Hastings Environmental Law Journal

Volume 14
Number 1 *Winter 2008*

Article 7

1-1-2008

Water Markets and the Cost of Improving Water Quality in the San Francisco Bay/Delta Estuary

David Sunding

David Zilbermann

Neal MacDougall

Water Markets and the Cost of Improving Water Quality in the San Francisco Bay/Delta Estuary

*David Sunding, David Zilbermann, and Neal MacDougall**

I. INTRODUCTION

There is a growing awareness of the economic dislocation caused by policies to stabilize and improve water quality. A notable and timely example of such regulation is the restoration of anadromous fisheries and the protection of endangered species by enhancing fresh water flows into the San Francisco Bay/Delta estuary, which will ultimately be accomplished by reducing surface water diversions to California farmers. This Article presents a method for measuring the short-term economic impacts of reducing agricultural water supplies under different water trading scenarios and applies the method to the problem of Bay/Delta water quality regulation. The economic analysis shows that water trading within agriculture can dramatically reduce the economic impacts of improving Bay/Delta water quality.

II. WATER QUALITY REGULATIONS IN THE SAN FRANCISCO BAY/DELTA ESTUARY

The San Francisco Bay/Sacramento-San Joaquin Delta estuary (hereinafter "Bay/Delta") is the largest and most productive estuary on the Pacific Coast. Its watershed drains 40 percent of California's land area, supports over 120 fish species, and includes the largest brackish marsh in the western United States. In the last two decades, however, the fish and wildlife resources in the Bay/Delta watershed have declined to record low levels.[1] Biologists believe that most of the decline has been caused by

*David Sunding, David Zilbermann, and Neal MacDougall are Visiting Assistant Professor, Professor, and Graduate Student, respectively, in the Department of Agricultural and Resource Economics at the University of California at Berkeley. This research was supported by a Cooperative Agreement with the United States Environmental Protection Agency for its review of the Bay/Delta water quality plan described in the text. The authors acknowledge helpful conversations with Richard Howitt, Michael Hanemann, Ariel Dinar, Patrick Wright and Palma Risler, and

increased exports of water from the Delta to cities and farms.[2] As evidence of this decline, two aquatic species are currently listed under the Endangered Species Act (hereinafter "ESA")—winter run salmon and delta smelt—and two other species are candidate for protection.

Two federal environmental agencies have statutory responsibilities to protect the Bay/Delta watershed: the Environmental Protection Agency under the Clean Water Act,[3] and the Department of the Interior under the ESA, the Fish and Wildlife Coordination Act, and the recently enacted Central Valley Project Improvement Act (hereinafter "CVPIA").[4] All of these laws, either directly or indirectly, will result in an increased quantity of water allocated to the estuary to improve water quality.

This Article assesses the economic impacts of reducing surface water diversions to improve water quality in the Bay/Delta estuary. Since agriculture uses 80 percent of the state's water supply and urban demands are increasing, the water needed to meet federal water quality requirements is likely to be reallocated from agricultural users. A key finding of this Article is that the impacts of water quality requirements depend to a large extent on how the burden for meeting the requirements is allocated among existing users. H*ow* cuts are spread among users is as important as *how much* water is taken for the environment.

Water trading can reduce the adverse impacts of environmental quality regulations if there are multiple users whose supplies can be cut and if there is a disparity in the productivity of water used in agriculture. This Article begins with an overview of agricultural water use in California, and demonstrates the large disparity in agricultural water productivity. We demonstrate that the least productive 50% of water used by the State's growers produces only 15% of total farm sales. There is thus ample reason to believe that water trading can significantly reduce the economic impact of

---

participants in seminars at UC Santa Barbara, the Water Resource Association, and the University of California Conference on Regional Water Constraints.

1. J. Callahan et al., *The San Francisco Bay/Delta Striped Bass Fishery: Anatomy of a Decline* (1989) (Working Paper No. 499, California Agricultural Experiment Station, Giannini Foundation of Agricultural Economics).

