, Los Angeles Region, 2003). The outfall located at the northeast end of the Three Springs area of Westlake Village discharges urban runoff directly into the lake. Multiple TMDLs (e.g. an in-line storm water filtration device) were installed to control sediment loading to Westlake Lake and remove urban runoff pollutants. First flush runoff is captured and treated before release to

Westlake Lake (California Regional Water Quality Control Board, Los Angeles Region, 2003).

Upper Stone Canyon Dam - Stone Canyon Reservoir- Stone Canyon Dam

Two large dam-reservoir systems regarding the volume are on the upper Stone canyon. The reservoir complex is actually two reservoirs – an upper and a lower reservoir – with related facilities for pumping, chlorinating, and piping reservoir water. The Stone Canyon Reservoir complex provides water to communities in Pacific Palisades, the Santa Monica Mountains, and West Los Angeles.

Upper Hollywood Reservior - Upper Hollywood Dam - Hollywood Reservoir - Mulholland Dam

Lake Hollywood is a man-made reservoir built in 1924 to hold more than 2.5 billion gallons of water. The reservoir is part of the Owens River Aqueduct system. The Mulholland Dam was built by engineer William Mulholland to provide Los Angeles with most of its drinking water. The Upper Hollywood dam was subsequently built in the northern part of the lake to provide additional reservoir capacity. As a reservoir for drinking water, the lake is protected from contamination by surface runoff. Two of the world's largest underground tanks next to the Upper and Lower Hollywood Reservoirs are now taking over the water strorage role previously played by Hollywood Reservoir to store and provide treated water to the distribution system with pipelines.

Malibu Lake - Malibu Lake Club Dam - Century Reservoir - Century Reservoir Dam - Malibu Creek Lagoon

The Century Reservoir and Malibu Lake dams, owned by the State Department of Parks and Recreation, and Malibu Lake Mountain Club Inc. and Rindge Dam (not shown on the map), located about 2.5 miles upstream from the Pacific Ocean (Wikipedia, 2006), obstruct water flows and fish passage (Heal the Bay, 2005). Fish advocates have called for the dam's removal because Rindge Dam is blocking steelhead trout from accessing the upper reaches of the Malibu Creek watershed. Malibu Lagoon (Photo 7.2), a 12 acre shallow water embayment, occurrs at the terminus of Malibu Creek. It had previously been used as dump site for fill material by CalTrans and others in the 1950s and 1960s. By the 1980s, the ecological functioning and health of the lagoon had

Table 7.3 Named lakes/reservoirs in Santa Monica Bay watershed

Name	NHD Area (acres)	Elevation (ft)	Perimeter (mi)
Westlake Lake	186.0	890.0	12.2
Lake Sherwood	136.9	954.8	4.4
Stone Canyon Reservoir	135.7	847.0	3.6
Hollywood Reservoir	75.3	715.7	3.1
Silver Lake Reservoir	73.9	449.0	1.6
Machado Lake	45.3	-	1.5
Malibu Lake	41.8	740.0	3.5
Franklin Canyon Reservoir	27.5	578.9	1.6
Palos Verdes Reservoir	23.2	-	0.7
Lake Lindero	13.8	959.7	1.3
Malibu Lagoon	11.7	15.1	1.1
Lake Eleanor	7.7	989.9	0.7
Ivanhoe Reservoir	7.4	452.0	0.5
Century Reservoir	5.9	659.0	0.6
Powena Reservoir	5.7	452.0	0.4
Del Rey Lagoon	5.1	-	0.5
Lake Enchanto	3.2	770.0	0.8
Morningside Park Reservoir	3.0	-	0.3
Nicholas Flat	3.0	-	0.4
Dominguez Reservoir	2.5	-	0.2
Santa Ynez Lake	1.0	-	0.1

declined. In addition, urbanization in the Malibu Creek watershed has increased the volume of water transported into the lagoon and urban pollution has significantly diminished water quality. Since the late 1980s, an ongoing community effort has been organized to assess lagoon health and develop restoration plans (Jones and Stokes, 2006). Habitat restoration projects have been carried out or planned by California Department of Parks and Recreation and California State Coastal Conservancy.

Upper Franklin Canyon Reservoir/Dam - Franklin Canyon Reservoir/Dam - Lower Franklin Dam - Off stream Grey Stone Reservoir

Franklin Canyon has three dams along the reach in association with the reservoirs including the upper and two lower Franklin reservoirs. The dam-reservoirs on Franklin Canyon were constructed by William Mulholland beginning in 1916 and both were finished and operational in 1916. The lower dam-reservoir (Photo 7.3) was the main facility and had an electric generating plant. The upper one was built for stability of the lower reservoir. After the 1971 Sylmar earthquake, a third reservoir was built, just north of the lower one to help contain the amount of water needed for the city (http://employees.oxy.edu/jerry/frankcan.htm).

Photo 7.2 Malibu Lagoon, Los Angeles County

Photo 7.3 Franklin Canyon Reservoir, Los Angeles County

Machado Lake

Machado Lake, also known as Harbor Park Lake, is an urban lake that serves as the flood retention basin for urban drains. Many canyons originating from the relatively steep Palos Verdes hills drain to the lake. It contains the largest area of original native riparian forest and freshwater marsh in L.A. County. Unfortunately, much of the biodiversity is disappearing due to habitat degradation (http://www.utopianature.com/kmhrp/whatis.html). Wilmington Drain is the main tributary that feeds the lake, and discharges approximately 65% of its runoff into the lake (LADPW & Dominguez Watershed Advisory Council, 2004). Wilmington Drain also conveys a certain amount of trash to the lake, which is the primary reason for the impairment of beneficial uses to the lake and may contribute to the elevated levels of coliform bacteria at the discharge points into the lake.

Impaired waters are identified in various lakes including Lake Lindero (15 acres), Machado Lake (45 acres), Lake Sherwood (135 acres), Malibu Lake (40 acres) and Malibu Lagoon (15 acres), approved by USEPA (California Regional Water Quality Control Board, Los Angeles Region, 2003).

7.4. Stream Flow and Annual Flood Dynamics

There are 13 stream gauging stations in the watershed that monitor the flow status (Table 7.4). But only six of them have flow records: USGS 11103500, 11104000, 11105500, LACDPW F38C-R, F54C-R, and F130-R. Both the USGS 11103500 and LACDPW F38C-R monitor flow status in Ballona Creek near Culver City. Starting in WY1978, the USGS stopped reviewing and publishing the records for the 11103500 site. LACDPW (F38C-R) has continued to provide full records for this site to the present. The stream gauge F54C-R coincides with the USGS 11104000, located at the mouth of Topanga Creek, monitored from 1930 to 1979 by USGS and from 1980 to date by LACDPW, respectively. The USGS 11105500 and F130-R stations monitor flows at Malibu Creek below Cold Creek (during 1931-1979 by USGS and 1980 to date by LACDPW, respectively). Mean annual daily flow, annual peak discharge, temporal trend test, and flood magnitude estimates for various recurrence events are summarized in Table 7.5 for three stations that have flow records longer than 20 years.

