Thematic Week: Water Economics and Financing

Thematic Axis: Water Markets

Title: New Frontiers for Water Management: The California Experience

Authors: Ellen Hanak

Senior Fellow and Associate Director of Research, Public Policy Institute of California, San Francisco, USA.

Abstract:

In rapidly growing regions in the United States, water managers face difficult challenges in mobilizing new water supplies to meet new demands. Environmental concerns have curtailed the scope for large new surface storage projects, and basin overdraft limits groundwater's potential as a source of expansion. Drawing on the California experience, this article explores modern water planning approaches, which focus on a portfolio of options including nontraditional sources (recycling, underground storage) and more efficient use of existing supplies (conservation and water marketing). It reviews the advantages and drawbacks of the elements of the portfolio and provides examples of innovative planning approaches.

California has made considerable progress in expanding non-traditional sources, particularly since the early 1990s, when a prolonged drought and a series of environmental rulings constrained traditional supply sources. Many of the current challenges are institutional, rather than technical. For water marketing, continued progress is needed to resolve concerns of third parties in the source regions. For underground storage, further development of aquifer management protocols is a precondition. Progress in urban conservation will require more aggressive use of tiered water rates and shifts in public perceptions regarding landscaping. Changing public perceptions is also key to the successful expansion of recycled wastewater

Keywords: *water policy, water supply, water conservation, interbasin transfers, groundwater management*

I. Introduction

California shares the water management challenges of many regions facing rapid population growth and constraints on supply expansion. Environmental concerns have curtailed the scope for large new surface storage projects, and in many cases are resulting in reductions in human uses. Widespread basin overdraft limits the potential of native groundwater as a source of expansion. As a result, the focus of water planning has progressively shifted toward portfolio approaches, which seek to meet urban demand growth by augmenting nontraditional supply sources (such as recycling, underground storage, and desalination) and by improving the efficiency of use of existing supplies (conservation and the market-based reallocation of water rights).

This article explores the advantages and potential problems associated with this new water planning approach in California. It focuses on four of the major "new" sources of water: water markets, groundwater banking, urban conservation, and recycled wastewater. Although each of these sources offers potential advantages, none are entirely straightforward to implement. Underground storage and water marketing are both potentially low-cost alternatives, but each faces significant institutional hurdles. Expansion of recycled water use can require modifications in plumbing systems and changes in public acceptability of reusing treated wastewater. Conservation can be costly in terms of the technological investments needed to enable the savings and the consequences for "quality of life" if it entails restrictions on landscaping, which can account for over half of residential water use.

California is a virtual laboratory for new approaches to water supply planning. The most recent *California Water Plan* (California Department of Water Resources (CDWR), 2005) projects that a diverse portfolio of nontraditional sources has a far greater potential to augment usable supplies than new surface storage over the next three decades. At the same time, the state's record on implementation provides ample illustrations of the challenges to innovation. Interestingly, many of the innovations that have occurred since the early 1990s were spurred by a combination of natural and legally-generated water shortages: a prolonged drought, from 1988 to 1994, and a succession of environmental rulings requiring cutbacks in human water uses. At present, the state is again reeling from these two factors, with a second year of very low precipitation and new court restrictions on water diversions to protect an endangered fish species. The crisis has led to a new round of policy proposals at the state and local level, and may spur a new round of innovation.

The article is organized as follows. The next section provides an overview of the basic supply and demand issues facing the state, drawing on the findings of the new *California Water Plan* (CWP, "the Plan"). In the third section, the focus turns to the four key nontraditional sources, with a discussion of advantages and drawbacks and of approaches being used to overcome implementation difficulties.[1] The fourth section summarizes these findings and notes some of the innovation challenges that lie ahead as a result of climate warming.

II. Supply and Demand: The Big Picture

As in other parts of the western United States, the staples of California's water supply are native groundwater reserves and "developed" surface water – river water harnessed in surface reservoirs and transported through conveyance channels, often across long distances. Surface storage investments were the predominant form of water supply expansion for most of the last century (Reisner, 1993; Hundley, 2001). Although some of these projects were undertaken locally, federal and state authorities have played a major role. In particular, the federally financed Central Valley Project (CVP), undertaken from the 1930s to the 1950s, serves farmers and cities in this large inland valley. In the 1960s, the State Water Project (SWP) launched investments to deliver water to farmers and cities further south. Southern California is also a prime beneficiary of federal investments along the Colorado River (Figure 1).