2. P. Moyle & R. Yoshiyama, *Fishes, Aquatic Diversity Management Areas, and Endangered Species: A plan to Protect California's Native Aquatic Biota*, California Policy Seminar, University of California at Berkeley, (1992); P. Williams, *Discussion of Trends in Freshwater Inflow to San Francisco Bay from the Sacrament-San Joaquin Delta*, 27 WATER RESOURCES BULLETIN, Apr. 1991, at 325; M. Rozengurt et al., *The Role of Water Diversions in the Decline of Fisheries of the Delta-San Francisco Bay and Other Estuaries* (1987) (Technical Report No. 87-8, Tiburon Center for Environmental Studies, San Francisco State University).

3. 33 U.S.C. §§ 1251-1387 (West 1994).

4. Pub. L. No. 102-575, 106 Stat. 4706 (1992).

reallocating water from agriculture by ensuring that only the least productive growers cease production.

The Article next introduces a short-run impact model for measuring the reduction in economic activity caused by a cut in surface water supplies to California agriculture. The model is based on the notion of asset fixity and envisions that growers will respond to changes in water supply conditions by altering their land allocation. This observation is supported by the behavior of California growers during the recent, severe drought of 1987-1992.[5]

The impact model is used to measure the change in State farm sales in several different water supply reduction scenarios. First, the model was run for cuts in surface water supplies of up to 2.5 million acre feet (hereinafter "MAF") annually, focusing on reductions between 0.8 and 1.3 MAF. Second, the model was run under two water trading environments: one in which CVP contractors receive proportional cuts in their supplies and cannot trade, and a scenario in which contractors can trade among themselves to make up for lost supplies or sell their remaining supplies. The central conclusion of this Article is that allowing water trading among growers can dramatically reduce the adverse economic impacts of improving Bay/Delta water quality. By maintaining an economically healthy agricultural sector while improving habitat in the important Bay/Delta estuary, water trading can help ensure the coexistence of agriculture and the natural environment.

III. CURRENT WATER APPLICATION PATTERNS

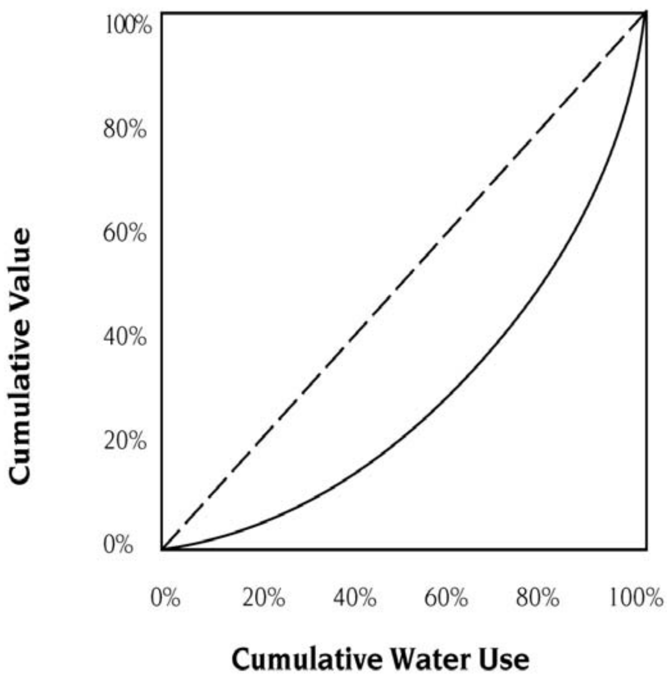
Water availability, amongst other reasons, has enabled California to become the largest agricultural producer in the nation, accounting for eleven percent of production by volume and thirteen percent by value. Value is proportionately larger than volume since California growers produce large amounts of high-value specialty crops and fresh produce. The soil in California is particularly well suited to high-value crops, and the warm climate enables longer growing seasons. The availability of irrigation water is necessary to fully utilize California's rich soil and advantageous growing environment. This becomes apparent in view of the fact that only two percent of total crop acreage in the grain belt—Iowa, Illinois, Kansas, Nebraska, and Missouri—is irrigated compared to twenty-six percent of agricultural land in California.

Despite the relative scarcity of water in California, growers in the state continue to produce a number of crops that have a relatively low value per unit of water applied. Field crops such as rice and alfalfa require relatively large amounts of water, while higher-value crops such as lettuce, tomatoes,

5. D. ZILBERMANN ET AL., HOW CALIFORNIA RESPONDED TO THE DROUGHT (1992).

grapes, citrus, broccoli and carrots have irrigation depth requirements ranging from one to over four acre feet per acre.

