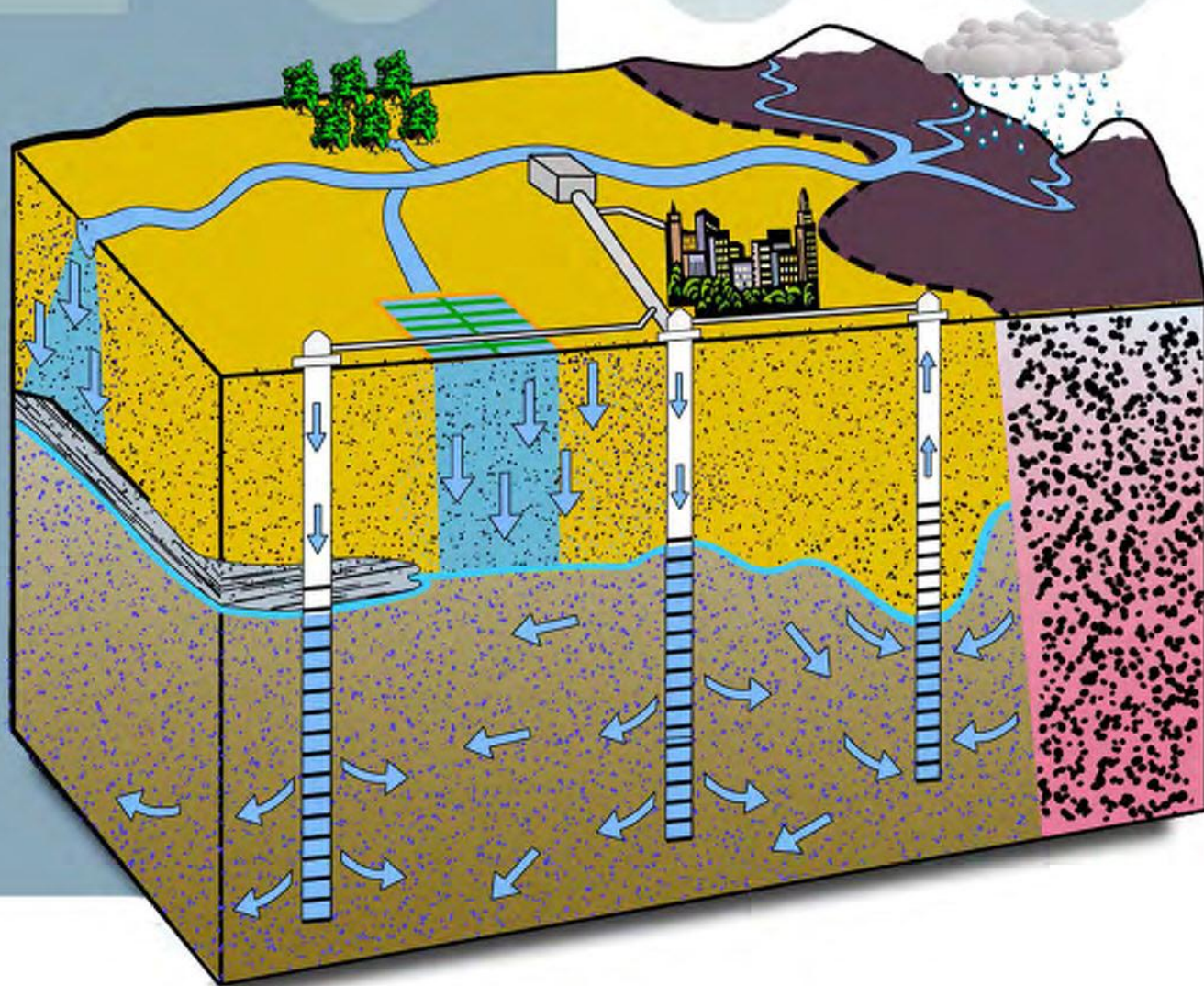


GROUNDWATER AND SURFACE WATER IN SOUTHERN CALIFORNIA

A GUIDE TO CONJUNCTIVE USE

Published by the Association of Ground Water Agencies



PREPARED FOR:



BY:



MONTGOMERY WATSON



L004310

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Background

The Association of Ground Water Agencies, or AGWA, was formed in 1994 by a group of eight groundwater basin management agencies. In 1995, it was incorporated in Southern California as a nonprofit Public Benefit Corporation.

Mission Statement

The mission of the Association of Ground Water Agencies is to promote interagency solutions that enhance the quality and management of groundwater resources.

AGWA's purpose is to create a forum for the discussion of groundwater issues for management of our groundwater basin resources, and to take action in connection with these. AGWA's primary objectives are to:

- promote enhanced management of groundwater basins
- improve the reliability of existing groundwater supplies
- assure the protection and enhancement of groundwater quality

Members and Affiliates

Membership in AGWA consists of Members and Affiliates. Membership as of July 1999 is listed below.

Members

Colleguas Municipal Water District
Chino Basin Watermaster
Eastern Municipal Water District
Kern County Water Agency
Main San Gabriel Basin Watermaster
Mojave Water Agency
Orange County Water District
Raymond Basin Management Board
San Bernardino Valley Water Conservation District
Six Basins Watermaster
Tehachapi-Cummings County Water District
Upper Los Angeles River Area Watermaster
Water Replenishment District of Southern California
Western Municipal Water District

Affiliates

Basic Compliance Engineering
Bookman-Edmonston Engineering
Cadiz, Inc.
CH2M Hill
Kornex H2O Science
Metropolitan Water District of Southern California
Montgomery Watson
Narver Associates
Pozmas and Associates
City of Riverside
San Gabriel River Water Committee
Setson Engineers, Inc.

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<http://www.water-ed.org>



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Executive Summary

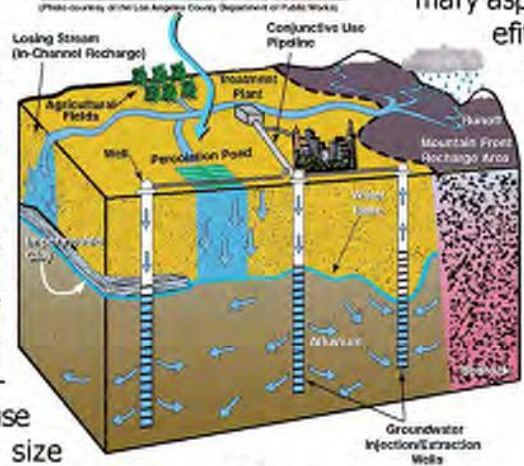
Groundwater (underground water) is a critical component of California's water supply. The semi-arid climate of California has prompted the development of our groundwater resource to supplement our surface water supply. Some critical facts about groundwater include:

- The amount of underground water stored in California is far greater than that stored in the state's surface water reservoirs, although only a portion of these groundwater resources can be practically and economically extracted for use.
- Groundwater serves as our only supply in those areas of the state isolated from surface water connections.
- In an average year, groundwater meets about 30 percent of California's urban and agricultural water need. In drought years, when surface supplies are reduced, groundwater supports an even larger percentage of use.
- As the state-wide population continues its growth toward a projected 47.5 million people by 2020, the demand for water will continue to increase and further development of our groundwater resources will help meet this demand.

- Meeting this demand will require significant improvements and innovations in how we optimize our existing water supplies. One of these ways is the storage of excess water during wet years beneath the ground for use during dry years. **This coordinated management of surface water and groundwater is called conjunctive use.**

The Association of Ground Water Agencies (AGWA), representing major groundwater basin management agencies throughout Southern California, formed in 1994 to promote interagency solutions that enhance the effective management of groundwater resources, especially conjunctive use. Focusing on 18 major Southern California groundwater basin groupings, this AGWA publication represents the most comprehensive evaluation to date of the potential to significantly improve the coordinated use of surface water and groundwater to meet California's water needs. Based on a survey of groundwater basin managers, this document describes areas where conjunctive use is (or may be) a viable groundwater basin management option, and will serve as a useful educational tool for teachers, legislators, elected officials, lay people, and technicians.

By no means a new concept, conjunctive use was first used in California during the Spanish mission era. Ongoing since the 1940s and shown in the photo on the next page, the spreading of surface water in Los Angeles County provides critical recharge of the underlying groundwater basins. Conjunctive use programs vary in size and type, depending on the specifics of a groundwater basin. The following figure depicts some of these storage and retrieval methods. Through the preparation of this guide, **AGWA has documented that over 21.5 million acre-feet of additional groundwater storage is available in Southern California groundwater basins, enough to fill Diamond Valley Lake, our largest surface water reservoir, 26 times.** One acre-foot of water is approximately 326,000 gallons, enough water to cover a football field to a depth of one foot. This stored water could be used during times of drought or natural disaster when surface water supplies are not available. This storage would reduce some of the need for the construction of large dams and reservoirs, which are expensive and often viewed as environmentally unfriendly.



This Guide represents the culmination of that effort, providing overviews for each of the 85 individual groundwater basins evaluated and grouped onto 18 maps. The Guide also explores five primary aspects of conjunctive use: 1) need, 2) benefits, 3) methods, 4) governance, and 5) potential problems.

In summary:

- Conjunctive use is a well-proven method to increase our ability to meet California's increasing water demand.
- Conjunctive use improves water supply reliability.
- The need for environmentally controversial surface water reservoirs may be reduced by conjunctive use programs.
- Assuming resolution of institutional, water quality, and other issues, over 21.5 million acre-feet of additional water can be stored and used in Southern California groundwater basins.

Summary of Long-Term Storage Potential of the Basins Included in This Guide.

Basin Groupings	Potential Storage for Use in Dry Years* (Acre-Feet)
Kern County Basin	8,000,000
Tehachapi/Cummings Basin	Not Available as of July 2000
Ventura County Basins	500,000
San Fernando Valley Basins	150,000
Raymond Basin	144,000
San Gabriel Basin	400,000
Los Angeles Coastal Plain Basins	1,089,000
Orange County Coastal Plain Basin	300,000
Six Basins	30,000
Upper Santa Ana River Basins	1,854,000
Bunker Hill Basin	0
San Jacinto Watershed Basins	1,284,000
Upper Santa Margarita River Basins	200,000
San Diego County Basins	270,700
Mojave River Basins	1,790,100
Hayfield Basin	500,000
Codiz Valley Basin	1,000,000
Coachella Valley Basin	4,000,000
TOTAL	21,511,800

* Calculated by groundwater basin managers

To evaluate this storage potential, AGWA surveyed each of the groundwater basin managers to obtain data used in this study. Montgomery Watson assisted AGWA in the analysis of data and presentation of survey results. The Water Education Foundation prepared the overview of conjunctive use. In analyzing each basin, this Guide includes information on basin location, basin management (governance), available storage, present operational safe yield, and basin sediments (geology).

A Guide to Conjunctive Use in Southern California

What is Conjunctive Use?

Conjunctive use is the coordinated management of **surface water** and **groundwater** supplies to increase the yield of both. The conjunctive use concept is intended to increase total supplies and enhance water supply reliability.

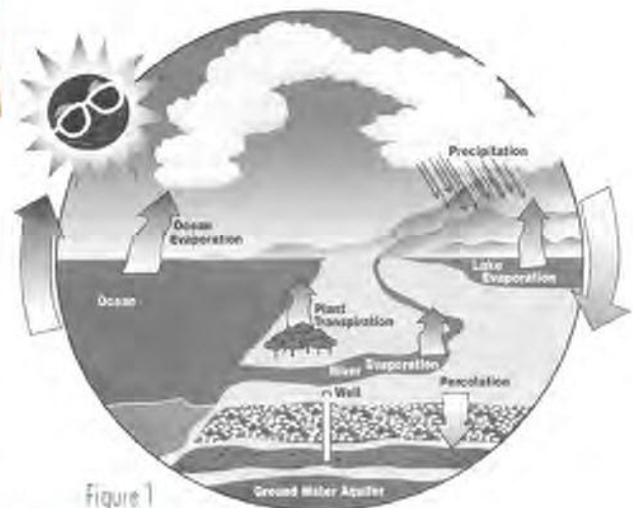


Figure 1
The Hydrologic Cycle
(courtesy of
Water Education Foundation)

Why Conjunctive Use?

Water is essential to life in California. It fuels industries, grows crops, provides habitats for thousands of plant and animal species, and allows over 33 million Californians a cool, refreshing drink.

In nature and without our intervention, water is continuously recycled. Water evaporates from oceans, lakes, streams and rivers, condenses into clouds, and returns to earth as precipitation, most commonly, in the form of rain and snow. From there, rain and melted snow flow back into lakes, rivers and oceans, replenishing these surface supplies and continuing the **hydrologic cycle** (Figure 1). Though much of California's water comes from these surface supplies, water from the surface also percolates into the ground creating California's largely unseen water supply: **groundwater**.

In California, on average, 15 million acre-feet (one **acre-foot** of water is approximately 326,000 gallons, enough water to cover a football field to a depth of one foot or supply one to two families for a year) of **groundwater** (underground water) are extracted from wells each year. With more than half of all Californians relying on **groundwater** for at least a portion of their water supply, **groundwater** supplies approximately 25-30 percent of California's water needs. The state's population is expected to reach 47.5 million by 2020 and approximately one-half (7 million people) of this growth is anticipated to occur in Southern California (Figure 2). With this growth will come an increased reliance on **groundwater**.

Benefits of Conjunctive Use

Predicted increases in population are compounded by the fact that California has the distinction of being very vulnerable to changing hydrologic conditions brought on by periods of floods and droughts. Our water system has been engineered to handle this fluctuating water cycle by building a

As defined previously, conjunctive use is the coordinated management of **surface water** and **groundwater** supplies to increase the yield of both. It is intended to increase total supplies and enhance water supply reliability—in essence to rely more on **surface water** supplies during wet or normal years and **groundwater** in dry years. This process can be enhanced by storing excess water supplies underground during wet years for use during the dry year—a form of drought proofing. Figures 3 and 4 illustrate the concept of conjunctive use and methods commonly used to introduce and remove **groundwater** from the subsurface.

Currently, during droughts, the state turns to aquifers as if they were savings accounts — relying on **groundwater** for as much as 60 percent of a year's supply to keep farm fields in production and urban areas supplied with water. In addition, Southern California receives a large part of its water from the Sacramento-San Joaquin Delta near San Francisco, Owens Valley east of the Sierra, and the Colorado River— all of which are subject to changing conditions from wet years to droughts.

The potential for conjunctive use projects is phenomenal given that **aquifers** in the state hold 850 million **acre-feet** of water, nearly 20 times the amount of water that can be stored behind all of California's dams. However, some of this amount may not be usable because of **salt water intrusion**, **subsidence**, poor quality, or high pumping costs. If California were flat, the volume of its **groundwater** would be enough to flood the entire state eight feet deep! In addition to a more assured supply of water during dry years, conjunctive use also can reduce pumping costs for water users because of the decreased lift. With more water in the aquifer, water is closer to the surface and therefore requires less energy (and money) to pump it out. Conjunctive use also can maximize water use more efficiently than **groundwater** and **surface water** projects operated separately — allowing for greater conservation.

