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Economic Magnitudes and Economic Alternatives in Lower Basin Use of Colorado River Water

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ECONOMIC MAGNITUDES AND ECONOMIC ALTERNATIVES IN LOWER BASIN USE OF COLORADO RIVER WATER*

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There is a problem. The water of the Colorado River, of which the major consumptive use is in irrigating agricultural crops, becomes quite saline as it reaches the lower end of the river on the U.S.–Mexico border. This fact is an international problem because the quality of the water delivered to Mexico is significantly poorer than the water delivered to U.S. users just 20 miles upstream. For example, in June of 1968, the mean salt concentration at Imperial Dam (U.S.) was 811 ppm, while the mean concentration at Morelos Dam (Mexico) was 1269 ppm.[1] These concentrations occurred even though extensive measures to alleviate the differential had already been taken in response to Minute No. 218[2] of the International Boundary and Water Commission. Similar conditions have prevailed until the current time, eventually culminating in the agreement of August 30, 1973 (Minute No. 242) whereby the U.S. would bring about a "permanent" solution through a $115 million dollar project including a water desalting plant in the Yuma area above Morelos Dam.[3]

The problem of equity between the two countries seems clear cut. The large differential in quality is created by actions of the United States. Since the United States is creating the problem it appears equitable that the United States bear the expense of solving it. Since Mexico is some distance further down the river it is reasonable that some quality differential exist. The agreement on a 115 ppm differential is surely equitable to the United States. Thus, in terms of equity between the two nations, it seems clear that there is a problem and that the problem is about to be at least temporarily solved. However, the real economic magnitude of the problem and the efficiency of the solution proposed are less clear. It is to these latter issues that this paper is addressed.

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1. Y. Gordon, Water Management Alternatives for the Colorado River Below Imperial Dam 20 (1970) (unpublished Ph.D. dissertation in Univ. of Ariz. Library).
2. 4 Int'l Legal Materials 545 (1965), 55 Dep't of State Bull. 555 (1965).
3. Minute No. 242, Preamble. Reprinted in this issue at p. 2.

A PHYSICAL-NUMERICAL DESCRIPTION

A complex of six irrigation districts in the southwest corner of Yuma County, Arizona, encompasses approximately 145,000 acres of irrigable cropland. In one of these districts a small amount of irrigation water is obtained from shallow wells. Some of this pumped water is reclaimed percolating water which is diluted with surface water in order to maintain the salinity content within tolerable limits. In each of the other five districts, all water supplies are obtained by surface diversions from the Colorado River, under contract with the U.S. Bureau of Reclamation.[4] These irrigation districts divert water in excess of their consumptive use and water rights, and deliver a return drainage flow to the Colorado River. The quantity of the drainage flow is subtracted from the total diversions so that the lands' water rights and consumptive use are in balance. The diversions are at Imperial Dam. The return flow is at Morelos Dam. The decrease in water quality in the 20-mile stretch of the river between Imperial Dam and Morelos Dam is obviously almost entirely due to the poor quality of the drainage flow which, for example, in June 1968, had a mean salinity of 3950 ppm. This water, mixed with the river's flow, created the 1269 ppm saline content of the water delivered at Morelos Dam in June 1968. In January of that same year a mean value of 5851 ppm was computed for the drainage flow.[5] When drain water is of this low quality, it is often diverted to below Morelos Dam where it merely flows into the Gulf of California and decreases the quantity of water delivered to Mexico.

The quantity of water used per acre varies widely among irrigation districts and within single districts. The 1961-64 average water use per acre was 6.72 acre-feet for the entire county. The range was from 5.41 acre-feet in the Yuma Valley District to 12.02 acre-feet in Yuma Auxiliary and 14.02 acre-feet in the Yuma Mesa Irrigation and Drainage District.[6] In 1968, the Wellton-Mohawk Irrigation District used only 5.5 acre-feet per acre in its valley areas, but used 12.1 acre-feet per acre in the mesa areas.

The two districts making the largest contribution to the drainage problem are the Yuma Mesa and the Wellton-Mohawk. The mesa area of the Wellton-Mohawk is the prime contributor within that district. In 1968, 115,329 acre-feet of water were delivered to 9,521 acres on

4. D. Jones, Economic Aspects of Agricultural Use of Colorado River Water in Yuma County, Arizona 7 (1968) (unpublished Ph.D. dissertation in Univ. of Ariz. Library); M. Kelso, W. Martin & L. Mack, Water Supplies and Economic Growth in an Arid Environment: An Arizona Case Study 84, 85 (1973).