Figure 1
Water Use Relative to Value Among California Crops



It is important to quantify the disparity between the water requirements of the various crops and their relative contribution to agricultural value. Figure 1 shows all crops in ascending order based on value per acre foot of water used in their production. The horizontal axis shows cumulative contribution to total agricultural water use and the vertical axis gives total contribution to total annual State agricultural value.[6] If water were equally productive in all crops and regions, then the use-value relationship depicted in Figure 1 would be the 45 degree line. For example, 50% of the water used by farmers would produce 50% of crop sales. Figure 1

6. Irrigation depth data: A. Dinar et al., *Modeling Regional Irrigation Decisions and Drainage Pollution Control*, *in* NATURAL RESOURCE MODELING 191-212 (1991); STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES, BULLETIN 160-93: CALIFORNIA WATER PLAN UPDATE (1993). Crop value data: D. ZILBERMANN ET AL., ECONOMIC IMPACTS OF WATER QUALITY REGULATION IN THE SAN FRANCISCO BAY/DELTA ESTUARY (1992).

suggests, however, that a number of crops in California use copious amounts of water while contributing relatively little to the State's economy. Indeed, Figure 1 shows that the least productive 50% of the water used in California agriculture produces just fifteen percent of annual farm revenues.

This disparity in agricultural water productivity across crops and regions implies that policy makers should use discretion in implementing policies that reallocate water from agriculture to the environment. If water is taken from high-value uses with no possibility of private exchange to replace lost supplies, then the cost of improving water quality may be needlessly large. We now turn to a description of an economic impact model of California water policy that measures the economic loss from Bay/Delta water quality standards in different trading environments.

IV. IMPACT MODEL

A. Modeling Agricultural Production and Water Use

This section describes a method for measuring the short-term economic impacts of water policy changes known as the "rationing" model. The discussion in this Article is mostly informal.[7] The model's name derives from its central feature: growers respond to changes in water allocations by fallowing land otherwise devoted to production of the lowest-value crops. This approach reflects the fact that growers have a large degree of flexibility when they make long-term decisions regarding irrigation technology and cropping patterns, but have only limited flexibility in the short-run.

The rationing analysis is motivated by the large degree of heterogeneity in California agriculture demonstrated earlier. The Central Valley consists of many production environments that vary in terms of weather, land quality, water availability, and marketing conditions. Existing crop allocation patterns have evolved over time to maximize the overall benefits from agricultural production. At each location, farmers have invested substantial resources in infrastructure, including equipment for harvesting, packing, and irrigation systems. As a result, crop mix choices are predetermined in the short-run and are appropriate for individual locations. Reductions in water supply that change the preconditions for a successful crop mix are likely to be met with the only response available to growers—they will cease production of certain crops by allocating the requisite water to other uses.

7. *See* D. SUNDING ET AL., THE COSTS OF REALLOCATED WATER FROM AGRICULTURE (1994).

In this respect, the rationing model is an example of the "putty-clay" approach to production economics pioneered by Houthakker and Johansen.[8] The approach has been refined and applied to agricultural settings by Hochman and Zilberman.[9] Putty-clay models treat consumption decisions as predetermined in the short-run by previous consumption technology choices. For example, the water consumption of urban households is determined by the type of toilet and shower head used, the type of landscaping installed, and other factors that are generally variable only in the long-run. The notion that irrigation technology choice is conditioned by soil quality and availability of groundwater has been well established.[10]

Another factor motivating the rationing approach is that there is evidence that there is a proportional relationship between applied water and crop output per acre within a given irrigation technology, at least below a certain level of applied water (the "crop water requirement"). Water application above the water requirement yields no additional output.[11] This finding implies that farmers' short-run response to cuts in their surface water supplies is to either irrigate a field wit the quantity of water required for maximum yield or not irrigate it at all.

