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Pricing Federal Irrigation Water: A California Case Study

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Forecasts of California water supply and demand to the year 2000 suggest that overall supplies will be ample. But according to the same studies, the state's total water supplies are distributed so unevenly geographically that a chronic shortage could develop in certain areas by the late 1980's.[1] Southern California—which currently accounts for two-thirds of the state's total water consumption—is particularly vulnerable to a potential shortfall. Despite an increase in projected demand, that area by the mid-1980's will lose over one-half of the 1.2 million acre-feet of surface water it currently receives annually from the Colorado River.[2]

Most proposed solutions to the problem have called for an expansion of supplies for prospective water-short areas, primarily by the construction of new dams and canals to bring more water from Northern to Southern California. Recently, the most intense debate has centered on the Peripheral Canal, a proposed addition to the State Water Project which would cross the Delta formed by the Sacramento and San Joaquin rivers at the head of San Francisco Bay and bring more water to Southern California. (An overwhelming negative vote from Northern California voters caused the plan to be rejected in the June 1982 election.) But programs to expand the Central Valley Project—the huge Federally-owned water system—also have created considerable controversy.

An alternative approach—an economic approach—would solve the problem through pricing reform, as a means of reducing the projected growth of demand.[3] According to this view, the projected supply-demand imbalance reflects the assumed continuation of inefficient pricing practices followed by Federal, state and local agencies (utilities) in pricing water at all stages of distribution. If water were priced higher, final-users would have a greater incentive to conserve, the projected demand would be lower, and some or all of the proposed new water facilities would not be required. The present article follows this approach in analyzing the pricing of surface irrigation water supplied from the Central Valley Project (CVP) and sold at wholesale by the U.S. Bureau of Reclamation (Bureau).

Agriculture accounts for about 85 percent of the total water consumed annually in California. The Central Valley Project is the single largest supplier, accounting for nearly 40 percent of total irrigation water, with the State Water Project and groundwater sources accounting for the remainder. The pricing practices followed by the U.S. Bureau of Reclamation in pricing irrigation water at wholesale thus significantly influence the general level of water prices ultimately faced by the important agricultural sector.

Economic theory suggests that resources would be allocated most efficiently if the Bureau based its rates for CVP irrigation water on the "long-run incremental cost" of supplying that water. This concept refers to the cost of delivering an additional unit (acre-foot) of water, taking into account the need to add more fixed factors, namely new plant facilities. Pricing all CVP irrigation water on the basis of the cost of the last increment would be the most efficient method of allocating scarce resources, because customers would then be aware of the cost of the resources required to bring them additional water.

In this paper an estimate of long-run incremental cost based on the cost of building the next scheduled block of capacity—namely, the proposed Auburn-Folsom South Unit—is developed. This estimated long-run incremental cost is far higher than the "replacement average cost"—the average cost of irrigation water from the existing plant (including both old and new facilities), when this plant is valued at its current replacement cost, i.e., the

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opportunity cost to society of the resources that are currently tied up in supplying water. The differential is even greater between incremental cost and "historical average cost"—the average unit cost of water from the existing plant, with the latter valued on a historical (original) cost basis. Most regulatory commissions use the historical pricing method for investor-owned utilities under their jurisdiction.

Yet today, the Bureau of Reclamation is realizing an average price for Central Valley Project irrigation water that does not even recover full historical average cost let alone the replacement average cost. In implementing reclamation law, which calls for such practices as basing rates on farmers' ability to pay and not charging interest on public funds invested in the CVP irrigation system, the Bureau is requiring taxpayers and electrical users to pay a substantial subsidy per acre-foot of Federal irrigation water supplied. The subsidy is even greater when the realized average price is measured against the "true" average cost—average cost on a replacement cost basis.

The purpose of this study is to describe and measure how Bureau prices for Central Valley Project irrigation water deviate from the efficiency model and to discuss the implications of higher relative water prices for the California agriculture sector's demand for Federal irrigation water.

Section I discusses the economic-efficiency argument for pricing on the basis of long-run incremental cost. As noted there, water utilities traditionally have followed other pricing methods because their operations presumably have been characterized by decreasing long-run replacement average costs owing to economies of scale. Under such conditions, pricing on the basis of incremental cost would fail to recover average cost valued on a replacement cost basis, and thus would result in a loss. But as Section II indicates in the case of the Central Valley Project, long-run incremental cost today actually is far higher than the average cost of CVP irrigation water, even when average cost is measured on a replacement basis. This suggests that water provision is no longer a decreasing cost industry. In Section III, we show that the prices realized by the Bureau do not cover the actual costs of supplying that water, partly because of the Bureau's failure to recover full historical cost, and partly because of the failure of the utility industry's historical accounting methods to reflect inflation over time. In Sections IV and V, we discuss some of the implications of higher Federal irrigation water prices for the demand for water, and also for the future development of the CVP irrigation system.

I. Rationale for Different Pricing Methods

Social objectives related to the development of the arid West and the creation of a prosperous farm sector have traditionally guided the Bureau of Reclamation in its pricing of irrigation water[4] (see Box). To foster these objectives, Federal reclamation law has limited the agricultural sector's repayment responsibility to its "ability to pay," a concept described later. But in the course of fostering such objectives, the Bureau not only has failed to recover the full historical average cost for irrigation water but has not even consistently utilized the traditional average-cost pricing method prescribed by utility regulatory commissions for private investor-owned utilities.

Under this standard historical average-cost method, the utility first determines its revenue requirement for a particular function, for example, electrical power or irrigation water.[5] This refers to the total costs that must be recovered through rates during a given period to compensate the utility for all the expenses incurred in supplying the product, including a return on invested capital.[6] Under present statutes, total revenues must exactly equal total costs, a requirement known as the budgetary constraint. Dividing total costs by the number of units expected to be sold in a given period yields the average unit cost—and thus the price—of the product. However, the "ability to pay" doctrine has led the Bureau to set its price below the level implied by this type of computation.

In economic theory, the value of the resources embodied in each unit of output is determined on the basis of the replacement cost of the plant employed. As we shall see, utility commissions have used economic theory as the rationale for pricing on the basis of average cost. But they have prescribed an accounting method for measuring average cost which understates the true replacement average cost.

But even if the Bureau had priced its water according to the true economic definition of average cost, that method still would not have been the most efficient in allocating resources. Theory also demonstrates that for efficient resource allocation the price per unit should be equal not to average cost but rather to incremental cost. Incremental cost is the change in total cost resulting from an additional unit of output—that is, the cost of producing one more unit of a good or service, or alternatively, the cost that would be saved by producing one less unit.

A fundamental precept of economics states that optimum efficiency is achieved when the prices of goods and services are equal to their marginal cost of production. Under such conditions, resources would be channelled into their most efficient uses.[7] This is because each price would reflect the value of the resources required to supply each particular good or service, and because consumers therefore would be provided with the proper price signals to make the choices that would yield society the most efficient use of resources. If price were less than marginal cost, consumers would be induced to consume an additional unit, even if the benefits were less than the marginal commitment of society's resources to produce that unit.

An important point is the distinction between short and long-run, which is based on whether or not plant size is fixed. Short-run calculations show how a firm's costs will vary in response to variations in output within the limits of a given amount of fixed plant. Long-run calculations show how costs vary during a planning period long enough to permit adjustment of the scale of productive (or distribution) facilities.

Water pricing decisions thus depend upon whether or not the scale of plant is to be increased. If new plant is scheduled during the planning period encompassed in the rate calculation, long-run incremental (marginal) cost is the appropriate basis for efficient pricing, i.e., price per unit should be equal to long-run incremental cost.[8] Long-run incremental cost equals the cost of water produced by the next block of new storage and conveyance facilities scheduled to be added. Under that approach, the price per unit thus reflects only the cost of water produced from new productive facilities—in contrast to the regulators' favored method of average cost pricing, which also reflects the cost of water from older facilities.

Regulatory agencies traditionally have not followed the incremental precept in establishing utility rates because of their assumption, in their rate setting, that utility operations are characterized by decreasing long-run average costs. Decreasing long-run costs are the result of increasing returns to scale, which mean that a larger plant has lower unit costs than a relatively smaller plant. Average production costs decline for the individual firm with any increase in the size of its plant (of one or more facilities). Economies of scale are internal to the operation of the individual firm, in contrast to external economies which arise out of the growth of the entire industry.[9]

Most importantly, economies of scale are defined for a particular point in time. At any given time, a firm would be operating in an output range associated with decreasing long-run average cost if expansion to a larger-scale plant (or system) built from scratch entailed lower average costs than a smaller plant also built at that time.

With increasing returns to scale, the long-run incremental cost associated with a given supply of water is less than its long-run average cost. Hence, if selling prices were established on the basis of incremental cost (the cost of the last unit), average cost would not be recovered, and the result would be a loss. But this "loss," as measured by economists, exists because of the specific manner in which average cost is defined, with reference to the *replacement* cost of fixed plant. In practice, incremental cost pricing could yield accounting profits because regulators traditionally have valued plant at historic (original) purchase prices. However, in an industry characterized by decreasing returns to scale and increasing average costs —the CVP case —incremental costs exceed average costs and thus incremental cost pricing would result in a profit in an *economic* as well as accounting sense.

Chart 1-A shows the characteristics of decreasing long-run average cost that originally led governments to grant utilities monopoly status and to institute average-cost pricing.[10] The demand schedule D, which shows the quantity that will be demanded by customers at each price, intersects the long-run average cost schedule (LRAC) at an output level where further expansion in plant size (scale) will reduce average unit cost, i.e., before the least-cost size.

To achieve the most efficient allocation of resources possible under regulated-monopoly conditions, the utility would have to follow incremental-cost pricing. Under that method, the price (P_{ic}) would be determined by the cost of production of the last unit, that is, by the intersection of the demand schedule (D) and the long-run incremental-cost curve (LRIC). But setting the unit price at P_{ic} would generate losses for the firm (or agency) under conditions of decreasing long-run average costs, in that the cost of the last unit of output would be less than the average replacement cost per unit. These losses would be represented by the area, $(P_1\text{-}P_{ic}) \times Q_{ic}$.