5. Gordon, *supra* note 1, at 22.

6. Jones, *supra* note 4, at 13.

the Wellton-Mohawk mesa. The Yuma Mesa irrigated 17,008 acres with 220,710 acre-feet actually delivered to the farmers.[7] Thus, much of the difficulty is being created on about 27,000 acres of cropland, using about 336,000 acre-feet of water.

How many farms are involved? There are about 400 farms in the entire county.[8] Assuming the same size distribution in the six-irrigation-district area as in the county as a whole, there would be about 300 farms in the six districts and some 56 farms in the two mesa areas.

AN ECONOMIC OUTPUT DESCRIPTION

One of the most productive areas in the United States in terms of yields per acre and farm income is being described. In 1960, average gross return per cropland acre was $335 in Yuma County compared with $226 in Arizona as a whole and $123 for the United States.[9] By 1972 average cash receipts per cropland acre in Yuma County were $380 (excluding government payments).[10] Net returns per acre to the land itself (the residual after computing all production, management and overhead costs except the cost of land) were computed by Jones as ranging from $29 per acre per year for small 80-acre farms to as much as $146 per acre per year for the large, efficient corporate farms of greater than 1,500 acres.[11]

The per acre value of production in the mesa areas tend to be above the average for the county. These areas are tending to specialize in citrus production where net returns may reach $300 to $400 per acre.[12]

Thus, while the total number of cropland acres contributing to the salinity problem is not large, and the number of farm owners involved is not large, the income generating potential of each acre is quite significant and the farm owners obviously do not wish to have this potential disturbed.

ALTERNATIVE IRRIGATION PRACTICES AND POSSIBLE EFFECTS

Gordon, in his study of management alternatives for the Lower Colorado area, commented as follows:

7. Gordon, *supra* note 1, at 67, 77, 78.
8. Jones, *supra* note 4, at 33.
9. Jones, *supra* note 4, at 5.
10. Arizona Crop & Livestock Reporting Service, Univ. of Ariz. & U.S. Dep't of Agriculture, Bulletin S-8, at 7, 82 (1973).
11. Jones, *supra* note 4, at 93.
12. R. Spears, Federal Income Taxes and the Structure of the Arizona Citrus Industry 58 (1966) (unpublished M.S. thesis in Univ. of Ariz. Library).

> It is apparent from the history of the area under study that development of the water systems of this region occurred haphazardly. Most of the developments were in response to random opportunities, emergency situations, or dire need. Systematic planning was totally lacking. The outcome was a patchwork of various systems, structures, etc.
>
> Nowhere can this be seen more clearly than in the drainage system of the lower reaches of the Colorado River. Only when conditions became grave was a solution sought. And then the treatment was always directed toward the effect rather than the problem. Thus, the "solution" took always the same form: removal of the drainage water.[13]

Well, we've done it again! The proposed desalting plant is an engineering solution to the effects of a problem which could have been avoided and even now could be reduced on the farm. It would require both on-farm investment and a great deal of legal effort to straighten out the confused water rights of the area; but the latter effort, especially, would surely be worth the effort.

My collegues and I have argued elsewhere[14] that the entire question of adequate water supplies in the arid State of Arizona is of an institutional-legal, man-made nature, and not of nature-made restraints. The argument will focus here, however, on management alternatives and their relative costs and benefits.

The immediate objective is to reduce the salinity in the water at Morelos Dam to 115 ppm above the salinity of the water at Imperial Dam. Let us examine the conditions of June 1968, referred to above, and see how this could be done. The measured flow at Morelos Dam was as follows:

Colorado River	96,261 acre-feet
Wellton-Mohawk Drain Canal	16,630 acre-feet
Total	112,891 acre-feet

The mean salt concentrations were:

Colorado River	811 ppm
Wellton-Mohawk Drain Canal	3,950 ppm
Weighted Average	1,273 ppm[15]

The difference in quality between Imperial Dam and Morelos Dam was four times the proposed allowable difference of 115 ppm.

