Go with the Flow

Why water markets can solve California's water crisis

By Amy Kaleita, Ph.D.

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Executive Summary

The years 2007 and 2008 were two of the driest in California's recent history. Adding to the climatic stresses, projected increases in the state's population, particularly in hot and dry inland areas, will demand more water. In these conditions, California still leads the nation in agricultural production, and that production applies almost 80 percent of the state's freshwater withdrawals as irrigation.

Given all that, one might think the water situation in California was bleak at best. But even in dry years, the problem in California is more of uneven distribution than insufficient supply—about 75 percent of the water supply originates in the northern third of the state, while 80 percent of the demand occurs in the southern two-thirds. To facilitate beneficial redistribution of water supply, California has a long history of large and costly water projects, with more on the horizon.

Research shows that there may well be more cost-effective strategies for providing water for Californians than continued centralized management and investment in massive infrastructure. California needs a policy that allows water consumers the flexibility to implement technology and management strategies best suited to their situation. The challenge for the Golden State is to move water from areas with abundance to areas with high demand, and to do so in the most efficient manner.

Key policy and management areas where change is needed include:

- appropriate pricing of this valuable resource, which will encourage conservation and creativity;
- facilitation of water transfers, which will decrease the need for additional major infrastructure projects;
- creation of consistent statewide or regional water markets.

Introduction: Dry times in the Golden State

In June 2008, California Governor Arnold Schwarzenegger issued a declaration that California is in a drought. "The governor is ringing the bell," Department of Water Resources director Lester Snow told the *San Diego Union-Tribune*. "We're heading over a cliff." The governor followed the drought declaration with an executive order to launch a campaign to facilitate water transfers, pursue federal aid, direct more state money to conservation projects, and pave the way for an emergency water bank, which, beginning in 2009, would be filled by water supplies purchased from farmers.

In July, the governor followed with a $9.3-billion water bond, backed by Senator Dianne Feinstein, a compromise plan that replaces an $11.9-billion proposal unveiled several months earlier. The bond will go to voters in November, pending approval by the legislature. The proposal includes $3 billion for reservoirs and other storage projects, with costs to be split between the state and local water providers; $2 billion for projects to use water more efficiently, protect its quality, and reduce runoff; $1.9 billion to develop a management plan for the Sacramento–San Joaquin River Delta; $1.3 billion for conservation programs along the Sacramento, San Joaquin, and Klamath Rivers and the Salton Sea; and more than $1 billion to improve groundwater quality and recycle water. The proposal also includes the possibility of a revised version of the controversial "peripheral canal" that would divert some freshwater around the delta.

The cost is significant, but it may be just a drop in the bucket, so to speak. A draft report to the governor's Delta Vision Blue Ribbon Task Force estimated that the cost of solving California's water problems may be between $12 and $24 billion over the next 10 to 15 years, and perhaps as much as $80 billion.

The governor's proposal to devote large amounts of funding to solving the "water crisis" echoes costly projects at local levels. In May, Los Angeles Mayor Antonio Villaraigosa unveiled a 20-year, $1.5-billion plan for increased infrastructure and conservation, including stricter enforcement of existing restrictions, free distribution of "smart sprinklers" to every home to control irrigation, and about a billion dollars for technological updates and improvements for recycling wastewater into drinking water. The Orange County Water District opened a similar recycling system in January, believed to be the largest such facility in the world, to the tune of $481 million.

This focus on water infrastructure investment as a solution is par for the course. While the most recent version of the Department of Water Resources' California Water Plan is more broad-minded in its approach to addressing water quantity and quality challenges, tradition-

ally, California Water Plans seem almost obsessed with big projects. As the 1983 Water Plan put it, “Only a substantial commitment to large-scale surface water storage and conveyance facilities would enable the major water supply problems in the State . . . to be brought under control in the next 30 years.”[1]

Certainly, centralized control of California’s large water projects has tried to address one of the fundamental problems with water supply in the state: the greatest demand for water is in the regions of the state with the least natural supply. Historically, the large infrastructure projects have aimed to increase conveyance and storage to offset this imbalance. It is not surprising that many groups, including the Association of California Water Agencies and farm workers associated with the California Latino Water Coalition, are hailing the governor’s proposal as, if not the best plan, then at least a crucial step in the right direction. They point to the numerous current and projected pressures on California’s stressed and aging water system. The editorial board of the *Sacramento Bee* stated that an “imperfect deal beats none at all.”[2]

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Those who care about bang for the buck have cause to be concerned, particularly at a time when the state is facing an estimated $15.2-billion budget deficit, and since just two years ago voters approved billions of dollars in bonds for some of the same initiatives, most of which funds are as yet unused. Concern over the costly strategies underpinning the governor’s proposal has forged an unlikely alliance of environmental activists and fiscal conservatives. Mindy McIntyre of the Planning and Conservation League (PCL) told the *San Diego Union-Tribune*, “Dams are a diversion, not a solution,”[3] and a joint letter from the PCL, the Environmental Justice Coalition for Water, the California Coastkeeper Alliance, and Sierra Club California states: “Water bonds alone have not brought California any closer to a comprehensive water solution. Asking Californians to spend billions more, without first addressing the underlying water management and policy problems in the state, can only produce the same disappointing results.”[4] Ironically, others, like conservative blogger Jon Fleischman, claim that the plan will do little to fix the state’s water problems and is more of a “Sierra Club wish list” of environmental initiatives than a comprehensive framework. Voters, meanwhile, are left to wonder whether simply sending a message in support of doing *something* is worth $9.3 billion or more, or whether the governor’s plan simply offers the same old ideas with a new and hefty price tag.

While attention to California's water infrastructure is certainly needed, it is difficult to determine whether the benefits of the governor's water proposal are truly worth the high cost. California's convoluted policies regarding water management heavily obscure the existing costs of the resource and its infrastructure. Some might argue that for a resource as precious and as critical as water, no cost is too great. But before—or at the very least *while*—billions of dollars are spent on more infrastructure, it would be wise to turn our attention to strategies through which significant and perhaps greater gains can be made without the need for additional major investment in an already investment-intensive water management system. In this study, we analyze California's water resources with close attention to current and future stresses, and we point out where gains can and should be made. We also recommend strategies to achieve these gains.