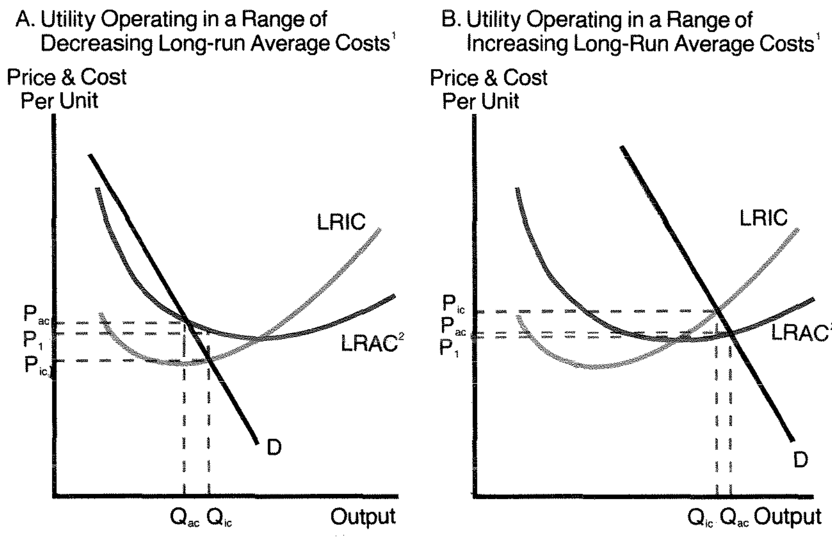
To avoid the necessity for public subsidies to offset these losses, rate-setting commissions originally selected average-cost pricing, incorporating in the average cost a rate of return on invested capital. Under this method, the maximum price per unit is set at (P_{ac}), the intersection of the demand schedule (D) and the long-run average cost curve (LRAC). Under conditions of true decreasing long-run average cost, this method of pricing results in a higher unit price and lower level of output than would result from the more efficient incremental cost method. This is because long-run average cost is above long-run incremental cost under such conditions.

Chart 1-B illustrates the price and output combinations that would result under alternative pricing methods if the utility were operating in a range of increasing long-run average costs due to the exhaustion of economies of scale. This situation characterizes most utility systems today; for example, the CVP is operating in an output range where further expansion in size raises the average unit production cost, that is, where the incremental unit cost is above the average cost, measured on a replacement basis. Under such conditions, pricing on the basis of long-run incremental cost results in a price (P_{ic}) and output level (Q_{ic}). That price would yield a profit beyond the return incorporated in average cost, in that the cost of the last unit of output would be more than the average cost per unit. The *excess profit* would be represented by the area, $(P_{ic} - P_1) \times Q_{ic}$.

To avoid excess profits, regulators could follow the replacement average-cost method, which would result in price (P_{ac}) and output level (Q_{ac}). But average-cost pricing, even under conditions of true increasing long-run average costs, results in an

Chart 1

Pricing Alternatives in a Regulated Monopoly Situation



[1]Describes behavior of costs at a given point in time.
[2]Based on plant valued at current prices, i.e., prices prevailing at the given point in time to which the cost schedules apply.

under-pricing of the product and a correspondingly greater and uneconomic amount of resources devoted to its production. The use of historical rather than replacement average cost results in a still lower price and greater uneconomic amount of resources devoted to its production.

II. Central Valley Project's Long-Run Incremental Cost

Congress has authorized a number of facilities to expand the Central Valley Project, some of which face an uncertain future due to environmentalist opposition and uncertain funding. For that reason, it is difficult to identify for analysis the next large block of capacity likely to be added to the system. The most likely candidate is the proposed Auburn-Folsom South Unit, located between Sacramento and Stockton. The project would consist of the Auburn Dam, the Folsom South Canal and several smaller structures, including the Sugar Pine Dam and Reservoir, the County Line Dam and Reservoir and associated conduits.[11] In addition to generating as much as 450,000 kilowatts of electric power annually, the project when fully operational would supply about 440,000 acre-feet of water for irrigation and 300,000 acre-feet for municipal and industrial uses in the southern Sacramento and northern San Joaquin Valley areas.[12]

To date, only the foundation of the Auburn Dam and some sections of the Folsom South Canal have been completed. Congress has authorized (obligated) nearly $2.2 billion for construction, including about $1.2 billion for irrigation purposes, but the actions of environmentalists and the failure of Congress to appropriate allocated funds have halted further construction.[13]

The project's long-run incremental cost would equal the annual cost of adding an acre-foot of water per year over the project's life. To compute this unit

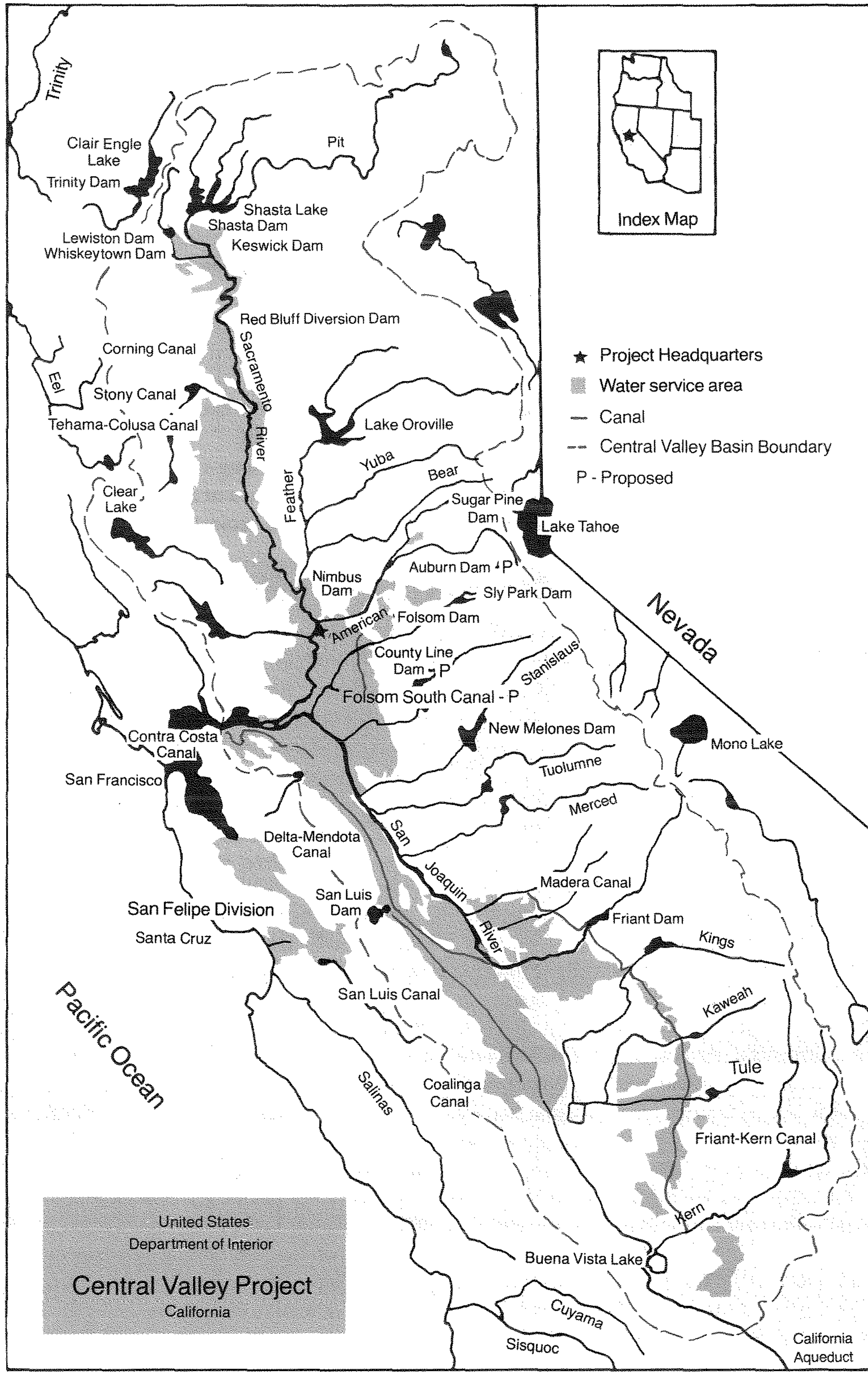
The Central Valley Project

In 1935, Congress authorized construction of the Central Valley Project (CVP) under the provisions of the Reclamation Act of 1902. That earlier legislation had two major objectives: 1) to permit the Federal government to develop the water storage and conveyance facilities necessary to bring arid Western lands under cultivation and 2) to promote widespread land ownership and a family-farm system of production. To encourage the latter objective, Congress restricted the sale of Federal irrigation water to farms 160 acres or less and required landowners to reside on their property.

Congress authorized the Central Valley Project to further implement those objectives. Its purpose was to bring surplus water from the Sacramento River in northern California to the San Joaquin Valley in the south, and thereby bring semi-arid land under cultivation. That need in turn arose from the uneven distribution of natural precipitation, both geographically and among seasons.

The vast Central Valley Basin extends for nearly 500 miles from the Cascade Range in the north to the Tulare Basin in the south, and encompasses more than one-third of California's total land area. In this area, precipitation normally ranges from an extreme of over 150 inches annually in the north to mere traces in the southeastern deserts. More than four-fifths of the State's precipitation falls in the northern one-third of the state, so that the central and southern two-thirds would have been semi-arid or arid without the importation of some of the north's surplus water. Moreover, nearly all of the precipitation occurs during the winter months. Water storage facilities therefore were necessary to redistribute surplus water from the winter to the summer months.

Initially, the Central Valley Project was devoted almost solely to meeting irrigation demands. But as the population of California grew, the project was expanded into a multi-purpose facility, capable of providing water not only for irrigation purposes but also municipal and industrial use, as well as hydroelectric power, flood control, recreation, and fish and wildlife benefits. Today, the completed system consists of 13 major Federal dams, plus numerous pumping and conveyance facilities and hydroelectric generating plants, all of which function as an integrated unit. In the provision of water, the system acts as a wholesaler, selling to water districts and private water companies, which in turn distribute the water at retail to end-users.