13. Gordon, *supra* note 1, at 57.
14. *See* Kelso, Martin & Mack, *supra* note 4, at 224-257.
15. That is:
(96,261 x 811) + (16,630 x 3950)=143,756,171
143,756,171 ÷ 112,891=1273 ppm

What if the return flow of drainage water were reduced by 75 percent? Drainage water would then equal 4,157 acre-feet. The difference of 12,473 acre-feet, if we may assume that it were not diverted and flushed through the soil, would flow down the river. If we further assume, for simplicity, that the concentration of the drainage flow remains constant at 3950 ppm, the salt concentration of the water at Morelos Dam would be 927 ppm, an increase of 116 ppm over the 811 base.[16]

My hydrologist friends tell me that this simplistic example is a reasonable representation of possibility. How could it be made to occur and what would be the costs and benefits? Gordon has given an example for the Wellton-Mohawk and Yuma mesas.[17]

Currently, the orchards of the area are flood-irrigated using from 12 to 13 acre-feet of water per acre. Gordon posits, on the basis of considerable analysis, that a shift to sprinkler irrigation could reduce water use to 5 acre-feet per acre, while a shift to trickle irrigation could reduce per acre use to 4 acre-feet, at the same time avoiding the salinity problem in crop growth.[18] If only the 5 acre-foot level were achieved on the two mesas, which comprise only 19 percent of the total acreage in the Yuma area, 40 percent of the water quality differential problem would have been solved. It seems reasonable that improved management practices on the remaining 81 percent of the land could solve the remaining 60 percent of the quality differential problem.

Gordon further gives examples of the economic benefits and costs to the farmers themselves and to their irrigation district if such improved management practices were adopted. Only the example for the Wellton-Mohawk mesa is summarized here. Absolute costs and benefits have been changed somewhat since 1968, when the study was made, but relative costs and benefits should be about the same.

The land is all leveled and prepared for flood irrigation. No further initial expense is necessary to continue current practices. These leveling costs were estimated by Jones at $91.50 per acre,[19] but may now be considered sunk costs and are no longer relevant in assessing future action. A change, either to sprinkler irrigation or trickle irrigation would, of course, require an initial fixed investment.

16. That is:
96,261 + 12,473=108,734 acre-feet of river flow
(108,734 x 811) + (4157 x 3950)=104,603,424
104,603,424 ÷ 112,891=927 ppm
927 - 811=116 ppm
17. Gordon, *supra* note 1, at 61-89.
18. *Id.*, at 69.
19. Jones, *supra* note 4, at 42.

The results of Gordon's analysis are presented in Table 1. Note that the farmers themselves, could *save* as much as $4.36 per acre per year by adopting the improved practices. Additional savings are possible by saving labor and material by fertilizing through the sprinkler system. It is also likely that a prevalent root disease caused by the fungus *phytophthora citrophthora* under conditions of excess moisture in the soil[20] would be reduced if not eliminated.

TABLE 1

A Comparison of the Costs to the Farmer of the Flood, Sprinkler, and Trickle Methods of Irrigation of Citrus in the Mesa of the Wellton-Mohawk Irrigation and Drainage District.[1]

		Method of Irrigation	
Item	*Flood*	*Sprinkler*	*Trickle*
Fixed Cost	0	21.39[2]	46.12[3]
Variable Cost[4]	19.50	16.75	10.40
Cost of Water[5]	35.00	12.00	9.00
Weed Control and Cultivation	30.00[6]	30.00[6]	15.00[7]
Total Cost	$84.50	$80.14[8]	$80.52[8]

[1] Source: Y. Gordon, Water Management Alternatives for the Colorado River Below Imperial Dam 75 (1970) (unpublished Ph.D. dissertation in Univ. of Ariz. Library).
[2] $210 per acre ammortized at 7%, 20% salvage value, 15 years life.
[3] $355 per acre ammortized at 7%, zero salvage value, 15 years life.
[4] Excluding cost of water, weed control and cultivation.
[5] 1968 delivered cost per acre.
[6] Average value from R. Young, W. Martin, & D. Shaw, Data for Arizona Crop Farm Planning 123 (1968).
[7] Interview with Business Dynamics, Inc. in Phoenix, Arizona, 1970, in Gordon, *supra* note 1, at 75.
[8] Does not include savings from fertilizer application.

Reduction in the amount of water applied to the land by the farmer would have impacts on the irrigation district. Savings would be reflected in the cost of pumping water lifted to the mesa and pumping the drain water from the valley. A reduction in revenue would be suffered by the district because less water would be sold. Increased revenue would accrue to the district through the sale of electrical energy to run the sprinklers. The net gain to the district would be $4.69 per acre. Since the district is a farmers' cooperative, the district's gain can be considered a gain to the farmers. Thus, total savings to the farmer would be about $9.00 per acre.

