CHAPTER 1

Introduction

The increasing demand for water has focused attention on improving groundwater management in California. But management of groundwater is complex. It involves court decisions, some statutory law, overlying landowners' rights to groundwater, complex technical issues and more than a century of political and institutional development and investment.

This handbook, published by the Groundwater Resources Association of California (GRA), covers many aspects of groundwater management, including information crucial to creating groundwater management plans, groundwater law, technical issues, and basic groundwater concepts. It is intended to provide general:

1) information for public officials who need a fundamental understanding of groundwater issues as they determine policies for the comprehensive management of water resources,
2) guidelines for the hands-on development and implementation of groundwater management plans, and
3) reference material for people that have an interest in California's groundwater.

It is designed for use by water district directors, managers and staff; city and county planning managers and staff; and other persons working in the water industry, such as geologists, engineers, planners and attorneys. It may be useful to farmers and agricultural water users who are concerned about their groundwater resources and what effect management may have on their livelihood. It also may provide information and concepts to other persons in a groundwater basin who may be affected by a management plan, even though they are not directly involved in the management process.

This handbook is intended to be a comprehensive publication on California groundwater management that supplements and references the available information and literature provided by agencies and consultants. This document provides current information on the complexities of California groundwater management and suggestions for workable solutions. It is also hoped this handbook can be used by state policy makers to provide a foundation for a statewide groundwater management policy to be developed and implemented at the local level.

What is Groundwater Management?

What is groundwater management? The answer probably depends on where you are and the person to whom you are speaking. However, the subject itself has become an integral component of water management due to California's droughts, environmental requirements and increasing water demands that result from relentless population growth and corresponding development. All of these issues increase our reliance on groundwater.

The terms themselves seem simple enough. Groundwater means water beneath the surface of the Earth, in the saturated zone. Of course you can't really see groundwater, and it's often difficult to tell just exactly where it is, how much of it there is and who's using it.

The definition of management can be even more nebulous. In terms of groundwater management in California, management is used to define an integrated program of pumping and recharge to achieve the long-term sustainability of the resource. Absent from the definition is who manages the resource, how much, when, where and, most importantly, why? So "groundwater management" means, at best, some level of supervision and coordination by someone over water of often-unknown quantity, quality, recharge and use.

More practically, groundwater management means a number of integrated actions related to groundwater pumping and recharge, both natural and artificial, to achieve the long-term sustainability of a specific resource.

Physical Setting

In 2004, more than 36 million people and 100 million acres make California the most populous state and one of the three largest states in the country. California is highly complex geographically and geologically, with greater variation of topography, climate and rock type than any of the other states in the continental U.S. The fifth largest economy in the world and most productive agricultural state in the union, California produces over half the fruits, nuts and vegetables in the nation.

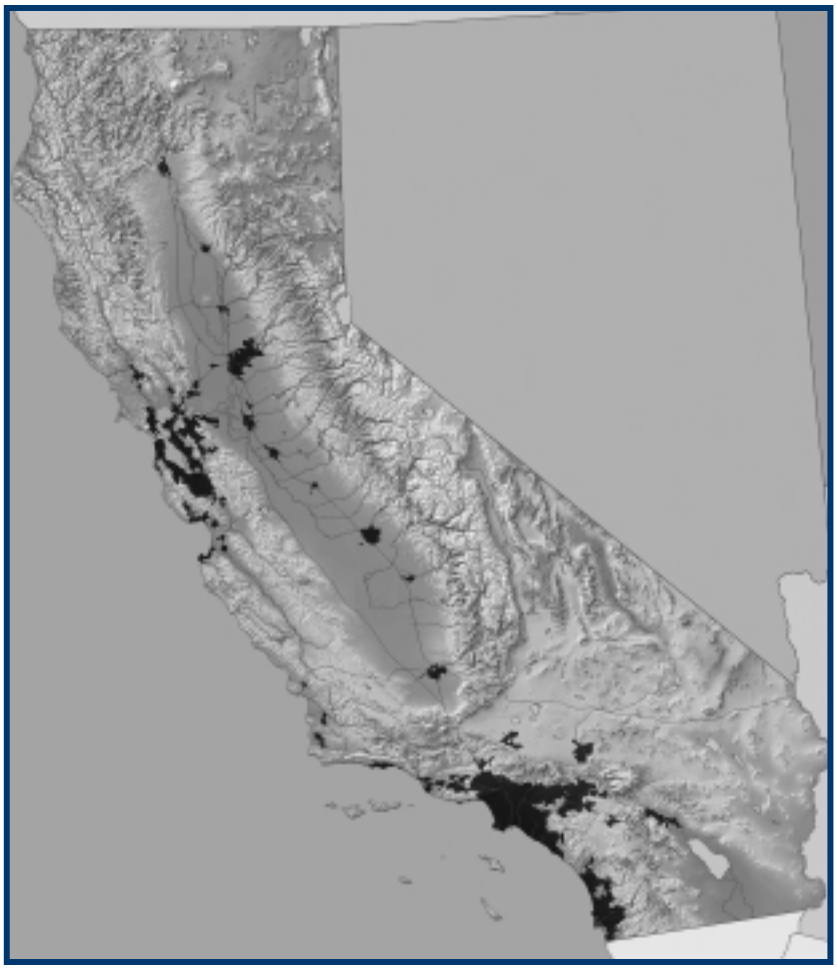
California is approximately 800 miles long, 100 miles wide and is bordered on the west by nearly 840 miles of Pacific Ocean coastline. Much of this border is marked by mountains which appear to rise from the sea. Some of its most notable topographic features are the north-northwest trending mountain ranges of the Coast Ranges on the west, the westward tilting Sierra Nevada mountains on the east, the Central Valley trough in between them, and the volcanic Cascade Ranges and Modoc Plateau in the northeast portion. Noteworthy features to the south include the east-west trending Transverse Ranges, the northwestward trending steep ranges and valleys of the Peninsular Ranges, the north and northwest trending mountains and intervening valleys of the Basin and Range desert, and the Mojave and Sonora Deserts to the southeast.