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California water resources

Statewide, the average annual precipitation is about 22 inches per year, which equates to slightly more than 180 million acre-feet (maf) of water raining into the state in an average year. An acre-foot (af), a common unit of measure for water at the landscape scale, is the volume of water that will cover one acre of land to the depth of one foot, and it amounts to 324,851 gallons. Not all of that water is available for use, however. Environmental losses like evaporation, and infiltration into the soil, will consume about two-thirds of the incoming precipitation in an average year. A portion of the remainder is necessary to supply minimum water requirements for various environmental functions, like minimum streamflow to support fish and other wildlife. The rest is partitioned into applications such as irrigation, household and drinking water, and industrial uses. Some of the water used for those purposes is eventually recovered, either through groundwater recharge or return flow to developed supply; however, some of these processes are quite slow, and others return the water with degraded quality. When considered statewide, California generally has sufficient water to satisfy most needs. Usually, the water problem in California is not one of insufficient supply, but one of uneven distribution.

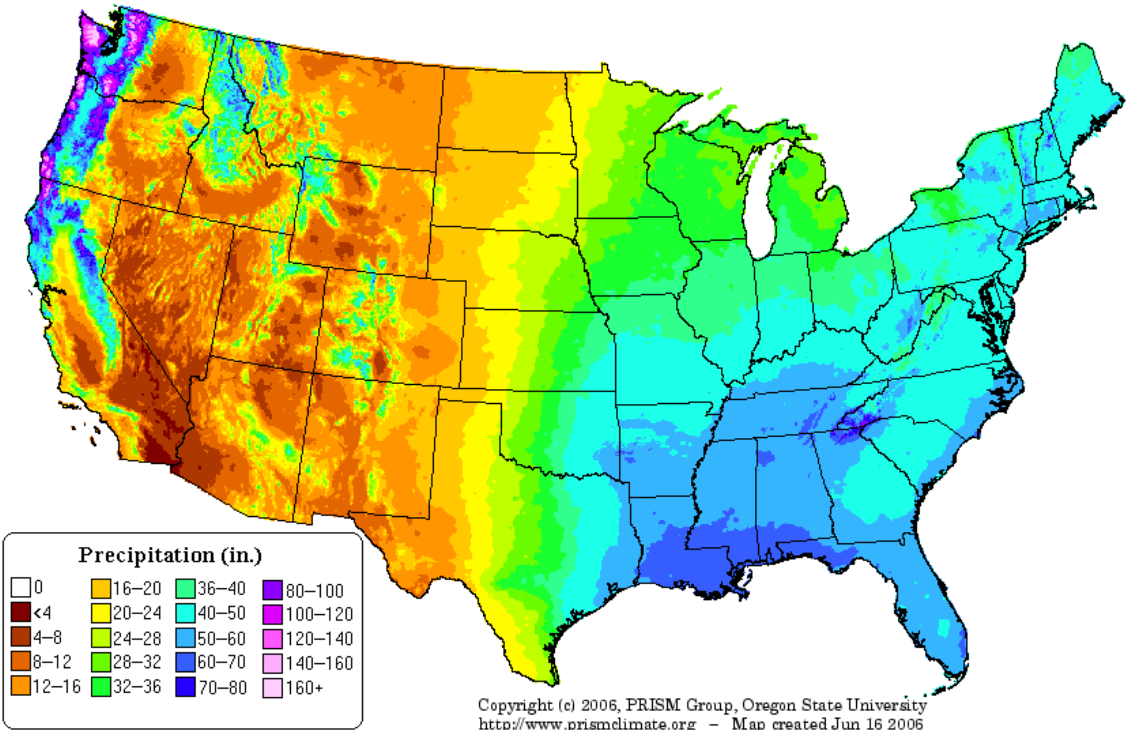
The water problem in California is not one of insufficient supply, but one of uneven distribution.

A map of annual average rainfall across the United States reveals that California has perhaps the most spatially variable rainfall patterns of any state, and with a large range. Del Norte County, for example, in extreme northwestern California, gets more than 80 inches per year. Imperial County, in the opposite corner of the state, gets less than five inches per year on average. The driest parts of California are located in the driest part of the United States, and the largest contiguous section of this very arid region is almost entirely within the state of California.

Exacerbating the differences between wet and dry regions, the drier regions, like Riverside and Imperial Counties, also tend to be the hottest, and because they are so hot and arid, evaporation rates are fully twice as high as evaporation rates in the wettest parts of the state, like Del Norte and Humboldt Counties. This means that what little precipitation does fall in the dry regions evaporates much more rapidly than precipitation in the wet parts of the state.

Just as rainfall varies across the state, the demand for water does as well. About 75 percent of California's water supply originates in the northern third of the state, while 80 percent of the demand occurs in the southern two-thirds.[5] Further, demand for water is highest during the summer, when there is generally little precipitation or snowmelt. To combat these basic prob-

Figure 1: Annual average precipitation across the continental United States



lems, California has constructed a complex and interconnected system of water storage and delivery that includes reservoirs, dams, pumping stations, and aqueducts. Altogether, this system transports about half of the state's water over distances up to hundreds of miles.[6]

About 75 percent of California's water supply originates in the northern third of the state, while 80 percent of the demand occurs in the southern two-thirds.

Complicating the situation further, much of the state's water supply is intimately linked to delicate ecosystems. The Sacramento–San Joaquin River Delta and San Francisco Bay form the West Coast's largest estuary, a coastal area where freshwater from rivers mixes with saline ocean water. It receives runoff from more than 40 percent of the state's land area, and nearly half of the state's total streamflow flows into the delta. A major habitat for fish and other wildlife, the delta also serves as a source of drinking water for 23 million people, more than 60 percent of the state's population. As early as 1919, the state and federal governments were working on a plan to ship water from the Sacramento River to the San Joaquin Valley. Together, the State Water Project and the federal Central Valley Project deliver water from the delta to farms and municipalities of the San Joaquin Valley and southern California. One original feature of the State Water Project was a peripheral canal to divert water directly from the Sacramento River to the pumps and aqueduct, bypassing the delta. In June 1982, voters rejected Proposition 9, which would have established the peripheral canal, and it remains controversial to this day.

