V. Where Do We Want To Be: California Water 2020

As long as we continue to mismanage our water resources, the gap between water demand and supply will continue to widen, exacerbating groundwater overdraft, surface water disputes, and water quality problems. We have the opportunity, tools, and ability to create a remarkably different urban and agricultural economy, one that can restore ecosystems and protect the environment while bringing forth innovation, equitable use of resources, meaningful work, and economic security. The vision presented at the beginning of this report offers a positive goal for California water planning and management. This section offers the analytical and technical background to support the goals identified in that vision. These goals meet the sustainability criteria developed earlier. How they might be achieved is discussed in the final section.

A. SUSTAINABLE URBAN WATER USE

The past approach of expanding urban water supplies by tapping ever more distant sources to meet presumed future demands is no longer appropriate in California. Increasingly, water managers must try to determine how to satisfy human needs and desires for water within the limits of the resources that are presently available.

What do humans need? According to health officials worldwide, the minimum amount of water a person "needs" for a healthy living standard is about 20 gallons per day (WHO 1971, NAS 1977). This benchmark includes sufficient water to provide adequate sanitation services, maintain human health, and prepare food. Water required to grow or produce food is not included, nor are typical municipal, commercial, and industrial water uses. Any domestic water use that exceeds that level, whether in support of people's livelihood or their lifestyles reflects personal, economic, and social choices, and patterns of urban living.

To satisfy the minimum water requirement described above, California in the year 2020 will require about 1.1 maf (less than 25 percent of the 1990 residential demand). Official projections based on conventional analysis for 2020 are that Californians will still use over 100 gallons per person per day more than this minimum.

Because the water required to meet basic human needs comprises a relatively small amount of total residential water use, meeting the minimum water requirement to maintain human health is not a serious challenge. By providing this minimum level of water for human consumption at lifeline rates, California will assure that the basic water needs of its citizens are met. Water use beyond the minimum water requirement should be guided by efficiency and equity considerations, as well as other measures to ensure that the renewability and quality of our water supply are maintained.

> ***We have the opportunity, tools, and ability to create a remarkably different urban and agricultural economy, one that can restore ecosystems and protect the environment while bringing forth innovation, equitable use of resources, meaningful work, and economic security.***

1. Residential Water Use

Permanent residential water savings by 2020 will come from improvements in both indoor and outdoor water-use efficiency and from conservation management practices. Indoor water savings will principally result from installing water-efficient fixtures in new and existing dwellings to meet existing standards. Smaller, yet substantial, savings will also be achieved through changing water-use practices (i.e., taking shorter showers, not running the faucet while shaving or brushing, and so on), but we do not include these behavioral changes in our estimates. Outdoor water savings will principally result from improving irrigation efficiency, reducing turf size, xeriscaping, and using reclaimed water for outdoor irrigation. Through improvements in indoor and outdoor water use, per-capita residential applied water use in 2020 will be less than 75 gallons per person per day, a more than 45 percent decrease from the 1990 per-capita water use level (see Table 3).

a) Residential Indoor Water Use

The greatest long-term, permanent indoor water savings will come from installing water-efficient fixtures in new construction and replacing conventional fixtures in existing residences, businesses, and industry. In recent years, in part due to the recent droughts, many new efficient appliances and fixtures have become available. Their sale is now mandated by the 1992 National Energy Policy Act's water-efficiency standards, which should have an enormous impact on urban water demand over the next 25 years.

Existing non-ULF (ultra-low-flow) toilets, faucets, and showerheads can be replaced with ULF toilets, water-efficient faucets, and showerheads when they break down or when houses are remodeled. Studies have commonly used natural turnover rates in the range of three to seven percent per year for toilets (California Urban Water Conservation Council 1992). Since the cost of toilets is substantially higher it is not unreasonable to assume the same turnover rates for faucets and showerheads. Using five percent as a conservative but realistic estimate of the natural turnover rate of residential water fixtures, over three-fourths of all Californians will live in homes that meet or exceed the water-efficiency standards of the NEPAct by 2020.

According to a number of studies, the NEPAct standards have the potential to reduce residential water use for toilets, showerheads, and faucets by 62 percent for fixtures installed prior to 1980 and 39 percent for fixtures installed between 1980 and 1992 (Vickers 1991, Vickers 1993). Results of the Institute's analysis, as illustrated in Table 14, suggest that the NEPAct water-efficiency standards will substantially reduce residential indoor applied water use in California by the year 2020 compared to conventional estimates of future urban demand.

If three-quarters of all indoor residential water-using fixtures (toilets, showerheads, and faucets) in California meet the NEPAct standards by 2020, total indoor residential water use will increase slightly from 3.1 maf in 1990 to 3.4 maf (a 10 percent increase from 1990), despite a 63 percent increase in population. If by 2020 California was to achieve complete replacement of all inefficient toilets, showerheads, and faucets, it could actually reduce indoor applied water use by about 0.3 maf from the 1990 level or a 10 percent decrease — a substantial reduction in per-capita indoor use. Savings are even possible in communities that have been active in promoting water-efficient fixtures and appliances. For example, in 1994 about 81 percent of the single-family homes in the Marin Metropolitan Water District, which already has a low per-capita residential water use, still had toilets that use 3.5 or more gallons per flush. In multi-family homes, 87 percent had toilets that use 3.5 or more gallons per flush (Fiske and Weiner 1994).

Table 14
2020 Residential Indoor Water Use

Scenario	Total Applied Residential Indoor Water Use (million acre-feet)	Per-Capita Applied Residential Indoor Water Use (gallons per person per day)
DWR 1990 Residential Indoor Applied Water Use [a]	3.1	91
DWR 2020 Residential Indoor Applied Water Use [a]	5.0	91
Residential Indoor Applied Water Use in 2020 with 75% Compliance with the 1992 NEPAct (vision)[b]	3.4	61
Residential Indoor Applied Water Use in 2020 with 100% Compliance with the 1992 NEPAct (vision)[b]	2.8	51

[a] *The DWR total applied residential indoor water use estimates are the product of the current residential water use percentage times the fraction of indoor use times total urban water use (59% x 2/3 x total urban water use) (DWR 1994a).*

[b] *The 2020 vision estimates of total applied residential indoor water use are based on 75 and 100 percent compliance with the 1992 National Energy Policy Act.*

Our analysis, as summarized in Table 14, does not assume improvements in the water-use efficiency of other major fixtures, such as dishwashers and washing machines. In fact, washing machines that use half the water of current models are available and improvements in technology are continuing to be made. Including these in our calculations would have reduced future residential indoor water use even more.

b) Residential Outdoor Water Use

In California, most outdoor use in the urban sector occurs during the dry summer months. Although detailed data on outdoor water use are not available, official estimates are that about 2 maf of potable water were used to water exterior landscaping in the residential, municipal, and commercial sectors in California in 1980. By 1990, urban outdoor water use had risen to over 3 maf (DWR 1994b). Using DWR's estimates, outdoor residential water use in 1990 was about 1.5 maf, with another 1.5 maf of outdoor water use divided among the other urban sectors. Under conventional projections, potable water demand for landscaping continues to increase as population grows and as development moves inland, where hotter and dryer conditions lead to higher per-capita outdoor use (DWR 1994b). By 2020, conventional trend analyses suggest that outdoor residential water use would grow by 1 maf.

This upward trend in outdoor water use need not continue. Many policies are already being explored to reduce demand for urban irrigation, including technological improvements that increase irrigation efficiency, reductions in the area of turf requiring water, replacement of lawns with native, drought-resistant plants, and replacement of potable water for turf irrigation with gray or reclaimed water. Studies have concluded that outdoor water use can easily be reduced by more than 25 percent simply by improving outdoor irrigation practices (Sunset 1987). Combining this with drought-resistant plants and substituting reclaimed water for potable water use, per-capita potable water use can be decreased by at least 50 percent.

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Reducing per-capita outdoor water use by 25 percent, achievable with the changes mentioned earlier, would result in an increase in total outdoor residential water use in the year 2020 of 350,000 af, instead of 1.0 maf, over 1990 levels. A 50 percent reduction, which would require more extensive changes, but could be accomplished with methods and technologies already available, would reduce total residential outdoor water use in 2020 to 1.3 maf, 200,000 af fewer than the amount used in 1990. These scenarios of applied outdoor water use are summarized in Table 15.

Table 15
2020 Residential Outdoor Water Use

Scenario	Total Applied Residential Outdoor Water Use (million acre-feet)	Per-Capita Applied Residential Outdoor Water Use (gallons per person perday)
DWR 1990 Residential Outdoor Applied Water Use[a]	1.5	46
DWR 2020 Residential Outdoor Applied Water Use[a]	2.5	46
2020 Residential Outdoor Applied Water Use with 25% Outdoor Savings (vision)[b]	1.9	34
2020 Residential Outdoor Applied Water Use with 50% Outdoor Savings (vision)[b]	1.3	23

[a] *The DWR total applied residential outdoor water use estimates are the product of the current residential water use percentage times the fraction of outdoor use times total urban water use (59% x 1/3 x total urban water use) (DWR 1994a).*

[b] *The 2020 vision estimates of total applied water use are based on 25 percent reductions in outdoor potable water use and 25 percent substitution of potable water use with reclaimed water.*

In summary, by 2020, as residential customers become more water conscious and reduce inefficient indoor and outdoor water uses, total residential water use could be in the range of 4.1 to 5.3 maf (compared to the 4.6 maf used in 1990 and the nearly 7.5 maf projected for 2020 by conventional approaches). Even with 100 percent compliance with the NEPAct water efficiency standards and with a 50 percent reduction in outdoor water use, per-capita residential water use will still be approximately 75 gallons per person per day. This exceeds Israel's 1990 per-capita water use of 70 gallons per person per day (Fishelson 1993). Nonetheless, it would be an enormous savings of nearly 3.5 maf per year over current California projections for 2020.

2. Non-Residential Water Use

Residential water use accounts for just under 60 percent of urban water use. The remaining urban use is divided among the commercial, industrial, and municipal sectors. Much commercial water use can be saved with technologies and policies similar to those available in the residential sector. The potential for those improvements has been documented elsewhere (Gleick, Stewart, Norman 1994).

The substantial improvements in water-use efficiency achieved by several individual industrial corporations over the past decade are also indicative of the kinds of savings possible in the industrial sector as a whole. The reuse and recycling of cooling water, for example, would considerably reduce industrial water demands for many large industries.

There is also considerable potential for changes in the structure of the industrial sector toward less water-intensive production. Many industries have already begun to explore low-cost water-efficiency projects. Plants that have already invested in conservation programs and technology would require increasingly larger investments to further reduce their water use.

Estimates of future conservation potential for the non-residential (commercial and industrial) sector are around 20 percent (EBMUD 1994). Table 16, for example, shows the conservation potential in a set of California's major industrial groups calculated by one industrial study (Wade et al. 1991). This study looked only at available conservation potential for half of California's water-using industries and did not consider the potential for substitution of reclaimed water. Nevertheless, this analysis provides background for estimates of future efficiency improvements in the industrial sector.

The Institute projects that the industrial and commercial sectors in 2020 will be both more water efficient at what they do and restructured toward less water-intensive practices. In the first case, we project that the average water-use efficiency for each component of California's industrial sector will increase by about 20 percent — the average improvement

Table 16
California Industrial Water Conservation Potential

Standard Industrial Classification Codes	Industry Group	1989 Industrial Water Use (thousand acre-feet per year)	Potential Conservation (thousand acre-feet per year)	Percent Savings (percent)
20	Food Groups	82.3	10.0	12.2
291	Refining	126.7	24.3	19.2
281	Chemicals	27.2	11.0	40.4
327	Concrete	19.1	1.8	9.4
372	Aircraft	13.6	2.1	15.4
265	Paper Boxes	12.4	3.6	29.0
357 and 367	Computers/Electronics	15.0	3.9	26.0
Miscellaneous	Other Industries	25.3	4.3	17.0
TOTALS		**321.6**	**61.0**	**19.0**

[a] *These estimates come from an incomplete survey of California industries and assume no change in technology.*

Source: Wade et al. 1991.

in water-use efficiency that could be achieved with full implementation of today's best available technologies and industrial processes. By 2020, new technologies will permit many industries to improve substantially beyond the best available in 1990, but we do not include such projections here.

In the second case, total industrial water-use efficiency is assumed to improve an additional 20 percent because of changes in the structure of the industrial sector, as opposed to improvements within each industry. Such changes are already underway. In the past two decades, several major industries that are also water intensive have become much less important to California's economy. For example, fabricated metal products, petroleum and coal products, and the primary metal sector produced one-fifth of the state's economic output in 1979. By 1990, this had dropped to less than one-tenth. These industries were responsible for 25 percent of California's industrial water use in 1979. During the same period, the manufacture of computers, electrical equipment, and scientific instruments went from generating 17 percent of state GDP to nearly 25 percent, while initially using only six percent of industrial water.

From 1980 to 1990, the combination of these changes reduced California's total industrial water use by an estimated 33 percent (DWR 1994a, 1994b). We project that an additional 40 percent drop over the next 25 years, described above, is well within the capability of the state's industries. Comparable savings may be available in other non-residential sectors.

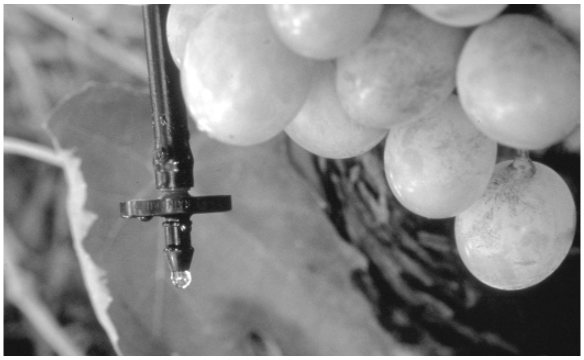
Unlike the residential sector where per-capita water use is expected to drop dramatically as a result of the NEPAct water efficiency standards, the impacts of the NEPAct non-residential water efficiency standards for fixtures and fixture fittings are less certain. They do not take effect until January 1, 1997, and they allow some exemptions for safety showers, toilets and urinals used in prisons, and other products that require unique designs and higher flow rates. Some commercial toilets are also allowed a higher water-use rate until they can be redesigned to operate reliably at lower volume. Any non-residential analysis will be further complicated by limited availability of non-residential water use data. Nonetheless, despite the uncertainty surrounding the impacts of the NEPAct on the non-residential sector, especially during the early years, by 2020 per-capita non-residential sanitary water use will be substantially less than it is today.

B. SUSTAINABLE AGRICULTURAL WATER USE

Agriculture has long played an important role in California. Much of the development of the state's water resources in the 20th century occurred with the idea that the water would be used by family farmers, thereby strengthening the nation's democracy, building the state's economy, and enhancing rural community. But despite the notable successes at producing food, the vision of a strong rural community based on small, independent, family farmers portrayed by the 1902 Reclamation Act has not been realized. Today, the challenge is to envision an agricultural sector that is vitally tied to rural livelihood and is consistent with the sustainability criteria.

Under almost any possible vision of California, the agricultural community will continue to play an important role in the future. The sustainability criteria mentioned earlier sketch only the outlines of what such a community could look like. There are many different ways for agricultural producers to use water to the benefit of their surrounding communities. Given enough time and information, farmers have long shown themselves to be flexible, dynamic, and innovative in response to water constraints, technological

There are many different ways for agricultural producers to use water to the benefit of their surrounding communities. Given enough time and information, farmers have long shown themselves to be flexible, dynamic, and innovative in response to water constraints, technological changes, and alternative agricultural policies.



Precise drip irrigation technology can reduce water applied to many crops. (Courtesy of DWR.)

changes, and alternative agricultural policies.

Farmers face various choices in water use given certain constraints and incentives. In general, farmers behave rationally, trying to maximize profits, and for them, water is merely one factor of production that affects net income. But farmers also make choices independent of profit maximization; experience, family traditions, and community values all factor into their decisions. More water use does not necessarily imply a healthier community; nor does less water use imply economic losses, as we demonstrate below. Short-term choices that affect water needs include what crops to grow, what sources of water (including ground water and surface water) to use, and how to irrigate. In the long-term, farmers are able to invest in more efficient irrigation technology, increase efficiency of on-farm delivery systems, install more groundwater pumping capacity or on-farm surface storage, permanently retire land, or leave farming altogether. All these long-term decisions by a farmer have different impacts on California's water supply.

The following scenarios were developed in an effort to estimate the potential consequences for agricultural water demands of modifying cropping patterns and fallowing land. The general purpose of the first set of scenarios was to provide some concrete estimates for the changes that would be necessary to eliminate unsustainable groundwater use. The second set of scenarios provides more comprehensive estimates of the effect of changing cropping patterns on water use and crop revenue.