Other advantages of conjunctive use include the ability to use and expand upon existing facilities, thus allowing for easier integration and a staged

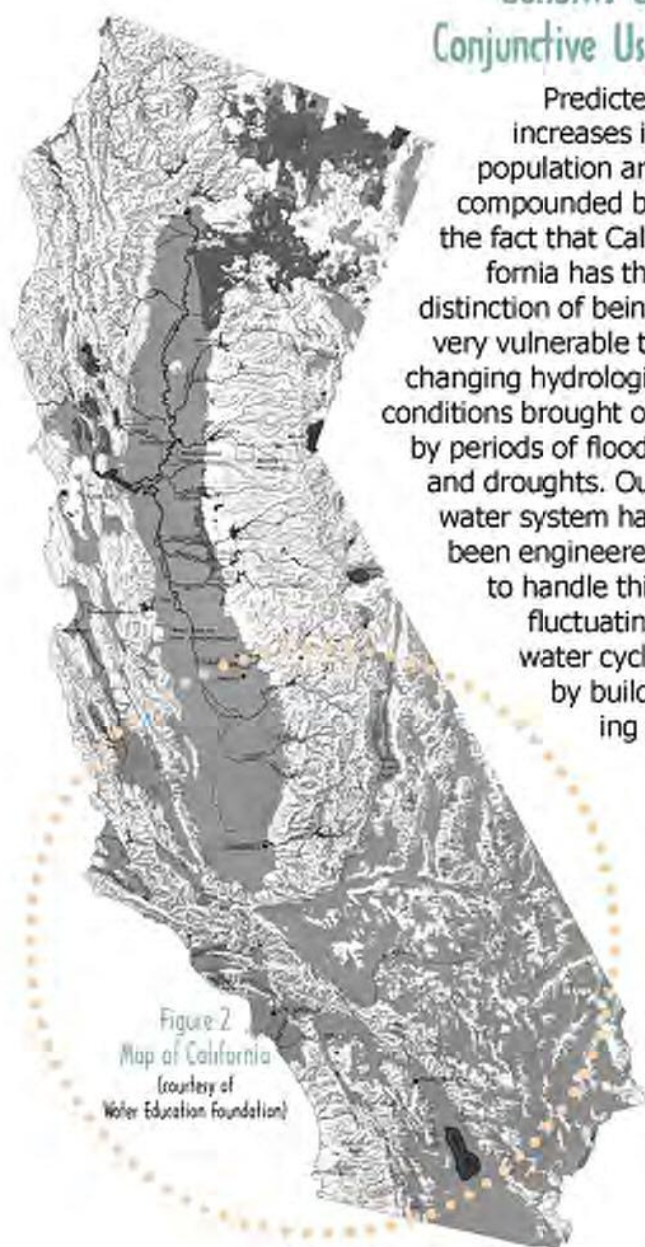


Figure 2
Map of California
(courtesy of
Water Education Foundation)

series of large, above-ground reservoirs to hold water when it is needed. Despite the integral role that above-ground reservoirs can have in conjunctive use, they are expensive to build and are viewed by some as environmentally damaging. Thus, greater use of storage capacity in **aquifers** via conjunctive use has become an increasingly popular alternative for water storage, thereby improving California's water supply.

development approach; a smaller drainage system; fewer costs from canal lining; reduced **evapotranspiration** losses; reduced danger from dam failure; and improved timing of water distribution. Other possible advantages and possible disadvantages are listed in Table 1. Actual advantages and disadvantages will vary by project.

Another method, **in-lieu recharge**, works on the idea of reducing the amount of water pumped from the **aquifer**. That is, those who would normally rely on **groundwater** wells to meet their water needs instead use excess surface water supplies when available. This allows **groundwater** supplies to be replenished indirectly.

Methods of Conjunctive Use

Conjunctive use can be applied in several ways. One method uses **artificial recharge** by placing the water directly into the **aquifers** through **percolation** and/or injection. **Percolation** occurs naturally as part of the **hydrologic cycle** but can be enhanced by creating spreading basins atop **aquifers**. Water also can be put into an **aquifer** using wells and pumps to inject water.



(Photo courtesy of the Los Angeles County Department of Public Works)

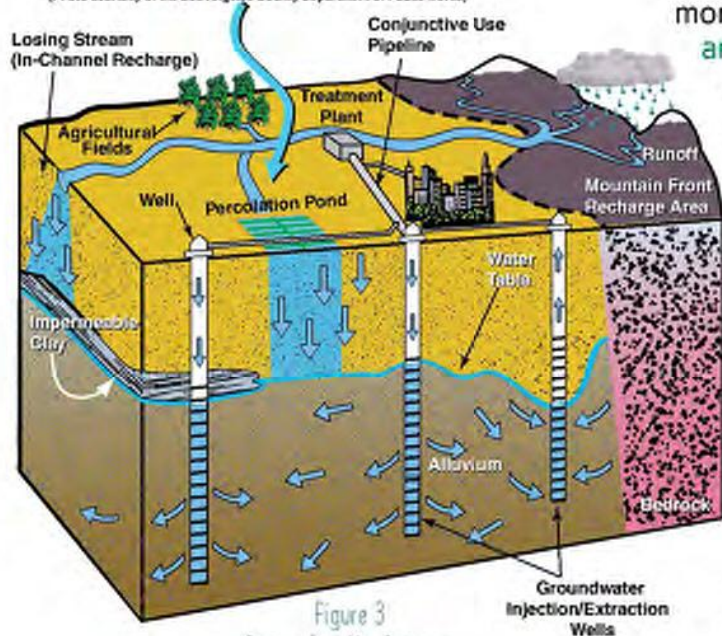


Figure 3
Conjunctive Use Program
Wet or Normal Year Operation

Rules Governing Conjunctive Use

In **groundwater** basins where **overdraft** occurs, **groundwater** users may work with the court to adjudicate a **groundwater** basin. Adjudication allows specific water rights to water users and compels the cooperation of pumpers. In other words, in adjudicated basins, the amount of **groundwater** that may be pumped annually by users is limited. This limit is generally based on the concept of "**safe yield**"—the amount of water that can be pumped each year without causing a continual reduction of water in storage (**overdraft**). The **safe yield** is dependent upon the average amount of water that can be stored in and used from the **groundwater** reservoir over a period of normal water supply under a given set of conditions. The **safe yield** of the basin, in some cases, can be substantially augmented by engineering controls. For example, more water can be made available through **artificial recharge** by spreading or injection wells, or by lowering **groundwater** levels to reduce **evapotranspiration**, to capture rejected **recharge**, or to capture surface water from streams. **Safe yield** augmented by such engineering controls is referred to as "**operational yield**" in this guide.

Of the 18 groundwater basins adjudicated in California, 17 lie in Southern California, primarily due to development pressures and an absence of adequate natural surface water supplies.

Another tool which helps manage groundwater use is AB 3030 (California Water Code Sections 10750-10756). Passed in 1992 by the State Legislature and placed into effect on January 1, 1999, this measure is intended

Table 1

POSSIBLE ADVANTAGES AND DISADVANTAGES OF USING AQUIFERS FOR STORING WATER UNDERGROUND*	
Possible Advantages	Possible Disadvantages
Water quality improvement	Less hydroelectric power through avoidance of dam construction
Water supply reliability	Greater power consumption to extract groundwater
Greater water conservation	Increase in salt loading
Decreased dependence on imported supply during dry years and emergencies	More involved project operation
Less additional surface storage required	More difficult cost allocation
Fewer drainage system improvements	Over-pumping may cause land subsidence
Greater flood control	Liquefaction from shallow groundwater levels
Ready integration with existing development	May require active control of salt water intrusion
Storage programs can be phased	May cause contaminant movement
Low evaporative losses	Increased groundwater monitoring
Improvement of power load and pumping plant use factors	Increased need for diversion and/or conveyance of surface water during wet years
Less threat from dam failure	
Better timing of water distribution	

* NOTE: Specific possible advantages and disadvantages will vary from project to project and should be evaluated on a case-by-case basis.

to provide local water agencies with the ability to tailor groundwater management plans to meet problems in their area (subsidence, salt water intrusion, contamination). The law does not allow local districts to impose binding water rights on pumpers but does, after a general election, allow them to impose fees on pumping. Additionally, in the 1994 case of *Baldwin v. County of Tehama*, it was determined that state law does not preclude cities and counties from regulating groundwater.

Problems Facing Conjunctive Use

Conjunctive use projects should be actively managed to avoid problems such as overdraft and pollution.

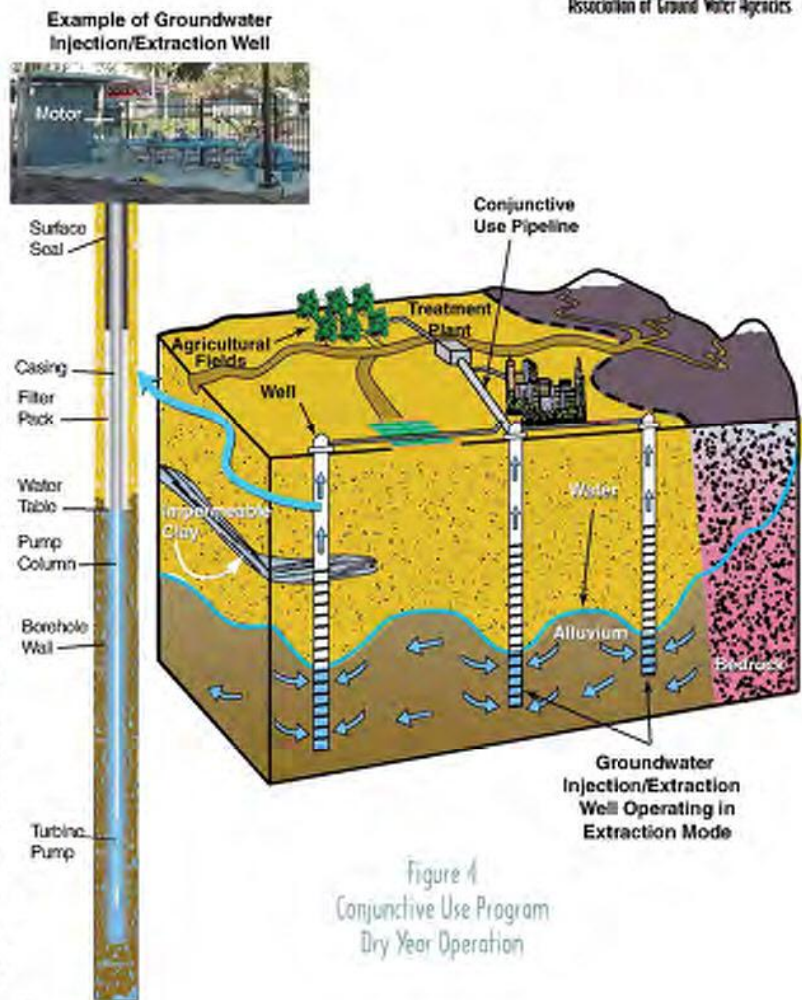
According to the California Department of Water Resources, in an average year, Californians use approximately 1.3 million acre-feet more groundwater than is either naturally or artificially

recharged. This groundwater overdraft can create problems including subsidence and salt water intrusion. Additionally, increasing basin yield may necessitate large fluctuations in water levels, which can contribute to these problems.

Subsidence may occur when too much groundwater is pumped and the subsurface sediments are drained. Once drained, these sediments can compact under the weight of the overlying soil, creating depressions and fissures at the ground surface.

Salt water intrusion also can result from lowering of water levels in an aquifer. For example, drawing large volumes of groundwater out of an aquifer can cause groundwater levels to be lower than sea level. When this occurs in a coastal location, seawater has a higher elevation than groundwater, thereby enabling seawater to flow from a higher elevation to a lower elevation into the aquifers and toward the areas where the groundwater was removed. Once salt water infiltrates a groundwater basin, water quality can be seriously degraded. Since the 1950s and 1960s, water agencies have combated this problem by injecting surface water into the ground or by recharging water in spreading basins. By doing so, a hydraulic barrier is created between the freshwater aquifer and the intruding salt water.

Pollution from both naturally occurring and man-made contaminants also can cause problems for groundwater users. Radon and arsenic, both natural byproducts of decaying rocks, occur in various areas throughout California. Contaminants from urban and agricultural centers can result from leaking gasoline tanks, sewers, landfills, industrial waste discharges, fertilizers, pesticides, and failed septic systems. In Southern California, fuels and solvents – the byproduct of military bases and private industries that support defense efforts – have been



found in several groundwater basins including the San Gabriel and San Fernando Valleys. These sites are being cleaned up under the supervision of local, state and federal agencies. High concentrations of nitrates and total dissolved solids resulting from agricultural activities also pose serious threats to groundwater quality.

Increased monitoring, detection and advanced treatment techniques are helping to curb these threats to groundwater.

Additional problems facing conjunctive use projects may include less new hydroelectric power production due to fewer new dams; decreased well pumping efficiency; more complex project operations and consequently, more difficult cost allocations; and the reliance on artificial recharge to keep the project operating.

Conjunctive Use Potential In Southern California

In preparation of this document, AGWA surveyed and collected information from 25 management agencies for approximately 85 individual **groundwater** basins in Southern California. The managers were asked to provide the following information for each basin:

- Conjunctive Use
- Replenishment Activities
- Overview of Groundwater Basin
- Water Supply and Demand
- Type of Aquifers Within Basin
- Basin Size
- Basin Storage Capacity

This information is presented on 18 maps showing individual basins or basin groupings. Figure 5 is an index map showing the relative locations of the 18 basin groupings featured in the guide. The configuration and location of basins shown on Figure 5 were taken from "California's Groundwater," published by the Department of Water Resources as Bulletin Number 118, in 1975. The numbering system shown on Figure 5 is arbitrarily assigned for this guide and generally progresses from north to south and west to east. The individual basin maps are provided on the following pages. Basin boundaries and descriptive information have been provided by the basin managers unless otherwise noted. A contact list of basin managers is included at the end of this report.



Figure 5
Index Map Showing the Relative Location
of Basin Groupings Featured in the Guide

1. Kern County Basin

Location

The Kern County Groundwater Basins are made up of many differing geologic and climatic areas. This report focuses on that portion which occupies the southern San Joaquin Valley, which is a broad alluvial, north-west-trending structural trough that constitutes the southern two-thirds of the Central Valley. The Basin is located within the Tulare Lake hydrologic region and is bounded on the north by the Kern County line, on the east by the Sierra Nevada foothills, on the south by the Tehachapi Mountains, and on the west by the Coast Ranges. The principal watershed is drained by the Kern River. Surface area of the Basin overlying viable groundwater is approximately 960,000 acres (1,566 square miles).

Basin Management

The Central Valley portion of the Kern County Groundwater Basin is an un-adjudicated Basin, which is managed through cooperative programs of individual Water Districts, the County of Kern, and the Kern County Water Agency. The Agency serves as a local contracting entity for the State Water Project (SWP). One of the primary purposes for the importation of SWP water into Kern County is to improve groundwater conditions within the Basin. Water management practices exercised by the Agency, the County, the City of Bakersfield and other Districts include the following:

- Groundwater recharge for overdraft correction and banking
- Importation to meet annual water requirements, and for conjunctive use and banking
- Population control
- Determination of groundwater storage
- Administration of water well ordinance
- Coordination with land use planning
- Controlling saline water intrusion
- Identification and management of recharge areas
- Groundwater quality and level monitoring
- Administration of groundwater quality and level databases

The Agency also administers Improvement District No. 4 (ID4), a successful conjunctive use program in the Metropolitan Bakersfield area. ID4 was created in 1971 to provide a supplemental surface water supply to augment local groundwater resources and to reduce the reliance on groundwater. ID4 has an annual entitlement of approximately 65,000 acre-feet from the SWP, approximately 60% to 70% of which is placed into groundwater storage by direct recharge and the remainder is delivered for urban use in-line of pumping groundwater through the Henry G. Garnett Water Purification Plant.

The Agency also administers Improvement District No. 4 (ID4), a successful conjunctive use program in the Metropolitan Bakersfield area. ID4 was created in 1971 to provide a supplemental surface water supply to augment local groundwater resources and to reduce the reliance on groundwater. ID4 has an annual entitlement of approximately 65,000 acre-feet from the SWP, approximately 60% to 70% of which is placed into groundwater storage by direct recharge and the remainder is delivered for urban use in-line of pumping groundwater through the Henry G. Garnett Water Purification Plant.