Further complicating the balance between water supply and ecosystem function in the delta, recent court-ordered protection of the delta smelt, a small fish found only in the delta, restricted the water flows from pumps in the delta during the 2008 spawning season. Federal wildlife authorities are expected to issue their own plan for smelt protection for subsequent seasons. In September, environmental activists asked the courts to invalidate the contracts of 42 irrigation districts until guarantees could be made of protection for the delta smelt, causing an uproar among southern and central California farmers already stressed by dry weather and pumping restrictions. In July, meanwhile, a federal court ordered state and federal regulators to come up with a plan for providing more water for salmon in the delta.

Other examples of controversy surrounding water diversions speckle California's hydro history. The notorious Owens Valley project is the central component in what some call California's "water wars." The city of Los Angeles is located in a semi-arid coastal plain, receiving too little rainfall and snowmelt to support the population of the city even at the turn of the last

century. At that time, the Los Angeles River's normal water level was capable of supporting no more than 220,000 people, according to the Municipal Water Bureau.[7] The population of the city of Los Angeles was already almost 320,000 by 1910.[8] The city set about acquiring water rights from farmers in the Owens Valley, and in 1913, the city completed construction of the 233-mile Los Angeles aqueduct, which diverted water from the Owens River. So much of the valley's water was diverted to the aqueduct that the Owens Lake eventually dried up entirely. The struggles between the city of Los Angeles and the municipalities and residents of the Owens Valley resulted in bitterness and litigation that continued for decades. (This battle inspired the 1974 Roman Polanski film *Chinatown*.) In 2006, the city of Los Angeles began rewatering sections of the Owens River in an attempt to restore some of the hydrologic and ecological function of the area.

To all these California peculiarities add the pressing issue of drought. The year 2007 was the second driest since 1950 (1976 was the driest during that period), and 2008 is shaping up to be just as dry, if not more so. In the northern Sierras and other parts of northern California, the spring of 2008 was the driest on record. Because of the repeated dry spells, reservoirs across the state are running low. As of July, Shasta Reservoir, the largest in the state, was at 48 percent of its capacity, and the second-largest reservoir, Lake Oroville, was projected to end this year with the lowest amount of water in more than 30 years.

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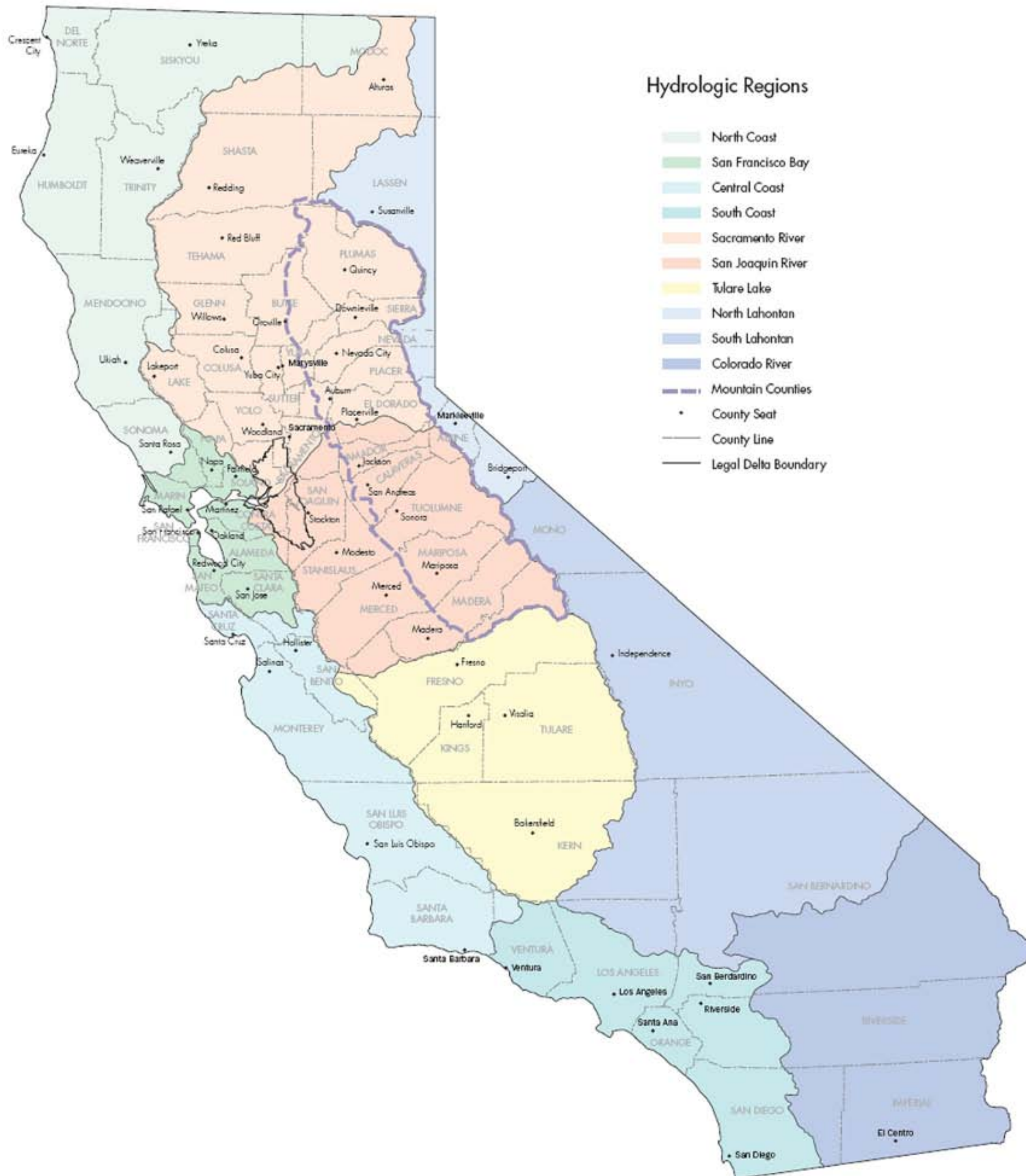
For purposes of understanding regional differences in the state's water resources, the California Department of Water Resources divides the state into 10 hydrologic regions, corresponding to the state's major water drainage basins. The delineations are based on natural water flow boundaries. A brief look at the water balances within several of these regions illustrates the complexity of trying to manage water resources across the state.[9]

The Colorado River hydrologic region—which includes areas that drain into the Colorado River, the Salton Sea, and other closed basins north of the border with Mexico—is the driest region in the state. Its annual precipitation of less than five inches a year yields approximately six million acre-feet per year on average. The area is so hot, however, that evaporation and other environmental losses actually exceed precipitation. The region also receives net inflows from the Colorado River of about four maf/yr on average. This is not sufficient to meet

Figure 2: California hydrologic regions[10]



demand within the region. With about 3.8 maf/yr in agricultural water uses and about 0.42 maf/yr in urban water uses, this zone operates on a water deficit largely by drawing down groundwater reserves, even in a wet year like 1998, when precipitation was more than 50-percent higher than normal. With its population expected to double by 2030, the Colorado River region will see increasing pressures on its already stressed water balance.

