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EFFECT OF AN IRRIGATION WASTEWATER QUALITY STANDARD ON AGRICULTURAL PRODUCTION

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EFFECT OF AN IRRIGATION WASTEWATER QUALITY STANDARD ON AGRICULTURAL PRODUCTION

Agriculture is under considerable pressure to become more aware of the impact of its production and processing activities upon the environment. The problem has also been recognized by agricultural economists, and requests have been made from within the profession to change the focus of research to include more questions concerning the environment [Ruttan, 1971; Brewer, 1971; and Castle, 1970].

This paper reports the results of an analysis designed to identify the impacts of the alternative methods of meeting an environmental standard and, more specifically, to assess the resultant incidence of benefits and costs resulting from alternative policies designed to achieve a quality standard for wastewater from irrigated agriculture.

Agriculture and the Environment

Areas in which agriculture has been implicated for having major effects on the environment are: (1) pesticide residues in the food chain, (2) excessive amounts of sediment in surface water as a result of erosion, (3) excessive amounts of total dissolved salts in surface water resulting from irrigation return flows, (4) pollution of the atmosphere through burning operations, and (5) eutrophication of surface and ground water by the runoff and leaching of cropland, and by runoff from concentrated livestock enterprises. The evidence against agriculture is fairly conclusive in all of these areas except eutrophication. Scientific research has failed to shed much light on the processes by which nutrients are transformed from the soil to the ground and surface waters.

Nitrogen is usually the limiting nutrient in crop production, and this need is satisfied primarily with applications of commercial fertilizers. Unlike most nutrients in the soil, nitrogen in nitrate form is water soluble, and is highly mobile in the soil strata. Some environmentalists have linked the occurrence of nitrogen in bodies of water close to agricultural areas with the increasing use of nitrogen fertilizers. Nitrogen in surface water has induced excessive growth of algae and other aquatic plants that require high amounts of oxygen when they die and decompose. In the case of ground water, health problems have occurred when water of high nitrate-nitrogen content has been used for human and animal consumption.

Cultivation and related agricultural practices are the primary causes of nitrogen loss in the soil, but little evidence is available to indicate the amount of loss by source. Nitrogen is usually lost through crop removal, erosion, nitrate leaching, and denitrification. Despite continuing research on this topic, some of the basic nitrogen transformations are little understood because of their complex nature. Nitrogen in the soil originates from many sources other than commercial fertilizers. Organic matter, symbiotic or nonsymbiotic fixation of atmospheric nitrogen, and assimilation of atmospheric nitrogen by micro-organisms contribute relatively large amounts. Alternative sources of nitrogen, and the complexity of its movement in the soil, are among factors making it difficult to determine the causal relation between the application of nitrogen fertilizers and the nitrate-nitrogen content of surface and ground water.

There is little agreement among experts on the extent of the nitrogen problem. Commoner [1968] has persistently contended that at least 15 percent of the nitrogen fertilizer applied in the United States is leached into surface water, and another 15 percent is lost to the atmosphere. He has called for a 10-year moratorium on the use of nitrogen fertilizer in the United States, and is currently conducting research to test his contentions. Viets and Hageman [1971] concluded from a search of the literature that the nitrogen pollution problem has not reached a crisis. They suggest that since applications of nitrogen are important in maintaining an adequate supply of agricultural commodities, procedures other than a ban on nitrogen should be explored. They report there is little indication of a general increase in the nitrogen content of the nation's water supplies, but that surface and ground water within regions of intensive agriculture are high in nitrogen. Viets and Hageman suggest that research efforts be concentrated on identifying, and reducing or eliminating, the local sources of nitrogen within those regions.

The San Luis Unit of the Central Valley Project

Many soil formations in the San Joaquin Valley in California are high in natural nitrogen. Agricultural pumping results in a rapid exchange of water between the aquifers and the surface. The leaching that results increases the nitrate-nitrogen content of the water in the aquifers to such a level that in many areas it exceeds the U.S. Public Health Service standards for water for human consumption.

The San Joaquin Valley is divided into two hydrological basins, the San Joaquin and the Tulare. The San Joaquin Basin, located in the northern part of the valley, is drained by the San Joaquin River. The water discharges into the Sacramento-San Joaquin Delta and eventually flows into the Pacific Ocean via the Suisun-San Pablo and San Francisco Bays. The Tulare Basin, comprising the southern half of the valley, is essentially a closed basin with respect to drainage. Within it, 3.8 million acre-feet of irrigation water are projected to be delivered annually by the state and federal water projects by the year 2020. It will be impossible to maintain a general salt balance within this closed basin unless the saline ground water resulting from increased irrigation operations is exported.