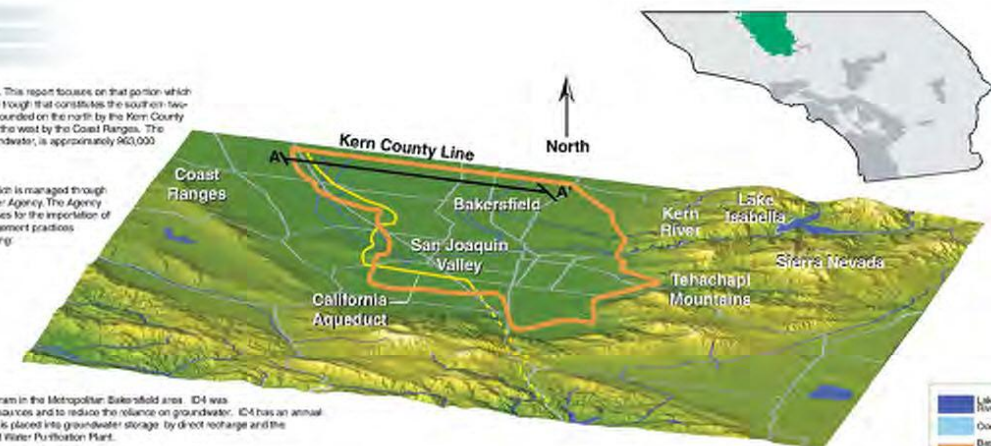
Groundwater banking programs differ from conjunctive use in that water may be imported to the basin for storage then may be exported from the basin for use by the entity banking the water. Conjunctive use programs typically are designed to help meet the water requirements of the users overlying the basin. Current conjunctive use and banking programs include the following programs for overlying users and bankers:

Banking Programs

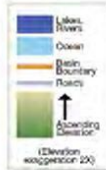
NAME	STORAGE (MAF)	ANNUAL YIELD (AF/Y)
- Kern Water Bank Authority Banking Project	1	227,000
- Agency Pioneer Recharge and Recovery Project	4	98,000
- Joint Agency and Bernardo Mesa Water District Banking Project	2	46,000
- Arvin-Edison Water Storage District MWD Banking Project	25	49,000
- City of Bakersfield - 2900 Acre Spreading Grounds	3	45,000
- Semitropic Water Storage District Banking Project with Metropolitan Water District Water, Alameda County Water Agency, Santa Clara Water District	1	223,000
- District, Vidler Water Company, Zone 7 Water Agency		
- Buena Vista Water Storage District and West Kern Water District Recharge and Recovery Projects	25	45,000

Overlying Use Programs

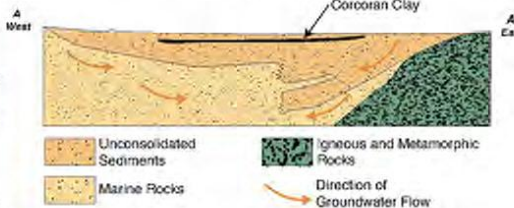
NAME	DEWATERED STORAGE (MAF)	ANNUAL WATER REQUIREMENTS (AF/Y)
- Arvin-Edison WSD	2.9	337,000
- Buena Vista WSD	0.3	134,000
- Corwillo WD	0.6	142,000
- Delano-Earhart ID	0.1	32,000
- Henry Miller	0.5	60,000
- ID4	3	119,000
- Kern Delta WSD	0.7	412,000
- North Kern WSD	0.9	212,000
- Rosedale-Rio Bravo WSD	0.4	111,000
- Semitropic WSD	2.2	544,000
- Shafter-Wasco ID	4	116,000
- Southern San Joaquin MUD	0.4	161,000
- Wheeler Ridge - Maricopa Water Storage District	2.0	345,000
- Kern-Tulare and Rag Gulch Water Districts	0.5	58,700



(Not to Scale)



Cross Section A-A'



(From USGS, 1965, Professional Paper 1401-C)

Available Storage

De-watered storage space is estimated to be about 12 million AF. Storage space used for current Banking Projects is about 4 million AF. Remaining de-watered space available for additional banking and overdraft correction is estimated to be 8 million AF.

Present Operational Safe Yield

The natural recharge of the Basin is about 160,000 AF/Y. The increase in operational yield for overlying users due to importation and conjunctive use is about 2 million AF/Y.

The maximum dry year recovery capacity of the Banking Projects is currently about 785,000 AF/Y provided enough water can be imported and placed into storage for recovery. The future increase in dry year recovery capacity is about 204,000 AF/Y provided increases in delta diversions or other surface supplies are made available.

Basin Sediments

Sediments that comprise the Basin are unconsolidated deposits of Tertiary and Quaternary age. These deposits include alluvium, lacustrine, deltaic, and flood-basin deposits consisting of sand and gravel with thin lenses of silt and clay, as well as the Tulare and Kern River Formations. In northeastern Kern County some water production is derived from the Santa Margarita and Clovis Formations. Unconsolidated sediments overlie the igneous and metamorphic basement complex of the Sierra Nevada to the east and marine rocks of the Coast Ranges to the west.

In the eastern third of the Basin, groundwater occurs primarily under unconfined and semi-confined conditions. In the north-central portion of the Basin the Corcoran Clay is present at depths from 300 to 600 feet. Below the Corcoran Clay, groundwater is confined.

The major sources of natural recharge are infiltration of rainfall on the valley floor and percolation of runoff from the Kern River and adjacent mountains. The Basin also receives imported water from the SWP and Federal CVP and return flow from applied water.

Conjunctive Use Potential

The results of ASWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 2,000,000 AF/Y. Additionally, the survey indicated the potential to store up to 8,000,000 AF of water for use in dry years and a potential increase in basin operational yield of 284,000 AF/Y.

2. Tehachapi/Cummings Basin

Location

The Tehachapi/Cummings Groundwater Basin is located between the southern end of the Sierra Nevada and the northeastern side of the Tehachapi Mountains. The Tehachapi/Cummings Groundwater Basin includes the Tehachapi Basin, Cummings Basin, and Britte Basin. Britte Basin is generally located between the Cummings and Tehachapi Basins but is not shown on the map because it lacks distinct boundaries. The basin is bounded on all sides by crystalline bedrock. The surface areas of the basins are as follows:

- Tehachapi Basin, 59 square miles (63,500 acres)
- Cummings Basin, 38 square miles (24,800 acres)
- Britte Basin, 12 square miles (7,900 acres)

Basin Management

The basin is adjudicated and is managed by the Tehachapi-Cummings Water District (Watermaster).

Available Storage

Not available as of July 2000.

Present Operational Safe Yield

The present operational safe yield of Tehachapi Basin is 5,500 acre-feet per year (AFY) and 4,090 AFY for Cummings Basin, and 500 AFY for Britte Basin (not shown on map), yielding a combined total operational safe yield of 10,090 AFY.

Basin Sediments

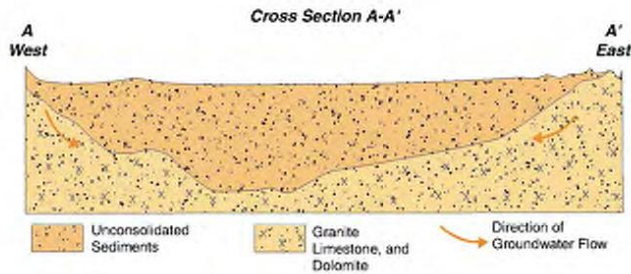
Basin sediments consist of unconsolidated deposits underlain by marine rocks.

Conjunctive Use Potential

The Tehachapi-Cummings Water District is currently conducting studies to determine the conjunctive use potential of the basin.



(Not to Scale)



3. Ventura County Basins

Locations

The groundwater basins of Ventura County are located beneath the Oxnard Coastal Plain and in the surrounding river valleys. The four largest valleys consist of the Santa Clara River Valley, Pleasant Valley, Arroyo Santa Rosa Valley, and Las Posas Valley. In total, there are 32 groundwater basins in Ventura County. Of these 32 basins, the 14 basins having total storage capacities in excess of 50,000 acre-feet (AF) each are listed and shown on this basin map.

Basin Management

The groundwater basins are generally not managed by a particular agency with the following noted exceptions:

Basin	Management Structure
Oxnard Coastal Plain and Forebay	State Legislation and Ordinances
Fillmore Basin	AB-3030 Plan and United Water Conservation District
Santa Paula Basin	United Water Conservation District
Piru Basin	United Water Conservation District
Arroyo Santa Rosa Basin	State Legislation and Ordinances
North Las Posas Basin	State Legislation and Ordinances

The Calleguas Municipal Water District (CMWD) and the Metropolitan Water District of Southern California (MWD), are currently developing a conjunctive use program in the North Las Posas Basin. The program calls for MWD to finance up to 30 injection and pumping wells in the basin. MWD will have the right to store up to 210,000 AF of water in the basin. During times of need, MWD will decrease its surface water deliveries to CMWD and replace that water with stored water extracted from the North Las Posas Basin.

Available Storage

The freshwater storage capacity of all Ventura County groundwater basins is 32,000,000 AF. Approximately 27,400,000 AF are currently in storage with 500,000 AF of available storage potential.

Present Operational Safe Yield

The present operational safe yield of the Basins of Ventura County is 176,538 acre-feet per year (AFY). Future operational yield is anticipated to increase by 87,600 AFY.

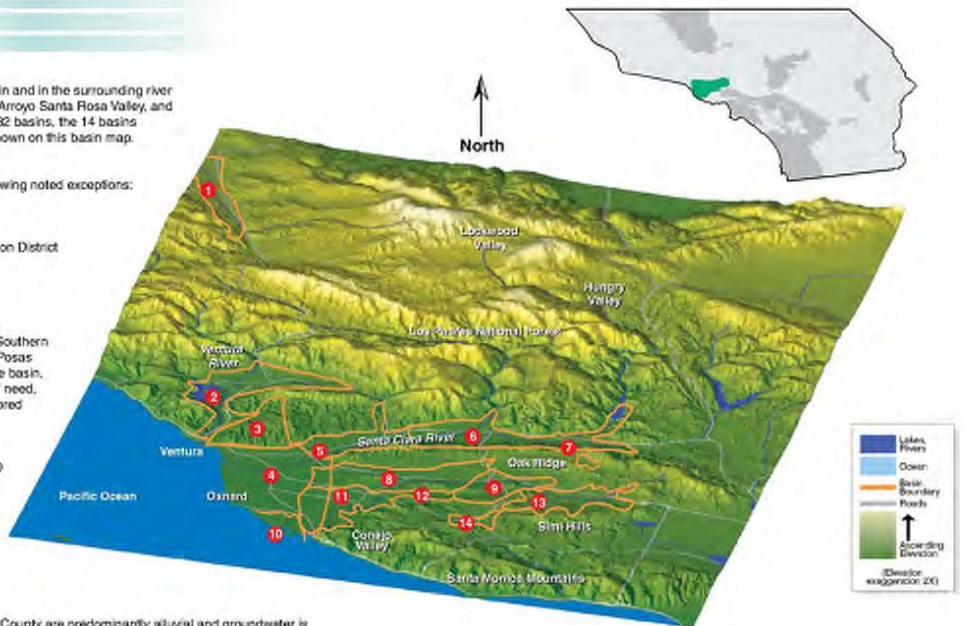
Basin Sediments

Sediments that comprise the groundwater basins underlying the river valleys of Ventura County are predominantly alluvial and groundwater is typically unconfined.

Sediments that comprise the larger groundwater basins of Ventura County are predominantly alluvial. Groundwater in these basins is both confined and unconfined. Several smaller basins in this area are comprised of sedimentary rocks, limited volcanics, and sandstone or siltstone. These smaller basins have limited storage potential.

Conjunctive Use Potential

The results of AQWA's survey indicate the potential to store up to 500,000 AF of water for use in dry years and a potential increase in basin operational yield of 87,600 AFY.



(Not to Scale)

Groundwater Basins	
1 Cuyama River	9 North Las Posas
2 Ojai & Ventura River Valley	10 South Las Posas
3 Mound	11 Mugu Forebay
4 Oxnard Coastal Plain & Forebay	12 Pleasant Valley
5 Santa Paula	13 Arroyo Santa Rosa
6 Fillmore	14 Simi Valley
7 Piru	15 Thousand Oaks

4. San Fernando Valley Basins

Location

The groundwater basins of the San Fernando Valley, located within the Upper Los Angeles River Area (ULARA) watershed, consist of the following:

- Sylmar Basin
- Verdugo Basin
- San Fernando Basin

The surface area of the ULARA watershed is approximately 514 square miles or 327,000 acres.

Basin Management

The groundwater basins are adjudicated under the auspices of the ULARA Watermaster. The basins were adjudicated on January 28, 1979 under the case referred to as the San Fernando Judgement.

Available Storage

The fresh water storage capacity of the San Fernando basins ranges from 0 to 550,000 acre-feet (AF). The actual amount of water in storage is determined by the ULARA Watermaster. Annual natural recharge and artificial recharge is approximately 44,000 and 61,000 acre-feet per year (AFY), respectively.

Present Operational Safe Yield

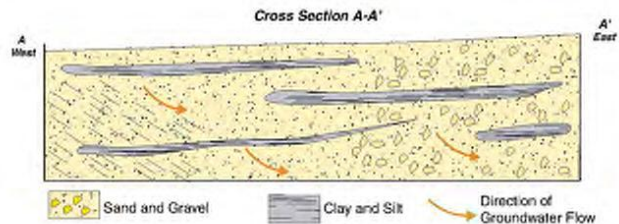
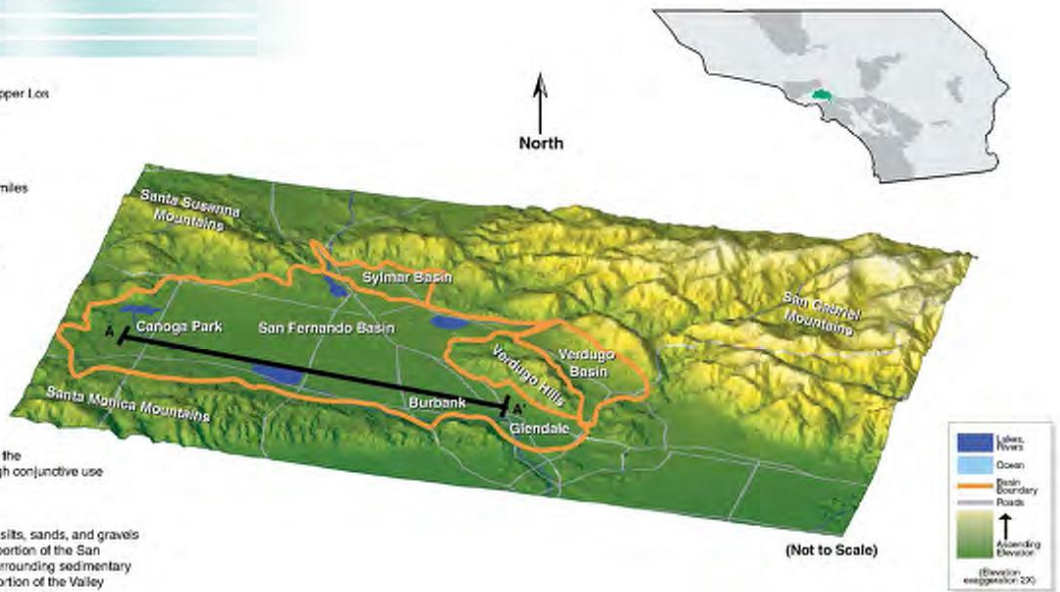
The present operational safe yield of the San Fernando Valley basins is approximately 105,000 AFY, providing approximately 15-20% of the water supply for the cities of Burbank, Glendale, and Los Angeles. Through conjunctive use programs, these cities have stored approximately 356,000 AF.

Basin Sediments

The alluvial sediments in the San Fernando Valley are a mixture of clays, silts, sands, and gravels that extend to a depth of at least 1,000 feet in some areas. The western portion of the San Fernando Valley is composed of fine-grained material derived from the surrounding sedimentary rocks in the Santa Susanna and Santa Monica Mountains. The eastern portion of the Valley consists of coarse sand and gravel deposits derived from the San Gabriel Mountains.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 43,700 AFY. Additionally, the survey indicated the potential to store up to 150,000 AF of water for use in dry years and a potential increase in basin operational yield of 27,300 AFY.



5. Raymond Basin

Location

The Raymond Groundwater Basin is located in the central portion of Los Angeles County. The basin is bounded on the north by the San Gabriel Mountains, on the south and east by the Raymond fault and adjacent San Gabriel Valley, and on the west by the San Rafael Hills and the Verdugo Basin. The entire basin lies within the watershed of the Los Angeles River. Principal streams include the Arroyo Seco, Eaton Wash, and Santa Anita Wash. The surface area of the Basin is 40 square miles or 25,600 acres.

Significant faults in the Basin include the following:

- Sierra Madre Fault System that trends southeast to northwest along the base of the San Gabriel Mountains.
- Raymond fault, which forms the southern boundary of the basin.
- Eagle Rock fault in the southwestern part of the basin.
- Eaton Wash fault, which occurs intrabasin on the eastern side.

Basin Management

The Raymond Basin was adjudicated in 1944, following the Superior Court Judgment *Pasadena v. Alhambra, et al.* This marked the first groundwater adjudication in the State of California. The Raymond Basin Management Board governs the basin.