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The Sacramento River region—which includes basins draining into the Sacramento River system in the Central Valley, from the Oregon border south through the American River drainage basin—receives a hefty 54 maf/yr in precipitation on average, about half of which is lost through evaporation and other environmental factors. Still, this leaves a sizable amount of water, for an area that sees about 8.5 maf/yr in agricultural uses and about 0.8 maf/yr in urban uses. However, the Sacramento River region has very high demands for water for environmental preservation, including minimum streamflows and deliveries to the delta region. Adding to the pressure on water supplies statewide, the future may hold even more stress.

Department of Water Resources predictions of climate change include warmer temperatures (which tend to cause higher demand for water, particularly in urban areas), the possibility of a 25-percent loss in Sierra snowpack by 2050, and more variable weather, including an increase in the probabilities of both flooding and drought. Further, California continues to be a desirable place to live and work. California's population increased from about 30 million in 1990 to about 36.5 million in 2005. The California Department of Finance projects that the population could exceed 48 million by 2030. More than half of this growth is expected to be in California's hot and dry (and already water-limited) inland regions, including the Sacramento metropolitan region, the San Joaquin Valley, and the Inland Empire.

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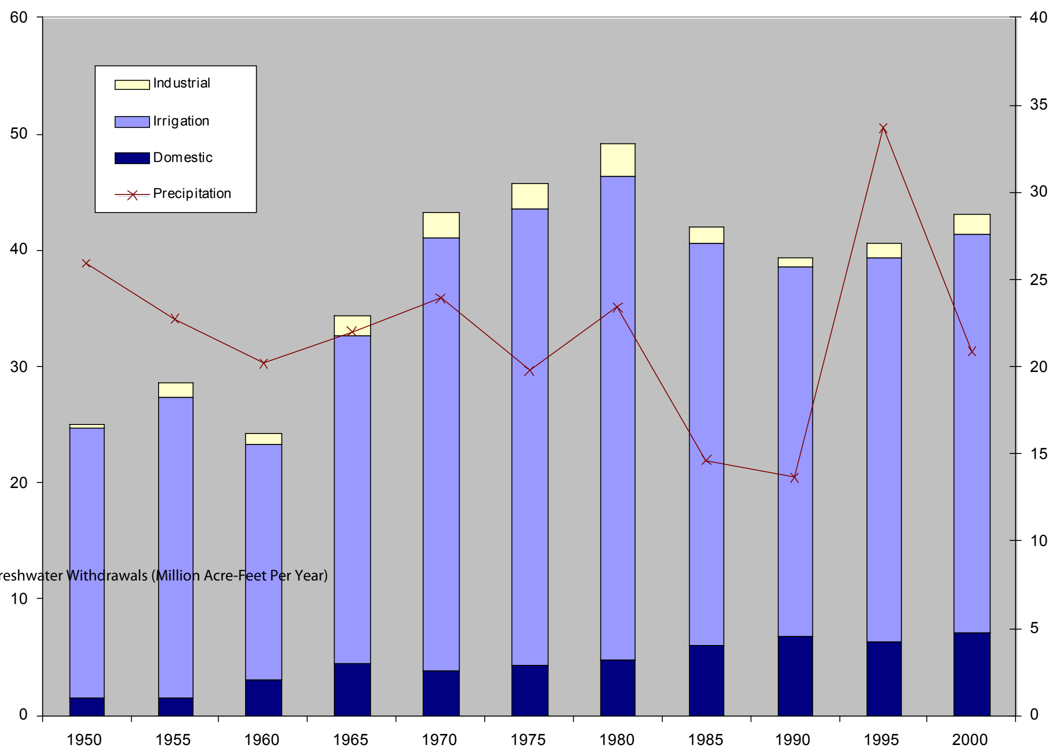
Trends in water use

Figure 3. Industrial, irrigation, and domestic freshwater withdrawal trends in California along with statewide average precipitation in corresponding years[11]



Historically, water use in California has been dominated by agriculture. While the total share of water consumption used for irrigation has declined since the 1950s, when it was at 90 percent, irrigation withdrawals still account for almost 80 percent of the total freshwater (surface and groundwater) withdrawals in the state. Domestic water withdrawals have been generally increasing since the 1950s, though per-capita consumption has actually decreased.

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Domestic water use

California's population is growing by about 600,000 people per year, so it is no surprise that domestic water use has generally been increasing. But that increase has not been proportional to population growth. Though per-capita water use decreased in the last five years of the twentieth century, the previous 40 years saw steady increases in water use per person. As explained in an analysis of residential water use by the Public Policy Institute of California (PPIC), there are a number of probable reasons for the increase in per-capita water use—rising incomes, which tend to cause greater demand for water-consuming appliances; increasing residential lot sizes; and faster population growth in hotter inland areas.[12]

The PPIC study predicts that disproportional population growth in inland areas will continue to cause a rise in per-capita residential water demand, for two major reasons: (1) inland areas tend to have larger lot sizes, and (2) inland areas tend to be hotter and drier, requiring more watering for a typical lawn. The California Water Plan suggests that about 40 percent of total residential demand is for outdoor use. The PPIC study cites a number of research results suggesting that, particularly in hot, dry climates, the percentage of residential water going for outdoor use could be higher—perhaps as high as 80 percent.

Agricultural water use

Almost half of all the irrigated acres in California use some form of what is known as surface irrigation. Surface irrigation, in which water is released from a pipe or gate to flow across the surface of a field, is most appropriate on mild and regular slopes, in areas with a sufficient water supply. The most common types of surface irrigation in California are border and furrow irrigation. In border irrigation, suitable for close-growing crops like forages and grasses, water is introduced at the head of the field and flows down the field in a uniform sheet. This is the most common type of irrigation on alfalfa in California, and represents about 20 percent

of all irrigated acres not including those used for rice.[13] Furrow irrigation uses small channels between crop rows to carry water down the field. Suitable for row crops, this is the most common type of irrigation for cotton in California, and represents about 21 percent of all irrigated acres not including those used for rice.[14] Rice production typically uses basin irrigation, in which the entire paddy is flooded.