Trinity
Clair Engle Lake
Trinity Dam
Lewiston Dam
Whiskeytown Dam
Pit
Shasta Lake
Shasta Dam
Keswick Dam
Red Bluff Diversion Dam
Corning Canal
Eel
Stony Canal
Tehama-Colusa Canal
Sacramento River
Lake Oroville
Yuba
Bear
Feather
Clear Lake
Sugar Pine Dam
Lake Tahoe
Nimbus Dam
Auburn Dam - P
Sly Park Dam
American
Folsom Dam
County Line Dam - P
Stanislaus
Folsom South Canal - P
Nevada
Contra Costa Canal
New Melones Dam
Mono Lake
San Francisco
Tuolumne
Merced
Delta-Mendota Canal
San Joaquin River
Madera Canal
San Luis Dam
San Felipe Division
Santa Cruz
Friant Dam
Kings
San Luis Canal
Kaweah
Pacific Ocean
Tule
Salinas
Coalinga Canal
Friant-Kern Canal
Kern
Buena Vista Lake
Cuyama
Sisquoc
California Aqueduct
Index Map
Project Headquarters
Water service area
Canal
Central Valley Basin Boundary
P - Proposed
United States
Department of Interior
Central Valley Project
California

cost, we estimate the future stream of annual costs in constant dollars—in this case, in 1981 dollars. We then determine the present value of this future stream of costs by discounting at an appropriate real rate of interest. Multiplying the present value by the real rate of interest yields the annual cost of investing resources in this project rather than using them elsewhere in the economy. Finally, dividing this annual cost by the project's expected annual output yields an estimate of long-run incremental cost (see Appendix A).[14]

For discounting purposes, we have used the real rate of return before taxes, i.e., a nominal rate of interest minus the current rate of inflation. Also, we have determined that rate on an opportunity-cost basis—one that assures the general taxpayer a rate of return on invested capital equal to that earned on average in a private-utility sector financed solely through long-term debt. This assumes little difference in risk between the Federal and private-utility sectors, since the latter is regulated to ensure a reasonable rate of return.

Specifically, we have selected a real discount rate of 10 percent—the real rate prescribed by the Office of Management and Budget for evaluating Federal projects.[15] The rate is also consistent with a 16 percent current nominal interest rate for new utility bonds, minus an inflation rate of 6 percent. Employing these assumptions, we estimate the long-run incremental cost of irrigation water from the proposed Auburn-Folsom South Unit project to be around $324/acre-foot.[16]

If it followed efficiency criteria, the Bureau would price *all* CVP irrigation water on the basis of incremental cost. In establishing rates for any given future period, the Bureau would set the unit price equal to the long-run incremental cost of the appropriate block of scheduled capacity. That practice would make wholesale customers aware of the economic value of the resources required to supply additional increments. Instead, in 1981, the Bureau realized an average price of slightly over $5/acre-foot for CVP irrigation water—in contrast to the $324/acre-foot price called for under purely economic criteria. This suggests that far more resources are devoted to the Federal supply of irrigation water than are warranted by the value of the agricultural commodities produced.

III. Differential Between Long-Run Incremental and Average Cost

Three basic reasons can be found for the huge differential between the estimated long-run incremental cost and the latest realized average price of CVP irrigation water. First, the Bureau has not followed the traditional utility pricing model, so that its average realized price is far below the full average cost determined on an historical accounting basis. Second, the traditional utility model fails to reflect replacement cost. Third, the long-run incremental cost of irrigation water would be higher than "true" (economic) average cost, measured by average replacement cost.

Traditionally, a utility determines the capital costs to be recovered through revenues on the basis of its historical (original) cost of plant and equipment. These capital charges include such items as depreciation, interest, and property taxes. During periods of rapid inflation, when the cost of new equipment rises far beyond the original cost of similar equipment acquired in the past, this historical accounting method yields a much lower estimate of average cost than the replacement cost method. Yet the Bureau does not even recover average cost determined under the historical accounting method. The reasons are: 1) reclamation law does not require the Bureau to recover interest on Federal funds invested in irrigation projects; 2) reclamation law limits the repayment responsibility of farmers to their "ability to pay"; 3) the Bureau supplies water under long-term contracts at fixed rates which are not adjusted upward to reflect the blending in of new higher-cost capacity; 4) the Bureau pays no property tax as would a private utility and 5) by periodically extending the assumed lifetime of the plant, the Bureau has reduced the amortization charged on past investments.

1. Interest subsidy: The Reclamation Act of 1902 required beneficiaries to repay the construction costs of Federal irrigation projects, but did not require payment of interest.[17] Congress has retained that interest subsidy ever since.

Some critics claim that an "opportunity" interest rate should be recovered on these Congressional appropriations, in the form of the prevailing average yield on long-term Treasury bonds at the time the debt is incurred.[18] The author would go even further and use the average rate paid by private utilities for new bond issues. In other words, the appropriate comparison should be between the Federal and private utility sectors, and not between the Federal utility sector and the Federal government sector in general. On that basis, the public would earn as great a return on funds invested in the Federal utility sector as it could earn from purchasing private-utility bonds. Over the 1948-81 period, the average yield on Aaa public utility bonds ranged from 2.6 to 15.6 percent.

2. *Ability to pay:* In a series of laws passed in 1914 and 1926, Congress extended the repayment period on irrigation projects from 10 to 40 years,[19] to help provide relief to hard-pressed farmers during recession periods. Then, in the Reclamation Act of 1936, Congress extended the repayment period to 50 years and introduced the "ability to pay" concept. Under that provision, farmers are required to repay only that portion of irrigation water costs they can afford. Their ability to pay (payment capacity) is measured as a residual equal to the net increase in revenues attributable to project water.

Table 1
Reconciliation of Realized and Imputed Unit Price for Central Valley Irrigation Water Under the (Historical) Average Cost Method (Dollars per acre/foot)

Fiscal Year[1]	Unit Price As Realized[2]	Actual Operation & Maintenance[4]	Imputed Costs[3]		Imputed Interest-Subsidized Unit Price[5]	Imputed Interest	Imputed Full-Cost Unit Price[6]
			Taxes	Amortization			
1948–1960	2.83	2.40	4.43	3.08	9.91	3.96	13.87
1961	3.48	3.72	5.02	4.19	12.93	5.48	18.41
1962	1.93	1.78	2.37	2.02	6.17	2.59	8.76
1963	2.37	1.95	3.29	2.75	7.99	4.18	12.17
1964	3.32	1.12	4.56	3.87	9.55	5.96	15.51
1965	2.14	2.29	2.93	2.50	7.72	3.78	11.50
1966	3.33	3.89	4.24	3.47	11.60	5.16	16.76
1967	1.88	1.52	3.31	2.59	7.42	3.78	11.20
1968	7.87	.77	12.85	9.89	23.51	19.68	43.19
1969	2.47	3.22	5.78	4.20	13.20	8.21	21.41
1970	4.16	3.38	5.38	3.99	12.75	7.71	20.46
1971	3.47	3.22	5.37	3.76	12.35	7.20	19.55
1972	4.46	3.53	5.62	3.94	13.09	7.37	20.46
1973	3.29	2.57	4.51	3.40	10.48	6.84	17.32
1974	3.70	2.33	3.71	2.86	8.90	5.67	14.57
1975	4.20	2.79	4.32	3.20	10.31	7.03	17.34
1976	6.84	4.60	5.56	4.13	14.29	9.14	23.43
1977	5.41	9.83	17.35	13.11	40.29	29.73	70.02
1978	4.02	3.83	3.90	3.99	11.72	8.92	20.64
1979	5.83	3.84	2.69	3.48	10.01	7.62	17.63
1980	4.55	3.91	2.84	3.67	10.42	9.66	20.08
1981	5.09	3.99	3.26	4.21	11.46	12.31	23.77

[1] Fiscal year ending June 30 until 1976, and ending September 30 for later years.

[2] Derived for any given period by dividing revenues from water sales to irrigation districts, under 9-c water-service type contracts, as reported by total sales to those districts. The recovery of costs associated with CVP-financed distribution systems under 9-d repayment type contracts is excluded from this analysis. For derivation see Appendix B, Table 1.

[3] For derivation of the various imputed-cost components, see Appendix B, Table 2. Note that 1968 and 1977 were drought years, i.e., years when water deliveries fell considerably, raising capital costs per unit. Also, in 1968 there was a large new investment in irrigation capacity.

[4] As reported by the Bureau of Reclamation. The Bureau is required by law to recover operation and maintenance costs incurred in supplying irrigation water from the Central Valley Project. Yet in some years, the realized price did not even cover operation and maintenance costs.

[5] Excludes interest.

[6] Derived on the basis of the average-cost pricing method, with costs determined on the basis of the original (historical) value of plant and equipment, in keeping with traditional regulated utility practice. For derivation see Appendix B, Table 2 and technical notes.

More specifically, the Bureau determines payment capacity by comparing the estimated gross income from a representative small farm in a given irrigation district under two different sets of dry and irrigated farming conditions. From the increase in gross income attributable to project water, the Bureau subtracts the increase in non-water costs required to increase farm yields. These include operating (variable) and capital (fixed) costs, plus a projected rate of profit (return on investment) sufficient to encourage the farmer to increase farm yields.[20] The Bureau then charges the irrigation district the cost of service or ability-to-pay price, whichever is *lower*. If the cost of service, excluding interest, exceeds payment capacity, the remaining costs are recovered from the sale of electric power and municipal and industrial water. The Bureau thus can legally shift a substantial portion of the costs of supplying irrigation water to other beneficiaries of Federal water, beyond the costs shifted through the initial cost-allocation process.[21]

3. Fixed-rate contracts: In contracts negotiated before 1975, the Bureau established water rates for each service area on an individual basis. That is, it charged either an ability-to-pay price or a cost-of-service figure for a service area's share of total CVP costs, whichever was lower.[22] The Bureau also followed a standard practice of granting irrigation districts 40-year fixed rate contracts. But because of this practice, the price realized during the life of the contract failed to recover increased operational, maintenance and new-facility costs.

