1988

Option Lease Water Markets in the Pacific Northwest

by

Norman K. Whittlesey

and

Joel Hamilton

Professors, Departments of Agricultural Economics, Washington State University and University of Idaho, respectively.

for
Contributed Paper Section, AAEA meetings, 1988

Topic Area
Natural Resource Economics

February 1988

Water power

#1552

Abstract

This paper investigates the feasibility of interruptible water markets whereby farmers in the Idaho Snake River Basin would sell water for instream hydropower production during low streamflow years. The analysis shows that the lost farm income from market participation is about ten percent of the increased hydropower production value.

OPTION LEASE WATER MARKETS IN THE PACIFIC NORTHWEST

Introduction

For most items of exchange, prices and quantities are set by market forces. Normally, this free market exchange is efficient and flexible in responding to changing conditions. Water is one of a small number of resources, however, that have usually been allocated by non-market mechanisms. The special treatment of water reflects its crucial role in the economic development of the arid lands of the west. In the western states, water rights have traditionally been acquired by appropriation, followed by beneficial use. To protect against "third-party" effects, transfers among uses and places of use have been severely restricted by state laws.

In spite of water's special role in the economy of the west, many people are asking whether the existing water institutions are too rigid to deal with today's problems, and if a move toward market forces might prove beneficial. Recently, interest in water markets has heightened, as illustrated in Anderson (1983), Whittlesey and Houston (1984), Wong and Eheart (1985), Gardener and Miller (1983), Houston and Whittlesey (1986), and Saliba and Bush (1987). This interest reflects the growing pressure on water supplies in many regions of the country, the increasing realization that institutional changes are probably necessary to improve the efficiency of water use, and the growing mood of the country to rely on privatization and market mechanisms to address resource allocation problems. The purpose of this paper is to investigate the economic feasibility of a water market involving irrigated agriculture in the Pacific Northwest.

Setting

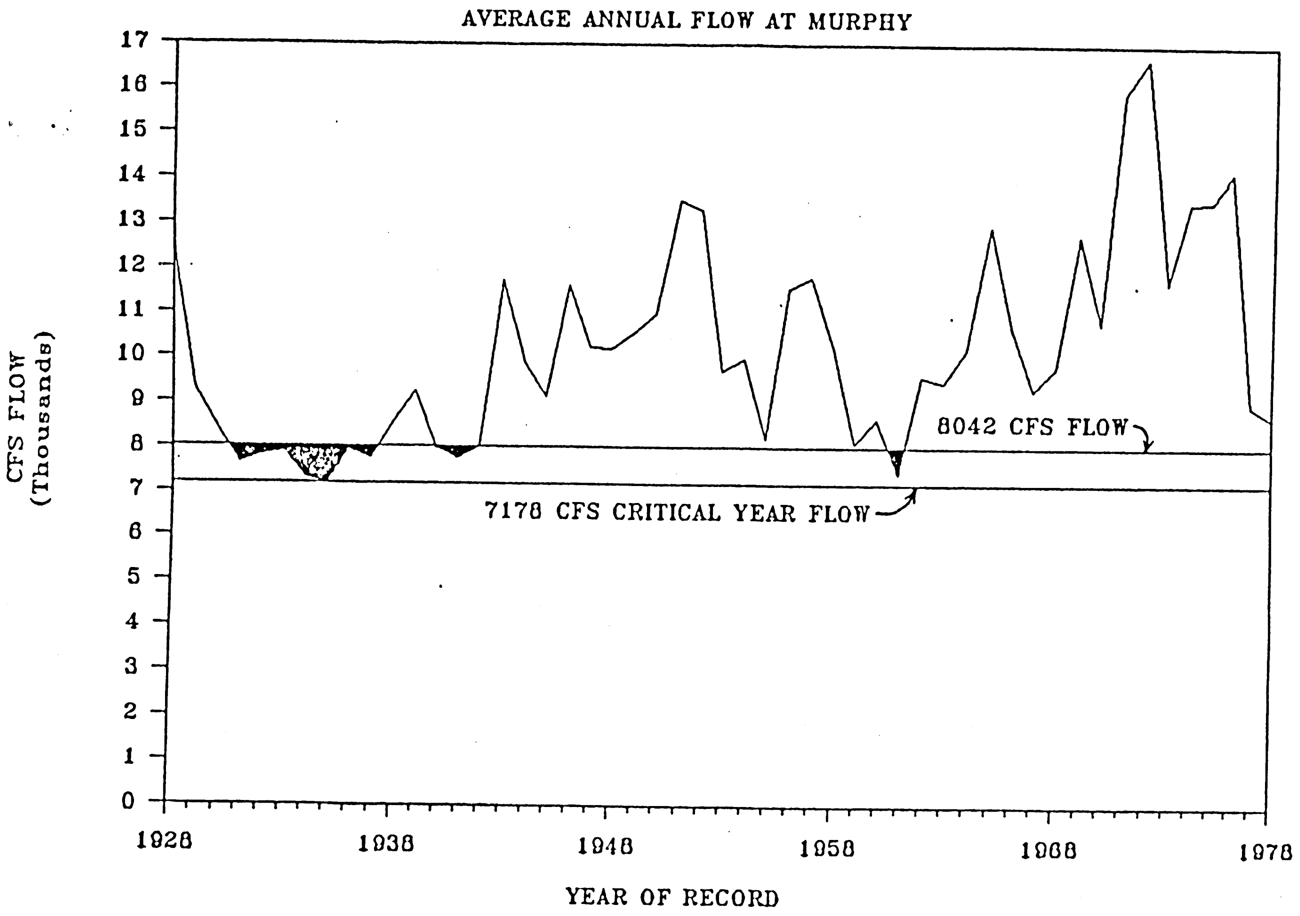
Irrigation is the dominant consumer of water in the Snake River Basin of the Pacific Northwest. Other consumptive uses, such as municipal and industrial, are minor in comparison to irrigation. Stream flows, including irrigation releases, are used for generating electricity as the water passes through hydropower dams. However, since a portion of this water is consumed by the crops, this reduces flows and electricity generation at each downstream hydropower dam. This means that irrigation and hydropower are the principal competing uses for water and would likely be the principal, although not the only, participants in any potential water market.