Table 17
DWR Groundwater Overdraft Estimates

Hydrological Region	1990	2020
	(thousand acre-feet)	
North Coast	0	0
San Francisco	0	0
Central Coast	250	250
South Coast	20	0
Sacramento River	30	30
San Joaquin River	210	0
Tulare Lake	650	590
North Lahontan	0	0
South Lahontan	70	70
Colorado River	80	70
CALIFORNIA TOTAL	**1,310**	**1,010**

All numbers are from DWR 1993, except those for the Tulare Lake Region, which are based on 1994a figures. The 60 thousand acre-feet savings in the Tulare Lake region from 1990 to 2020 is based on the expected overdraft reduction given in DWR 1993.

1. Eliminating Groundwater Overdraft in 2020

In the following agricultural scenarios, we explore how groundwater overdraft could be eliminated by the year 2020 with minimal negative impacts on the agricultural community. Long-term overdraft of groundwater continues to be the major, unsustainable practice in California agriculture. This practice persists because groundwater use is neither monitored nor regulated in most major groundwater basins. To meet the sustainability criteria, a statewide system of groundwater monitoring and regulation must be implemented, and the long-term overdraft of ground water must be eliminated.

> ***To meet the sustainability criteria, a statewide system of groundwater monitoring and regulation must be implemented, and the long-term overdraft of ground water must be eliminated.***

Although there are other unsustainable practices associated with agricultural water use, groundwater overdraft has been one of the most persistent. In fact, problems associated with groundwater overdraft have long played a role in justifying major public works, such as the Central Valley Project. Yet in 1990, California still had 1.3 maf of groundwater overdraft, not including emergency pumping due to the drought. According to projections by the DWR, groundwater overdraft can be expected to continue in average water years through 2020. Table 17 shows DWR estimates of overdraft in 1990 and 2020.

A variety of measures could be used to eliminate groundwater overdraft, including taking more water from rivers and streams or building major new supply projects. These have been the traditional responses. Because the sustainability criteria require maintaining a minimum amount of water for ecosystems, and because new supplies to offset groundwater overdraft are unlikely for political and economic reasons, our analysis focuses on changes in cropping patterns and total irrigated acreage.

Our basic assumptions are fairly straightforward and conservative. We assume no improvement in overall irrigation efficiency, despite the fact that substantial improvements in some areas are both possible and likely. We assume no improvements in crop yields in order to increase revenues, though again, such improvements are both possible and likely. Instead, we focus on shifting crop production away from low-valued, high-water-using crops towards higher-valued, low-water-using crops.

2. Methodology

The two scenarios are based upon reductions in low-value, water-intensive crops: irrigated alfalfa, pasture, rice, and cotton.[11] The first set of projections, the "Balanced Groundwater" scenario, reduces irrigated alfalfa and pasture acreage within each hydrologic region to the point where the amount of water saved equals the amount of groundwater overdraft projected by DWR in 2020. The second scenario, "Agricultural Restructuring," also eliminates groundwater overdraft, but, in addition to reductions in alfalfa and pasture, the acreage of rice and cotton are scaled back to 1960 levels. While the first scenario explores the minimum changes needed to correct groundwater overdraft, the second scenario analyzes the effects of a more streamlined, highly productive agricultural industry.

In each scenario, two water-reduction approaches are used to give a range of estimates of the total irrigated acreage and the economic impacts on agriculture. In the first approach, cropland freed by alfalfa and pasture reductions is left fallow. This method of reducing agricultural water use will have the greatest impact on agricultural revenues and thus produces the worst-case impacts on the agricultural sector. The second approach reallocates cropland to higher-value, lower water-using crops. In this method, acreage of the water-intensive crops are reduced in each region, and the land freed up is proportionately reallocated to the other less water-intensive crops already grown in the region. This method gives a more positive estimate of the impact on agricultural income.[12] The predicted impacts of achieving each scenario's objectives can be reasonably expected to fall somewhere in between the fallowing and crop-switching estimates.

We note, however, that many of the complexities associated with crop switching are not accounted for in the scenarios. For instance, economic considerations such as the increased costs of production associated with converting alfalfa and pasture acreage to higher value crops are not considered. Also, a portion of the land in each hydrological region now used to grow these crops is considered marginally productive, and therefore may not be suitable for other crops. For simplicity, it is assumed that in the crop switching cases, all the existing crops in a region can be increased proportionally to make up for acreage reductions in alfalfa and pasture and other low-value water-intensive crops, and that crops not currently grown in a particular region are not introduced.

The scenario calculations are carried out in the following manner. First, average unit evapotranspiration of applied water is computed by

Cotton – a relatively water-intensive, low-valued crop – being harvested near Kettleman City, California. (Courtesy of DWR.)

Cows grazing on irrigation pasture in central California. (Courtesy of DWR.)

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[11] Although other field crops and corn generate lower revenue per unit consumed water than cotton, they are less water-intensive than cotton. Another reason we chose to reduce cotton acreage in our scenarios is that it is currently the state's largest single crop in terms of irrigated acreage.

[12] The best case economic outcome would come from assuming that all land taken away from water-intensive, low-value crops is reassigned only to the highest valued crop grown in a region. We did not explore this option.

crop for each hydrologic region using DWR figures (1994a). Then, to calculate consumed water, these unit evapotranspiration figures are multiplied by the projected irrigated acreage for each crop in each hydrologic region. The calculated water use for 2020 using DWR's irrigated acreage predictions serves as the base case scenario. Water savings from our scenarios are compared with this base case.[13]

The impact on agricultural revenue is determined by multiplying the total irrigated acreage of each crop by the average revenue per acre in 1988 as reported in Sunding et al. (1994). The revenue estimates should be considered very approximate. Actual economic impacts will depend on a wide range of factors, including actual market prices, federal subsidy programs, and complicated third-party impacts from switching crop types. More detailed analysis using more sophisticated agricultural market models will ultimately be required to resolve these questions.

3. Balanced Groundwater Scenario (BGS) Results

The main objective of this scenario is to eliminate the estimated annual average one million acre-feet of groundwater overdraft in the year 2020 by reducing alfalfa and irrigated pasture acreage. As shown in Table 17, groundwater overdraft is expected to be a continuing problem in half of the state's ten hydrologic regions. Tulare Lake alone accounts for about 58 percent of the state's groundwater overdraft in 2020. Tables 18 and 19 compare the results of both fallowed land and crop switching cases of the BGS to DWR's 1990 and 2020 estimates.

Compared to DWR's 2020 projections, most of the reductions in irrigated acreage in the fallowed land case occur in the Central Coast and Tulare Lake regions with only small reductions in the Sacramento River, South Lahontan and the Colorado River regions. In this case, the Central Coast and Tulare Lake regions account for 86 percent or 232,000 acres of the statewide reductions in alfalfa and pasture. The Central Coast, in addition to a 100 percent reduction in alfalfa and irrigated pasture, must fallow an additional 115,000 acres of other crops to eliminate groundwater overdraft. The Central Coast is particularly affected because 21 percent of its total water use in the year 2020 is expected to come from overdrafted groundwater. Even if the Central Coast were to grow no alfalfa and pasture in 2020, there would still be over 150,000 acre-feet of overdraft. Loosening the constraints on this analysis somewhat could have permitted fallowing of low-valued crops in other regions and transferring water freed up to the Central Coast region to maintain production of these high-valued crops. In reality, such transfers are likely to occur, but we chose not to include that possibility here.

In the crop reallocation case, reductions in total crop acreage are required only in the Central Coast and Tulare Lake regions. In the other three regions — Sacramento River, South Lahontan, and Colorado River — overall acreage stays the same, but enough water is saved to eliminate groundwater overdraft by proportionally increasing all other crops grown in each region to make up for reductions in alfalfa and pasture. In Tulare Lake, the complete fallowing of alfalfa and irrigated pasture land is offset by a slight increase in acreage of all other crops from the DWR's 2020 projections.

Overall, elimination of groundwater overdraft in 2020 in this scenario requires a reduction in statewide irrigated acreage of only 4.1 percent in the fallowed land case and 3.3 percent in the crop switching case. What is the cost to agricultural producers to achieve this groundwater balance? Intuitively, one would think that severe negative economic impacts would coincide with significant reductions in water and land use by the agricultural sector. In fact, at the state level, the opposite is true. Using 1988 estimates of crop farm revenues, this scenario results in a net farm revenue increase from 1990 of $149 million in the fallowed land case and $454 million in the crop switching case, as higher-valued crops begin to substitute for alfalfa and pasture. The growth in farm revenue in the crop switching case

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[13] Our calculations of consumed water do not match agricultural water use figures in DWR's Bulletin 160-93 report because our method of calculating total consumed water does not include additional "irrecoverable losses." These losses are included in the DWR's "depletion" figures for the state (DWR 1994a). By reducing overall consumed and applied water use in agricultural, these losses will be reduced by our approach as well.

Table 18
Balanced Groundwater Scenario:
Comparision of Irrigated Crop Acreage, Consumed Water, and Revenues for 1990 and 2020

Crop Area Irrigated (thousand acres)

Hydrological Region	1990 DWR[a]	2020 DWR[a]	2020 Balanced Groundwater Scenario Fallowed Land	2020 Balanced Groundwater Scenario Crop Switching
North Coast	326	346	346	346
San Francisco	61	64	64	64
Central Coast	528	566	412	412
South Coast	319	184	184	184
Sacramento River	2,145	2,186	2,175	2,186
San Joaquin River	2,008	1,952	1,952	1,952
Tulare Lake	3,212	3,061	2,871	2,911
North Lahontan	161	169	169	169
South Lahontan	61	48	32	48
Colorado River	749	726	713	726
California Total	**9,570**	**9,302**	**8,918**	**8,998**

Water Consumed (thousand acre-feet)

Hydrological Region	1990 DWR[a]	2020 DWR[a]	2020 Balanced Groundwater Scenario Fallowed Land	2020 Balanced Groundwater Scenario Crop Switching
North Coast	504	553	553	553
San Francisco	67	67	67	67
Central Coast	758	800	551	551
South Coast	544	320	320	320
Sacramento River	4,745	4,783	4,754	4,754
San Joaquin River	4,014	3,703	3,703	3,703
Tulare Lake	7,001	6,431	5,841	5,841
North Lahontan	393	408	408	408
South Lahontan	248	204	134	134
Colorado River	2,987	2,876	2,806	2,806
California Total	**21,261**	**20,147**	**19,137**	**19,137**

Crop Revenue (million 1988 dollars)

Hydrological Region	1990 DWR[a]	2020 DWR[a]	2020 Balanced Groundwater Scenario Fallowed Land	2020 Balanced Groundwater Scenario Crop Switching
North Coast	265	304	304	304
San Francisco	127	138	138	138
Central Coast	1,461	1,600	1,237	1,237
South Coast	822	500	500	500
Sacramento River	1,839	1,999	1,995	2,034
San Joaquin River	2,367	2,593	2,593	2,593
Tulare Lake	4,123	4,439	4,348	4,486
North Lahontan	66	73	73	73
South Lahontan	40	27	20	91
Colorado River	1,082	1,137	1,131	1,188
California Total	**12,191**	**12,811**	**12,340**	**12,645**

[a] *DWR numbers are derived from DWR 1994a.*

Table 19
Balanced Groundwater Scenario:
Comparison of Irrigated Acreage by Crop for 1990 and 2020 Scenarios (thousand acres)

Crop	1990 DWR	2020 DWR	Balanced Groundwater Scenario	
			Fallow Land	Crop Switching
Grain	988	909	904	928
Rice	517	498	498	513
Cotton	1,244	1,194	1,194	1,236
Sugar Beets	216	197	196	202
Corn	403	409	408	415
Other Field	491	455	452	464
Alfalfa	1,135	947	725	622
Pasture	956	813	766	724
Tomatoes	352	338	335	343
Other Truck	1,021	1,251	1,175	1,214
Almond/Pistachio	510	561	561	572
Other Deciduous	570	585	581	615
Subtropical	419	392	389	394
Grapes	748	753	735	752
TOTAL CROP AREA	**9,570**	**9,302**	**8,919**	**8,998**

Source: DWR numbers are from DWR 1994a.

would have been even higher but for the decrease in farm revenues from the Central Coast region. This cost to agriculture in the Central Coast area must be weighed against the potentially far worse economic effects of continued groundwater overdraft in the region, which could lead to salt-water intrusion in some areas, rendering groundwater supplies unsuitable for farming. Compared to the agricultural revenues implied by DWR's 2020 crop mix, agricultural revenue in California in the fallowed land case is only 3.7 percent less than with the groundwater overdraft. In the crop reallocation case, state agricultural revenues only drop 1.3 percent. This range of costs to eliminate groundwater overdraft are indeed small considering the benefits of sustainable agricultural water use.

4. Agricultural Restructuring Scenario (ARS)

While the Balanced Groundwater Scenario gives an indication of the changes necessary to minimally fulfill the sustainability criteria, the Agricultural Restructuring Scenario (ARS) explores the sensitivity of agricultural water demand and revenue to further changes in state cropping patterns. In addition to saving 1.01 maf of groundwater overdraft as described above, this scenario explores further reductions in the acreage of two other water-intensive, low-value crops — cotton and rice. DWR projects only slight declines of 698,000 acres (about 4 percent) of rice and cotton acreage between 1990 and 2020. We assume that between 1990 and 2020 irrigated rice and cotton acreage is slowly reduced by about one-third, back to the levels planted in 1960 — a comparable 30-year period of change. In 1960 there were 375,000 acres of rice and 810,000 acres of cotton irrigated statewide. Irrigated pasture, which decreased in acreage by about 40 percent between 1960 and 1990 is assumed to drop another 40 percent over the next 30 years. We assume that the acreage of alfalfa, which drops 45 percent between 1990 and 2020 in order to eliminate groundwater overdraft in the Balanced Groundwater Scenario, drops no further. These assumptions envision California agriculture as a highly productive and efficient enterprise, using much less water overall to produce more higher-value crops. Tables 20 and 21 summarize the results of this scenario.

In the ARS fallowing case, all ten hydrologic regions experience reductions in irrigated acreage compared to DWR's 2020 forecast. The decrease of 119,000 acres of rice in the Sacramento River region accounts for most of

Table 20

Agricultural Restructuring Scenario:
Comparision of Irrigated Crop Acreage, Consumed Water, and Revenues for 1990 and 2020

Crop Area Irrigated (thousand acres)

Hydrological Region	1990 DWR[a]	2020 DWR[a]	2020 Agricultural Restructuring Scenario	
			Fallowed Land	Crop Switching
North Coast	326	346	315	346
San Francisco	61	64	63	64
Central Coast	528	566	412	412
South Coast	319	184	183	184
Sacramento River	2,145	2,186	1,977	2,186
San Joaquin River	2,008	1,952	1,848	1,952
Tulare Lake	3,212	3,061	2,565	3,058
North Lahontan	161	169	143	169
South Lahontan	61	48	29	48
Colorado River	749	726	685	726
California Total	**9,570**	**9,302**	**8,219**	**9,145**

Water Consumed (thousand acre-feet)

Hydrological Region	1990 DWR[a]	2020 DWR[a]	2020 Agricultural Restructuring Scenario	
			Fallowed Land	Crop Switching
North Coast	504	553	491	529
San Francisco	67	67	65	66
Central Coast	758	800	551	551
South Coast	544	320	316	319
Sacramento River	4,745	4,783	4,161	4,478
San Joaquin River	4,014	3,703	3,418	3,592
Tulare Lake	7,001	6,431	5,073	5,841
North Lahontan	393	408	342	389
South Lahontan	248	204	121	134
Colorado River	2,987	2,876	2,697	2,790
California Total	**21,261**	**20,147**	**17,233**	**18,687**

Crop Revenue (million 1988 dollars)

Hydrological Region	1990 DWR[a]	2020 DWR[a]	2020 Agricultural Restructuring Scenario	
			Fallowed Land	Crop Switching
North Coast	265	304	294	332
San Francisco	127	138	138	140
Central Coast	1,461	1,600	1,237	1,237
South Coast	822	500	499	503
Sacramento River	1,839	1,999	1,911	2,200
San Joaquin River	2,367	2,593	2,533	2,692
Tulare Lake	4,123	4,439	4,113	5,171
North Lahontan	66	73	64	86
South Lahontan	40	27	19	91
Colorado River	1,082	1,137	1,112	1,241
California Total	**12,191**	**12,811**	**11,920**	**13,693**

[a] *DWR numbers are derived from DWR 1994a.*

Table 21
Agricultural Restructuring Scenario: Comparison of Irrigated Acreage by Crop for 1990 and 2020 Scenarios (thousand acres)

Crop	1990 DWR	2020 DWR	Agricultural Restructuring Scenario	
			Fallow Land	Crop Switching
Grain	988	909	904	1,088
Rice	517	498	375	375
Cotton	1,244	1,194	810	810
Sugar Beets	216	197	196	227
Corn	403	409	408	474
Other Field	491	455	452	534
Alfalfa	1,135	947	725	622
Pasture	956	813	574	574
Tomatoes	352	338	335	393
Other Truck	1,021	1,251	1,175	1,355
Almond/Pistachio	510	561	561	655
Other Deciduous	570	585	581	707
Subtropical	419	392	389	458
Grapes	748	753	735	872
TOTAL CROP AREA	**9,570**	**9,302**	**8,219**	**9,145**

Source: DWR numbers are from DWR 1994a.

the reductions in irrigated rice. Nearly all of the 384,000 acres of reductions in cotton occur in the San Joaquin River and Tulare Lake regions.

