EFFICIENT WATER USE IN CALIFORNIA: EXECUTIVE SUMMARY

PREPARED IN PART FOR THE CALIFORNIA STATE ASSEMBLY RULES COMMITTEE AND IN PART UNDER A GRANT FROM THE ROCKEFELLER FOUNDATION

CHARLES E. PHELPS, MORLIE H. GRAUBARD, DAVID L. JAQUETTE, ALBERT J. LIPSON, NANCY Y. MOORE, ROBERT SHISHKO, BRUCE WETZEL

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Rand
SANTA MONICA, CA. 90406
PREFACE

This report is one of seven documenting the findings of Rand's study of water use efficiency in California. The study was commissioned by the California State Assembly in the autumn of 1976 and was supported in part by a grant from the Rockefeller Foundation. Its purpose was to examine current water use efficiency and to suggest ways to improve it. The focus of the study was deliberately set statewide, although particular areas of the state receive attention in some reports. It was not designed to solve problems that have drawn recent attention, such as the 1976-77 drought and its exacerbation of the groundwater overdraft problem in the San Joaquin Valley. Rather, the focus has been widened across a broad expanse of time and across all sources and uses of water. It is a study of long-range water use problems and solutions, rather than of immediately perceived short-term problems.

This report provides a summary of a series of research reports examining ways to improve efficiency of water use in California. The entire series of reports analyzes surface water use and distribution, groundwater management, opportunities for enhanced conjunctive use of surface and groundwater, and water planning within the state. The companion reports are:


*Efficient Water Use in California: Groundwater Use and Management,* by David L. Jaquette and Nancy Y. Moore, with Albert J. Lipson, R-2387/1-CSA/RF, November 1978.


These reports should be of interest to those concerned with California water policy and its implications for other states and the nation.
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I. INTRODUCTION

When California became a state in 1850, the frontier was still open. California had few people, vast open spaces, and large amounts of natural resources. Under such circumstances, it was not necessary for California miners, farmers, and other water users to account for the impacts upon others of their resource uses. Those impacts were in general minimal.

As California has developed from a frontier to a modern society, many of the ways of the frontier have been replaced by complex systems that attempt to maximize total net benefits obtainable from a given set of resources. Some of California’s water laws and institutions have made such a transition, but some have not. These laws have historical roots reaching back into English common law, Mexican pueblo law, and western mining law. These bodies of law were developed under very different principles and for different reasons. The conflicts arising from the different philosophies of these laws have been primarily resolved in our courts, rather than through a systematic restatement of water law through legislative process. The result has been that California water law decisions have been made primarily to protect specific private water using rights, rather than to provide maximum benefit to society as a whole. Unfortunately, because of economic and hydrological considerations, protection of individual interests has not necessarily led to maximization of total benefit to the members of our society.

As will be discussed in more detail below, there exist some important areas of divergence between private water rights protection (as those laws have developed in California) and maximum social benefit. The lack of management of groundwater is almost certainly a case in point. The persistent tying of water use to specific parcels of land is almost certainly another. Overlying groundwater use (the right to pump water for use on the land overlying the basin), riparian surface water use (water for use only on lands touching the river bank from which the water is drawn), and appropriative use specifying the place and the manner of water use are all important examples of legal structures that can reduce the efficiency of water use. As a simple example, in a water-short agricultural area, it is obvious that society is better off if the limited water is used on the most productive soil in order to maximize agricultural output. If the water happens to be tied to poor agricultural land through riparian or overlying groundwater law, or through restrictions on transfer of appropriated water, then agricultural output and farm profits have been reduced.

We must face the important fact that today’s water rights law has been in place for considerable time, and decisions about water use, property investment, and business locations have been made in the belief that the water available under these laws will also be available in the future. Changes in the water law that fundamentally alter this distribution will be met with considerable opposition, particularly if they fundamentally alter the distribution of wealth associated with those water rights. This fact alone compels us to consider the redistributive effects of any changes we might propose in the water law and in the structure and management of the institutions supplying and delivering water throughout the state. To this purpose, we now turn to a more complete description of our water system, the
consequences of its structure, and suggestions for improving the efficiency of water use within that system.

The changes we propose may seem too radical to some, and too conservative to others. Our recommended modifications to surface water law and institutional arrangements, however, are quite minor in an important respect: If the water using community wished to retain its present water use patterns, those patterns would remain largely unchanged despite changes in the legal environment. However, if water users respond—as we believe they will—to the new incentives we pose, uses of water within the state could change substantially. But these changes would all be made through voluntary transactions between individuals, and hence would benefit both parties. The changes we recommend could be accomplished with very little or no modification of existing water users' ability to use water that they currently use.

BACKGROUND OF WATER USE IN CALIFORNIA

Water supply in California is fundamental not only to the way people in the state live, but also to the way many earn their livings. A diverse set of agencies develops this surface and groundwater supply and distributes it to a variety of users, ranging from large agribusinesses to individual apartment dwellers.

Approximately 200 million acre-feet (MAF)1 of water from rain and snow fall in California each year. Approximately 40 MAF of this total are used by man each year; slightly over one-half of the applied water comes from surface water and the remainder from groundwater. Agriculture accounts for 85 percent of all water use within the state, urban users account for 13 percent, and the remaining 2 percent goes to miscellaneous uses.

Nature provides the largest proportion of California's water during winter and spring, whereas the largest demands occur in the summer and fall. Fifty-five percent of California's water supply comes from the northern one-third of the state, but 75 percent of the use occurs in the central and southern two-thirds of the state. Thus, the water system must store water across time and transport it across space to meet the demands of water users.

The complex network of water supply and water users in California has developed over the past century under laws and institutions adapting to changing conditions and circumstances. It is valuable to reassess periodically the effectiveness of this body of law and these institutions. One reason for reassessment at this time is the proposed expenditure of some $3.5 billion for the construction of new water supply facilities for the State Water Project (SWP) and the federal Central Valley Project (CVP).

PURPOSE OF THIS STUDY

The present study was undertaken to assess the implications, for long-term water use efficiency, of current water law and institutional arrangements. We focus

1 One acre-foot of water is the amount that would cover one acre of land one foot deep, or 325,900 gallons.
on the concepts of water rights and how they are used under current practice. Our analysis has shown that the treatment of water rights is one of the most crucial factors in achieving efficiency of water use. When water use rights are assigned in California, the recipient has received something of considerable value, whether these be rights to surface water or groundwater. Our research has indicated that some modifications in the way water rights are treated in California law could lead to increases in the efficiency of water use throughout the state. A very rough approximation suggests that removing existing impediments to efficient use would increase the wealth of Californians by several billion dollars. By contrast, existing water rights and distribution systems (also by a very rough approximation) add some $10 to $20 billion in aggregate to Californians' wealth. We recognize, however, that changes in water rights law cannot be accomplished readily without altering the distribution of wealth in our society. It is this confrontation—redistribution of wealth while making changes that would achieve efficiency of water use—that has made political consensus for any change in the water law difficult to achieve. Thus, we have placed considerable attention on the wealth distribution effects of changes in legal and institutional structures.

In this study, efficiency is defined as the condition where the added cost of supplying water to a water user (the marginal cost) just equals the added benefit (the marginal benefit) to that user. A water supply system can be inefficient because it supplies either too little or too much water, and both types of inefficiency occur in California. Efficiency does not mean that water use has to be reduced; it means only that marginal costs must equal marginal benefits.

All relevant costs to society must be taken into account when calculating marginal costs. In addition to the costs accounted for by the water supply agency or water user, hidden social costs, such as those imposed by water suppliers on others, must also be included. There are several situations, most notably the withdrawal of groundwater, in which private costs diverge from social costs. This study suggests mechanisms for correcting the divergence.

The study findings are reported in detail in separate reports on water rights and water districts, on groundwater use, on conjunctive use of surface and groundwater, and on the planning processes of the important governmental agencies involved in water supply. Our conclusions are summarized briefly next, with relatively brief expositions of the logic and evidence used to derive these conclusions following in the body of this Executive Summary. The companion reports from this study provide a more detailed analysis of the water supply and use within the state, with recommendations set forth in a more detailed fashion as well.
II. MAJOR CONCLUSIONS

There is no general state policy to encourage efficient use of water within California, and in fact there are substantial impediments to efficient use embodied in state water law, administrative decisions, and organizational behavior within the water industry. Significant changes in water law and in organizational operations are required to lead to efficient water use within the state. These can come about only through legislative action in several major areas—surface water development and use, groundwater management and conjunctive use, and planning within the state. The changes proposed in our reports will, if adopted, increase the efficiency of water use in the state. If adopted in piecemeal fashion, the overall enhancement of efficiency almost certainly would be considerably less than if a general reformulation of water policy toward efficient use were adopted. A modification of the state constitution to specify efficient use as at least a part of the meaning of "reasonable and beneficial use" of water would surely enhance and accelerate movement toward efficient use.

SURFACE WATER MANAGEMENT

Water development, distribution, and use within the state have not been efficient. The lack of legal ability and economic incentives to transfer water to its most highly valued uses within the state has meant that water development has sometimes proceeded inappropriately, and that the water available has almost certainly not been put to efficient use. Consequently, some households, industries, and agricultural users have often paid a higher price for water than is necessary, or have simply not had appropriate amounts of water made available to them. This mispricing is a statewide problem, affecting considerable amounts of water use within the state (Schelhorse et al., 1974). Moreover, inefficient water use has likely reduced aggregate farm profits and the value of agricultural output for the state. This can occur when the constraints on water use do not allow the available water to be put to the most productive and profitable uses.