[1] For a more detailed discussion of the full range of supply options, see Hanak (2007).

Figure 1. California Surface Water Projects
Source: California Department of Water Resources, 2005

In normal rainfall years, groundwater provides roughly one-third of all water used by the agricultural and urban sectors combined – and more in dry years – with the balance provided by surface water. In 2000, this combined demand totaled 53.2 Gm^3 of applied water use, with four-fifths going to farmland irrigation (CDWR, 2005).

Every five years or so, the state updates its projections of supply and demand. The most recent *California Water Plan Update*, completed in December 2005, presents several scenarios of demand growth (Table 1). The two key sources of growth are urban and environmental uses. Using recent population projections of 14 million new residents between 2000 and 2030 (+ 40%), the "less resource intensive" and "current trends" baseline scenarios for the urban sector project demand growth by 1.7 to 3.7 Gm^3 per year (17 to 34%), depending on whether modest or more aggressive conservation is achieved with existing and planned programs. This figure jumps to more than 7

Gm^3 under the "more resource intensive" urban scenario, which allows for higher population growth, a greater share of new population in hotter inland areas, and rising per capita use.

Table 1. Water Demand Growth Scenarios and Source Replacement Needs, 2000–2030 (Gm^3)

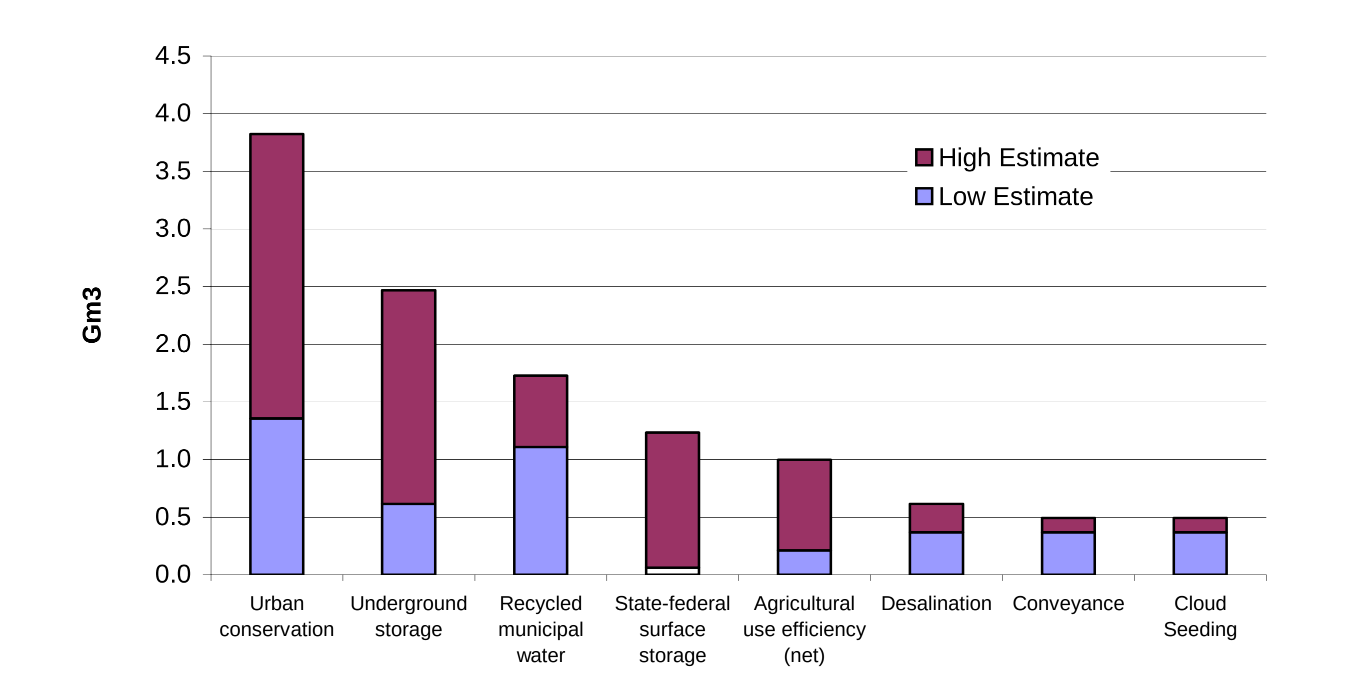
Demand growth	Current trends scenario	More resource-efficient scenario	Less resource-efficient scenario
Urban	3.7	1.7	7.2
Environment	0.6	1.2	0.0
Agriculture	-4.3	-3.6	-2.3
Net change	0.0	-0.6	4.8
Replacement needs (all scenarios)			
Colorado River	1.0		
Groundwater overdraft	1.2 – 2.5		
Net change	2.2 – 3.5		