In the ARS crop switching case, reductions in total crop acreage occur only in the Central Coast and Tulare Lake. The Central Coast's crop mix is the same in all four scenario cases because of the required fallowing of other crops in order to stop overdraft. Because the Tulare Lake area is the main cotton-producing region in the state, the large reduction in cotton from DWR's 2020 estimates frees up enough water to bring back into production 146,000 of the 150,000 acres of the land fallowed in the Balanced Groundwater scenario's crop switching case. Also worth noting is that the South Lahontan region significantly shifts crop types because of a high present concentration of alfalfa and pasture production.

Statewide, the fallowed land case in the ARS scenario sees a significant 14.1 percent decrease in irrigated acreage from 1990. Meanwhile, consumed water is reduced over 4 maf from DWR's 1990 projections and 2.9 maf from their 2020 figures. The results of the ARS crop reallocation case are the most positive of all the cases in both scenarios. Because additional crops are grown in place of the reduced cotton, rice, alfalfa, and pasture acreage, irrigated acreage statewide falls only 4.4 percent from 1990 and only 1.7 percent compared to DWR's 2020 number. In terms of consumed water, this case saves 2.6 maf compared to 1990 and 1.5 maf compared to DWR's projected 2020 agricultural water consumption.

The range of impacts on agricultural revenue of the fallowed land and crop switching cases is quite large. In the fallowed land case, revenue decreases only 2.2 percent compared to 1990 but 7.0 percent compared to DWR 2020 projections. In the crop switching case, agricultural revenues actually increase by 12.3 percent over 1990 and 6.9 percent over DWR's 2020 projections. Even the Tulare Lake region, which undergoes massive cropping adjustments in this scenario's crop switching case, shows an increase in revenues of 16.5 percent over DWR's 2020 projections.

5. Summary

These two scenarios, the Balanced Groundwater Scenario and the Agricultural Restructuring Scenario, give a range of the possible changes in irrigated acreage and impacts on agricultural income of achieving sustainable water use in the agricultural sector. Table 22 summarizes the basic findings of these calculations. In general, the statewide impacts on total irrigated acreage and total revenue are small, although specific regions such as the

Central Coast and Tulare Lake are disproportionately affected in the fallowing cases. In the most optimistic crop switching case of the Agricultural Restructuring scenario, 1.5 maf of water are saved with only a 1.7 percent decrease in irrigated acreage compared to DWR's 2020 projections. Meanwhile, total revenues are estimated to be $882 million higher than the $12.8 billion in revenues estimated using DWR's 2020 projections. Even in our worst case, the fallowing case of the Agricultural Restructuring Scenario, total agricultural revenues decrease only seven percent compared to revenue estimates using DWR's 2020 forecast. While the Institute recognizes that it is impossible to accurately predict the price of specific farm products thirty years into the future, the basic trends hold true. An increase in the production of high-value, labor-intensive crops such as fruits and market vegetables and a reduction in low-value crops such as alfalfa and irrigated pasture will help California's agricultural economy.

Thus, for the vision of 2020 presented at the outset of this report, we believe that the crop switching case of the Agricultural Restructuring Scenario is feasible. While this scenario is optimistic, these changes are still modest compared to what could be done, such as serious changes toward efficient production, low-water using crops, greenhouse production, ornamental exports, and aggressive crop genetics. We chose not to explore these more aggressive possibilities. To give an idea of how little we really changed the agricultural sector, even under the ARS scenario alfalfa, irrigated pasture, cotton, and rice will still account for 29 percent of California's irrigated acreage and 38 percent of the state's agricultural consumed water. This future vision is one of a more highly productive agricultural sector that uses water much more efficiently, but it still looks much like the one that exists today.

While we calculate only the direct impacts of these scenarios, the actual affects on the farmers and the surrounding communities will depend on the measures used to accomplish them. In particular, we did not analyze the indirect impacts on associated industries such as livestock and dairy, agricultural employment, and those living in rural agricultural communities. These effects are important and must be considered in fashioning paths toward the future we envision. Crop and water subsi-

Table 22
Summary of Balanced Groundwater and Agricultural Restructuring Scenarios

Balanced Groundwater Scenarios

California Totals	1990 DWR	2020 DWR	2020 Fallow Land	Percent Change 1990-Fallow Land	2020 Crop Switching	Percent Change 1990-Switching
Irrigated Acreage (thousand acres)	9,570	9,302	8,918	-6.8	8,998	-6.0
Agricultural Consumed Water (thousand acre-feet)	21,261	20,147	19,137	-10.0	19,137	-10.0
Total Revenue (million 1988 dollars)	12,191	12,811	12,340	1.2	12,645	3.7

Agricultural Restructuring Scenarios

California Totals	1990 DWR	2020 DWR	2020 Fallow Land	Percent Change 1990-Fallow Land	2020 Crop Switching	Percent Change 1990-Switching
Irrigated Acreage (thousand acres)	9,570	9,302	8,219	-14.1	9,145	-4.4
Agricultural Consumed Water (thousand acre-feet)	21,261	20,147	17,233	-18.9	18,687	-12.1
Total Revenue (million 1988 dollars)	12,191	12,811	11,920	-2.2	13,693	12.3

Source: DWR 1994a and Pacific Institute Analysis.

dies and their role in sustaining small family farmers and agricultural employment should also be considered. The possibility of investing the gains from water transfers and environmental restoration into rural community and economic development should be explored. Finally, new programs to encourage agricultural practices that save water, increase economic opportunities, and protect the environment need to be implemented.

C. SUSTAINABLE ENVIRONMENTAL WATER USE

Human development has forever changed California's natural environment. Urbanization, agriculture, and the creation of extensive water infrastructure to supply our cities and industries have all transformed natural ecosystems. In some cases, shrinking habitats, polluted air and water, or changes in natural water flows have forced species into extinction. In other cases, humans have been able to coexist to varying degrees with the surrounding flora and fauna. Because water resources are so vital for environmental quality, the sustainability criteria presented in Section III require that water quantity and quality be explicitly and flexibly managed to maintain the health of ecosystems.

Water policy should be designed to avoid irreversible environmental impacts, such as species extinction and destruction of unique habitats. The key to such a strategy is flexibility.

Determining exactly what environmental water requirements should be, however, is an extremely difficult task. First, scientific information must be gathered about the complex interactions among water quality and quantity, and ecosystem health. Then, societal judgments need to be made about what level of ecosystem health is "enough" if other societal goals conflict with maintaining pristine ecosystems. Finally, other water-management questions will have to be answered: how much water is needed to meet environmental goals during average and drought years, which human and environmental purposes can be fulfilled simultaneously, and at what times should water be allocated during each season? Far better knowledge of natural processes and human interactions will be needed to guide these decisions.

While the scientific understanding needed for good management is improving, there are still great uncertainties in determining environmental water requirements. In the absence of scientific certainty, it is advisable to take a precautionary approach towards the environmental implications of water management. In particular, water policy should be designed to avoid irreversible environmental impacts, such as species extinction and destruction of unique habitats. The key to such a strategy is flexibility. The rest of this section describes the process that we believe should guide sustainable environmental water management.

1. Determining Environmental Water Needs

The ecosystems for which water must be maintained include both natural ecosystems where there is minimal human interference and ecosystems that are highly managed by humans. In some cases, water needed for environmental purposes will exclude consumptive human uses, such as when society chooses to preserve free-flowing rivers. In many other cases, environmental goals will be reached while also pursuing human uses. For example, flooding rice fields improves rice production, while simultaneously providing wildlife habitat and satisfying air quality concerns. However, because environmental water needs can sometimes be met in conjunction with human needs, and because the timing of environmental water allocations must vary seasonally and year-to-year, it is sometimes difficult to accurately quantify ecosystem water needs in the same manner as urban and agricultural water demands. Societal decisions will have to be made regarding the degree to which ecosystems should be maintained or restored and the indicators by which to measure ecosystem health.

Rather than viewing ecosystems as direct competitors for water resources, an integrated management framework should be adopted. In this framework human and ecosystem uses are considered together and, where possible, are satisfied simultaneously. Managing water and environmental resources in an integrated way makes sense since each region is connected by the flow of water. Activities upstream can have severe impacts on ecosystems and economic production downstream. Properly integrated watershed planning can maintain the adequate mosaic of habitat to sustain environmental goals as well as to allow economic development in appropriate and manageable areas.

Various environmental goals have already been set by public actions and are described in Section IV. These goals include preservation of stretches of several northern California rivers through the federal and state Wild and Scenic Rivers acts, minimum flow requirements in some river stretches, protection of wetlands and endangered species, and restoration of certain anadromous fisheries as required by the CVPIA. In December 1994, after years of negotiations, an interim agreement was reached on quality and outflow requirements in the Bay-Delta, although questions about implementation of the plan still remain to be resolved. These acts are only the beginning of a new era of joint water and environmental management.

Achieving these goals will require political consensus and flexible institutional structures. Ultimately, management will have to follow an adaptive model where decisions are to be reviewed frequently based on the latest information and caution is to be exercised with respect to possible irreversible actions. Standards and indicators of ecosystem health need to be further identified, improved upon, and monitored on a continuous basis. Monitoring can be accomplished through networks and coalitions of both governmental and non-governmental agencies.

2. Environmental Vision 2020

By 2020, California's natural environment can be substantially revitalized. Because total urban and agricultural water use can remain constant or decline between 1990 and 2020, more water can be made available to protect preserved rivers, streams, and wetlands, restore aquatic, wetland, and riparian habitats, sustain populations of threatened and endangered species, and maintain water quality. Specifically, water in California's Wild and Scenic Rivers must continue to be protected at both the state and federal levels. Long-term Bay/Delta standards that include both technical and institutional approaches to protect vulnerable species at certain times of the year and to maintain water quality should replace the interim standards. Water should be allocated to restore some of the native anadromous fish runs in the San Joaquin River and elsewhere. There should be no further net loss of wetlands, greater efforts should be made to restore degraded wetlands, and sufficient water should be reserved for protected wetlands. Opportunities for the integrated management of agriculture and seasonal wetlands should be pursued further. And, as an added goal, attempts should be made to return high-altitude mountain waters to pure, drinkable conditions.

Much effort is required to restore ecosystems that have been severely damaged by past water development. How much restoration and at what quality will have to be guided by a democratic political process that includes local communities. When local communities are adversely impacted by restoration efforts, funds should be made available to mitigate the impacts. Through improved private and public stewardship of our natural resources, California can pursue more environmentally-compatible forms of economic activity.

Land-use planning and water-resources management must be explicitly linked, even in remote areas normally thought of as pristine. For example, an appropriate goal, described briefly in the opening Vision section, is to restore drinkable streams to the Sierra Nevada. In recent years, the formerly pristine streams of the high mountains have become contaminated and can no longer be used for drinking without some form of treatment because of cattle grazing, large numbers of human users, and poor sanitary behavior. Restoring these streams to drinkable levels would require more comprehensive land-

Melting snow in the Sierra Nevada provides much of California's water. (Courtest of DWR.)

management policies on the part of land managers and better education of the users of that land.

For urban and rural development, land-use management is also a vital component of proper water management. Rather than building first and then finding the water, the potential demands for water from proposed developments should be assessed in the planning stages. Developers should have to demonstrate that they have a secure and adequate supply of water that will not require further environmentally-harmful water development.

Lastly, areas that are largely undeveloped should be preserved and protected for future generations. The State and Federal Wild and Scenic Rivers acts already accomplish this objective to some degree. Lands under federal and state management should be identified for wilderness designation, with the highest priority given to those watersheds that are most critical to maintaining water quality, endangered species, or vital habitat.

3. Summary

Where will the water come from to achieve this vision? While the DWR predicts that the net agricultural and urban water demands will total 39.2 maf in 2020, our vision as summarized in Table 23 projects a combined net water demand of only 35.3 maf. Compared to projected average year supply of 37.5 maf, we project no gap between supply and demand. Rather, there is a modest cushion of 2.2 maf, which can remain flowing in rivers and streams. Furthermore, intelligent use of reclaimed water may permit a further reduction in potable water requirements in urban and agricultural communities, decreasing pressure on natural ecosystems during droughts. Our vision is, therefore, accomplished through conscientious and feasible urban and agricultural water-saving strategies.

Table 23

Comparison of Water Balances for DWR and 2020 Vision

California	DWR 1990	DWR 2020 million acre-feet	Vision 2020
Net Water Demand[a]			
Agriculture[b]	26.8	24.9	23.3
Urban[c]	6.8	10.5	8.2
Societal Net Demand	33.6	35.4	31.5
Other Net Water Demands[d]			
Wetlands	1.1	1.3	1.3
Additional Bay/Delta Outflow	0.0	1.0	1.0
Other[e]	1.5	1.5	1.5
Total Demands	36.2	39.2	35.3
Total Supply[f]	35.1	36.9	37.5
Total Supply minus Demand	-1.1	-2.3	2.2

Source: DWR (1994a) and Tables 1 and 2.

[a] *Net Water Demand equals the sum of water consumed, irrecoverable losses, and agricultural return flow or treated municipal outflow leaving an area.*

[b] *Net agricultural demand for 2020 Vision calculated by adding irrecoverable losses and outflow to Table 1's 2020 Consumed Water estimate. Irrecoverable losses are calculated at the same percentage of net demand as DWR's 2020 projection. Outflow is assumed to be the same as for DWR's 2020 projection.*

[c] *Net urban demand for 2020 Vision is the same as Table 2's 2020 Total Applied Urban Water Use. We assume no reuse of water other than our estimates of reclaimed water use.*

[d] *2020 Vision assumes that Other Demands are the same as DWR 2020.*

[e] *Other includes major conveyance losses, recreation uses, and energy production.*

[f] *Total supply for DWR includes reclaimed water. The 2020 Vision figure includes our higher estimate of reclaimed water.*

VI. How Do We Get There: Technologies and Practices for Sustainable Water

A desirable vision of the future is of limited value without any guidance how to get there. The vision laid out at the beginning of this report was developed making straightforward assumptions about the role and availability of technology, the applicability of different policies, and the behavior of institutions. There is no need to assume any magic formulas or new technologies to reach a sustainable water future; nor is there any need for heroic actions on the part of any individuals, organizations, or sectors. The kinds of decisions and institutions necessary to move toward this positive vision are little different from the kinds of choices already available. This is the good news. The bad news is that there is no assurance that policymakers and the public will agree on the goals to seek or on the ways to reach them. This section offers some guidance for the kinds of tools that have proven effective in California and elsewhere that would move toward achieving the vision described above.

A. TECHNOLOGIES AND PRACTICES TO REDUCE WATER REQUIREMENTS

Water-using technologies play an important role in determining the level of water needed to satisfy particular demands. As a result, attention has focused in recent years on both understanding water demands and on developing and marketing new, more water-efficient technologies to meet these demands. Many such technologies are available for every sector, ranging from low-flow toilets to electronic controllers on irrigation equipment to sophisticated changes in industrial processes.

If no technologies are available on the market, they must be developed to commercial levels. If they are on the market but too expensive, their costs to the consumer must be reduced. Financial or regulatory incentives can be provided to manufacturers to speed product development, optimize production, and thus reduce market prices. Incentives can be provided to water agencies to purchase these technologies and install them for customers. Incentives can be provided to industry to alter water-using processes. And incentives can be offered to individuals to purchase and install equipment to reduce water demand. Savings are available in every sector. Technologies and business practices in which water-efficiency improvements are available are described below for a variety of sectors.

1. Residential Sector

a) Residential Bathroom and Kitchen Fixtures

For several years now, electric utilities have been developing and offering a wide range of programs to try to save energy by increasing residential energy-use efficiency. These programs include educational programs, improved availability of efficiency equipment for customers, the direct installation of such equipment, and audit programs. The same potential exists for water, and water utilities are now beginning to implement similar activities. In addition to water savings, improved water-use practices can also save substantial energy and reduce investments in wastewater treatment programs.

The kinds of decisions and institutions necessary to move toward this positive vision are little different from the kinds of choices already available. This is the good news. The bad news is that there is no assurance that policymakers and the public will agree on the goals to seek or on the ways to reach them.

Some water utilities are now beginning to offer direct distribution and installation of water-efficiency technologies, at no cost to consumers. Many of these technologies are more cost effective than building new infrastructure, with rapid paybacks to the utility from water and energy savings. For utility programs, few new financial incentives are likely to be necessary, though the cost of operating the programs should be recoverable.