In 1960, the U.S. Congress approved the San Luis Unit of the Central Valley Project, located in the Tulare and San Joaquin Basins, as a Federal reclamation project. Among other things, it authorized delivery of 1.09 million acre-feet of water to the 553,000-acre Westlands Water District. At that time, the District was pumping from a rapidly diminishing supply of ground water. The Bureau of

Reclamation recognized the drainage problem in the authorizing legislation, Public Law 86-488, which stated that an export drain be provided for some 262,000 acres that will eventually require drainage.

Drainage Water Disposal -- Who Pays?

In 1965, the Federal Water Pollution Control Administration responded to public concern about the effects of drainage water on the Delta and San Francisco Bay. An FWPCA investigation concluded that the drainage water could be discharged into the Delta providing the nitrate-nitrogen content of the water was less than 2 parts per million.

Studies by the California Department of Water Resources indicated that the current drainage water in the Westlands Water District contains an average of 33 ppm NO_3 [California Department of Water Resources, 1971]. On the basis of this information, the Bureau of Reclamation and the Environmental Protection Agency, together with the California Department of Water Resources, formed the Interagency Agricultural Wastewater Study Group. This investigative body was to inventory the nitrogen conditions in the potential drainage areas, evaluate the possibility of control of nitrates at the source, evaluate the drainage water quality, determine the change in the nitrogen content of the water during transit, and study the feasibility of various methods of nitrate removal from drainage water.

Certain important economic considerations which might be crucial in determining the optimal method to meet the quality standard were overlooked, however. Methods for regulating the discharge of wastes into the environment have included systems of standards, the legal process, the market solution, and systems of charges and subsidies. Many economists have favored the last two methods for two reasons. First it is easier for firms to respond, in their own interests, to prices rather than to regulations. Second, it is believed that the costs of achieving a standard will be minimized if these methods are utilized and, therefore, an efficient allocation of resources will be achieved in the Pareto sense. The market solution must be dismissed as a viable alternative for two reasons: 1) the absence of clearly defined property rights or liability rules, and 2) the virtual certainty that it would be inefficient to organize a water quality market within the study area. However, it is the hypothesis of this study that a system of effluent charges on wastewater could lead to a more efficient method of achieving the quality standards than that provided by the alternative methods. Briefly, the economic rationale for this hypothesis is that either a charge on effluents or a payment to reduce discharge will serve to induce the combination of resources that will minimize the costs associated with waste disposal within a given area.[1/]

Study Objectives

Specifically, the objectives of the study were to provide comparisons of the cost of drainage water treatment, the amounts of agricultural production and resource use, and the returns to land and management under the following alternative methods of achieving the standard. The standard can be achieved either by treating the wastewater or by reducing or eliminating certain agricultural practices to reduce the amount of NO_3-N in the drainage system. The specific alternative methods are:

1. The cost of wastewater treatment absorbed by the public sector.
2. The cost of treatment recovered by increasing the price of project water.
3. The cost of treatment recovered by charging each producer according to the amount of drainage water released to the San Luis Drain.
4. The cost of treatment recovered by charging each producer according to the amount of NO_3-N released to the San Luis Drain.

1/ Randall [1972] claims that on the theoretical level this statement is not true. He maintains that charges on effluents or a payment to reduce discharge will cause the same allocation of resources only where no consumers are involved, capital is a free good, and transaction costs are zero. Randall concludes that charges on effluents, as compared to a system of payments to reduce discharge, will result in a higher degree of pollution abatement and fewer and higher-priced commodities.

5. The cost of treatment recovered by charging each producer according to the amount of N fertilizer applied to drained areas.

Procedure

A multiperiod linear programming model based on an infinite horizon was selected to derive a set of cropping patterns that would maximize the present value of all future returns to land and management in the Westlands Water District, subject to the supply of resources and the drainage water quality constraint. The basic model used was developed by Isyar [1970] to determine an optimum time-path development for 13 irrigation districts in the western San Joaquin Valley. The model was modified for this study to estimate the quantity and the nitrogen content of drainage water resulting from a given cropping pattern. The relationship between the amount of nitrogen fertilizer applied, by soil types, and the resultant nitrate-nitrogen content of the drainage water was estimated, using ordinary least squares regression from data on 37 field drains located in the San Joaquin Valley. The data were collected by the California Department of Water Resources [1971]. Soil types were specified in the model by a series of dummy variables.