Mean Annual Daily Discharge

The flows in Malibu Creek are under the regulation of Lake Sherwood Dam, Lake Eleanor Dam, and Malibu Lake Dam. The mean annual daily flow at Malibu Creek above Cold Creek (F130-R or USGS 11105500) is 26.8 cfs from 1932-2005. The observed annual daily flow has significantly increased over time (Figure 7.6a). Historically, Malibu Creek had very low and no flows in this reach in winters. But continuous flows have occurred in the stream since the late 1960s (i.e. 1967). Studies have shown that in the last 50 years, and particularly the last 25 years, many of these northern headwater areas have been developed as residential neighborhoods (Jones & Stokes, 2006). As a consequence, flows in the creek are augmented by flows contributed from increased urban storm runoff, irrigation used from imported waters, and effluent from Tapia Water Reclamation Facility located about one mile above the confluence since the late 1960's (Jones and Stokes, 2006). Augmentation flows support the southern steelhead habitat in the lower reach (Carroll, 1994).

Table 7.4 Stream flow stations in Santa Monica Bay Watershed.

STA_ID	Station name	Drainage (mi^2)	Elevation (ft)	Upstream regulation	Flow status	Flow records From	Flow records To
11103500/F38C-R	BALLONA C NR CULVER CITY CA	89.5	12	Y	E/P	19280301	To date
11104000/F54C-R	TOPANGA C NR TOPANGA BCH CA	18	265.6	N	E	19300101	To date
11104400	MALIBU C A CORNELL CA	37.6	ND	N	ND	ND	ND
11105200	COLD C TRIB NR MALIBU BEACH CA	0.3	ND	ND	ND	ND	ND
11105410	COLD C A PIUMA RD NR MONTE NIDO CA	7.7	ND	ND	ND	ND	ND
11105500/F130-R	MALIBU C AT CRATER CAMP NR CALABASAS CA	105	430.5	Y	E	19310201	To date
11105580	ZUMA C A RAINSFORD PL NR MALIBU CA	8.6	ND	ND	ND	ND	ND
11105660	ARROYO SEQUIT A CARRILLO ST BCH NR PT MUGU CA	11	ND	N	ND	ND	ND
11105700	LITTLE SYCAMORE C NR NEWBERRY PARK CA	1.4	ND	N	ND	19601127 [a]	19730211 [a]
11105780	BIG SYCAMORE CYN C NR POINT MUGU CA	20.8	ND	ND	ND	ND	ND

Topanga Canyon above the mouth is monitored by the F54C-R or USGS 11104000 station from WY1930 to date. The lower reach is free of upstream regulation and flow used to run freely and seasonally in it. No significant increase is detected with the mean annual daily flow over time (Table 7.5); however, low flows started to appear even in the dry summers since the 1980's. The annual flows correspondingly increased from 5.9 cfs (WY1930-1980) to 9.6 cfs (WY1981 to date) (Figure 7.6b).

Table 7.5 Mean annual daily discharge, temporal trend test, annual peak discharge, temporal trend test, and flood frequency and magnitude estimates

STA_ID	Mean annual daily discharge (cfs)	Sig.(2-tailed)	Coefficient of variation	Average peak discharge (cfs)	Sig.(2-tailed)
11103500/F38C-R	48.3	0.002**	0.615	12530.0	0.001**
11104000/F54C-R	7.3	0.499	1.51	2473.6	0.622
11105500/F130-R	29.0	0.020**	1.29	4827.3	0.088

Mean annual daily flow observed in Ballona Creek near Culver City from 1928 to 1978 was 40.8 cfs (Figure 7.6c). During the early period, perennial flow was running in the creek, lined with dense vegetation that met the Pacific Ocean in a broad expanse of tidal lagoons and wetlands (LADPW, 2004) (Photo 7.4; compare with Photo 7.5). The main creek, fed by various intermittent streams originating from the Santa Monica Mountain canyons, could freely shift its course when winter rains swelled it. Over time, many of these tributaries disappeared as they crossed the coastal plain mainly due to percolation to groundwater and urban pavement. During the flow monitoring period, baseflow (i.e., the 10th percentile of the annual daily flows) had increased significantly ($R^2 = 0.7$) from 0.8 to 9.4 cfs, which was largely due to the increasing discharge from urban storm drains.

Similar urbanization processes have occurred elsewhere, for example, in the Dominguez channel watershed, where channels were dredged, marshes were filled, and wharves were constructed at the beginning of this century (LACDPW & Dominguez Watershed Advisory Council, 2004). Since the majority of the watershed is urban land, natural drainages are converted to urban drainages which conduct flow through an extensive network of underground storm drains. The Dominguez Slough was completely channelized and became the drainage

Photo 7.4 Ballona Creek in 1922

Photo 7.5 Sepulveda Channel that drains to Ballona Creek taken in 2006

endpoint for runoff from a highly industrialized area. These urban drains generally originate at curb inlets on city streets and increase in size as they progress in the downstream direction to an open channel or detention basin. In some locations the drainage system is no longer adequate, and localized flooding occurs during storms.