In 1975, the Bureau introduced several modifications in its pricing policies for *new* contracts. It began to utilize an average-cost pricing method, by dividing total system costs for a given period by the number of units expected to be sold. It also introduced adjustment clauses into its contracts to reflect changes in costs. But these provisions called for rate adjustments every five years to reflect only operation and maintenance costs, and every ten years to reflect added capital costs. Finally, the first adjust-

Table 2
Imputed Costs (Cumulative) as a Percent of Realized Unit Price[1]

Fiscal Year	Unit Price As Realized	Operation and Maintenance[2]	Including Taxes	Including Amortization	Including Interest
1948–1960	100.00	84.9	241.3	350.2	490.1
1961	100.00	107.0	251.4	371.7	529.4
1962	100.00	92.0	214.6	319.0	452.7
1963	100.00	81.9	220.8	336.5	512.5
1964	100.00	33.8	170.9	287.5	466.7
1965	100.00	107.0	244.2	361.0	538.1
1966	100.00	116.5	244.0	348.0	502.7
1967	100.00	80.7	257.0	395.2	596.5
1968	100.00	9.8	173.0	298.7	548.7
1969	100.00	130.1	363.9	533.8	865.9
1970	100.00	81.2	210.7	306.7	492.4
1971	100.00	92.6	247.2	355.6	562.7
1972	100.00	79.1	205.2	293.6	459.0
1973	100.00	78.2	215.2	318.6	526.5
1974	100.00	62.9	163.2	240.5	394.0
1975	100.00	66.4	169.0	245.1	412.5
1976	100.00	67.2	148.6	208.9	342.5
1977	100.00	181.6	502.3	744.4	1293.9
1978	100.00	95.4	192.4	291.8	513.9
1979	100.00	65.8	112.0	171.6	302.2
1980	100.00	86.1	148.5	229.0	441.4
1981	100.00	78.4	142.4	225.1	467.0

[1] The imputed unit costs were calculated under the (historical) average-cost accounting method. In this table, each imputed cost item is cumulatively added and expressed as a percent of realized price. For example, in 1981, the addition of imputed taxes and amortization to operation and maintenance costs equalled $11.46/acre-foot. This figure was 225 percent of the realized unit price, or 125 percent higher.
[2] In some years, the Bureau of Reclamation realized a price greater than the cost of operation and maintenance alone. The imputed price reflecting only that one cost would have been lower than the realized price.

ment was delayed until long after the initial delivery of water. In 1981, the Bureau introduced further reforms in this process, but the basic system still had the same drawbacks as before.

4. Taxes: The Bureau of Reclamation pays no local property taxes on lands occupied by the Central Valley Project. In contrast, private water utilities in California over the 1960-77 period paid annual property taxes averaging about 2.6 percent of their total plant investment. Their property tax burden then dropped to an average of 1.7 percent of capital investment during the 1978-81 period as a result of the passage of Proposition 13.

5. Amortization: The Bureau is required by law to repay each dollar borrowed for investment in Federal irrigation facilities within 50 years after the first delivery of water, but it has not repaid such borrowings on a systematic basis. With its low rates, in fact, the agency frequently has failed to recover even its annual operation and maintenance costs, as required by law. And with its inadequate revenues, the Bureau actually has extended the repayment life for *all* CVP irrigation facilities each time new facilities have been added to the system.[23]

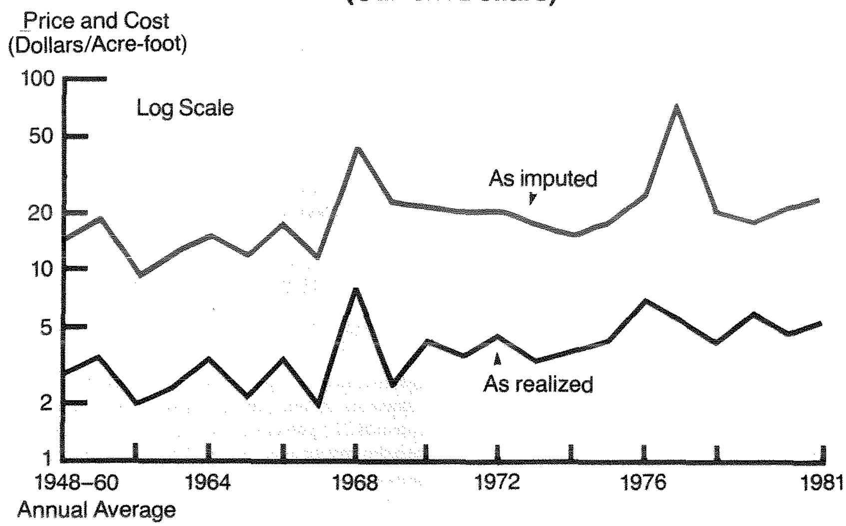
The author has reestimated CVP irrigation costs for the 1949-81 period on the basis of the methodology employed by privately-owned utilities.[24] The adjustments for the "full cost" unit price, calculated under the historical average cost methodology, included the addition of an imputed property tax and interest return on invested capital, as well as the recalculation of amortization of Congressional appropriations for the irrigation function. All these costs were determined on the basis of capital investments valued at original prices. The author adopted Bureau estimates of operation and maintenance costs, and of the irrigation share of total CVP investment (Tables 1 and 2).

With adjustments made for imputed property taxes, amortization and interest costs, the Central Valley Project actually incurred an average unit cost of at least $23.77 per acre-foot of irrigation water in 1981, calculated on an historical accounting basis, instead of the $5.09 per acre-foot actually realized (Table 1). Had rates been raised to reflect this full average cost, the price for CVP irrigation water in 1981 would have been 367 percent higher than the amount actually charged (Table 2).

In any given year, the difference between the imputed historic full-cost unit price and the price actually realized represents the total subsidy paid by the general taxpayer and electrical power users for each acre-foot of irrigation water delivered. (In this case, we used cost figures derived from plant and equipment valued at original purchase prices.) Multiplying this subsidy by total acre-feet delivered, we

Chart 2

Central Valley Project Irrigation Water Costs Under the Historical Average Cost Method, 1948–81 (Current Dollars)



obtain a total annual subsidy of $77 million for 1981, and of $966 million cumulative for the entire 1948-81 period (Table 3).

The interest subsidy is by far the largest single contributor to the overall subsidy. In 1981, the subsidy amounted to $51 million, or 66 percent of the total subsidy. Over the entire 1948-81 period it amounted to about $484 million or 50 percent of the total subsidy.

Both the average realized and imputed price rose over the post-World War II period (Table 4 and Chart 2). Because of the use of the historical-cost approach, both realized and imputed prices (especially the latter) trended downward over time in constant dollars however (Table 4 and Chart 3). Nevertheless, had the Bureau charged the higher imputed price rather than the realized price, farmers would have been encouraged to reduce their consumption of irrigation water. Instead, irrigators increased their annual deliveries of water from an annual average of 0.78 million acre-feet during the 1948-60 period to 4.12 million acre-feet by 1981 (Appendix B, Table 1).

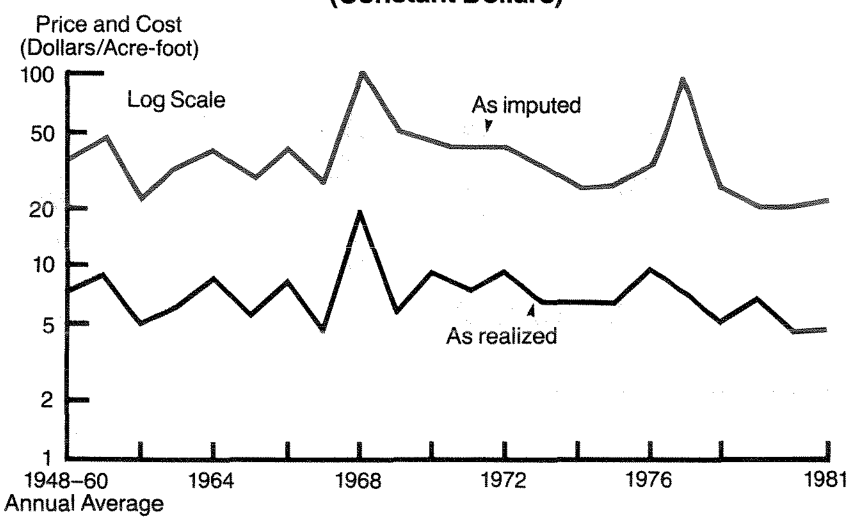
The average-cost figure of $24/acre-foot, as calculated by the traditional private-utility accounting method, is still only a fraction of the estimated long-run incremental cost of $324/acre-foot. This does not necessarily mean that the Central Valley

Table 3
Estimated Annual Subsidy to Users of Central Valley Project Irrigation Water (Historical Accounting Method)

	Subsidy ($ Millions)		
Fiscal Year	Interest[1]	Other[2]	Total[3]
Total, 1948–1960	36.96	66.24	103.20
1961	5.39	9.28	14.67
1962	5.28	8.64	13.92
1963	9.03	12.13	21.16
1964	9.79	10.24	20.03
1965	9.86	14.53	24.39
1966	9.72	15.58	25.30
1967	9.55	14.01	23.56
1968	19.70	15.66	35.36
1969	19.42	25.37	44.79
1970	19.49	21.68	41.17
1971	19.41	23.95	43.36
1972	19.06	22.31	41.37
1973	22.63	23.79	46.42
1974	22.62	20.69	43.31
1975	27.87	24.16	52.03
1976	28.96	23.61	52.57
1977	31.43	36.86	68.29
1978	31.18	26.93	58.11
1979	30.80	16.88	47.68
1980	42.32	25.71	68.03
1981	50.69	26.23	76.92
Total, 1948–1981	481.16	484.48	965.64

[1] Derived by multiplying the imputed interest per acre-foot by the number of acre-feet sold.
[2] Derived by subtracting the realized price from the interest-subsidized imputed price and multiplying by the total acre-feet of water sold.
[3] Derived by subtracting the realized price from the full-cost imputed price (historical accounting basis) and multiplying by the total acre-feet of water sold.
Source: Computed by the author.