To correct these deficiencies, we propose a set of changes in state law, in the practices of the SWP and of local water districts, and in the pricing and methods of allocation of water in general.

- State water law and water district policies should eliminate prohibitions on sale (transfer) of water both within and between the districts and should facilitate voluntary transfers whenever possible.
- Title to water should be passed from water district to water user in a way that would provide full economic incentives to transfer water to parties valuing its use more highly. Under current water district practice, there is little or no incentive for an individual user to transfer water to more highly valued uses.
- Water should be priced by water agencies at the cost necessary to bring more water into the water system (the marginal cost). Because the incre-
mental water is often more expensive than water from the primary source, this may provide a profit to the water agency. There are several ways to dispose of this profit (which is necessary, since the water district cannot make a profit legally). Use of increasing block pricing (described below) is one technique. For multipurpose water agencies (e.g., cities involved in water supply) the profits can simply be added to general funds.

- The SWP should initiate marginal cost pricing for its own facilities. One way to do this is to sell shares in the output of each proposed facility within the SWP at their true marginal cost. This would avoid the current average cost pricing practice of the SWP, which has led to the proposed construction of facilities with marginal costs up to four times the price that would be charged for the water under current SWP practices.

- Use of property taxes for water project financing should be curtailed in general. Methods of financing that more directly link the payment for water projects with the direct benefits from receiving the water should be substituted, long-term contracts for delivery of specific amounts of water being the most desirable of all.

- In-stream uses of water can be well-served through the appropriation process, although this is not now allowed under California water law. Where private interests are viewed as insufficient to permit purchase of appropriations, public agencies could be authorized to purchase in-stream appropriations from other users. Thus, for example, the Department of Fish and Game or a private trout farm might undertake to establish an in-stream appropriation on a stream to sustain trout populations. Similarly, an organization of outdoor enthusiasts might purchase an in-stream appropriation for such activities as rafting, possibly with some state assistance (if deemed appropriate by the Legislature or the departments involved).

GROUNDWATER MANAGEMENT

Groundwater use throughout much of the state is not well controlled, leading to permanent increases in pumping costs that could be avoided with proper basin management. The theory is sufficiently well developed to allow reasonably accurate calculation of the benefits from basin management (Wetzel, 1978). At present, the necessary supporting data do not exist to make exact calculations, but available data suggest that benefits from basin management would exceed costs in most areas of groundwater use in the state.

Further, the lack of systematic basin management appears to have contributed to the inability of private and governmental parties to optimally employ conjunctive use of surface and groundwater resources. If legal rights to basin storage become more clearly defined, and if mechanisms are devised for distributing some of the benefits to those landowners under whose land the storage is occurring (a basin-rental concept), then there appears to be the opportunity to increase the output of the existing surface water system by large amounts through conjunctive use (Jaquette, 1978). The state has a clear interest in seeing that sufficient groundwater management arises whenever economically feasible because of this potential saving of added surface development costs.
These considerations have led us to conclude that the state policy on groundwater should be modified in the following ways:

- Groundwater basins throughout the state should be brought under basin-wide management (or at least a level of control including nearly all parties in zones of benefit). This conclusion is tempered by the general criterion that benefits of basin management (reduced pumping costs, enhanced abilities to engage in conjunctive use) should exceed the costs of forming and managing the basin control entity. Preliminary analysis shows that benefits substantially exceed the costs of management.

- Groundwater management may logically be indicated even in the absence of surface water substitutes for pumping. The issues of overall water use and groundwater management cannot and should be divorced.

- Political and equity factors lead us to believe that local basin management is preferable to state management.

- We find no distinct advantage of one form of basin control over another (e.g., groundwater management district v. adjudicated basin) and recommend that neither form be required as the sole form of management.

- The state should delineate groundwater basin boundaries so as to avoid either overlap or exclusion of some areas from any defined basin.

- A "general-district" groundwater management act should be established to reduce costs of formation of such districts. These districts should have broad powers to tax, set quotas, and engage in conjunctive use operations.

- Groundwater management cannot accomplish its full potential benefit without controlling pumping directly, either through quotas, pump taxes, or combinations thereof. Massive application of surface imports will not solve the groundwater problem, particularly if the surface imports are subsidized (sold at less than marginal cost).

- If the state constitution is interpreted to require efficient use (through the requirement for reasonable and beneficial use), then the state has a more direct role in requiring groundwater management, including state formation and management of a basin management entity if local entities do not develop appropriate management independently. In this context, we repeat our previous caveat: Groundwater basin management is efficient only if benefits of management exceed costs. Thus, the state should not enter into basin management merely because local management fails to develop, but rather only after demonstrating that benefits appear to exceed the costs of management.

- Other state tools available to induce local groundwater management include reduction or elimination of new or existing surface imports in the event of failure to establish local groundwater control.

- With local basin control including enhanced abilities and incentives to engage in conjunctive use, the state should pursue a more aggressive release of water from the SWP for underground storage. Basin management is essential to achieve fully efficient conjunctive storage.

- Aggressive conjunctive use can be enhanced by improved medium-term (3-to 6-month) weather forecasting. Investments in improving such forecasting techniques appear profitable.
WATER SUPPLY PLANNING

The third area of our analysis involved water planning, especially as undertaken by state, federal, and local governmental agencies. Water planning within the state currently takes place in the absence of any consistent, well-specified goals. Also, the planning process of today is poorly suited to adapting to any changes in water law and institutions that might arise in the future. If a water market were to emerge, the state's planning process would have difficulty in adapting to this new environment.

The planning process within the state's Department of Water Resources (DWR) appears to be primarily driven by the need to meet the SWP contractual commitments to eventually supply 4.2 MAF. The justifiability of project additions on general economic criteria is not considered. Proponents of SWP expansion point to the SWP contract for justification of all expansion, stating that the water users are paying for their total water supply, hence that it must be justified. Unfortunately, the conclusion does not follow from the premise. Since the SWP contract charges only the average rather than the marginal cost for capital used in the system, there is an inherent tendency for overexpansion within the SWP. (Interest-rate subsidies and use of property taxes to help pay for capital costs of the SWP provide further incentives for over-construction in this system.) Since the current contract specifies the pricing mechanism, the only currently available mechanism to correct this erroneous incentive is the planning process, but planning is not used for this purpose.

Our analysis of the water planning within the state has concluded that:

- Consistent long-range goals should be adopted by the Legislature for water use. If efficiency is a desired goal, the strongest way to achieve this goal is to declare constitutionally or by statute that "reasonable and beneficial use" of water requires attention to efficiency of water use. Efficiency would best be defined, in such circumstances, in terms of pricing to reflect incremental costs of water to the water system broadly defined, rather than within narrow project or agency confines.
- To justify project expansion the state should use economic criteria that would require that added benefit from new projects exceed added cost. Use of appropriate discount rates in such an analysis is critical.
- Planning should be undertaken at levels other than the SWP, e.g., to assist local water agencies in their planning, and for groundwater control. Current DWR activities include such efforts. However, added data collection in some areas appears crucial.
- The planning process within the DWR should be made consistent with the structure of whatever type of water market exists within the state. If, as we suggest in our reports, a more active water market is instituted through legal and institutional change, the planning process must be considerably modified to account for such changes if planning is to actually enhance the efficiency of water use in California.
- As a logical part of state planning, the state should seek congressional reauthorization of federal facilities to allow transfer of federal project waters from initial recipients to subsequent users. Primarily because of the restrictions of congressional authorization, federal water planning and
project construction involve considerable use of subsidies to water users, average cost pricing of water (similar to the pricing practice in the SWP contract), and a lack of integration of federal construction of water projects with overall state water interests.

We realize also that the complex nature of water supply and reuse makes it difficult to quantify the benefits and costs of a particular water supply system or a particular water using activity. These are difficult problems to solve at present partly because appropriate data on water uses are lacking, but also because there is little use for such data under current law and administrative practice. A legislative mandate for efficient use of water (marginal benefit equaling marginal cost) would provide incentives to develop data appropriate to such decisionmaking.
III. SURFACE WATER DEVELOPMENT AND USE

Water supply in California comes from two separate and distinct sources: surface water and groundwater. The laws governing the supply and the institutional arrangements by which water is provided differ importantly for these two sources.

Approximately 55 percent of the state's water supply is surface water, developed either by direct withdrawal from flowing rivers or by the use of dams for intermediate storage of river water. The legal rights to use surface water come either through having property literally on the banks of a river, i.e., riparian rights, or through employing a legal process of appropriation.

Riparian users are entitled to use water without specific quantity limits but only on the lands physically contiguous to the surface water source. This, like all water use within the state, is subject to the constitutional requirement of reasonable and beneficial use and subject to sharing equitably with other riparians. Riparian use normally has the highest priority among surface water uses and accounts for about 10 percent of the state's water use.

The remaining surface water use is authorized through a system of appropriation. A specific permit system governs all appropriative water uses initiated after 1914. After receiving permission from the relevant state authority (currently the State Water Resources Control Board (SWRCB)), the user may withdraw a specified quantity of water (usually measured in terms of flow rate, e.g., cubic feet per second) for a specified portion of the year. A change in any of these conditions requires the approval of the SWRCB. Of course, appropriative use is also subject to the criterion of reasonable and beneficial use. Appropriative rights acquired before 1914 do not require such a permit.