There is a direct connection between increased efficiency of water use and other sustainability goals, such as increasing energy efficiency. For example, reducing water use in residential and commercial bathrooms and kitchens will have a direct effect on reducing energy use for heating water, and on the emissions of air pollutants from that energy use. Table 24 shows an estimate of the average U.S. reductions in water use expected to result from the conversion of residential water fixtures to more efficient models, as required by the National Energy Policy Act of 1992. Also shown in this Table are the anticipated reductions in utility electric energy demands associated with that water use and the per-capita emissions of carbon dioxide, nitrogen oxides, and sulfur dioxide (Vickers 1993).

Table 24
Water Use, Energy Demand, and Atmospheric Pollutants Associated with Residential Plumbing

Period	Maximum Daily Water Use (gallons/capita)	Utility Annual[b] Electrical Demand (kWhr/capita)	Annual Atmospheric Emissions (lbs/capita/kWhr)
Pre-1980 Fixtures	54.5	57	110.7
1980-1994 Fixtures	33.9	35	68.7
Post-1994 Fixtures[a]	21.4	22	43.4

[a] *Using 1.6 gallons/flush toilets, 2.5 gallons per minute showerheads, and 2.5 gallons per minute faucets.*

[b] *For heating water.*

Source: Vickers 1993.

Over 77 percent of all indoor residential water use in California goes to toilets, faucets, and showerheads. A wide range of water-efficiency devices are available on the market, including ultra-low flow toilets and showerheads, toilet tank displacement "dams," and faucet aerators. For the most part, these devices are inexpensive, and many manufacturers are beginning to compete for the growing market. For example, in 1993 the Rocky Mountain Institute reported that there were over 17 manufacturers of high-efficiency showerheads producing over 30 different models (Jones 1993). The largest barrier to wide distribution of these devices appears not to be their cost, but lack of information about their savings, concern about their quality, and uncertainty about how to acquire and install them (Gleick, Stewart, Norman 1994). Programs that focus on reducing these barriers are needed.

Ultra-low flow toilets (ULFT) can reduce the amount of water required to dispose of wastes by as much as 75 percent and are now required by the 1992 NEPAct. While this will change the water use in new construction and remodels, additional incentives or ordinances may be needed to get ULFT into existing buildings. In this case, additional financial incentives to manufacturers, distributors, builders, and contractors can increase their penetration into the retrofit market. Some water agencies and utilities are offering some form of rebate to encourage customers to purchase and install ULFTs. The rebate can be a flat dollar amount, a percent of the sales price, or a flat rate depending on the toilet price (e.g., $50 for a $200 toilet, $100 for a more expensive toilet). The Metropolitan Water District of southern California, for example, offers its member agencies a one-time $154 per acre-foot of water saved in programs to retrofit low-flow toilets (T. Quinn, Metropolitan Water District, personal communication, 1994).

At the extreme end of the spectrum are composting toilets that generally need no sewer hook-up, septic system, or plumbing. While these toilets are larger than conventional toilets, they may be attractive options in remote applications and sites with special plumbing limitations. They may also be useful in small cottages or cabins where they are only used periodically, though some designs function best when used continuously (Rocky Mountain Institute 1993). Composting toilets reduce water used for flushing to zero, thus eliminating about 35 percent of typical residential indoor water requirements.

b) Residential Appliances

Several major indoor household appliances such as dishwashers and washing machines consume substantial amounts of water. Unlike residential bathroom fixtures, the number and quality of water-efficient appliances available for sale are small, and their costs, relative to their water-inefficient cousins, are high. Strong incentives are needed to encourage manufacturers and distributors to increase market availability and share for these appliances, and for consumers to purchase and install them.

Several manufacturers are now beginning to explore more efficient appliances, such as horizontal-access washing machines. This technology appears to be a particularly strong candidate for direct financial incentives, though additional research is necessary to more precisely quantify actual water and energy savings in home use. Horizontal-axis clothes washers have long been popular in Europe and are now beginning to enter the U.S. market. At least one U.S. manufacturer, Frigidaire/White Westinghouse, produces a full-size, front-load, horizontal-axis machine, though a second company, Staber, is introducing a machine. By some estimates, when compared with typical top-loading machines, these machines require only one-third as much detergent and bleach, two-thirds as much total water, and one-third as much hot water and energy for a comparable load of wash (Shepard 1992). Because of the low-volume production, extra shipping costs, and more complex electronics and timing mechanisms compared to top-loading machines, horizontal-access machines cost substantially more to produce. Some industry experts believe, however, that due to economies of scale, there may be no significant price difference under full production. In 1992, Southern California Edison offered a $75 rebate for horizontal-axis washers, and the Seattle Water Department is considering a rebate to manufacturers to increase commercial availability of these machines (A. Jones, Rocky Mountain Institute, personal communication, 1994, Barakat and Chamberlin 1994).

A major joint study by Seattle City Light, the Seattle Water Department, and various utilities and manufacturers is now underway to evaluate horizontal-axis machines. The study will include a laboratory analysis of actual performance, an in-home end-use study, and an assessment of market barriers to adoption of efficient machines. There is a strong feeling, however, that a market transformation is needed to bring costs of efficient machines down to a comparable level with present machines (S. Hill, Seattle Water, personal communication, 1994). There are many ways to do this, such as providing rebates to customers who purchase such machines, rebates to the manufacturer to make up the difference in cost with conventional systems, or efficiency standards. Recent U.S. policy actions have focused on the development of new standards for manufacturers, and a national committee comprised of utilities, manufacturers and federal regulators is now working to identify efficiency standards for large residential appliances to go into effect near the turn of the century.

c) Residential Landscape Water Use

The high use of water for lawns suggests that paying attention to the efficiency of lawn and garden irrigation may produce large water savings in the residential sector. Typical residential irrigation methods are estimated to be only 50 to 80 percent efficient, with the remainder of the water evaporating, running off the landscape, or percolating to deeper soil levels. These low efficiencies suggest considerable room for improvement. Simply correcting these inefficiencies could result in as much as a 50 percent savings in outdoor water use. Incentives to install efficient watering equipment, or to replace high-use lawns with drought-tolerant plants (xeriscaping), are also effective ways to reduce residential water needs. Table 25 lists options for landscape efficiency programs.

Among the barriers to improving residential irrigation efficiency are lack of information to consumers on actual watering requirements, low prices for water, and lack of incentives for architects, designers, builders, and managers to implement and operate more efficient systems.

Past approaches to reducing landscape water use included watering restrictions and other measures that often led to decreases in garden quality. More recent efforts focus on maintaining the function and quality of landscapes while reducing their water demands, such as through changes in technology, changes in plant types, and more sophisticated operation. Recent experience has documented that water-efficient landscaping not only reduces water demand, but reduces the need for fertilizers, herbicides, fuel, and labor. For example, a 1990

Table 25
Common Options for Landscape Water-Efficiency Programs

Design and Management Opportunities	Utility Program Options
Alternative supplies (gray- or reclaimed water)	Awards
Computer-controlled irrigation	Demonstration gardens and landscapes
Computerized plant selection	Design requirements for new building
Drip irrigation and improved sprinklers	Educational videos and pamphlets
Improved irrigation scheduling	Landscape water-use audits
In-depth planning and design	Ordinances and restrictions
Landscape design software	Rebates
Lawn de-thatching and aeration	Seminars and workshops
Limited fertilization	Training for landscape professionals
Limited turf areas and taller grass	
Moisture meters	
Proper maintenance	
Rock gardens, decks, and patios	
Soil conditioning and mulching	
Subsurface irrigation	
Use of native plants	

(Source: Chapin 1994)

study comparing conventional and water-efficient landscapes in northern California documented savings of 54 percent for water, 25 percent for labor, 61 percent for fertilizer, 44 percent for fuel, and 22 percent for herbicides (Chapin 1994).

The cost of improving residential irrigation efficiency can be borne by different users, including water utilities, homeowners, and builders. Water utilities can invest in such improvements rather than investing in new supply. Homeowners can invest to reduce water use and water bills. When building new homes, the cost of installing water-efficient landscaping can be approximately equal to the cost of installing conventional landscaping, and can be *made* approximately equal by a set of financial incentives when the costs are higher.

Financial incentives to manufacturers to produce more efficient equipment at competitive prices, or rebates to consumers to purchase such equipment can increase market shares. For example, a wide range of computer controllers for lawns are available, in varying degrees of sophistication, ranging from simple battery-operated devices for home use that function on the time-of-day principle to central computer control systems, capable of integrating on-line information on weather forecasts together with real-time information from moisture sensors in the ground. These more advanced systems are only useful for very large landscapes and irrigators. In some circumstances, incorrect use of these timers can lead to overwatering and an increase in residential water use (Henggeler 1991).

2. Industrial, Municipal, and Institutional Sectors

a) Industrial, Municipal, and Institutional Water-Use Equipment

A wide range of water-efficient technologies or business practices are becoming available for the industrial and commercial sectors. Some of these, such as efficient cooling towers, are general to many industries; others, such as commercial laundering, are specific to particular sectors. Both general and specific examples are discussed below, but overall, incentives to install more water-efficient technologies and to alter practices to reduce water demand can be effective in all sectors. This is particularly true where new technologies are beginning to appear and where the need for both education and information on alternatives remains high.

Industrial and municipal water use for heating, ventilation, and cooling requirements can be high. For southern California and other semi-arid regions, cooling towers often use one-third to one-half of all water, yet these systems are often poorly managed and operated, relying on few or no electronic controls and once-through cooling (J. Sweeten, Metropolitan Water District, personal communication, 1994). Incentives to alter operating styles, to increase reuse by increasing system passes, or to install control systems can often save substantial quantities of water, as well as reduce the cost of wastewater disposal. In addition, some new technologies, such as ozone treatment of cooling tower water for disinfecting without chemicals, may appear on the market with modest economic encouragement. These systems may increase energy use compared to conventional systems, so the tradeoff between higher energy use and lower chemical use must be carefully evaluated.

The Metropolitan Water District, for example, suggests that process cooling water requirements in a section of the primary metals industry in its operating area can be reduced from over 110 million gallons per year to under 30 million gallons per year with a simple payback period of 4.8 years (MWD 1994). Similar savings are available in other industrial sectors as well.

Other high-volume commercial and institutional water users worth further study include laundries, car washes, sports/fitness centers, certain fast-food restaurants, and toilets in commercial and industrial locations. Incentives are needed to improve the market availability and penetration of more efficient technologies, such as those that can replace one-pass coolers for compressors (as used in hotel icemakers).

As an example, commercial laundries use substantial amounts of water, and energy to heat that water. Like the residential sector, some efficient machines are available on the market, but they have not achieved significant market share because of higher costs and limited selection. In particular, the use of horizontal-axis commercial machines is limited to large-capacity uses. More attention to this market, as mentioned earlier in the residential section, could produce significant savings (S. Hill, Seattle Water, personal communication, 1994).

There have recently been some dramatic claims about the ability of "ozonated laundering" to practically eliminate both hot water and detergent use, with savings on water costs, energy, chemicals, labor, and sewage fees. Initial user reports are favorable, but far more research is needed on how the approach works, how reliable it is, and what the best applications are. Reports from two Marriott hotels in Florida indicate that laundry could be done in 118° F water, rather than 140° F water, with detergents and bleaches almost completely eliminated. Water used dropped from 3.5 gallons of water per pound of laundry to 1.6 gallons of ozonated water per pound with comparable reductions in sewer costs. An increase in electricity use partially offsets these savings. According to Christensen (1993), laundry industry publications are giving cautious but increasingly positive reports of this technology.

b) Municipal, Industrial, and Institutional Landscape Water Use

Large "turf" irrigators often consume substantial amounts of water, particularly in the western United States. Reducing water demand by these users is in part a question of modifying taste and behavior, and in part a question of installing alternative technologies, such as dual systems for reclaimed water, buried precision irrigation equipment, and more flexible systems to control the application of water. Among the equipment that could, or should be available for improving the efficiency of large turf irrigation are more "intelligent" automatic controllers, which work together with moisture sensors that monitor actual water needs. Incentives need to be directed at equipment producers, at home buyers and sellers, and at builders.

A wide range of computer controllers for irrigating large areas of turf are already available, in varying degrees of sophistication. All of these systems benefit from the training of users; none are "set and forget" systems, though advances are likely to produce such systems in the next several years. At the extreme, one can purchase central computer controlled systems, capable of integrating online information on weather forecasts together with real-time information from moisture sensors in the ground. An example of these more advanced systems is the California Irrigation Management Information System (CIMIS), which links irrigators with a statewide data bank of weather information. These data permit more accurate estimates of soil moisture and projected water needs.

A variety of pilot programs to test moisture sensors are being implemented, such as a program at the Center for Irrigation Technology at Fresno State University, which is evaluating moisture sensors from 11 different manufacturers. The general purpose of such sensors is to evaluate the moisture content of the soil, and to send a signal prohibiting further watering unless the soil needs it. Such sensors can be extremely expensive (on the order of $300 each) making their large-scale distribution unlikely at this time (S. Silva, Metropolitan Water District, personal communication, 1994). The potential savings, however, is extremely large; some manufacturers and independent analysts say up to one-third of the water used for lawn irrigation could be saved (R. Miller, Calsense, personal communication, 1994, E. Norum, consultant to CIT, personal communication, 1994) and enormous additional potential exists in the agricultural sector (see below). Unfortunately, the mere installation of these kinds of sensors is usually insufficient to produce sustainable savings. Training of individuals to maintain and modify their operations under changing conditions is also very important, ruling out extensive use of sensors in the residential market (R. Miller, Calsense, personal communication, 1994). A better set of applications would be in city parks, median strips, and industrial complexes.

Because these sensors and computer controllers represent new technologies and new markets they are not usually produced by large, established manufacturers. Smaller, innovative firms are involved in design and marketing, and these firms are less motivated by tax incentives for research and development and manufacturing; rather they see the need to stimulate the creation of the market by raising rates for water, setting standards, or rebating some fraction of the cost of the product (R. Miller, Calsense, personal communication, 1994). These approaches are discussed later.

3. Agricultural Sector

Agriculture is by far the greatest consumer of water in California and, indeed, in the United States. In many regions, far more water is withdrawn and applied to fields than is actually required to grow crops. This inefficient use of water occurs primarily because the low cost of water provides little incentive for farmers to improve water use efficiency. Associated with this often-inefficient use of water are a large set of secondary issues related to contamination of surface and ground water with agricultural chemicals, adverse impacts on wildlife and ecosystems, and controversies between urban and agricultural water demands.

Several possible futures for the agricultural sector are attainable, with often contradictory implications for present action. One possible long-term goal is to maintain certain agricultural production (such as income levels or crop types or employment levels). Another is to maintain the amount of water consumed while continuing to increase yields and production. A third is to maintain adequate diets for a growing population, which may require ever-increasing amounts of agricultural production. In all such circumstances, water constraints, both in terms of availability and quality will play a role. How do different sustainability goals affect fresh water availability and quality? What incentives are needed to improve irrigation efficiency? How much improvement can we legitimately expect? If the price of water is low, how can investments in new irrigation technology be expected? Without exception, experts on agricultural irrigation efficiency contacted for this report cite the most important incentive to increase efficient water use is to raise the price of water, which for farmers, is almost always subsidized. Yet it was also pointed out that unless agricultural policies permit farmers to move water around, by selling it or leasing it, there is little incentive for farmers to conserve water. Thus, by 2020, substantial agricultural water conservation will likely be the result of higher water rates coupled with the implementation of innovative ways of transferring water.

On-farm irrigation water is useful to farmers only when that water goes to grow crops or to leach unwanted salts from the root zone. Excessive use of irrigation water leads to increased evaporation, unintended percolation to ground water, and unnecessary runoff. Often, excess runoff carries with it agricultural chemicals, such as fertilizer nitrates. While increased irrigation efficiency can reduce water losses and protect and enhance water quality, improvements in efficiency can sometimes lead to lower water quality, or to reduced leaching of salts from soils. The decision about how to best manage irrigation water is thus a complex one, requiring considerable information about the environmental, economic, and productivity implications of different actions.

Improving the efficiency of agricultural water use is already a very high priority in many regions in California and the western U.S. Yet the problem of determining actual irrigation efficiencies and how those efficiencies can be improved is extremely complicated.

Among the factors that must be considered are soil and land characteristics, crop types, irrigation technology, management practices, and agricultural policies and prices.

The major sustainability goal for the agricultural sector adopted by the Institute is to increase, if not maximize, regional agricultural yields (both economic and crop yields) per unit of water consumed without compromising groundwater or surface water quality, or the quantity of water available to maintain natural ecosystems that depend on those water resources. This maximization must take place in the context of explicit goals and resources — farmers will compare the costs of achieving such increases with other economic and social goals.

a) Irrigation Technologies

Many irrigation technologies currently exist on the market. Such technologies include advanced sprinkler systems, drip irrigation systems, agricultural water station networks, real-time moisture monitoring, and central computer controllers. Reducing the cost of laser-leveling, surge valves, and tailwater retention ponds can also reduce water use or improve the quality of irrigation runoff (Pinkham 1994). In addition, while the importance of improving the dissemination of efficient irrigation technology has been acknowledged by many experts, others feel that there is no lack of technology available; rather the impediments to the adoption of new technology are often institutional and educational rather than economics.