Each crop activity in the linear programming model represented the production of a crop under a specific combination of soil types and levels of nitrogen fertilizer application. This configuration of the model permitted changes in the levels of nitrogen fertilizer use and in the use of certain soil types for certain crops, in response to changes in the price of fertilizer and/or various effluent charges on drainage.

Future prices of specialty crops used in the model were assumed to change from present levels in response to the additional acreage projected for California. Dean and King [1971] estimated the price changes that would occur, using estimates of price elasticity of demand and the projected increases in demand and supply of the specialty crops. Appropriate market constraints were placed on the activity levels of these crops to reflect the District's own projected cropping plans.

The cost estimates of nitrate removal from agricultural drainage water used in the model were secured from the California Department of Water Resources. These costs were developed by the Interagency Agricultural Wastewater Study Group in tests conducted at the Interagency Wastewater Treatment Center in the San Joaquin Valley.

Five different configurations of the multiperiod linear programming model represented the alternative methods of meeting the constraint on drainage water quality. Model I assumed that the cost of nitrate removal would be absorbed by the public sector. Model II added the cost of nitrate removal to the price of the project water sold in the District. Model III allocated the cost of nitrate removal to the users of the San Luis Drain on the basis of the amount of water they release to the Drain. Model IV charged the users on the basis of the amount of NO_3-N they deposited in the Drain. Model V placed a charge on nitrogen fertilizer used on the land under drainage. For Models II, III, IV, and V, the charge or price was parametrically varied upward to a point at which total revenue generated by the charge equaled the total cost of nitrate removal, or at which the nitrate concentration of the drainage water resulting from the optimal cropping pattern was less than 2 ppm.

The amount of resources that will be available, and the schedule of water costs over time that were used in the linear programming model are indicated in Table 1. The present 480,000 acres of irrigated land is expected to increase to 553,000 acres by 1983, as water delivery facilities are completed. Approximately 33,000 of these acres will require drainage by 1979, and the area will increase to 262,000 acres by the year 2011.

The 609,000 acre-feet of ground water presently available for pumping is expected to decrease to 479,000 acre-feet by 1995. Project water deliveries will increase from the present level of 525,000 acre-feet to 1,091,000 acre-feet by 1983. The cost of pumping ground water is expected to remain constant over time

TABLE 1. Projected Land Available for Production, Land Requiring Drainage, and Water Availability and Cost in the Westlands Water District Over Time

	1972	1976	1979	1983	1988	1995	2005	2001
Available land 1/	480	524	544	553	553	553	553	553
Land requiring drainage 1/	0	0	33	84	148	213	250	262
Ground water available 2/	609	547	508	485	480	479	479	479
Cost of pumping ground water 3/	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
Project water available 2/	525	800	1,060	1,091	1,091	1,091	1,091	1,091
Project water cost 3/	9.00	11.67	13.00	13.00	13.00	13.00	13.00	13.00

1/ 1,000 acres

2/ 1,000 acre-feet.

3/ Per acre-foot.

Source: Bureau of Reclamation and Yuksel Isyar, The Potential Agricultural Development of the West Side of the San Joaquin Valley, California. Unpublished Ph.D. dissertation, Dept. of Ag. Econ., University of California, Davis, CA, Dec. 1970.

at \$22.50 per acre-foot, whereas the price of project water will increase from the present \$9.00 per acre-foot to \$13.00 per acre-foot by 1979.

Results

The costs of achieving the standard and identification of financial responsibility, given the assumption of the five models, are presented in Table 2. The total social costs of using Model I represent the present value of future treatment costs. In Models II through V, the costs are defined as the reduction in income to producers due to the imposition of the costs of achieving the standard. Since the objective function of the linear programming model is expressed as the present value of all future returns to Westland producers, the social costs of achieving the environmental standard were calculated as the difference between the Model I objective function value and the objective function values of Models II through V. Therefore, the social costs represent those costs associated with inducing producers to meet the standard by reducing production and changing agricultural practices, and/or those costs associated with constructing, maintaining, and operating a treatment plant.

