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FINDING WATER FOR GROWTH: NEW SOURCES, NEW TOOLS, NEW CHALLENGES[1]

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ABSTRACT: Rapidly growing regions such as the western United States 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 widespread basin overdraft has limited ground water'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, desalination, 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, provides examples of innovative planning approaches, and assesses the role for supportive government policies.

(KEY TERMS: water policy; water supply; planning; urbanization; water conservation; interbasin transfers; ground-water management; water scarcity economics.)

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INTRODUCTION

In regions facing rapid population growth – including much of the Western and Southeastern United States – the task of mobilizing new water supplies to meet new demands has become increasingly complex. Environmental concerns have severely curtailed the scope for large new surface storage projects, and widespread basin overdraft limits ground water's potential as a source of expansion. As a result, the focus of water planning has progressively shifted toward portfolio approaches, which seek to augment supplies through nontraditional sources (such as recycling, underground storage, and desalination) and through more efficient use of existing supplies (conservation and the market-based reallocation of water rights).

Although each of these new 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, more importantly, in the way people think about reusing treated wastewater. Desalination is becoming more plausible, but it is still a relatively high-cost source. Finally, although the benefits of conservation are readily apparent, this option 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.

This article explores the advantages and potential pitfalls of the new water sources for the 21st century.

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The analysis focuses on the California experience. California is an interesting case because it is a virtual laboratory for new approaches to water supply planning. The most recent *California Water Plan* (CWP) (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.

The article is organized as follows. The next section provides an overview of the findings of the new CWP and the changes it implies relative to traditional supply patterns. In the third section, the focus turns to a discussion of the advantages and drawbacks of key nontraditional sources, including approaches being used to overcome implementation difficulties. The fourth section highlights the new roles for planners and for governments in modern water planning, and the final section summarizes the main conclusions.

STATEWIDE WATER PLANNING IN CALIFORNIA: THE RISE OF NONTRADITIONAL SOURCES

As in other western states, the staples of California's water supply are native ground-water 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 (notably by utilities in greater Los Angeles and the San Francisco Bay Area), 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) picked up where the CVP left off, delivering water to farmers and cities further south. Southern California is also a prime beneficiary of federal investments along the Colorado River.

In normal rainfall years, ground water 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). As elsewhere in the West, one justification of surface water projects for agriculture was to limit ground-water overdraft. Federal policies subsidizing agricultural surface water persist to this day (Grossi, 2004).

Large-scale state water planning exercises laid the basis for these projects. The 1930 *State Water Plan* provided the architecture for the CVP (California Department of Public Works, 1930). Following its initial release in 1957, the California Department of Water Resources (CDWR) has updated the CWP ("the Plan") eight times (CDWR, 1957, 1966, 1970, 1974, 1983, 1987, 1994, 1998, 2005). The first CWP and early updates focused on the expansion of surface water investments through the SWP. Beginning in the 1970s, however, concerns over the environmental effects of these projects gained momentum, and it became clear that new dams would need to jump much higher hurdles to gain approval. One casualty was the SWP itself, which had to scrap plans for expansion to full capacity when some rivers were declared "wild and scenic" and off-limits for dams and diversions (Hundley, 2001).

It took time for state water planning documents to incorporate these new realities. In response to public criticisms of earlier plans, the 1998 update of the CWP was the first to explicitly examine a range of supply options. But the result was less than encouraging. The Plan concluded that although new options such as water transfers and recycling might help at the margin, California nevertheless faced the prospect of chronic water shortages by the year 2020 (CDWR, 1998). As public comments on the draft plan made clear, it was easy to infer that new surface storage would be a necessary complement to any innovations the state might pursue (CDWR, 1998, Appendix 1B).

The most recent CWP update, finalized in December 2005, represents a break with the past. For one, the process was overhauled to become more transparent. It included a public advisory committee and an extended public review panel, employed facilitators to solicit input from these groups, and made interim documents on methods and data available through the Internet. Also in the interests of transparency, the planning team was requested to develop estimates of recent water use from actual water years, rather than the normalized "average" and "dry" years used in earlier reports, and to project demand growth according to various scenarios. And significantly, the Plan firmly embraces the portfolio approach to water supply planning, spotlighting how much water could be mobilized by 2030 from a wide range of sources.