Appropriative rights are held in some cases by individuals or corporations, but they are much more commonly held by public entities organized for the purpose of supplying water. The federal CVP, the California SWP, and all local water districts with water rights fall into this category. (In some cases, appropriative rights have originated with an individual and have later been turned over to local water districts.) An agency must obtain an appropriative water right before surface water development may be undertaken. The SWP depends partly on the Feather River for its water, but also substantially depends on unregulated Delta flows. Water is stored in Northern California and the large bulk of it is then transferred to Central and Southern California. The CVP captures water in the northern part of the Central Valley (at Trinity and Shasta Dams) and in other projects farther south in the state and delivers that water to users in both Northern and Central California. The SWP supplies local water districts only, and these local agencies are responsible for the ultimate distribution to users. Nearly all of the CVP supply is distributed in the same way. As with other water within the state, most of these supplies are consumed in agricultural uses.
LOCAL WATER DISTRICTS

There are approximately 1000 local water districts scattered throughout the state. The smallest distribute several thousand acre-feet of water each year, and the largest distribute millions of acre-feet of water. Some districts depend entirely on water supplied by federal or state projects, whereas others partly or wholly develop their own water supplies. Local water districts undertake approximately half of the surface water development within the state. This water, together with that purchased from federal and state developments, accounts for a considerable majority of all surface water development within the state. The remaining development is accounted for by riparian users, mutual water companies, cities, and individuals who appropriate small amounts. Most notable among the cities that develop water are the City of Los Angeles (taking water from the Owens Valley through the Los Angeles Aqueduct) and the City of San Francisco (Hetch-Hetchy Reservoir and aqueduct system).

Revenue Sources

Local water districts finance most of their development and purchase of water by combinations of property taxes, assessments, and water tolls. Power sales and interest on portfolios held by the districts also provide some revenue. Some districts depend wholly on water tolls and others depend wholly on property taxation to finance their operations, but on the average, statewide water districts receive roughly 25 percent of their revenue from property taxation, 20 percent from other sources, and the remaining 55 percent from water tolls (California Controller, undated). The total revenue of water-retailing agencies in California is approximately $0.5 billion per year, or about $25 per acre-foot of water delivered. However, the marginal costs to acquire and deliver water range from about $1 per acre-foot in some agricultural districts to over $150 per acre-foot in some urban districts.

Water Allocation within Water Districts

The mechanisms by which water is allocated for eventual use within water districts vary considerably. In most agricultural districts the right to have water delivered from the district is assigned in proportion either to acreage owned or to assessed value within the district. This right is seldom quantified through contract or law in a form that can be transacted. When a farmer within a water district desires to use water, he typically may request delivery of quantities up to his share of the district's supplies. He pays the water toll per acre-foot specified by the water district board of directors. Costs not covered by the water toll are usually covered by property taxes or assessment.

Water use per acre of land can differ considerably, even within a district, depending on such factors as choice of crop, irrigation techniques, or the practice of dry ranching instead of farming. Thus, water deliveries per acre within water districts are often far from uniform.

Water District Voting: Majority and Minority Interests

Votes within water districts can be allocated either on a per-person basis or per acre of land owned or per dollar of assessed value. Particularly in the latter case,
single entities (or coalitions of very small numbers of entities) can effectively gain control of a water district board of directors. At the extreme, some districts within the state are completely controlled by single corporations or individuals (Goodall, Sullivan, and De Young, 1978).

Inevitably, when a water district is financed partly by property taxes, some persons within the district pay disproportionately large assessments and taxes, relative to water use, and others pay disproportionately little. The mechanisms by which boards of directors for water districts are established allow the formation of majority and minority coalitions, and these coalitions have the potential for using the property tax mechanism to effect a wealth transfer from the minority to the majority interests. The extent to which this occurs cannot be accurately determined in many water districts, but it does occur with some frequency. Of the approximately 50 water agencies we visited during the course of this study, the most disproportionate use of the property tax occurred where 80 percent of the district’s tax revenue came from persons who received only 20 percent of the water. Property taxes are also used as a means to transfer wealth within the Metropolitan Water District of Southern California, where revenue is systematically transferred out of the Los Angeles area and into Orange and San Diego Counties. Property taxation is also used to provide reduced water tolls for agricultural users and to replenish groundwater (see Schelhorse et al., 1974).

Aside from the redistributive potential of property taxes and assessments, their use in water districts also causes a distortion of water costs to the user. Since property tax payments are independent of the amount of water used, only the water toll has any potential for affecting water use decisions. Both economic theory and a substantial amount of evidence support the belief that water users are sensitive to the price of water and will increase their water use when the price is reduced. The sensitivity is least when the price of water is very low and appears to increase as water prices increase (Moore, 1962; Moore, Snyder, and Sun, 1974; Schelhorse et al., 1974).

When the water supply is partly paid for by property taxes—particularly somebody else’s taxes—the price to the user is almost certain to be lower than the costs of supplying that water. These situations result in inefficient use of water: Too much water will be used because of the incentive presented to the user. While there is probably not a lot of “waste,” in the sense that the water users ignore the incentives facing them, the incentives (prices lower than marginal cost) will not lead to efficient water use. Covering of some costs by property tax revenues contributes to the inaccuracy of the signal sent to water users. We therefore recommend that such use of taxation be reduced and eventually eliminated as current property-tax-based bond projects are paid off. New uses of property taxes and assessments to support water development and use should be curtailed, as part of an effort to get appropriate incentives to water users within California. Proposition 13’s passage may enhance the transfer to nonproperty-based funding, e.g., through use of water tolls and revenue bonds rather than general obligation bonds, property taxes, or assessments.

Two arguments have been offered to justify use of property taxation in water supply financing. First, it is argued that the long-term nature of water supply projects makes it impossible to finance the construction without the long-term commitment implied by property taxation. But this argument is misplaced. Private
parties often agree to very long-term projects, with considerable initial capital financing, without resorting to property taxation (an example is the Alaska Pipeline). Long-term contractual commitments can be established between water users and water districts, and between water districts and wholesalers of water, which would solve the financing question without resorting to property taxation. It would even be possible, as is common in private financial markets, to use the equity in property owned by the water users as collateral on the long-term financing arrangements.

Second, it has been argued that all lands within water districts benefit from the presence of water supply even when they do not actually use the water, and thus that all landowners should be required to help pay for the water supply. If, indeed, unwatered lands receive some benefit just from existing within a water district, the landowners could be given the opportunity to pay a standby charge for a possible future right to receive water, or else could forgo the option of receiving future deliveries from the district, as an alternative to mandatory taxation of all land. This should solve problems of equity concerning unanticipated beneficiaries while still retaining the correct incentives for efficient water use. Any charges for standby rights should be related to their cost, not to estimates of enhancement of property values.

Water District Pricing

The next important question regarding water district behavior regards how water tolls are set. Because of the zero-profit constraint on water districts, water is almost invariably priced at its average cost (after property taxes have paid some district costs). In water districts that have two or more sources of water (e.g., local development plus purchase from the SWP), the costs of the incremental supply are higher than the average costs (which include some quantity of lower cost water). Average cost pricing, therefore, results in inefficient water use because the marginal cost of water exceeds the average cost. This would be true even if no taxation were employed by the district. We suggest three possible solutions to this problem.

1. **The water districts could sell all water at full marginal cost.**

   In many cases, the district would earn considerable profits with this policy. Since these profits cannot be distributed to constituent members conveniently, the district would have to use them either for construction or repair of water supply facilities (which may not necessarily be appropriate) or to reduce taxes and assessments. However, it might not be possible to reduce taxes sufficiently to redistribute all profits, particularly if the district has not been relying heavily on taxes. The district’s board of directors might not consider this a desirable course of action, in any event.

2. **An increasing marginal block pricing structure could be used.**

   If water districts were to price a given initial amount of delivered water at a low price (as low as zero) and then charge all users the full marginal cost for additional water, efficiency could be achieved for most users, while still meeting the zero-profit constraint. The "profit" of the operation would be distributed to each water recipient by virtue of the minimal (or zero) charge for initial quantities, but efficiency
would still be induced through the price of the highest block. Two problems remain with increasing block pricing, however. First, if there is wide diversity in the amounts of water required by different users, there may be substantial disparities in the distribution of "profits," relative to current distributions. (With average cost pricing, distribution of economic profits within the water district is proportional to water use, since the most expensive water is sold at less than marginal cost. With marginal cost block pricing, the distribution is independent of total water use.) Thus, large water users may strongly object to such a mechanism. The alternative of tying block pricing to acres irrigated—that is, allocating one low-priced block per acre of land irrigated—would solve this political problem. For example, the first, say, 2 acre-feet of water per acre irrigated might be delivered at no charge, then all subsequent water per acre would be priced at the marginal cost of water. Unfortunately, this mechanism implicitly subsidizes irrigation of additional land and thus presents some problems from an efficiency standpoint. On net, however, the concept is likely to enhance considerably the efficiency of water use within water districts. Finally, we should point out that adoption of increasing block pricing cannot alone solve the problems of water use efficiency in the state, as generally desirable as such pricing might be. This is true because the use of increasing block pricing leaves the problem of cross-district cost differentials unsolved. If two water districts face different water supply costs—for example, because of the history of water rights and development undertaken by each—trading between them would improve efficiency and could provide gains to water users in both districts. But even the use of increasing block pricing within each district would not lead to such trading. Thus, an alternative mechanism should be considered to achieve efficient water use in California.