Available Storage

The fresh water storage capacity of the basin is a minimum of 250,000 acre-feet (AF). As of June 30, 1999, approximately 56,000 AF of water was stored in the Basin by various parties and approximately 194,000 AF of unused storage was available. Raymond Basin recently began implementation of a conjunctive use program with Metropolitan Water District to store 75,000 AF of water for use during dry years.

Present Operational Safe Yield

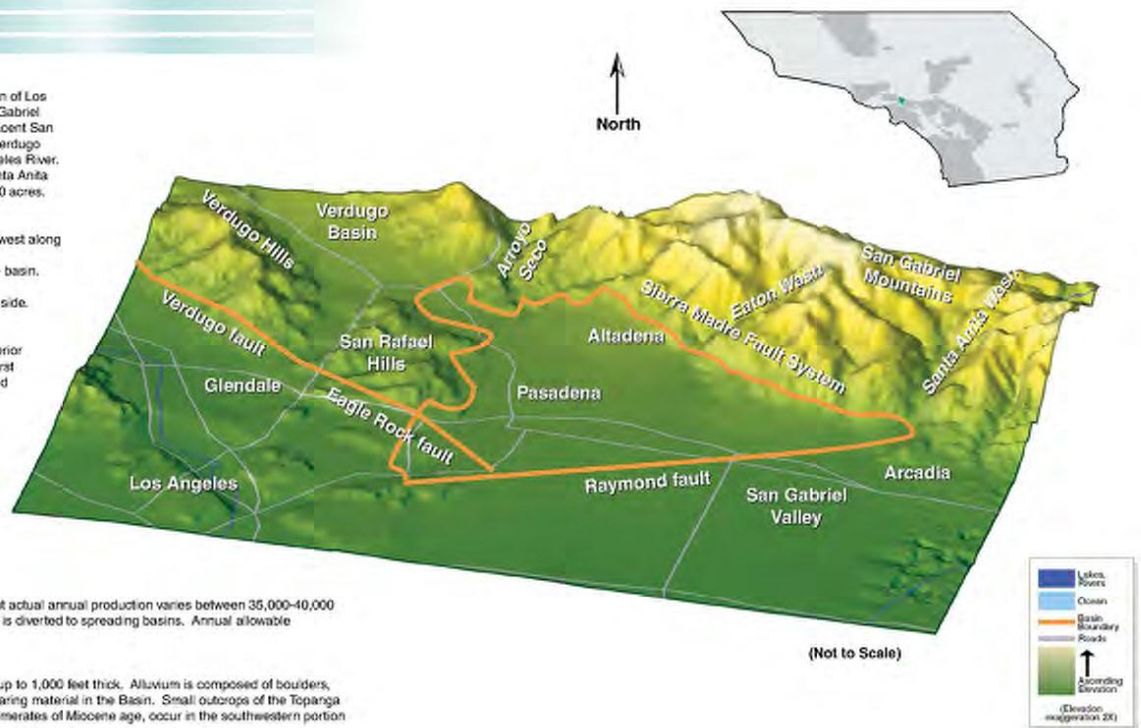
The present operational safe yield of the Basin is 30,622 AFY, but actual annual production varies between 35,000-40,000 AFY depending upon the amount of local storm runoff water that is diverted to spreading basins. Annual allowable extractions vary between 35,000-43,000 AFY.

Basin Sediments

Raymond Basin is underlain by unconsolidated alluvial deposits up to 1,000 feet thick. Alluvium is composed of boulders, gravel, sand, silt, and clay, and constitutes the principal water-bearing material in the Basin. Small outcrops of the Topanga Formation, which consists of consolidated sandstone and conglomerates of Miocene age, occur in the southwestern portion of the Basin.

Conjunctive Use Potential

The results of AGWA's survey indicate the potential to store an additional 144,000 AF of water for use in dry years.



6. Main San Gabriel Basin

Location

The Main San Gabriel Basin underlies eastern Los Angeles County, beneath most of the San Gabriel Valley and a portion of the upper San Gabriel River watershed. The basin is bounded by the San Gabriel Mountains to the north, San Jose Hills to the east, Puente Hills to the south, and by a series of hills and the Raymond fault to the west. The basin is drained by the San Gabriel River and Rio Hondo. The surface area of the Basin is approximately 167 square miles or 106,800 acres.

Basin Management

The Main San Gabriel Basin Watermaster is the agency charged with administering adjudicated water rights and managing groundwater resources within the basin. The Watermaster, a nine-person board appointed by the Los Angeles County Superior Court, administers and enforces the provisions of the Judgement that established water rights and the responsibility for efficient management of the quantity and quality of the basin's groundwater.

The Puente Subbasin is located in the southeast portion of the map, and is hydraulically connected to the basin, with no barriers to groundwater movement. However, the Puente Subbasin is not within the legal jurisdiction of the Watermaster, and is thus considered a separate entity for management purposes.

Available Storage

The freshwater storage capacity of the basin is estimated to be about 8.6 million acre-feet (AF). Of this amount, approximately 400,000 acre-feet is usable for water supply. Historically, the maximum utilization of basin storage has been 900,000 AF; however, the storage available for imported and reclaimed water is dependent upon the water surface elevation at the Baldwin Park Key Well. When the water surface elevation exceeds 250 feet, neither imported nor reclaimed water can be placed in storage, except in the eastern portion of the basin. Therefore, the amount of storage generally available for imported or reclaimed water will vary from nothing to approximately 400,000 AF. To date, 170,000 AF has already been committed to various producers and agencies for cyclical storage.

Present Operational Safe Yield

The operational safe yield of the basin is determined annually by the Watermaster and has ranged from a low of 140,000 AF to a high of 230,000 AFY averaging almost 200,000 AFY since 1973-74. The operational safe yield for fiscal year 2000-01 is 220,000 AFY.

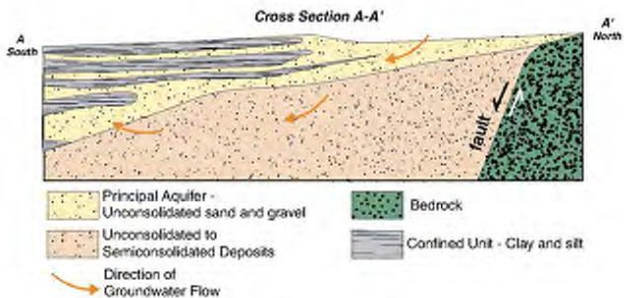
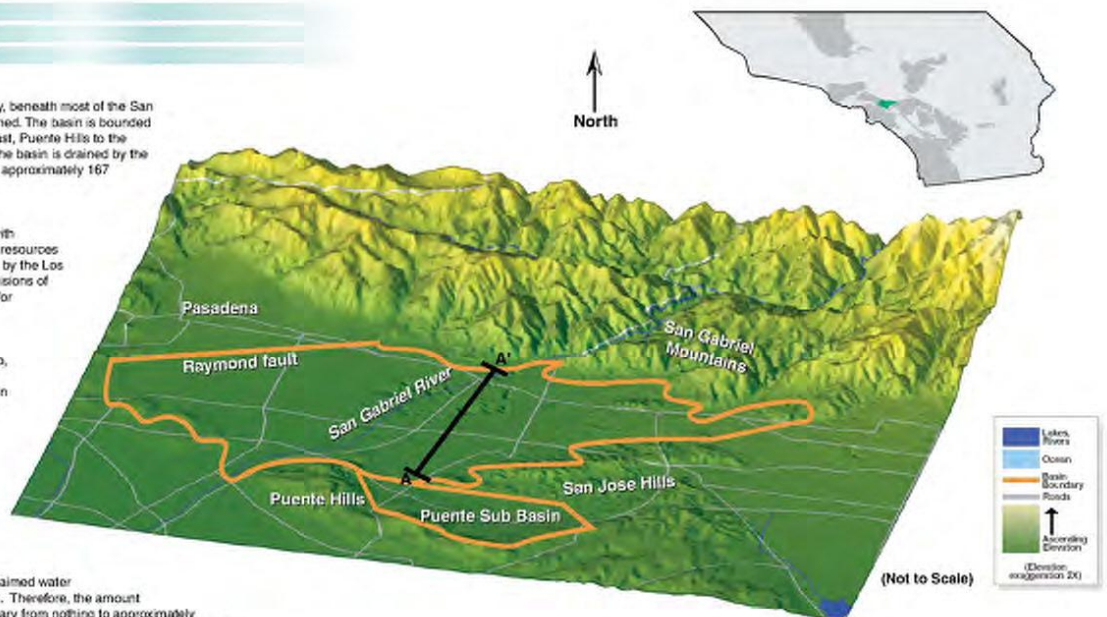
Basin Sediments

The principal water-bearing formations of the basin are unconsolidated and semi-consolidated sediments that range from fine-grained sands to coarse gravel.

The major sources of groundwater recharge are infiltration of rainfall on the valley floor and percolation of runoff in unlined storm channels and off-channel spreading grounds. The basin also receives imported water and return flow from applied water.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 78,000 AFY. Additionally, the survey indicated the potential to store up to 400,000 AF of water for use in dry years and a potential increase in basin operational yield of 187,000 AFY.



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7. Los Angeles Coastal Plain Basins

Location
The Los Angeles Coastal Plain is underlain by a structural basin formed by folding of the consolidated sedimentary, igneous, and metamorphic rocks that underlie the basin at great depths. Although the subsurface structure of the coastal plain is complex, two major northwest-trending troughs, which are separated for most of their length by the Newport-Inglewood Fault Zone (uplift), contain the sediments that compose the aquifer system. These sediments are as thick as 20,000 feet in some areas.

The Los Angeles Coastal Plain is bordered by the Santa Monica Mountains to the north, the Palos Verdes Hills and Pacific Ocean to the west, the Puente, Elysian, Repetto, and Merced Hills to the northeast, and the Los Angeles/Orange County line to the east and southeast. Primarily the Los Angeles and San Gabriel River systems drain the Coastal Plain.

The Coastal Plain is divided into four groundwater basins:

- The **Central Basin** extends over most of the coastal plain, east and northeast of the Newport-Inglewood Uplift. The basin occupies approximately 278 square miles (177,920 acres) and contains unconfined and confined alluvial aquifers (further subdivided into the Montebello Forebay, Los Angeles Forebay, Whittier Area, and Central Basin Pressure Area).

- The **West Coast Basin** extends southwesterly from the Newport-Inglewood Uplift to Santa Monica Bay. Its drainage divide on the Palos Verdes Hills, and to San Pedro Bay. The basin occupies approximately 172 square miles (110,080 acres) and contains mostly confined alluvial aquifers.

- The **Santa Monica Basin** is bounded by the Santa Monica Mountains to the northwest, the Hollywood Basin to the northeast and east, the West Coast Basin to the south, and Santa Monica Bay to the west (further subdivided into the Coastal, Chamwick, and Central sub-basins). The basin occupies approximately 46 square miles (29,440 acres) and contains mostly confined alluvial aquifers.

- The **Hollywood Basin**, which is approximately 15 square miles (10,240 acres) in size, is an east-west syncline that lies between two branches of the Hollywood fault. The basin is bounded by the Newport-Inglewood Uplift on the west, the Elysian Hills on the east, the La Brea High to the south, and the Santa Monica Mountains to the north. The aquifers are both confined and unconfined.

Basin Management

The Central and West Coast Basins are both adjudicated. The California Department of Water Resources is the court-appointed Watermaster and the Water Replenishment District of Southern California has assumed the role of groundwater basin manager.

The Santa Monica and Hollywood Basins are neither adjudicated nor formally managed.

Total Stored Water	Present Operational Safe Yield	Available Storage
Central Basin - 12,000,000 AF ¹	Central Basin - 217,320 AFY ²	Central Basin - 789,000 AF
West Coast Basin - 6,000,000 AF	West Coast Basin - 64,468 AFY ¹	West Coast Basin - 360,000 AF
Santa Monica Basin - 1,100,000 AF	Santa Monica Basin - 100 AFY ²	Santa Monica Basin - not available
Hollywood Basin - 200,000 AF	Hollywood Basin - 4,400 AFY ²	Hollywood Basin - not available

Basin Sediments

Deposition in the Los Angeles Coastal Plain has been largely influenced by sea-level fluctuations, combined with alluvial sedimentation related to ancestral river systems that traversed the Coastal Plain. Water-bearing sediments are primarily of Pleistocene age and 11 aquifers have been named:

- Semi-perched
- Gage
- Lynwood
- Gage
- Gardena
- Serrano
- Artesia
- Hollywood
- Sanyciso
- Exposition
- Jefferson

Groundwater also occurs in the Pliocene Pico Formation, but generally of insufficient quantities and quality to supply production wells.

Each aquifer consists of a distinct layer of water-yielding sand and gravel usually separated from other sand and gravel beds by clay and silt confining units. In many places, however, the water-yielding sediments of the different aquifer may be in direct hydraulic contact with each other, or the intervening confining units contain sufficient sand and gravel to allow water to pass between adjacent aquifers.

A layer of clay and silty clay of marine and continental origin, which is all or near the land surface over most of the coastal plain, is a competent confining unit where it does not contain large amounts of sand and gravel. This confining unit ranges from less than 1 foot to about 100 feet in thickness. In the Los Angeles and Montebello Forebays, the confining unit is not present, and groundwater is under unconfined, or water table, conditions.

Freshwater is contained within deposits that range in age from Holocene to late Pliocene. The main freshwater body extends from depths of less than 100 to about 4,000 feet. At greater depths, the water is saline and unpotable. The freshwater body is thickest near the axis of the troughs where water-yielding sediments reach their greatest thickness, and thinnest where these sediments overlie anticlines or become thin at the margins of the aquifer system.

The Montebello and Los Angeles Forebays are areas of groundwater recharge, whereby deep aquifers are hydraulically connected to the ground surface and further characterized by the absence of the Redblaze aquifer (a thick silty clay layer). The Pressure Area is typified by the presence of the Redblaze aquifer near the ground surface, thereby preventing groundwater recharge.

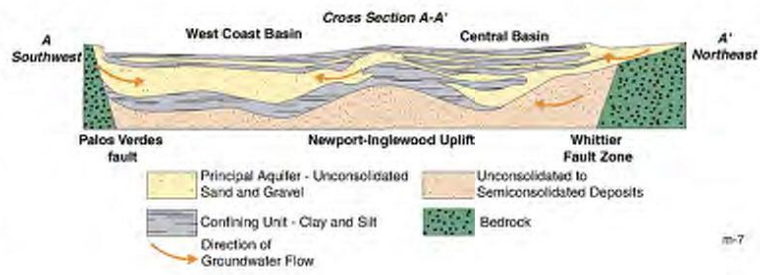
Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 64,000 AFY. Additionally, the survey indicated the potential to store up to 1,088,000 AF of water for use in dry years and a potential increase in basin operational yield of 64,300 AFY.

¹ Adjudicated amount
² DWR Bulletin 101-B, 1962 "Safe Yield Determinations", Table 27



(Not to Scale)



8. Orange County Coastal Plain Basin

Location

The Orange County groundwater basin underlies the Orange County Coastal Plain, beneath the broad lowlands known as the Tustin and Downey Plains. The basin is bounded by the Los Angeles County Line, Coyote Hills, and Chino Hills to the north, the Pacific Ocean and Newport-Inglewood Uplift to the west, the Santa Ana Mountains to the east, and non-water bearing formations that occupy the southern half of Orange County to the south. The surface area of the basin is approximately 350 square miles or 224,000 acres.

Basin Management

The basin is managed by the Orange County Water District (OCWD) and is not adjudicated.

OCWD was created in 1933 by California State legislation to manage and protect the vast groundwater basin under north central Orange County. Since that time, OCWD has tripled the yield of the basin through a tradition of innovation that includes expansion and improvements to recharge facilities, employment of well head and other treatment technologies, water research, conservation and reclamation projects. OCWD's Water Factory 21, which remains a model for water reclamation around the world, provides millions of gallons of water each day to create a fresh water barrier against seawater intrusion and to replenish the basin. OCWD's Green Acres irrigation and industrial water project frees up thousands of acre-feet of potable water each year.

OCWD supplies reliable, high-quality groundwater to more than 23 cities and water agencies serving 2 million residents. The basin is recharged primarily from the Santa Ana River and to a lesser extent from imported water purchased from the Metropolitan Water District of Southern California. OCWD monitors the groundwater extracted each year to ensure that the basin is not overdrawn and carries out an assessment program to pay for operating expenses and the cost of imported replenishment water.