Figure 1 presents these estimates. 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,

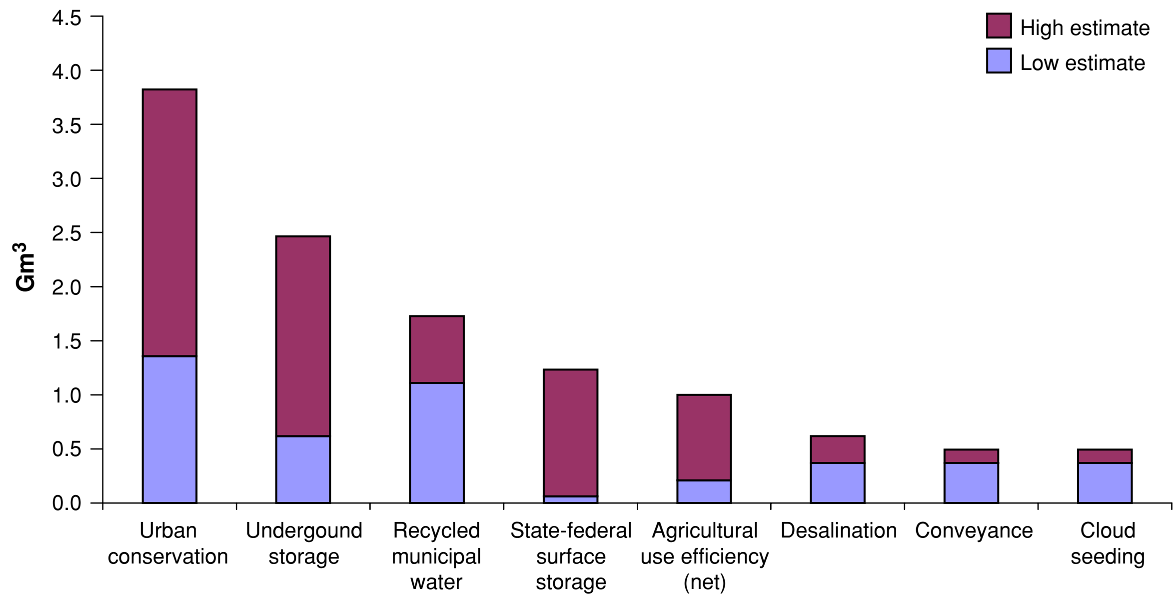

FIGURE 1. Annual Production Potential From New Water Sources and Conservation, 2000-2030. Source: California Department of Water Resources, 2005.

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 has the potential to generate roughly 0.5 Gm^3 per year.

Simply summing these strategies overstates the net supply potential, because some – for instance, surface and ground-water storage – could compete for the same supplies or facilities. On the other hand, there are also many opportunities for synergies among portfolio elements. In particular, water markets create incentives for both conservation 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 water-use efficiency. According to the Plan's water demand projections, agricultural water use is expected to decline by 5-10%, due to various market forces including a shift to higher value, less-water-using crops and residential development of farmland (Table 1). Such reductions present opportunities for transfer and for basin recharge.

This comprehensive approach results in a more optimistic picture of California's potential water future than the last CWP update, with sufficient scope for reallocation and supply expansion to accommodate growth in urban and environmental demand and to offset reductions in some existing sources (Table 1). 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 1.2-2.5 Gm^3 of annual groundwater overdraft. Since the early 1990s, over 1 Gm^3 per year has been returned to instream uses to protect endangered aquatic wildlife, and environmentalists estimate that an equivalent volume is needed to enhance these protections. Using recent population projections of 14 million new residents (+40%) by 2030, the "less resource intensive" and "current trends" baseline scenarios for the urban sector project demand growth by 1.7-3.7 Gm^3 per year (17-34%),

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	
Ground-water overdraft		1.2-2.5	
Net change		2.2-3.5	

Source: CDWR, 2005.

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 and rising per capita use.

The Plan's release has not occurred without controversy. On the one hand, some analysts have criticized the conservation estimates as too low (Gleick *et al.*, 2005). On the other hand, some farming and water agency representatives have argued that the Plan underemphasizes the need for new surface storage. (See, for instance, the public review draft comments of the California Farm Bureau, the California Farm Water Coalition, and the Association of California Water Agencies). On the technical side, critiques noted that the Plan does not consider the supply alternatives in an integrated manner. (See public review draft comments by Jay Lund, professor of civil and environmental engineering at University of California, Davis and Metropolitan Water District of Southern California).

Nevertheless, 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.