3. A third solution is to have water districts issue contracts for specific amounts of water delivered to each of its "large customer" constituent members or issue options that would be freely tradable within and across water districts.

This would require only simple changes in present water district operations, since districts must now know generally how much water is to be delivered to each user. Water district laws would need to be modified to remove specific prohibitions against the sale of water outside of the district. It may be necessary to make cooperation among districts, whenever technically feasible, a legal requirement, since some water districts may be loath to accommodate movement of their water supplies outside of district boundaries. All costs incurred for any transfer of water should be paid by the parties involved in the transfer; this will eliminate requests for transfers where costs exceed benefits.

**Implementing a Water Market**

The intent of this proposed modification in water district operation (item 3, above) would be to establish sufficiently firm rights to water use that sales or trades of those rights could occur at the level where water use decisions are made. This means that the largest water users (usually farmers) would have the option of selling some or all of their water supplies to persons who value them more highly (to other farmers, for example), retaining the economic profit from such sales.
Because the water district member would be given clear title to the water, he would have a full incentive to make such transactions when they were appropriate.

Under current institutional arrangements, there is little or no incentive for such sales to occur, even when they would be highly valuable to society. Water districts have little or no incentive to make such transfers on a uniform basis, and large water users have little or no legal ability to sell water outside their water districts. Only if the water user is given a reward for changing his water using patterns will such transactions occur in any significant number. Even the removal of current barriers to such transactions will not induce trades and sales unless the water users can see clear benefits from reducing their water use. Our proposed mechanism would provide the correct incentives.

Under this proposal, each water district would issue shares of each of its water sources to each "large" water user within its district. (Small users would probably best be served with some sort of on-demand system, using marginal cost pricing or increasing block marginal cost pricing, in order to minimize total transactions costs of operating the water district.) The assignment would be made contractually, with no specific restrictions on resale of the rights to use that water embedded in the contract. The water user would then be able to use the water (typically about the same amount of water he receives under district operations) or sell the rights to use the water to another party. Some such sales would require approval of the SWRCB under current legal practice, particularly if the buyer were located such that the point of use would be different. Some water sales, probably most within a given water district, and possibly all within single project systems (e.g., the SWP, the CVP—but see below for other complications), and all sales of pre-1914 appropriate rights could likely proceed without such approval being required.

There are some potentially important legal issues to be resolved before such changes could be implemented. For example, issuance of water use "shares" to lands within a district not now receiving water deliveries might be challenged as nonbeneficial, although sale for reuse has been declared as a beneficial use of water in at least one court decision. The method of assigning shares might also be challenged, no matter what basis was chosen. Because water districts that hold water rights are said to hold those rights in trust for the landowners within the district, it may be that the only legally feasible method of allocation is proportional to land area. (See Phelps, Moore, and Graubard, 1978, for a further discussion.)

Finally, certain changes in the water district laws would have to be made, along with changes in operating policy of the SWP and the CVP, if all potential water sales were to be carried out. Some water district laws forbid sales of water outside the boundaries of the district, and others only when that water is declared "surplus." The SWP has an operating policy at present of not allowing sale of SWP water to noncontracting agencies. Finally, the restrictions inherent in the operation of the Bureau of Reclamation's CVP appear to be considerably binding at present. The limitation that the water be used only on "family farms" is one obvious constraint on water transfers, despite the current frequency with which that restriction is violated under grandfather clauses. Additionally, the CVP claims title to return flows from water used by its customers once that water leaves the area of use. To allow completely free transfers of CVP water, some reauthorization or modification of CVP operations would likely be required.

The methods chosen for the water district to price the shares of water sold would in some cases be important, even if there were free trading of water supplies.
allowed. Some users will not be physically in a position to sell their water, or there may be only a few potential buyers able to receive that water. Thus, any continuation of inappropriate water pricing to such water users would lead to inappropriate amounts of water use by such entities.

In cases where there are multiple sources of water within a water district, it will probably best serve the cause of efficiency if shares in each water source are treated separately, and each sold at their full marginal cost. For example, if a water district has a fixed supply of its own water (say, 100,000 acre-feet) from an appropriate right at a cost of $6 per acre-foot, and purchases an additional 50,000 acre-feet of water from the SWP at $24 per acre-foot, then appropriate pricing would be to sell shares in the first 100,000 acre-feet at $6 per acre-foot, and the remainder at the full cost of $24 per acre-foot. The alternative would be to blend the sources together and charge the average cost of $12 per acre-foot. Such a pricing system would enhance the amount of SWP water demanded by the water users within the system, because they would incorrectly view the marginal cost of water as $12 per acre-foot rather than $24. Particularly if such water could be sold to other water users at a higher price, there appears to be little reason to continue to subsidize the purchase of the more expensive source through average cost pricing.

The pricing mechanism indicated above would guarantee that the local water district remain nonprofit, while still charging water users the full marginal cost of water supplies. However, it is the clear assignment of title to the water supplies—the key element of our recommendation—that will lead to significantly enhanced efficiency through water transfers.

**Consequences of Establishing a Water Market**

There is still the question of whether a substantial number of transfers would occur under this proposed modification of water supply arrangements. Available evidence indicates that there would be. First, during the drought year of 1977, a series of transfers occurred that (with very few exceptions) had two important characteristics in common: (1) The users who offered their water for sale held clear title to the water, and (2) there was generally no need to deal with a change in appropriation through the SWRCB for the transaction to occur. The water sales generally fell into three categories: sales of water from individual farmers (with individual water rights) to the Bureau of Reclamation water bank plan, intradistrict sales of water from farm to farm, and sales of pumping rights within adjudicated basins in Southern California. All sales across water district boundaries were made by persons holding clear title to the water, and SWRCB approval was unnecessary. The almost total lack of sales when either of these conditions was missing is strong evidence of the importance of the incentives.¹

¹ Perhaps the most important counterexample was the sale of over 400,000 acre-feet of water by the Metropolitan Water District of Southern California to the DWR for distribution in their drought relief program. The water was sold at a cost just sufficient to pump replacement supplies from the Colorado River. Thus the economic profit associated with the water made available was passed on to the eventual recipient. The Metropolitan Water District appears to have made the water available as a gesture to enhance the chances of passage of a major water construction bill that was pending in the Legislature at the time.

There are also numerous sales or transfers of water within some water districts; these are often accomplished informally through rental of land from one farmer to another, with subsequent transfer of water from one parcel to the other. Such sales can achieve only a fraction of the potential benefits of unconstrained transfers.
Further evidence about the potential supply of water to be made available for transfers can be deduced from studies of demand for water. These studies show that the amount of water desired for use in agriculture, industry, and residences is sensitive to the cost of that water. For agricultural water users, that sensitivity (the demand elasticity) increases as the price becomes higher (Moore, Snyder, and Sun, 1974; Moore, 1962). When one water user can sell water to another user, the relevant price of water to him is not what he paid for it, but what he can obtain for it by selling it. Thus, if water has been acquired from a water district for $5 per acre-foot, but another water user is willing to pay $30 per acre-foot for it, the original water user’s decisions about water use will be strongly influenced by the price he can get for selling it. That user will keep enough water to satisfy his demands at the $30 price and will sell the remainder to maximize his net revenue. For agricultural and industrial users, this is simply a question of maximizing profits. The magnitude of response to changing water prices is considerable, although there is still some uncertainty about the appropriateness of the available estimates. (See Schelhorse et al., 1974, for a summary of this literature.)

In particular, these estimates all assume that the price of land is fixed, when in real life it will likely vary as water prices change. Moving from a $5 per acre-foot water price to a $20 per acre-foot price would likely alter the responsiveness of water demands to price, potentially rendering inaccurate the existing studies. For purposes of this policy analysis, this means that there is no reliable way to estimate accurately the magnitude of response to increased transferability of water, although there remains good reason to believe that the response will be significant. (Transfers occurring during the 1976-77 drought are cataloged in Phelps et al., 1978.)

**Phasing and Timing of Transfers**

Available evidence suggests that a system such as we have proposed may lead to substantially larger volumes of water being traded throughout the state than occurs at present. Given that the state has little experience with such a system, there may be strong political pressure against its institution, if for no other reason than fear of the unknown. Some communities may fear a massive sellout of water, leading to considerable structural changes in local economies. Several factors suggest that this will not happen. First, it appears that the economics of farming will make massive transfers of water away from any one area uneconomical to the individuals making water use decisions (see Hedges, 1974). A more likely adjustment is modification of cropping patterns and intensity of irrigation on available land.