Chart 3
Central Valley Project Irrigation Water Costs Under the Historical Average Cost Method, 1948–81 (Constant Dollars)



Project faces decreasing returns to scale and increasing long-run average costs. Those theoretical concepts depict cost and output alternatives facing a firm (or agency) at a moment of time under the assumption of constant technology and factor prices (Chart 1-B). A firm would be operating in an output range associated with increasing long-run average costs if expansion to a larger scale plant (or system) built from scratch today entailed higher average costs than a smaller plant built today. In that case, long-run incremental cost would be above average cost, with both determined on the basis of plant and equipment valued at today's prices. This contrasts with the traditional private-utility practice of determining average cost. Under that method, long-run incremental cost would be above average cost simply because of the failure of the utility industry's average-cost methodology to reflect the effects of inflation on equipment prices.

To determine whether the CVP may in fact be facing increasing long-run average costs due to the exhaustion of economies of scale, we have estimated the average cost of irrigation water with capital costs valued at current replacement prices rather than historical prices. Under the replacement accounting method, we have valued the entire plant in 1981 dollars, and have then compared the incremental cost of water from new plant with the average cost from the existing system, both valued at today's prices (Table 5).

The aggregate value of annual plant investment in 1981 dollars, $1.7 billion, represents the replacement value of the entire system. After calculating that value, we next calculated the average or unit cost of irrigation water from this sytem by dividing the total annual cost (capital, operation and maintenance, and taxes) by the number of acre-feet delivered.[25] This procedure yielded a $48/acre-foot average replacement cost for irrigation water, and a

Table 4
Constant Dollar Realized and Imputed Unit Prices
(Dollars per acre-foot)

	Current Dollar Unit Price				Constant Dollar Unit Price[3]		
Fiscal Year	Unit Price As Realized	Imputed Interest-Subsidized Unit Price	Imputed Full-Cost Unit Price[1]	Producer Price Index[2]	Unit Price As Realized	Imputed Interest-Subsidized Unit Price	Imputed Full-Cost Unit Price[1]
1948–1960	2.83	9.91	13.87	38.82	7.28	25.53	35.72
1961	3.48	12.93	18.41	39.18	8.88	32.99	46.99
1962	1.93	6.17	8.76	39.08	4.95	15.79	22.41
1963	2.37	7.99	12.17	39.15	6.07	20.41	31.09
1964	3.32	9.55	15.51	39.13	8.49	24.42	39.63
1965	2.14	7.72	11.50	39.46	5.42	19.56	29.15
1966	3.33	11.60	16.76	40.55	8.22	28.62	41.33
1967	1.88	7.42	11.20	41.44	4.53	17.91	27.03
1968	7.87	23.51	43.19	42.23	18.64	55.67	102.28
1969	2.47	13.20	21.41	43.56	5.68	30.31	49.16
1970	4.16	12.75	20.46	45.35	9.17	28.11	45.13
1971	3.47	12.35	19.55	46.67	7.44	26.46	41.88
1972	4.46	13.09	20.46	48.02	9.29	27.26	42.62
1973	3.29	10.48	17.32	50.60	6.50	20.71	34.23
1974	3.70	8.90	14.57	56.82	6.51	15.66	25.65
1975	4.20	10.31	17.34	65.41	6.43	15.76	26.52
1976	6.84	14.29	23.43	70.20	9.74	20.35	33.37
1977	5.41	40.29	70.02	74.44	7.27	54.12	94.06
1978	4.02	11.72	20.64	79.96	5.02	14.66	25.81
1979	5.83	10.01	17.63	88.04	6.63	11.37	20.02
1980	4.55	10.42	20.08	100.00	4.55	10.42	20.08
1981	5.09	11.46	23.77	109.23	4.66	10.49	21.76

[1] Calculated on the basis of the historical average-cost accounting method.

[2] Producer price index, all finished goods, 1980=100.

[3] Dollars per acre/foot in constant dollars; derived by dividing current dollar prices by producer price index.

total 1981 subsidy of nearly $175 million.[26] The difference between this figure and the much higher incremental cost suggests that the Central Valley Project is operating in an output range of increasing long-run average cost, reflecting decreasing returns to scale.

Economists would argue that, for efficient allocation of resources, the Bureau of Reclamation should price all CVP irrigation water on the basis of long-run incremental cost, estimated here at about $324/acre-foot. A second-best option would be for the Bureau to price water at least on the basis of the estimated $48/acre-foot replacement average cost. Only that approach would permit recovery of the true cost to society of the resources tied up in supplying water. Recovery of the estimated $24/acre-foot historical average cost, although an improvement over current Bureau practice, would not recover this ''true'' average cost.

IV. Impact of Higher Water Prices

Would higher prices for CVP irrigation water lead to a reduction in the quantity demanded? Some analysts argue in the negative, because of agriculture's essential need for water. They maintain that a given amount of water is required to produce a given yield for any crop, that the amount is dictated by soil and climatic conditions, and that it is invariant to higher water prices. Thus, because of the limited technical substitutability between water and other productive inputs,[27] demand for irrigation water is price inelastic, i.e., relatively unresponsive to a higher (or lower) price.[28] Proponents of this

Table 5
Imputed Unit Price of Central Valley Irrigation Water, Replacement Average Cost Method

Fiscal Year	Investment in Irrigation Plant[1] ($ Millions)	Conversion Factor[2]	Investment in Irrigation Plant ($ Millions, 1981 Dollars)
1948–1960	178.74	2.73	487.96
1961	26.73	2.30	61.47
1962	.41	2.30	.94
1963	90.82	2.29	207.98
1964	21.83	2.28	49.77
1965	6.62	2.26	14.96
1966	1.66	2.22	3.69
1967	1.19	2.16	2.57
1968	166.96	2.09	348.95
1969	2.15	2.03	4.36
1970	6.17	1.96	12.09
1971	4.83	1.88	9.08
1972	1.48	1.82	2.69
1973	53.12	1.79	95.08
1974	6.13	1.67	10.24
1975	64.31	1.44	92.61
1976	20.48	1.36	27.85
1977	38.69	1.30	50.30
1978	5.89	1.22	7.16
1979	4.07	1.14	4.64
1980	100.06	1.07	107.06
1981	64.24	1.00	64.24
	866.57		1,665.69

Replacement Cost Per Acre-Foot (1981 Dollars) = (Capital Cost[3] + Operation & Maintenance Cost + Property Taxes)/Acre-Feet of Irrigation Water Delivered
= ($166.57 m. + $16.45 m. + $13.43 m.)/4.12 m.
= $47.69

[1] Excluding distribution-system investment from canalside to farmgate under CVP, 9-c water service contracts.

[2] Calculated by dividing the 1981 implicit price deflator for producer durable equipment by the actual deflator for each year.

[3] Capital cost of the entire project (1981 dollars) multiplied by a 10-percent real interest rate.

Source: Annual Investment Data: U.S. Bureau of Reclamation, Mid-Pacific Regional Office, Sacramento. Computation by author.

thesis consequently maintain that resorting to higher prices to allocate available supplies would be ineffective.

Examination of the literature shows that the elasticity of demand for irrigation water varies according to the price range being considered.[29] That is, the responsiveness of quantity demanded to a given percentage change in price varies along a given demand schedule. Early studies covering the 1950's and early 1960's supported the argument for inelastic demand.[30]

But those results were biased by the absence of a wide range of observable prices over which to test the demand responsiveness. More recent studies, based either on observed water-use and price combinations or on linear-programming estimation techniques replicating the cost-minimizing behavior of California farmers, show that water demand is price elastic at a price of over $20 per acre-foot. One of the latest studies, which utilizes an even more advanced programming model of Central Valley agriculture, shows an elasticity coefficient of -1.5 for a price range of $25-35/acre-foot.[31] For prices above $35/acre-foot, the elasticity coefficient then drops to -0.5.[32]

In summary, at water prices prevailing currently, agricultural water demand is not very price responsive, but it should respond substantially at higher prices. Indeed, given a demand of 3.8 million acre-feet at a price of $25/acre-foot, and given an elasticity coefficient of -1.5, a ten-percent price increase would reduce the quantity demanded by 570,000 acre-feet. This would be sufficient to eliminate the need for the proposed Auburn-Folsom project.

To maximize profit from any given crop on a given parcel of land, a farmer will purchase and apply additional units of water until its marginal revenue product equals its price.[33] The "marginal revenue product" refers to the net addition to total revenue resulting from the last increment of water, after subtraction of all other non-water operating (variable) and capital (fixed) costs.[34]

Farmers might react in three different ways to sharply higher prices of CVP irrigation water.[35]

Table 6
Indicators of Impact of Higher Water Price on the California Agricultural Sector

Leading Crops (1980)[1]	Value of Production ($ Thousands)	California as Percent of Total Domestic Production	Water Cost as Percent of Total Production Cost[2]
Cotton	1,389,342	28.2	2.72
Grapes	1,215,585	91.6	1.49
Hay	723,316	5.9	4.81
Tomatoes	490,310	79.2	0.78
Almonds	473,340	95.0	1.29
Rice	423,612	24.3	1.55
Lettuce	382,563	74.4	0.96
Wheat	357,945	3.6	4.82
Oranges	224,548	18.9	2.72
Strawberries	201,266	75.3	4.31
Sugar Beets	182,930	24.8	2.76
Peaches	176,438	66.4	0.34
Walnuts	168,300	95.0	1.39
Potatoes	157,590	6.2	2.26
Corn, for Grain	151,268	0.5	3.24

[1] Crop ranking based on value of production, 1980.

[2] Water cost excludes cost of application. Total production costs include all variable and fixed cultural and harvest costs (including water application), imputed rent on land and return to management. The latter two returns are actually part of profits and should not be included in costs, but were included here because of lack of relevant data.

Source: California Department of Food and Agriculture, *California Agriculture Statistical Review*, 1980. Giannini Foundation of Agriculture Economics, *Agricultural Water Use and Costs in California*, Information Series 80-2, Bulletin 1896.