Where water is scarce, sprinklers and microirrigation may be more appropriate.[15] Sprinkler irrigation systems include not only permanently installed systems, such as those used in turf watering, but also movable systems more common for field crops. In California, about 16 percent of irrigated acres use some form of sprinkler irrigation. About 33 percent of irrigated acres use some form of microirrigation, in which hoses or pipes convey water across the field, and the water drips or trickles slowly out onto the soil or directly into the root zone through emitters in the line. Because of the cost of installing a microirrigation system, and because it is well suited to watering plants at specific locations near the emitters, this type of system is most appropriate for high-value crops; in California, 70 percent of vineyards and 69 percent of almond and pistachio orchards use microirrigation.[16]

Ideally, all water applied to a crop through irrigation would go towards meeting the crop's water needs. In practice, however, it is impossible to apply irrigation water with 100-percent efficiency. There are invariably losses, sometimes minor but sometimes significant, through the irrigation supply system itself, in the form of leaks, spills, etc. Surface irrigation is subject to sometimes high rates of evaporation loss because of the extent of the exposed water surface. Sprinkler irrigation suffers losses from wind. Table 1 shows the range of application efficiencies (water available for use by the crop compared to water delivered by the system) for various types of irrigation systems. But this tells only part of the story.

Crop water needs are not always easy to determine, so calculating and delivering precisely the right amount of water to meet these demands, and for other beneficial uses (such as frost protection or fertilizer application through irrigation water), is not simple. Further, crop needs and available soil moisture are rarely uniform in space, but delivering spatially variable amounts of water is not possible with most simple irrigation systems. Management of the irrigation system and schedule has a significant impact on the system's overall efficiency. Many systems are *not* well designed or well managed, meaning considerably lower application efficiencies in practice than those listed in table 1. Management of surface irrigation is perhaps the most challenging; therefore, to achieve optimal efficiencies with surface irrigation is particularly difficult. Of course, not all excess irrigation is lost from the overall water distribution system.

Irrigation water that percolates through the root zone and is not used by the crop eventually becomes streamflow again by traveling laterally and rejoining the surface water supply, or becomes part of groundwater reserves. Irrigation water that runs off can run into surface drainage systems and eventually rejoin the regular water supply downstream. On the other hand, water lost to evaporation is not available for later use downstream. Efficiency improvements can address both types of loss, but because some efficiency improvements decrease returns to downstream flow, efficiency improvements usually do not result in a one-to-one increase in overall available water supply.

Table 1: Range of application efficiencies for various irrigation systems (assuming good design and management)[17]

System Type	Description	Application Efficiency Range (%)
Surface Irrigation		
Basin	Field is surrounded by small earthen berms, so that area can be shallowly flooded	60–95
Border	Water is released at the top of the field, and raised borders guide the water in a uniform sheet downslope to the end of the field	60–90
Furrow	Water is released at the top of the field and flows downslope to the bottom of the field in small furrows or channels	50–90
Sprinkler Irrigation		
Hand move	Ground-based portable sprinklers	65–80
Center pivot and linear	Mechanically continually moving above-ground sprinklers	70–95
Solid set	Permanently installed ground-based sprinklers (common in turf and residential applications)	70–85
Microirrigation		
Point source emitters	Water leaves hose system at specific points (emitters) along the line	75–95
Line source emitters	Water leaves a porous hose all along the line, as in a soaker hose	70–95

Despite the relatively dry climate in much of the state, California's agricultural portfolio contains several water-intensive crops. About two maf of California's water are used to irrigate more than half a million acres of rice.[18] Cotton, a crop well suited to hot and wet environments, is grown on nearly 700,000 acres using primarily surface irrigation. More than a million acres of alfalfa (representing about 1.2 percent of the land area of the state), the vast majority of which are surface irrigated, consume four or five maf of water a year. By its nature, surface irrigation requires application of several inches of water at a time (other systems can effectively be used to apply considerably less).

Providing adequate but not extra water to all parts of a field using surface irrigation is always difficult; adequately watering the downslope end of the field without overwatering the upslope end is a challenge. Irrigation scheduling—essential for efficient irrigation system operation—is particularly difficult with alfalfa, because the cutting schedule can put challenging limitations on when irrigation can be done.

Because of the high water demand and the difficulties of efficient surface irrigation, some have suggested that growing alfalfa in California is a bad idea. The Natural Resources Defense Council says: "California devotes 20 percent of its developed water supply to a crop that generates less than one-tenth of one percent of the state's economy. Given the degraded state of California's rivers and growing demands for water for higher value agricultural crops and urban areas, is this an efficient use of a precious resource?"[19] It is not quite that simple. Alfalfa is a major feedstuff for dairy cows. California is the leading state in the nation in milk and cream production, and dairy is the state's leading farm product in terms of net value.[20] California is actually a net importer of alfalfa hay, indicating that even the supply currently grown in the state is not enough to satisfy demand.[21]

While the water demands are high, alfalfa has a number of environmental benefits compared to other field crops, like corn—reduced soil erosion, improved soil structure, and no need for nitrogen fertilizers, a major source of water quality degradation and a significant consumer of fossil fuels. As a feedstuff for dairy cattle, alfalfa generates a larger amount of biomass per unit of water applied than a number of other types of feedstuff.[22] One study found that, in terms of the efficiency of water conversion into food products (measured as food quantity, energy, or protein), alfalfa compared favorably with several other crops.[23]

Again, in California, spatial distribution is a problem. A full 15.6 percent of the state's forage crops (predominantly alfalfa) are grown in Imperial County, one of the most, if not *the* most, water-stressed areas in the state.[24]

California water management

In California, all surface water supplies are owned by the state, with individuals and groups having rights to use the water (the majority of groundwater in California remains unregulated). California water rights are somewhat of a hodgepodge of various approaches: the *riparian system*, based on English common law, in which owners of land adjacent to a body of water have equal rights to use the water; the *prior appropriation system*, in which the first person or group to use the water establishes rights to the water for future use, and all subsequent users have junior rights; and *pueblo rights*, derived from Spanish law involving municipal use of water that flows through a city. This combined system of plural water rights, known as the California Doctrine, continues to be defined and refined by the courts. Although there have been modifications to the doctrine's "use it or lose it" approach to water allocation that is governed by prior appropriation, the system remains largely a disincentive for users to conserve, lest they lose their rights to the water in the future.