This issue became explicit during the June 1994 interim election in California, when an initiative was on the ballot to provide an exemption from property tax reassessment for farmers who install water-efficient irrigation technologies. A remarkably diverse and unusual coalition opposed passage of this initiative, which was defeated by a sizable majority. Environmental groups argued that the proper way to improve irrigation efficiency was to raise the price of water for farmers. Some farm organizations opposed passage on the grounds that many farmers have already installed such equipment and there should be no new tax break for those that had so far failed to do so. Others opposed it on the grounds that the general public would be paying, through a higher tax burden, for a tax break for a small number of farmers (Fresno Bee 1994). This experience suggests that if some sort of financial incentive is deemed necessary, care should be exercised in how to implement it.

b) Land and System Management

Another desirable goal is to take land out of production when that land contributes excessively to poor quality agricultural runoff. Financial incentives for this kind of land management can play a big role in improving overall water quality at a modest cost. At present, there are several programs to purchase and retire poor quality agricultural lands by state and federal governments. California is implementing a bill to finance land retirement, and the new Central Valley Project Improvement Act permits the Secretary of the Interior to use land retirement as means of acquiring water supplies (C. Congdon, Environmental Defense Fund, personal communication, 1994).

Interviews with several irrigation districts and farming representatives suggest that system management is very important, including changes in irrigation timing, mode of operation, and system design. New ways of controlling irrigation systems (such as software programs, computer controllers, and more accurate monitoring) are increasingly available, but not yet well implemented.

c) Reducing Delivery Losses

In some regions, substantial quantities of agricultural water are lost between its source and the point of final use, through seepage from unlined irrigation canals to evaporation from the surface of aqueducts and reservoirs. When water from agricultural delivery systems seeps into a groundwater aquifer used by other farmers, it is often possible to recapture the water through groundwater pumping. True losses occur only when water is evaporated away or seepage is chemically contaminated or lost to a saline sink. Monitoring and measuring real losses are hard to do, but preventing the losses is not — canals can be lined with an impervious material and pipes maintained, if the cost of doing so is below the cost of finding equivalent amounts of new water. Recently, third parties, mostly urban water utilities, have begun to approach irrigation water districts to offer to participate in capturing some of this lost water. In return for all or some of the water "saved," the third party covers the cost of lining the canal and transporting the water. These actions are often extremely cost-effective ways of increasing overall water availability. Secondary issues, however, arise when the water that traditionally seeped out of the canals is subsequently used by other users. For example, the Metropolitan Water District of southern California has recently offered to pay for lining the All-American Canal along the U.S./Mexico border in return for the water "saved" by eliminating seepage. Approximately 100,000 acre-feet of water are estimated to be lost in this fashion. In fact, one user's loss is often another user's gain. In this case, Mexican agriculture in the Mexicali Valley pumps approximately this amount of water directly attributable to seepage loss from the canal and claims that the U.S. cannot line the canal without consultation with Mexico (Hayes 1991). This dispute is currently unresolved.

Unlined irrigation canal in the North Sacramento Valley. (Photo: P. Gleick)

B. ECONOMIC MECHANISMS

Moving toward more efficient, ecologically sound, and sustainable patterns of water use requires major changes in the way water is valued, allocated, and managed. Central to the effort to revamp the way California manages its water resources will be pricing policies that reflect the costs of water to particular users at particular times of use. Historically, water prices have not fully reflected the costs, both social (environmental degradation associated with water development) and capital (opportunity costs of plant and equipment), of providing water to users.

1. Rate and Pricing Policies

Some water utilities are now seeking ways to modify their rates and exploring alternative pricing structures to help ensure more productive and efficient use of water (Morris 1990). Through such policies they hope to delay the need for additional water supplies, avoid all or part of the estimated $6 to $7 billion in improvements to comply with the Safe Drinking Water Act, and reduce the cost of treating wastewater to comply with Clean Water Act standards (Curry 1994).

Many possible rate structures could be implemented. Figure 12 shows some of the common urban rate structures. Already, two rate structures — *seasonal* and *increasing-block or tiered-block rates* — are being used to encourage conservation in areas that have chronic water shortages or limited capacity. *Seasonal rates* are implemented for water consumed during a utility's peak-use season, either as a means of recovering the incremental cost of providing water or as an inducement to conserve water because of inadequate or constrained supply. *Increasing-block rates* use two or more rate blocks with increasing unit rates as consumption increases.

It is common practice to apply tiered-block rates separately to residential and nonresidential customers because of the large differences in water use. The separate rate schedules for each class can encourage large-volume customers within each class to reduce usage. For example, according to the DWR, increasing-block rates work well with large water users (commercial, industrial, and governmental) only if the differences between the blocks are significant (Curry 1994).

In the residential sector, significant and permanent savings result when water rates are combined with indoor and outdoor fixture replacement programs, water audits, and landscaping ordinances. For large industrial, commercial, and governmental customers, monetary rebates (as a reward for conserving water) coupled with higher rates can produce significant water savings.

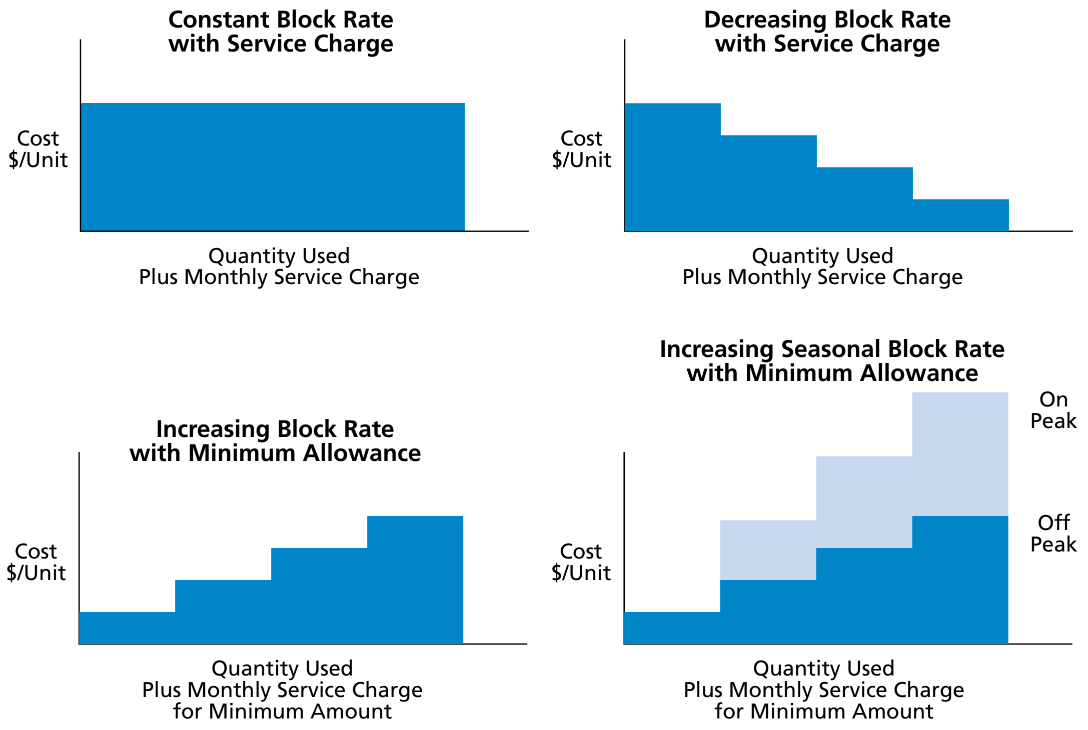
That rates influence demand for water has been shown repeatedly by empirical research. The measure of this relationship between the price of water and its use is called the *price elasticity* of demand, which gauges the expected response in demand given a change in price. The water utility industry had for a long time assumed implicitly that the price elasticity of demand for water by residential customers was zero, i.e., higher prices have no effect on quantities demanded. However, numerous recent studies show that it can be as high as 50 percent (see, for example, Dziegielewski et al. 1991). Table 26, below, summarizes some of these recent findings.

The price elasticity figures in Table 26 can be interpreted in the following way: a 10 percent increase in the price of water would result in decline in single-family residential water demand of 1 to 3 percent during the winter and 2 to 5 percent during the summer. Similarly, one might expect demand by multi-family residential customers to decline by 0 to 1.5 percent in the winter and 1/2 to 2 percent in the summer. This simple illustration shows that demand is more elastic in the summer season than in the winter season (off-peak season).

Results from other empirical studies also show that outdoor water use is more responsive to price than indoor use, especially in the summer months when outdoor use is greatest. Because outdoor use tends to be much more discretionary than indoor water use, people are more able and/or willing to adjust outdoor water use as prices change. Because outdoor water use occurs mainly in the "peak" summer months, the cost of providing water to satisfy "peak" outdoor demand is higher than during other periods. For this reason, outdoor use should be priced at a higher rate during "peak" periods of the year, either as a means of recovering the incremental cost of providing water during peak periods or as an inducement to conserve water because of seasonally limited supplies.

Elasticity of demand also varies depending on whether it is viewed in the short- or long-run. While price is less effective in changing residential water use in the short-run, it plays

Figure 12
Urban Water Rate Structures



Source: Modified from DWR 1994a.

Table 26
Price Elasticity Estimates for Residential Water Use

Single-family Residential Customers	Range of Elasticities		
Winter season	-0.10	to	-0.30
Summer season	-0.20	to	-0.50
Multi-family Residential Customers			
Winter season	0.00	to	-0.15
Summer season	-0.05	to	-0.20

Source: Mitchell and Hanemann 1994.

an important role in guiding long-run water use decisions. A Tucson, Arizona study that examined residential water demand between 1974 and 1980 found long-run elasticity of demand to be nearly twice that of the short-run (Mitchell and Hanemann 1994).

Evidence suggests that water is chronically overused because it is consistently underpriced.

All of this evidence suggests that water is chronically overused because it is consistently underpriced. With demand for urban water continuing to outpace supply, urban water agencies face a new reality where providing a reliable, affordable service will depend as much on how they manage demand as on how they manage supply. Innovative ways to price water services to encourage more efficient use, and adaptation of cost-effective conservation, efficiency, reuse, and recycling measures will be key to meeting tomorrow's needs.

2. Ratebase Water Conservation and Efficiency

Permitting regulated water agencies to put expenses for conservation and efficiency programs into their ratebase, as occurred in the energy industry in the late 1980s, would go a long way toward putting these programs on the same footing as new supply projects. Under current policies, water utilities are, for the most part, unable to receive a return on investments in water conservation and efficiency programs, unlike investments in new supply projects. Absent policies that place conservation and efficiency on the same footing as new supply projects, such strategies will continue to be viewed only as emergency drought response options.

3. Agricultural Water Policies

There are several different actions that local water agencies can take to restructure the way that farmers use water (see Table 27). In the short-term, districts can implement increased block rates, ration allocations, move allocations from one farmer to another, negotiate inter-district transfers, improve management of deliveries, increase groundwater use, change the use of existing surface storage, and implement information sharing and education on conservation techniques among its members. In the longer-run, districts can improve delivery-system efficiency, increase storage capacity and groundwater pumping capacity, negotiate long-term transfers, renegotiate water contracts with state and federal agencies, and implement better planning and monitoring.

The state and federal agencies responsible for operating the SWP, CVP, and other supply projects also play a role in agriculture's use of water. On a short-term basis, these agencies can improve management of deliveries, facilitate inter-district short-term transfer markets, and provide assistance with conservation for districts and individual producers. In the long term, changes in public policy and planning can also have important effects. For example, the CVPIA requires the re-allocation of 800,000 af to environmental uses. Federal commodity programs also influence the types and quantity of crops planted, crop prices, and ultimate water demand. Zilberman et al. (1993) found that about 40 percent of California crop acreage is under some federal or state price and income support program. The state can also implement statewide groundwater regulation or facilitate local groundwater management. Finally, statewide planning can better coordinate the various uses of water to ensure that the sustainability criteria are being met.

Many other important factors influence the producer's choice of what crops to grow, how much to grow, and how much water to apply. For example, trends in global commodity markets such as the North American Free Trade Agreement and the General Agreement on Tariffs and Trade affect crop prices. The financial condition of farms is also important since generally only financially sound farms can undertake large capital investments in efficiency equipment.

4. Lessons from San Joaquin Drainage Areas

The experience of several districts on the west-side San Joaquin Valley shows the tremendous flexibility of agriculture to adapt to changing conditions. Through district-level conservation programs and tiered pricing San Joaquin Valley west-side farmers increased irrigation efficiency and reduced drainage water in an effort to reduce some of the severe drainage problems there.

Table 27
Possible Responses to Water Cutbacks in the Agricultural Sector

Level of Response	Short-term (same year as cutback)	Long-term (3 or more years)
Farm	• Fallow crop land • Improve irrigation scheduling • Increase groundwater pumping • Buy or sell water via transfers within district or between districts • Water-stress crops • Switch type and amount of crops planted	• Change total size of farm operation • Change crop types and rotations • Invest in more efficient irrigation technology • Increase on-farm water storage • Increase groundwater pumping capacity • Leave farming or relocate
District	• Restructure water rates • Ration supply • Buy water from other districts • Increase groundwater pumping • Initiate intra-district water trading • Improve operations and management of water deliveries • Implement educational and technical assistance programs for farmers	• Improve delivery system efficiency • Increase storage capacity • Increase groundwater pumping capacity • Negotiate long-term water transfers • Renegotiate state and federal contracts • Build planning and management infrastructure • Implement conjunctive use programs for ground and surface water
State and Federal	• Set up interdistrict short-term transfers • Improve delivery efficiency • Provide conservation assistance	• Restructure agricultural commodity subsidies • Renegotiate water contracts • Build planning and management infrastructure

The Broadview Water District implemented a tiered pricing rate structure in 1988. This small district of 10,000 acres next to the Westland Water District grows primarily cotton, melons, wheat, alfalfa seed, and tomatoes. They were faced with the problem of having to reduce the volume of contaminated drainage water flowing into the San Joaquin River. An increasing block rate for water use was seen as one way to help achieve drainage reductions and a program to implement such a structure was developed. The rate was set at $16 per acre-foot for the first 90 percent of the 1986 to 1988 applied water average and $40 per acre-foot for any additional water. Accounting for water was fairly accurate because of careful monitoring.

By 1991, only seven of 47 fields exceeded the tier levels (see Table 28). The district average applied water decreased 19 percent, from 2.81 acre-feet/acre for 1986-88 to 2.27 acre-feet/acre in 1991. During this same period melons, wheat, and alfalfa seed crop production decreased, but there was an increase in tomatoes harvested (MacDougall et al. 1992). Drainage was both reduced substantially and smoothed out over the season. The drainage volume decreased from an average of 3,521 af per year over 1986-88 to 2,665 in 1990; salt discharges decreased from 26,000 tons to under 22,000; and boron decreased from 30.3 tons to 26.2 tons (Wichelns and Cone 1992). In addition to the rate changes, discussions and workshops with farmers facilitated the exchange of information, contributing greatly to the success of the program (Wichelns and Cone 1992).

A review of water conservation experiences in irrigation districts concluded that accurate measurement and comprehensive metering are essential for efficient water management (Thomas et al. 1990). If all districts in the San Joaquin Valley achieve the level of efficiency of applied water achieved by the most efficient districts, then according to 1984 data, more than 671,000 af are potentially available for reallocation from the San Joaquin Valley alone.

While local experiences cannot be easily generalized to the state as a whole, they do point to promising areas for adapting to water cutbacks. The distinction between savings in applied water and savings in consumed water should be kept clear. Increased irrigation efficiency can lower applied water requirements, but actual water consumed may not change unless the crop evapotranspiration requirements change by either growing different crops or fallowing land.

Table 28

Broadview Water District's Tiered Water Pricing Experience[a]

Crop	1986-88 average	1989	1990	1991	Percentage Change (86-88 to 91)
Acres					
Cotton	4,100	4,649	4,416	3,828	-6.6%
Melons	1,095	1,279	814	198	-81.9%
Wheat	939	708	903	304	-67.6%
Alfalfa Seed	813	694	549	456	-43.9%
Tomatoes	627	840	850	662	5.6%
Total	**7,574**	**8,170**	**7,532**	**5,448**	**-28.1%**
Acre-feet per acre					
Cotton	3.20	3.34	2.84	2.40	-25.0%
Melons	2.11	1.93	1.79	1.46	-30.8%
Wheat	2.30	3.02	2.18	1.60	-30.4%
Alfalfa Seed	2.06	1.84	1.88	1.36	-34.0%
Tomatoes	3.22	2.72	3.03	2.69	-16.5%
Weighted Average	**2.81**	**2.90**	**2.60**	**2.27**	**-19.2%**
Total acre-feet applied					
Cotton	13,120	15,528	12,541	9,187	-30.0%
Melons	2,310	2,468	1,457	289	-87.5%
Wheat	2,160	2,138	1,969	486	-77.5%
Alfalfa Seed	1,675	1,277	1,032	620	-63.0%
Tomatoes	2,019	2,285	2,576	1,781	-11.8%
Total	**21,284**	**23,696**	**19,575**	**12,364**	**-41.9%**

Source: Broadview Water District 1992 Drainage Operation Plan as cited in MacDougall et al. 1992.