Second, there are physical limitations on how much water can be transported to other areas, because of the capacity constraints on the canals of the SWP and the CVP. However, if these economic and physical constraints seem too frail, legal constraints can also be imposed. One such constraint would be to increase the size of allowable transfers slowly, for example, by allowing a water seller to transfer only 25 percent of his water in the first year, 50 percent the second year, 75 percent the third year, and then unlimited transfers in subsequent years. This would give ample time to observe the effects of the transfers and take action if undesired side-effects arose.
A second legal constraint possible would be to limit over time the cumulative transfers that any individual or corporation might make. For example, a limit might be set that no more than half of a person's total water allocation could be transferred out of a basin in any 10-year period. While this might allow 100 percent transfers in any year or series of years (e.g., a multiyear drought), it would prevent a massive movement of water, and hence of economic activity from the region. If such constraints are imposed, it would also seem wise to eventually phase out or relax them, so as to eventually allow more complete transfers. Both the time-phasing and the general cumulative transfer constraint could serve to protect the surrounding communities from immediate and precipitous changes in the economic activity of the areas that might occur with a large and sudden transfer. Although our analysis suggests that massive transfers out of a given region would not occur, we do indicate how protections of local community interests can be built into a transfer system.

The Political Aspects of Water Transfers

We had earlier discussed briefly the legal implications of reassigning water rights to individuals, and allowing those rights to be resold freely. In addition, there would appear to be at least two types of political problems associated with such a system of water transfers. There is first the internal problem within a water district of how to assign title to the water. While there is some indication from previous legal decisions that such assignment would have to be made proportional to the amount of land owned, other systems may evolve. Voting systems within each water district may prove to be important in such decisions, and the differences between land-based voting and per-person voting districts may lead to considerable difference in the types of processes chosen to assign the water rights.

The magnitude of wealth involved is considerable. For a typical 160 acre farm receiving 4 acre-feet of water per acre of land, the assignment could involve some 640 acre-feet of water per year, which could have a resale value of nearly $13,000 if the water price at the Delta rose to $20 per acre-foot. (The proposed expansions of the SWP would cause water to be considerably more expensive than this, even with the current SWP contract.) The present value of receiving that amount of water forever would be nearly $180,000 at a discount rate of 7 percent.

The magnitudes of wealth involved suggest a potential second political problem. Parties outside the water industry may perceive that the state, by moving to a water transfer system, has in fact given something of substantial value to the persons who initially receive water allocations. In fact, there would not really be new wealth created by such a change, and careful assignment of water title could even allow the current distribution of that wealth to remain unchanged. What would happen is that the wealth could be converted into money, rather than forcing the recipients to use their water allocations (perhaps inefficiently) on the land to which they were originally allocated. Breaking the tie that currently exists between land and water will create new wealth only through elimination of inefficiency. It is important to understand that most of the potential wealth arising from water use now exists; it would only be made more visible in a water market.
WHOLESALE AGENCIES

In considering how a water market might function, two particular problems should be mentioned regarding the role of the major wholesale water agencies in the state, i.e., the SWP and the CVP.

A major problem regarding the SWP is the pricing of new water storage facilities. The current SWP contract specifies that the price of new capital facilities must be averaged in with the price of older, cheaper facilities, so that all entitlements to firm-yield water delivery are priced at the average system cost. The current Delta charge (which primarily pays for the Oroville Reservoir system) is under $10 per acre-foot of firm yield per year. Proposed expansion of the SWP could have costs of up to $245 per acre-foot. Marginal cost pricing would yield a substantial amount of economic profit to the SWP. However, the current SWP contract specifies that the economic profits from this system must be used only for construction of future projects, and those profits are distributed in proportion to water use.

Two solutions to this problem are possible. First, if the SWP is to maintain its zero-profit policy, a preferable pricing system would be for the SWP to sell shares in each of its facilities to contracting water districts, each facility being priced at its own costs. It would be necessary to allocate shares in the yield of existing facilities (e.g., the Oroville Dam), but this could readily be done on the basis of final firm-yield entitlements. (Under the above-proposed modifications, each water district could in turn allocate its shares in each SWP facility to its constituent members and could allow the rights to water from those shares to be bought and sold freely.)

An important feature of this proposed amendment to the SWP contract is that if the contracting water districts decided to retain precisely their current demands for firm water, their average cost of water would be unchanged. However, we believe that water districts, responding to the wishes of their members, would reduce their demands, turning instead to alternative sources of water supply. (One likely source is transfers of water from existing water users.) The point is simply that the contracting water districts collectively cannot be made worse off by such a proposed change in the contract. However, individual contractors may find such an arrangement unpalatable, for a variety of reasons, and may wish to maintain the current contract. This contract specifies an open-ended cost arrangement for the contractors, which leads to the unusual circumstance that the SWP is proposing to build facilities with marginal costs 5 to 10 times larger than the marginal value of water to the recipients. Whether such a contract could withstand a legal test on the constitutional issue of reasonable and beneficial use of water is a question we cannot answer here.

A second alternative arises if the local water districts—the customers of the SWP—are required by law to price at marginal cost. Then, it would be sufficient for the SWP to provide data to their customers on actual marginal costs of water from the SWP. The pricing within each district would then lead to correct amounts of water being chosen by each water user. But, as discussed earlier, such pricing may be difficult to achieve in current water district operations.

The CVP presents the same problem as the SWP in terms of average cost pricing (rather than marginal cost pricing) of water supply facilities. In addition, CVP practices include direct and deliberate subsidies to farms. We propose that the State of California seek to modify the authorization of the CVP and other relevant federal projects. Our proposed reauthorization would establish rights of current
"family farms" to receive subsidized water from the CVP, but with the allocations made specifically to farmers, either directly by the CVP or indirectly through local water districts (by means of the mechanism discussed above). Two key changes in the authorization would be (1) to allow those shares to be sold and (2) to have the CVP forgo rights to the return flows of water produced under CVP operations. Return flows are now contractually specified to belong to the CVP. This would allow the small family farms to continue to receive the subsidy they now have but would allow for more efficient use of the state's waters through the gains from voluntary trades and sales that would occur.

IN-STREAM USE

Some uses of water take place in the actual natural environment of the stream or river, rather than through diversion. Indeed, the pleasure of seeing and hearing a flowing stream is one such use. Important commercial in-stream uses include fisheries and fish-hatching areas. Other types of in-stream use include river rafting and kayaking, recreational fishing, and provision of environmental habitat for other forms of wildlife (e.g., duck ponds). Current state law deals only sporadically with such uses and generally places them in an inferior position to consumptive out-of-stream uses. The most important recognition of this is the current legal requirement that an appropriation of surface water exercise physical control of the water, for example, by diversion or use for hydroelectric generation. In recent court decisions (California Trout v. SWRCB and California Department of Fish and Game v. SWRCB), it was held that an in-stream appropriation for maintaining fish populations could not be issued. The appellate court decisions indicated that such an action would "eliminate piscatorial purposes from the balancing process prescribed by the Legislature." They concluded that "A grant of prior instream appropriation rights to the department [of Fish and Game] would tie the [State Water Resources Control] Board's hands as to future uses. The water appropriated by the department would be unavailable for other yet unforeseen and overriding uses."

We have concluded that there is nothing particularly inconsistent with current policy and the use of in-stream appropriations, so long as the appropriations are sufficiently transactable. Thus we urge consideration of a statutory change allowing in-stream appropriation. Under such an arrangement, for example, a private trout fishing farm could maintain in-stream flows for fish-hatching that might otherwise be unavailable. Such flows could either be acquired from the state or purchased from other water users. There may be cases where the state feels that the interests of in-stream water users are too diverse and too spread out to lead to appropriations being filed under such a system. Allowing various state departments (e.g., Fish and Game) to file for appropriations on behalf of the public, or to purchase them from other water users, would provide some in-stream use protection. The benefit of such a system from an efficiency point of view is that the value of the water to other users (e.g., farmers, factories, or city dwellers) would be directly faced by the potential appropriators of the water for in-stream use. While budget increases would be required, for example, for Fish and Game to finance purchases of such appropriations, we feel that this is an appropriate signal to send to in-stream users. Such budget increases could be made from general funds or from increased user fees (e.g., fishing or rafting licenses) at the discretion of the department and the Legislature.
IV. GROUNDWATER MANAGEMENT

THE ISSUES

Groundwater use and control are at least as important for water use efficiency within the state as are the issues involving surface water use. In our studies of groundwater management, we have surveyed existing practices, studied the conceptual gains from achieving management, and considered legal and administrative mechanisms by which such management might be achieved.

The gains from groundwater management arise for two distinct reasons. The first, and perhaps the more prominent in past studies of groundwater use, is control of the "common pool" groundwater problem. Stated simply, each groundwater user within a given basin inflicts costs on other pumpers by his own pumping. These costs arise because the groundwater table is lowered by each extraction of water, thus increasing the pumping lifts faced by other pumpers in the basin. The private pumping decision does not take into account the costs imposed on others, but only privately perceived costs. Thus the costs to society of groundwater pumping are systematically larger than the costs perceived by each individual. Establishing an explicit management plan that takes into account the differences between private cost and social cost is the only way to correct the loss in efficiency.

The other way water use efficiency could be improved through better groundwater management is through enhanced conjunctive use of groundwater and surface water. Under existing groundwater operations, it is difficult to reach agreement about how much groundwater to store temporarily underground for later use, by whom it should be stored, when it should be extracted, and by whom it should be used when extracted. If a groundwater management organization or entity is empowered to manage a basin, not only in terms of rates of extraction but also in terms of use of the basin for storage of imported water, then gains in overall water use efficiency can be obtained. In a simulation study of reservoir management strategy, our research found opportunities to produce substantial increases in the firm yield of the state's water supply system through more aggressive conjunctive use.