The highest and lowest points in the continental U.S. are located in California. In the southern Sierra Nevada, Mount Whitney has an elevation of 14,494 feet. Approximately 80 miles to the southeast of Mount Whitney is Bad Water, Death Valley at 282 feet below sea level. Refer to Figure 1-1 for a topographical relief map.

Figure 1-1
California Topography

The dramatic topographic relief of California, shows the mountain ranges in lighter tone and indicates the Central Valley by the deep gray tone. The major population centers are indicated in black.

Figure courtesy of MWH America, Inc.



The U.S. Geological Survey (USGS) developed a map of ten hydrogeologic provinces for the state, considering hydrology, geology, climate, and landforms, with province boundaries determined on the basis of watershed and groundwater basin extent (Figure 1-2).[1] Figure 1-3A shows California groundwater basins, which are relatively permeable materials, consisting of basin fill (gravel, sand, silt and clay deposited by flowing water and lakes) and volcanic rocks. Public supply wells in the state are shown relative to the presence of groundwater basins in Figure 1-3B and listed in Table 1-1. Note that Figure 1-3B does not include the numerous private wells in the state.

The amount of water available in California is dependent upon the climate, which has been defined as an arid to semi-arid Mediterranean type. On an average annual basis, roughly two-thirds of the normal precipitation occurs in the northern one-third of the state (Figure 1-4) in the Northern Coast Ranges, Klamath and Sierra Nevada hydrogeologic provinces, with significant runoff in the northern Central Valley province. The southern two-thirds of the state receives little rainfall, and nearly all the precipitation occurs between November and March, with the minor exception of some limited summer thun-

[1] USGS. 2003. *Framework for a ground-water quality monitoring and assessment program for California.* USGS Water Resources Investigation Report 03-4166.

Figure 1-2 Hydrogeologic Provinces

Hydrogeologic provinces of California, based on hydrology, geology, climate, landforms, watersheds and groundwater basins.

Figure courtesy of USGS.[F1]

- **Northern Coast Ranges** — Dominated by low-permeability marine metamorphic rocks, with groundwater basins of thin alluvial sands, gravels, silts and clay.
- **Southern Coast Ranges** — Mostly low-permeability rocks like those described for the North Coast, with the addition of a core of granitic rocks, some non-marine sandstones and conglomerates, with groundwater basins of thin- to moderately-thick alluvial sands, gravels, silts and clay.
- **Klamath Mountains** — Dominantly low-permeability granitic and metamorphic rocks with wells obtaining water from bedrock fractures.
- **Modoc Plateau and Cascades** — Low- to high-permeability volcanic rocks including lava flows, ash, volcanic fragments, mudflows, volcanic domes and mountains, with groundwater basins of thick to thin deposits of volcanically-derived sands, gravels, silts and clay.
- **Central Valley** — Moderate- to high-permeability alluvial sands, gravels, silts and clay hundreds to thousands of feet thick. Contains California's largest aquifer system.
- **Sierra Nevada** — Low-permeability granitic and metamorphic rocks with wells obtaining water from bedrock fractures.
- **Basin and Range** — Low-permeability granitic, metamorphic, and volcanic rocks with groundwater basins of thick alluvial sands, gravels, silts and clay.
- **Transverse and Selected Peninsular Ranges** — Low-permeability granitic and metamorphic rocks with groundwater basins of thick alluvial sands, gravels, silts and clay.
- **San Diego Drainages** — Low-permeability granitic and metamorphic rocks with groundwater basins of thin to thick alluvial sands, gravels, silts and clay.
- **Desert** — Low-permeability granitic and metamorphic rocks with groundwater basins of thick alluvial sands, gravels, silts and clay.

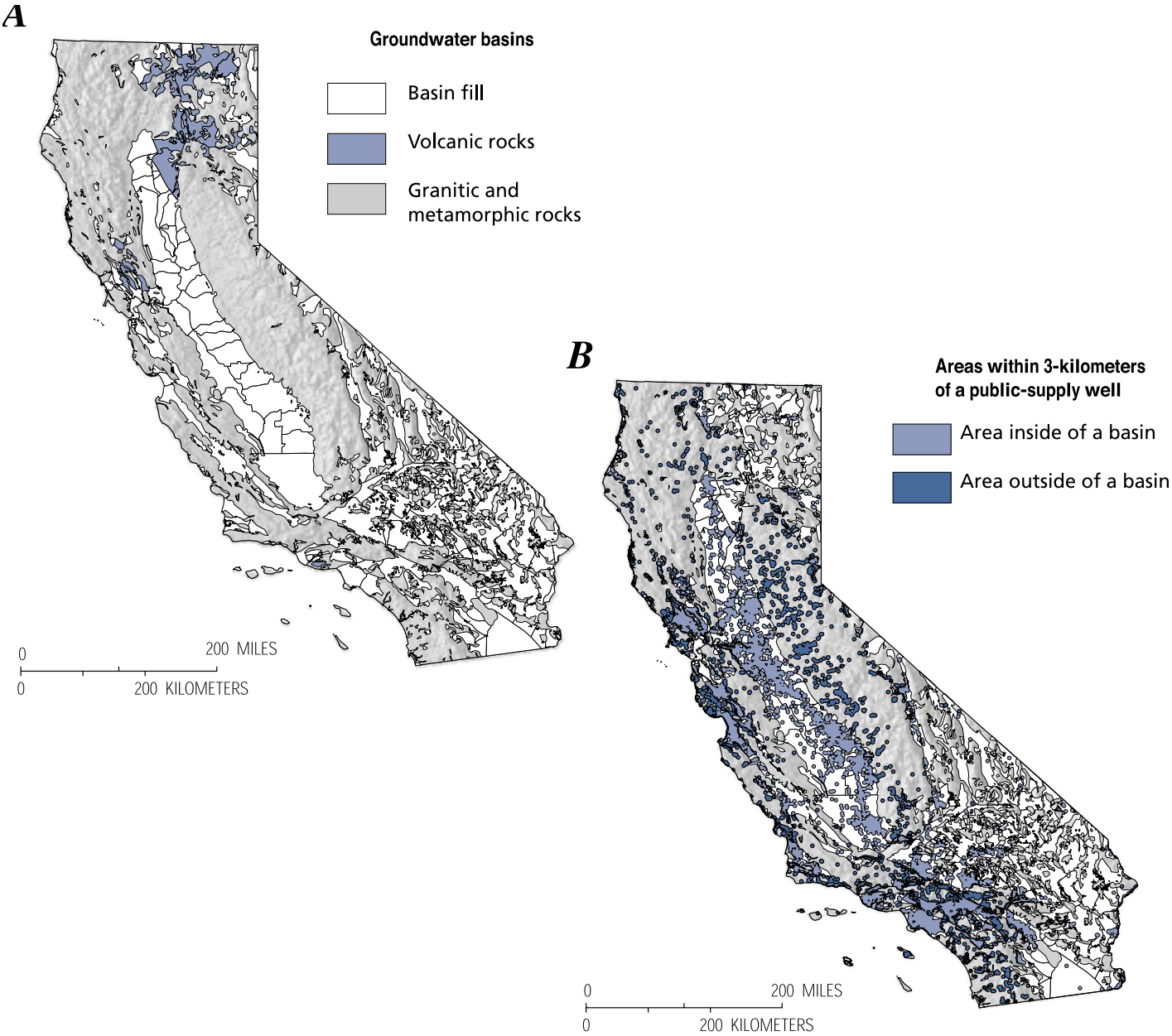
F1 USGS. 2003. *Framework for a ground-water quality monitoring and assessment program for California*. USGS Water Resources Investigation Report 03-4166.