As indicated in Table 2, the lowest total social cost of meeting the standard was achieved by Model III, which assumed that the treatment costs are recovered by charging drain users on the basis of drainage water quantity. This conclusion is consistent with the hypothesis that a charge made on effluents will lead to a solution that minimizes the cost of achieving a standard.

Model III places the cost of achieving the standard on the firms responsible for the drainage effluent. As the cost of treatment is mostly a function of drainage quantity, Model III represents the classical case of an effluent charge system. The costs of achieving the standard under Models I and II are \$17.7 million. The rationale underlying these models is that the drainage should be treated and the costs paid either by the public sector (Model I), or by the producers by adding

TABLE 2. Calculated Costs of Achieving Nitrate-Nitrogen Standard on Drainage Water in Westlands Water District 1/

	Cost to public	Cost to WWD producers	Total social costs
		$1,000,000	
Model I: Treatment costs recovered from public sector	17.7	0.00	17.7
Model II: Treatment costs added to project water cost	0.00	17.7	17.7
Model III: Treatment costs recovered by charging drain users on basis of drainage water quantity	0.00	14.7	14.7
Model IV: Drain users charged on basis of NO_3-N in drainage water	0.00	26.6	26.6
Model V: Drain users charged on basis of N fertilizer applications	0.00	26.7	26.7

1/ Costs are in terms of present values.

the cost to the project water price (Model II). Models IV and V are structured to induce the producers to meet the standard either through reducing the amount of production or by curtailing those practices which cause the effluent and, therefore, avoid the treatment costs. The rationale is that if the amount of nitrates were reduced to meet the standard, the need for treatment would be eliminated. These plans proved to be the most costly of those tested.

To explain the difference in the cost estimates obtained in each model, it is necessary to present more detailed results from each model. The resource use and drainage water characteristics obtained by the solution of Model II are presented in Table 3. The multiperiod linear programming model was divided into eight periods, namely, 1972-74, 1975-77, 1978-80, 1981-85, 1986-90, 1991-2000, 2001-2010, and 2011+. The optimal cropping patterns and resource use derived in the solutions for Models I through V were identical with respect to the first five periods, and did not include the drainage of any irrigated land until the sixth period (1991-2000).

Because of the relatively low quality of land that requires drainage, the high cost of installing and maintaining a field drainage system, and the limited supply of project water, it would be suboptimal for the District if farmers decided to drain land prior to 1991. The first soils that will require drainage are low in productivity, and normally used for low-valued field crops such as wheat and barley. Full deliveries of project water to the Westlands Water District will provide irrigation for about 350,000 acres of land. Therefore, the project water must be supplemented by ground water in order to maintain production on all available land. Given the assumptions of the model, the returns to land and management would be negative on the low-quality land if drainage was installed and production maintained. Therefore, only those results relating to the subject of the paper, namely the resource use and drainage water characteristics of the last three time periods, will be presented.

TABLE 3. Calculated Land Use and Water Use, and Characteristics of Subsurface Drainage Water in the Westlands Water District Over Time, Assuming Treatment Costs are Added to the Project Water Price (Model II)

	1991-2000	2001-2010	2011+
Land use (1,000 acres)			
Acres irrigated and not drained	340	303	291
Acres irrigated and drained	56	108	135
Total irrigated acres	396	411	426
Idle land	157	142	127
Total land	553	553	553
Water use (1,000 acre-feet)			
Project water	1,091	1,090	1,090
Ground water	140	195	245
Total water use	1,231	1,285	1,335
Subsurface drainage water			
Annual amount transported by San Luis Drain (1,000 acre-feet)	38.5	85.2	105.9
NO_3-N content (ppm)	13	25	28
Average cost of treatment per acre-feet of drainage to achieve standard	$35.70	$32.93	$33.68
Total annual costs of treatment to achieve standard ($1,000,000)	1.37	2.81	3.57
Average cost added to project water price per acre-foot	$1.26	$2.58	$3.28

Also, the results obtained from Model I are not presented as the cropping patterns, amounts of resource use, and drainage water characteristics are identical to those derived in Model II. The only difference between the results of Models I and II was in the objective function values. The differences between the values represent the cost of drainage treatment to meet the quality standard without imposing any incentives on producers to change their practices to improve drainage quality.