CURRENT GROUNDWATER MANAGEMENT

A variety of management tactics to control groundwater exist throughout the state, some involving direct controls of rates of extraction, others involving groundwater extraction taxes, and still others involving replenishment of groundwater through importation of surface supplies. These management activities have been undertaken by local water districts, by special water agencies, and by management entities established through agreements reached among pumpers within a groundwater basin.

The most common form of groundwater management throughout the state is simple replenishment of groundwater with surface water, when it is available at a sufficiently low price. Such activities are undertaken by a large number of local
water districts, particularly throughout the Central Valley and Southern California.

Our research in groundwater management strongly supports the conclusion that the full benefits from groundwater management cannot be achieved without controlling extraction rates, either directly (by quotas) or indirectly (by taxes on pumping). Without such control, the common pool problem will continue to make water use inefficient within any basin. Thus we consider replenishment alone as only partial management and unlikely to achieve a fully efficient level of groundwater management and use. (See Jaquette and Moore, 1978, for a discussion of these activities.)

The state has a number of groundwater management plans, almost exclusively in Southern California, which directly control rates of extraction. These plans are primarily formed through court adjudications of groundwater pumping rates, following upon a period of pumping finally viewed by basin users as self-damaging. These adjudicated basins have been successful in controlling pumping in their regions using a wide range of administrative and legal solutions to the common pool problem. Indeed, one could almost say that no two forms of groundwater management are alike within the group of adjudicated basins, as one might expect from the diversity of user profiles, hydrology involved, and compromises necessary to obtain legal settlement of the issues. Some of the basins impose a direct quota on extractions and allow these quotas to be traded or sold freely among users within the basin. (We discuss below the importance of trading the quotas.)

Another prominent groundwater management operation in Southern California is the Orange County Water District (OCWD), which was formed specifically to control groundwater extraction within the Santa Ana River Basin. The OCWD's primary tool to limit pumping is a tax on groundwater extractions, coupled with use of tax revenues to reduce the cost of surface water imports for those using less than the basin average mix of groundwater to surface water.¹

Important analogs to groundwater management exist in the area of crude oil extraction. In large fields, owners almost always agree on extraction rates to control individual incentives to overpump. This concept is known as "unitization," and is directly comparable to the concept of groundwater management to control extraction rates of water. Similarly, compensation to large numbers of homeowners for (individually) small amounts of mineral rights is often undertaken by oil companies. This is an analog for compensation of landowners renting out basin storage space for conjunctive water use.

A more complete description of groundwater management activities is contained in Jaquette and Moore (1978) and in Lipson (1978).

THE CONCEPT OF OPTIMAL GROUNDWATER CONTROL

While existing groundwater management practices have achieved much, there remains still an area with potentially large gains in efficiency of water use through

¹ The use of tax revenue to reduce the cost of surface water was chosen to sustain most or all water using activities within the OCWD area even while groundwater extraction was being reduced. This system, while reducing groundwater use, has the unfortunate effect of increasing overall water use within the OCWD beyond what is efficient. This occurs because the subsidy reduces surface water prices to a level below the marginal cost of delivering the water.
more extended groundwater management activities. The available literature on optimal groundwater management is summarized and extended by Wetzel (1978); the key consideration is that a centralized decision process is necessary to make truly optimal decisions about pumping rates in order to achieve maximum efficient use of a groundwater basin. A simple illustrative example follows.

Let there be 100 identically sized farms overlying a single basin. One pumper is considering extracting an additional acre-foot of water, which will increase his gross revenue by $100. The pumping will add to his total pumping costs by $85, so that his net marginal revenue is $15. The pumper perceives that by pumping this water, he will increase his own groundwater pumping costs slightly in all future years (since the water table will have fallen slightly); the present value of those future costs is $.20 for each acre-foot he pumps today. Thus, the net benefit to this farmer of pumping an acre-foot of water is $14.80. But the reduction in the groundwater table also imposes a cost on each of the other 99 farmers in the basin—also $.20 present value for each. Thus, the overall true cost for pumping the acre-foot of water is the sum of $85 of private costs for the farmer, and $20 total increased future pumping costs for all of the 100 farmers in the basin—a true total cost of $105. Since only $100 benefit is produced, to pump the water is not truly efficient. Yet the farmer in the example will want to pump the water because it appears to be an efficient and wise choice from his own perspective.

Society would be better off if the water were not pumped, because the cost savings from future pumping for the basin as a whole exceed the gains to the individual. A tax of $20 per acre-foot, if levied on all basin pumping, would equalize private and social costs. It would lead to more efficient decisions being made about water use. If the value of using the water today rose above $105, the farmer would still choose to pump it, but it would then be a truly efficient decision. If future conditions changed so that the future pumping costs rose to $30 total, rather than $20, then the tax should also be increased to $30. The optimal tax is determined by the costs imposed on all basin pumpers.

In this example, a tax of $20 must be collected to ensure correct decisionmaking where the net benefit is only $5. (There is a $20 saving in future pumping costs, but a loss of $15 in extra farm revenue this year.) This demonstrates the importance of redistribution of the tax proceeds in making each and every pumper better off. With careless redistribution, he would be worse off and would not voluntarily comply with such an arrangement. Mechanisms to redistribute the pump taxes include property tax "rebates," per-capita distributions, and distributions based on past groundwater use, to name only a few.

IMPLEMENTING GROUNDWATER CONTROL

A wide variety of organizations exist in California that have the power to control groundwater extraction. The most predominant form has been an adjudication, where agreements are reached setting pumping rates for each groundwater pumper. In many of these operations, explicit quotas are set forth each year for every pumper in the basin, quotas that in some basins may be (and are) readily bought and sold. Other adjudications rely on combinations of taxation and quotas. (See Lipson, 1978, for detailed descriptions and analyses of these systems.)
In other cases, water districts have been used to manage groundwater. These districts are empowered to levy extraction taxes, but the taxes have been used to raise revenue for replenishment rather than to control extraction. In no case we have studied are such taxes set explicitly to control pumping optimally. The important messages to be learned from these agencies are:

1. There are multiple ways of achieving groundwater management involving extraction control, with no one way dominating others in terms of efficiency of operation or efficiency of water use.

2. Local water users may find considerably different management vehicles attractive, and without negotiated agreement among pumpers, no management is likely to be instituted.

3. The costs of forming a management organization can be substantial.

In the adjudications studied by Lipson (1978), adjudication costs ranged from several hundred thousand dollars to $5 million. In more complex cases, the costs of adjudication (if that is the path chosen) could be well above historic figures, but recent adjudications were completed with significantly lower costs and in much less time than earlier efforts (Lipson, 1978). To determine whether or not basin management is truly desirable, one must compare likely benefits from basin management with costs of management.

GROUNDWATER MANAGEMENT BENEFITS—ACTUAL PRACTICE

While the theory strongly supports the belief that groundwater management that controls extraction rates is beneficial, it is more difficult to derive actual estimates of benefits that might be obtained through management in currently uncontrolled basins in California. One available study (Brown and McGuire, 1967) provides some estimates for portions of the Central Valley’s Kern River area. Converting their estimates into current dollars and extrapolating to the entire Tulare/San Joaquin/Delta-Central Sierra region (with 9 MAF annually pumped in those regions), it seems that benefits would be at least $45 million per year in pumping costs forgone even if the average benefit were only one-quarter as large as that estimated by Brown and McGuire for their study region. If per-acre-foot benefits were as estimated by Brown and McGuire, then annual benefits for the lower Central Valley area would be at least $180 million per year. In addition, electricity and fuel costs have increased over twice as fast since the Brown and McGuire study as have other costs, so that actual benefits are very likely to be substantially higher than their estimates. The present value of having an annual saving of $180 million (using a 7 percent discount) exceeds $2.5 billion. It is a figure such as this which should be used to consider whether or not it is worth the legal and administrative costs to form and manage groundwater pumping controls in these basins. These estimates are very imprecise and are subject to considerable variation as the price of surface water, the value of crops, the discount rate chosen, and pumping costs vary. (For further detail, see Jaquette and Moore, 1978.)
POLITICAL CONSIDERATIONS FOR GROUNDWATER MANAGEMENT—DISTRIBUTION OF WEALTH

Almost any mechanism selected to control groundwater pumping has the potential for considerable redistribution of wealth, either among pumpers within a basin, or even to persons outside a basin. The simple fact that many basins are not controlled throughout the state, even though it is generally believed that control would be beneficial, suggests that redistribution issues may dominate the decisions about support of or opposition to groundwater control. These issues are important no matter what form of management is selected.

If a system of control is selected that utilizes quotas, the distribution of the quotas determines the wealth of the basin pumpers. If these quotas can be traded freely among pumpers, then the most efficient use of water within the basin can be achieved, even if the initial quota assignment does not itself provide for efficient use. Without free trading of quotas, the initial assignment of quotas would not only determine the wealth distribution but also would adversely affect efficiency of water use. It is important to realize that the initial assignment of quotas (property rights to pumping) can make or break any basin control plan politically and, thus, must be undertaken with considerable care, probably involving extensive negotiation with basin participants. Experience in California over the last 30 years underscores this problem.