One additional response available to growers that may be implemented even in the short-run is to increase groundwater pumping. The rationing model is, however, built on the assumption that growers keep their level of groundwater pumping fixed. Two basic facts underlie this assumption. First, growers may have pumping constraints determined by existing well capacity that prohibit large increases in pumping volume in the short term. This capacity constraint exists most notably in the southern and western San Joaquin Valley where the majority of groundwater pumping occurs. Second, allowing growers to substitute groundwater for surface water artificially reduces economic impacts in the short run. There are, of course, potentially large long-run economic costs resulting from

8. H. Houthakker, *The Pareto Distribution and the Cobb-Douglas Production Function in Activity Analysis*, in REVIEW OF ECONOMIC STUDIES 27-31 (1956); L. JOHANSEN, PRODUCTION FUNCTIONS: AN INTEGRATION OF MICRO AND MACRO. SHORT-RUN AND LONG-RUN ASPECTS (1972).

9. E. Hochman, & D. Zilbermann, *Examination of Environmental Polices Using Production and Pollution Microparameter Distributions*, in ECONOMETRICA (1978).

10. M. Casewell & D. Zilbermann, *The Effects of Well Depth and Land Quality on the Choice or Irrigation Technology*, AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS (1986); M. Casewell & D. Zilbermann, *The Choices of Irrigation Technologies in California*, 67(2) AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS 224-234 (1985).

11. J. Letey et al., A *Crop-Water Production Function Model for Saline Irrigation Waters*, in SOIL SCIENCE OF AMERICAN JOURNAL 1005-1009 (1985); J. Letey & A. Dinar, *Simulated Crop-Water Production Functions for Several Crops when Irrigated with Saline Waters, in* HILGARDIA 1-31 (1986).

groundwater overdraft, including increasing pumping costs and possible subsidence. Numerous economic studies have shown that groundwater mining essentially trades current gains for future losses. Average profits over the long-run with and without groundwater mining are nearly equal.[12] The rationing model, as configured for this study, constrains growers increasing their rate of groundwater withdrawal.

In summary, the rationing model has a number of desirable properties. The rationing approach accurately captures growers' short-run response to changes in water supply policy by emphasizing land allocation. The model is also consistent with the best scientific information on the crop-water relationship. Perhaps most important, the rationing model can be explained easily to policymaker not formally trained in economics.

B. Modeling Water Trading and Reallocation Scenarios

The rationing model can be configured to consider various trading and reallocation scenarios. The basic unit of analysis is comprised of 86 individual water districts receiving water from the Central Valley Project (hereinafter "CVP"), and the model considers production of 34 crops including vegetables, field crops, and perennials. The rationing model is thus one of the most detailed representations of California water policy impacts.

The numerous individual water districts are grouped into five contiguous regions with similar growing conditions: Delta-Mendota Canal, Friant-Kern Canal, San Joaquin and Mendota Pool, San Luis/Cross Valley Canal and Tehama-Colusa. In reality and in the model, water is traded within each of the five regions. Water is thus allocated efficiently *within* each of these regions but not necessarily *among* regions.

California's water conveyance system is imperfect, resulting in serious physical constraints to interregional trading. For example, it is difficult for a grower on the Friant-Kern system to trade his CVP allotment with a grower on the Delta-Mendota Canal since the water would have to be conveyed through the Delta. Further, pumping constraints at the Delta motivated by endangered species concerns may make it difficult for a grower in the Tehama-Colusa region of the Sacramento Valley to trade with a grower in the San Luis/Cross-Valley Canal region south of the Delta.

The rationing model is employed to measure the costs of improving Bay/Delta water quality in two alternative water trading scenarios: *proportional* and *efficient* reallocations of water from CVP contractors to the environment. Proportional implementation occurs when supply reductions are allocated

12. M. Gisser, *Groundwater: Focusing on the Real Issue*, *in* JOURNAL OF POLITICAL ECONOMY 1001-1027 (1983); O. Burt, *The Economics of Conjunctive Use of Ground and Surface Water*, *in* HILGARDIA 31-111 (1964).

proportionally to past use in each of the regions; again, water is allocated efficiently within each region. Efficient implementation allows trading among all five regions to determine the final allocation of the supply cuts. In this scenario a grower can resort to the market to make up for lost supplies or sell water to another grower if this is more profitable than producing a crop.

Comparing the economic costs of these two policies measures the potential efficiency gain from market implementation of Bay/Delta water quality regulations. While it seems likely that the efficient scenario will have lower economic costs than proportional implementation, the magnitude of the welfare gain is very much an open question.