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In 1887, California lawmakers provided for the creation of irrigation districts under local public control, and in 1911 provision was made for the establishment of local municipal water districts. By the beginning of the twentieth century, distribution of a large proportion of the water resources in the state was under the control of public municipal and irrigation districts as well as some private water companies.

The rate structures for pricing water are as locally specific and as numerous as the providers. Rate structures fall into four general categories, though many water providers use a combination of rate structures. With flat rates, users pay a single fee for access to water, and the total charge does not vary with the amount of water used. This type of pricing structure is still common for residential users in the Central Valley, much of which is unmetered. Also common are uniform structures and increasing block structures. With uniform structures, users are charged the same amount for every gallon of water used. Increasing block structures mean that per-gallon charges increase at higher usage rates. Decreasing block structures, which essentially provide a discount for high-consuming users, are now rare in California. Also rare is seasonal pricing, where water prices vary by time of year.

Agricultural users are typically charged considerably lower rates than other users, thanks to a combination of federal subsidies, many in the form of reduced repayments for construction

of major federal infrastructure such as the Central Valley Project. For example, according to a study from the Environmental Working Group, the average price for irrigation water from the Central Valley Project in 2002 was less than 2 percent the price for residential drinking water in Los Angeles, and one-tenth the estimated cost of producing replacement water supplies from proposed new dams and reservoirs.[25] This difference reflects not only the effect of subsidies, however, but also the greater costs of conveyance over longer distances, and higher levels of treatment for drinking water supplies versus irrigation water supplies.

A sampling of water rates from around the state illustrates the huge variation in prices by region and by type of user. In the very dry Colorado River hydrologic region, irrigation water costs $7 to $17 per acre-foot.[26] In the moderately dry South Coast region, irrigation water costs $394 to $548 per af, and in the relatively wet North Coast region, irrigation water costs $4 to $13 per af. Residential users in the Colorado River zone pay a flat $23 per month in Needles, and a fixed $24.10 per month plus a uniform $483 per af in Calipatria. (Typical indoor water use for a household of four people is 0.03 af per month.) Residential water users in Thousand Oaks, in the South Coast zone, pay $10.70 plus $892 per af. In the North Coast region, residential users in Santa Rosa pay $4.65 plus $864 per af.[27]

Because of regional and by-customer differences in both availability and price, transfer of water rights from one group to another is often considered desirable by one or more parties. However, water transfers are rarely easy to arrange. A number of factors affect the ability to arrange a transfer, not the least of which is the physical infrastructure available for doing so. Other factors include how cooperative neighboring or otherwise affected districts might be and whether or not there are environmental or third-party concerns that must be addressed. Finally, the approval of governmental entities and regulators, as well as affected agencies, must be obtained.

The approval process for short-term water transfers can be particularly lengthy and cumbersome.

The approval process for short-term water transfers can be particularly lengthy and cumbersome. For this reason, the Westlands Water District, a junior rights holder for irrigation water within the Central Valley Project allocation, recommends that "[b]oth state and federal agencies must improve their water transfer implementation process. The length of time and paperwork needed for approval slows the process, often resulting in a missed opportunity. Because it can take several months to implement a transfer, hydrologic or demand conditions can change—

especially with crop needs—impacting the necessity to complete the transfer. The approval process must be streamlined."[28] The Westlands Water District, however, does successfully operate an informal trading system among agricultural users within the district. This trading system is the largest in the country in terms of volume.[29]

Long-term water transfers can provide reliable water quantities with lower per-volume transaction costs than short-term transfers. However, because long-term transfers reallocate water for several years or more, they are often met with apprehension among the potential selling users and communities. Concern over long-term water rights impacts, third-party effects, and environmental impacts can add to the skepticism over long-term transfers. The Owens Valley controversy provides an example of the bad blood that can result from long-term transfers, but it also offers some useful insights into factors that need to be considered in any long-term transfer arrangement. Specifically, transaction costs for long-term transfers can go up when there are disputes over the long-term value of the resource, when the "market" includes only one buyer and only one seller, and when negative third-party effects (and associated political intervention) are significant.[30]

Using less water

Are there easy steps that can be taken to reduce the amount of water consumed in the state of California? Or are the good times coming to an end, as land-use lawyer Cary Lowe suggested in an op-ed in the *Los Angeles Times*?

> As things stand now California is rapidly approaching the limits of growth. Those areas of the state with limited local water supplies already are off-limits for development, and those sectors of the economy that are big users of water, such as agriculture, are cutting back. We can extend the period of growth and prosperity by pursuing the measures mentioned above. What remains to be seen is whether that will just postpone the day of reckoning—when we have done all we can do to cut consumption but demand still exceeds supply. At that point, California will have reached the limit of its growth.[31]

Indeed, water limitations have already stalled building projects, and some areas have implemented various types of regulations on water consumption, but there is much "low-hanging fruit" remaining to be picked, and changes in the state's approach to water management can go a long way towards addressing the problem. These management changes, which we will discuss in detail later, are underpinned by the notion that for the most part, California's water consumption can be limited using existing technologies and approaches, without significant damage to the quality of life in California or the economic health of the state.

A variety of technologies are available for limiting or decreasing water consumption across different sectors. Because outdoor water use accounts for 40 percent or more of residential water demand—and because such a large proportion of the projected growth in the state is in hot, dry inland areas where lot sizes are large and single-family homes are the norm, strategies for decreasing outdoor residential water use will yield a large return on investment in terms of overall water savings.

So-called smart sprinklers use on-site monitoring of soil and/or weather conditions and adjust lawn irrigation rates and timing accordingly. The PPIC study found that such devices were cost-effective where water is scarce, because the cost of the devices is generally lower than the costs of securing additional water supply.[32] Converting some landscaping from turf and other high-consuming vegetation to less water-intensive vegetation is also effective at decreasing residential water demand. Perhaps most important, flow meters and water pricing that requires consumers to pay for the volume of water they are using, as discussed below, will facilitate homeowners' making choices appropriate for their own needs and outdoor activities.