Use of a pump tax presents a similar problem. If the tax is set for optimal basin extraction patterns, the revenue from the tax can often exceed considerably the pumping costs saved through basin control. Thus, the redistribution of that tax will determine political support or opposition surrounding the use of the tax. In many existing water districts, tax revenue can be used only to reduce the price of surface water purchased by basin participants, either for direct use or for groundwater basin replenishment. (The OCWD is constrained this way.) Because of the limited abilities to redistribute the tax, it is almost certain that the basin tax level has not been set to determine the optimal pumping rates, but rather to determine how much surface water should be subsidized to reduce groundwater pumping. The overall effect of such operations is certain to be an overuse of water within the basin because of the subsidy to use of surface water, even though the groundwater basin itself may be controlled in an equilibrium involving no further overdrafting. In general, basin pump taxes used to purchase replenishment water have been set in order to support a fixed level of replenishment, rather than being chosen to optimize basin pumping rates. The inability of the water district to redistribute the receipts from pump taxes in some nondistortive way has led to reduction in the overall benefits that might be obtained from basin management. One method to reduce this problem is to assign quotas to existing pumpers and to require a tax on any water pumped in excess of that base quota. By this mechanism, the actual tax receipts are minimized, while basin pumpers all (or nearly all) find that they face the correct social cost when making decisions about pumping rates.

The issue of potentially reduced water use following introduction of groundwater management also looms large in the political debate surrounding groundwater management in California. Current groundwater users have always taken the position that surface imports are necessary to replenish the groundwater supply,

* This is not meant to imply that temporary overdrafting is necessarily undesirable.
and that it is desirable always to maintain the existing level of water using activities through such imports. But such a position cannot be considered accurate in general. Consider the typical time path of water use in a basin. New pumpers enter a previously unpumped area and find the water table relatively near the surface, with water typically low in cost. (In California, it costs about $1 per acre-foot of water per 10 feet of lift. Thus a 30-foot lift is equivalent to about a $3 per acre-foot pumping cost.) At such low water prices (compared, say, with imported water costs of $30 per acre-foot, for an example), there is considerable incentive to mine the groundwater basin. Indeed, this is generally a desirable thing to do. But in concept, water using activity could arise that places a marginal value of only $3 per acre-foot (to use our example) on the water. As the groundwater table falls through systematic mining, the pumping costs would increase to $5, $10, and finally to $30 per acre-foot. (At this point, it would be just as cheap to import more surface water at $30 per acre-foot.) Some of the water using activity that depended on water costs of $3 per acre-foot will have vanished. Some water using activity that could be sustained at $25 per acre-foot will eventually become impractical, but in an interim period, it would be profitable to carry out such uses.

A pump tax, or a quota system, will hasten the day when such ultimately unprofitable pumping activity ceases. In so doing, it will cause the water user who is “eliminated” to lose profits but will save all future pumping costs for those pumpers remaining in the basin. Thus, it is not necessarily desirable to continue all historical water using activity within the basin.

We can think of no circumstances under which it would be desirable to guarantee $3 per acre-foot water forever to those water users who first entered basin pumping on the premise that water would cost $3 per acre-foot to pump. Indeed, to state the reverse highlights the case: We cannot think of any circumstances under which it is desirable to spend $30 per acre-foot for water to support all future use of water that is valued at only $3 by the water user. The same statement can be made for any value of water use less than the cost of supplying it. Efficiency requires that marginal benefit equal marginal cost. If water is valued at less than its true costs of supply, then that use is inefficient. To argue that all historical groundwater uses should be maintained through surface imports is tantamount to arguing that inefficient water uses should be sustained because there will of necessity be water users within the basin who value the water less than its full social cost.

Groundwater management will almost invariably lead to eventual cessation of some water uses where the water is least valued. This complicates the wealth distribution problem raised earlier. One must ask how much of the gains from pumping control will be shared by those persons who are not involved in the final equilibrium pumping activity. Pumpers who forgo pumping to bring the basin into control, whether because of a pump tax or because of a quota system, are “paying a price” to reduce ultimate pumping costs for those who remain in pumping activity or for new pumpers. The same point can also be stated in reverse: Even those who eventually exit from pumping activity are currently imposing a cost upon those who ultimately remain pumpers. This is true because their current uses of groundwater, while profitable on the basis of individual calculations, in fact impose added pumping costs on other pumpers. The “marginal” pumpers exist today only because of the lack of appropriate calculations of true costs of pumping. Nevertheless, these pumpers do indeed exist, and their existence raises the question: “Who should share in the gains from pumping control?”
In concept, this appears to us to be the ultimate political question regarding groundwater basin management. In basin management in Southern California, the problem has frequently been resolved through imports of surface water to allow all water using activity to be sustained, but we repeat that this is not necessarily the only, or even a desirable, solution. The water using activity is desirable only if the marginal benefit of the water matches the marginal cost of supplying it. Various mechanisms to control groundwater pumping already exist within the state by which eventual nonpumpers can be allowed to share in the gains from basin control, even if their water using activity ceases. Under a quota system, for example, each existing pumper can be issued quotas for pumping that can be sold to those who eventually choose to pump the groundwater. Receipts from the sale of quotas are one compensation for those who forgo pumping to achieve basin equilibrium. If pump taxes are the form of control, then the tax revenues could be used to purchase land and remove it from water using activity. The rich variety of activities available under current basin management plans will almost certainly suggest other mechanisms—we have not supplied a comprehensive list—all of which will allow all current pumpers to share in the cost savings of basin control, even if they eventually forgo all water using activity. The decisions about how these users are compensated form the crux of the political process necessary to achieve basin control. Compensation agreements appear to be central to those successful basin control plans established in Southern California (Lipson, 1978).

BASIN MANAGEMENT AND CONJUNCTIVE USE

Property Rights to Storage

Basin management can facilitate efficient conjunctive use of surface and groundwater storage. Therefore, a basin management plan should include control not only over groundwater pumping, but also over the storage space of an aquifer. Under current law, such storage space is not fully identified as being under any person's or agency's control, so the rights to its use are not clearly understood by either water users or managers. A groundwater management authority—be it a water district or an entity established by an adjudicated agreement overseen by the courts—should be given the same control over the storage space within its boundaries as it is given over the groundwater itself. Then the groundwater aquifers could be used in clear and unfettered fashion for conjunctive purposes. The most recent adjudication plans in Southern California include some powers to store water for future use.

Past attempts at conjunctive use with the SWP have generally failed in part because of the lack of clear authority over the storage space. The State Department of Water Resources, for example, has met considerable local opposition to using Sacramento Basin aquifers for storage of wet-year surplus flows because the proposed plans have specified deliberate dewatering of the basin and refilling with SWP water. Under the San Fernando decision, the recharge water would belong to the SWP clients. Except in a few adjudicated basins, under current law there is no mechanism by which the landowners overlying the proposed storage basin could be compensated for the loss of their valuable resource, i.e., the higher groundwater
table that they could use at any time. This problem could be solved by instituting basinwide management with authority to use or lease dewatered space for water storage. Then those whose land was being used for storage could be rewarded directly.

Aggressive Conjunctive Use

We have shown that substantial gains could be realized from a more aggressive conjunctive use of groundwater and surface water (Jaquette, 1978). Under pumping conditions prevalent in the Sacramento Valley, for example, it is possible to produce enough “new” water supply, using existing surface storage facilities plus conjunctive use of groundwater basins to make construction of several proposed new dams unnecessary. This further benefit of groundwater control can be of considerable importance in terms of the state’s water development costs. For example, the Shasta Reservoir alone can produce over 1 MAF of additional water per year at a marginal cost of $50 (the average cost being much lower) if the wet-year runoff can be stored in relatively shallow aquifers. The Sacramento Valley area provides one such aquifer system, where pump lifts are typically less than 50 feet, so pumping costs are below $5 per acre-foot. Consideration of reduced electrical power generation only slightly modifies the scope of such operations (Jaquette, 1978).

Our research shows that draining surface reservoirs more aggressively during the autumn and deliberately percolating the water into groundwater basins is a desirable strategy. The benefit of this technique is that during a wet year, more of the runoff can be stored in the dam. The potential cost occurs if the wet year does not materialize, in which case the water must be reextracted from the groundwater basin and redistributed. River systems where dam capacity is small relative to the annual runoff would benefit most from such operations. A system obviously has much to gain when a very shallow groundwater basin can be used for the augmented storage because there will be years when reextraction will become important. For pumping lifts of $50 per acre-foot (water at approximately 500 feet), there is no gain to be realized from this storage activity. The proposed conjunctive use system trades off anticipated energy costs against the capital costs of new dam construction. The tradeoff produces net cost savings in many circumstances.

With such a system, the ability to predict the weather some six months into the future would obviously be of considerable value. During years when heavy rainfall is predicted, an even more aggressive strategy is desirable, lowering reservoirs and placing released water underground, whereas a less aggressive strategy is the best choice in years that are predicted to be relatively dry. If six-month forecasts could be improved to the accuracy of current one-month forecasts (60 percent correct on high-low prediction), this aggressive groundwater replenishment system incorporating weather forecasting would produce even more water. The value of forecasting to the state is in excess of $2 million per year from new water alone. Since increased conjunctive use is economically viable and with forecasting it becomes even more profitable, the state should direct attention to overcoming the political and institutional barriers to the conjunctive management necessary to implement these two water supply augmentation alternatives.
V. WATER SUPPLY PLANNING WITHIN CALIFORNIA

Planning water development in California is undertaken by the State Department of Water Resources, the Bureau of Reclamation of the U.S. Department of the Interior (USBR), and by some local water agencies. Our analysis finds that this planning process does not fully support efficient use of water in several important ways, and in some cases inherently leads to inefficient use of water. Our studies of water planning within the state lead us to conclude that:

- The state should adopt consistent long-range goals for water development. If efficiency is a desired goal, then a statutory or constitutional declaration to that effect would be the most effective way to promote efficient use. A declaration by the Legislature that "reasonable and beneficial use" of water requires attention to efficiency of water use would be an important step. Efficiency would best be achieved by pricing of water to reflect incremental costs of water to the water system broadly defined, rather than within narrow project or agency confines.