Figures 1-3A and 1-3B Groundwater Basins and Public Supply Wells

These figures depict California's groundwater basins as mapped by the California Department of Water Resources (DWR). Public supply wells are displayed as within or outside a groundwater basin.

Figures courtesy of USGS.

Note: Figure 1-3B does not include the many thousands of private wells in California.[F2]



[F2] USGS. 2003. *Framework for a ground-water quality monitoring and assessment program for California*. USGS Water Resources Investigation Report 03-4166.

Table 1-1
California Hydrogeologic Metrics[T1]

Province	Total area of province (km²)	Number of watersheds in province	Number of groundwater basins in province	Total area of basins (km²)	Percent basin to province total area	Number of public supply wells inside basins	Number of public supply wells outside basins
Northern Coast Ranges	38,000	176	79	6,000	15	770	280
Southern Coast Ranges	42,000	89	74	13,000	30	1,740	480
Klamath Mountains	23,000	51	7	300	1	20	110
Modoc Plateau and Cascades	39,000	70	55	21,000	54	240	40
Central Valley	53,000	8	36	53,000	100	5,360	0
Sierra Nevada	66,000	161	22	2,000	3	330	1,170
Basin and Range	36,000	56	45	16,000	45	260	20
Transverse and Selected Peninsular Ranges	22,000	167	33	8,000	36	2,720	800
San Diego Drainages	10,000	163	25	1,000	10	180	120
Desert	81,000	110	96	56,000	69	1,240	60
Totals	**410,000**	**1051**	**472**	**176,000**	**43**	**12,860**	**3,080**

Note: DWR Bulletin 118-2003[T2], *California's Groundwater*, has identified 515 groundwater basins and sub-basins. A sub-basin is created by dividing a groundwater basin into smaller units using geologic and hydrologic barriers or, more commonly, institutional boundaries.

[T1] USGS. 2003. *Framework for a ground-water quality monitoring and assessment program for California*. USGS Water Resources Investigation Report 03-4166.

[T2] DWR. 2003. *California's Groundwater.* p 90. Bulletin 118-2003.

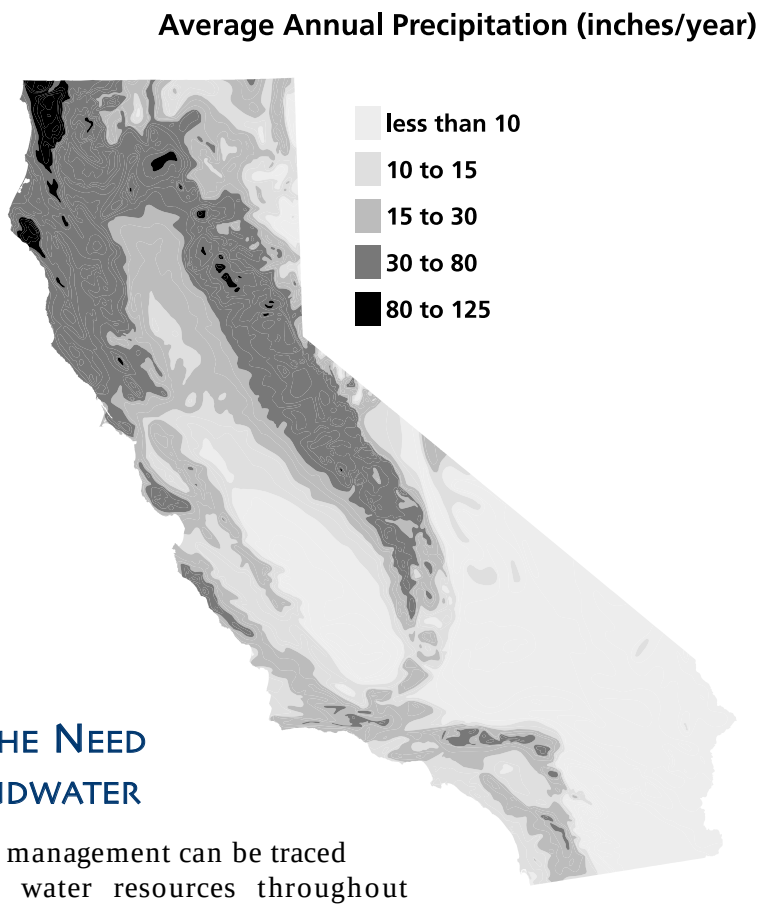
derstorms. A significant amount of precipitation falls in the mountain ranges and in the northern third of the state as snow, which during the spring melt, flows into the Sacramento River and the ocean.