In most studies, agriculture has the lowest marginal value of water among those uses compared, but agriculture consumes more water than all other uses combined. This is certainly true in the Pacific Northwest and in particular the state of Idaho, which is the setting for this study.

This paper looks at the possibility of "option leases" where the farmer would contract to make available a specified amount of water for hydropower generation in dry years. In other years the water would be available for irrigation as usual. Farmers have a number of possible alternatives for coping with less water. They might irrigate more efficiently, shift to different crops, or practice "deficit irrigation." Using less water generally translates into lower crop production, higher risks, or higher costs of production. Each of these possibilities involves costs to the farmer which establish the minimum payment that would be necessary to induce the farmer to voluntarily sell or lease a quantity of water for hydropower production.

In the Pacific Northwest, the majority of electricity is still generated by water power. This means that the amount of electricity generated is critically dependent on the weather determinants of snow pack and stream flow, and on irrigation depletions. Figure 1 shows the historic stream flow at Swan Falls dam, at the lower end of the upper Snake River. This figure, developed by Hamilton and Lyman (1984), shows the average annual flow which would have

Figure 1. WATER NEEDED TO ASSURE 8042 CFS FLOW



occurred over the 51-year period between 1928 and 1978, given the level of irrigation and hydropower development present in 1980. While these 1928-78 flows averaged 10,215 cfs, they ranged from a high of 16,701 average cfs in 1972 to a low of 7,178 average cfs in 1935. These river flows are erratic, and the hydropower generation based on these flows is similarly erratic.

Electricity consumers, and hence electric utilities, place a large premium on supply reliability. The firm power yield of hydroelectric generation systems is the level of power that could be generated in the historic low-flow year of record. For the upper Snake River, this "critical year" is 1935, corresponding to the lower horizontal line in Figure 1.

This quantity of firm power can be sold by utilities at a premium value because of the guarantee of being able to deliver this power. All the power produced by the utilities with stream flows above this line is called surplus power and commands a much lower price because its delivery cannot be guaranteed. The surplus power currently commands a value of about 2.77 cents per kwh, while the firm power is sold at 5.65 cents per kwh, a difference of 2.88 cents per kwh of power. These values are the current avoided cost for providing each class of power.

The purpose of this paper is to investigate a water market that would raise the lower horizontal line in Figure 1 by paying farmers not to divert water for irrigation during low stream flow periods. The higher the firm power curve is raised, the greater becomes the probability that agriculture would have to deliver water in any given year. For example, if the utility were committed to maintaining flows at an annual average of 8,042 cfs, then they would expect to take delivery from the water market 19.6 percent of the time. This is illustrated by the second horizontal line in Figure 1, and the quantities of water that would have to be delivered by agricultural are shown by the shaded portions of the hydrograph. A block of approximately 600,000 acre feet of water now being consumed by agriculture would have to be under long-term contract to assure a 8,042 cfs annual flow. One hundred percent of this block of water would be required in 1 year out of 51, 82 percent in another year, 70.5 percent in a third year, and so on. In all, some delivery would be expected in 8 years out of 51, but only 8.3 percent of the contract water would be needed in the long term average. Actually, some water would be required in two additional years, but the quantities would be so small that they were not evaluated in this analysis.