Model I assumed the drainage costs would be transferred to the public sector; Model II added the costs to the price of project water. The same acreage would be drained under solutions derived from Models I and II. The reason for the like amount of acreage is that the marginal value product of ground water is about double the administrated price of project water delivered to the Westlands Water District. Since the cost of treatment will range from about $1.25 per acre-foot of project water in the time period 1991-2000 to about $3.25 at full development, the administered price plus the per acre cost of nitrate removal would remain lower than the marginal value product of water and not affect the total use of water in the district. The result would be to transfer back to society a portion of the income from the producers who use project water. This would be in the form of drainage water of higher quality.

Under the assumptions of Model II, 157,000 acres, or approximately 28 percent of the total land in the District, will be idle in the time period 1991-2000. This amount will decrease to about 127,000 acres, or 23 percent, by full development in 2011 (Table 3). The amount of drained land was 56,000, 85,200, and 135,000 acres, respectively, for the last three time periods. The corresponding drainage quantities resulting from these acreages were 38,500, 85,200, and 105,900 acre-feet.

The total annual costs of treatment presented in Tables 3 and 4 were determined using a decreasing average cost function with respect to the quantity of

TABLE 4. Calculated Land Use and Water Use, and Characteristics of Subsurface Drainage Water in the Westlands Water District Over Time, Assuming Model III 1/

	1991-2000	2001-2010	2011+
Land use (1,000 acres)			
Acres irrigated and not drained	340	330	324
Acres irrigated and drained	12	47	58
Total irrigated acres	352	377	382
Idle land	201	176	171
Total land	553	553	553
Water use (1,000 acre-feet)			
Project water	1,091	1,090	1,090
Ground water	0	0	0
Total water use	1,091	1,090	1,090
Subsurface drainage water			
Annual amount transported by San Luis Drain (1,000 acre-feet)	13.3	43.9	53.9
NO_3-N content (ppm)	39	32	31
Average cost of treatment per acre-feet of drainage to achieve standard	$59.80	$38.95	$36.14
Total annual costs of treatment to achieve standard ($1,000,000)	.80	1.71	1.95

1/ Model III assumes treatment costs are recovered by charging producers according to quantity of drainage water.

drainage and constant average costs on the basis of NO_3-N content.[2/] This procedure accounts for the differences in the average cost of treatment in the three time periods. The total annual cost of treatment for each time period was divided by the amount of project water sold in the District to determine the increase in the project water price, which amounted to \$1.26, \$2.58, and \$3.28 per acre-foot for each respective time period.

Table 4 contains the results obtained from Model III, which was the least cost alternative to achieve the water quality standard. The rationale of the assumptions of Model III was to simulate an effluent charge system. The most desirable such system would be one that reflected both quantity and quality aspects of the drainage water similar that would reflect the characteristics of the cost function for treatment. However, the complications encountered in the administration and monitoring of such a system would probably prohibit its implementation. As the cost of treatment is primarily a function of the quantity rather than the quality, charges were based on the amount of drainage water disposed of in the San Luis Drain.

In comparing the costs of achieving the standard by the systems simulated in Models II and III, the treatment costs resulting from Model III were substantially reduced by reducing the amount of drainage water. This was achieved by reducing the amount of irrigated acres about 10 percent, and deriving a cropping pattern that yielded smaller amounts of drainage water. The saving in treatment costs from Model II to Model III was about \$3 million greater than the loss of income from reduction in irrigated acres, as reflected in the difference of costs presented in Table 2.

2/ Average costs based on quantity range from about \$74.00 per acre-foot at 5,000 acre-feet of drainage treated annually to about \$24.00 per acre-foot at 90,000 acre-feet of annual drainage. The additional costs due to quality amount to \$0.31 per ppm of NO_3-N per acre-foot of drainage.

The assumptions of Models IV and V represent effluent charge systems based on the NO_3-N content of the drainage water and the amount of nitrogen fertilizer applied to drained land. As the drainage water quality standard was established on maximum amounts of NO_3-N in drainage water, it is logically consistent to establish an effluent charge system based on the production of that effluent. This would provide incentive to producers to change or curtail agricultural practices that create the undesirable situation. Charges based on the amount of effluent in drainage water is a direct approach to the problem, but the monitoring of each producer's drainage would present substantial administrative problems. On the other hand, a system that taxes applications of nitrogen fertilizer might avoid some administrative problems, but it attacks the problem directly, as N fertilizer is only one of many factors resulting in NO_3-N drainage water. However, placing limits on N fertilizer have been suggested [Commoner, 1968].