California's population distribution is as unequal as the distribution of average annual precipitation. Although two-thirds of the rainfall falls in the northern one-third of the state, two-thirds of the people live in the southern, drier one-third of the state. With the exception of the Northern Central Valley, agricultural production is also largely located in drier areas of the state including the Southern Central Valley, Southern Coast Ranges, Transverse and Peninsular Ranges, and desert provinces.

Figure 1-4
California
Precipitation

This figure depicts California's average annual rainfall over a 60-year-period.

Figure based on Teale Data Set, courtesy of DWR.



History Defined the Need to Manage Groundwater

The need for groundwater management can be traced to the development of water resources throughout California's history. When Europeans first arrived in California, water was abundant relative to demand, the groundwater basins were full and supplied water to many streams, wetlands and riparian habitats. The early mission settlements in the later 1700s were located adjacent to streams to provide irrigation for fruits and vegetables. As settlers began to use water for irrigation, domestic and industrial uses and other needs, groundwater supplemented the surface water they used from springs, streams, lakes and ponds.

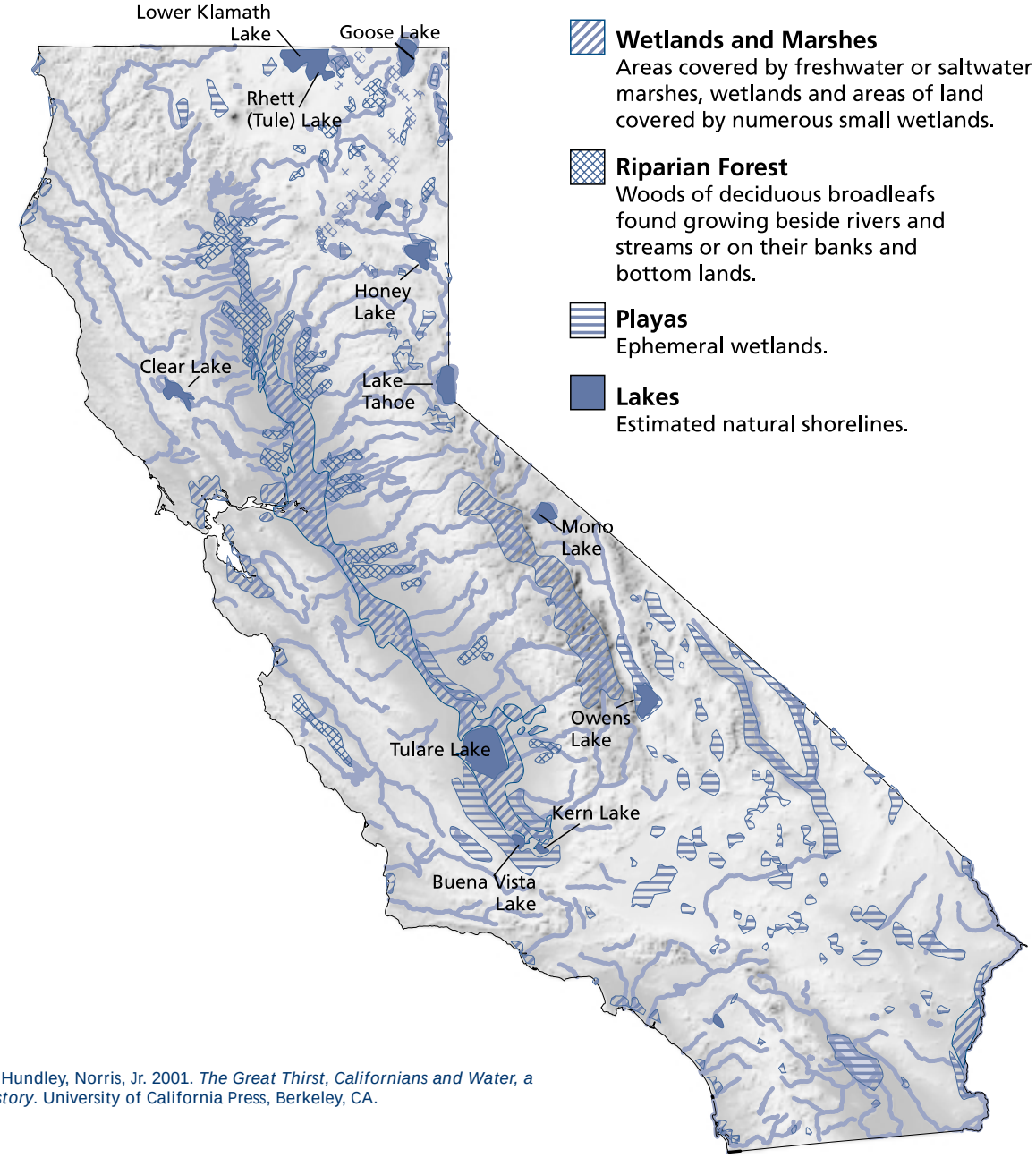
As the use of groundwater increased, water levels dropped. This created storage space in aquifers that surface runoff often refilled during wet seasons. Some of this groundwater recharge came directly from rainfall, but most came from water entering the aquifers through the banks and beds of rivers and streams and from irrigation water infiltrating back down to the water table. The amount of water in streams and wetlands declined as more water percolated through the stream bottoms to recharge depleted aquifers. In some basins, the amount of water pumped was more than the runoff available in the streambed to recharge the basin. This caused many streams, marshes and wetlands to dry up (see Figures 1-5 and 1-6). In very wet years the river channels filled again. This process continues today.

In the early 1900s, with the advent of the gasoline- and electric-powered turbine pump, California drew heavily on groundwater for its vigorous irrigated agricultural and urban economies, resulting in the depletion of groundwater supplies in many of the basins in the southern portion of the state. Over a short period of time, there was recognition of the lack of a reliable water supply with the periodic wet and dry years, and the mismatch of demand

Figure 1-5
The California Aboriginal or Natural Waterscape

Pre-European settlement, more than 5 million acres of seasonal, permanent wetlands and riparian habitat existed in California stretching from the Modoc Plateau and Klamath River Basin in the north to the Imperial and Coachella Valleys in the south. Dense deciduous forests and wetlands supported an abundance of fish, game, and waterfowl. California's groundwater basins were all full, in a state of natural equilibrium with surface water; groundwater would recharge in the mountains and alluvial fans, and then discharge into the wetlands and streams in the valleys.