[a] *Tiered pricing adopted in 1988. Farmers paid $16 per acre-foot for all water applied below the tiering levels shown below and $40 per acre-foot for water applied above these levels.*

	Acre-feet per acre
Cotton	2.90
Melons	2.11
Wheat	1.90
Alfalfa Seed	1.90
Tomatoes	2.90

C. INFORMATION AND EDUCATION APPROACHES

Information and education are crucial components of any successful water management and planning programs. The recent droughts in California provide numerous examples where voluntary efforts to reduce water use were successful because of the effective dissemination of information (DWR 1993a).

If water utilities, irrigation districts, or state and federal water purveyors want to promote or require conservation among their customers, they need to understand how these customers use water; that is, they need to answer the question "How is water used?" To understand how customers use water, the water utilities need to conduct customer surveys and audits. They then need to use the information from the customer surveys and audits to persuade the customers to change their usual way of operation. Water use varies depending on the type of customer, facility or business, climate, and many other variables. For this reason, appropriate methods of reaching each type of customer will vary.

The need to use water more efficiently also must be effectively communicated to the water users. This will require aggressive media campaigns and dissemination of information (describing current and future water conditions). In addition, water agencies in cooperation with electric utilities and government need to successfully address issues such as:

- the cost effectiveness of conservation or efficiency measures (i.e., customers must be given good reason to change);
- the direct and indirect effect of the measure on profits;
- the availability of financing, which is especially important when the customer's budget does not include funds to cover the initial capital cost of plant improvement projects. This is also extremely important for low-income households that cannot afford capital outlays for new fixtures or appliances;
- the need to convince businesses and facilities about the accuracy of the information on which the recommendations are based; and
- the need to publicly recognize companies that are water efficient.

1. Audits

A major barrier to efficient water use is the lack of information about the role of behavior, and the availability and cost of water-efficient technologies. Such information can be provided in many ways, including educational programs and "informational incentives," defined by the California Urban Water Agencies as "the provision of information for which customers would otherwise have to pay" (Barakat and Chamberlin 1994). Evidence suggests that site-specific information on current water use is extremely effective at influencing customer behavior and the adoption of conservation technologies.

Audits typically have two components: (1) a detailed site-specific survey of current water uses and needs; and (2) provision of site-specific information on alternative, more efficient technologies and practices. Such audits are typically conducted either by the local water utility or by a commercial operation. In the former case, the cost is typically borne by the utility. In the latter case, the cost of the audit is often offset by some agreement to share the savings that accrue from implementing the suggested changes. For both cases, identifying ways to reduce the price or cost of audits would increase their likelihood of being undertaken.

Audits of water use have the potential to identify substantial savings of water in almost all sectors. Financial incentives to get utilities or private contractors to offer audits could be extremely valuable, but almost all studies done of audits emphasize that they need to be combined with programs to ensure that identified savings are actually attained, by getting customers to implement, and maintain, the proposed changes. Mechanisms to encourage the adoption of the recommended changes are discussed later.

a) Residential Audits

Residential audits provide residential customers with indoor and outdoor evaluations of water use and needs. Audits are conducted by either trained utility staff or outside contractors. Some audits specifically involve direct installation of conservation devices, while others are purely informational. Some training is required for auditors, and the cost of a typical residential audit is about $45 to $75 when an audit of outside water use is included (Barakat and Chamberlin 1994).

b) Industrial Audits

Industrial audits are highly site specific and far more difficult to do than residential audits, given the often highly complex nature of industrial practices. These audits include detailed assessments of how and why water is used in a facility and may require temporary monitoring at a variety of points in a process, evaluating the heating, ventilation, and air-conditioning systems, and testing of water-using equipment. The cost of industrial water audits depends on a wide range of factors, including the type of process, the services provided, and the extent of the audit. The Metropolitan Water District of Southern California estimates its industrial water-management studies cost $5,000 to $15,000, based on what their customers would have to pay for comparable audits by the private sector. Because of the expense and difficulty of such audits, few water agencies offer them, although estimates of possible water savings in audited industries range as high as 30 to 40 percent (Brown and Caldwell Consultants 1990).

c) Commercial and Institutional Audits

Commercial and institutional activities can also benefit from detailed water-use audits, which can include all the components of a residential audit (indoor fixtures, outdoor turf irrigation) as well as reviews of heating, ventilation, and air-conditioning systems. Institutional energy and water audits of all federal facilities are supported by the Energy Policy Act of 1992, which requires implementation of efficiency measures with a payback period of ten years or less. Commercial and institutional audits are typically less complicated and less expensive than industrial audits and may focus on high-volume, peak-period users or on customers with single-pass cooling systems or large areas of outdoor turf irrigation.

d) Large Landscape Audits

Some municipal, institutional, or industrial customers maintain large landscapes (such as lawns) requiring irrigation. These landscapes are often large consumers of water. Landscape audits typically cost about $200 per acre and require outside expertise or training.

2. Other Training Programs.

Another educational activity to help water consumers take conservation actions or to implement conservation measures is a training program or workshop. Such courses can be offered or sponsored by the water utility for specific groups of customers or for particular kinds of technologies or practices, such as landscape irrigation. Incentives to offer, or to take, such workshops can improve the success of conservation programs in a wide range of sectors. Agricultural training is often available through extension services and other state or university programs. More effort is needed to get information on water issues into these programs.

D. REGULATORY APPROACHES

Since educational and economic incentive programs will not motivate everyone to conserve, regulatory approaches must also be evaluated and considered. Legislation setting standards has been used for many purposes, such as saving energy, ensuring safety, protecting human health, and preventing environmental degradation. Recently, there have been some modest efforts to set standards for water-using technologies and behaviors. Setting water-efficiency standards for common fixtures — such as toilets, showerheads, and faucets — can be a critical component of a permanent and reliable water conservation strategy. Legislation and regulation at the local, state, and federal levels are playing an increasing role in establishing water conservation requirements for water utilities and the public. Standards establish technological norms that ensure a certain level of efficiency is built into new products and services. As the stock of water fixtures is replaced with more efficient fixtures, there will be continuing permanent reductions in water demand. Other approaches, such as landscape ordinances aimed at societal preferences, can also be used to alter water-use patterns.

1. Technology Standards

A variety of technology-based standards are being used to reduce water demand. For example, following the severe drought of 1976-77, state law in California required more efficient toilets (3.5 gallon-per-flush) in all new construction. On a more local level, several communities including Los Angeles, Petaluma, Santa Monica, and Sebastopol, have passed ordinances requiring the use of high-efficiency water fixtures in all new construction, remodeling, and additions. More recently, the 1992 National Energy Policy Act (NEPAct) established national standards for toilets, urinals, showerheads, and faucets. The efficiency standards are shown in Figure 13 below and took effect January 1, 1994. As pre-1994 fixtures are replaced with more efficient fixtures as required by the NEPAct, per-capita water use is expected to drop substantially.

The NEPAct has three basic water components: the establishment of maximum-water-use (efficiency) standards for plumbing fixtures, product marking and labeling, and recommendations for state and local incentive programs to accelerate voluntary fixture replacement. Studies of the NEPAct's impact on domestic water use show that they will be substantial. Replacing an existing 5 to 7 gallon-per-flush toilet with a 1.6 gallon-per-flush toilet will, by itself, save up to 20 percent of total indoor water use for a family of four. One study concluded that the introduction of these efficiency standards will reduce residential water use for toilets, showerheads, and faucets by 62 percent when replacing pre-1980 fixtures and 39 percent when replacing fixtures installed between 1980 and 1993 (Vickers 1993).[14] Based on our analysis, we estimate that the NEPAct water-efficiency standards will reduce residential water use for toilets, faucets, and showerheads by approximately 57 percent for pre-1980 and post-1980 fixtures combined. That the standards will have substantial impacts even in communities with robust water conservation programs is unquestionable.

The passage of the NEPAct will not only influence water demand, but also the volume of wastewater generated over the next several decades. Yet little discussion about the potential impacts of the NEPAct water-efficiency standards has occurred at the state level. For example, DWR's Bulletin 160-93 and Bulletin 166-4 failed to incorporate its requirements into their analysis (DWR 1993, 1994a, 1994b). At the utility level, the expected demand reductions will influence important policy and planning decisions, but few utilities have yet to estimate their impacts.

a) Housing and Landscape Ordinances

Better land-use policies, including landscaping ordinances and other regulatory measures to promote multi-family housing should be explored. Because multi-family structures share landscapes or have significantly smaller landscapes, and generally have fewer water-using appliances, average per-capita water use is lower than in detached single-family residences. A 1985 study conducted by the Planning and Management Consultants for the Metropolitan Water District concluded that the average annual single-family water use was 384 gallons per day, 128 gallons more than the average multi-family home (see Table 29 below). The study concluded that a person residing in single-family home used 140 gallons per day, or 46 gallons more than someone residing in a multi-family residence (Dziegielewski et al. 1991). Outdoor water use

Table 29
Estimates of Average Annual Water Use In Southern California

Residential Sector	Gallons per dwelling per day	Gallons per person per day
Single-family	384	140
Multi-family	256	94
All residential	327	119

Source: Dziegielewski 1991.

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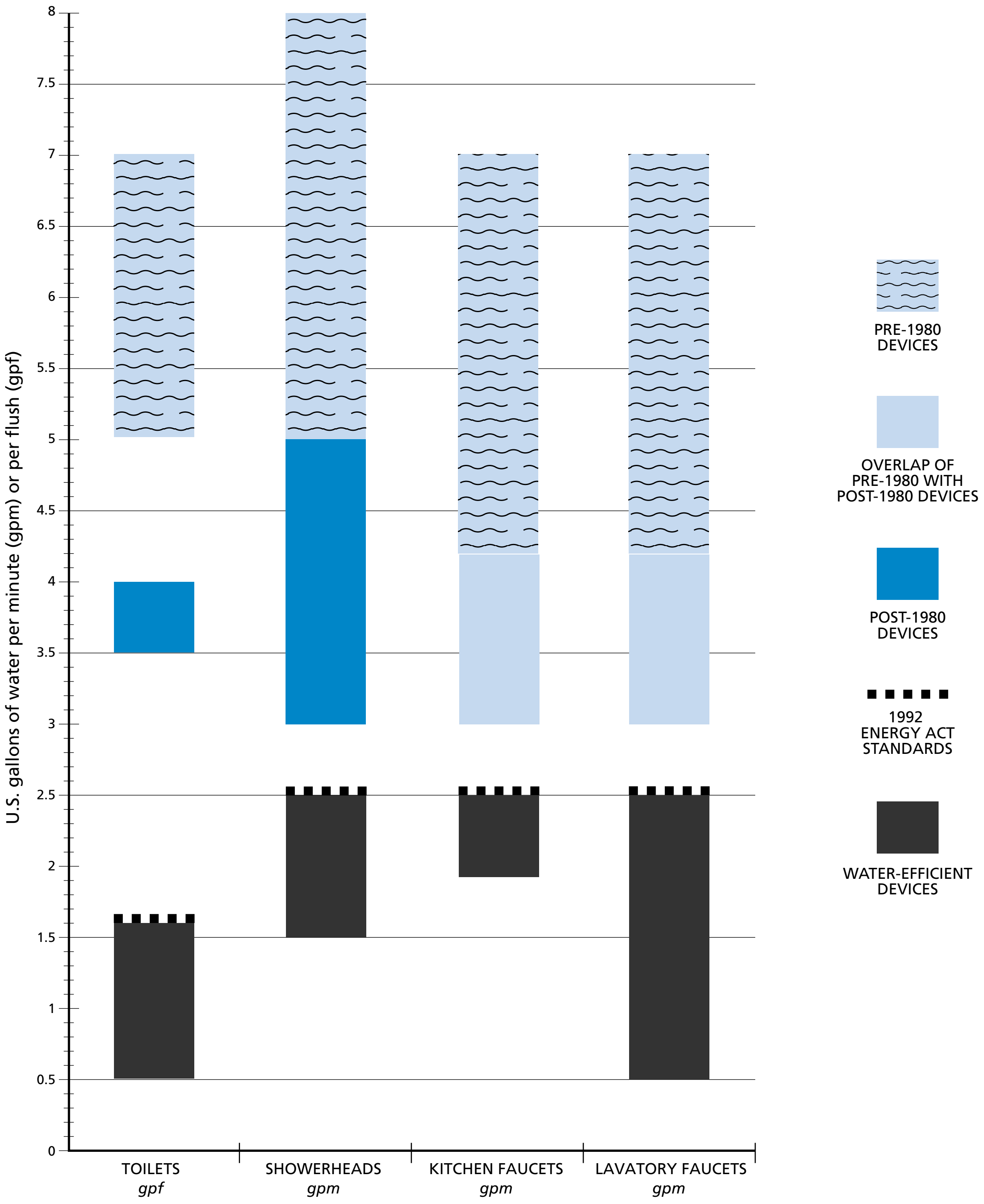
[14] These estimates are consistent with the 57% potential savings estimates for faucets, showerheads, and toilets we calculated for existing California equipment.

Figure 13

Water Used by U.S. Faucets, Showerheads, and Toilets

A comparison of the approximate range of water used by pre-1980 devices, post-1980 devices, and water-efficient technologies.



Source: Modified from Rocky Mountain Institute 1991.

in multi-family dwellings was less than 18 percent of total household use, compared to 35 percent in single-family units (Dziegielewski et al. 1991). An increase in the share of multi-family housing, as a percentage of total housing stock, would result in substantial water savings statewide. Such a trend was evident in California between 1970 and 1980, but appears to have leveled off during the 1980s (see Table 30).

Table 30
Percentage of Single- and Multi-Family Households in California

	1970	1980	1990
Single-Family	76%	63%	63%
Multi-Family	24%	37%	37%
Total	**100%**	**100%**	**100%**

Source: DWR 1994b.

Landscape water-conservation ordinances that limit turf size, require xeriscape landscaping, and/or improve management practices can also produce substantial outdoor water savings. Because of the multitude of factors involved, such ordinances should be enacted at the local level, preferably by the local water agency. However, if the water agency does not have the authority to enact ordinances, it should work with cities, counties, the state, and green industry in the service area to develop and implement landscape water-conservation ordinances. A structure for doing this has already been developed by the Water Conservation Landscaping Act of 1991 (California Government Code sections 65590 *et seq.*). This Act required that by January 1, 1993 all cities and counties in California either adopt the Model Ordinance (the Model Water Efficient Landscape Ordinance was adopted in August 1992 and is codified in Title 23 of the California Code of Regulations sections 490-92) or issue findings that they do not need such an ordinance.

If the city or county did nothing, then the state's model ordinance would automatically go into effect. Because of the Landscaping Act, many cities got serious about outdoor water conservation. Contra Costa County, for example, now limits turf to 20 percent of landscape area in some home developments.

Xeriscaping shows the greatest promise of creating sustainable and reliable outdoor water savings. A study conducted by North Marin Water District found that landscapes with about half as much lawn as traditional yards required 54 percent less water, 25 percent less labor, 61 percent less fertilizer, and 22 percent less herbicide (RMI 1991).[15] Similarly, an East Bay Municipal Utility District study of single-family houses comparing daily water consumption with water-conserving landscapes against traditional turf-oriented landscapes estimated residential water savings at 42 percent (RMI 1991).

b) Best Management Practices (BMPs)

The California Urban Management Council has developed the *Memorandum of Understanding Regarding Urban Water Conservation in California*. As of June 1994, there were 170 signatories to the Memorandum of Understanding (MOU), including 111 water agencies and 59 public interest groups. The MOU contains 16 best management practices that address interior and exterior water use.

Best Management Practices

- Interior and exterior water audits and incentive programs for single family residential, multifamily residential, and governmental/institutional customers
- Plumbing, New and Retrofit
- Distribution system water audits, leak detection, and repair
- Metering with commodity rates for all new connections and retrofitting existing connections
- Large landscape water audits and incentives
- Landscape water conservation requirements for new and existing commercial, industrial, institutional, governmental and multifamily developments
- Public information
- School education

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[15] The seven principles of xeriscaping are: good planning and design, limited turf areas, efficient irrigation, soil improvements, mulches, low-water use plants, and appropriate maintenance (RMI 1991).

