Increasing farm water supply by conservation

Gerald L. Horner □ Charles V. Moore □ Richard E. Howitt

Improving first-use efficiency and other measures could help meet projected deficits

Agriculture uses about 84 percent of the developed water supply in California. The U.S. Water Resources Council projects an 11.7 percent increase in total water use for California between 1975 and 2000. Nonagricultural uses are expected to increase by 52.3 percent during this same period. Very few would question that, during the remainder of this century, heavy pressures will be exerted on California's water supply. The possibility of conserving and redirecting the use of existing water supplies has been proposed as at least a partial solution to this problem.

Our purpose here is to give some estimates of the amount of irrigation water that could be voluntarily conserved and made available for reuse in the San Joaquin Valley. Quantities that could be saved from conservation activities have never been empirically estimated, even though David C. Davenport and Robert M. Hagan have concluded (in *Agricultural Water Conservation in California, with Emphasis on the San Joaquin Valley*, Dept. of Land, Air, and Water Resources, UC Davis):

> A savings of about 2 percent of the state's water applied to agriculture conserves only approximately 0.65 million acre-feet, an amount that alone is insufficient to meet California's current net deficit of 2.3 million acre-feet, now reflected as groundwater overdraft.

This estimate is based on reducing soil surface evaporation by use of drip irrigation in young orchards (0.2 million acre-feet), reducing flows to brackish water tables in the San Joaquin Valley (0.045 million acre-feet), and reducing flows to the Salton Sea in the Imperial-Coachella Valley area (0.4 million acre-feet). This amounts to about 0.645 million acre-feet or 2 percent of the 33.8 million acre-feet of the total water applications in California.

The 2 percent estimate does not include water loss through evaporation or evapotranspiration from nonirrigated areas, phreatophytes, and water flowing unnecessarily to saline sinks. Initially this omission may not seem important, because water losses on nonirrigated land are not seen as related to losses on irrigated land. In large arid irrigated areas such as the San Joaquin Valley, most of the water losses on nonirrigated land during the summer originate from irrigation water impound structures, conveyance facilities, or irrigated fields. Local, state, and federal water policy planners need information on how much water can be saved through conservation and what can be done with the conserved supply.

Some studies have placed little or no value on improving the first use of water by increasing efficiency of distribution or field irrigation systems and thereby saving the cost of capital and energy needed to recapture system losses. To be unconcerned about irrigation efficiency, one must assume that virtually all of the field return flow and deep percolation is subsequently recovered and used, and at a fairly low cost.

Ignoring these considerations places one in the position of assuming there is an unlimited supply of free energy. The entropy law states that energy and materials tend to disperse in a system unless acted upon by another source of energy. Thus, as long as energy is limited in supply and relatively expensive, it is important to improve first-use efficiency and avoid spending additional energy to recapture the dispersed water lost from the system through deep percolation and field runoff.

The *California Water Atlas* estimates the amount of water lost from the agricultural system and not eventually recycled by subsequent agricultural operations. The state's agriculture applies about 31.6 million acre-feet per year (1972 estimates). Of this amount about 6.2 million acre-feet are lost in deep percolation, but the Water Atlas assumes that all of this amount is recaptured and used for subsequent irrigation. The Water Atlas also estimates that 7.7 million acre-feet are lost in surface return flows from irrigation operations and water conveyance facilities. Of this amount, 4.2 million acre-feet are eventually recycled and 0.4 million acre-feet are used for saline repulsion. *This leaves a remainder of 3.1 million acre-feet of water lost to incidental evapotranspiration and to saline sinks. These are recoverable return flows that are not recovered, and they represent almost 10 percent of the water applied for irrigation.*

We are not suggesting that irrigation water conservation be undertaken to eliminate 100 percent of the losses, or that return flow systems, canal lining, and pumping from the unconfined aquifer recapture every drop of water lost. Simple economic analysis suggests that conservation practices should be initiated where the additional water supplies created could be transferred to higher-valued uses, or where a reduction in diversions would lower the individual farm's total water bill.

The opportunity for these payoffs exists in the San Joaquin Valley where the groundwater overdraft is about 1.7 million acre-feet according to Davenport and Hagan. Most of the effect of the overdraft is in the southern Valley, and the potential for large water saving exists in the northern Valley. Water saved by conservation could be transferred by existing conveyance and impoundment facilities. The important questions are how much water could be made available by conservation and how the institutional structure could be modified to accommodate such transfers.

A recent study by Daniel J. Dudek and Gerald L. Horner provides additional information on how much water is lost to deep percolation and how much of that deep percolation is actually pumped from the unconfined aquifer and recycled for irrigated agriculture. The study did not, however, attempt to estimate the actual amount of surface return flows recaptured for reuse. By combining the information on surface return flows provided by the Water Atlas and the estimates of groundwater pumping from Dudek and Horner, a total estimate of recoverable return flows that are not currently being recycled is possible (see table at right).

Unrecovered recoverable return flows are the sum of the deep percolation and surface return flows not recycled either for irrigation or saline repulsion. In the state, they amount to 3.1 million acre-feet, or 14 percent of the developed water supply and nearly 10 percent of applied water. The values for the San Joaquin Valley from the Water Atlas are derived from the state totals as a proportion of applied water. By this procedure, the Valley unrecovered recoverable return flows are estimated at 1.6 million acre-feet. However, this assumes that 100 percent of deep percolation is recovered and recycled. A recent federal-state study indicates that a substantial portion of deep percolation may not be recycled, either, because quality is poor or perched water tables are formed and the resulting drainage water is evaporated or exported from the basin.