The value of this kind of flow augmentation scheme to an electric utility has two components. First, the power that is generated with water delivered by the market will be firm power (represented by the shaded areas in Figure 1). This power would be valued at 5.65 cents per kwh. Second, the availability of this critical year generation capacity firms up a like quantity of power in all other years, increasing its value from 2.77 cents to 5.65 cents per kwh. This is represented by the unshaded areas between the two horizontal lines in Figure 1. As the target flow and intervention probability increase, a greater percentage of contract water must be delivered, so more is valued at 5.65 cents and less at 2.88 cents per kwh. As an example, this paper focuses on the expected market benefits of firming up stream flows to 8,042 cfs.

It is important to note that change in consumptive use is the quantity of primary interest in this analysis. A unit of water that is diverted to irrigation but merely returned to the river at a later time is still available for hydropower production. To obtain real changes in the power output requires a change in the consumptive use level of water by irrigation. However, it is assumed that a controlling agency operating such a water market could not tell a farmer how to irrigate his farm or what crops to grow in order to affect the consumptive use of water. It is only practical to control the level of water that is delivered to the farm. In this analysis it is assumed that changes in consumptive use will be obtained by anticipating the management response of farmers to changing water supplies and then controlling the level of delivered water to farms. A farmer who responds less efficiently than assumed would necessarily give up a greater portion of his consumptive use than required by the market. Therefore, farmers would be expected to always respond with at least the level of managerial efficiency assumed in operating the market.

Procedure

The uncertainty of participating in such a market is considered by showing the range of possible outcomes that can occur for a typical farm. The analysis considers several farm types in southeast and southcentral Idaho. Cropping patterns, irrigation systems, and sources of power for irrigation pumping are only some of the variables that are considered in this analysis. The loss of net agricultural income from market participation becomes the lower bound on the amount of compensation required by agriculture to justify participation in the market. The difference between this necessary level of compensation and the maximum benefit that can be derived from stream flow augmentation measures the water market benefit or economic feasibility. Net farm income is a return to land investment, irrigation system costs, machinery investment costs, management, and other fixed costs. A linear programming analysis was used to investigate the expected response of irrigators to changing water supplies and to assess the costs to agriculture from participation in a water market. The innovative procedure used to develop a linear programming model of irrigated farms that could measure the various responses of irrigation to changing water supplies is discussed in detail in Whittlesey, Hamilton, and Halverson (1986).

Under the conditions of the interruptible water market, a participating farmer would have his full water supply in most years. On the average, a farmer's water supply would be interrupted in 8 years out of 51. In these 8 years of interruption, the amount of water consumptive use to be given up by a participating farmer would vary from as little as 10 percent of his normal water supply to as much as 50 percent. To be politically feasible, this study assumed that no region of agriculture was allowed to give up more than 50 percent of its water supply in any given year. It was further assumed that the farmer would always know his seasonal water supply prior to the time of planting for spring crops.

Since reductions in water consumption were the focus of this study, it was necessary to establish a relationship between water consumption and the amount of water delivered to a particular farm. The differences between water delivered and water consumption for individual farms are a reflection of the level of irrigation efficiency for that farm. As water becomes more scarce to all farm types, the level of irrigation efficiency increases due to greater inputs of management and labor. The relationship between water supply and water consumptive use for each farm was estimated by first establishing the base level quantity of water use without a restricted supply. This base level water supply was then parametrically reduced to determine associated water consumptive use levels.

The average consumptive use of water on the representative farms in southern Idaho ranges from 18-20 inches per year. To obtain a 50 percent reduction in this level of consumptive use under the most extreme conditions would require a sacrifice of approximately 9 acre-inches of water. Hence, obtaining 600,000 acre-feet of water for stream flow augmentation would require the market participation of approximately 800,000 acres of irrigable land.

Results

The representative farms responded in different ways to water shortages when participating in the water market. For illustration, irrigation management choices with limited water supply for a rill irrigated farm are briefly described. The percentage of cropland devoted to each crop, the level of consumptive use and irrigation efficiency obtained with an unrestricted water supply were close to those currently existing for farms in the region. The rill irrigated farm applied more than 58 acre-inches of water per acre. Of this, 19.26 acre-inches were consumptively used by crops to provide an irrigation efficiency of 33 percent. Irrigation labor used to derive this level of irrigation efficiency was 4.62 hours per acre of irrigated cropland. In comparison, with a 50 percent water supply reduction, average irrigation efficiency had increased to 50 percent, consumptive water use averaged 14.47 acre-inches per acre, and irrigation labor increased to 5.73 hours per acre. No land was idled until water supply had been reduced by 63 percent.