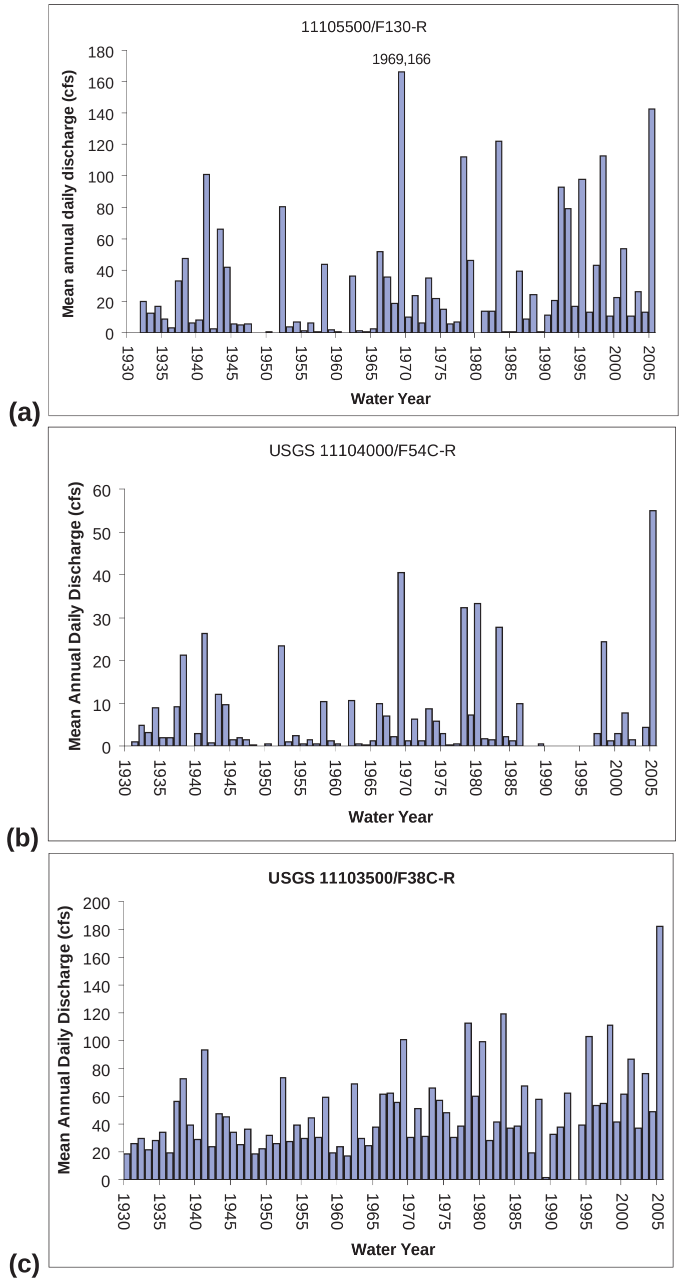


Figure 7.6 Mean annual daily flows in (a) Malibu Creek at the confluence with Cold Creek at USGS 11105500/F130-R; (b) Topanga Canyon above the mouth at USGS 11104000/F54C-R station; and (c) Ballona Creek near Culver City at USGS 11103500/F38C-R station.

Flood Dynamics

Malibu Creek is subject to frequent winter floods. Historically, the flood flows are under the regulation of Lake Sherwood Dam, Lake Eleanor Dam, and Malibu Lake Dam. The 1938 large river flows (i.e., 5- to 10-year flood events) inundated much of the current Malibu plain area (Jones and Stokes, 2006). This event was frequently exceeded since 1938 (Figure 7.7a) and flooding consequently occurred in the creek. The January 25, 1969 flood (i.e., a 100-yr flood event) caused damages to cableway at the gauge site.

As many of the northern headwater areas have been developed as residential neighborhoods (Jones and Stokes, 2006), increasing storm flows and quicker flood flow response poses an increasing flood risk to the downstream areas. Topanga Canyon experiences periodic flooding along its creek channels. Throughout the 20th century, heavy rains have come once or twice a decade to Topanga Canyon, with major floods recorded in 1938, 1969, and 1980 (Figure 7.7b). Heavy rainfall on the soaked hillslopes has done damage to the entire watershed, causing inundation and slides in the uplands with destructive erosive flooding of the creek areas. During major floods, low-lying areas, including Topanga Center and some houses, have experienced minor inundation. The main damage however has been to roads, primarily Topanga Canyon Boulevard. In the “worst flood of last century”, February 16, 1980 (peakQ = 20,200), Topanga Canyon Boulevard was altogether gone in two

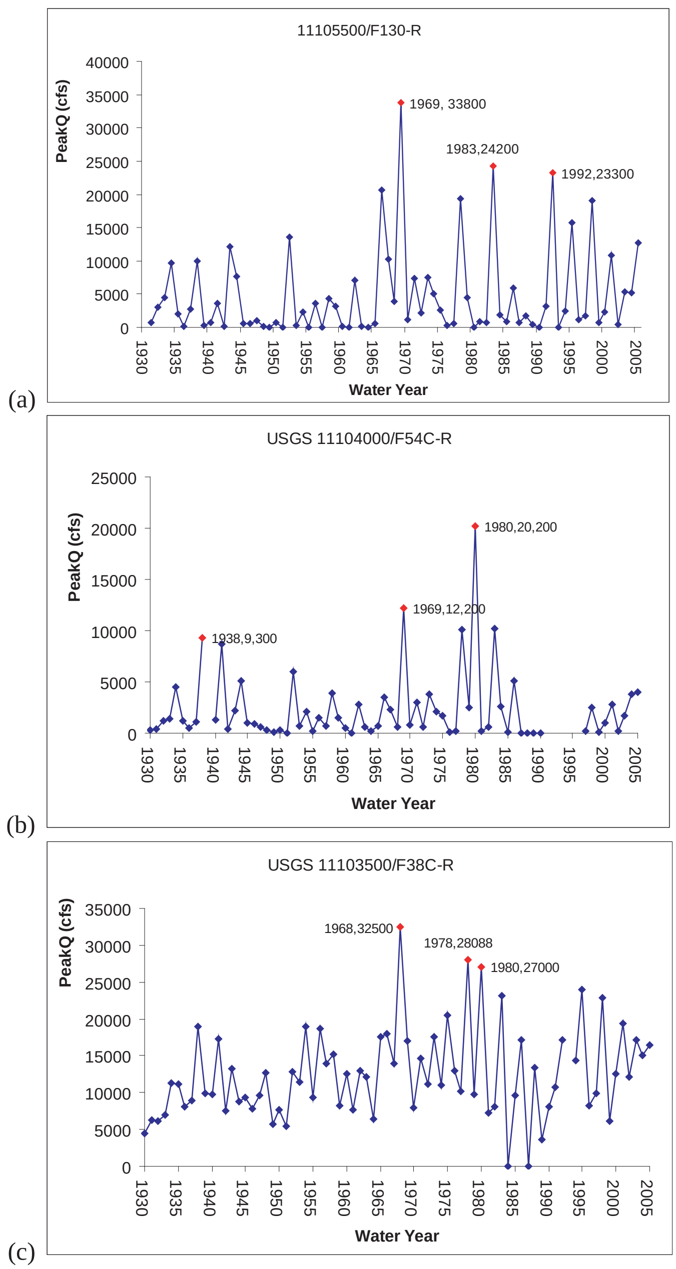


Figure 7.7 Flood peak discharge in: (a) Malibu Creek at the confluence with Cold Creek at USGS 11105500/F130-R; (b) Topanga Canyon above the mouth at USGS 11104000/F54C-R station; and (c) Ballona Creek near Culver City at USGS 11103500/F38C-R station.

long stretches of up to 200 yards, and it collapsed in half a dozen other locations that required massive repairs (Topanga Canyon Floodplain Management Citizens' Advisory Committee, 1996).

Similar to the Malibu Creek sub-watershed, sprawling development is associated with the increasingly impervious nature of the watershed, especially surrounding the hills and ridges of Old Topanga Canyon Road and Topanga Canyon Boulevard (Topanga Canyon Floodplain Management Citizens' Advisory Committee, 1996). Increasing storm runoff from the paved impervious area has potentially posed higher flood risks to local communities without appropriate mitigation plans.

Ballona Creek experienced both natural flooding and also urban flooding. Until the 20th Century, winter rains flooded farms, homes and businesses once every several years. As urban development moved west of downtown Los Angeles, various tributaries began to be channelized, dredged, grouted, or filled in. Only a few channels remain open for major portions of their length, including the Sepulveda Wash (also known as Walnut Creek) and Centinela Creek Channel (LADPW, 2004) before continuing approximately nine miles to Santa Monica Bay. Most of the tributaries draining to Ballona Creek are controlled by structural flood control measures, including debris basins, storm drains, underground culverts, and open concrete channels (Photo 7.5). Due to the extensive modification of the creek and tributaries, natural hydrologic functions have been significantly reduced in the watershed. With approximately 40% of the watershed covered by impervious surfaces, runoff enters the creek and tributaries more quickly, and in greater volume from storm events than occurred prior to development. Baseflow and annual flood peak discharge significantly increased during the period of 1928-1978 (Figures 7.7c).