California background figure courtesy of DWR. (Modified after Hundley.)[F3]

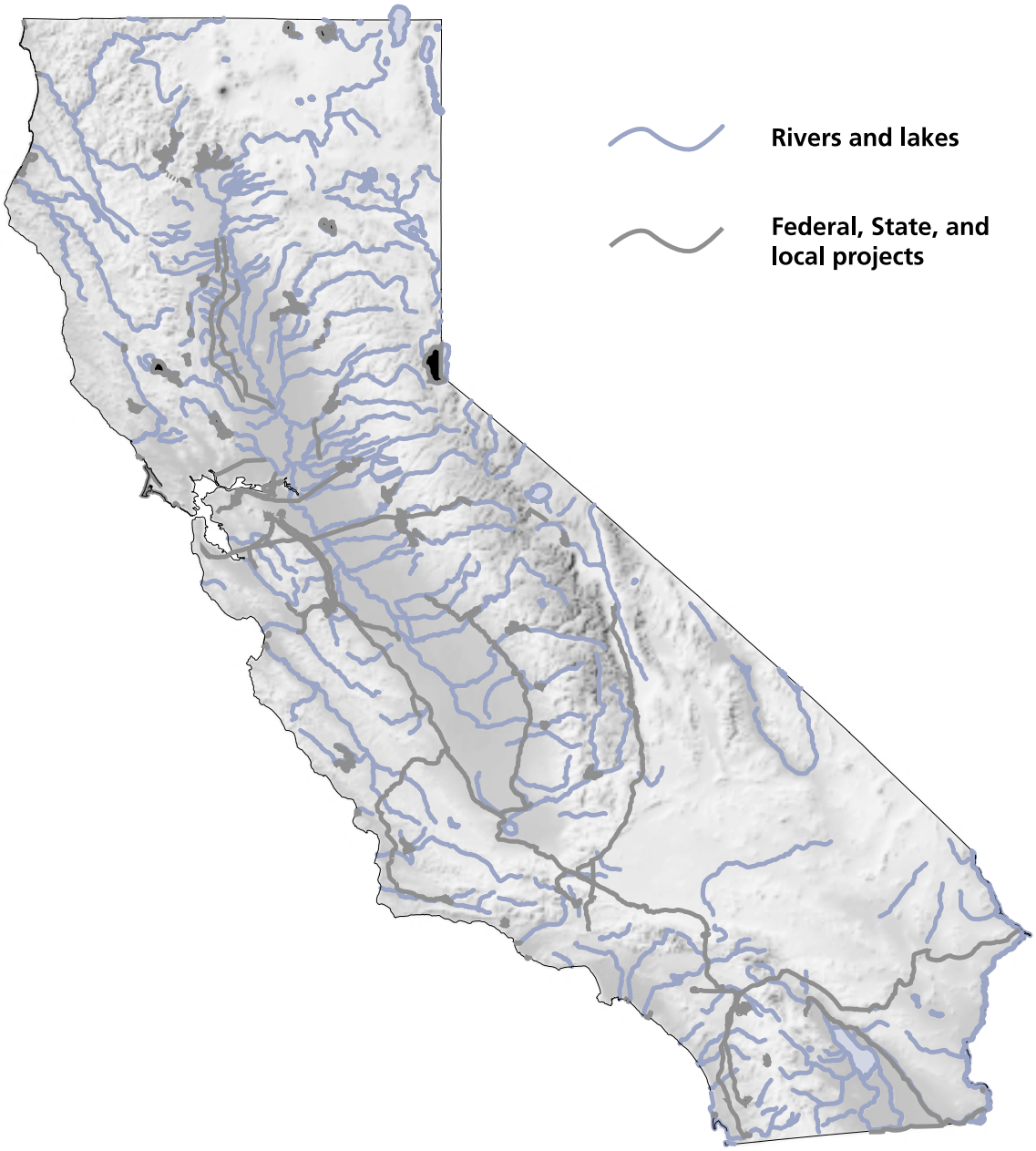


[F3] Hundley, Norris, Jr. 2001. *The Great Thirst, Californians and Water, a History*. University of California Press, Berkeley, CA.

Figure 1-6
The California Developed Waterscape

A complex system of federal, state and local drainage projects which move water from the wetter, water-rich areas of the state to the drier, water-poor areas of the state. More than 90 percent of the wetlands are gone, streams are largely disconnected from groundwater in the valleys, and many of California's groundwater basins are in overdraft, a result of the combination of groundwater mining and loss of the surface water connection in many places. A good portion of the dense deciduous forests are gone, and many fish, game and waterfowl species have declined significantly or disappeared.

Figure courtesy of DWR (modified).



versus supply with seasonal variations. Periodic dry periods typically lasting several years, known as droughts, occurred in the 1800s and 1900s leading to water shortages. The snowmelt runoff provided a lot of runoff in the spring, but there was not much runoff available in the late summer when crops were maturing. These factors provided the impetus to find alternatives that met the water demands and expansion of irrigated agricultural and urban growth.

What is an Aquifer?

A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.[2]

See Chapter 2 for more detailed information on aquifers and hydrogeology. For the definitions of other technical terms, refer to the list of definitions provided at the back of this book.

As first noted by John Wesley Powell (1879),[3] second director of the USGS, the entire southwest lacks precipitation adequate for agriculture without irrigation. Similarly, there is a lack of adequate local precipitation to support the widespread urbanization that has occurred in the drier parts of California. The mid-1900s was a time of dam construction and surface-water reservoir filling. Development of the large southern California population was made possible only by the construction of government-subsidized major hydraulic projects including the Los Angeles Aqueduct, Colorado River Aqueduct, Central Valley Project and State Water Project, that were all designed to move water from the water-rich to the water-poor parts of the state (Figure 1-6). These major hydraulic projects were for flood control and importation of water supplies, first from the Owens Valley east of the Sierra Nevada, then from the Colorado River, and finally from northern California. Equally, the development of irrigated agriculture in California was possible due to these same government projects.