Decreasing agricultural water demands is less straightforward, because there is a great variety of crops, landscapes, soil types, and climates, and strategies that work on one farm may not work on another. It is not simple, and sometimes not advisable, to make wholesale changes in the types of irrigation used, even when those types are not necessarily appropriate to the water balance in the region. As noted by the Food and Agriculture Organization of the United Nations, "The choice of an irrigation method also depends on the irrigation tradition within the region or country. Introducing a previously unknown method may lead to unexpected complications. It is not certain that the farmers will accept the new method. The servicing of the equipment may be problematic and the costs may be high compared to the benefits. Often it will be easier to improve the traditional irrigation method than to introduce a totally new method."[33]

Indeed, there are a huge number of options available for improving irrigation efficiency and limiting agricultural water use. Education and technical support for farmers desiring to make changes in their irrigation management remain important components in agricultural water management across the state.

For example, tail-water reuse systems can capture surface irrigation water that would otherwise run off the field. The recovered water can be reused on the original field or used on one nearby. Employed by many growers in the Imperial Irrigation District (IID), this strategy has allowed the IID to transfer some water to urban use. Other farmers using surface or basin irrigation have used laser land leveling to create uniform topography in a field, improving irrigation uniformity. In sprinkler irrigation, low-energy precision application (LEPA) systems reduce wind and evaporation losses; these systems can increase water use efficiency by 20 to 40 percent. For all types of irrigation, improved techniques for monitoring soil moisture and weather and for assessing crop demand allow for more effective irrigation scheduling, decreasing the chances of overapplication of water.

A more extreme adjustment is to switch to a different crop entirely. Over the last 30 years, the number of acres under surface irrigation has been steadily decreasing. In 1970, approximately 80 percent of the irrigated land in California was under surface irrigation. Today that figure is only 50 percent,[34] while the number of acres in some form of microirrigation has been on the rise. Some of the decrease in surface-irrigated acres is due to land use change—conversion of agricultural areas to residential development—but a lot of the shift has been related to transition from field crops to vine and orchard crops.

Together with forestry, fishing, and hunting, agriculture generates only about 1.5 percent of the state's total GDP.[35] For this reason, some have suggested that its disproportional use (consumptive *or* applied) of the state's water resources is wildly inappropriate, and that perhaps massively scaling back on agricultural production is the answer. But GDP paints only part of the picture. If one considers the economic ripple effect from this sector—each dollar earned in the agricultural sector stimulates additional activity in terms of further production, job creation, and value addition—then agricultural production and processing account for 6 to 7 percent of the state's economy.[36] Further, California leads the nation in agricultural production, bringing in the highest cash receipts of any state, and leading the nation in production of a vast array of agricultural products, including almonds, asparagus, broccoli, carrots, grapes, hay, milk, and strawberries.[37]

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Clearly, technologies exist for limiting both domestic and agricultural water use even further. Some argue that use of these technologies should be mandated at the state and/or local level (though usually these proposed mandates focus on urban water use), and indeed in many places specific restrictions have been put in place. In January 2008, the city of Long Beach began restricting homeowners to once-a-week lawn watering. Sacramento prohibits lawn watering during the hottest and sunniest part of the day, or to such an extent that water runs into storm drains. Ironically, in June a Sacramento home was declared a public nuisance and its owners threatened with a hefty fine after they let their lawn turn brown in response to the governor's drought declaration. It turns out that city landscaping ordinances require lawns to be watered.[38]

Another pitfall in regulating water consumption behavior is that the regulations must often be quite specific, which means that promoting widespread water conservation through regulation requires a laundry list of government prohibitions and incentives to address each specific point of potential waste. The Metropolitan Water District of Southern California, for example, offers incentives for low-flush toilets, high-efficiency washing machines, and residential weather-based irrigation controllers, among other programs. At the same time, the nation's largest installer of water gardens and waterfalls reports that the popularity of backyard ponds and waterfalls has been growing rapidly in southern California over the last five years, with "more than a 300-percent growth in backyard pond installations in recent years."[39]

Because water consumption for both domestic and agricultural purposes is often very user-specific, the most efficient and effective strategies for a given situation are also user-specific. Like the Sacramento couple, some residents would elect to forgo a lawn altogether; others may choose to replace all or part of their lawn with plants requiring little water; others may elect to maintain lawn space for recreational purposes and conserve water elsewhere. The most effective policies will be ones that allow users the flexibility to implement the technology and management best suited to their situation.

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Mandates do not seem to be necessary when the signals of scarcity are present. A number of farmers, for example, facing cuts in water allocations, are already making changes in their cropping systems or irrigation management. Some of these changes—switching from water-consumptive crops to hardier vegetation, or even stumping trees in orchards and fallowing fields altogether—are extreme, but others are simply belt tightening: more sophisticated irrigation scheduling and flow control.

Solution strategies

The complexities of California's water allocation and management approach, coupled with the state's significant regional differences in climate and demand for water, cause California's water stress to be more acute than necessary. The problem is not so much one of critical lack of supply as one of convoluted management. As discussed above, California's current water policy is based on centralized control rather than market incentives. Arbitrary rules set by state resource agencies govern who gets how much water and at what price, causing prices to vary greatly among users and ensuring that they do not reflect the water's true value. Conservation approaches can significantly decrease demand in the most consumptive sectors, and flexibility in moving water from areas with water to spare (either naturally or by choice) to areas with high demand can alleviate many of the current and projected shortages. However, achieving that kind of distribution will require changes to California's existing policies. Key areas where change is needed are outlined below.

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Appropriate pricing

A major barrier to adoption of conservation strategies is, of course, cost. The cost of implementing these strategies may actually be lower than the true cost of wasting water—but most often, consumers never see the true cost, and, thus, the economic benefits of conservation are obscured.

In the most extreme example, in the places in California where flat rates are still used for residential water supply, there is absolutely no incentive (beyond personal commitment) to conserve. Fortunately, in 2004, the state legislature passed AB 2572, which requires that all utilities with 3,000 or more customers install meters over the next two decades and begin using whatever meters have been installed for billing by 2010. This is a step in the right direction.