OCWD has one of the most sophisticated groundwater protection programs in the world using an array of monitoring wells. The wells provide input to a three-layer groundwater model of the basin that is used for basin management.

Available Storage

The freshwater storage capacity of the basin is 1,000,000 AF and there are 300,000 AF of available storage.

Present Operational Safe Yield

The present operational safe yield of the basin is 350,000 AFY and this is expected to increase in the future by 130,000 AF.

Basin Sediments

The aquifers comprising the basin extend over 2,000 feet deep and form a complex series of interconnected sand and gravel deposits. In the coastal and central portions of the basin, these deposits are more separated by extensive lower permeability clay and silt deposits. In the inland area of the basin, generally northeast of Interstate 5, the clay and silt deposits become thinner and more discontinuous, allowing groundwater to flow more easily between shallow and deeper aquifers. The northeast portion of the basin includes a coarse-grained unconfined forebay area. Moving toward the coast, the basin becomes confined with finer-grained sediments overlying the coarser-grained aquifer.

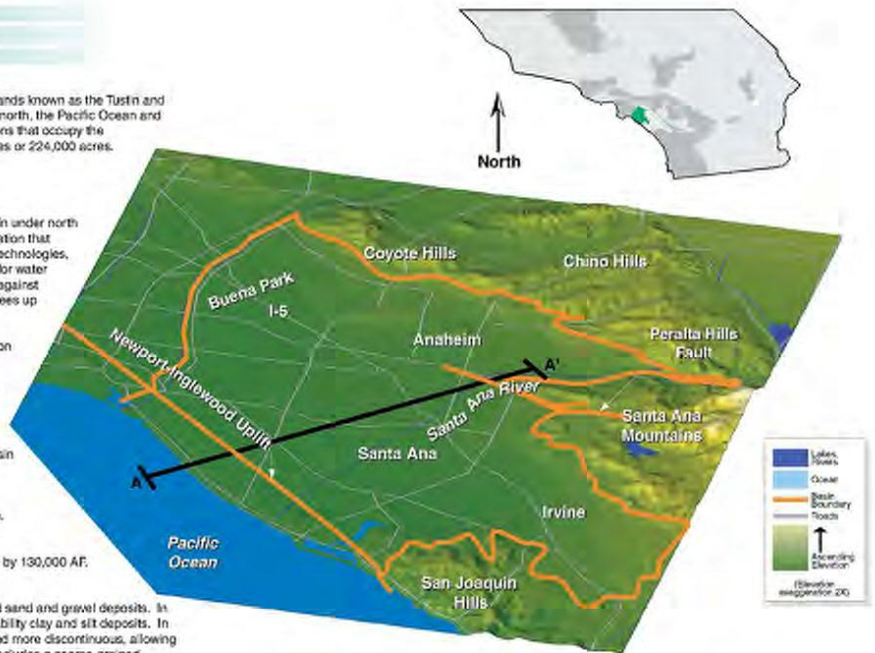
The basin is divided into two hydrologic components, the forebay and pressure areas. The forebay/pressure boundary generally delineates the area where surface water or shallow groundwater can/cannot move downward in significant quantities. The boundary represents a transition zone where low-permeability clay and silt deposits increasingly occur in near-surface sediments southwest of the boundary.

The forebay refers to the area of intake or recharge, where the majority of recharge to the basin occurs primarily by direct percolation of Santa Ana River water. The forebay area, underlying most of the cities of Anaheim, Fullerton, and Villa Park, and portions of the cities of Orange and Yorba Linda, is characterized by highly permeable sands and gravel with low clay and silt deposits.

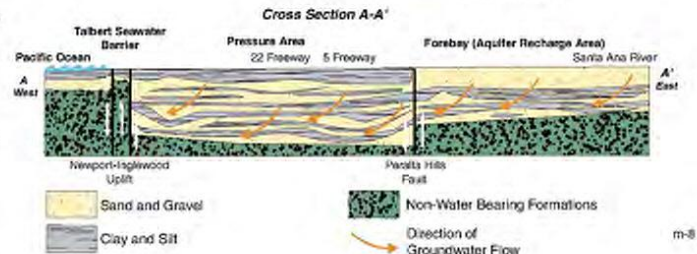
The pressure area is defined as the area in the basin where surface water and near surface groundwater are prevented from percolating in large quantities into the productive aquifers by clay and silt layers at shallow depths. Most of the central and coastal portions of the basin fall within the pressure area.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 150,000 AFY. Additionally, the survey indicated the potential to store up to 300,000 AF of water for use in dry years and a potential increase in basin operational yield of 130,000 AFY.



(Not to Scale)



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9. Six Basins

Location

Six Basins is comprised of the following groundwater basins:

- San Antonio Canyon Basin
- Live Oak Basin
- Upper Claremont Heights Basin
- Lower Claremont Heights Basin
- Pomona Basin
- Ganesha Basin

Six Basins underlie the cities of Claremont, La Verne, and Pomona in northeastern Los Angeles County and northwestern San Bernardino County.

Basin Management

The Six Basins Watermaster was formed by a stipulated agreement, the final judgement becoming effective January 1990. The judgement establishes groundwater rights and provides a structure for the operation and management of the Six Basins.

Available Storage

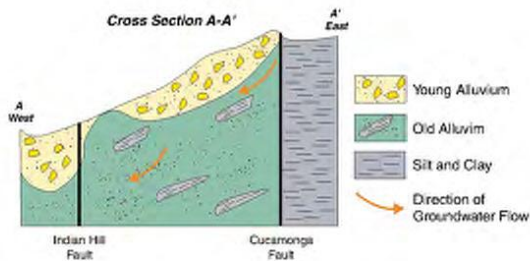
The available freshwater storage capacity of the aquifer is 30,000 acre-feet (AF).

Present Operational Safe Yield

The present operational safe yield of Six Basins is 24,000 acre-feet per year (AFY).

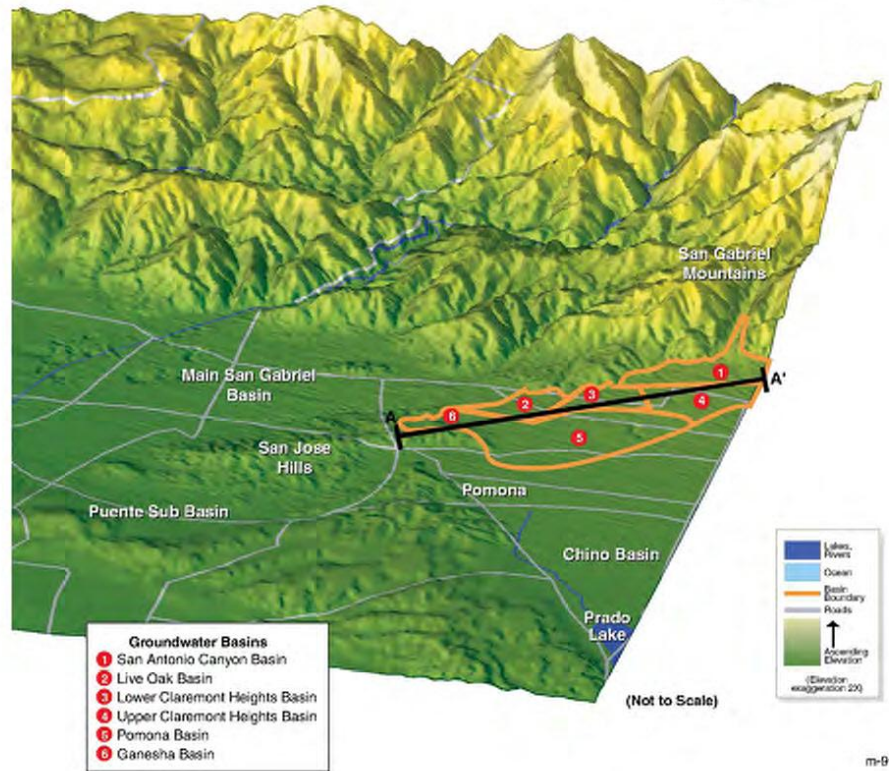
Basin Materials

Aquifer materials consist primarily of sand and gravel deposited as alluvial fans. Silt and clay deposits increase with distance away from the San Gabriel Mountains. Basin depth generally increases with distance away from the San Gabriel Mountains, but is complicated by faulting.



Conjunctive Use Potential

The results of AGWA's survey indicate the potential to store up to 30,000 AF of water for use in dry years and a potential increase in basin operational yield of 30,000 AFY.



10. Upper Santa Ana River Basins

Location

The groundwater basins of the upper Santa Ana River watershed consist of the following:

- Chino Basin
- Cucamonga Basin
- Rialto Basin
- Colton Basin
- Riverside Basin

Chino Basin consists of approximately 235 square miles (154,400 acres) of the Upper Santa Ana River Watershed and underlies portions of San Bernardino, Los Angeles and Riverside Counties. The basin is bounded to the north by the San Gabriel Mountains and the Cucamonga Basin, to the south by the La Sierra area and the Temescal Basin, to the east by the Colton and Rialto basins, Jurupa Hills, and Pedley Hills, and to the west by the Chino Hills, Puente Hills, and the Pomona and Claremont basins.

Cucamonga Basin comprises approximately 22 square miles (14,000 acres) and is located at the base of the San Gabriel Mountains near the communities of Upland, Rancho Cucamonga, Etiwanda, and Fontana. The San Gabriel Mountains bound the basin to the north. The Red Hill fault bounds the basin on all other sides.

Rialto and Colton Basins are located in western San Bernardino County. Bunker Hill and Lytle Basins bound the basin to the northeast; the San Bernardino Mountains bound the basin to the northwest; and Chino Basin, Jurupa and Pedley Hills bound the basin to the west.

Basin Management

Chino Basin is an adjudicated basin managed by the Chino Basin Watermaster (Watermaster). The Watermaster was established under a judgement entered in the Superior Court of the State of California for the County of San Bernardino, entitled "Chino Basin Municipal Water District vs. City of Chino et al". The Basin has been operated as described in the 1978 judgement.

Cucamonga Basin was adjudicated in 1958 and is jointly managed by the Cucamonga County Water District and San Antonio Water Company. The Rialto and Colton Basins were adjudicated in 1961.

Available Storage

The unused storage capacity in Chino and Riverside-Colton Basins is 1,000,000 acre-feet (AF) and 98,000 AF, respectively. Cucamonga Basin has no unused storage capacity.

Present Operational Safe Yield

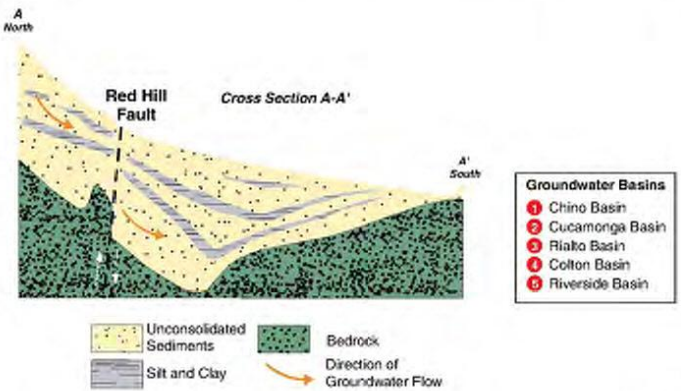
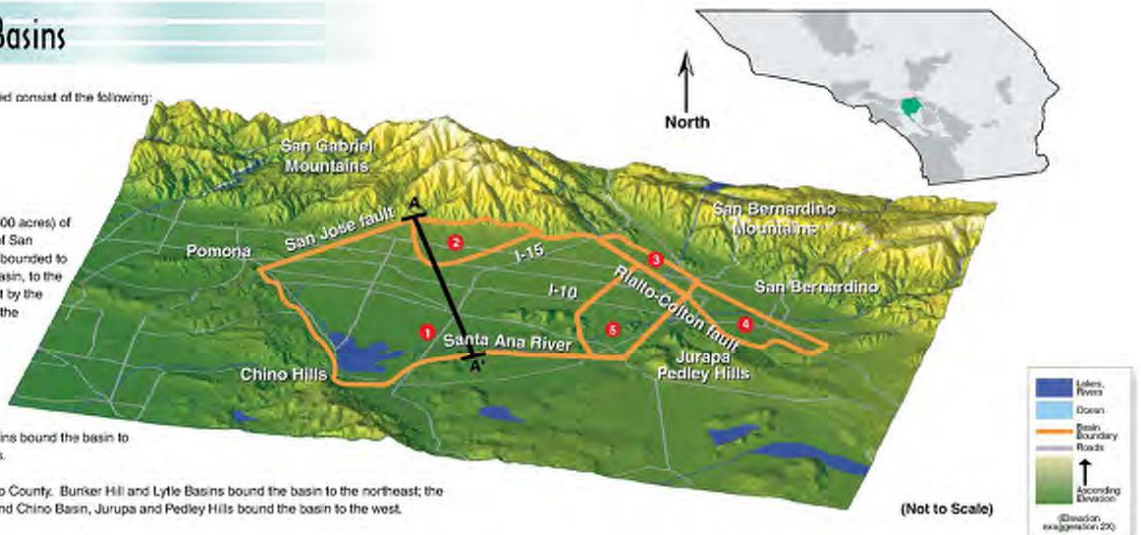
The present operational safe yield of Chino Basin is 145,000 acre-feet per year (AFY), and that of Cucamonga and Riverside-Colton Basins is about 14,000 to 22,000 and 9,000 AFY, respectively.

Basin Materials

Sediments in Chino Basin are alluvial in origin and derived from the surrounding San Bernardino and San Gabriel Mountains. Sediments are coarser in the northern part of the basin and the aquifer is unconfined. From north to south, the aquifer becomes finer-grained and semi-confined. Alluvial sediments also dominate in Cucamonga Basin, Rialto, and Colton Basins.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 43,000 AFY. Additionally, the survey indicated the potential to store up to 1,854,000 AF of water for use in dry years and a potential increase in basin operational yield of 47,000 AFY.



11. Bunker Hill Basin

Location

The Bunker Hill Groundwater Basin is located in San Bernardino County, and is partially overlain by the City of San Bernardino. The basin is bounded on the northeast by the San Andreas fault, on the southwest by the San Jacinto fault, on the southeast by the Crafton Hills fault, and on the northwest by the San Bernardino Mountains.

Basin Management

The basin is adjudicated. The San Bernardino Valley Municipal District (SBVWCD) Watermaster manages the basin.

Available Storage

The fresh water storage capacity of the basin is estimated at 1,432,000 AF. Currently, the basin is essentially full.