C. Economic Impact Measures

The basic output of the rationing model is the change in regional agricultural sales, in dollars, resulting from shifts in water policy. There are solid theoretical arguments for using gross revenue as the economic impact measure versus grower profit. The change in grower profit is an appropriate measure of social value only when factors of production such as labor and machinery can be costlessly redeployed in other sectors of the economy.[13] While this assumption might arguably be realistic in some industries, it is certainly not true in agriculture. Agricultural machinery and other non-human inputs such as chemicals are highly specialized. Farmworkers have an especially difficult time obtaining employment in sectors outside agriculture, especially in a state such as California where the vast majority of field workers are Hispanic and often have little job training or language skills. Using gross revenue as a welfare measure more accurately captures the value of the reduction in economic activity resulting from reduced diversions of surface water.

The rationing model is also used to measure the total change in the value of economic activity in the State and the number of jobs lost as a result of improving Bay/Delta water quality. These figures are calculated using multipliers taken from an input-output model created to analyze water resource problems in California.[14]

V. COSTS OF IMPROVING WATER QUALITY

The overall impacts of the two water reduction plans on revenue losses are summarized in Table 1 for two levels of aggregate supply reductions.

13. R. JUST ET AL., APPLIED WELFARE ECONOMICS AND PUBLIC POLICY (1982).

14. CALIFORNIA DEPARTMENT OF WATER RESOURCES, BULLETIN 210: MEASURING ECONOMIC IMPACTS, THE APPLICATION OF INPUT-OUTPUT ANALYSIS TO CALIFORNIA WATER RESOURCES PROBLEMS 23 (1980).

Losses under the efficient reallocation are consistently less than losses under the proportional reallocation, demonstrating that the economic costs of improving Bay/Delta water quality are reduced by water trading within state agriculture. Due to its high degree of disaggregation, the model also measures regional impacts from reducing surface water diversions.

A. Aggregate Impacts

The CVPIA directs that 0.8 MAF of water be taken from agriculture in an average water year. The rationing model shows that the economic costs of this action to improve water quality are only $40 million annually with unrestricted water trading and nearly $100 million in the proportional implementation scenario. Nearly 2,000 jobs are lost under the efficient solution, and more than twice as many are lost under the proportional reduction.

Table 1
Aggregate Impacts of Improving Bay/Delta Water Quality

		Supply Reduction	
	Implementation	8000,000	1,300,000
Lost Farm Revenues			
($'000)	Efficient	40,217	96,616
	Proportional	97,379	224,876
Lost State Product			
($'000)	Efficient	46,247	111,896
	Proportional	102,857	226,630
Lost Jobs			
(Person-Years)	Efficient	1,012	2,436
	Proportional	2,245	5,401

Table 1 also displays impacts when 1.3 MAF are reallocated in a normal year. Additional 0.5 MAF reduction beyond the initial 0.8 MAF level will result in an additional $60 million in lost farm revenue under the efficient solution and about $125 million under the proportional solution. The impact on labor will be around 2,400 lost jobs under the efficient solution, and about 5,400 lost jobs under the proportional solution. Thus, the economic costs of an additional 0.5 MAF incremental cut is larger than the costs of the initial 0.8 MAF reallocation mandated by the CVPIA.

Table 1 also shows declines in State product as surface water diversions decline. The State product multipliers are crop-specific, so the effect of a one-acre reduction in vegetables is greater than a similar reduction in field crops. Vegetables have greater linkages with the State economy as they require substantial resources for production, harvesting, processing and marketing, so eliminating an acre of vegetable production has more impact on the broader economy.

B. Regional Impacts

The proportional and efficient implementation schemes have different regional impacts as well as different total impacts. These distributional effects aid in assessing community impacts outside the agricultural sector. The farm revenue loss functions are disaggregated among each of the five regions and are presented in Table 2.