Source: California Department of Water Resources, 2005

Environmental water demands, estimated at over 1 Gm^3 per year since the early 1990s, are projected to double to enhance protections for endangered aquatic wildlife. In contrast, agricultural demands are expected to decline by 5 to 10% under the three scenarios as a result of various market forces (shifts to less water intensive crops, development of some agricultural lands). On balance, the scenarios imply that overall demand could be stable or even decline slightly, if water currently used in farming could be transferred to urban or environmental uses. However, there is also a need to make up for some losses of existing supplies: Under interstate agreements, California will lose 1 Gm^3 per year of Colorado River water by 2015, and the Plan has also set the objective of eliminating an estimated 1.2 to 2.5 Gm^3 of annual groundwater overdraft.

To replace these sources and meet new demands, the Plan explored the potential for mobilizing water from a wide range of sources (Figure 2). The low-end figures show gains based on current path actions; high-end estimates imply stepped up efforts. The prominence of nontraditional sources is striking. The three largest categories, each potentially generating over 1.5 Gm^3 per year, include urban conservation, underground storage, and municipal wastewater recycling. By contrast, new surface storage under state and federal sponsorship is expected to generate at most 1.2 Gm^3 annually. Anticipated gains from agricultural use efficiency are also more limited, with up to 1 Gm^3 per year in net reductions anticipated. A host of other strategies – desalination, cloud seeding, and improvements in conveyance facilities and operations – each have the potential to generate roughly 0.5 Gm^3 per year.

Figure 2. Annual production potential from new water sources and conservation, 2000-2030



Source: California Department of Water Resources, 2005.

Simply summing these strategies overstates the net supply potential, because some – for instance, surface and groundwater storage – could compete for the same supplies or facilities. But there are also opportunities for synergies among portfolio elements. In particular, the potential for water marketing creates incentives for both agricultural use efficiency and for underground storage. Also, the estimates exclude two options: regional and local surface projects (for which no figures were available) and voluntary reductions in agricultural water use for reasons other than efficiency gains (which proved too contentious a topic for the planning process, as discussed below).

Although there have been some debates on the particulars, the Plan's main message – that California's water supply needs will increasingly be met through a diverse set of options – is now widely accepted. Many of these options are considered more environmentally friendly than traditional surface storage projects, and they are often less costly. Yet although none is entirely new and untested, each presents challenges.