ADVANTAGES AND DRAWBACKS OF THE NEW SUPPLY OPTIONS

The CWP provides a general framework for assessing where the state is headed and how conditions vary across broad hydrologic regions. But the primary responsibility for accommodating demand growth and adjusting to supply reductions lies with the hundreds of water utilities operating throughout the state. The optimal mix of solutions will differ by locality and region, depending on costs and reliability. Utilities are often willing to make tradeoffs between these two factors. Of course, feasibility also depends on the ability to overcome institutional barriers and to gain public acceptance. On these last two points, local agencies are often paving the way through trial and error.

The following discussion indicates the relative attractiveness and drawbacks of the 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.

Urban Conservation

Conservation is a demand-side measure to free up supplies. The high-end estimate of potential applied water savings as shown in Figure 1, on the order of 3.8 Gm^3 per year, comes from a study by the California Bay Delta Authority (CBDA, 2005); it represents the maximum feasible level attainable with today's technology irrespective of costs. Estimates that do incorporate a cost-effectiveness yardstick 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 US \$270 to \$650 per 1,000 m^3, and a study by the Pacific Institute (Gleick *et al.*, 2003), concluded that 2.8 Gm^3 could be saved for US \$740 per 1,000 m^3 or less – a threshold the authors deemed relevant for most alternative sources. They estimated that a substantial volume of new water would more than pay for itself thanks to the associated savings in energy (less hot water for low-flow showers and washing machines, less frequent use of irrigation systems) and other inputs (fewer losses of fertilizer, pesticide, and seeds from overwatering). It should be noted that 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 ground-water 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 *et al.* (2003) acknowledge, there may be considerable "educational, political, and social barriers" to achieving these savings. California's experience over the past 15 years highlights both the potential and the challenges.

Nonprice conservation tools include "soft" programs, such as public education, and "hard" programs, such as regulations. Pricing tools include increasing the direct charges for water use and providing rebates for adopting more water-efficient technologies. Both types of tools have been promoted actively since the early 1990s, when California was reeling from a multiyear drought.

Statewide regulations introduced at that time include 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 http://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% 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.

As MWDSC's chief executive officer readily acknowledged when discussing water infrastructure challenges at a 2002 conference, indoor plumbing retrofits are the "low hanging fruit" of water conservation (statement by Ron Gastelum at the UCLA Anderson Forecast conference, "California Infrastructure," Westin Bonaventure Los Angeles, September 25, 2002). 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, 2005), 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% 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 (http://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). 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 http://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; Mansur and Olmstead, 2005; Olmstead *et al.*, 2005). California made progress in tiered rate adoption during the early 1990s drought, but there has been little forward movement since then, and 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). However, in the Central Valley, this figure dropped to under one-fifth, and nearly half of all homes did not even have water meters.

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. 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, including information on how high water users can cut back without turning their yards into dustbowls.

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).

Agricultural Conservation

The CWP estimates of potential savings from agricultural water use efficiency are considerably lower – a fact that has not gone without notice in light of the much larger volume of agricultural relative to urban water use. However, the numbers are not strictly comparable. In contrast to the urban estimates, which show savings of applied water, the agricultural estimates are confined to net savings of irrecoverable flows (i.e., excluding the part of applied use which is recoverable by other users as surface or ground water). For agricultural water, net savings are the only relevant metric, because only net flows can be transferred to other uses. (The ratio of urban net to gross savings is also considerably higher in California – roughly two-thirds, *vs.* a little over a quarter for agriculture, CBDA, 2005.)

The CWP estimates that net savings of up to 1 Gm^3 per year could be achieved at an annualized cost of US \$215 to \$555 per 1,000 m^3. Because most of this spending would not be cost-effective for farmers, it argues for substantial public subsidies. However, a body of literature show that public subsidies to support agricultural conservation will often be ineffective in achieving real savings, in part, because they may encourage farmers to use the saved water on their own farms (for a recent study and review of the literature, see Scheierling *et al.*, 2006). The chances of net savings may be higher when the efficiency investments are supported by water purchases from urban agencies, for whom water in this cost range can be an attractive proposition. For instance, two long-term transfers of water between urban agencies in Southern California and the Imperial Irrigation District, a water-rich agricultural district near the Mexican border, have supported efficiency investments (Hanak, 2003).

Recycled Municipal Water

To some, recycling wastewater is just another form of conservation, because it enables a supply augmentation from the initial 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 US \$740 per 1,000 m^3 including treatment and delivery.

Nor is recycling always as environmentally friendly as it might appear at first glance. Recycling typically results in reduced discharges of treated effluent into rivers and streams. If the resulting change in streamflows 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, battles must be won to convince the public 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 ground-water 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 scrap 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 0.615 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 “Ground-water Replenishment System,” which should begin recharging the ground-water basin with 86 Mm^3 per year of highly purified recycled water in 2007 (http://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.