Urban flooding in the Santa Monica Bay watershed is evidently occurring elsewhere in the channelized and underground urban drains. For example, the channelized Dominguez Channel is designed to contain most storm flows and protect from overbank flooding except on very rare events that exceed the design discharge. Although the main channel serves effectively as flood control, there are some local areas subject to flooding from drainage originating outside the channels. The local drainage system, which consists of an extensive network of underground storm drains, will become inadequate for conveying flashy storm water as urban and subdivisions expand.

7.5. Groundwater Recharge and Extraction

There are six groundwater basins located in the watershed (Table 7.6). One of the groundwater basins, the Coastal Plain of Los Angeles, contains three complete subbasins (i.e., the Santa Monica Basin, West Coast Basin, and Hollywood Basin) and a portion of the Central Subbasin (Figure 7.8). Water detention and recharge basins located throughout the watershed are generally maintained for groundwater replenishment, flood stormwater retention, and sediment debris removal. Most of them are located in the West Coast Basin (Figure 7.5), for example, the Walteria Lake retention basin, Amie basin, and Del Amo detention basin. They are fed by underground storm drains with basin sides cleared of vegetation; however, several of them support a small amount of native riparian vegetation and thus provide small islands of natural habitat (LADPW & Dominguez Watershed Advisory Council, 2004).

Table 7.6 Groundwater basin data summary

Groundwater Basin/Subbasin Name	Area (acres)	Average well yield (gpm)	Groundwater storage capacity (af)	Ground-water in storage (af)[a]	Ground-water recharge (af)	Average annual extraction (af)	Average TDS (mg/L)
COASTAL PLAIN OF LOS ANGELES							
Santa Monica	32,100	ND	1,100,000 [e]	Unknown	Unknown	Unknown	916
Hollywood	10,500	ND	200,000 [e]	Unknown	28,700 f	3,300 [f]	526 [g]
West Coast	91,300	ND	6,500,000 [f]	1,100,000	95,638	51,673	456
Hidden Valley	2,210	ND	ND	ND	ND	ND	453
Central	177,000	1,730	13,800,000 [h]	1,100,000	122,638	204,335	453
Thousand Oaks Area	3,110	39	130,000m	113,000 [m]	ND	ND	1410
Russell Valley	3,100	25	10,570		350-650	600	800-1,200
Malibu Valley	613	1,030					1,310

Russell Valley Basin - Hidden Valley - Thousand Oaks Area Basin

All three basins are relatively small alluvial basins and currently unmanaged. Groundwater produced in the Russell Valley and Hidden Valley primarily comes from fractures within the volcanic rocks of the Conejo Formation and the underlying sedimentary rock. Groundwater in Thousand Oaks is generally found in the unconfined alluvium, although some groundwater is found in the underlying sedimentary rocks and fractures within the volcanic rocks. Production from these three basins is not used or is used in very limited quantities for municipal water supply (DWR, 2004). Water quality in Hidden Valley has been reported to be good to fair with TDS concentrations below 800 mg/L (DWR, 2004). TDS and sulfate both exceed their MCL for some wells in the Russell Valley Basin. The quality of water produced from the sedimentary and volcanic units is generally poor in the Thousand Oaks Area and Conejo-Tierra Rejada Volcanic Basin (DWR, 2004).

Malibu Valley Groundwater Basin

This basin is a small alluvial basin located along the Los Angeles County coastline. Prior to 1965, groundwater was the primary source of drinking water in the Malibu area. According to the LADPW, this basin lacks the capability to produce sufficient water supplies and is not included in their water supply planning (LADPW, 2005). All known wells that used to provide water supply have been abandoned. Seawater intrusion occurred in 1950 and 1960, when seawater advanced 0.5 miles inland (DWR, 1975). In December 1954 and April 1969, chloride concentrations exceeding 100 mg/L were found in groundwater in the coastal part of the basin (DWR, 1975). Recharge of the basin is from percolation of precipitation, runoff, and effluent from domestic septic systems.

Coastal Plain of Los Angeles

The Coastal Plain of Los Angeles Groundwater Basin comprises Hollywood, Santa Monica, West Coast, and Central Coast subbasins. Historically, high groundwater levels in some portions of the watershed resulted in marshes and surface springs. In general, most of these surface springs have ceased or been capped (such as the former Centinela Springs in Inglewood) (LADPW, 2004). However, high groundwater levels still exist in many of the same locations where they used to be, including West Hollywood, La Cienega, Venice, and portions of Culver City. In these areas, the high groundwater table may cause seepage into below-grade spaces and increase the risk of liquefaction during seismic events.

Groundwater Basin in the Coastal Plain of Los Angeles is primarily recharged both naturally and artificially. Natural recharges include infiltration of precipitation and applied water and subsurface flow from adjacent basins. With approximately half of the surface drainage area paved by impervious surfaces and the concrete lining of drainage channels, the surface area open to direct percolation from stream channels and infiltration of rainfall has been substantially reduced. Artificial recharge is conducted to replenish groundwater at spreading grounds or seawater barrier wells to make up the annual overdraft and to address water quality issues by the Water Replenishment District of Southern California. There is no direct groundwater recharge for the Santa Monica subbasin and Hollywood Basin (DWR, 2004). The West Coast Basin is mainly recharged by imported water and some recycled water at injection wells. Seawater intrusion and TDS concentrations prevent full utilization of the Santa Monica subbasin and West Coast subbasin. Two Superfund sites were designated by the U.S. EPA (U.S. EPA, 2002), namely, the Del Amo site and the Montrose Chemical Corporation site, located near the Dominguez Channel for the contamination remediation. The groundwater in the West subbasin is affected and threatened by the MTBE (methyl tertiary butyl ether) contamination. The EPA has been working with the City of Santa Monica and the Regional Water Quality Control Board to require cleanup of the MTBE contamination since 1996. Under orders from the EPA and the Los Angeles Regional Water Quality Control Board, the oil companies have extracted more than 346 million gallons of contaminated groundwater and removed over 4,000 cubic yards of contaminated soil. Approximately 6,000 pounds of MTBE have been recovered (Department of Justice, 2005).

In the Central Basin, recharge mainly comes from artificial replenishment of runoff, recycled, and imported waters through the Rio Hondo and San Gabriel River spreading grounds (DWR, 1999). A small portion of natural flow contributes to the replenishment of the basin through Whittier Narrows from the San Gabriel Valley (see Chapter 5). The possible migration of contaminated groundwater from the San Gabriel Basin (see Chapter 5) into the Central Basin remains a large threat even though a local well testing program has detected low levels of perchlorate in two wells. In response to the seawater intrusion problem, a seawater barrier, the Alamitos Barrier, was constructed in 1966 to protect fresh groundwater supplies in the lower portion of the Central Basin, as well as a portion of the Coastal Plain Area in Orange County (DWR, 1999).