- Commercial and industrial water conservation
- New commercial and industrial water use review
- Conservation pricing
- Landscape water conservation for new and existing single family homes
- Water waste prohibition
- Water conservation coordination
- Financial incentives
- Ultra-low flush toilet replacement programs

In addition to the BMPs that water utilities have committed to implement, the following are potential BMPs that can and should be implemented:

- Rate structure and other economic incentives and disincentives to encourage water conservation
- Efficiency standards for water using appliances and irrigation devices
- Replacement of existing water using appliances (except toilets and showerheads whose replacements are incorporated in BMPs) and irrigation devices
- Retrofit of existing car washes
- Gray water use
- Distribution system pressure regulation
- Water supplier billing records broken down by customer class (e.g., residential, commercial, industrial)
- Swimming pool and spa conservation including covers to reduce evaporation
- Restrictions or prohibition on devices that use evaporation to cool exterior spaces
- Point-of-use water heaters, recirculating hot water systems, and hot water pipe insulation
- Efficiency standards for new industrial and commercial processes

The MOU is voluntary and leaves it up to the participating utility to decide what BMPs it will or will not implement. That is, although a measure is listed as a BMP, a water district is not required to carry it out if it is deemed technically infeasible, socially unacceptable, or economically unjustified for that area (Vickers 1991). While giving districts the flexibility to not implement measures that are "technically infeasible" and "economically unjustified" is reasonable, it may not be reasonable to permit them to refuse to implement programs that are only "socially unacceptable." For this reason, the state should consider requiring all water utilities to implement BMPs that are "technically feasible" and "economically justified" regardless of their "social acceptability." Other mechanisms to ensure implementation of urban BMPs should also be explored.

E. TECHNOLOGIES AND PRACTICES TO INCREASE SUPPLIES

While the overall quantity of fresh water resources is fixed, there are technologies and practices that can be adopted that increase water availability on a regional or seasonal basis. For example, dams have traditionally been built in part to capture water during wet periods for use during later dry periods. Aqueducts and pipelines move water from areas of water surplus to areas of high demand. And technologies that permit water reuse can effectively reduce demand for new water by increasing the number of times the same quantity of water can be used. The following sections describe the advantages and disadvantages of an untraditional set of technologies and practices that are likely to be considered in the next few decades. This set of alternatives has been chosen to be consistent with the sustainability criteria developed earlier.

1. Wastewater Treatment and Use

There is broad agreement that reclaimed wastewater is a resource that can meet many existing water requirements. There is less agreement about how to encourage the use of this resource and about the extent to which wastewater can be used. By far, the most important first step to encouraging the use of wastewater is to do a comprehensive assessment of the likely uses for wastewater, the quality of water required to meet those needs, the availability of wastewater as a function of quality, and the relative costs of treating and delivering this resource. Some work in this area is already underway, such as the activities of the Central California Regional Water Recycling Project, which is evaluating the potential of using more than 200,000 acre-feet per year by 2010, on top of existing wastewater use activities in the San Francisco Bay Area and surrounding areas.

Southern California has comparable planning activities underway, in large part because for some southern California municipalities, the costs of delivering reclaimed water are far below the costs of delivering State Water Project supplies over the Tehachappi Mountains. Several cities, such as San Diego, have adopted ordinances that encourage or require the use of reclaimed water wherever feasible and wherever beneficial to public health, safety, and the environment (San Diego Ordinance 0-17327, July 24, 1989). Such ordinances should expedite the use of reclaimed water.

Increasing the use of recycled water from either waste-treatment plants or from water recovered from industrial processes can reduce the need for potable water. This is particularly true for large industrial users. Refineries, for example, are significant users of water, and increasing their use of reclaimed water can greatly reduce overall water demand in certain water districts. There is no requirement that potable water be used in cooling towers, but the use of reclaimed water for cooling may require replumbing. Financial incentives to promote such replumbing may be necessary. The Chevron Richmond Refinery in northern California currently uses just under 11 million gallons of water per day, half of which is lost to evaporation from cooling towers. At present, all of this water is drinking water supplied by the East Bay Municipal Utilities District (EBMUD). EBMUD and Chevron have developed a plan, however, in which all of this cooling water will be replaced with municipal reclamation water by 1996, effectively reducing the consumptive use of potable water by the refinery by 50 percent (P. Yolles, Pacific Institute, field visit, 1994).

In Los Angeles, a new water recycling facility, the Hyperion Plant in the Western Central Basin, will produce 70 million gallons per day of tertiary treated water. A secondary pipeline system, to permit the use of this water, is now being built, and the water from this system is being artificially priced at 80 percent of the price of potable water in order to stimulate the market for its use.

2. Graywater and Rainwater Use

The use of graywater and rainwater collection systems can dramatically reduce overall potable water needs. Graywater systems collect water from sinks, washing machines, and showers, filter it, and store it for use in toilets, urinals, or most typically, lawn irrigation. There are few commercially manufactured graywater systems in the U.S., but the Office of Water Reclamation in Los Angeles estimates that individual homes with such systems can reduce overall water consumption by 50 percent (RMI 1993).

Similarly, rainwater collection systems in some regions can provide substantial portions of all non-potable residential water needs. Once common in the U.S., rainwater collections systems can also reduce total water flows to wastewater systems, reducing the need for new systems or the load on existing systems. On the island of Hawaii, local government has developed guidelines to help residents build safe catchment and storage systems, and 25,000 people are estimated to rely on rainwater for their entire water supply (Chapin 1994).

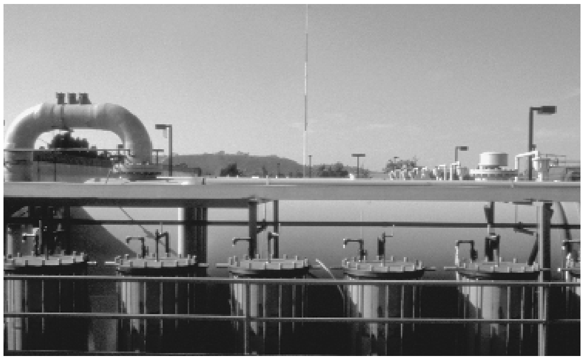
A major barrier to the widespread adoption of both graywater and rainwater systems is the resistance often encountered when there is a fundamental change in the system with which people are familiar. Such changes can be brought about, but often require long periods of time.

3. Alternative Treatment Systems

Substantial expenses are incurred by communities and municipalities for wastewater treatment facilities. Current provisions of the Clean Water Act are quite specific about the standards and technologies required for treating water, and these facilities are often extremely expensive to build and operate. Many of the water-efficient technologies discussed above contribute to reducing the cost of wastewater treatment by reducing the overall volume of water requiring treatment, which either decreases the size of facilities required or delays the need for new facilities. A different approach, however, is to use alternative technologies for treating wastewater, such as using the abilities of wetlands and marshes to clean up certain kinds of wastewater using natural processes.

At the moment, several innovative groups are doing research into these technologies, which can offer several advantages, including reduced energy costs, lower land requirements, and the ability to address sewage problems at a smaller scale than typical conventional secondary treatment systems. Some of the groups claim that their systems can provide tertiary quality treatment for roughly the same price as conventional secondary treatment systems (S. Sargert, Ocean Arks, personal communication, 1994). Ocean Arks, a company in the northeast, designs, builds, and operates smaller-scale waste-treatment facilities with a focus on using the biological advantages of wetlands/marsh systems. They are operating a 30-40,000 gallon per day system in Frederick County, Maryland to treat residential sewage and a test facility in Toronto to treat wastewater from a distribution warehouse for the Body Shop. They are also designing facilities for the state of Vermont to treat 100,000 gallons per day and for the city of San Francisco for treating storm water runoff.

A niche where such alternative facilities could be extremely useful is where septic tanks are in disfavor and where residential communities are trying to protect ground water. At present, 30 percent of the U.S. population is not served by sewers and depends on septic tank/leach field technology. Most small communities are unable for technological and economic reasons to build major waste-treatment facilities, making these kinds of smaller unconventional systems particularly attractive. Among the needs to expand the field are further technical demonstrations, some financial incentives to permit communities to consider non-traditional approaches, and removal of restrictions in current legislation on the kinds of facilities built. In particular, opening up the provisions of the Clean Water Act to permit innovative systems to compete is urgently needed. To upgrade systems from septic tanks to some alternative system, or from secondary to tertiary treatment may require tax credits or low-interest loans to individuals, companies, and communities (S. Sargert, Ocean Arks, personal communication, 1994).



A major, and expensive, desalination plant was built in Santa Barbara following the drought of the late 1980s and early 1990s. (Courtest of DWR.)

4. New Supply

Given the large potential for increased water-use efficiency in all sectors, we are reluctant to recommend here incentives for new supply options that move water from water-rich to water-poor regions, or that require the construction of large new water-storage facilities, particularly in the western United States. Such traditional approaches have entailed enormous environmental and economic costs, and the realization of these costs is a major impediment to the construction of any new facilities. One possibility stands out, however, that meets our sustainability criteria: the use of saltwater or brackish water desalination *when that desalination is accomplished with renewable energy.*

By far the vast majority of global desalination technology today relies on fossil-fuel generated electricity or heat. As of early 1991, few solar-powered desalination facilities had been constructed due to their higher costs. While this option is economically infeasible today, the costs of photovoltaics have been dropping continuously and significantly for several years, and the next 25 years are likely to bring some dramatic changes. Solar desalination may become an attractive way to supplement fresh water availability, especially in remote or arid regions with few alternatives (Gleick 1993).

Another unusual possibility is water transportation from out-of-state sources through non-structural means, such as "bag" technology currently under development. Water has long been shipped in emergency situations via tanker from one region to another. In 1994, for example, substantial amounts of water were brought to Japan by tanker to mitigate the impacts of a severe drought there (U.S. Water News 1994b). The problem with tankers is their relatively low volume and the relatively high cost of transportation. In 1995, at least three independent companies are exploring the use of large synthetic bags for transporting water around the world. These bags could be linked together to form "trains" and towed through the oceans to the point of need. As of mid - 1995, the technological feasibility of such an approach has not been proven, though demonstrations by some of these innovators appear imminent. Ultimately, their utility will depend on the economics of the method and the politics of finding reliable water suppliers willing to ship water to other regions.

VII. Conclusions and Recommendations

"It is hereby declared that because of the conditions prevailing in this State the general welfare requires that…the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare."
—Article X of the Constitution of the State of California.

The management and protection of California's freshwater resources have reached a crucial period. In the last decade, it has become obvious to many that the traditional water policies that helped California become the agricultural and economic force it is today are not up to the task of meeting the challenges of the 21st century. Yet the very groups responsible for preparing the state for the coming challenges are mired in the policies of the past. For the past year, the Pacific Institute has been exploring alternative paths into the next century in the hopes of trying to provide new insight into appropriate water policies. This report takes a unique look at how the state might begin to plan for a truly sustainable water future, presents a positive vision of what that future might look like, and discusses how such a vision might be achieved.

A. THE PROBLEM

California's current patterns of water use are unsustainable. Groundwater use is unmonitored and uncontrolled and in many places groundwater is being used at rates faster than it is being replenished. Ever increasing amounts of water are required to meet urban demands, adding to the conflict among agricultural, urban, and environmental interests. Urban water use is inefficient and poorly managed. Environmental water needs are poorly understood and rarely met. Fish and wildlife species are being driven to extinction and habitats are being destroyed by development. And official projections are that such problems will continue indefinitely.

According to the California Department of Water Resources, California water policies — and problems — in the year 2020 will be little changed from today. The state will grow the same kinds of crops, on about the same amount of land. Rapidly growing urban populations will still use water inefficiently, wasting large amounts of water on inefficient toilets and sinks, and on watering household and municipal lawns. Many groundwater aquifers will still be pumped faster than they are replenished by nature. Millions of acre-feet of treated wastewater will be dumped into the oceans, rather than recycled and reused. Water needed to maintain California ecosystems and aquatic species will come and go with the rains and with human demands. Every drought and flood will have a greater and greater effect on society and the natural environment.[16] And expected water demands will exceed available supplies by several million acre-feet — a gap projected in every official "California Water Plan" produced since 1957. We believe that state water planners have been planning for a future that is increasingly unlikely and undesirable.

During the past 50 years, water-resources planning in California has relied on making projections of future populations, per-capita water demand, agricultural production, levels of economic productivity, and so on. These projections are then used to predict future water demands. As a result, traditional water planning always projects future water demands independent of, and typically larger than, actual water availability. Planning then consists of suggestions of alternative ways of bridging this apparent gap between demand and supply.

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[16] See, for example, previous Pacific Institute reports: "The Societal and Environmental Costs of the Continuing California Drought (Gleick and Nash), July 1991 and "Environment and Drought in California 1987-1992: Impacts and Implications for Aquatic and Riparian Resources" (Nash), July 1993.

The prevailing ethic in California has been to plan for future growth by building more dams, reservoirs, and canals to transport water from areas of surplus to areas of deficiency.

The costs to the state of this future — lost industrial competitiveness and revenue, destroyed natural resources, continued uncertainty about long-term water supplies, and further ill-will among urban, agricultural, and environmental interests — can be avoided. Trend is not destiny, and official projections are not inevitable outcomes. It is time to develop new tools and approaches to solving California's water problems.

B. WATER PLANNING FOR THE 21ST CENTURY

Traditional approaches for projecting water demands assumes that the future will look virtually identical to what it does today, with the same social structures and desires and without resource, environmental, or economic constraints. Even ignoring the difficulty of projecting future populations and levels of economic activities, there are many limitations to this approach. Perhaps the greatest problem is that it routinely produces scenarios with irrational conclusions, such as water demand exceeding supply and water withdrawals unconstrained by environmental or ecological limits.

Sustainability Criteria for Water

1. A minimum water requirement will be guaranteed to all humans to maintain human health.
2. Sufficient water will be guaranteed to restore and maintain the health of ecosystems. Specific amounts will vary depending on climatic and other conditions. Setting these amounts will require flexible and dynamic management.
3. Data on water resources availability, use, and quality will be collected and made accessible to all parties.
4. Water quality will be maintained to meet certain minimum standards. These standards will vary depending on location and how the water is to be used.
5. Human actions will not impair the long-term renewability of freshwater stocks and flows.
6. Institutional mechanisms will be set up to prevent and resolve conflicts over water.
7. Water planning and decision-making will be democratic, ensuring representation of all affected parties and fostering direct participation of affected interests.

These initial assumptions can, and should, be directly challenged. The future can look quite different than today, as indeed, today looks quite different than the California of the 1960s. What is needed for the next century is a process that will resolve water conflicts by setting new goals and priorities for water-resource planning. In this report, we present a Vision for California for the year 2020 in which water-resources planning and use are sustainable, both socially and environmentally.

There has been plenty of rhetoric recently around the terms "sustainability" and "sustainable development." What do we mean by sustainability in the context of fresh water resources, and why do we use the term here? We define sustainable water use as "*the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it.*" California's water resources should be managed so that today's human and environmental needs are met, and so that the resource base is maintained for the use of future generations. Thus, water-related problems such as the overdrafting of groundwater, the chemical contamination of water supplies, and the loss of aquatic species and unique habitats mean that current water management practices are unsustainable. Continuing these practices is like squandering away an inherited fortune leaving nothing for our children. Sustainable water use requires keeping the resource base intact for future generations rather than destroying it for short-term gain.

Is sustainability a scientific concept? Not exactly. Sustainability is a social goal, much like equity, liberty, or justice. Public value judgments must be made about which needs and wants should be satisfied today and which should be put off or met in a different manner. In Table 4 and here, we present a set of sustainability criteria for water. These criteria, developed over the past year in discussions with academic, governmental, and non-governmental interests working on California, national, and international water problems, embody the value judgments that humans and natural environments should have access to a minimum amount of water necessary for survival, that the renewable characteristics of water resources should not be impaired, and that the process of water planning and management be democratic, fair, and open.

An ethic of sustainability will require a fundamental change in how we think about water. Rather than trying to find the water to meet some projection of future desires, it is time to plan for meeting present and future human and ecological needs with the water that is available, and to determine what desires can be satisfied within the limits of our resources. This is an essential change, and will require some new thinking at the highest levels.

Water-resource planning in a democratic society requires more than simply deciding what project to build next or evaluating which scheme is the most cost-effective. Planning must provide information that helps the public to make judgments about which "needs" and "wants" can and should be satisfied. Water is not only a common good and community resource, it is also used as a private good or economic commodity; it is not only a necessity for life, but is also a recreational resource; it is imbued with cultural values and plays a part in the social life of our communities. The principles of sustainability and equity can help bridge the gap between such diverse and competing interests.

Rather than allowing water policy to be determined by the outcomes of fights among the most powerful and wealthy interest groups, goals to further a genuine common interest can be forged and real conflicts can be resolved in a fair and equitable manner based on democratic ideals. In the absence of democratic dialogue, water-resource development can only continue down a course plotted decades ago, one that may have been appropriate then, but which fails to meet the challenges of the next century.

We have the opportunity, tools, and ability to create a remarkably different urban and agricultural economy, one that can restore ecosystems and protect the environment while bringing forth innovation, equitable use of resources, meaningful work, and economic security. The vision presented at the beginning of this report offers a positive goal for California water planning and management.

