management programs, however, other factors must be considered to provide complete information about direct and indirect impacts—including environmental issues.

Questions about the accrual of useful water yield and its true value need to be resolved. For example, changes in watershed vegetative cover type and reduction in density will result in greater quantities of runoff—but part of it will be delivered during the wet season in regions where no storage capacity is available to hold the additional water until it might be beneficially used. Some have suggested that this is a nonbeneficial result. However, recent constraints on water quality and quantity of flow that must be maintained in major river systems in California tend to favor management policies upstream that will generate more runoff from tributary watersheds. Likewise, during critical drought periods, the prior reduction of nonbeneficial use of water by native trees and shrubs or by riparian plants near streams—and, in some instances, by the phreatophyte types that may develop along water courses—will be invaluable aids in conserving limited supplies of runoff waters.

Water-conservation measures and water-supply schemes should be planned in concert. Programs to increase the yields of watersheds—including precipitation modification programs to gain more input to the watershed and upstream or downstream developments to gain greater efficiency for water production—must recognize the inherent potential of many vegetative types to use up greater amounts of water if it becomes available. Such increased water losses may radically detract from the desired watershed response.

Site selection and management plans need to be carefully devised to incorporate knowledge of soils, geology, and vegetative growth characteristics as well as other watershed factors that could create undesirable or environmentally unacceptable results, such as accelerated soil erosion, degradation of the quality of runoff waters, or increased flood risks.

A reevaluation of management methods to consider current and future needs of total watersheds, including the downstream components, is needed.

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Ground-water management

Verne H. Scott
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If adequate water supplies are to be continually available, and if periods of drought are to be dealt with effectively, management of ground water is essential on every farm and in every city, county, water district, and region using ground-water resources.

Ground-water management means having short- and long-range plans for efficient use of that resource. Traditionally, there has been concern that ground-water management has involved formal agreements, regulations, pump taxes, controls, or other forms of legal constraints. This need not be the case. Successful management involves a clear understanding of the needs, a concise definition of the goals, and a realistic implementation scheme that can be achieved by cooperation and coordination.

In California, ground water is a significant resource that must be developed and wisely used and conserved. The gross storage capacity of the ground-water basins of California is estimated to be more than $1{,}000 \times 10^6$ acre-feet, whereas the gross storage capacity of surface reservoirs in the state, under planned development, will be only 77×10^6 acre-feet. Only part of the ground-water storage capacity is usable from a physical or economic point of view, but estimates place the usable storage at well over 250×10^6 acre-feet. This will be more than five times the total available active storage of all surface reservoirs that are planned for construction in California.

Management of this large ground-water resource is essential if it is to meet the supply and storage needs of the future. Management is also required if undesirable effects such as land subsidence, salt-water intrusion, deteriorating water quality, and higher pumping costs are to be minimized.

Management by individuals

What can the individual well owner do to manage ground water? He can:

- Carefully assess his water requirements, including alternative supplies, seasonal requirements, quality considerations, and maximum short-term needs.
- Locate, design, construct, and develop new wells in accordance with modern design criteria to meet specific needs.
- Operate new and old wells, individually or in groups, to achieve maximum efficiency.
- Monitor well and pump performance and maintain operating records.
- Rehabilitate wells as required.

Design of wells should consider localized effects, such as mutual interference among wells, geologic boundaries, and presence of surface streams for recharge purposes. Also, a well owner who has both surface and ground-water supplies should, in general, make use of the surface supply during wet periods and rely on ground water during dry years. This will make better use of the ground-water storage.

Regional management

How can effective ground-water management be accomplished on a regional scale? The geologic and hydrologic boundaries of a ground-water basin do not normally coincide with the boundaries of those political entities that might need to manage ground water. The regional management area usually includes various jurisdictions—cities, counties, water districts, and possibly others.

Traditionally, ground-water management on a regional basis has been in response to crisis situations—such as drastic lowering of water levels, unacceptable deterioration of quality, notable land subsidence, or critical shortage of surface supplies. These problems have been dealt with largely via lengthy and costly litigation or negotiation. Design and implementation of a ground-water plan in advance of a major crisis could minimize such litigation, as well as inefficient use of water and supply shortages during dry periods.

Effective ground-water management within a region consists of setting policy and developing and implementing a plan. The policy should establish long-range goals that consider economic principles, social values, environmental considerations, and institutional constraints. The plan should include specific objectives, such as determining the quantity and quality of the ground-water resource, developing technically feasible management alternatives, evaluating those alternatives, and implementing appropriate action. The plan also should provide for regular monitoring of ground-water conditions and for periodic updating.

Creating ground-water management policies is extremely difficult in light of existing ground-water law and the relatively unregulated approach to the ownership and use of ground water. Nevertheless, policies must be established based upon two factors: (1) current quantity and distribution of ground water in the region and (2) its quality.