Present Operational Safe Yield

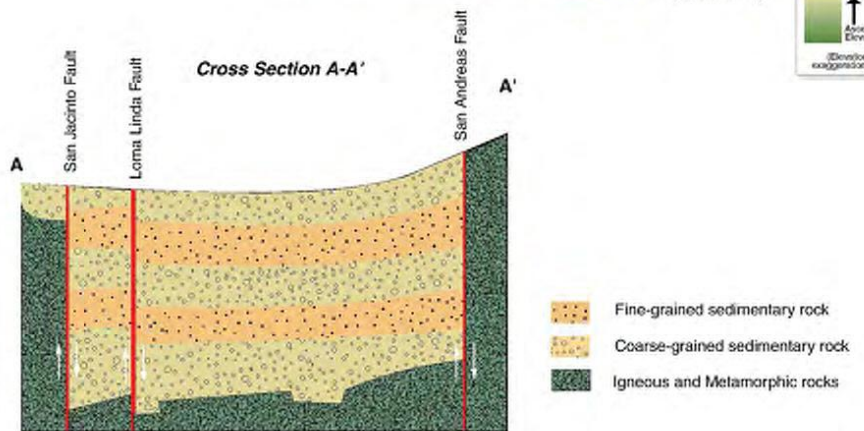
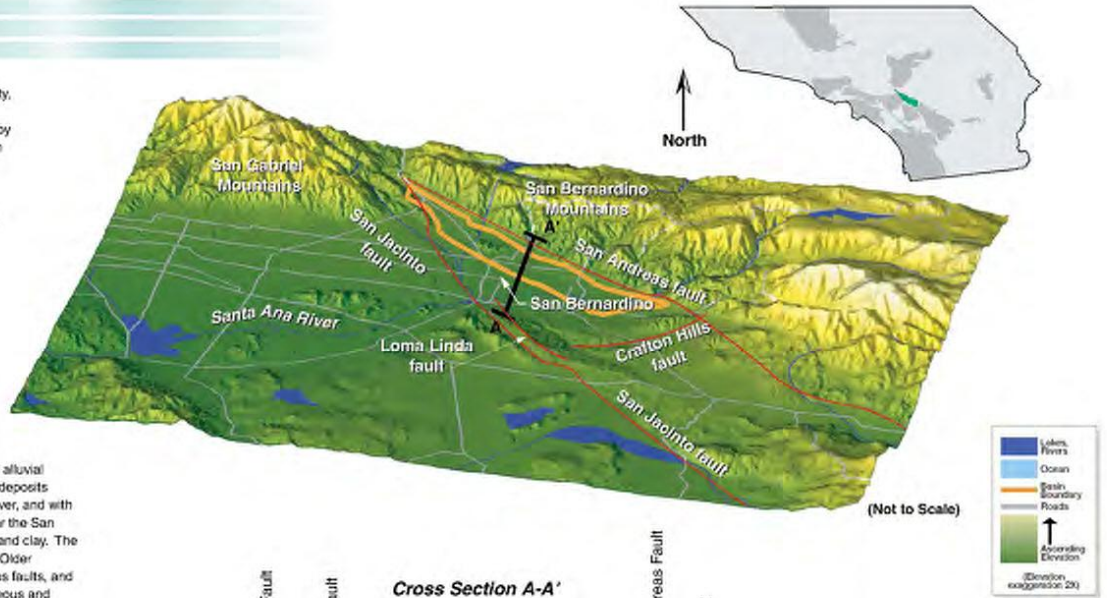
The present operational safe yield of the basin is 224,300 AFY.

Basin Sediments

The basin is a sediment-filled structural trough between the San Andreas and San Jacinto faults in the upper part of the Santa Ana River Watershed near the base of the San Bernardino Mountains. Sediments generally consist of unconsolidated alluvial fan deposits derived from the surrounding mountains and hills. These deposits interfinger with river-channel deposits, primarily from the Santa Ana River, and with freshwater marsh deposits associated with groundwater discharge near the San Jacinto fault. Younger alluvium consists of boulders, gravel, sand, silt, and clay. The depth to the base of the younger alluvium ranges from 70 to 110 feet. Older alluvium consists of gravel, sand, silt, and clay, is fractured by numerous faults, and constitutes the principal aquifer of the area. A bedrock complex of igneous and metamorphic rocks underlies valley fill sediment.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 6,000 AFY. The basin is full so there is currently no storage space available for dry year storage.



12. San Jacinto Watershed Basins

Location

The basins of the San Jacinto Watershed are located in western Riverside County and consist of the following subbasins:

- Lakeview
- Perris North and South
- Winchester
- San Jacinto - Lower Pressure
- Menifee
- East Valley or East San Jacinto Groundwater Basin Area
- San Jacinto - Canyon
- San Jacinto - Intake and Upper Pressure
- Hemet

Basin Management

The Lakeview, Perris North, Perris South, Winchester, San Jacinto Lower Pressure, and Menifee subbasins are managed under the West San Jacinto Groundwater Management Plan (AB3030) adopted in June 1995. The Eastern Municipal Water District (EMWD) is the basin manager under the Plan. The basins are not adjudicated.

The San Jacinto Canyon, Intake and Upper Pressure, and Hemet subbasins are known as the East Valley or East San Jacinto Groundwater Basin Area. EMWD, local agencies/cities, and private groundwater producers are working to develop a groundwater management plan. The basins are not adjudicated.

Available Storage

The freshwater storage capacity of the basins of the West San Jacinto Groundwater Management Plan Area is 5,254,500 AF, and there are 726,000 AF of available storage. The freshwater storage of the basins of the East Valley Area is 5,080,000 AF and there are 558,000 AF of available storage.

Present Operational Safe Yield

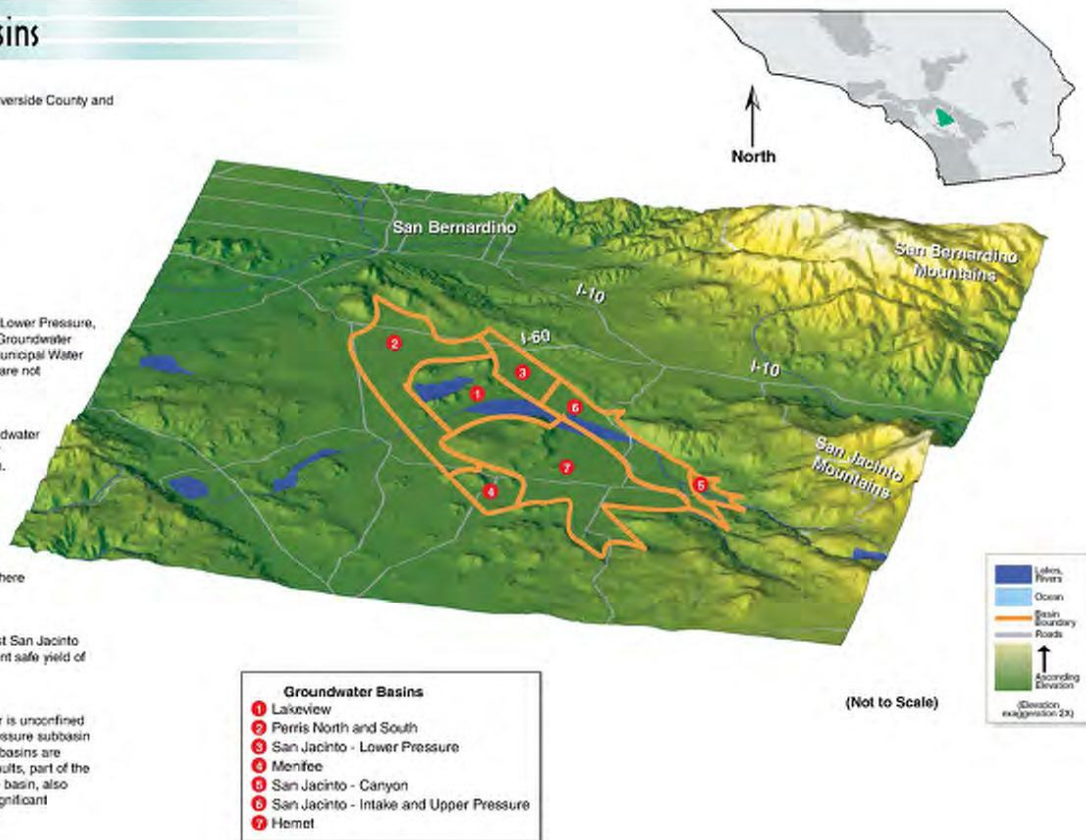
The present operational safe yield of the nine subbasins in the West San Jacinto Groundwater Management Plan Area is 22,000 AFY and the present safe yield of the three subbasins in the East Valley Area is 60,000 AFY.

Basin Sediments

The groundwater aquifers consist of alluvial deposits. Groundwater is unconfined with the exception of the groundwater in the San Jacinto Lower Pressure subbasin which is a confined aquifer. The San Jacinto Upper and Lower subbasins are defined by the graben formed by the Casa Loma and Claremont Faults, part of the San Jacinto Fault Zone. The fault zone, in the northeast part of the basin, also contains the Park Hill, Bautista, and other named faults, and is a significant feature in the Basin.

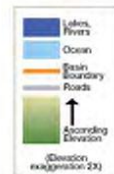
Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 3,000 AFY. Additionally, the survey indicated the potential to store up to 1,284,000 AF of water for use in dry years and a potential increase in basin operational yield of 10,000 AFY.



- | Groundwater Basins | |
|--------------------|---|
| 1 | Lakeview |
| 2 | Perris North and South |
| 3 | San Jacinto - Lower Pressure |
| 4 | Menifee |
| 5 | San Jacinto - Canyon |
| 6 | San Jacinto - Intake and Upper Pressure |
| 7 | Hemet |

(Not to Scale)



13. Upper Santa Margarita River Watershed Basins

Location

There are three major groundwater basins of the Santa Margarita River Watershed:

- Santa Margarita Basin (location shown on map 14 due to its location in San Diego County)
- Temecula Basin
- Anza Valley

The Santa Margarita Basin is located in northwestern San Diego County and underlies Camp Pendleton (See map 14). Temecula Basin is located beneath and around the City of Temecula, in south-central Riverside County, and Anza Valley is located to the east along Highway 371 and to the south of the San Jacinto Mountains and to the west of the Santa Rosa Mountains.

Basin Management

The Santa Margarita River Watershed is adjudicated under federal court jurisdiction. The Santa Margarita River Watershed Watermaster is not charged with basin management but does collect and manage data. The Santa Margarita Basin is managed by Camp Pendleton; the Temecula Basin is largely managed by Rancho California Water District and to a lesser extent by Murietta Water District; and Anza Valley is not managed. Currently, the watershed has three ongoing conjunctive use projects, two of which are operated by Rancho California Water District and one by Camp Pendleton. Rancho California Water District imports water for recharge into spreading basins and extracts the water using wells. The District also owns Vall Lake on Temecula Creek. During wet years, water is impounded behind Vall Lake and later released, recharged in spreading basins and the creek bottom, and extracted by wells. Camp Pendleton operates a seasonal conjunctive use project whereby water is diverted and stored in O'Neil Lake during the wet months and later released back into the river for recharge in the fall.

Available Storage

The freshwater storage capacity of the Santa Margarita River Valley is 29,000 AF and is currently full. The storage capacity of the Temecula Basin is 2,000,000 AF with 200,000 AF of available storage.

Present Operational Safe Yield

The present operational safe yields of the Santa Margarita Basin, Temecula Basin, and Anza Valley are 5,600 AFY, 37,700 AFY and 12,000 AFY respectively.

Basin Sediments

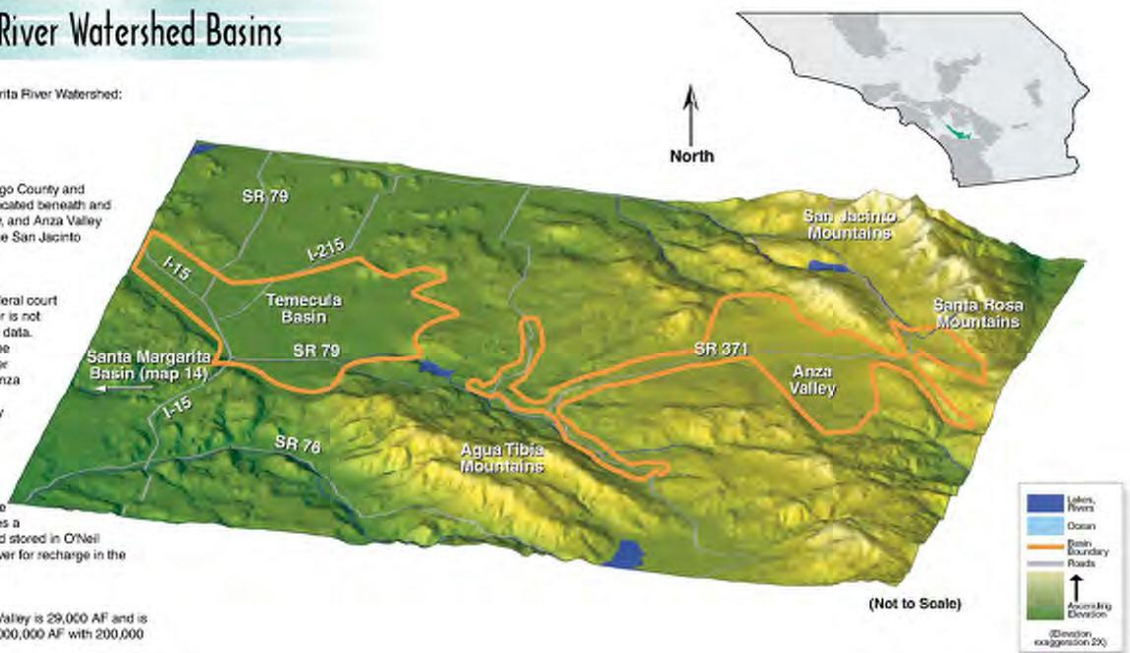
Groundwater generally occurs in three aquifer zones:

- Younger to older alluvium (Top Zone)
- Paluba Aquifer (Middle Zone)
- Temecula Arkose (Bottom Zone)

All three zones are present in the Temecula Basin, whereas younger alluvium dominates the Santa Margarita Basin and both older and younger alluvium comprise the Anza Valley.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 10,000 AFY. Additionally, the survey indicated the potential to store up to 200,000 AF of water for use in dry years and a potential increase in basin operational yield of 10,000 AFY.



14. San Diego County Basins

Location

San Diego County overlies numerous groundwater basins. Seven of the basins, each with a total storage capacity greater than 10,000 AF, are listed below and shown on the map.

- Santa Margarita River Basin
- Warner Basin
- San Pasqual Basin
- Santa Maria Basin
- Santee/El Monte Basin
- Mission Valley Basin
- San Diego Formation Aquifer
- San Luis Rey River Basin

Basin Management

Water rights court decisions have been rendered within the Santa Margarita Basin, upper San Luis Rey River, lower Tijuana River Valley, and the San Diego River watersheds. Other watersheds in the county remain non-adjudicated; however, a number of agencies have long-standing surface water rights.

Available Storage

The combined fresh water storage capacity within the alluvial aquifers is estimated to exceed 700,000 acre-feet (AF). In addition to the shallow alluvial aquifers, a deeper aquifer exists in the southwest corner of the county, termed the San Diego Formation Aquifer. The San Diego Formation aquifer has been estimated to have a storage capacity in excess of 960,000 AF. Though active management of both groundwater pumping and groundwater quality, storage in these basins can be utilized for conjunctive use.

Present Operational Safe Yield

The present operational safe yield of these basins is approximately 60,000 AF.

Basin Sediments

The principal aquifer materials are alluvium, semi-consolidated sediment, and to a lesser degree, consolidated sediment, residuum, and fractured crystalline rock. Unconsolidated deposits of alluvium and residuum are typically found near the surface in major river and stream valleys.

Conjunctive Use Potential

The results of AGWA's survey indicate the potential to store up to 270,700 AF of water for use in dry years and a potential increase in basin operational yield of 41,500 AFY.



15. Mojave River Basins

Location

The Mojave Basin, traversed by the Mojave River, extends from the north side of the San Bernardino Mountains to the north and east through the cities of Victorville and Barstow. The basin is comprised of the following subbasins:

- Alto
- Centro
- Baja
- Este

Basin Management

The Mojave Water Agency (MWA) oversees groundwater production and recharge within the basin. The basin is adjudicated, with the goals of balancing pumped groundwater with imported water and natural recharge. In addition to returning groundwater levels to those of the 1930s. Although MWA does not currently restrict groundwater pumping, well owners must pay an assessment for groundwater pumped in excess of an annual allowance determined by MWA. Alternatively, a well owner may acquire unused pumping allowances from well owners located in the same groundwater subbasin. Ultimately, the assessment value will be equal to the cost of delivery and replacement of groundwater pumped in excess of the well owners allowance.

Two pipelines bring imported surface water to the Mojave Basin. MWA currently oversees the operation of four groundwater recharge facilities that draw water from these pipelines. The recharge facilities and associated theoretical maximum recharge rates are listed below.

In addition to the above recharge facilities, discharges from Lake Silverwood occasionally provide recharge to the west fork of the Mojave River. Historic discharge rates vary from 2,000 to 25,000 AFY.

Available Storage

Water levels in the Mojave Basin have been declining since the 1930s. As a result, the amount of available storage for conjunctive use has increased substantially. Since one of the goals of the basin adjudication is to return groundwater levels to pre-development conditions, the available storage may decrease in the future. Presently, the available storage of the basin is estimated as follows:

Subbasin	Available Storage
Alto	1,041,500 AF
Centro	217,700 AF
Baja	415,000 AF
Este	115,500 AF

Present Operational Safe Yield

The present operational safe yield of the Basin is summarized in the table below:

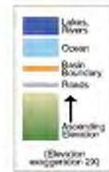
Subbasin	Present Operational Safe Yield
Alto	69,860 AFY
Centro	33,380 AFY
Baja	20,680 AFY
Este	7,160 AFY

Basin Sediments

The Mojave Basin is comprised of sand, gravel, and occasional clay deposits created by the Mojave River and surrounding streams. Impermeable metamorphic and igneous rocks that comprise the San Bernardino Mountains limit the southern extent of the basin. Intermittent streams generated by winter and summer precipitation supply natural groundwater recharge to this sedimentary basin.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 46,000 AFY. Additionally, the survey indicated the potential to store up to 1,790,100 AF of water for use in dry years and a potential increase in basin operational yield of 24,000 AFY.