Five sites were placed on the Federal EPA's Superfund list for pollution remediation (U.S. EPA, 2002), namely, Operating Industries, Inc. at Monterey Park, CA; Pemaco Maywood site at Maywood, CA; the Cooper Drum Company site at South Gate, CA; Omega Chemical Corporation at Whittier, CA; and Waste Disposal, Inc. at Santa Fe Springs, CA. Ground water sampling analysis conducted at these Superfund sites indicates the presence of volatile organic compound concentrations significantly above background levels in near-surface and deep soil samples, as well as perched ground water and an underlying regional aquifer (U.S. EPA, 2002).

8. CONCLUSIONS, RECOMMENDATIONS, AND CHALLENGES

The hydrologic system of the GVP study area has been altered to accommodate urban development, resulting in a sophisticated system that integrates the natural drainage system with heavily engineered hydrologic components. According to the Strahler stream classification system, approximately 77% of the stream system's length is classified as 1st and 2nd order streams,which drain about two thirds of the entire study area. These streams are mainly located in Los Angeles National Forest, Los Padres National Forest, and the Santa Monica Mountains National Recreation Area. These streams flow through steep vegetated canyons, carrying large amounts of eroded debris off the slopes to enter valley plains, and meet urban development head on. In order to coexist with dense urban communities, urbanized stream reaches have been highly engineered to minimize flood risk. Only very few natural riparian landscapes remain along these river banks. Such high order stream reaches include, for instance, the lower Los Angeles River, Tujunga Wash, San Gabriel River, and the lower Santa Clara River.

Drainage areas surrounding the first and second order streams have remained relatively pristine and support rich riparian habitats. In the Santa Clara watershed these natural drainage areas are found along 4th and 5th order streams. For example, Sespe Creek is the only stream in southern California designated as a California Wild and Scenic River. It supports many riparian dependent species that are not found in abundance elsewhere on the southern or central coast of California. In the urban landscape, into which such natural streams used to flow, the drainage areas have been altered by urban sewer/drainage systems. Natural flow conditions in these streams are now severely disturbed and subject to the impacts of land cover/land use change and hydraulic intervention. Surface and groundwater quality deterioration thus occurs at some places, which consequently endangers habitat and native species that rely on specific hydrologic systems and conditions.

8.1. General Recommendations for Watershed Asset Protection

Several principle recommendations arise from this report, all of which support and inform region-wide planning efforts from the perspective of watershed health assessment. First of all, efforts should be directed at preserving those headwaters located (mainly) within national forests, which are sources of natural surface water and groundwater and the primary refuge for many species. Generally these are also first and second order catchments in upland zones. In the Santa Clara River watershed, higher order catchments are also still intact and need to be strictly protected, for example Sespe Creek. The Arroyo Sequit is a designated "Significant Watershed", home to the endangered steelhead trout as well as several other target species of plants and animals and thus warrants major efforts designed to protect the features and functioning of this watershed.

Second, conservation and restoration of open space areas within many suburb catchments, where the natural heritage of the watershed still remains, is important. Such targets for protection include the Los Angeles River at the Glendale-Whittier Narrows section, and the Arroyo Seco section passing through the City of Pasadena – both areas of ongoing protection and restoration activities. These ecological conservation efforts are designed to restore the natural plant communities to improve habitat value and biodiversity, sustainability, and landscape aesthetics. The Arroyo Seco restoration project can become an exemplar to hydrologic and ecological preservation and restoration. In the San Gabriel River watershed, portions of Carbon Creek have loose riprap or composite banks, earthen bottoms, or other substrates that support limited herbaceous emergent vegetation on the sides of the channel. These urban riparian habitats need to be preserved, since they provide both some habitat and hydrologic value while at the same time accommodating urban development.

Third, the installation of selected water quality improvement projects, including Best Management Practices (BMPs), can help restore impaired water bodies and bring the region's waterways into compliance with existing and future TMDLs. Various reaches in the watershed are impaired by nonpoint and point source pollutants such that water quality and habitats along the reach are threatened by hazardous substances, pollutants and contaminants. Many of those stream reaches and water bodies are identified as Superfund sites and listed in California 2002 Clean Water Act Section 303(d) for the water quality enhancement. In addition to these Superfund sites, local restoration and repair projects should be planned to bring back compromised hydrologic and ecological functions.

For example, the naturalization and restoration project currently underway in Las Virgenes Creek will enhance the water quality of the creek by constructing a vegetated habitat with canopy to deflect the sunlight, thereby drastically reducing the algal blooms for which this segment has been listed under the Clean Water Act Section 303(d). TMDL projects need to be implemented for water quality improvement in Ballona Creek. Revolon Sough and Beardsley Wash in the Calleguas Creek watershed have trash problems, which exceed the existing water quality objectives necessary to protect the beneficial uses of the river. Many sites throughout the watershed share similar impairments such as high bacterial and nutrient levels, nuisance algal blooms (eutrophication), and trash along creek banks. Comprehensive identification of all sites that potentially warrant remediation relies on further scientific research including additional data gathering, water quality monitoring, modeling, and planning studies.

Flow and flood assessments based on gauged flow data indicate increasing urban flood risks and augmented flow conditions throughout the study area. Those sites that are facing increasing flood magnitude and mean annual daily flow are identified in this report. Increasing annual floods recorded in Calleguas Creek near Camarillo and along Revolon Slough indicate the need for flood control improvements, bank stabilization and more structural basins to accommodate the encroachment of agricultural and urban land development into places that used to function as floodplains. In the Los Angeles River watershed, significant increases in flood peak discharges are also detected at various sites as a result of urban development, for instance, Compton Creek Alhambra Wash, Verdugo Wash, Burbank Western Channel, Arcadia Wash, Rio Hondo, and Rubio Wash. The drainage areas along these reaches are highly urbanized with more than 80% of the land converted to impervious surfaces. Although up to 74% of the watershed area is regulated by dams, reservoirs, detention basins, and spreading grounds, most structures were constructed on the low order streams (i.e., 1st and 2nd order). The influence of impervious urban surface and effluents of urban water use on hydrologic processes is substantial. Over time the capability of flood protection structures built on low order streams in prior periods is exceeded by the increasing flood peaks and the loss of hydrologic features that have served historically to extenuate flood risks in the watershed.

Projects designed to mitigate urban flood risk and flood magnitudes are already being considered at various sites such as Sun Valley along the Tujunga Wash, Topanga Canyon, and Dominguez Channel. In many cases, the main channel serves effectively as flood control, but the local drainage system, which consists of an extensive network of underground storm drains, has become inadequate for conveying flashy storm water as urban subdivisions expand. Relatively large local scale urban flooding thus remains a real possibility.