An added complication to California's complex water distribution and the long-term transfer of water from northern to southern California is the San Francisco Bay and the delta formed by the confluence of the Sacramento and San Joaquin Rivers, referred to as the Bay-Delta. Roughly two thirds of southern California's water supply passes through the Bay-Delta, which suffers from water quality issues, levee integrity and ecological habitat degradation. Attempts to bring a restoration solution to the Bay-Delta and balance California's water quality demands and interests, through the formation of CalFed in 1994, a collection of state and federal agencies, have been challenging. The Bay-Delta Water Authority was formed recently to continue work begun by CalFed.

The mid to late 1900s marked the end of an era in dam construction and the birth of the environmental movement. No longer would the damming of a river be a simple matter of meeting a current or future water demand. Now the likelihood of constructing a new surface water storage facility is very low. Many areas rely on a combination of groundwater and surface water because neither source by itself is adequate to supply all the water needed in

[2] Jackson, J.A. and Bates, R.L., eds. 1987. *Glossary of Geology*. Third Edition. American Geological Institute. Alexandria, VA.

[3] Powell, J.W. 1879. Report on the lands of the arid region of the United States. *Report to the U.S. Congress*. p 195. Washington, D.C.

The Central Valley Project

The Central Valley Project (CVP) construction began in 1937 and was completed in 1948 by the Bureau of Reclamation. Originally constructed for the primary purposes of providing a reliable water supply to agricultural interests in the south Central Valley and for flood control. The CVP:

- reaches some 400 miles, from the Cascade Mountains near Redding in the north to the Tehachapi Mountains near Bakersfield in the south;
- consists of 20 dams and reservoirs, 11 power plants, and 500 miles of major canals, as well as conduits, tunnels, and related facilities;
- manages some 9 million acre-feet (maf) of water;
- annually delivers about 7 maf of water for: agriculture (5 maf), urban (0.6 maf), and environmental uses (1.2 maf);
- generates 4.5 billion kilowatt hours of electricity annually to meet the needs of about 2 million people; and
- dedicates 800,000 acre-feet per year to fish and wildlife and their habitat and 410,000 acre-feet to State and Federal wildlife refuges and wetlands.

The State Water Project

The State Water Project (SWP) construction began in 1961 and was completed in 1973 by the DWR. Constructed for the primary purpose of storing and distributing water statewide, it also provides flood control, power generation, water quality improvement, recreation and enhancement of fish and wildlife. The SWP:

- reaches some 600 miles, from the Sierra Nevada foothills near Oroville in the north through the delta and San Joaquin Valley over the Tehachapi Mountains south to the Peninsular Ranges ending at Perris reservoir;
- consists of 32 dams and reservoirs, five power plants, 17 pumping plants, 660 miles of major canals, as well as conduits, tunnels, and related facilities;
- manages some 5 maf of water;
- annually delivers between 2 and 3 maf of water for agriculture (30 percent), and urban (70 percent), when available; and
- generates 6 billion kilowatt hours of electricity annually and uses about 8 billion kilowatt hours of electricity annually, to move the SWP water across the state.

the basin. Consequently, there will continue to be increased demands on groundwater resources and better groundwater management is required.

California Groundwater Today

California uses more groundwater than any other state in the nation. Nearly one sixth of all groundwater withdrawals in the nation,[4] and nearly half of California's drinking water supply comes from wells. Of the 515 groundwater basins and sub-basins in the state, approximately half provide water for public supply, farms, factories, towns and homes. About 30 groundwater basins account for the preponderance of groundwater used by pub-

[4] USGS. 2004. *Estimated use of water in the United States in 2000*. USGS Circular 1268.

lic supply wells.[5] Water in some basins may contain salts or other contaminants that render the groundwater unusable for most purposes unless it is treated.

In the year 2000 groundwater extraction in California was estimated at 17 maf.[6] Agricultural irrigation accounted for the majority of the pumpage at 13 maf, and domestic and public supply accounted for 3.4 maf. Refer to Table 1-2.

Using average values, the following discussion illustrates the statewide groundwater budget. It is an illustrative example only. The actual values vary considerably from year to year. In an average year, approximately 15 maf of groundwater is extracted for irrigation and municipal and industrial use. Approximately 6.5 maf of applied water (a mix of surface water and groundwater) recharges aquifers by means of deep percolation. The net use of groundwater is then approximately 8.5 maf.

Table 1-2
Year 2000 California Water Use
Values in million acre-feet*

Source water	Public Supply	Domestic	Irrigation	Other**	Total
Surface Water	3.6	0.03	21.2	1.17	26
Groundwater	3.1	0.3	13	0.6	17
Totals	**6.8**	**0.33**	**34.2**	**1.67**	**43**

* USGS. 2004. *Estimated use of water in the United States in 2000.* USGS Circular 1268.

** Includes livestock, aquaculture, industrial, mining and thermoelectric power.

In an average year, natural recharge from rainfall and streambed seepage totals approximately 7 maf. The net use of groundwater is approximately 8.5 maf. Thus, the annual "average" overdraft (water shortage) is approximately 1.5 maf. These relationships are illustrated in the equations in the following sidebar How Does Overdraft Occur?

Faced with a limited groundwater supply and seemingly unlimited claims to rights to use groundwater, more efficient management of groundwater is a necessity in California. More and more people are realizing the need for better management of water resources. Managing groundwater, like managing a checking account, requires careful consideration of a variety of elements if workable solutions to problems are to be found.

Effective groundwater management relies on five major elements that establish the framework for sound planning and implementation: political, legal, institutional, technical and economic. These elements are interrelated and are all required for effective management of groundwater resources.

[5] USGS. 2003. *Framework for a ground-water quality monitoring and assessment program for California.* USGS Water Resources Investigation Report 03-4166.

[6] USGS. 2004. *Estimated use of water in the United States in 2000.* USGS Circular 1268.

How Does Overdraft Occur?

Overdraft occurs when more groundwater is removed from a basin than is replaced by recharge over a period of many years. Estimation of groundwater removed includes extraction, natural outflow and native plant consumption. The equations below illustrate the cyclical process that often ends up in an annual statewide shortage of groundwater. Refer to Chapter 2 for more information on natural hydrologic cycles and technology.