Policies on quantity may vary

widely. For example:

■ Maintaining a constant amount of ground-water storage, such as the goal of the Raymond Basin decision, which apportioned the "safe yield" of the basin.

■ Providing for a zone of regulatory storage, such as the goal in the San Fernando Basin where ground water is alternatively removed and recharged in response to water requirements and surface water conditions.

■ Mining the ground-water supply, as is being practiced in the high plains area of west Texas.

Another management policy involving ground-water quantity may address the prevention of subsidence. An example is the plan being implemented in the Santa Clara Valley using artificial ground-water recharge.

From the standpoint of water quality, policies may vary from enhancing or maintaining ground-water quality—as is being implemented in coastal basins of southern California via water spreading and injection—to allowing ground-water quality to degrade by the introduction and disposal of wastes.

In developing a ground-water management plan, the principal technical details include: the definition of aquifers; calculation of ground-water storage; analysis of water levels and associated changes in storage; determination of direction and rate of ground-water flow; determination of pumpage, perennial or safe yield, and overdraft; consideration of natural and artificial recharge; and evaluation of water quality.

A good ground-water management plan considers alternative actions. These may include coordinated use of surface- and ground-water supplies; importation of supplemental surface supplies for direct use or ground-water recharge; cyclic pumping on a seasonal, annual, or longer period; use of well fields; artificial ground-water recharge; modified patterns of pumping; and possible segregation of surface- and ground-water supplies depending on specific quality considerations.

Finally, drought conditions impose additional burdens. Ground-water sources may make it possible to provide adequate supplies for domestic consumption and irrigation of essential crops during critical periods of short surface supplies. But only through a good management program, designed to replace the ground water removed from storage during a drought, can ground water be continually available to meet both short-term emergency and long-term sustained needs.

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Can water pricing encourage conservation? Some principles and some problems

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Development or conservation? Build new dams and canals or eliminate inefficient and wasteful uses? New water development has not been eliminated as a possible future alternative. For the moment, however, conservation of existing supply and increased efficiency of use seem to dominate decision-making processes. A major problem to be resolved thus becomes: How do we get people to stop wasting water and use it more efficiently?

It has been suggested that market-oriented pricing of available supplies is the most simple and rational approach to increased efficiency of water use and equitable allocation of this vital resource. (Reducing demand for water by increasing water use efficiency is also supported by those who question construction of new and additional water projects.)

Two methods of resource allocation by using prices are possible: (1) administer a set of fixed prices that, in effect, would ration water among users, or (2) encourage a system of variable prices responding to market conditions. A combination of the two methods now operates in California.

Mechanics of price conservation

Reliance on a system of freely variable market prices appears more feasible than reliance on arbitrarily administered prices. The flexibility of freely variable market prices enables adjustments to occur between uses in an individual farm or business as well as among numerous users in an industry or area.

Marketing institutions and legal arrangements have to be flexible enough, however, to permit transfer of water from one user to another in response to higher bidding prices. Before freely variable market prices can be used to effect water conservation in California, the institutional barriers to transfer of water between and among water agencies and users must be relaxed or eliminated. If a price-oriented system is to function, water-short districts or individuals would have to be free to bid for and negotiate for water from districts or individuals willing to sell it.

How would this work? Price-oriented allocation is based on the simple economic principle of supply and demand. Other things being equal, as the price of a commodity goes up, quantity demanded of that commodity goes down. Demand is "price inelastic" if the quantity used changes but little as price changes greatly. It is "elastic" if large quantity changes result from relatively small price changes. Thus, if demand for a water is inelastic, price conservation schemes make little sense, because people will continue to use large amounts of the commodity even if price increases are relatively great.

Is the demand for water elastic or inelastic? Many communities operate on a flat-rate water charge depending on lot size. Water use in such communities is insensitive to changes in the level of these charges. Introduction of metering tends to reduce water consumption levels. But, as has happened with steadily rising gasoline prices, consumption then may tend to return to precrisis levels, with only minor grousing about the high cost of living! In general then, residential water pricing by any method will not reduce the quantity demanded, unless the final user sees that changes in his consumption are significantly reflected in his water bill.

Industrial water users appear to be more responsive to changes in the price of water. Consumptive use of water by a factory or refinery tends to be fairly low. Most of the water going into a plant goes out of it as a waste-carrying effluent, often becoming a problem to downstream users or overburdening the municipal sewage treatment system. Either an increase in the price of water or a requirement to treat effluent waste will tend to cause the industrial user to recycle effluent water, thus lowering total quantity demanded. Depending on the amount of the price increase, it may even become economically feasible to introduce new, more water-efficient manufacturing processes.

Agricultural water price relationships

The nature of agricultural demand for water is not as clear-cut. In agriculture, the prime determinant of water use