Table 2
Regional Reductions in Farm Revenues ($'000)

		Supply Reduction	
	Implementation	8000,000	1,300,000
Delta-Mendota	Efficient	850	2,658
	Proportional	8,778	22,863
Friant-Kern	Efficient	2,010	28,542
	Proportional	29,967	86,301
San Joaquin-Mendota Pool	Efficient	840	12,839
	Proportional	46,816	98,732
San Luis-Cross Valley Canal	Efficient	16	23
	Proportional	24	718
Tehama-Colusa	Efficient	36,501	52,554
	Proportional	11,794	16,262
Total	Efficient	40,217	96,616
	Proportional	97,379	224,876

When water supply cuts are implemented as in the proportional scenario, the San Joaquin-Mendota Pool and the Friant-Kern regions are the most seriously impacted because so much land in the southern and western San Joaquin Valley is devoted to production of high-value crops. The value of agricultural production drops in these regions by a total of around $75 million dollars under the 0.8 MAF reduction, and by over $180 million annually under the 1.3 MAF reduction. Under the efficient reduction scheme, production patterns in the four San Joaquin Valley regions are relatively unaffected by the supply reductions, while the Tehama-Colusa region is the most affected due to its emphasis on rice and other field crops. Tehama-Colusa farm sales fall by around $35 million annually under the 0.8 MAF cut and by over $50 million under the 1.3 MAF cut.

Table 2 shows the change in the value of regional crop sales resulting from the agricultural water supply cut. The impact calculations for each region do not include proceeds from or expenditures on water transfers. Rather, the rationing model only measures the value of the reduction in economic activity since the transfer payments net out in aggregate. Table 2 indicates where the water for Bay/Delta improvement will come from, and shows where agricultural production will be curtailed as a result.

Third party impacts from improving Bay/Delta water quality will be largest in the southern and western portions of the San Joaquin Valley under proportional implementation of the supply cuts. Under efficient implementation, third party impacts will be largest in the Sacramento Valley. It is important to remember, however, that the *total* third part impacts of reducing agricultural water supplies are minimized under the efficient implmentation scheme allowing interregional trading.[15]

VI. CONCLUSIONS

The Bay/Delta estuary is at the core of California's water conveyance system, and managing water quality in this important resource is the central policy issue faced by those controlling water allocation in the State. The Bay/Delta is also at the confluence of two major movements in western water policy: increasing recognition of the environment as a legitimate demander of water and increasing acceptance of market mechanisms to allocate water. This Article demonstrates that these two forces are complementary in the sense that market implementation of water quality regulations can minimize their adverse economic impacts.

To environmental economists, the notion that markets have the potential to ameliorate the impacts of environmental quality regulations is almost second nature. What is surprising in the case of California water, however, is the magnitude of the savings. If 1.3 MAF of water are diverted from agriculture's surface water supply, trading can cut revenue impacts by more than half. This result follows from the huge diversity in agricultural water productivity seen in Figure 1; half of all the water used by California growers produces only 15% of all State farm sales. These conclusions, in

15. *See also* L. DIXON ET AL., CALIFORNIA'S 1991 DROUGHT WATER BANK (1993).

particular the dramatic savings generated by water trading, should be borne in mind by all groups seeking to reconfigure State water policy.

It is also important to give some context to the revenue loss measurements in Table 1. California growers produce close to $20 billion in output each year. A $100 million loss from improving Bay/Delta water quality amounts to less than one percent of State farm sales. Losses may be high among some groups of water users even though aggregate losses are low. Junior water rights holders will bear most of these losses.

The rationing model analysis indicates the importance of trading between growers in the Sacramento and San Joaquin Valleys. Under the proportional implementation scheme, growers in southern and western regions of the San Joaquin Valley suffer the largest losses from reducing water supplies. The efficient scheme allows these growers to buy water from those in the Tehama-Colusa area of the Sacramento Valley. The net effect of this transfer is to substitute lost grain production north of the Delta for lost fruit and vegetable production south of the Delta. If cross-Delta conveyance is limited by physical and institutional constraints, losses from improving Bay/Delta water quality will be higher. While some serious constraints on Delta conveyance may be required to protect Bay/Delta fisheries, configuring the impact model to allow unrestrained conveyance measures the total potential benefits of north-south trading.

There are a number of real, difficult conflicts in California water policy, a fact to which those currently engaged in debates about the future of the Bay/Delta estuary can attest. What nearly all sides are looking for, however, is a formula by which California agriculture can coexist with the natural environment. This Article demonstrates that by maximizing the value of scarce water used to produce food and fiber, water trading can help ameliorate the perceived conflict between environmental quality and economic activity.