In the meantime, many existing debris basins and dams are operating at capacity, and may soon exceed capacity because of augmented flow and sediment discharges. These old facilities need to be examined and retrofitted accordingly. For example, Sycamore Debris Basin, situated in Sycamore Canyon, was built in 1981 with the capacity of 15,000 cubic feet and was unable to detain recent 100-year storm events (VCWPD, 2005). The capacity of the Runkle Dam on Runkle Canyon cannot handle 100-year storm peak flow and fails to provide the necessary protection of downstream areas of the watershed. The Santa Rosa Road Debris Basin constructed in 1957 by the Soil Conservation Service mitigates increased flows due to development to a certain degree; however, the lack of an adequate improved channel downstream of Arroyo Santa Rosa results in the generation of a large floodplain (VCWPD, 2003). A systematic evaluation of the conditions of dams, detention and debris basins and prioritization for retrofitting and upgrading should be a high priority.

Groundwater contamination exists in groundwater basins throughout the study area. Overpumping, seawater intrusion, and a rising groundwater table are also problems at certain groundwater basins. Beside an integrated system of regional groundwater extraction and recharge regulation, site-specific projects are necessary to help improve groundwater quality and storage. With no physical or hydraulic barriers to seawater intrusion groundwater levels must be managed to minimize contaminating potable water resources. In addition, new storage projects require regulatory approval and new well restrictions should be imposed on specific aquifers to limit coastal pumping and seawater intrusion. Water extraction from overdrafted groundwater basins should be strictly managed and replenishment of groundwater storage should be considered with native water or imported water. Infiltration facilities might need to be installed at places that have adequate surface water or reclaimed water resources. And the stored water thus can be delivered to replenish overdrafted groundwater basins.

8.2 Challenges and Data Gaps

There are many challenges to finding complete, high quality data for a geographical region the size of the Green Visions study area. The result is a series of stubborn data gaps and analytic limitations. Additionally, the sheer scale of the area limits the practicability of obtaining and reviewing all pertinent planning and assessment documents.

Data gaps that were encountered during this assessment of existing hydrologic conditions are identified for future purposes.

Incomplete Data

Parts of spatial or attribute data can be missing. Because of the broad study area and its many jurisdictions, coverages were often merged from multiple individual sets of data. Data within individual data sets were sometimes missing, or entire data sets were missing or unavailable. For example, debris basin datasets were obtained from Ventura County Flood Control Department and Los Angeles County Public Works. Only very limited attributes are attached with each spatial dataset. No consistently complete attributes were available for the entire study area in this case.

Inaccurate Data

Many data are outdated, and conditions may have changed since the data were originally compiled. Stream and watershed classifications are conducted based on improved NHD datasets released in 1999. The 1999 NHD datasets contain hydrographic data interpreted from U.S.G.S topographic maps, which were produced in years ranging 1960s to 1980s. The 1999 NHD datasets reflect the hydrographic conditions whenever they were recorded. Various improvements were made to the 1999 NHD datasets using urban drainage data, topographic data and aerial photos. But only a partial coverage of the urban drainage data and aerial photos was obtained for this improvement effort.

Data Resolution

Data developed at different scales may appear dramatically different when compared. This is the result of many factors, such as the degree of difference in scale, the data type, and the minimum mapping unit (i.e., the smallest area accurately mapped in the data). Small-scale data (i.e., data covering large geographic areas but not detailed close up) may be too general compared to large-scale data (i.e., data covering small geographic areas with detail close up). Small-scale data may look inaccurate when compared with large-scale data; however, it may still be suitable for regional analysis. But as water quality interventions become increasingly common in urban neighborhoods, large-scale data are a must in order to conduct impact studies.

Lack of Data

Given the expense of developing or securing GIS data sources, lack of data is a common challenge. In some cases, data are proprietary and can be obtained at cost. In other cases, data useful for a GIS have not been developed; or the data are in a format that is incompatible, and conversion is not practical. The lack of urban drainage system data is a particularly big problem. And this is a critical dataset for delineating catchment areas and conducting flow and pollutants analysis in urban areas. Many water models cannot be run reliably without good quality drainage system data. Channel dimension characteristics are not available either, which are required for modeling flood hydraulics and flood risk.

8.3 Future Research

Understanding the past and present of southern California's watershed assets is the key to being able to shape the future. Further efforts should endeavor to address the following tasks, in order to better understand the hydrologic system in the Green Visions study area:

- Improve existing data quality and obtain more in-depth GIS datasets such as urban drainage data, channel dimension data, water operations data, and flood mapping.

- Collect historic vegetation and habitat data to assist water and habitat restoration planning.

- Improve water quality/quantity monitoring at the sites which are identified to have potential water resource/contamination problems.

- Identify and monitor hydrologic changes among watersheds in response to urban development.

- Develop hydrologic computer models to simulate various conditions in the watershed, and develop runoff management strategies to reduce runoff amounts under different scenarios.

- Develop hydrologic models to simulate surface water, imported water, and groundwater interactions in the study area in order to provide information for water resource management.

Such data collection and research will become increasingly crucial. Population growth, increasingly stringent water quality regulations, diminishing access to imported water – all of these dynamics make understanding the region's water regime and setting priorities for watershed asset protection more vital. In the longer term, increasing temperatures associated with global climate change will likely increase the risk and magnitude of floods, inundation, pollution, and salt water intrusion, making it ever more important for both water professionals and residents alike to understand southern California's watersheds and how to protect their life-sustaining assets.

AMEC Earth & Environmental, 2005. Santa Clara River Enhancement and Management Plan (SCREMP). Prepared for the Ventura County Watershed Protection District and the Los Angeles Department of Public Works. http://www.santaclarariverparkway.org/wkb/scrbiblio/screm pfinal.

Bachman, S., Detmer, D., and C.Hg., 2006. Chloride in the Piru Basin. http://www.swrcb.ca.gov/rwqcb4/html/permits/tentative_order/Individual/newhall/07_0719/SCOPE/SCOPE%20Attachment%20ChlorideinthePirubasin,UWCD,April2006.pdf.

Black & Veatch, Nancy Clemm, Kennedy/Jenks Consultants, Jeff Lambert, Luhdorff & Scalmanini Consulting Engineers, Reiter/Lowry Consultants, Richard Slade and Associates, LLC, 2005. 2005 Urban Water Management Plan. Prepared for Castaic Lake Water Agency, Newhall County Water District, CLWA Santa Clarita Water Division, Valencia Water Company, and Los Angeles County Water District #36. http://www.clwa.org/about/publications.cfm.

Brick, T., 2003. A Water Budget for the Arroyo Seco Watershed. Arroyo Seco Foundation in partnership with North East Trees as part of the CALFED Arroyo Seco Watershed Management Plan and Education Program. http://www.arroyoseco.org/AS_Water_Budget.pdf.

CCWSC (Calleguas Creek Watershed Steering Committee), 2006. The Calleguas Creek Watershed Wetland Restoration Plan. http://www.calleguas.com/ccbrochure/ccwrp.PDF.