Underground Storage

Underground storage, or ground-water banking, involves the conjunctive use of surface and ground water. Conjunctive use exploits the interannual variability of rainfall, promoting greater use of ground water 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. For either method, a typical precondition is 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 ground-water 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 1-1.5 Gm^3 in recent normal to wet years, or roughly 6% of average annual ground-water use.

Ground-water 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 US \$136 per 1,000 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 1,000 m^3, depending on the source and the year.) Reaching the upper end of 2.5 Gm^3 (Figure 1) would also require substantial investments in conveyance and re-operation of surface reservoirs.

Relative to surface storage, ground-water banking is generally considered an environmentally friendly option. However, it has some potential drawbacks. 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 ground-water 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 (fertilizers and industrial chemicals) also raises water-quality issues for conjunctive use in some areas.

Third, ground-water 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. Most Southern California basins have such procedures in place, 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.

Water Transfers

Water marketing is another option with the potential to be both low-cost and beneficial to the environment, and both state and federal policies have actively promoted its use since the early 1990s. 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 1, 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.

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). One such party is the environment, because transfers can alter the water supply conditions upon which wildlife depends. 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 western water law, 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.

California's water market has grown steadily since the early 1990s drought, totaling 1.5 Gm^3 annually by the early 2000s (Hanak, 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 US $100 per 1,000 m^3 for local deals within the Central Valley to US $500 per 1,000 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. One component of the environmental market directly benefits other users as well. The Environmental Water Account (EWA), established in 2001, acquires supplies for fisheries agency managers. EWA flows are used to offset the interruptions in pumping needed to protect fish at critical points in the season – thus providing a more flexible alternative than pure regulatory actions.

Desalination

Desalination of seawater – an option that has gained much media attention in recent years – is now on the drawing board of utilities in a number of coastal communities, and the CWP anticipates up to 500 Mm^3 will be on line by 2030. Although the projected costs have fallen, they remain substantial in comparison with most other options – in the range of US $1,000 to $1,850 per 1,000 m^3 according to the Task Force on Water Desalination (CDWR, 2003b). Energy is a major cost component, as are high-performance filters.

Utilities are willing to consider such price tags because desalination offers the prospect of high reliability. In communities along California's Central Coast, unconnected to the state's major water conveyance channels, desalination is also one of the few remaining options for augmenting supplies. In Southern California, desalination is planned as part of a much broader mix, and the projects are relying on subsidies of US $250 per acre-foot ($308 per 1,000 m^3) from MWDSC, the regional wholesaler. These regional projects show that as long as the right plumbing is available, inland locations can benefit from seawater desalination. Indeed, Las Vegas has been exploring the possibility of financing desalination in Southern California, in exchange for some of California's Colorado River allotment (Brean, 2004).

Desalination technology also applies to brackish ground water. Southern California utilities are already producing 100 Mm^3 of clean water annually with this method, and the CWP anticipates that this amount could double over the coming decades. Both types of desalination must find environmentally acceptable ways to dispose of brine or concentrate; ocean water desalination must also mitigate risks to marine organisms at seawater intakes.

Cloud Seeding

It may come as some surprise that this new technology is already in full swing, with about a dozen active projects in the Sierra Nevada foothills. Although quantification is difficult, cloud seeding proponents consider this method to be both effective and quite inexpensive. The CWP puts a conservative estimate of current annual supply benefits at 370-500 Mm^3 per year, with about US $3 million spent on operations, and considers that a similar volume is potentially available at an annual cost of $23 per 1,000 m^3. It is worth noting, however, that a scientific consensus regarding the efficacy of cloud seeding remains elusive (see National Research Council, 2003, which proposed a large research effort to reduce the uncertainties of the technology; see also Garstang *et al.*, 2005).

Surface Storage

With all of these new sources in sight, what does the future hold for the traditional strategy to expand surface storage? Storage is a linchpin of western water systems, because rainfall is highly variable across space and time. California relies on three storage options – surface reservoirs, aquifers, and mountain snow pack. Concerns about the environmental effects of surface storage notwithstanding, many hold the view that some expansion is necessary, particularly in light of predictions that climate change will reduce the storage capability of the snow pack. (For recent analyses of the potential water supply effects of climate change in California, see Tanaka *et al.*, 2006 and Hayhoe *et al.*, 2004.) Farm groups also seek expansion to restore supplies they have lost to environmental mitigation since the early 1990s.