	Groundwater extraction	15 maf
-	Deep percolation of applied water	- 6.5 maf
=	Net groundwater use	= 8.5 maf
	Natural recharge (precipitation and stream flow)	7 maf
-	Net groundwater use	- 8.5 maf
=	± Change in groundwater storage	= - 1.5 maf*

*(*The subtraction sign indicates a shortage.)*

The Groundwater Account

To view groundwater management from a practical, everyday perspective, try to imagine a checking account with an unknown amount of funds… that is accessible by just about anyone.

There doesn't seem to be a problem with account withdrawals until one day you receive a notice that the account is approaching overdraft and that you may be limited from withdrawing funds in the future. Some people don't believe the account is approaching overdraft and simply ignore the notice. Other people do believe it and start withdrawing funds as fast as they can. Unfortunately, nobody seems to know how much money is being withdrawn or deposited or who is conducting the transactions. Someone suggests transferring funds from a savings account but no one can agree on whose savings account it's going to come from, how much should be transferred, how much everyone should pay, or who is in charge.

Everyone claims a right to the funds but no one can agree as to who is entitled to what. No one seems to be in charge of the account, but everyone wants to withdraw money from it.

So it goes with the groundwater account, where there are more claims to water rights than there is water. Of course, our analogy to a checking account differs from a groundwater basin in that a checking account will simply run out of money. A groundwater basin will not actually run out of groundwater, but it can be depleted so far as to render the groundwater practically unavailable or degrade its quality beyond use.

Just as we should not manage a checking account by unlimited and unplanned withdrawals, groundwater basins should also not be managed in such a reckless manner.

Is this the way you would want to manage your money?

The Tragedy of the Commons

Garret Hardin[7] called unlimited access to a natural resource, in which everybody can use the resource but no one is responsible for managing the resource, the tragedy of the commons. The result of the tragedy of the commons is that each party contributes by acting in their personal interest and maximizing their use of the resource, contributing to the depletion of the resource. Groundwater is one such resource. In an effort to avoid groundwater depletion, many communities are attempting to manage groundwater in a sustainable manner.

Sustaining California's Groundwater Resources

What is Groundwater Sustainability?

Sustainability has many different meanings. There is no universally accepted scientific definition of groundwater sustainability. Recent examples of definitions of groundwater sustainability typically include reference to not causing unacceptable damages or consequences for future users.[8],[9] Groundwater sustainability is defined in this book as it is characterized by the USGS:

"The development and use of groundwater in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences."[10]

Groundwater sustainability means long-term protection and maintenance of groundwater quality and quantity for future generations. Unacceptable consequences that could result from poor groundwater management include:

- overdraft, or depletion of the groundwater supply,
- increased extraction costs,
- well deepening or replacement costs,
- water quality degradation, including salinity intrusion,
- land subsidence,
- decreases in streamflow, and
- environmental damage.

Why is Groundwater Sustainability Critically Important?

Groundwater is a critical component of California's water supply, with over half of the state's drinking water supplied from aquifers. Groundwater, like surface water, is vital to public health, the environment and the economy.

[7] Hardin, Garrett. 1968. *The Tragedy of the Commons*. 162 Sci. 1243.

[8] GRA. 2003. *Developing, Managing and Sustaining California Groundwater Resources*. White Paper.

[9] National Ground Water Association. 2004. *Groundwater Sustainability*. White Paper.

[10] USGS. 1999. *Sustainability of Groundwater Resources*. USGS Circular 1186.

What Are the Challenges to Achieving Groundwater Sustainability?

Managing groundwater is a challenge for many reasons that include:

- increased demand due to population pressure;
- past and present natural and anthropogenic contamination;
- groundwater managers must rely on hydrologic data from many sources, including water level measurements from wells, because groundwater is hidden from view;
- it is expensive to build monitoring wells, and then collect and evaluate the data;
- data are typically lacking in frequency of measurement, spatial coverage, quality, and data reporting is not always consistent and understandable;
- the physical and chemical principles governing groundwater are not well understood by most people; and
- water rights for groundwater are different than water rights for surface water, even though surface water and groundwater are an interconnected resource.

Why is Monitoring Vital to Sustainability of Groundwater Quality and Quantity?

Groundwater monitoring is an investment in groundwater as a resource. Evaluation of data allows managers to detect changes over time and make management decisions to protect the resource.

Elements of Groundwater Management

Comprehensive groundwater management requires defining goals and objectives, and addressing the elements discussed below. A

Sustainable Development

In the 1980s, increased concern about the effects of economic development on health, natural resources and the environment led the United Nations to publish the Brundtland Report.[11] The report defined Sustainable development as:

"Development which meets the needs of the present without compromising the ability of future generations to meet their own needs."

In June 1992, the Rio Earth Summit[12] declared that:

"The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations."

Sustainable development is not just about environmental protection, but about sustained economic growth and social equity.

Sustainable development encourages the conservation and preservation of natural resources and of the environment, and the management of energy, waste and transportation. Sustainable development is development based on patterns of production and consumption that can be pursued into the future without degrading the human or natural environment. It involves the equitable sharing of the benefits of economic activity across all sections of society, to enhance the well-being of humans, protect health and alleviate poverty. If sustainable development is to be successful, the attitudes of individuals as well as governments with regard to our current lifestyles and the impact they have on the environment will need to change.

Excerpt from *Encyclopedia of Sustained Development*
http://www.doc.mmu.ac.uk/aric/esd/index.html

[11] United Nations Commission for Sustainable Development. 1987. *Our Common Future* (i.e., The Brundtland Report).

[12] United Nations Conference on Environment and Development. Rio de Janeiro. 3-14 June, 1992.

groundwater management plan provides a road map for solving problems and providing new opportunities by outlining the powers, procedures, actions, budget and timetable of a groundwater management program. Such a plan will result in more effective use of the groundwater resource in conjunction with surface water. The primary elements of groundwater management are political, legal, institutional, technical and economic.

Political

The political element of groundwater management may be the most critical consideration in terms of actually developing, adopting and implementing a plan. Political groundwater management is a process in which the local community reviews several alternatives and makes authoritative choices. The political process prioritizes a wide array of values and legitimizes decisions in a collective decision-making process.