CDFFP (California Department of Forestry and Fire Protection), Teale Data Center GIS Solutions Group, and Tierra Data Systems, 1999. Calwater 2.2.1. http://gis.ca.gov/catalog/BrowseRecord.epl?id=30288.

CDM., 2005. Draft Technical Report: Watershed Management Plan for the San Gabriel River Above Whittier Narrows. http://www.rmc.ca.gov/plans/sgr_wmp.html.

CERES (California Environmental Resources Evaluation System), 1997a. McGrath Lake. http://ceres.ca.gov/wetlands/geo_info/so_cal/mcgrath_lake.html.

City of Thousand Oaks, 2003. Wastewater Collection and Hill Canyon Wastewater Treatment Plant. http://www.ci.thousand-oaks.ca.us/city_hall/depts/public_works/wastewater/default.asp.

Crowell, J. C., 1952. Geology of the Lebec Quadrangle, California. California Division of Mines Special Report 24.

CRWQCB (California Regional Water Quality Control Board, Los Angeles Region), 2003. 2002 Clean Water Act Section 303(d) List of Water Quality Limited Segments. http://www.swrcb.ca.gov/tmdl/docs/2002reg4303dlist.pdf.

CRWQCB. 2006. State of the Watershed – Report on Surface Water Quality The Santa Clara River Watershed. http://www.santaclarariverparkway.org/wkb/scrbiblio/rwqcb2006.

Department of Justice, 2005. Oil Companies Pay EPA to Settle Santa Monica MTBE Clean Up Costs. Feb 16. http://www.usdoj.gov/opa/pr/2005/February/05_enrd_067.htm.

Dowling, K., 2006. Waterscape Long Beach. http://pangea.stanford.edu/courses/gp104//waterscape/viewscaperk.php?entry=78.

DWR (California Department of Water Resources), 1961. Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County. Bulletin No. 104.

DWR. 1975. California's Ground Water. Bulletin 118.

DWR, 1994a. Dams within the Jurisdiction of the State of California. Bulletin 17-93.

DWR, 1994b. The California Water Plan Update. Bulletin 160-93, October 1994, Volume 1, Sacramento, CA. http://rubicon.water.ca.gov/v1cwp/sgw.html.

DWR, 1998. The California Water Plan Update. Bulletin 160-98, Volumes 1 and 2, Sacramento, CA. http://www.waterplan.water.ca.gov/previous/b160-98/TOC.cfm.

DWR, 1999. Watermaster Service in the Central Basin, Los Angeles County, July 1, 1998 – June 30, 1999.

DWR, 2004. California's Groundwater. Bulletin 118, 2003 update. http://www.groundwater.water.ca.gov/bulletin118/.

EIP Associates, 2004. Santa Clarita General Plan Technical Background Report. http://www.santa-clarita.com/vgp/tbr/SCV%20TBR%20(2004-02-27)%20-%20Web.pdf.

Ethington, P,J., Kooistra, A.M., and De Young, E., 2000. Los Angeles County Union Census Tract Data Series, 1940-1990 Version 1.01. Created with the support of the John Randolph Haynes and Dora Haynes Foundations. Los Angeles, University of Southern California.

Flood Protection Subcommittee, 1996. Flood Protection Report: Santa Clara River Enhancement and Management Plan (SCREMP). http://www.santaclarariverparkway.org/wkb/projects/scremp.

Fox Canyon Groundwater Management Agency United Water Conservation District, Calleguas Municipal Water District, 2006. Fox Canyon GMA Management Plan Draft. http://publicworks.countyofventura.org/fcgma/Reports/GMA%20Management%20Plan-Final%20Draft%20Feb07.pdf.

Goodridge, J., 1997. California's Rainfall Records: 1862-1997. CD ROM. CD produced by USDA Forest Service, Pacific Southwest Research Station, Arcata, California.

Guinn, J. M., 1890. Exceptional Years: A history of California Flood and Drought. Publications of the Histroical Society of Southern California I: pp. 33-39.

Heal the Bay, 2005. Fish Migration Barrier Severity and Steelhead Habitat Quality in the Malibu Creek Watershed. Produced for California State Coastal Conservancy and California Department of Parks and Recreation. http://www.healthebay.org/assets/pdfdocs/streamteam/SteelheadReport.pdf.

Hutchinson, M.F.,1995. Interpolating Mean Rainfall Using Thin Plate Smoothing Splines. International Journal of GIS 9, 305 403.

Hutchinson, M.F., 2004. ANUSPLIN Version 4.3. http://cres.anu.edu.au/outputs/anusplin.php.

Jennings, C. W., 1994. Fault Activity Map of California and Adjacent Areas with Location and Ages of Recent Volcanic Eruptions. California Geologic Data Map Series, Map No. 6. California Division of Mines and Geology.

Jones and Stokes, 2006. Malibu Lagoon Restoration and Enhancement Plan Draft. Prepared for: California Department of Parks and Recreation, Resource Conservation District of the Santa Monica Mountains, and the California State Coastal Conservancy. http://www.healthebay.org/currentissues/mlhep/.

Lebow, R., 1998. Southern California Climate. http://www.urbanedpartnership.org/target/fragile_habitats/climate.html.

Los Angeles County Sanitation Districts, 1997. State Of California State Water Resources Control Board Meeting Order No. WQ 78-7.

Los Angeles and San Gabriel Rivers Watershed Council, EIP Associates, and Heal the Bay, 2005. Compton Creek Watershed Management Plan. http://www.lasgrwc.org/publications.html.

LADPW (Los Angeles County Department of Public Works), 2002. LADWP Breaks Ground on Project to Bolster San Fernando Valley Water Quality. http://findarticles.com/p/articles/mi_m0EIN/is_2002_Nov_12/ai_94164532.

LADPW, 2004. Ballona Creek Watershed Management Plan. http://www.ladpw.org/wmd/watershed/bc/bcmp/masterplan.cfm.

LADPW, 2005. Urban Water Management Plan 2005. Prepared for LADWP Waterworks District No. 29, Malibu and The Marina del Rey Water System by Water Resources Unit. http://ladpw.org/wwd/web/docs/reports/District%20No.%2029%20-%202005%20Urban%20Water%20Management%20Plan.pdf.

LADPW and Dominguez Watershed Advisory Council, 2004. Dominguez Watershed Management Master Plan. http://ladpw.org/wmd/watershed/dc/DCMP/masterplan.cfm.

Metropolitan Water District of Southern California (MWD), 2007. Groundwater Assessment Study - A Status Report on the Use of Groundwater in the Service Area of the Metropolitan Water District of Southern California. Report Number 1308.

McCuen, R.H.: 2003. Modeling Hydrologic Change. Florida. CRC Press.

MIG and CDM, 2005. The Integrated Regional Water Management Plan. Prepared for Watershed Conservation Authority and County of Los Angeles Department of Public Works Watershed Management Division. http://www.ladpw.org/wmd/irwmp/index.cfm?fuseaction=documents.

Montgomery Watson, 2000. Groundwater and Surface Water in Southern California, A guide to Conjunctive Use.