III. Promises and Pitfalls of the Nontraditional Supplies

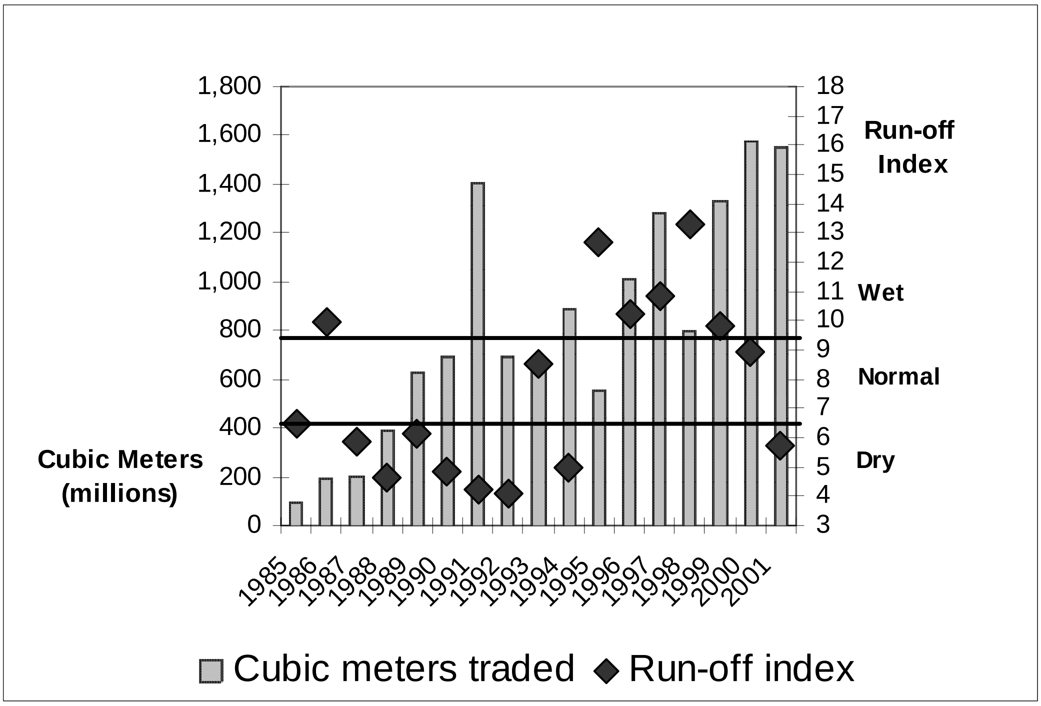
The following discussion indicates the relative attractiveness and drawbacks of the four main options for reallocating and augmenting supplies. Cost estimates are for annual deliveries of "raw" water, excluding treatment costs to meet drinking water standards. They include the amortized costs of capital plus operations and maintenance. The discussion begins with the water marketing, which does not explicitly appear in Figure 2, but which has significant potential to be both low-cost and beneficial to the environment.

Water Transfers

Determining the amount available from future transfers has been a contentious issue for the *CWP* update, because some agricultural interests argue that transfers do not augment supplies. Agricultural water-use efficiency gains, listed in Figure 2, do imply transfer activity. But, as noted, agricultural water use is also likely to decline because of various market forces, opening up greater market potential.

State policy began actively promoting water marketing in the early 1980s, by changing the laws to facilitate transfers. One essential step was to make it possible to lease water without losing the water rights. The state played a major role in launching the market during the drought of the late 1980s and early 1990s, initially by arranging for individual drought purchases, and then by running a large-scale drought water bank (Hanak, 2003). Since the early 1990s, both federal and state officials have promoted the use of the water market to meet environmental demands as well. As a result of these actions, the state's water market has grown steadily since the early 1990s drought, totaling 1.5 Gm^3 annually by the early 2000s (Figure 3). Market growth since the mid-1990s occurred despite favorable precipitation conditions, spurred in part by farmers seeking replacement water to compensate for cutbacks due to new environmental restrictions. Since the early 2000s, several large long-term leases and permanent transfers have been arranged to support development plans in urban areas.

Figure 3. California: Annual Water Transfers and Rainfall Run-off, 1985 – 2001



Note: Includes short and long-term transfers. Run-off is measured by the Sacramento River 40-30-30 index.

Source: Hanak (2003).

The main obstacles to transfers stem from their potential to harm "third parties" – those other than the buyer and seller (National Research Council, 1992; Hanak, 2003). In many regions outside of California, one of the key concerns is for third party impacts to the environment, because transfers can alter the water supply conditions upon which wildlife depends. In California, this can also be a concern, but there are legal protections: California law requires transfers to mitigate potential environmental harm, and both government and civil watchdogs may object to proposed transfers on these grounds. As is generally the case in the water law of states in the western United States, California's "no injury" protections also apply to other water users. However, these protections do not generally extend to another key set of third parties – the residents of source communities. If transfers are associated with a decline in farming, such communities may fear the potential for an associated drop in local business activity and tax receipts. As a result, there can be considerable political pressure against transfers (Hanak and Dyckman, 2003).

Over this time, buyers and sellers have gained experience in dealing with third party concerns, and more recent deals aim to limit the risk of economic harm to source communities. Such concerns have led to the establishment of mitigation funds for some transfers and to rules limiting the amount of land fallowing in any given area. Both principles have been applied in a prominent recent deal – the long-term transfer of Colorado River water from the Imperial Irrigation District to San Diego County.

Although lead times to meet environmental and community requirements can be substantial, transfers do indeed provide a relatively low-cost water source to urban agencies, with annual prices ranging from under \$100 per 1000 m^3 for local deals within the Central Valley to \$500 per 1000 m^3 or more for deliveries to cities on the Southern Coast. By the early 2000s, urban agencies accounted for roughly one quarter of all purchases, but recent and pending contracts could add nearly 1 Gm^3 over the coming decade alone (CDWR, 2005). Environmental programs have also benefited from the market, with state and federal purchases of up to a third of total volumes for instream flow and wildlife habitat. The balance has been purchased by farmers with high-value crops and insufficient water rights.