California has no statewide groundwater management statute or program, so the management of groundwater resources remains at the local level with a variety of local interests. Within a given groundwater basin, a multitude of local public agencies and private entities may be formally involved in groundwater management activities. Entities with an active interest in the basin are considered stakeholders.

Basin stakeholders typically have divergent interests, powers and rights. Often they are also reluctant to relinquish those powers and rights or alter their positions, relative to their interests, even though such action might provide basin-wide benefits. Consequently, the development of a groundwater management plan should include at the outset a determination of the stakeholders within the basin and an approach as to how their interests, powers and rights might be addressed.

Political considerations will play a critical role in selecting the appropriate institutional framework of the plan and the strategies and components within the plan. Failure to evaluate and address the political landscape will often lead to a failure of any proposed plan.

Legal

Similar to its political counterpart, the legal element of groundwater management is critical because it centers on the fundamental issue in most water controversies: water rights. Irrespective of the form of groundwater management considered or employed, groundwater rights, and in many cases surface water rights, must be considered and addressed.

Overlying landowners almost always are concerned about the impacts that regulatory control may have on their water rights, regardless of the availability of water, and they are often cautious about groundwater management programs. Consequently, the nature and extent of groundwater rights in the basin may help dictate the form and substance of a groundwater management plan. For example, in overdrafted groundwater basins overlying rights may be at risk due to prescription, and management may be considered simply an attempt to restrict production. In other instances, conjunctive use operations may result in fluctuating groundwater levels and fluctuating stream flows, with associated legal challenges from producers in the basin.

In many cases, stakeholders will be faced with a variety of other legal considerations as a groundwater management plan is being developed and implemented. Environmental review under the California Environmental Quality Act (CEQA) may be required. Similarly, basin operations may occur in areas where there are threatened or endangered species. Operators in the basin may also face well interference impacts, significant decreases in groundwater storage and widespread groundwater contamination. Issues related to city or county ordinances designed to manage groundwater may also require consideration.

Institutional

Concurrent with the actual physical management and operation of a groundwater basin is the question of governance, which includes the act, manner, function or power of government. In developing any type of groundwater management plan, the jurisdictional question of who is going to govern and how management will be accomplished must be addressed.

Governance implies an organizational focus that requires consistent and intelligent decision-making regarding technical information. Institutions represent opportunities to achieve a mix of political, legal, technical and economic management. Faced with a variety of these issues, stakeholders can employ a wide variety of institutional mechanisms to develop and implement a groundwater management program. These mechanisms include:

1) coordinated agreements,
2) adjudication, and
3) utilization of general act and special act district powers, like water replenishment district powers, land use and police powers through ordinances or use of the Groundwater Management Act [Assembly Bill (AB) 3030, (1992)].

Refer to Chapter 6 for more information on AB 3030.[13]

Concurrent with determining the form of groundwater management to be used, the area where the plan will take effect must be identified and agreed upon. Ultimately, the entities within the basin will have to designate some type of responsible authority for developing and implementing the plan or they will have to provide a mechanism for coordinated management among different plans.

Technical

The technical element of groundwater management requires an understanding of the unique physical characteristics of the basin. A fundamental necessity in any groundwater management program is an understanding of basin hydrogeology, including basic groundwater occurrence and movement. Every plan should include a process to develop an understanding of the:

- location of recharge sites,
- amount of recharge,
- location of extraction facilities,
- amount and spatial distribution of extraction,

[13] Water Code section 10750, *et seq.*

- water quality,
- amount of groundwater in storage,
- location where the extracted groundwater is used,
- aquifer boundaries,
- aquifer characteristics,
- potentially contaminating activities, and
- saline water intrusion.

A plan should include a method for monitoring groundwater quantity and quality and for analyzing, cataloging, evaluating and reporting on the data obtained. Data collection and evaluation will allow decisions to be made in a manner that will maintain a long-term supply of water, protect recharge areas and maintain and improve groundwater quality.

Economic

The economic element of groundwater management may be the most practical, as even the greatest plan in the world will not be implemented if an agency cannot afford it. However, the cost of not implementing a groundwater management plan must be included in the analysis before deciding that a plan is not economically justified.

Even the best solutions to water resource management and water supply problems cannot be implemented unless they can be financed in politically and institutionally acceptable ways. Regional projects typically should be financed differently than local projects. Infrastructure and associated water supply sources for new development also typically should be financed differently than infrastructure needed to overcome historical overdraft problems.

Whatever the specific issues facing a local agency, it will be crucial to develop accurate analyses of costs and benefits of proposals in comparison with the no-action alternative, as well as effective financing mechanisms for the various management activities considered by the plan.

Groundwater Management Policies

The five elements in developing and implementing a groundwater management plan at the local level are not formalized in any statewide policy of groundwater management. Because groundwater basin management options vary widely in California, state policy makers have historically been faced with the difficult proposition of formulating statewide groundwater management policies, which can be developed and implemented at the local level. The development of any comprehensive local policy related to groundwater will require continued evaluation, discussion and debate by local stakeholder representatives and thus any suggestions for proposed policies are not included in this document. Rather than serving as a policy document, this handbook provides information related to the current status of groundwater management approaches and practices in California, and identifies a number of policy issues that the state legislature, the State Water Resources Control Board (SWRCB), Department of Pesticide Regulation (DPR), Department of Toxic Substances Control (DTSC), the Department of Health Services (DHS), DWR, and other policy makers may wish to consider.

Underlying any policy considerations should be the general consensus of the water community: local management is the preferred approach to groundwater management in California. However, the complexity of California's hydrogeologic regions combined with its arcane system of water laws necessitates creative management approaches for each local agency.

It is the intent of this handbook to provide guidelines for development of groundwater management programs that are tailored to manage groundwater successfully within the political, legal, institutional, technical and economic constraints and opportunities that exist within each basin or sub-basin. Management of water resources is different in every basin. Consequently, no two groundwater management programs will be the same.

GRA hopes that this handbook will provide ideas and guidance that will lead each agency to develop and implement a creative and effective groundwater management program for their basin or sub-basin.

Chapter 1 References:

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Figure References

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F2 Ibid.

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