The effluent charge systems simulated in Models IV and V were estimated to be the most costly alternatives of those evaluated (Table 2). The amount of resource use and quality of drainage derived in these models were approximately the same for each time period (Tables 5 and 6). The charge on NO_3-N and the price of N fertilizer were parametrically increased in each time period from zero to a level at which the amount of NO_3-N in the drainage was less than 2 ppm, or the revenue generated by the charge equaled the treatment costs. The former condition was achieved in Model IV by charges of \$1.35, \$1.40, and \$1.85 per pound of NO_3-N in the three respective time periods (Table 5). The additional charges per pound of N fertilizer in the same time periods to achieve the standard in Model V were \$0.94, \$1.80, and \$1.80 (Table 6). These two effluent charge systems achieved the standard by reducing the output of nitrates and eliminating the need for treatment. Therefore, the total costs of these systems are represented by losses of about \$26.6 million (Model IV) and \$26.7 million (Model V) in returns to land and management in the Westlands Water District.3/

3/ Represents the present value of all future returns to land and management.

TABLE 5. Calculated Land and Water Use, and Characteristics of Subsurface Drainage Water in the Westlands Water District Over Time, Assuming Model IV 1/

	1991-2000	2001-2010	2011+
Land use (1,000 acres)			
Acres irrigated and not drained	340	303	291
Acres irrigated and drained	45	60	58
Total irrigated acres	385	363	349
Idle land	168	190	204
Total land	553	553	553
Water use (1,000 acre-feet)			
Project water	1,091	1,090	1,090
Ground water	99	34	0
Total water use	1,190	1,124	1,090
Subsurface drainage water			
Annual amount transported by San Luis Drain (1,000 acre-feet)	25.5	35.0	32.8
NO_3-N content (ppm)	0	2	0
Average cost of treatment per acre-foot to achieve standard	0	0	0
Total annual costs of treatment to achieve standard	0	0	0
Charge per lb. of NO_3-N in drainage water 2/	1.35	1.40	1.85

1/ Model IV assumes a system of charges to producers according to the amount of NO_3-N in their drainage water.

2/ One acre-foot of water with 20 ppm of NO_3-N contains about 54 lbs. of NO_3-N.

TABLE 6. Calculated Land and Water Use, and Characteristics of Subsurface Drainage Water in the Westlands Water District Over Time, Assuming Model V 1/

	1991-2000	2001-2010	2011+
Land use (1,000 acres)			
Acres irrigated and not drained	340	303	291
Acres irrigated and drained	45	58	58
Total irrigated acres	385	361	349
Idle land	168	192	204
Total land	553	553	553
Water use (1,000 acre-feet)			
Project water	1,091	1,090	1,090
Ground water	99	31	0
Total water use	1,190	1,121	1,090
Subsurface drainage water			
Annual amount transported by San Luis Drain (1,000 acre-feet)	25.5	33.0	33.0
NO_3-N content (ppm)	0	4	4
Average cost of treatment per acre-foot to achieve standard	0	0	0
Total annual costs of treatment to achieve standard	0	0	0
Surcharge on N fertilizer per pound	$ 0.94	$ 1.80	$ 1.80

1/ Model V assumes a system of charges on nitrogen fertilizer used on drained land.

Conclusion

The results of this analysis indicate the differences in efficiency of alternative pollution control systems in achieving a drainage water quality standard, and the diverse impacts on agricultural production and resource use. Adding the cost of treatment to the price of project water is an alternative that would be attractive to the Westlands Water District for a number of reasons. First, the marginal value product of water in the District is sufficiently above the administered price of project water to cover the treatment costs without decreasing the amount of water used by producers. Second, it provides the District with a convenient system for allocating revenue, and third, it maximizes the production of agricultural commodities, but it is not the least-cost alternative available.

The equity implications of each alternative should also be determined and conside considered in a water quality management policy. However, the equity questions raised by the standard are complicated and beyond the scope of this study. The Bureau of Reclamation project was originally justified on the basis of the production of agricultural commodities. If the same criterion is used to judge the success of the project, a policy other than the most efficient or the most equitable probably should be implemented.

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