16. Hayfield Basin

Location

The Hayfield Groundwater Basin is located in Riverside County, east of the Coachella Valley, west of Chuckwalla Valley, and south of the Eagle Mountains. Surface area of the basin is approximately 37 square miles (23,900 acres).

Basin Management

The Basin is neither adjudicated nor formally managed.

Available Storage

The total estimated storage capacity of the basin is 2,800,000 acre-feet (AF), with about 2,000,000 AF of native water in storage.

Present Operational Safe Yield

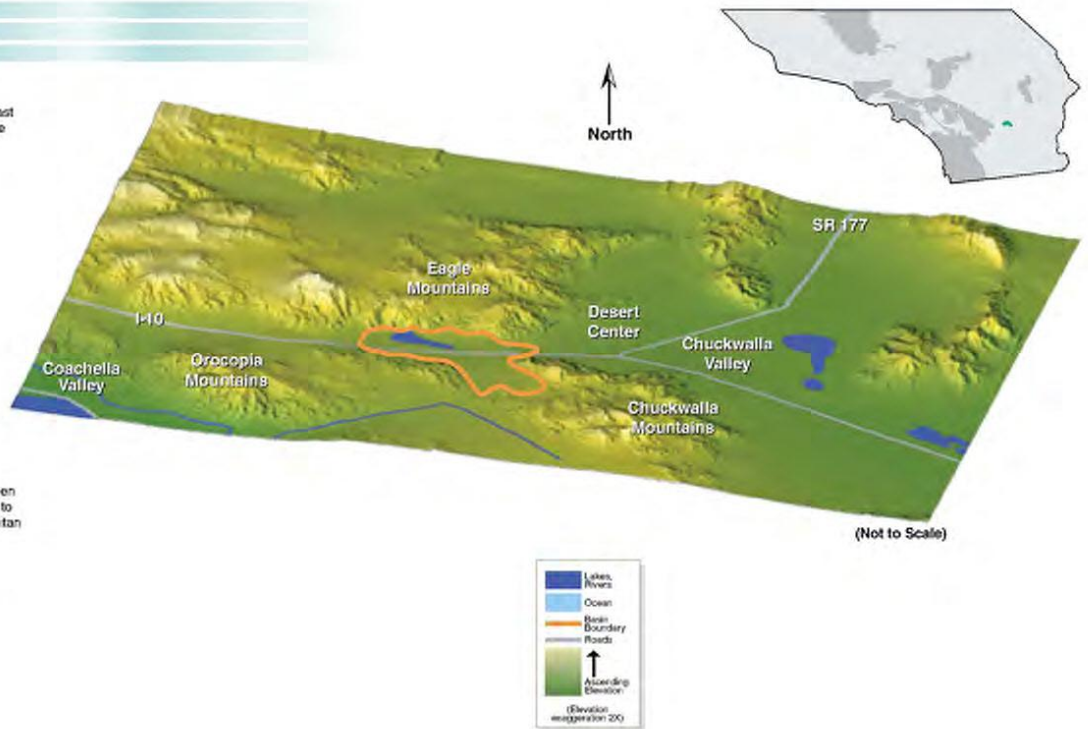
The present operational safe yield is undefined. Future operational yield may be 150,000 acre-feet per year (AFY) in a drought year.

Basin Sediments

Basin sediments consist of alluvial deposits with interbeds of sand, gravel, silt, and clay. Groundwater is unconfined.

Conjunctive Use Potential

The results of AGWA's survey indicate the potential to store between 500,000 and 800,000 AF of water for use in dry years. A program to utilize this storage potential is currently being planned by Metropolitan Water District of Southern California.



17. Cadiz Valley Basin

Location

The Cadiz Groundwater Storage and Dry-Year Supply Program is located in portions of the Cadiz and Fenner Valleys in the Mojave Desert of eastern San Bernardino County. The aquifer system to be utilized by this conjunctive use program underlies an area known as Fenner Gap, located between the Marble and Ship mountains, approximately ten miles east of Bristol Dry Lake and ten miles north of Cadiz Dry Lake. The watershed that supplies groundwater recharge to the program area covers an area of approximately 1,300 square miles (832,000 acres), and includes the Fenner Valley, Orange Blossom Wash, and a portion of Lanfair Valley.

This conjunctive use program is a cooperative venture between Metropolitan Water District of Southern California (MWD) and Cadiz Inc. (Cadiz) a publicly traded agricultural and water development company. Cadiz owns more than 27,000 acres in the program area and has developed approximately 1,600 acres of citrus orchards, table grape vineyards, and specially row-crops utilizing the indigenous groundwater. MWD and Cadiz have conducted extensive engineering and hydrological studies in the program area, including an 8-month pilot spreading basin test to measure site-specific infiltration rates. Over the 50-year term of the proposed program, MWD will store water imported from its Colorado River Aqueduct during periods of excess supply. This stored water and indigenous groundwater will be conveyed back to the Colorado River Aqueduct as needed. In cooperation with the United States Bureau of Land Management (USBLM), MWD has completed a Draft EIR/EIS and a supplement to the Draft EIR/EIS. Program facilities will include spreading basins, extraction wells, a 35-mile conveyance pipeline to the Colorado River Aqueduct, and a pumping plant.

Basin Management

The aquifer system in the vicinity of the program area is not adjudicated. Cadiz, the primary groundwater user in the area, operates its agricultural wellfield in compliance with a groundwater monitoring and management plan developed under the auspices of San Bernardino County. The conjunctive use program, and all future agricultural operations in the program area, will be operated under a comprehensive groundwater monitoring and management plan that has been developed in cooperation with the USBLM, United States Geological Society (USGS), National Park Service (NPS) and San Bernardino County. All program operations will be overseen by a Basin Management Group to be represented by the U.S. Department of the Interior, MWD, San Bernardino County, and Cadiz.

Available Storage

The volume of indigenous groundwater in storage in the vicinity of the proposed program wellfield is estimated to be in the range of 3.65 to 6.69 million acre-feet. The conjunctive use program is designed to accommodate storage of up to 150,000 acre-feet/year of water imported from the Colorado River Aqueduct, with a total storage capacity at any given time of approximately 1 million acre-feet.

Present Operational Safe Yield

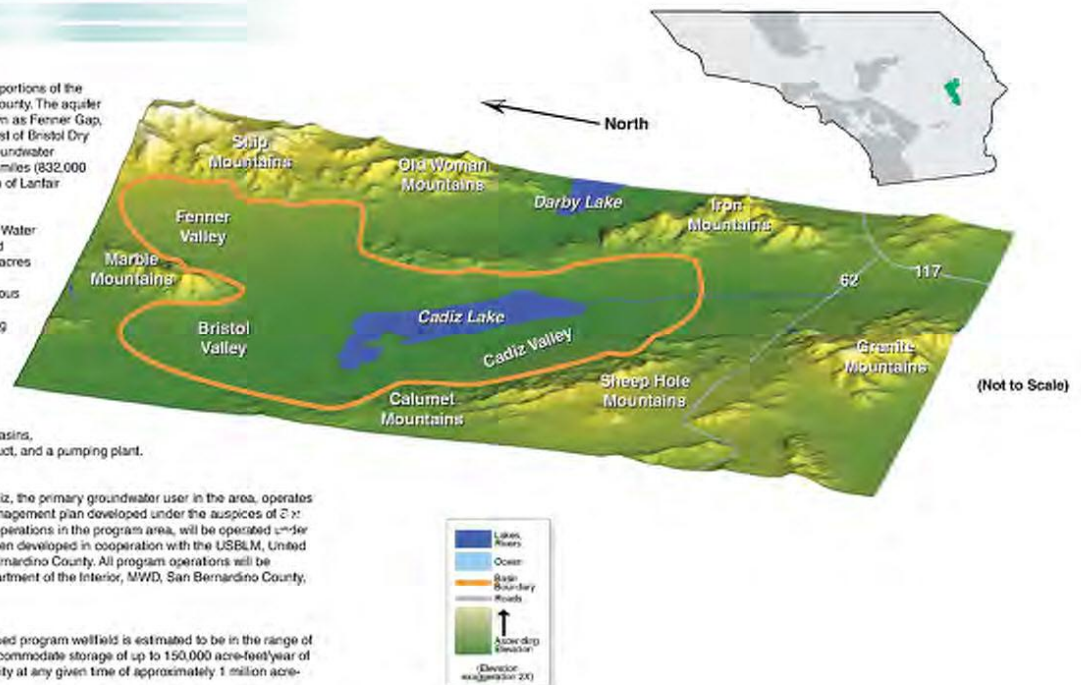
Estimates of safe yield will be refined as more data become available during operation of the conjunctive use program. Storage and extraction of imported water and transfers of indigenous groundwater will be authorized by the Basin Management Group only to the extent these operations will not adversely impact critical environmental resources in and surrounding the program area.

Basin Sediments

The aquifer system underlying the conjunctive use program area is composed of alluvial sediments of mid- to late-Tertiary and Quaternary age. These sediments are derived from Precambrian basement rock, Paleozoic sediments, and Tertiary volcanic rocks that are exposed in the mountain ranges in and surrounding the watershed. Geophysical surveys indicate that this alluvial fill locally exceeds 3,500 feet in thickness beneath portions of the program area.

Conjunctive Use Potential

The results of AGWA's survey indicate the potential to store up to 1,000,000 AF of water for use in dry years.



18. Coachella Valley Basin

Location
The Coachella Valley is located approximately 107 miles east of Los Angeles. The vast majority of the valley lies within Riverside County. Coachella Valley is bounded on the north by the San Bernardino and Little San Bernardino Mountains, on the east by Mecca Hills, on the south by the Salton Sea and Santa Rosa Mountains, and on the west by the San Jacinto Mountains. The San Andreas, Banning and Mission Creek faults separate the valley into three sub-basins: the Indio, Mission Creek and Desert Hot Springs sub-basins. Each of these faults is effective barriers to groundwater flow. The Whitewater River drains the valley to the Salton Sea, which has no outlet.

Basin Management
The Coachella Valley Stormwater District was formed in 1915 followed by formation of the Coachella Valley River District (CVRD) in 1918. These districts merged in 1937. In 1918, a contract was awarded to construct spreading facilities northwest of Palm Springs to recharge stormwater from the Whitewater River.

The Coachella Valley is heavily dependent on groundwater and imported water to meet water demands. In response to declining groundwater levels, CVRD signed a contract with the federal government to construct the Coachella Branch of the All-American Canal, which was completed in 1949. Canal water is delivered to farms and golf courses for irrigation.

In 1963, CVRD and Desert Water Agency (DWA) signed contracts with State of California for 61,200 acre-foot per year (AFY) of entitlements to State Water Project (SWP) water. CVRD and DWA exchange their SWP entitlements with the Metropolitan Water District of Southern California (MWD) for Colorado River water. This exchange water is recharged at the Whitewater Spreading Facility located north of Palm Springs. CVRD, DWA and MWD signed an advanced delivery agreement in 1964 that allows Metropolitan to store surplus Colorado River Water in the valley. CVRD and DWA have also purchased unused SWP water when it is available. Since 1963, over 1.7 million acre-foot (AF) imported water has been recharged at the Whitewater facility. MWD currently has about 290,000 AF of water stored in the valley.

CVRD and DWA also have active water recycling and water conservation programs. Currently about 8,000 AFY of recycled water is used for park and golf course irrigation. Water conservation programs focus on public information, school education, and use of water-efficient irrigation systems and landscaping techniques.

CVRD is completing a water management plan to resolve the on-going groundwater overdraft. This plan includes increased water conservation, water recycling, delivery of Colorado River water to additional farms, golf courses and municipal users and groundwater recharge. CVRD has conducted a pilot recharge test program at Dike No. 4 located south of La Quinta. If successful, a facility capable of recharging 30,000 to 60,000 AFY could be constructed at this location. Additional recharge facilities are also being evaluated. Additional imported water is expected to come from SWP entitlement transfers and quantification of California's Colorado River allocation.

The groundwater basin is not adjudicated. However, CVRD and DWA collect replenishment assessments from groundwater producers in the northwestern portion of the Indio sub-basin.

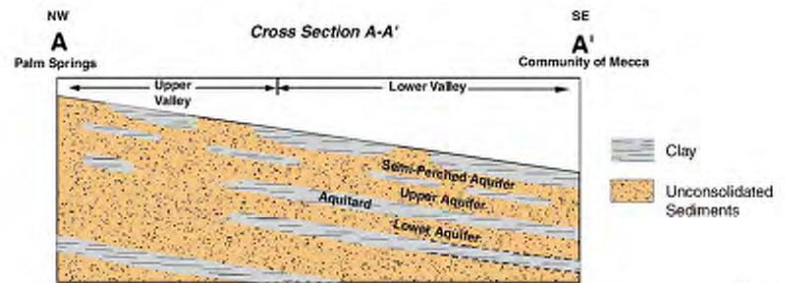
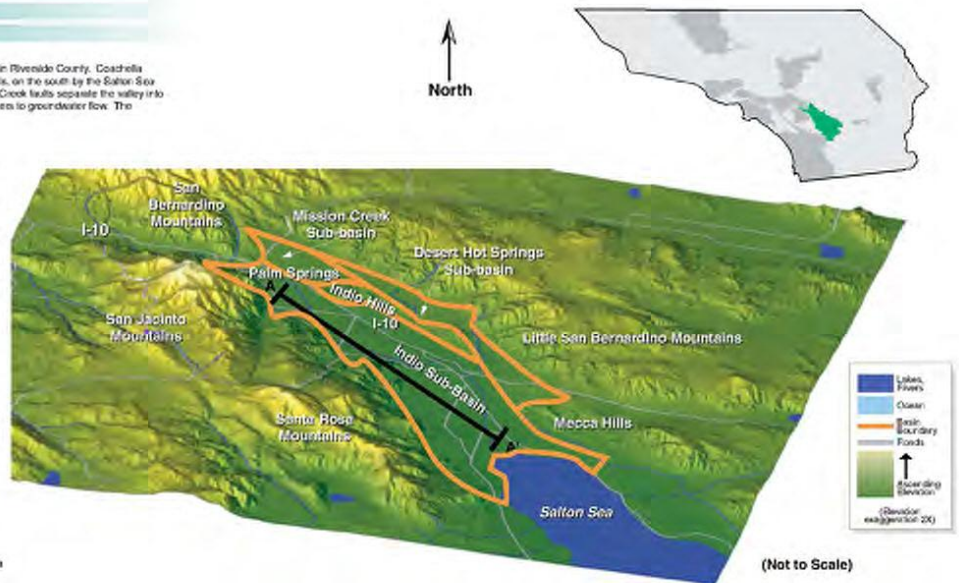
Available Storage
The first water storage capacity of the valley is approximately 37 million AF. Of this amount, the Indio sub-basin has a capacity of about 30 million AF. Available storage capacity in the Indio sub-basin is about 4 million AF.

Present Operational Safe Yield
The present operational safe yield of the valley is estimated to be 220-250,000 AFY.

Basin Materials
The conceptual hydrogeological model of the Coachella Valley includes four zones:
 • The Semi-Perched aquifer and intervening recharging layers (correlated with Recent lake deposits and alluvium)
 • The Upper aquifer (correlative with Upper Pleistocene Alluvium)
 • An aquiclude
 • The Lower aquifer (correlative with the Pleistocene Ocotillo conglomerate)

South of Indio, all four hydrostratigraphic units are clearly present in the center of the Indio sub-basin. At the margins of the sub-basin, the proportion of clay decreases thereby allowing for continuity between the Upper and Lower aquifers. Because of the thick clay aquiclude separating the Upper and Lower aquifers, groundwater recharge is limited to the margins of the Valley. North of Indio, the aquiclude is discontinuous or absent throughout most of the sub-basin. Therefore, this area provides greater opportunity for direct groundwater recharge.