Underground Storage

Underground storage, or groundwater banking, involves the conjunctive use of surface and groundwater. Conjunctive use exploits the cross-year variability of rainfall, promoting greater use of groundwater in dry years to maximize underground storage of excess surface water in wet years. “Active recharge” programs use spreading ponds or injection wells. The alternative is “in-lieu” recharge, whereby water users substitute pumping with surface water use in wet years to allow the aquifer to replenish faster. Either method generally requires unused space in the aquifer, made available by excess pumping in prior years. In parts of urban Southern California, active recharge programs have existed for decades (Blomquist, 1992; CDWR, 2003c).

More recently, water users have recognized that groundwater banks can store water not only for those overlying the basin, but also for users elsewhere in the state, in a manner similar to surface water reservoirs. Successful projects of this nature have developed in Kern County, at the southern end of the Central Valley, where irrigation districts are storing water that urban utilities may call on in dry years (Thomas, 2001). There has also been some experimentation with using relatively full aquifers – such as those north of Sacramento – for storage. In such cases, the retrieval occurs first, to be followed by recharge. According to the latest *CWP*, artificial recharge has accounted for 1 to 1.5 Gm^3 in recent normal to wet years, or roughly 6 percent of average annual groundwater use.

Groundwater banking projects can deliver water at a very low cost. A group of projects recently submitted to CDWR for financial support had a weighted average annual cost of \$136 per 1000 m^3. (Not all of these estimates included the costs of acquiring the surface water for storage, which can vary from negligible to several hundred dollars per 1000 m^3, depending on the source and the year.) Reaching Figure 2’s upper end of 2.5 Gm^3 would also require substantial investments in conveyance and re-operation of surface reservoirs.

Relative to surface storage, groundwater banking is generally considered an environmentally friendly option. However, it has some potential drawbacks from both technical and institutional standpoints. First, both storage and retrieval are slower than with surface storage. When the objective is to capture and store a large volume of flood flow during a relatively short amount of time, recharge capacity may be a limiting factor. Similarly, retrieval from groundwater banks is often limited by pumping capacity. Second, water quality concerns may arise from mixing water from different sources. This presents an obstacle, for instance, to storage of recycled water in the Mojave Basin (Victor Valley Wastewater Reclamation Authority, 2004) and to storage of treated drinking water in some Central Valley communities (Cooper, 2004). Contamination from overlying land use also raises water-quality issues for conjunctive use in some areas.

Third – and perhaps most importantly - groundwater banking can only be successful when there is a sound basin management system (Thomas, 2001; Hanak and Dyckman, 2003). Without clear accountability procedures, bankers run the risk of not being able to retrieve the water they store, and their neighbors run the risk of seeing the aquifer depleted from excessive retrieval. These issues are particularly important when outside parties are involved – and they have led to some of the same types of conflicts as those associated with water transfers. Because groundwater management is a local prerogative in California, there is considerable variation in the extent to which protocols and procedures are in place. Most Southern California basins are actively managed, and the progress made since the mid 1990s in Kern County has been facilitated by management protocols. Improvements in management are a priority elsewhere in the Central Valley to realize the full potential of this water supply strategy.

Urban Conservation

Conservation is a demand-side measure to free up supplies. The release of the *CWP* generated considerable discussion because the potential savings appear so high – on the order of 3.8 Gm^3 per year. This estimate may overstate potential savings, however, because it represents the maximum feasible level attainable with today's technology irrespective of costs (California Bay Delta Authority (CBDA), 2005). Estimates that do consider cost-effectiveness are more modest but nevertheless substantial. The CBDA study estimated potential annual water savings of up to 2.6 Gm^3 at an annual cost of $270 to $650 per 1000 m^3, and a study by the Pacific Institute (Gleick, et al, 2003), concluded that 2.8 Gm^3 could be saved for $740 per 1000 m^3 or less – a threshold the authors deemed relevant for most alternative sources. These various estimates relate to applied water rather than consumptive use. For many urban agencies, this is a relevant metric, because demand growth is measured in terms of applied water use. However, applied use measures overstate net savings to the overall system somewhat, because many return flows from inland areas either recharge the groundwater basin or are reused downstream. (For the more populous coastal areas, most excess applied water is "lost" to the ocean).