First, if a given crop still represents the most profitable opportunity on a given parcel of land, the farmer might continue to grow the same crop but cut back water usage to the point where its marginal revenue product equals the higher price. This cutback would be accompanied by some reduction in crop output or introduction of more efficient irrigation methods. Alternatively, the farmer might shift to another crop that yields a higher net return per acre-foot of water, which could mean a shift away from low-valued field crops to higher-valued specialty crops. Or again, the farmer might simply withdraw land from irrigation, if irrigated crops fail to yield a positive profit or if they yield less profit than dry-land farming. In summary, if the price of water is raised, farmers may react by reducing output, changing the input mix (for example, using more capital intensive irrigation methods), and/or shifting cropping patterns.

The elasticity of demand for irrigation water varies significantly, depending on type of crop. Price elasticity increases, in general, the greater is the substitutability of other factor inputs for water, and the greater is the water share of total production costs. But elasticity varies inversely with the ability of farmers to pass on higher water costs to consumers in the form of higher food and fiber prices.

For all 15 of California's major crops, water currently comprises a small percentage of total production costs (Table 6). This reflects the low level of current water prices, and suggests why the price elasticity of demand at current ranges is generally low. Nevertheless, the data also show considerable variability in the importance of water costs among various products.

For certain field crops—especially, hay, wheat and corn—water costs comprise a relatively large proportion of total production costs. This factor alone suggests that any given increase in water prices would affect those products significantly. On the other hand, water comprises a relatively small percentage of total costs for tomatoes, peaches, lettuce, grapes and nuts. In reaction to higher water prices, farmers thus might tend to switch away from field crops to specialty crops such as those.

California farmers also account for a relatively small share of total domestic production of field crops. For corn, wheat and hay, for example, their shares of the national market amount to only 0.5, 3.6 and 5.9 percent, respectively (Table 6). This suggests a relatively elastic demand for water, due to farmers' inability to influence the price of the final product and thereby pass on higher water costs to consumers.

V. Summary and Conclusions

If efficiency of resource allocation were the only criterion, the Bureau of Reclamation would price all irrigation water from the Central Valley Project on the basis of long-run incremental cost—the cost of delivering an additional acre-foot of water from the next scheduled block of new capacity. This approach would be the most efficient because it would make customers aware of the cost of the resources required to bring them additional water. But this approach also would return huge annual profits to the Bureau of Reclamation or to the U.S. Treasury. This is because long-run incremental cost is far higher than the system's average cost of irrigation water, determined as economists would measure average cost on the basis of replacement value of plant. In addition, a switchover to strict incremental cost pricing could cause a major shrinkage in both water usage and the size of California's agricultural sector.

The second-best option from an efficiency standpoint would be pricing of irrigation water on the basis of average cost, determined on a replacement cost basis. This method would at least recover the cost of the resources already embodied in the system, valued at today's prices. It would also enable the Bureau to generate sufficient revenue to perpetuate the existing capacity. A case also could be made for the Bureau to include all cost elements that would be incurred by a debt-financed private investor-owned utility—annual operation and maintenance costs, plus interest expense and property taxes (opportunity-cost basis), plus steady amortization of capital borrowed from the U.S. Treasury.

Pricing on this basis would at least make customers aware of the resources already expended in the system, and would provide farmers with a strong incentive to reduce water consumption. In fact, empirical studies suggest that agricultural demand is elastic above a retail price of around $20 per acre-foot.

When Congress passed the Reclamation Act of 1902, it clearly intended beneficiaries of Federal water projects to repay their original construction costs as well as operating costs. It provided a subsidy, however, by not requiring repayment of interest on capital invested, and later increased that subsidy through the ability to pay concept and other measures. In some years indeed, irrigation water rates have even failed to recover operation and maintenance costs, despite the legal requirement to do so. Moreoever, had the Bureau priced irrigation water to reflect all costs measured on a replacement accounting basis, the average realized price by 1981 would have been nearly ten times as high as the price actually realized.

By charging highly subsidized rates for Federal irrigation water, the Bureau has spurred the growth of consumption beyond the growth that would otherwise have occurred had it priced water to reflect the true average cost of service. Had it priced water on the basis of long-run incremental cost, the amount of resources devoted to the construction of Federal irrigation projects in California would have been still smaller. Instead, the consumption of water and the size of the Federal irrigation system have expanded beyond the point where the net return to the last unit of water, in terms of agricultural revenue, is equal to the cost of supplying that extra unit. This suggests that more resources have been devoted to the construction of the Federal irrigation system in California than are warranted by agricultural benefits.

The social objectives that justified the earlier granting of subsidies—namely, the development of the arid West—may no longer be appropriate. Today's environment is dominated by intense competition for water among competing users—households, energy producers, and farmers. To some observers, the correct policy issue remains the perennial one—what size farms should get the subsidy? Should the 160-acre limit be enforced or expanded? Others would argue, however, that there should be no water subsidy at all. In this view, the focus should be on pricing reform, to improve the efficiency of water usage through the use of more efficient irrigation methods and shifts to less water intensive crops. Indeed, Congress logically should give more attention to the role of the price mechanism in reducing the projected growth of irrigation water demand, not only in California but throughout the West.

Appendix A: Calculation of Incremental Cost of Irrigation Water, Proposed Auburn - Folsom South Unit

The following technical note describes the methodology and assumptions employed by the author to estimate the incremental cost of irrigation water from the proposed Auburn-Folsom South Unit. The incremental cost of irrigation water from this project includes the capital costs (depreciation and interest), taxes, and operation and maintenance expenses to be recovered over the project's life. Each of these costs is expressed as a stream over time and then discounted to determine present value. (However, the present value of the capital costs can be shown to be equal to the initial construction costs). The *annual* cost is then equal to the real interest rate multiplied by this present value. We add these annual costs and then divide by the expected average annual output in acre-feet.

The real interest rate is used to discount capital costs. Taxes and operation and maintenace costs are discounted by the nominal interest rate, because they are assumed to reflect inflation in the future. We assumed both the annual property tax and depreciation rates to be 2 percent of plant value, based on the 1981 tax rate and on a 50-year service life for plant and equipment. We used a real discount rate of 10 percent and a nominal interest rate of 16 percent as the discount factors.

Variable List:

r	= Real Interest Rate	k	= Initial Capital Outlay
i	= Nominal Interest Rate	K	= Stream of Capital Costs
Π	= Inflation Rate	om	= Annual Operation & Maintenance Costs
δ	= Depreciation Rate	OM	= Stream of Operation & Maintenance Costs
t	= Tax Rate	T	= Stream of Tax Costs
p	= Annual Water Production	C_I	= Incremental Cost

Each of the cost streams can be expressed as follows:

$$K = (r+\delta)k, (r+\delta)k(1-\delta),(r+\delta)k(1-\delta)^2,(r+\delta)k(1-\delta)^3 \ , \ . \ . \ . \ .$$

$$T = tK+tK(1-\delta),tK(1-\delta)^2,tK(1-\delta)^3, \ . \ . \ .$$

$$OM = om(1+\Pi),om(1+\Pi)^2,om(1+\Pi)^3, \ . \ . \ .$$

Taking the present value of each cost stream:

$$PV(K) = \frac{(r+\delta)k}{1+r} + \frac{(r+\delta)k(1-\delta)}{(1+r)^2} + \frac{(r+\delta)k(1-\delta)^2}{(1+r)^3} + \frac{(r+\delta)k(1-\delta)^3}{(1+r)^4} + . \ . = k$$

$$PV(T) = \frac{tk}{(1+i)} + \frac{tk(1-\delta)}{(1+i)^2} + \frac{tk(1-\delta)^2}{(1+i)^3} + \frac{tk(1-\delta)^3}{(1+i)^4} + \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . = \frac{tk}{i+\delta}$$

$$PV(OM) = \frac{om}{(1+i)} + \frac{om(1+\Pi)}{(1+i)^2} + \frac{om(1+\Pi)^2}{(1+i)^3} + \frac{om(1+\Pi)^3}{(1+i)^4} + \ . \ . \ . \ . \ . \ . \ . \ . = \frac{om}{i-\Pi} = \frac{om}{r}$$

Multiplying the present value of each cost stream by the real rate of interest and dividing by production of 440,000 acre-feet yields an incremental cost of $324/Acre Foot of Water

C_I = (Real Interest Rate (Capital Cost + Taxes + Operation and Maintenance))/Annual Water Production

$$C_I = (r(k+\frac{tk}{i+\delta} + \frac{om}{r}))/p$$

$$C_I = (.10(1217\times10^6 + \frac{24.34\times10^6}{.16+.02} + \frac{7.6\times10^6}{.10}))/440x10^3$$

$$C_I = \$324/\text{Acre-Foot}$$

Appendix B: Adjustment of Central Valley Project's Realized Average Price (Private Utility Basis)

The following technical note describes the methodology used by the author to adjust the Central Valley Project's realized average price for irrigation water delivered at canalside for the 1948-81 period, to include the major cost items and historical accounting methodology employed by private-owned water utilities. The realized and imputed prices appear in Appendix B, Tables 1 and 2 respectively.

Taxes: Annual property-tax payments were imputed by applying the average property-tax rate for two privately-owned California water utilities in any given year to the Central Valley Project's total irrigation plant in service as of that year, valued on an historical cost basis.

Amortization: Amortization costs were imputed annually for the 1948-81 period by developing a straight-line depreciation schedule. Depreciation was calculated by applying the average life of service of the equipment to the total value of the plant in service, measured on an historical (original) cost basis. This amortization procedure follows that used by most private utilities. The average service life of the CVP's total irrigation plant is estimated to be 75 years. For any given year, depreciation thus was calculated as 1/75th of the total value of irrigation plant in service. Since depreciation is calculated on a 75-year basis, compared with the Bureau responsibility to recover borrowings within a 50-year period, depreciation charges thus calculated would fall short of meeting the CVP's payment responsibilities. A reconciliation charge therefore was calculated, representing the difference between 1/50th and 1/75th of the value of the plant in service.