C. THE VISION FOR 2020

A prosperous, healthy California is possible by 2020, with enough water for urban residents, a vibrant agricultural community, and a robust environment. Within 25 years, California can achieve a more sustainable pattern of water use without severe impacts on any particular sector. Groundwater overdraft can be eliminated, urban and agricultural water use can be more efficient and productive, and the protection and restoration of California's natural ecosystems can be enhanced. At the same time, the process of planning and managing the state's water resources can be made more democratic and open, bringing in whole segments of the state's population who have previously been outside the policy making process. The sustainable vision presented here would produce a more stable business environment, reduce the uncertainty over water supplies, and increase the state's economic vitality and competitiveness.

To reach this positive vision, we do not assume here any significant new supply infrastructures will be built, nor do we assume that drastic advances in technology are necessary. Similarly, the changes necessary for achieving sustainable water use in California do not require "heroic" or extraordinary actions on the part of any individual or sector. Instead, these changes are likely to come about by applying incremental technological innovations, trying changes in governmental and industrial policies, and by an evolution in personal values. All of these are already common characteristics of California society.

Can these sustainable futures be achieved? Yes, given appropriate attention and will, California's water policies can be substantially modified over the next quarter century, just as they have over the past twenty-five years. *Will* a sustainable future be achieved? That is a question that only the public and their elected officials can answer. Many economic, political, and cultural forces are at work in society changing our lifestyles, technologies, and institutions, and these forces will continue. The dialogue on how to harness these forces in a new direction must begin now.

D. MAJOR CONCLUSIONS

California water use is not sustainable and current water planning is not up to the task of dealing with the water problems of the 21st century.

- California water policies, both formal and informal, permit or even encourage a wide range of unsustainable practices such as groundwater overdraft, unconstrained urban demand, inefficient water use, and water-supply contamination. Current planning practices continue to use tools developed decades ago when populations and demands were lower, when the principal problem was developing the physical infrastructure to move water around, and when environmental concerns were an unimportant part of the overall equation. All of these conditions have changed, except for our planning institutions.

Continuing down the current path will lead to worsening social, economic, and environmental conflicts over water.

- Present policies and planning will lead to a large gap between water supply and expected demand. Official projections, done by the California Department of Water Resources every few years since 1957, always project water demand exceeding water supply, often by several million acre-feet.
- Present water policies reduce future flexibility and increase the risk of economic instability due to disruptions in water supply. Under conventional projections, the lack of a buffer between demand and supply greatly constrains the flexibility of agricultural, industrial, and commercial water users.
- Present water policies produce uncertainty and a risk of future unreliability during periods of drought and shortage. During dry periods, the only option is emergency response, state-imposed cutoffs, and a higher risk of economic dislocations.

By 2020, California can achieve a more sustainable pattern of water use without severe impacts on any particular sector.

- The focus of this report is to define a new, sustainable approach for water planning and policy, to present a positive water vision for California in the year 2020, and to evaluate how such a vision can be reached. We conclude that such a vision is possible without any single water-using sector bearing the brunt of the changes. We further conclude that over the 25 years between now and 2020, many of the changes we highlight can be accomplished easily.

Modest re-organization of California's agricultural sector can save millions of acre-feet of water.

- The agricultural sector can be more efficient, with lower total water demand and higher agricultural revenues.
- Totally eliminating groundwater overdraft in California is possible with modest changes in cropping patterns. Eliminating groundwater overdraft is a requirement of the sustainability criteria presented above. Current overdraft is about 1.3 million acre-feet per year, and official estimates are that it will still exceed 1 million acre-feet per year in 2020. In our Balanced Groundwater Scenarios, groundwater overdraft can be completely eliminated by fallowing modest amounts of land now devoted to growing water-intensive, low-value crops. If that land is then reallocated to growing other crops already grown in those regions, net agricultural revenue actually increases.
- By 2020, with only modest shifts in cropping patterns, agricultural net water demand could decline by 3.5 million acre-feet while farm income rises by $1.5 billion (1988 dollars). In the Agricultural Restructuring Scenarios, additional shifts in the production of alfalfa, irrigated pasture, rice, and cotton were explored. Changes in acreages planted in these crops back to acreages planted over the previous 25 years (mid-1960s to 1990) produce significant improvements in the overall water productivity of the agricultural sector.

Extensive improvements in the efficiency of residential, industrial, and commercial water use can save millions of acre-feet.

- Average residential water use in 2020 could be 46 percent lower than the current 137 gallons per person per day, using only existing technology. Applying the existing water efficiency standards set in the 1992 National Energy Policy Act, California residential water use will drop substantially. Reducing outdoor residential water use through xeriscaping and changes in watering technology could also significantly reduce residential water use.

- Use of reclaimed water can increase from 0.4 million acre-feet in 1992 to 2 million acre-feet in 2020. The official state goal is to increase the use of reclaimed water to 1 million acre-feet. We estimate that this could easily be doubled, if efforts were made to identify potential uses, and if economic and regulatory barriers to the use of such a resource were reduced.
- Industrial water-use efficiency could increase 20 percent over today's efficiency. The limited industrial water-use surveys done to date for California and elsewhere suggest considerable potential to improve the efficiency of water use. In some sectors, improvements of 50 percent or more are possible. We conservatively estimate an additional 20 percent can be achieved in California industry using existing technologies. Further changes in the make-up of California's industrial sector away from water-intensive industries will further reduce industrial water demand as a function of economic output.

California's environment can be protected far better than it is today by innovative and flexible water management.

- By 2020, more than 2 million acre-feet of water can be reallocated from urban and agricultural uses to a wide range of environmental needs. Savings identified above in the agricultural and urban sectors can be left in streams, rivers, and refuges for California's stressed natural ecosystems. We believe, however, that the absolute amount of water available for California's environment is less important than better management of that water. In particular, flexible management that takes into account seasonal needs and variable quality requirements may prove effective at helping the state restore vital and valuable aquatic ecosystems.
- High mountain streams can be restored to drinkable conditions. It should be possible, at low cost, to restore high-altitude streams in the Sierra Nevada to a drinkable condition. Minor changes in land-use affecting a small number of livestock operators, and better education of the growing number of back-country hikers and campers could have the desired effect.

A major effort is needed to improve our understanding of water supply and use. Major gaps in water data make it difficult to develop and implement rational water plans.

- No one knows for sure how much groundwater is used, who uses it, and for what. This particular lack of data hampers efforts to control groundwater overdraft and impedes the development of rational statewide water planning. While the unconstrained use of groundwater is in the strong interests of some, it is antithetical to rational water planning in a water-short region.
- Residential, commercial, industrial, and municipal data on water use are spotty, at best. There is need for a comprehensive statewide water-use survey. Despite the importance of addressing questions about water demand, far less is known about the characteristics of how California's water is used than about the characteristics of supply.
- Data for on-farm water use are rarely measured directly. Statewide data are needed on how much water is actually applied, evaporated from crops, returned to groundwater, and so on, as a function of crop, irrigation method, climate, and soil type. Improvements in information on agricultural water use will improve the agricultural industry's attempts to become more efficient and profitable.
- The water requirements for restoring and maintaining different ecosystems are poorly understood, complicating rational joint management of water among farmers, cities, and the environment. The needed information includes requirements on flows, timing, and water quality.

E. MAJOR RECOMMENDATIONS

Pricing policies that subsidize the inefficient use of water at taxpayer expense should be eliminated.

- Most federal and state water subsidies should gradually be reduced and then eliminated. In particular, the 1982 Reclamation Reform Act acreage limitations should be enforced, repayment schedules for federal water projects should more accurately reflect the costs of providing water to different users, and double subsidies should be eliminated.
- Federal crop subsidies for growing low-value, water-intensive crops should gradually be reduced and then eliminated. Of particular concern are crop subsidies for water-intensive crops that receive federally subsidized water as well.
- Urban and agricultural water rates should reflect the cost of service, including non-market costs.

The non-renewable use of groundwater in California should be ended.

- The state should establish a comprehensive groundwater monitoring program and database with open access.
- Institutional mechanisms for managing groundwater use at the local level should be implemented in accordance with standards set by the state. There has been considerable success in limited areas of California to establish local groundwater monitoring and management. The experience in these "adjudicated basins" offer some guidance for setting up such systems statewide. While local management seems both feasible and preferable, some consistent standards set by the state would help prevent abuse of the system.

Efforts to promote the use of water-efficient technologies and practices should be greatly expanded.

- Existing federal and state water efficiency programs should be implemented and expanded. The 1992 National Energy Policy Act put in place residential and commercial water-use efficiency standards for fixtures. Implementing these broadly would have a dramatic impact on urban water demand.
- New and better agricultural, residential, industrial, commercial, and institutional efficiency programs are required. These programs can include regulatory, economic, and educational components. A wide range of sectors are not presently served by any programs that provide incentives, standards, or education on the potential for improving water-use efficiency. Efforts should be made to reach these sectors.
- Water rates for all sectors should be designed to encourage efficient use of water.

Environmental water needs should be better understood and met.

- Critical wetlands should be identified and preserved together with the water needed to maintain them. Degraded wetlands should be restored.
- Water flow and quality standards should be set on a flexible seasonal basis and regularly reviewed.
- Biological resources should be comprehensively monitored.
- Long-term agreements to protect the Bay-Delta region must be implemented. Interim agreements have been reached, but long-term agreements are needed, as are efforts to implement current agreements.
- California's Wild and Scenic rivers must continue to be protected at both state and federal levels. Shortly after the turn of the century, official protections for these rivers will have to be renewed.
- Water should be allocated to protect and restore native anadromous fish runs. Many salmonid species are threatened or endangered because of water policies that failed to take account of fish needs. Integrated management should address these needs.
- Integrated management of agriculture and seasonal wetlands should be pursued further. Some initial success has been achieved with the rice industry. Other options should be explored for joint management with other agricultural sectors.

Legislative, regulatory, and administrative support should be given to those water transfers that improve water efficiency, enhance California's natural environment, and promote the overall well being of rural communities.

- Standards for water transfers should be developed to ensure that they are fair and do not harm the environment. The rapid movement toward permitting water transfers must not ignore possible adverse impacts on ecosystems. At the same time, methods of helping the environment through such transfers should be explored.
- A fund should be established to mitigate adverse impacts of water transfers on rural economies, communities, and the environment. The fund should be supported with fees imposed on transfers. Rural communities may be adversely affected by water transfers over which they have no direct say. These impacts should be evaluated and ways of mitigating adverse economic and social consequences should be developed prior to permitting inter-regional transfers.

Far greater use of reclaimed water is possible in California and should be encouraged through economic and regulatory incentives.

California water-planning institutions should be reorganized to prepare for the 21st century.

- California water planning can be more equitable and democratic by bringing in groups that have been excluded from the process. In particular, rural communities, small farmers, and inner city residents are not typically included in water-planning activities.
- The state should consider separating statewide water planning and data activities from current water project operations. Organizations responsible for building, maintaining, and operating major water projects may not be the proper water-planning organizations of the future since major new projects are increasingly considered inappropriate solutions. Separating these planning and management functions may be appropriate.
- A new independent planning organization can be created by streamlining existing water planning groups. No new bureaucracy is required — rather the existing planning groups from different organizations can be combined into an independent administrative structure.

A statewide system of water data monitoring and exchange should be created.

- Water data must be much more widely collected and distributed. Major gaps in data, and major gaps in the distribution of those data, must be closed.
- An organization that collects, maintains, and freely distributes state water resources data should be created. Far better distribution of water data should be possible, given the rapid growth of electronic data sharing capabilities.

Lifeline water allocations and rates should be implemented for the residential sector.

- A minimum water requirement should be available at lifeline rates for all residents of California.

Land-use planning and water-use planning must be better integrated.

- All new urban developments must demonstrate a secure, permanent supply of water before approval.
- Protection of prime agricultural land and the water required to support these lands should be studied. Efforts to minimize the adverse effects of urbanization on agricultural productivity could be combined with efforts to protect certain water supplies for agricultural communities.

VIII. Glossary

acre-foot
the volume of water required to cover one acre to the depth of one foot; equals 1,233 cubic meters, 43,560 cubic feet, or 3.259×10^5 gallons.

Agricultural Restructuring Scenario (ARS)
the Agricultural Restructuring Scenario (ARS) in this report explores the sensitivity of agricultural water demand and revenue to changes in certain California cropping patterns.

anadromous fish
fish that spend at least part of their life cycle in the ocean and then return to freshwater streams to spawn; includes salmonoid species.

applied water demand
the gross amount of water that is withdrawn from a water distribution system. Agricultural applied water equals the amount of water delivered to the farmgate. Urban applied water is the amount delivered to the intake of a city's water system. Applied water includes the water that returns to groundwater, a stream, canal, or other supply source that can be reused or recycled and thus is not the same as net water demand. (See consumed water, depletion, and net water demand.)

aquifer
an underground bed or layer of earth, gravel, or porous stone that stores water.

average water year
the average annual hydrologic conditions. Because precipitation, runoff, and other hydrologic variables vary from year to year, planners project future scenarios based on hydrologic conditions that typically include average, wet, and drought years.

Balanced Groundwater Scenario (BGS)
this scenario explores changes in cropping patterns such that long-term groundwater withdrawals do not exceed long-term groundwater recharge rates.

Bay-Delta
the Sacramento-San Joaquin river delta extending to the San Francisco Bay. The Bay-Delta is the largest remaining estuarine system on the West Coast of the United States.

consumed water
in this report, consumed water in agriculture is the same as ETAW. (See depletion, ETAW).

CVPIA
Central Valley Project Improvement Act of 1992 (Public Law 102-575).

depletion
the water consumed in a certain area that is no longer available for use by any other party. As defined by the DWR, depletion includes the ETAW, irrecoverable losses, and water that flows to salt sinks (such as the ocean).

dual-distribution piping
a water distribution system that uses one set of pipes for the distribution of potable water and a separate set for distribution of reclaimed water.

Department of Water Resources (DWR)
the California state agency responsible for long-term water planning, operation of the State Water Project, and state water conservation programs.

ecosystem
a system of interacting physical and biological units, including the flora, fauna, and geophysical environment.

evapotranspiration (ET)
the amount of water used by plants for necessary biological functions. Includes the water evaporated from plant surfaces and surrounding area, retained in plant tissues, and transpired (given off).

evapotranspiration of applied water (ETAW)
the portion of the total evapotranspiration that is provided by water applied through irrigation.

fallowed land
farm land that could grow crops but that is left unplanted.

graywater
household wastewater that can be collected for reuse in non-potable uses. Graywater systems exclude all toilet waste.

groundwater basin
a reservoir of groundwater defined by the aquifers underlying a particular land area.

groundwater overdraft
the act of withdrawing more water from a groundwater basin than is recharged over an extended period of time.

hydrologic region, also hydrologic study area (HSA)
a study area used by the DWR to analyze water use and hydrologic conditions. The DWR divides California into 10 hydrologic study areas based on watersheds (see watershed).

irrecoverable losses
the water lost to a salt sink or lost by evaporation or evapotranspiration from a conveyance facility, drainage canal, or in fringe areas.

irrigated crop acreage
the total amount of land area that is irrigated, including acreage that is double cropped.

irrigation efficiency
the ratio of water used for evapotranspiration and the total water applied through irrigation. Efficiency can be calculated at the farm, district, or basin levels.

lifeline rates
subsidized rates for a minimum amount of water.

maf
million acre-feet.

NEPAct
the National Energy Policy Act of 1992 (Public Law 102-486, 102nd Congress).

net water demand
as defined by the DWR, the amount of water needed in a water service area to meet all requirements. It includes the ETAW, irrecoverable losses, and outflow leaving a service area. It does not include the water reused in an area.

normalized demand
as defined by the DWR, normalized demand is the actual demand adjusted to account for water conditions that are not average. Thus, the 1990 water demand used by DWR (1994a) is not what was actually used in 1990, since that was a drought year. Water demand was adjusted upward to reflect DWR's estimates of what water demand would have been had it been an average water year. The DWR's 1990 agricultural water demand figure is based on the average irrigated acreage of the 1980s. The DWR's 1990 urban water demand is based on the average of per capita use from 1980 to 1987.

per-capita water use
the amount of water used by a person. Typically, averaged over some time period and population.

potable water
water suitable for drinking.

subsidence
the lowering of the land surface in response to changes in the characteristics of the underlying earth. Subsidence can occur when the groundwater level is lowered or when underlying materials are removed either by mining or solution or oxidation of solids.

urban water use
includes residential, industrial, commercial, and municipal water use.

wastewater (municipal)
water previously used by residential, commercial, industrial, and institutional users.

water reclamation
the treatment or processing of wastewater to make it reusable.

water recycling
normally involves the capture and reuse of wastewater by one user or use.

water reuse
the use of reclaimed water for direct beneficial purposes.

watershed
the area of land from which all precipitation and/or runoff drains into a single river. Also called drainage basin or river basin.

xeriscaping
the practice of using native vegetation and water-efficient irrigation practices to reduce outdoor water use.

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