- The state should use economic criteria to justify water project development and should employ a realistically high discount rate in making benefit/cost calculations. New projects should be built only when added benefits from the project exceed added costs.

- The state should give more assistance to local planning efforts. While there is considerable help given now, assistance to local planning could be improved in a variety of ways. Data collection, for example, is often sporadic, and even elementary knowledge of the magnitude of groundwater pumping within a water district's boundaries is often unknown. Our research leads us to conclude that state assistance with local planning is a valuable activity that should be expanded.

- The planning process should be made consistent with whatever type of water market exists. If a more active water market emerges (as we discuss previously in this report) then state planning functions should be modified considerably to account for the functions of the market and the information contained in market activities. In the absence of a market, state planning can be used to enhance efficiency of water use through application of such tools as benefit/cost analysis.

- The state should seek reauthorization of federal water projects to allow greater flexibility of federal project operation, and choice of federal construction projects more in line with overall state water policy.

FEDERAL AND STATE PLANNING

Planning by the USBR includes considerable economic input into construction decisions and requires that benefits and costs of water projects be compared directly. Other inputs into the decision process sometimes lead to construction of water projects with calculated benefits just equal to costs, but the general require-
ment that benefits exceed costs is common. The techniques by which the USBR calculates benefits and costs are well standardized, and the data are generally available to make alternative calculations for those disagreeing with actual bureau studies. Standardized federal decisions dictate the choice of the discount rate, i.e., how future benefits and costs are made commensurable with current benefits and costs. The USBR uses a farm budget method for calculating benefits of projects to supply irrigation water. We show this method to be an accurate assessment of actual benefits under some conditions, but an overstatement of benefits in other pertinent circumstances. (See Moore, Graubard, and Shishko, 1978.)

The bureau methodology overstates benefits when the bureau supplies a large part of the water, which is the case in California and in many western states. Further, like any benefit/cost analysis, the bureau's methods are subject to potential manipulation through overstatement of benefits, understatement of costs, or use of a discount rate that is too low. Finally, bureau pricing policies subsidize water use through average cost pricing and deferral of interest payments, features which may well overwhelm the general desirability of their planning procedures in terms of real effects on water use efficiency.

Many of the features of federal water planning within the state derive from the overall authorization of the U.S. Bureau of Reclamation, so that to a considerable extent the bureau is forced to promote inefficient use of the state's water. Thus the state would be well-advised to seek overall reauthorization of the Bureau of Reclamation to allow water developed from these projects to be put to highest-valued uses. In particular, this would require allowing recipients of bureau water to transfer that water to other uses and would require that the bureau give up title to return flows from applied bureau water.

State planning in the DWR is primarily driven by the presence of binding SWP contracts for future water deliveries. The closest that current planning could come to achieving efficient use is to minimize the costs of constructing new capacity to meet SWP contracts, but this is not even a guaranteed outcome. Within the context of planning to meet SWP contractual commitments, environmental and political constraints impinge upon the decision, but planners have only limited capacity to modify the amount of firm water supply for which planning is taking place. Thus, there is really no effective mechanism by which benefit-cost analysis can enter the planning process and (because of the structure of the SWP contracts) strong reason to believe that inefficient choices about capacity expansion are taking place. The concept that pricing might be a useful planning tool seldom enters DWR calculations. "Requirements" for water are generally calculated without reference to alternatives that might affect water use, for example, the price charged.

There is disagreement among officials of the DWR with whom we have spoken about the role of economic planning actually ongoing in DWR. An economics manual was assembled, but the extent of its use is unclear. We have not been able to find direct evidence that a consistent set of economic principles has been applied to planning decisions within the DWR, in contrast to the procedures at the USBR, for example. We believe that planning within the DWR would be markedly enhanced by formal adoption of a specific set of economic guidelines for planning.

Perhaps most troublesome about the planning process within the DWR is the lack of long-range planning goals. The California Constitution sets forth certain criteria for water use within the state, but only in the most general terms. Long-
term goals are usually specified by the Director of the DWR during the annual programming and budgeting exercise. These long-term goals can change with each change of directorship. Since planning and construction of water projects often span decades and almost certainly the tenure of several DWR directors, the potential for lack of consistency can interfere with the planning process considerably. For example, the current Director has chosen to emphasize the potentials for waste water reclamation within the SWP, and in the 1976-77 drought considered ordering reductions in deliveries of firm yield to the various contractors to offset presumed savings in water from such uses. Other directors may choose to adopt other approaches to water management. We believe that the Legislature should consider implementing a general set of goals for planning in the DWR that would be consistent through the various administrative changes that are bound to occur. The strongest such guidelines would define "beneficial and reasonable use" of water, forcing attention to efficiency considerations.

Finally, we believe that the economic and legal environment surrounding water use within the state substantially affects the planning processes undertaken by the DWR. Since the procedures for optimal planning differ for different circumstances, we distinguish four cases which might arise, each of which would require different activities to enhance efficient use of water through planning.

In Case I, there is presumed to be no water market, and the state is presumed to have binding expansion contracts for future water deliveries. (This is essentially equivalent to the existing situation.) In this case, optimal planning requires long-run cost minimization through choice of timing and sizing of projects to meet the contractually obligated expansions. Even this choice, however, is modified through choice of the discount rate (the presumed interest rate chosen by the project). In previous DWR planning, the state adopted an average interest rate for the SWP that was unreasonably low.

In Case II, we presume a nonprofit water utility (such as the SWP or the bureau), but without binding expansion contracts (similar to the bureau today). Here, optimal planning requires that benefits of each project be assessed through appropriate methodology and compared with resource costs necessary for project construction and operation. The most serious problem facing planners in this environment is informational—the data and methodology necessary to assess benefits and costs accurately are often considerable and may have a substantial margin for error. However, given the accuracy of such studies, the methodology exists to choose the optimal timing and sizing of projects to maximize public well-being.

In Case III, we presume a nonprofit utility with no binding expansion contracts and an active market for water. (Such a market does not really exist within California today but could be achieved through a variety of mechanisms that we discuss elsewhere in this and companion reports.) In such an environment, the planning process is considerably simplified, for the state can take signals from the market as to the desirability of added construction. One simple device available is to have the state simply sell shares in proposed water projects at marginal cost. If a sufficient number of buyers exist to buy water at that price, the project's benefits, by definition, exceed costs and should therefore be undertaken.

In Case IV, we allow the state water agency to make a profit. In such a case, it can use a variety of operating strategies, including selling "firm" water at a price necessary to meet full project costs and speculating with nonfirm water in a spot
market for water. Other strategies are obviously also available. The state's water planning would in this case take on the joint function of water development and provision of revenues for the state treasury. Crude calculations of profits obtainable under such a situation suggest that the SWP could make profits in excess of $100 million annually for the state treasury if such a practice were adopted. This would extract the implicit profits from SWP operations that are now being passed on to water users through average cost pricing, and would put those profits in the state treasury. If the SWP were privately owned, the transfer of these profits to the state treasury would be, essentially, a 100 percent "windfall profits" tax on recipients of SWP water.

**SUMMARY**

We have proposed here (and we discuss in further detail in companion reports) a series of modifications in California water law, and in the operations of major elements of the California water system. The general intent of these proposed changes is to enhance the efficiency with which water is used. The mechanisms that seem most viable to us are to enhance the incentives for water users to transfer water to more highly valued uses, so that water use decisions generally will reflect the full marginal cost of water within the state.

In the case of groundwater, we recognize the potentially large divergence between private costs recognized by each individual pumper and the full costs to society involved with additional groundwater extraction. This divergence leads us to propose basinwide groundwater management systems for all groundwater using regions. We see no clear gain, necessarily, to having one form of management over another, for example, in choosing between district management (with a pump tax) and adjudication or contractual agreement among parties involved. From available data, it appears to us that the benefits exceed the costs of such arrangements by a considerable amount, although there are some limited circumstances wherein the benefits would be less than the prospective costs. The state has a role in defining the conditions under which management entities should arise and in defining the basins over which management should take place. Technical assistance to the local entities would almost certainly be produced, at least in part, at the state level to minimize costs of achieving management.

The overriding state interest in this issue really derives from the interrelationships, both in supply and demand, of surface and groundwater. Efficient use of the water resources of the state could almost certainly be enhanced both by increased transferability of water and by explicit control of groundwater basins to avoid common pool pumping costs. The state is in a position to establish more efficient use, through modification of the legal and institutional environment facing water users. Establishing efficient use as central interpretation of "reasonable and beneficial use" may be the most direct way to accomplish this end. The available evidence suggests a clear gain to the state, to water users within the state, and to other citizens of the state if such actions are adopted.
BIBLIOGRAPHY