Conjunctive Use Potential
The results of ADWR's survey indicate existing conjunctive use programs have increased the basin operational yield by 50,000 AFY. Additionally, the survey indicated the potential to store up to 4,000,000 AF of water for use in dry years and a potential increase in basin operational yield of 80,000 AFY.



Responses to AGWA's Questionnaire

Compiling the survey responses, AGWA has estimated the storage available for conjunctive use in some 85 groundwater basins of Southern California. For the purposes of this guide, conjunctive use potential includes both dry-year or longer-term storage and shorter-term programs such as annual put and take or seasonal storage operations. By using the groundwater aquifer for storage, surplus water available in wet years is used to meet future dry-year demand as shown in Figure 6. Stored water can also be used to increase the basin yield.

Many basins already have conjunctive use programs in place. Existing conjunctive use programs currently provide an estimated 2.5 MAF of water per year as shown on Figure 7.

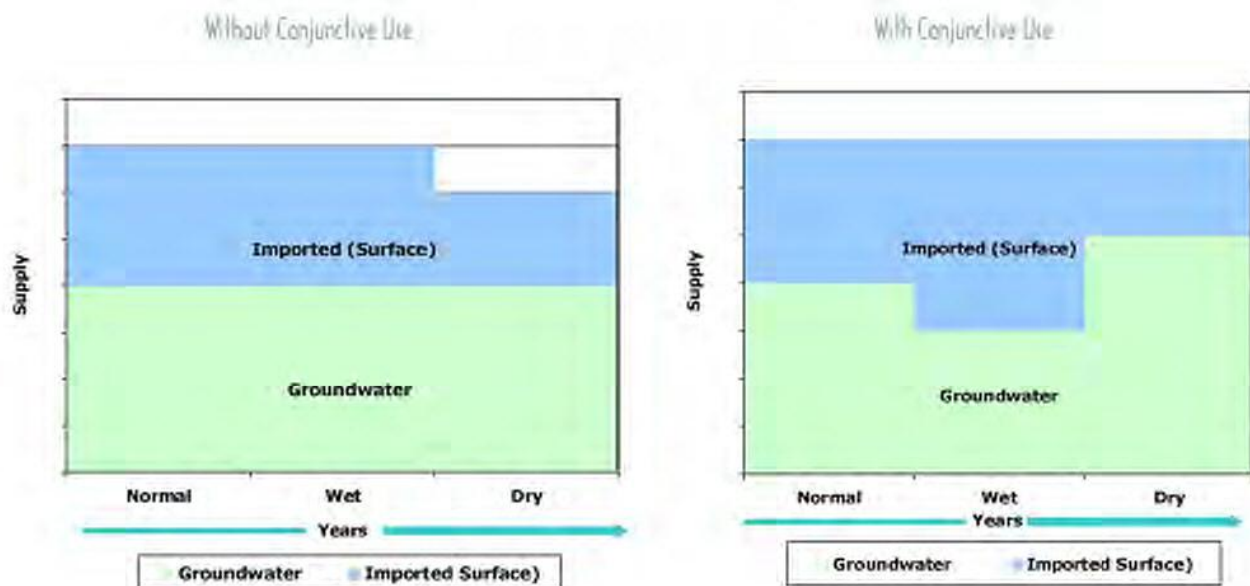
However, these existing programs represent only a small fraction of the conjunctive use potential identified by the AGWA survey throughout South-

ern California. Figure 8 illustrates the dry-year storage available by basin, which totals 21.5 million acre-feet (MAF) for all basins combined. The short-term storage, or future increase in operational yield, totals 1.3 MAF per year as shown on Figure 9.

Summary

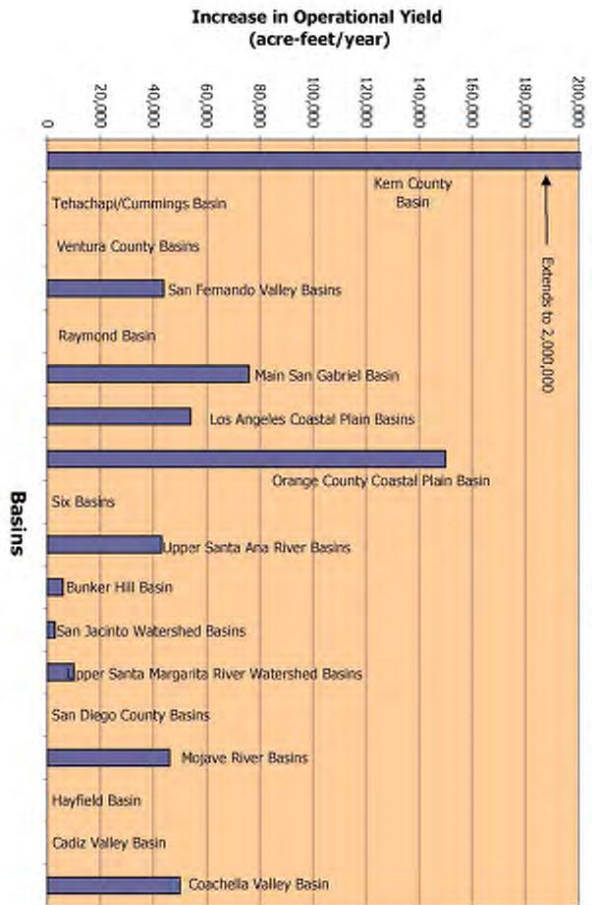
Over the centuries, people have devised ways to regulate the flows of surface water systems by impounding rivers and streams behind dams to capture and retain water for use in dry periods and releasing controlled amounts in order to accommodate downstream demands. However, substantial amounts of water remain unused, particularly in wet years, due to inherent limitations in these surface water systems. Major improvements in these systems could be achieved by coordinating the use of both surface water and groundwater. This coordination involves diverting and/or conveying water for storage underground

Figure 6
Conjunctive Use for Dry Year Storage



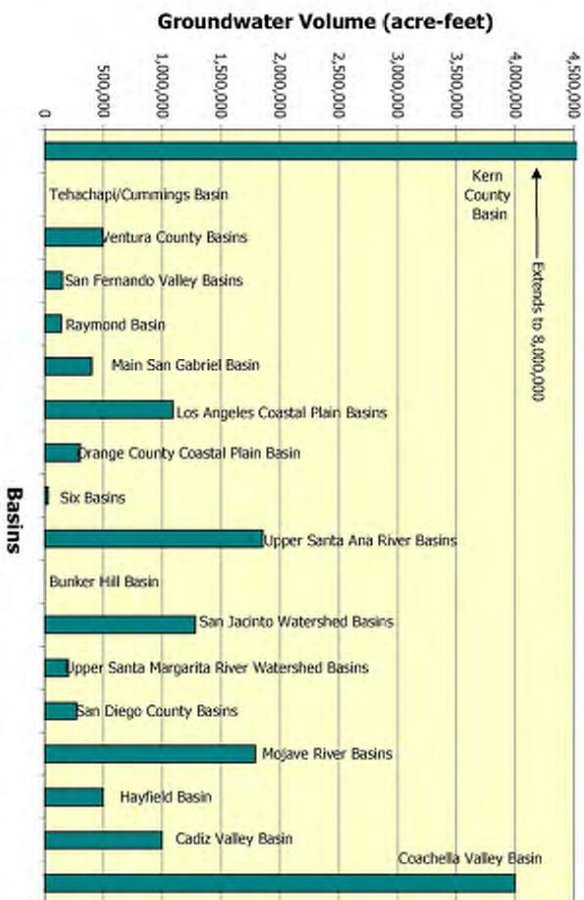
Existing Increase in Basin Yield from Conjunctive Use Programs

Figure 7



Potential Dry Year or Long Term Groundwater Storage From Conjunctive Use

Figure 8



when surface water is in abundance to provide reliability during drought periods. During droughts, the stored water can be pumped from underground and used to meet present demands. Stored underground water may also be used to meet "peak" demand, so that surface water storage and distribution systems can be built to an average-demand capacity rather than a peak load capacity. Such "conjunctive use" of groundwater and surface or imported supplies improves the overall reliability, efficiency and value of our water system.

Through the data collected in the preparation of this guide, AGWA has documented the following:

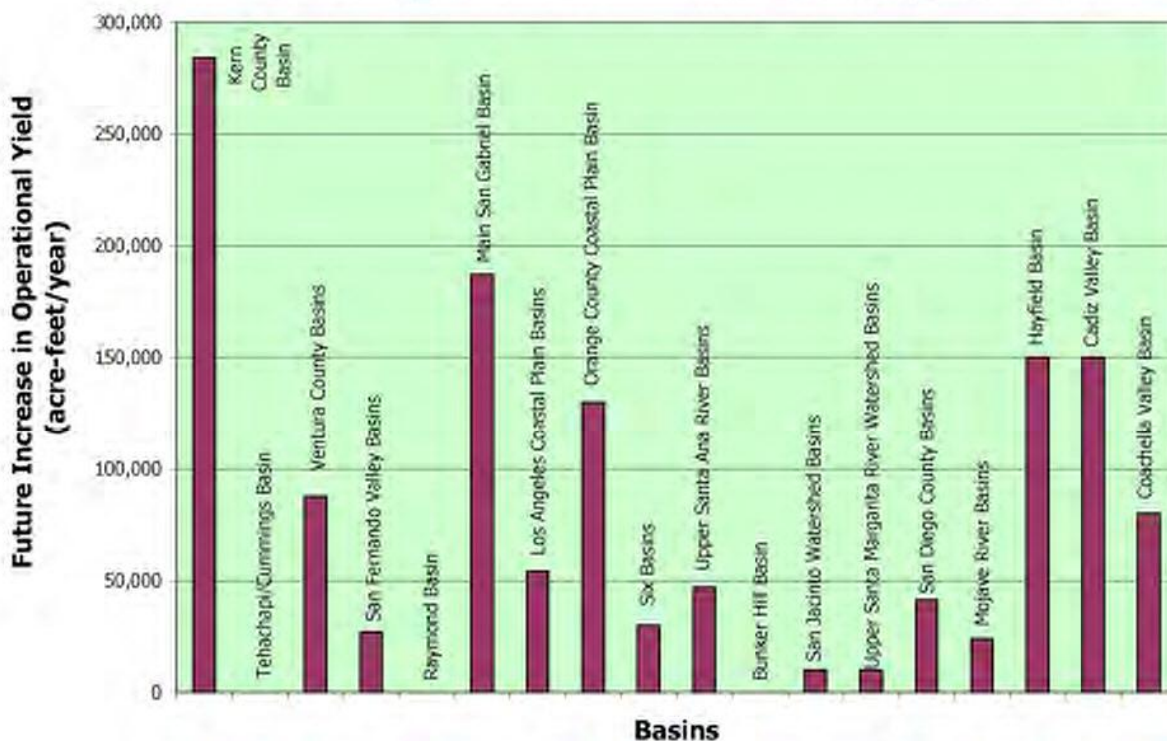
- Conjunctive use is a well-proven method to increase our ability to meet California's increasing water demand.
- Conjunctive use improves water supply reliability.

- The need for additional, environmentally controversial, surface water reservoirs may be reduced by conjunctive use programs.
- Assuming resolution of institutional, water quality, and other issues, over 21.5 million acre-feet of additional water can be stored and used in Southern California groundwater basins.

Conjunctive use is becoming a key part of California's overall water management strategy for allocating an increasingly scarce resource among a steadily growing population. This guide demonstrates that in Southern California basins alone, approximately 21.5 million acre-feet of additional conjunctive use potential is available, enough to fill Diamond Valley Lake, Southern California's largest surface water reservoir, 26 times over. This stored water could be used during times of drought or natural disaster when surface water supplies are reduced or not available.

Figure 9

Potential Annual Operational Yield Increase from Conjunctive Use



Glossary

acre-foot—325,851 gallons, or enough water to cover an acre of land 1 foot deep. An acre-foot can supply the annual needs of between one and two average California households.

artificial recharge—the purposeful addition of surface water to a groundwater basin by human activity such as percolation ponds or injection wells.

aquifer—a geologic formation that stores, transmits, and yields significant quantities of water to wells or springs.

available storage—the current amount of space in a groundwater basin that can be used for water storage.

confined aquifer—an aquifer that is bound above and below by impermeable layers of soil or rock.

conjunctive-use potential—For the purposes of this guide, conjunctive use potential includes both dry-year or longer-term storage and shorter-term programs such as annual put and take or seasonal storage operations.

dry year—a year with below-average precipitation.

evapotranspiration—the combined losses of water through the processes of evaporation and uptake and use by vegetation (transpiration).

extraction—the process of withdrawing groundwater from storage by pumping or other controlled means.

groundwater—water stored underground in pore spaces within rocks and other alluvial materials and in gaps between fractured hard rock.

hydrologic cycle—the natural recycling process powered by the sun that causes water to evaporate into the atmosphere, condense, and return to the earth as precipitation.

impermeable—having a texture that does not permit water to move through quickly.

in-lieu recharge—an indirect method of recharge caused by reducing the amount of water pumped from the aquifer.

operational yield—The augmentation of safe yield by the use of engineering controls (i.e. re-

charge basins, injection wells) such that more water is made available to meet an increased demand.

overdraft—intentional or inadvertent withdrawal of water from an aquifer in excess of the amount of water that recharges the basin over a period of years.

percolation—the movement of water through small openings within a porous material.

permeability—the capability of soil or rock to transmit water.

recharge—flow to groundwater storage from precipitation, irrigation, spreading basins and other sources of water.

safe yield—the amount of water that can be pumped each year without causing a continual reduction of water in storage (overdraft). The safe yield is dependent upon the average amount of water that can be stored in and used from the groundwater reservoir over a period of normal water supply under a given set of conditions.

saturated zone—the area below the water table in which the soil is completely saturated with groundwater.

seasonal (short-term) storage—For the purposes of this guide, the short term or seasonal storage quantity represents the amount of water that can be put in and taken out of storage on an annual basis.

salt water intrusion—the movement of salty water into fresh water aquifers. When groundwater pumps draw up fresh water from the aquifer, salty water can flow into the aquifer and make it unuseable.

subsidence—lowering or sinking of the land surface due to a number of factors, of which groundwater extraction is one.

surface water—water that remains on the earth's surface in rivers, streams, lakes, reservoirs or oceans.

unsaturated zone—the subsurface zone, usually starting at the land surface and ending at the water table, that includes both water and air in spaces between rocks.

Contact List of Basin Managers

Map	Basin Name	Management Agency	Contact Person	Phone Number
1	Kern County Basin	Kern County Water Agency	Rick Iger	661-634-1469
2	Tehachapi/Cummings Basin	Tehachapi-Cummings County Water District	John Otto	661-822-5504
3	Ventura County Basins	United Water Conservation District	Dana Wisehart	805-525-4431
4	San Fernando Valley Basins	Watermaster - Upper Los Angeles River Area	Melvin Blevins	213-367-1020
5	Raymond Basin	Raymond Basin Management Board	Ronald Palmer	818-790-4036
6	Main San Gabriel Basin	Main San Gabriel Basin Watermaster	Carol Williams	626-815-1300
7	Los Angeles Coastal Plain Basins	Water Replenishment District of Southern California	Robb Whitaker	562-921-5521
8	Orange County Coastal Plain Basin	Orange County Water District	William Mills	714-378-3200
9	Six Basins	Three Valleys Municipal Water District	Mario Garcia	909-621-5568
10	Upper Santa Ana River Basins	Chino Basin Watermaster	Robert Neufeld	909-484-3888
11	Bunker Hill Basin	San Bernardino Valley Water Conservation District	Tom Crowley	909-793-2503
12	San Jacinto Watershed Basins	Eastern Municipal Water District	Behrooz Mortazavi	909-928-3777
13	Upper Santa Margarita River Watershed Basins	Santa Margarita River Watermaster	James Jenks	760-728-1028
14	San Diego County Basins	San Diego County Water Authority	Daniel Diehr	619-682-4100
15	Mojave River Basins	Mojave Water Agency	Mark Lund	760-240-9201
16	Hayfield Basin	Metropolitan Water District	Steve Arakawa	213-217-6052
17	Cadiz Valley Basin	Metropolitan Water District	Steve Arakawa	213-217-6052
18	Coachella Valley Basin	Coachella Valley Water District	Tom Levy	760-398-2651