Dudek and Horner used a mathematical programming model based on 400 soil-specific locations in the Valley. The model was linked to a mass balance hydrology model of the unconfined aquifer for the same soil-specific locations. Data on cropping patterns, water applications, groundwater pumping, deep percolation, and unconfined aquifer depths were used to estimate the amount of unconfined pumping needed to maintain historical aquifer depths. This procedure yielded an estimated 2.32 million acre-feet as unrecovered recoverable return flows, which include estimates of both unused surface return flows and unused deep percolation. This amount is equivalent to 13 percent of the water applied in the San Joaquin Valley and to 17 percent of the developed water supply. Admittedly, this is a crude estimate that could be refined by measuring the incidental evapotranspiration and unused return flows that occur in the San Joaquin Valley.

In conclusion, data from the *California Water Atlas* and a corroborating mass balance study leave little doubt that conserving irrigation water has the potential for supplying a substantial amount of water that could be used in agriculture. To assume that improving first-use irrigation efficiency has no impact on the net supply of water in the San Joaquin Valley ignores the existing data for the region. The Water Atlas indicates that 1.6 million acre-feet of surface return flows are available for reuse, and Dudek and Horner estimate that 1.71 million acre-feet are available from unused surface return flows and another 0.61 million acre-feet are available from unused deep percolation. The total 2.32 million acre-feet are available for reuse in agriculture at various costs ranging from almost nothing to relatively high amounts. The optimal amount of reuse should be determined by estimating the financial rewards for reducing on-farm water use. In comparison, the combined safe yield of enlarged Shasta, Auburn, Cottonwood, and Los Vaqueros reservoirs is 2.26 million acre-feet with costs ranging up to $300 per acre-foot. As an alternative method of meeting the projected deficit, voluntary on-farm conservation has significant potential.

Gerald L. Horner and Charles V. Moore are Agricultural Economists, Economic Research Service, U.S. Department of Agriculture, located at the University of California, Davis; and Richard E. Howitt is Associate Professor, Department of Agricultural Economics, UC, Davis.

What is conservation?

Charles V. Moore

Conservation is often perceived simply as "using less," but most water conservation activities affect the state of the system in three other ways: First, these activities change the time in which the resource is used: for example, a storage dam changes water flows from the time of surplus in the spring to the summer, when water is scarce and has a higher use value. Second, reducing use through more efficient irrigation makes it possible to move the water saved to another location where its value in use is higher. Third, conservation is related to quality, the concentration of existing salts in irrigation water and addition of salts from the soil. Since concentrated salts cause taste problems and shorten equipment life, users of recycled irrigation water and urban wastewater operate at a cost disadvantage in comparison with those in other areas without these problems.

Agricultural water use and return flows in California and the San Joaquin Valley

Source	California	San Joaquin Valley	
	Water Atlas*	Water Atlas*	Dudek & Horner†
	million acre feet		
Developed water supply	21.90	11.33	13.31
Irrigation water applied	31.60	16.35	17.40
Deep percolation	6.20	3.21	2.39
Deep percolation recycled	6.20	3.21	1.78
Surface return flow	7.70	3.98	4.24
Surface return flows recycled	4.20	2.17	2.31
Surface return flows used for saline repulsion	0.40	0.21	0.22
Unrecovered recoverable return flows	3.10	1.60	2.32
Percent of:	%		
water applied	9.81	9.79	13.33
water supply	14.16	14.12	17.43

NOTE: Two other California Dept. of Water Resources studies support these results: *The Hydrologic-Economic Model of the San Joaquin Valley*, Bulletin 214, Dec. 1982, and the State Linear Programming Model, prepared by D. Turner.
* *California Water Atlas*, prepared by Governor's Office of Planning and Research and California Department of Water Resources, Sacramento, 1979.
† Daniel J. Dudek and Gerald L. Horner, "Integrated Physical Economic Resource Analysis: A Case Study of the San Joaquin Valley," U.S. Environmental Protection Agency Research Agreement No. 12-7-16-8-1985, Final Report (forthcoming).

Conservation is often defined as "wise use." This raises the questions of wise use for whom, when, where, and at what cost? Section 102 of the California Water Code states, in essence, that the limited water supply belongs to the people of the state. To maximize statewide benefits (gross state income is one measure), water must be allocated and used efficiently at every level with respect to timing, location, and quality. The ultimate goal of conservation is to use the resource so efficiently that no further change could be made that would increase the net benefits to the state.

Conservation is a concept. Maximum benefits are the goal. What is implemented are practices and investments including additional storage, transfer, water use technology, and water quality factors.

The major institutional impediment to reaching this goal is the failure of laws and institutions to send a clear signal to all water users indicating the true scarcity value of water. Resource economists are in general agreement that a quasi-market for water would be the most efficient method of providing such a signal.

Final users now analyze their investments in conservation based on the nominal charges for water and not on its scarcity value to the state. Increased economic efficiency by the user, whether agricultural or urban, requires that water be treated as any other input in a production process: water should be applied until the cost of the last unit applied is just equal to its unit value in use. Investment in water-conserving activities is optimized in the same way. Economic concepts such as marginal cost pricing are as necessary as engineering technologies if conservation is to be implemented.