National Park Service and Santa Monica Mountains National Recreation Area, 1999. Environmental Assessment: Circle X Environmental Assessment. http://www.nps.gov/archive/samo/cxea/cx1.htm.

National Hydrography Datasets (NHD), 1999, http://nhd.usgs.gov/newsletter_list.html.

Orsi, J., 2004. Hazardous Metropolis: Flooding and Urban Ecology in Los Angeles. University of California Press, Berkeley, CA.

Panaro, D., 2000. Fox Canyon Groundwater Management Agency. Written Communication to R.R. Davis (DWR). March 21.

PRC Environmental Management, Inc., 1996. Remedial Investigation Technical Memorandum, Installation Restoration Program, NAWS Pt. Mugu. 14 volumes.

Saint, P. K., Hanes, T. L., and Lloyd, W. J., 1993. Waterbodies, Wetlands and Their Beneficial Uses in the Los Angeles Region. (4) Volume 2: Wetlands and Their Beneficial Uses. 220 pp.

Sanitation Districts of Los Angeles County, 2006. San Jose Creek Water Reclamation Plant. http://www.lacsd.org/csdhome1.htm.

Schwarz, J., 1991. A Water Odyssey: The Story of Metropolitan Water District of Southern California. Los Angeles. Metropolitan Water District of Southern California.

Setmire J.G., 1985. A Conceptual Ground-Water-Quality Monitoring Network for San Fernando Valley, California. U.S. Geological Survey Water Resources Investigations Report 84-4128.

Sheng, J., Wilson, J. P., Chen, N., Devinny, J.S., and Sayre, J.M., 2007. Evaluating the Quality of the National Hydrography Dataset for Watershed Assessments in Metropolitan Areas, GIScience and Remote Sensing 44, 283-304.

Slade, R. C., 1990. Assessment of Hydrogeologic Conditions Within Alluvial and Stream

Terrace Deposits, Acton Area, Los Angeles County. Prepared for County of Los Angeles, Department of Public Works and ASL Consulting Engineers.

Southern California Associated Governments, 2001. http://www.scag.ca.gov/.

Southern California Earthquake Data Center (SCEDC), 2006. Faults of Southern California, Los Angeles Region. http://www.data.scec.org/faults/lafault.html.

State of California Resources Agency, 2001. San Gabriel and Los Angeles Rivers Watershed and Open Space Plan. http://www.rmc.ca.gov/projects/commonground.html.

Strahler, A. N.,1952. Dynamic Basis of Geomorphology. Geological Society of America Bulletin, 63, 923-938.

The California Resources Agency, San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy, Santa Monica Mountains Conservancy, 2001. Common Ground from the Mountains to the Sea-Watershed and Open Space Plan San Gabriel and Los Angeles Rivers. http://www.rmc.ca.gov/plans/common_ground.html.

The Department of City Planning, 2002, Draft Environmental Impact Report City of LA EIR. No. 2003-1922 (EIR). http://www.lacity.org/pln/EIR/WestchesterDEIR/WCIntro.pdf.

Topanga Canyon Floodplain Management Citizens' Advisory Committee, 1996. Topanga Creek Watershed Management Study. Prepared for Los Angeles County Board of Supervisors. http://www.topangaonline.com/twc/water/TACR.html.

ULARAW (Upper Los Angeles River Area Watermaster), 1999. Watermaster Service in the Upper Los Angeles River Area. Los Angeles County; 1997-98 Water Year, Los Angeles California.

ULARAW, 2006. Watermaster Service in the Upper Los Angeles River Area. Los Angeles County; 2004-05 Water Years. Los Angeles California.

USDA (United States Department of Agriculture), 2003, Comprehensive River Management Plan Sespe. http://www.fs.fed.us/r5/lospadres/documents/crmp/sespe-plan.pdf.

URS Cooperation, 2004. Flood Mitigation Plan for Ventura County, California. Prepared for Ventura County Watershed Protection District. http://www.countyofventura.org/rhmp/docs/FMP-Section%201.pdf.

U.S. Census Bureau, 2001. The Federal State Cooperative Program for Population Estimates. http://www.census.gov/population/www/coop/estimates.html.

USDA Natural Resources Conservation Service, 1995. Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon. http://gis.ca.gov/catalog/BrowseRecord.epl?id=3447.

USACE-Los Angeles District Reservoir Regulation Section, 1990. Water Control Manual Hansen Dam Tujunga Wash, Los Angeles County, California.

USACE-Los Angeles District Reservoir Regulation Section. 1990b. Water Control Manual Brea Dam Brea Creek, Los Angeles County, California.

USACE-Los Angeles District, Reservoir Regulation Section. 1991. Water Control Manual, Santa Fe Dam and Reservoir, San Gabriel River, California. www.spl.usace.army.mil/resreg/htdocs/SantaFe/Chapter3.pdf.

USACE-Los Angeles District Reservoir Regulation Section, 1997. Santa Fe Dam. http://www.spl.usace.army.mil/resreg/htdocs/snfe.html.

USEPA (U.S. Environmental Protection Agency), 2002. National Priorities List Sites in California. http://www.epa.gov/superfund/sites/npl/nar937.htm.

USEPA, 1999. San Gabriel Valley (Area 1) Interim Record of Decision - San Gabriel Valley Superfund Site, El Monte Operable Unit Los Angeles County, California. http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/webdisplay/oid-35739ac0c0b0bcc7882569b00004b6ea?OpenDocument.

USGS, 2003. Geologic Setting of the Transverse Ranges, Province Southern California Geology, Southern California Areal Mapping Project (SCAMP). http://scamp.wr.usgs.gov/scamp/html/scg_prov_trans.html.

U.S.Water Resources Council, 1981, Guidelines for Determining Flood Flow Frequency. U.S. Water Resources Council Bulletin 17B, 28 p.

UWDC (United Water Conservation District) and Castaic Lake Water Agency, 1996. Water Resources Report on the Santa Clara River, http://www.santaclarariverparkway.org/wkb/scrbiblio/scrempwater.

UWCD, 1996. AB3030 Groundwater Management Plan for Piru/Fillmore Basins. 30 pp.

UWCD, 1999. Surface and Groundwater Conditions Report: Water Year 1998. 64 pp.

UWCD, 2001. Surface and Groundwater Conditions Report Water Year 2000 Supplement. Prepared by Groundwater Resources Department. September. http://www.unitedwater.org/report/adcr/.

VCWPD(Ventura County Public Works Agency Watershed Protection District), 1996. Ventura County Groundwater Quality Assessment Report. 57 p.

VCWPD, 2003. Calleguas Creek Watershed Study Present Condition. http://www.calleguascreek.org/ccwmp/.

VCWPD, 2005. Integrated Watershed Protection Plan, Ventura County. May http://water.lgc.org/ventura/ventura-resources/IWPP%20Summary%20Report%20Zone%203.pdf/view.

Wikipedia, the free encyclopedia. Rindge Dam. http://en.wikipedia.org/wiki/Rindge_Dam. Retrieved on May 2nd, 2006.