Because it makes no additional demands on water resources, conservation is the ultimate environmentally friendly option. It can also be both cost-effective, and – if the savings are durable – reliable. Yet, as Gleick and his colleagues acknowledge, there may be considerable "educational, political, and social barriers" to achieving these savings. California's experience over the past fifteen years highlights both the potential and the challenges.

Conservation programs have been promoted actively since the early 1990s drought. Much of the focus has been on non-price tools, including "soft" programs, such as public education, and "hard" programs, such as regulations. There has also been some use of pricing tools, particularly rebates for adopting more water-efficient technologies.

Statewide regulations introduced in the early 1990s included requirements to use low-flow toilets and showers in new construction. Programs to encourage various other measures, including technology retrofits in older homes, have been spearheaded by the California Urban Water Conservation Council (CUWCC), a voluntary association of water utilities formed in 1991. The CUWCC promotes and tracks the adoption of 14 Best Management Practices, and it is nationally recognized as a leading authority on conservation. (For its materials on conservation programs, see www.cuwcc.org).

The programs have sparked some noted successes. Thanks to an aggressive low-flow toilet retrofit program, the City of Los Angeles was able to make up for substantial surface water cutbacks required as part of an environmental mitigation settlement (Los Angeles Department of Water and Power, 2001). More generally, the six-county service area of greater Los Angeles, served by the Metropolitan Water District of Southern California (MWDSC), has reduced per capita use by over 10 percent since the late 1980s, saving enough water to accommodate most of the growth the region has experienced since then (MWDSC, 2005). Indoor plumbing retrofits have played a central role.

The tougher challenge is outdoor uses, which account for roughly half of residential water use, and even more in hotter inland areas. California's growth patterns are compounding this challenge, with half of the new residents by 2030 expected to settle in inland counties (Johnson, 2005). The development footprint in these regions is also less "water-wise." They have a higher share of single-family homes (Hanak and Davis, 2006), which use more water than multifamily units

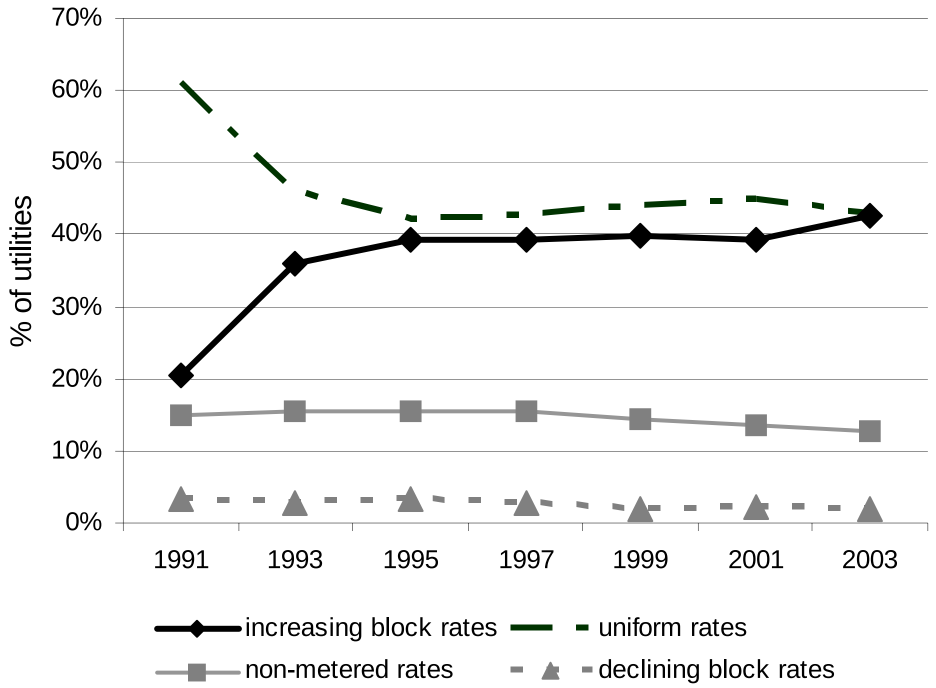
(Dzieglielewski, et al, 1990). Single-family lots in inland areas are also larger than those in temperate coastal zones. Given climate and size differences, a typical grass-covered yard in the fast-growing high-desert areas like Palm Springs (Riverside County) or Lancaster (eastern Los Angeles County) has consumptive water needs nearly three times as high as a yard in coastal Santa Monica (Hanak and Davis, 2006).