Interest: Interest payments on an opportunity-cost basis were imputed for any given year n by the formula:

$$P_n = \sum_{y=1948}^{n} i_y A_y$$

where: P_n = total interest payment in year n
i_y = Moody's Aaa interest rate on public (private investor) utility issues in year y
A_y = unamortized portion of appropriations received in year y as of year n

This formula simply states that total interest payments in any given year P_n, equal the sum of all interest payments on outstanding CVP debt in that year. In other words, total interest payments equal new debt (for irrigation plant) times the prevailing interest rate, plus any unamortized old debt multiplied by the rate(s) in effect when the debt was incurred. The first debt was assumed to be incurred in 1948, the earliest date for which data were available. Each increment in debt was amortized on a straight-line basis by 1/50 each year after it was incurred, in line with the 50-year payback period specified by law. Note that Moody's Investor Service refers to private investor-owned utilities as public utilities, using that term in a general sense.

A consistent series showing annual Congressional appropriations to the CVP was not available. A proxy for "new debt" was developed by taking the total value of the plant in service, i.e., the capital stock, and calculating the annual change, i.e., the new investment added each year. That proxy was used under the assumption that borrowing was for capital investment.

Appendix B, Table 1
Average Price for Central Valley Irrigation Water, As Realized

Fiscal Year	Revenues[2]	Water Sales[3]	Realized Unit Price[4]
1948–1960[1]	2.20	.78	2.83
1961	3.42	.98	3.48
1962	3.95	2.04	1.93
1963	5.13	2.16	2.37
1964	5.46	1.64	3.32
1965	5.57	2.60	2.14
1966	6.28	1.88	3.33
1967	4.75	2.53	1.88
1968	7.88	1.00	7.87
1969	5.85	2.36	2.47
1970	10.49	2.52	4.16
1971	9.37	2.70	3.47
1972	11.52	2.58	4.46
1973	10.89	3.31	3.29
1974	14.73	3.98	3.70
1975	16.65	3.96	4.20
1976	21.68	3.17	6.84
1977	5.72	1.06	5.41
1978	14.04	3.50	4.02
1979	23.58	4.04	5.83
1980	19.93	4.38	4.55
1981	20.99	4.12	5.10

[1] Annual average computed from cumulative totals for the 12-year period 1948–1960.

[2] Millions of dollars. Revenues from irrigation sales under 9-c water-service contracts as reported by the U.S. Bureau of Reclamation.

[3] Millions of acre-feet.

[4] Dollars per acre-foot. Derived by dividing revenues from water sales to irrigation districts by acre-feet of water sold.

Source: Revenues and sales data from U.S. Bureau of Reclamation, Mid-Pacific Regional Office. Realized unit price derived from that data by author as described in footnote 4.

Appendix B, Table 2
Average Price for Central Valley Irrigation Water, As Imputed on a Private-Utility Cost Basis[1] (Cost data in millions of dollars)

	Variable Costs	Fixed Costs							
Fiscal Year	Operation Maintenance	Property Tax[2]	Depreciation[3]	Reconciliation Depreciation & Amortization[4]	Total Costs Excluding Interest	Interest[5]	Full Costs[6]	Interest-Subsidized Unit Price (Dollars/acre-foot)	Full-Cost Unit Price (Dollars/acre-foot)
1948–1960	1.87	3.45	1.60	.80	7.72	3.08	10.80	9.91	13.87
1961	3.65	4.93	2.74	1.37	12.69	5.39	18.08	12.93	18.41
1962	3.63	4.84	2.75	1.37	12.59	5.28	17.86	6.17	8.76
1963	4.20	7.12	3.96	1.98	17.26	9.03	26.28	7.99	12.17
1964	1.85	7.49	4.25	2.12	15.70	9.79	25.49	9.55	15.51
1965	5.96	7.64	4.34	2.17	20.10	9.86	29.96	7.72	11.50
1966	7.32	8.01	4.36	2.18	21.87	9.72	31.59	11.60	16.76
1967	3.83	8.36	4.37	2.19	18.76	9.55	28.31	7.42	11.20
1968	.77	12.87	6.60	3.30	23.54	19.71	43.24	23.51	43.19
1969	7.61	13.67	6.63	3.31	31.22	19.42	50.64	13.20	21.41
1970	8.52	13.59	6.71	3.36	32.17	19.49	41.66	12.75	20.46
1971	8.68	14.48	6.77	3.39	33.32	19.41	52.73	12.35	19.55
1972	9.12	14.52	6.79	3.40	33.83	19.06	52.89	13.09	20.46
1973	8.51	14.91	7.50	3.75	34.68	22.63	57.31	10.48	17.32
1974	9.26	14.79	7.58	3.79	35.43	22.62	58.05	8.90	14.57
1975	11.05	17.09	8.44	4.22	40.81	27.87	68.68	10.31	17.34
1976	14.56	17.65	8.72	4.36	45.28	28.97	74.25	14.29	23.43
1977	10.39	18.35	9.23	4.62	42.58	31.43	74.01	40.29	70.02
1978	13.40	13.61	9.31	4.65	40.97	31.18	72.15	11.72	20.64
1979	15.53	10.89	9.36	4.68	40.46	30.80	71.26	10.01	17.63
1980	17.15	12.44	10.70	5.35	45.63	42.32	87.95	10.42	20.08
1981	16.45	13.43	11.55	5.78	47.21	50.69	97.91	11.46	23.77

[1] These costs represent the author's interpretation of the amounts that should have been recovered directly by the U.S. Bureau of Reclamation in the form of revenues for water delivered to irrigation districts if the Central Valley Project had been operating as a private investor-owned utility, using the historical average-cost accounting method to determine unit price. The costs consist of the variable costs as actually measured and reported by that agency, plus computations of fixed costs to include imputed property-tax payments, interest charges reflecting the opportunity cost of capital, and a straight-line depreciation and amortization charge to repay all outstanding debt on a consistent and continuous basis.

[2] Derived by applying an estimated California property-tax rate for private investor-owned water utilities (property taxes paid as a percentage of total plant in service) to the Central Valley Project's total irrigation plant (excluding CVP-financed distribution facilities from irrigation districts to the farm gate), valued on an historical-cost basis.

[3] Private water utilities recover their long-term borrowings for capital investment through their depreciation charges. The average service life of the Central Valley Project's total irrigation plant is estimated to be 75 years. Straight-line depreciation has been used so that depreciation is 1/75th of the total value of the plant in service, measured on an historical-cost basis.

[4] Depreciation is calculated on an average 75-year basis, whereas the Central Valley Project is required to amortize (pay back) its borrowings within a maximum of 50 years. The "reconciliation" charges represent the difference between 1/50th and 1/75th of the value of irrigation plant in service.

[5] Derived on an "opportunity cost" basis; total interest payments in each year equal the product of new debt and the current Moody's average Aaa interest rate for public (private investor-owned) utilities, plus the product of old amortized debt and the interest rate in effect when the debt was incurred. Debt is reduced (amortized) on a straight-line basis by 1/50th each year after it is incurred. Total value of irrigation plant in service was used as a proxy in determining outstanding debt, under the assumption that borrowing was for capital investment.

[6] Purchasers of Central Valley Project irrigation water have been allowed an interest subsidy by law (i.e., the Bureau of Reclamation is not required to recover through its rates any interest on public funds appropriated by Congress for Central Valley irrigation projects). Therefore, we calculate a price without interest (i.e., an interest-subsidized imputed price) in addition to the full-cost unit price. Prices are in dollars per acre-foot.

Source: For data pertaining to the private-utility sector: Moody's Investors Services, *Moody's Public Utilities Manual*. Average property-tax rates per year derived from data for California Water Service Company and Southern California Water Company. For reported data pertaining to the Central Valley Project, U.S. Bureau of Reclamation, Mid Pacific regional office, Sacramento.

FOOTNOTES

1. For the most comprehensive recent assessment of the long-term outlook for U.S. and California water supplies and demands see, U.S. Water Resources Council, **The Nation's Water Resources 1975–2000** (Washington, D.C.: U.S. Water Resources Council, 1978). See especially, Volume 3: Analytical Data Summary and Volume 4: California Region, pp. 17–30. Also, **Governor's Commission to Review California Water Rights Law, Final Report** (Sacramento, December 1978).

2. Southern California refers to the area south of the Tehachapi Mountain Range, the natural barrier that sets the south apart from the rest of the state. An acre-foot of water is the amount of water required to cover one acre one foot deep. The measure is equal to 325,851 gallons of water. California's loss of Colorado River water will occur as a result of a 1963 Supreme Court decision declaring that Arizona is entitled to over one-half of the Colorado River that has been coming to California. The diversion will take place as soon as the Central Arizona Project is completed, making the re-routing possible.

3. The literature on the pricing of water is relatively sparse compared with that for other important resources such as energy and non-fuel minerals. Important contributions include: Jack Hirshleifer, James C. De Haven and Jerome W. Milliman, **Water Supply Economics, Technology and Policy** (Chicago: The University of Chicago Press, 1960);

Joseph Bain, Richard Caves and Julius Margolis, **Northern California's Water Industry** (Baltimore: Resources for the Future, 1966); Charles E. Phelps, Morlie H. Graubard, David L. Jacquette et. al., **Efficient Water Use in California** (Santa Monica: Rand Corporation, November 1978); and Donald Erlenkotter, Michael Haneman, Richard E. Howitt and Henry J. Vaux, Jr., "The Economics of Water Development and Use in California," **California Water Planning and Policy, Selected Issues** (Berkeley: University of California, June 1979), pp. 169–207.

4. For a discussion of the social objectives embodied in early reclamation law, see E. Phillip Le Veen, "Reclamation Policy at the Crossroads," **Public Affairs Report,** Vol. 19 (Berkeley: Institute of Governmental Studies, October 1978). Also, Alan R. Dickerman, George E. Radosevich and Kenneth C. Nobe, **Foundation of Federal Reclamation Policies; an Historical Review of Changing Goals and Objectives** (Fort Collins: Colorado State University, 1968); William E. Warne, **The Bureau of Reclamation** (New York: Praeger Publishers, 1973).