It is recognized that the results of changed management practices in the Wellton-Mohawk mesa is probably the most dramatic example

20. Interview with R. H. Hilgeman, 1970, in Gordon, *supra* note 1, at 110.

in the area of possible water savings and increased economic benefits to the farmer. However, it is still fairly clear that the quality differential problem could be solved (by the farmers themselves) without massive government investment in a desalting plant (or anything else) most probably at a net economic gain to the farmers of the area.

Given this situation, why don't the farmers of the area simply solve the problem? First, we are speaking of relatively new technologies; investment risk is involved, and the benefits per acre to the farmers themselves are not *that* large. And, of course, farmers of the area naturally do not view the international problem as their problem. It is the problem of the Federal Government. Perhaps some other incentives could be offered to induce farmer action.

POSSIBLE INCENTIVES

Since it is currently the Federal Government's responsibility to reduce the water quality differential, it would be just as logical for the Government to install the new sprinkler or trickle irrigation systems as it is for the Government to build a desalting plant. Total subsidy should not be necessary, however. Since, disregarding risk and uncertainty, the new irrigation practices would have net benefits to the individual farm owners, merely reducing risk by guaranteeing loans at low interest should be sufficient.

One current disincentive to water conservation is the water price structure in some of the districts. For example, in the Yuma Mesa District, the first nine acre-feet per acre costs a flat $12.15,[21] whether the water is used or not. Certainly the water should be sold by the acre-foot instead of merely being a fixed cost associated with land ownership.

Finally, the Boulder Canyon Project Act[22] and the Gila Project Act[23] both state that the Federal Government divert water to the districts for "beneficial consumptive use" only. Although it is clear that 13 acre-feet per acre is hardly beneficial consumptive use, defining beneficial consumptive use through litigation would be complicated and time consuming. Economic incentives and disincentives are probably the better choice.

COMPARATIVE COSTS

The construction cost of the proposed desalting plant, including the cost of the drainage canal extending to the Gulf of California, is

21. *Id.*, at 78.
22. Boulder Canyon Project Act, 43 U.S.C. § 617 (1971).
23. Gila Project Act, 43 U.S.C. § 613 (1971).

given by the U.S. Department of Interior as $98,050,000.[24] Costs per acre-foot of desalinated water at the plant are:

Capital Costs	$42
Operating Costs	$94
Total Costs	$136

while estimated costs per acre-foot of blended water delivered to the Colorado River are:

Capital Costs	$50
Operating Costs	$75
Total Costs	$125

Total annual costs are estimated as

Capital Costs	$6,685,000
Operating Costs	$9,851,000
Total Costs	$16,536,000

Power requirements are estimated at 276 million kilowatt hours per year, requiring 35 megawatts of electric generating capacity.

If the annual costs are put on a per acre basis, and one assumes that the entire 145,000 acres in the area is the problem, the *annual* per acre cost is $114. If the 27,000 acres on the mesas are assumed to be the major problem, the *annual* per acre cost is $612.

The above estimates may be compared to estimates of the marginal value of water in the Yuma area of $2 to $12 per acre-foot[25] or the typical marginal value of irrigation water throughout Arizona of about $8 per acre-foot.[26]

Alternatively, compare *annual* investment per acre of $114 or $612 with *sale* prices of land in the area ranging from $900 to $2,000 per acre.[27] Wildermuth, Martin, and Rieck give $1,100 per acre, including buildings and irrigation equipment, as the typical sale price in 1969.[28] Thus, the yearly cost of desalinating the drain water from these farms could buy out the farms themselves in from 2 to 9 years. Also, the yearly cost of desalinating the drain water would equal the one-time cost of investment in sprinkler systems or trickle irrigation systems in 2 to 3 years. In addition the latter investment

24. Office of Saline Water & Bureau of Reclamation, U.S. Dep't of Interior, Colorado River International Salinity Control Project, Special Report 19, 20 (1973). Reprinted in the Appendix to this article.

25. Jones, *supra* note 4, at 84.

26. Kelso, Martin & Mack, *supra* note 4, at 161-163.

27. Jones, *supra* note 4, at 91.

28. J. Wildermuth, W. Martin & V. Rieck, Cost & Returns Data for Representative General Crop Farms in Arizona, 253 Arizona Agricultural Experiment Station Rep. 85 (1969).

could be made by the private sector in anticipation of increased net incomes.