Technology fixes are also emerging for outdoor water use: "smart" irrigation systems that are sensitive to the weather can reduce watering by 20 percent or more. Utilities are also looking to landscaping solutions, to cut back on the use of turf and other plants more suited to wetter climates. Over the past few years, MWDSC has been promoting "California friendly" gardens and encouraging builders and garden supply chains to participate (www.bewaterwise.com). A few localities are following the regulatory approach of Las Vegas and some Arizona utilities, restricting turf in new homes to just a portion of the total area (e.g., back yard only). And some are considering the Las Vegas model of offering financial incentives for landscaping changes, by paying customers to replace turf with low water-using plants. (See www.snwa.com and Hanak and Browne, 2006). Many of these policies have been endorsed by a state-sponsored Landscape Task Force, composed of stakeholders from the water and landscaping sectors (CUWCC, 2005).

The other side of incentives is the water rate structure. In particular, tiered rates, which charge higher marginal rates for higher levels of water use, can be an important tool for outdoor conservation (Chestnutt et al, 1997; Olmstead, et al, 2005; Mansur and Olmstead, 2005). Recent analysis – using multiple regression techniques to control for weather and other factors – finds that California communities using tiered rates had ten percent lower household water use than communities with uniform rates, and 25 percent lower use than communities without volumetric fees (Hanak, 2008).

California made progress in tiered rate adoption during the early 1990s drought, but there has been little forward movement since then (Figure 4). Progress has been slowest in the inland areas where this could make the biggest difference. As of 2003, half of the state's population was subject to a tiered rate structure (Hanak, 2005). But in the Central Valley, where summers are hot and lots are larger, this figure dropped to under one-fifth, and nearly half of all homes did not even have water meters.

Figure 4. Utility Rate Structures in California, 1991-2003



Source: Hanak, 2005.
Note: The chart reports the share of utilities with each rate structure (total = 100 percent), using data from 214 utilities present in the survey in all years.

For a variety of reasons, rate reform has proven extremely contentious in some inland areas. No doubt, residents appreciate the ability to live in the midst of green oases during the hot, dry summer, and they recognize that the introduction of meters or tiered rates could make this more expensive. Such objections have recently arisen in the area around Palm Springs – a desert zone where landscaping accounts for up to 80 percent of residential use – where the local utility has been pushing for the introduction of tiered rates (Desert Sun Wire Service, 2008). But fear of the unknown may also be a factor. In professional meetings discussing rate reform, utility officials have noted that some residents assume even low water users will pay higher bills, when in fact the opposite is often true. Similarly, "rate shock" for high water users can lead to pressure to undo reforms (American Water Works Association, 2004). This suggests that public education programs are an essential part of a reform package.

Another barrier to conservation programs is that the savings might make room for growth (Hanak and Browne, 2006). When the public holds such views, utility boards, elected by local voters, are often in weak positions to counter them. This is where state regulations may play a useful role. When California's legislature passed a law in 2004 requiring the phase-in of water meters, it took the heat off local officials, who are now free to lobby for earlier introduction of the measures (e.g., Hood, 2005). Given the potential savings, requiring utilities to adopt tiered rates – or to justify why they are not necessary – is another potential area for legislative mandates.

Recycled Municipal Water

To some, recycling wastewater is just another form of conservation, because it augments usable supplies from a given water source. But quite different issues are at stake. Because most recycled water is not sufficiently processed or certified to meet drinking water standards, it requires separate plumbing. Incremental processing and redistribution costs can also be high. When limited to outdoor uses, recycled water must be sold at a discount, and it risks being in excess supply in wet winter months. Thus, although it is relatively reliable, recycled water is not necessarily a financial bargain. The potential for cost effectiveness is greater for new construction and new treatment plants. The California Recycled Water Task Force (CDWR, 2003a) estimated average unit costs of expansion on the order of \$740 per 1000 m^3 including treatment and delivery.