But even where pricing is done by volume consumed, the rates rarely reflect the true cost of the water. More accurate water pricing will certainly not be painless—but neither is the current situation of below-cost pricing in times of drought, where overconsumption exacerbates supply problems and results in mandatory cutbacks and regulation. Further, undervaluing water does not allow consumers judiciously to accept some scarcities. The net result is increased costs overall, according to one study, which pointed out that in many cases, the economic costs of water scarcity are lower than the costs of providing additional water either through new sources, efficiency improvements, water conservation, or reallocations from other water uses.[40]

A controversial but necessary measure to ensure water conservation not only by urban users, but also in the use category accounting for some 80 percent of the state's water consumption, is the removal (or, at the very least, limitation) of price supports and subsidies for agriculture. Agricultural growers are businesspeople, so when water is cheap, infrastructure to conserve is not worth the investment. Where the price reflects the actual cost, conservation strategies will become cost-effective.

At the same time—and this can't be taken lightly—a rise in food prices across the board is a likely outcome. Already, increased costs of fertilizer and energy inputs coupled with growing global demand have caused food prices to increase in the United States by 7.5 percent over the last year, according to the Bureau of Labor Statistics.[41] Increased irrigation costs will only add to the inflation of food prices. Nonetheless, agriculture is a major consumer of water in the state and must therefore have a major role in conservation.

Some subsidies will have to be cut back in any case. A report from the Public Policy Institute of California notes that because some federal loans for infrastructure haven't been paid off fast enough and are now coming due, agricultural water prices will have to increase. The report projects that overall agricultural water prices will increase by 68 percent statewide between 2000 and 2030, and that decreases in agricultural water consumption will follow.[42]

Facilitating water transfers and building a water market

The major impediment to water transfers from one user or user group to another is the significant amount of bureaucratic red tape involved in arranging a transfer. Eliminating many of the bans and restrictions would yield significant benefits in alleviating regional water shortages.

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This is part of the governor's temporary drought relief plan, and it is important to note that California has actually done this before, relatively successfully, during the last major drought period in the late 1980s and early 1990s. The California Emergency Drought Water Banks of 1991 and 1992 were state-coordinated programs that lifted bans on water transfers in order to facilitate moving water from lower-valued to higher-valued uses. The state offered farmers $125 per acre-foot for water, and then sold the water to municipalities. In 1991 (the drier of the two years), more than 500,000 acre-feet were moved from agricultural to municipal users

through the bank. According to one study, as one of the economic consequences of the 1991 water bank, urban areas supplied with banked water received a $91-million benefit.[43] Another report found that growers who participated in the bank reduced their operating costs by more than 10 percent and increased their farm investments, which included purchases of irrigation efficiency equipment.[44]

In 2001, researchers at UC Davis completed an extensive simulation of water market reallocations regionally and statewide as part of the CALFED project.[45] Their findings indicated that water markets in California would greatly reduce scarcity costs, decrease the need for additional major infrastructure projects, and have the potential to reduce greatly or even eliminate urban water scarcity, among other benefits, enabling continued growth of the state. In a corollary study, they found that even under significant climate change, growth could be sustained. However, they added that some of the necessary changes in that case would be painful for some—uncompensated loss, for example, in the agricultural sector, particularly in the hottest and driest regions of the state.[46]

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Moving towards an open water market

Water transfers are undoubtedly a good first step, but they can lead to an inconsistent and somewhat ad hoc set of laws. Legislation is necessary, therefore, to make fundamental changes that would create a consistent, statewide water market. A 1998 report by the Pacific Research Institute explains the steps necessary to create a fully functional water market:

> 1. Ownership of water rights would transfer from the state to water users. The initial allocation of these rights needs careful determination and will face political controversy, but the most equitable distribution should rely on current usage. Chile used this approach in 1981 when the country successfully created a market system for water. The Chilean government granted existing water users secure property rights without charge, and sold unallocated rights in an open auction.
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> However, because such distribution favors users who are currently taking more water than they need, some redistribution should take place to rectify the most blatant misallocations, and any water users who lose rights in the initial allocation process should

receive compensation. Individuals and environmental groups that would leave the water instream for fish habitat and water quality should be given ownership of rights allocated for environmental purposes. If any unallocated rights remain, those rights should be sold in an open public auction.

This shift in ownership would also address the problem of subsidies because the government would no longer set the price of water. Rather, market forces would determine the price to reflect the water's true cost.

2. Rights must be secure and fully transferable. Owners need to be able to sell or lease their rights to willing buyers for any use, including leaving water instream to enhance water quality and habitat. In Oregon this is working well—environmental groups lease water rights from farmers and leave the water instream so salmon are able to spawn.

3. Legislation would need to address water transportation and distribution. The state's water transport network represents a natural monopoly in which public agencies control the means of water transportation. For a market system to work efficiently, water traders must be able to use the existing infrastructure for transactions. The traders would have to negotiate a transportation rate with the local water districts to use their infrastructure for transport.

For example, in the San Diego transfer, the Metropolitan Water District (MWD) transports the water through the Colorado River Aqueduct. The San Diego County Water Authority, who bought the water from the Imperial Irrigation District, negotiated with the MWD, and decided on a rate to pay the MWD for transporting, or wheeling, the water. Similar statewide negotiations could establish [fair] and feasible rates.[47]

Conclusion: Solving the distribution problem

California faces a unique combination of challenges in water supply—diverse climates, increasing population, agricultural production of some water-hungry crops, and, currently, drought. But exacerbating the challenges posed by California's water issues is a convoluted approach to allocating and managing water resources, coupled with below-cost prices for many consumers.

Governor Arnold Schwarzenegger and Senator Dianne Feinstein are promoting a costly water bond to funnel money into California's water storage and conveyance infrastructure. However, it may very well be more cost-effective to avoid construction and instead invest in policies that encourage conservation. Strategies exist for effectively reducing water consumption in a number of sectors.

It may very well be more cost-effective to avoid construction and instead invest in policies that encourage conservation.

The water problem in California is not insufficient supply but uneven distribution. Evidence abounds that the Golden State's heavily regulatory approach is not solving the distribution problem. Indeed, as this paper has noted, the lifting of various bans and restrictions helped get water where it needed to go during drought conditions in the early 1990s. In the current drought, government should strive for a similar, proven approach, rather than imposing more regulation.

California leaders should adopt new policies that cultivate appropriate pricing signals along with a supportive policy framework that allows for the transmission of those signals. Californians also need the ability to respond to those signals through transfers of water in a free and open market. That will keep water, and the economic opportunities that go with it, flowing in the Golden State for the benefit of all Californians.

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