The deliberations on statewide surface storage have occurred under the auspices of CALFED, a joint state-federal program to restore the ecosystem of the San Francisco Bay Delta while securing water supplies to urban and agricultural users. CALFED's 2000 Record of Decision included an agreement to explore options for five new surface storage projects (CALFED Bay Delta Program, 2000).

The expansion program remains highly contentious, with most environmental groups opposing it, despite claims that the environment could be a primary beneficiary. Funding has also been a stumbling block. With hoped-for federal contributions lagging, water users have been forced to reexamine the issue of who should pay. Although firm cost numbers are not available, one CALFED study (CALFED Bay Delta Program, 1999) estimated a range of US $185 to over $1,200 per 1,000 m^3. It concluded that although some urban agencies would be willing to pay for such water, farmers would require substantial subsidies to use it. Because urban agencies have a range of other cost-effective options, significant taxpayer support would be required to fund expansion at the proposed scale. A central discussion under way concerns the appropriate level of public subsidies, given the potential for broader public benefits, including improved capacity to manage environmental flows (CBDA, 2004).

Although less in the spotlight, local and regional projects to expand surface storage and conveyance are a key component of urban strategies in some areas. In contrast to the CALFED projects, which are not viable without general taxpayer funds, these projects are principally funded by local users.

Interestingly, recent debates concerning one of California's oldest local storage projects – San Francisco's O'Shaunessy Dam in Yosemite National Park – have considered the potential for living with less, rather than more, storage. The goal of dam removal would be the restoration of the Hetch Hetchy Valley, the "twin" of the adjacent Yosemite Valley. Null and Lund (2006) show that the re-operation of other reservoirs within the system could allow dam removal without significant increases in water scarcity, although there would be some lost hydropower and some increases in water treatment costs. In light of these findings, the debate has now shifted from the question of feasibility to the question of restoration costs, which a state study recently put in the range of US $3 to $10 billion (California Resources Agency, 2006).

NEW ROLES FOR PLANNERS, NEW ROLES FOR GOVERNMENTS

Even if some large new surface storage projects do go forward, it is clear that water supply planning has entered a new era. The possibilities are exciting, but they are also complex. Environmental approvals are now a major component of virtually any strategy except conservation, and many elements in the water portfolio call for coordination between utilities and other parties. Recycling programs require partnerships between water and wastewater utilities. Water marketing involves negotiation not only between buyers and sellers, but also with community interests. Ground-water banks require management protocols. Conservation and recycling programs need to work with builders as well as the public. And the list goes on.

To succeed, utilities must also improve coordination with each other. The strength of a portfolio approach to water supply is the flexibility it affords if some strategies take longer than planned or do not pan out. Also, strategies like desalination, storage, and even water transfers have minimum efficient scales. Many utilities are too small to truly benefit from this approach on their own. This makes regional cooperation an essential part of modern water planning.

Finally, successful long-term planning requires utilities to work together with cities and counties, the local land-use authorities. Water demand growth depends on variables within their purview – not only how many homes and businesses, but also the footprint of development. Local land-use policies can facilitate or hinder the adoption of key new water sources, including conservation and recycling. Land-use decisions can also have consequences for water quality and the ability to recharge ground-water basins.

Thus, water planning has moved beyond the realms of engineering and hydrology, to encompass ecology, land-use, and collaborative decision-making. This has dramatically altered the roles and responsibilities of planners in local and regional water utilities, and it has brought numerous "nonwater" agencies into the mix. How can government policies help foster a successful transition? And how can utility planners better integrate their work with those working within other local entities? California's experience suggests some pathways.

Mostly Carrots, Few Sticks

California's state government has taken a multipronged approach to promoting sound local resource planning, using a combination of regulations, incentives, and technical backstopping (Hanak, 2005). These policies have been mainly facilitative in nature, in keeping with the strong "local control" paradigm that pervades California water and land-use politics.

The first element in the policy toolkit is planning legislation. Since the mid 1980s, all utilities serving at least 3,000 customers have been required to prepare long-term Urban Water Management Plans (UWMPs) every 5 years. In 2001, two "show me the water" laws required utilities and land-use authorities to ensure that adequate long-term water supplies are available prior to the approval of large developments (greater than 500 homes). These laws rely on citizen enforcement – the ability to file a lawsuit for noncompliance.