Recycling is not always as environmentally friendly as it might appear at first glance, either. Recycling typically results in reduced discharges of treated effluent into rivers and streams. If the resulting change in stream flows will have negative effects on wildlife habitat, communities may be required to modify their plans. This occurred in the coastal city of San Luis Obispo, where the recycling plan conflicted with endangered steelhead trout habitat (*Water Reuse News*, 2003).

Finally, and perhaps most importantly, the public needs to be convinced of the safety of recycled water. In California, there have been several well-publicized cases of public resistance. In the mid 1990s, the city of Los Angeles launched a project to recharge the groundwater basin with tertiary-treated recycled water and invested in a new treatment plant. In 2000, when the project was about to come on line, bad publicity of what came to be known as the "toilet to tap" program forced the city to abandon the recharge plans and instead try to find irrigation and industrial customers (Sanitation Districts of Los Angeles County, 2005).

Using recycled water outdoors has also sparked controversy. In the Bay Area community of Redwood City, officials planned to introduce recycled water for some outdoor uses as a way to accommodate growth (Redwood City, 2004). Some residents were concerned about potential health risks of switching to recycled water on lawns and playing fields. Following a year of contentious debates, a modified plan was approved in early 2004. The compromise required that recycled water not be used in areas where children play and that some playing fields switch to artificial turf.

These factors help keep recycled water use to only 615 Mm^3, roughly one-tenth the volume of water that gets processed by wastewater treatment plants each year. The task force's projections of a three- to fourfold expansion over the coming decades assume that utilities will be able to overcome this resistance through public education and outreach. One promising enterprise is Orange County's "Groundwater Replenishment System," which began recharging the groundwater basin with 86 Mm^3 per year of highly purified recycled water in 2007 (www.gwrsystem.com). Cognizant of the pitfalls of bad publicity in neighboring Los Angeles, local officials have devoted a great deal of attention to public education since the early planning stages, and they have used opinion polling to help shape the message. In light of recent water shortages, Los Angeles' mayor has announced that his city will relaunch a recycled water initiative – this time, taking a cue from the more positive experiences in Orange County (Connell, 2008).

IV. Conclusions and Future Challenges

California's recent experience offers some interesting insights into the changing world of water planning in regions facing rapid population growth and environmental constraints on supply expansion. Constraints on the continued development of the two traditional mainstays of the water supply portfolio - surface storage and native groundwater reserves – need not spell an impending water crisis. Measures to broaden the portfolio with nontraditional sources (recycling, underground storage) and with more efficient use of existing supplies (conservation and water marketing) can help supplies keep pace with demand. These new sources often come in at lower financial cost and pose fewer risks to the environment than the traditional elements of the portfolio.

However, each of these strategies requires planners to tackle some important institutional and political obstacles. For water transfers, finding ways to mitigate economic harm in the source regions is essential. For groundwater banking, solid institutional rules on the use of the aquifer and good monitoring are preconditions. For urban conservation, much of which now relates to outdoor uses, there is a need to work with the public, builders, and landscape professionals to make new technologies and landscaping alternatives available. There is also a need to engage in rate reform – a sometimes delicate process given the sense of entitlement many large water users have, especially when conservation is used to support new growth. State and federal governments are most effective in a supporting role, with local and regional agencies taking the lead. Financial incentives, technical support, legislation, and regulations all have a role to play in spurring local and regional water agencies to collaborate, innovate, and invest in the water supplies for the 21st century.

Looking ahead, California's water planners will also face new challenges as a result of climate warming. Although there is still uncertainty about the impacts on average levels of precipitation, models agree that the state will see a reduction in snowpack and a shift in seasonal runoff as a result of warming, a process already underway (Cayan et al. 2006, Knowles, Dettinger, and Cayan 2006). Many of the portfolio management tools that California water managers have been developing to cope with demand growth, droughts, and increasing environmental water requirements will also serve them well in adapting to climate change (Hanak and Lund, 2008, forthcoming). But a changing climate will also require new types of experimentation and innovation in several areas. First, it will require new thinking about the interrelationship between water supply and flood management, to make better use of surface and underground reservoirs as runoff patterns shift. Second, it will require continued innovation in water markets to develop tools to cope with greater uncertainty – such as long-term, multi-year options. Third, because warming also has negative implications for habitat of protected aquatic species, it will require new assessments of how to manage environmental flows effectively, while continuing to make water available for human uses. In the future, as now, California will not be alone in needing to meet these challenges, and there is much to be gained by exchanging information and experiences.

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