A simple way of viewing the magnitude of the decision to build the desalting plant is as follows. The U.S. Government, instead of building the desalting complex, could accomplish their purpose just as well by paying each farmer of the Yuma area, in return for the farmers reducing their drainage flow by whatever method they see fit, $114 per acre per year for the next 50 years. Given that such income would be guaranteed and riskless, it would be a rather attractive alternative from the farmers' point of view.

This paper has focused on U.S. cost and benefit comparisons because it is the U.S. who has chosen the desalting alternative as a solution to its international problem. However, one might note that water costing $125 per acre-foot will be delivered to Mexico to grow wheat, cotton, garden crops, alfalfa, and safflower,[29] of which the average value added per acre-foot was estimated as $80 for cotton and garden crops and $14 for wheat, alfalfa and safflower.[30] Even with current rates of net crop returns, average value added per acre-foot does not approach the cost.

IN CONCLUSION

Recently a great deal of interest has been shown in the problem of water salinity in the Lower Colorado Basin. In just the past one year, for example, the Office of Water Resources Research (OWRR) has funded a regional project among the basin states, the ultimate objective of which is to measure the cost of the increasing salinity and to study remedial measures. The Western Agricultural Experiment Stations, in cooperation with the USDA, have done likewise—the objectives of their studies are similar to the OWRR project. Both groups are cooperating heavily with the Bureau of Reclamation and the USDA Water Salinity Laboratory at Riverside, California. This author is associated with each of these efforts in one way or another, and has an additional project of his own.[31]

Very few definitive answers have as yet come from any of these efforts. However, the idea appears to be emerging that with proper management on the farm, the costs of managing salinity need not be

29. *See* Furnish & Ladman, *The Colorado River Salinity Agreement of 1973 and the Mexicali Valley,* in this issue, Table IV.

30. R. Young & W. Martin, *The Economics of Arizona's Water Problem,* 16 Arizona Rev. 9, 10 (1967).

31. W. Martin, Evaluation of Agricultural Adjustment to Irrigation Water Salinity: A Case Study for Pinal County, Arizona, Feb. 1973 (Project Statement, Water Resources Center, Univ. of Ariz.).

high. Thus, it is somewhat frustrating to watch the results of poor past planning and present political necessity bring about enormous public expenditures on structural remedies at this time. One may hope for future times when efforts will be directed toward problem causes rather than problem effects.

APPENDIX[1]

COLORADO RIVER INTERNATIONAL SALINITY CONTROL PROJECT SUMMARY OF FEDERAL COSTS (50 yrs. @ 5-5/8% Interest)

	Costs ($1,000)
Capital Costs[2]	
Desalting complex	
Installation cost	98,050
Interest during construction	13,095
Subtotal capital cost	111,145
Annual equivalent capital cost	6,685
Coachella Canal lining	
Installation cost	21,450
Interest during construction	1,160
Subtotal capital cost	22,610
Annual equivalent capital cost	1,360
Total installation costs	119,500
Total interest during construction	14,255
Total capital costs	133,755
Annual equivalent capital costs	8,045
Operating Costs (Annual)[3]	
Desalting complex	9,851
Coachella Canal lining (non-Federal)	0
Total annual operating costs	9,851
Total Project Annual Equivalent Costs	17,896
Desalting complex	16,536
Coachella Canal lining	1,360

[1] Both tables in the Appendix are reprinted from Office of Saline Water & Bureau of Reclamation, U.S. Dep't of the Interior, Colorado River International Salinity Control Project, Special Report 19, 20 (1973).

[2] Installation (or construction) costs plus interest during construction.

[3] Operation, maintenance, replacement and power costs.

UNIT COST OF SELECTED ACCOMPLISHMENTS
associated with the primary project objective of satisfying the salinity differential of 115 ppm ± 30 ppm TDS as provided in Minute No. 242 of the International Boundary and Water Commission

ACCOMPLISHMENTS	*Units*	*Unit Costs*[4]
DESALTING COMPLEX		
Desalting Plant Facilities		
Salt removal		
Tons per year	560,000	30
Dollars per ton		
Blended Drain and Product Water (delivered to Colorado River)		
Acre-feet per year	132,000	125
Dollars per acre-foot		
Capital costs		(50)
Operating costs		(75)
Million Gallons per day	117	39
Cents per 1,000 gallons		
Capital costs		(16)
Operating costs		(23)
COACHELLA CANAL LINING		
Water Savings		
Acre-feet per year	132,000	
Dollars per acre-foot		10

[4] Economic costs—based on 50 years at 5-5/8 percent interest.