The second element has been financial carrots. Thanks to the availability of billions of dollars in water bond funds, the state has been able to reward local entities for positive actions (Rueben and de Alth, 2005). Since 2002, state grants have been contingent upon submission of a complete UWMP, and regional projects have a funding priority.

The third element is technical support. For UWMPs and water adequacy reviews, this has primarily consisted of outreach on how to comply with the law. (For information on these programs, see http://www.owue.water.ca.gov.) For ground-water management, CDWR has become more involved in some regions, participating in basin management initiatives.

Although compliance is far from perfect, these "soft" policies have made a difference (Hanak, 2005). Of the roughly 400 utilities required to submit UWMPs in 2000, 84% did so, up from 75% 5 years earlier. Compliance is likely to improve in the next round, because the stakes are higher: a well-documented UWMP can now serve as evidence of adequate long-term supplies under the "show me the water" laws. These laws, in turn, have already generated considerable review activity. Successful lawsuits against noncompliant agencies have underscored the importance of preparing well-documented UWMPs and water adequacy reviews, to avoid having development projects stopped by court order.

Given the amounts at stake, there is little doubt that financial incentives have played a role. CDWR has been able to send more than one utility back to the drawing board to include missing UWMP elements. The prospect of financial support has also spurred many agencies to develop regional proposals (http://www.grantsloans.water.ca.gov). The hope is that these collaborations last beyond the duration of state grants, as agencies see the value of joint efforts.

Meanwhile, policies of a more regulatory nature have focused on conservation. They include legislation requiring the use of low-flow plumbing fixtures in new homes since the early 1990s and, starting in 2007, the sale of water-efficient washing machines. They also include laws requiring municipal utilities to introduce water meters. The metering law uses carrots and sticks: noncompliant utilities will be ineligible for financial support, and they may be denied new water supply permits. Going forward, there may be more room for state prodding to adopt conservation-oriented rate structures, to ease the political pressures on local utility boards.

Pushing the Envelope

The new environment also provides opportunities for local-level innovations. Over the past decade or so, California has seen the creation of numerous county and regional water users groups, bringing together utilities, land-use agencies, flood control authorities, and representatives of local business and environmental groups. Outcomes include ground-water management plans and regional water planning frameworks that take an increasingly integrated approach to resource management. In the Chino Basin, these collaborations have led to modifications in the storm drainage network to improve basin recharge, simultaneously diminishing the flow of polluted run-off (http://www.ieua.org/RecycledGroundwater.html). Various run-off catchment systems, including cisterns under parking lots, are being developed in neighboring Los Angeles County with the help of Tree People, a local environmental group (http://www.treepeople.org/trees/default.htm).

Innovations are also springing from collaborations with developers. In the projects noted above, agencies are working with builders to incorporate better stormwater capture systems into new homes. MWDSC and the Southern California building industry have developed the concept of a "California friendly home," which includes indoor and outdoor water-saving elements. Las Vegas has gone a step further, with a new certification process for "water smart homes." One firm has already committed itself to be a certified "water smart builder," producing only homes that meet the label's strict requirements (http://www.snwa.com/html/cons_wshome.html).

Last, but not least, the new environment offers opportunities for better integration of the water and land-use planning processes. The East Bay Municipal Utilities District, a large Bay Area utility, revises its demand projections using general and specific plan updates within its service area. Land-use agencies, in turn, are starting to take a more thorough look at the water side of the equation. (For a discussion of the benefits of this approach and some practical guidelines, see Johnson and Loux, 2004 and Waterman, 2004.) Sonoma County recently included a water resources element as part of its general plan update (Sonoma County, 2006). There is not yet a consensus on the need for such steps; California's legislature recently rejected bills that would make a water element mandatory because of the additional cost burden for local governments. Given the potential benefits of more integrated water and land-use planning in regions facing growth pressures, there is a strong likelihood that these investments would pay off.

CONCLUSIONS

California's recent experience offers some interesting insights into the changing world of water planning in regions facing rapid population growth. Constraints on the continued development of the two traditional staples of the water supply portfolio – surface storage and native ground-water reserves – need not spell an impending water crisis. Measures to broaden the portfolio with nontraditional sources (recycling, desalination, 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.

Assembling a broader water supply portfolio requires water planners to broaden their horizons beyond hydrology and engineering. To successfully implement many of the new supply strategies, local and regional water agencies need to work not only with each other, but also with local land-use authorities, local wastewater utilities, builders, and the public. Unlike the days of yore, when state and federal agencies spearheaded the construction of large surface storage projects, the state and federal governments will now be 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.

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