5. For a description of the average-cost pricing methodology followed by private investor-owned water utilities in establishing the level of rates, see American Water Works Association, **Water Rates Manual** (Denver: American Water Works Association, 1972).

6. For private investor-owned utilities, the return on invested capital consists of three components: 1) interest payments on bonded indebtedness, 2) dividends on preferred stock, and 3) a return to common-equity holders, a residual amount which becomes available to these owners only after all other legitimate claims of the company have been settled. The first two are specified on the bond indenture and the preferred-stock certificates. At present, Federal reclamation law does not require the Bureau of Reclamation to recover any return on long-term borrowings for investment in the Central Valley Project irrigation system. We argue in this article, however, that reclamation law should be changed to require the return of interest to the U.S. Treasury for funds appropriated for such investment, and that the rate of interest should be determined on an opportunity-cost principle.

7. For proof that marginal-cost pricing of all goods and services leads to optimum welfare, see Edward Berlin, Charles J. Cicchetti and William J. Gillen, **Perspective on Power, A Study of the Regulation and Pricing of Electric Power,** A Report to the Energy Policy Project of the Ford Foundation (Cambridge: Ballinger Publishing Company, 1975), pp. 127–130.

8. In a perfect-competition model, there is one situation in which short and long-run marginal (incremental) costs are equal—that is, in long-run competitive equilibrium. In this situation, plant capacity has been adjusted to its optimum size for achieving a given level of output. It is assumed that a firm starts from scratch in planning its optimal-size production facility. In reality, this optimum is never realized. Instead, firms operate with plants of various ages, and must make decisions with regard to adding new capacity, either for replacement or growth purposes. Pricing on the basis of short-run costs would not necessarily recover the capital costs associated with this new plant.

Marginal cost, strictly speaking, refers to the additional cost of supplying a single, infinitesimally small additional amount. Incremental cost refers to the average additional cost of a larger finite addition to production. Since rate changes are relatively infrequent, additions to output where costs must be recovered are of an incremental rather than marginal magnitude.

9. The cost curves for an individual firm are drawn under the assumption that the firm has no influence on the prices of the factors of production it uses. Internal economies therefore are those enjoyed by a firm apart from any change in factor prices. When an industry as a whole expands its output, the prices of factor inputs may be affected. External economies affect the slope of the industry supply curve.

10. This chart, to emphasize, depicts the economic model of decreasing long-run average costs that originally characterized the operations of individual utility firms and led regulators to prescribe average rather than incremental-cost pricing. The cost schedules shown in Chart 1A depict the behavior of long-run average and incremental costs at a given point in time. Capital costs—i.e., amortization and interest—are determined on the basis of the current cost of plant and equipment valued at the time of the planning decision. This conforms with the economist's definition of average and incremental cost. Although this model provided the rationale for pricing on the basis of average cost, regulatory commissions have prescribed the historical accounting method for valuing plant and equipment. This method differs from the economic model in that average costs are determined on the basis of plant valued at original cost. As we shall see, most utility commissions continue to prescribe average-cost pricing even though utilities are currently characterized by increasing long-run incremental costs, even in the static sense as defined in economic theory.

11. For a physical description of this project see, U.S. Department of the Interior, Bureau of Reclamation, **A Financial Analysis of the Authorized Central Valley Project, Past, Present, Future** (Sacramento: Bureau of Reclamation, May 1972), pp. 7–9. For a summary of the official cost-benefit analysis of the project see, U.S. Department of the Interior, Water and Power Resources Service, **A Summary of Economic Reanalysis Related to the Auburn-Folsom South Unit Central Valley Project, California** (Sacramento: Water and Power Resources Service, September 1980). This analysis was challenged by the U.S. General Accounting Office, **Federal Charges for Irrigation Projects Reviewed Do Not Cover Costs** (Washington, D.C.: Comptroller General of the United States, 1981), pp. 23–27 and 44–72.

12. In its cost-benefit analysis of the Auburn-Folsom South Unit project, the Bureau of Reclamation estimated the average annual output of the project to be 550,000 acre-feet of irrigation water annually. Discussion with the staff of the General Accounting Office and the California Department of Water Resources indicated that the 440,000 acre-foot estimate is more realistic.

13. These figures are as of the beginning of 1982 (January 1, 1982) and therefore really reflect costs as of 1981. See, U.S. Department of the Interior, Bureau of Reclamation, **Project Data Sheet** (Sacramento: Bureau of Reclamation, January 1, 1982). In developing our estimate of long-run incremental cost, we subtracted out the estimated distribution cost from canalside to farmgate.

14. For the methodology for determining the long-run incremental cost of water, see Hirshleifer et. al., *op. cit.* pp. 152–165. Due to the absence of additional literature on long-run incremental costs, the author had to use literature available in the electric utility area. See, for example, Charles R. Cichetti, William G. Gillen and Paul Smolensky, **The Marginal Cost and Pricing of Electricity: An Applied Approach** (Cambridge: Ballinger Publishing Company, 1977; Charles R. Scherer, **Estimating Electric Power System Marginal Costs** (Amsterdam: North Holland Publishing Company, 1977; and Ralph Turvey, **Optimal Pricing and Investment in Electricity Supply, An Essay in Applied Welfare Economics** (Cambridge: Massachusetts Institute of Technology, 1968).

15. Office of Management and Budget, Executive Office of the President, "Discount Rates to be Used in Evaluating Time-Distributed Costs and Benefits," **Circular No. A-94**, Revised (Washington, D.C.: Office of Management and Budget, March 27, 1972). The 10-percent real discount rate called for in this policy memorandum is still in effect.

16. The General Accounting Office estimated the long-run incremental cost of irrigation water from the Auburn-Folsom South Unit project at canalside to be $73.17 in 1978, with interest at 7½ percent. Our figure is much higher because of the use of later cost data and methodological changes. See U.S. General Accounting Office, **Federal Charges for Irrigation Projects Reviewed Do Not Cover Costs, op. cit.**, page 58.

17. For affirmation of this point see, *Ibid*, pp. 1, and 9–10. Also, E. Phillip Le Veen, *op. cit.*, page 1 and U.S. General Accounting Office, **Reforming Interest Provisions in Federal Water Laws Could Save Millions** (Washington, D.C.: Controller General of the United States, October 22, 1981), page 5.

18. The U.S. General Accounting Office reached this conclusion in a recent study of the interest subsidy. **Reforming Interest Provisions in Federal Water Laws Could Save Millions, op. cit.**, page 19. That agency argues for the use of the "constant maturities yield" rate series.

19. U.S. General Accounting Office, **Federal Charges for Irrigation Projects Reviewed Do not Cover Costs, op. cit.**, pp. 4–10.

20. *Ibid*, pp. 10–11 and 15–19.

21. The Bureau of Reclamation uses the "separate costs-remaining benefits" method of allocating total project costs to various functions, i.e., water, electric power, flood control, etc. Critics charge that the Bureau does not allot a sufficient proportion of total costs to the irrigation function. For a description of that process see, U.S. Department of the Interior, Office of Audit and Investigation, **Review of the Central Valley Project Bureau of Reclamation** (Washington, D.C.: Office of Audit and Investigation, January 1978), Appendix III. For a critical evaluation see, Ralph Nadar Associates, **Damming the West**.

22. U.S. Department of the Interior, Water and Power Resources Service, **Central Valley Project Water Service Rate Policy** (Sacramento: January 8, 1981), pp. 1–3.

23. U.S. Department of the Interior, Office of Audit and Investigation, *op. cit.*, page 63.

24. Major cost items were included only if appropriate. For example, the return to equity owners was excluded because the Central Valley Project is financed solely through Congressional appropriations.

25. Capital costs equal the present value of the total investment in plant, valued in current dollars. Again, we used a real discount rate of 10 percent for this calculation.

26. The difference between this replacement cost estimate ($47.69/acre foot) and the average price actually realized by the Bureau for CVP irrigation water in 1981 ($5.09/acre-foot), multiplied by the number of acre-feet of water delivered (4.12 million acre-feet) yields an estimated total subsidy to irrigators of nearly $175 million for that year.

27. For a discussion of this view, characterized as the "water-is-different syndrome," see Maurice Kelso. "The Water is Different Syndrome, or What is Wrong with the Water Industry?" Paper Presented at the Third American Water Resources Conference, American Water Resources Association, San Francisco, California, 1967.

28. The formula for arc elasticity of demand is percentage change in quantity divided by percentage change in price. The resultant numerical value is the coefficient of price elasticity. When the elasticity coefficient exceeds one, demand is said to be elastic. When the value of the elasticity coefficient is less than one, demand is said to be inelastic. And when the value of the coefficient is one, demand has unitary elasticity.

29. For a summary of this literature see, Larry D. Schelhorse, et. al., **The Market Structure of the Southern California Water Industry** (La Jolla: Copley International Corporation, June 1974, pp. 167–175.

30. For example, based on a cross-section sample of 38 irrigation districts in California in 1958, Bain estimated a price elasticity of demand of −0.64. See Joseph Bain, et. al., *op. cit.*, page 176.

31. This estimate was reached by Richard E. Howitt, William D. Watson and Richard M. Adams, "A Reevaluation of Price Elasticities for Irrigation Water," **Water Resources Research** (August 1980), page 623. These authors used a quadratic programming model.

32. *Ibid*.

33. For a detailed analysis of the concept of the demand for irrigation water see, Joseph Bain, et. al., *op. cit.*, pp. 675–686. These authors refer to marginal revenue product as "net value of marginal product."

34. The Bureau of Reclamation uses a marginal principle in calculating payment capacity but calculates the measure incorrectly. The agency determines the additional gross revenue attributable to a new increment of irrigation water, but the agency then incorrectly subtracts out all additional variable and fixed costs plus a return on investment to arrive at a residual value that represents the amount the farmer can afford to pay for water. As correctly measured, marginal revenue product should be the additional profit yielded by the last increment of water. Profit should not be treated as a cost, as is the practice of the Bureau. Instead, it should constitute the residual value that measures ability to pay. By treating the return to management and investment as a cost, the Bureau underestimates "ability to pay."

35. Joseph Bain, et. al., *op. cit.*, pp. 679–681.