A farm committed to the water market was assumed to be enrolled for 25 years and the estimated impact on participating farms was based on that length of time. Given that water supplies can range from 100 percent to 50 percent of current consumptive use levels, there is increased uncertainty about farm income under the market conditions. While the probability of being interrupted in any given year may be known, the actual supply of water that may be available in any succeeding year is uncertain. To illustrate the uncertainty associated with water market participation, a long run market simulator was run for a 25-year period 30 different times. The results of selected simulations are shown in Table 1. A number 1 indicates no interruption of the water supply, while a number 9 indicates a 50 percent level of reduction in the consumptive use water supply.

Table 1. Selected Draws for Market Participation over a 25-Year Period.[a]

Draw No.	Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	5	1	1	2	1	1	1	2	1	1	1	7	1	1	1	1	5	1	1	1	1	1	1	5	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	5	1	1	1	1	1	5	6	1	1	1	7
11	9	1	5	1	1	7	1	1	1	1	1	1	1	4	1	1	1	6	1	1	1	1	1	1	1
14	1	1	1	1	8	7	1	7	7	1	1	1	5	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	8
29	8	1	1	4	1	1	1	1	1	5	1	1	1	1	1	2	1	1	5	8	1	1	1	4	1
30	1	1	1	1	1	1	1	1	1	1	1	1	9	1	5	1	1	1	2	1	1	1	1	1	1

[a] Numbers represent percent reduction in consumptive use: 1 = 0%, 2 = 10%, 3 = 13%, 4 = 15%, 5 = 18%, 6 = 25%, 7 = 35%, 8 = 40%, and 9 = 50%.

While the expected value for the parameters associated with market participation would be the same under all conditions, the actual outcomes can vary widely. For example, in draw 17, a participant would have the first 24 years with no water supply interruption. Others, like draw 14, begins with 4 consecutive years with no supply interruption, followed by 4 out of the next 5 years with 35 percent and 40 percent supply reductions. Draws 11 and 29 begin the first year with a 50 and 40 percent supply reduction. The water supply condition in early years has a large effect on the long-term desirability of participating in the market. Also, the range of outcomes that can be expected will partially determine the type and amount of compensation that would be required for farms in a market.

The stream of income over each 25-year period was discounted to a present value using a 6 percent real discount rate (RDR). Table 2 summarizes the average annual net farm income for participating and nonparticipating farms. For example, the center pivot farm in south central Idaho (CP-SC) would have an

Table 2. Effect of Water Option Market Participation on Income from Irrigated Farming

	Annual Income					Present Value of Farm Income[b]			
		With Program					With Program		
Farm[a]	W/O Program	Max	Min	Ave	Ave Loss	W/O Program	Ave	Max Loss	Ave Loss
				(dollars per acre)					
1. CP-SC	169	169	124	166	2.59	2158	2123	80	34
2. Rill-SE	134	134	92	131	2.60	1711	1676	72	34
3. Rill-SC	160	160	112	158	2.70	2048	2012	78	36
4. SR-SE	153	153	114	151	2.06	1961	1934	62	27
5. SRL-SC	167	167	114	164	2.70	2134	2098	83	36
6. SRH-SC	185	185	138	182	2.69	2366	2330	77	36

[a] Farm types are: Rill-Southeast Idaho (RILL-SE); Sideroll-Southeast Idaho (SR-SE); Rill-Southcentral Idaho (RILL-SC); Sideroll-Zero Lift-Southcentral Idaho (SRL-SC); Sideroll-200 foot lift-Southcentral Idaho (SRH-SC); Centerpivot-500 foot lift-Southcentral Idaho (CP-SC).

[b] Present value calculations at a 6 percent real discount rate (RDR) are based on a 25-year period and averaged over 30 replications.

average net farm income of $169 per acre if not participating in a water market. The average net income for the participant farm over 25 years and 30 replications is $166 per acre, an actual difference of $2.59 per acre. However, over this time period, net income could range from $124 to $169 per acre. The water supply interruptions are infrequent, however, and agriculture is relatively undisturbed over time by participating in the water market. Table 2 also shows the present value of net farm income for each representative participant and non-participant farm. The effects range from a present value average loss of $36 per acre for three farm types (RILL-SE, SRL-SC, and SRH-SC) to $27 for the rill irrigated farm in Southeast Idaho. Changes in the value of crops produced or the costs of inputs could alter these results.

Since many farmers would wish to have a guarantee that they would never suffer any income loss under the most extreme conditions of market participation, the maximum net loss that might be incurred is also shown in Table 2. Representative farms would have maximum present value losses ranging from $72 to $83 per acre. The average and maximum losses in net farm income shown in Table 2 represent a range of possible values that would have to be covered by a minimum compensation scheme through the water market. Perhaps the most meaningful information in Table 2 for a farmer considering market participation is the average annual loss in dollars per acre, a value of about $2.50 per acre for all farms.

The purpose of an interruptible water market would be to increase the supply of firm power by converting non-firm power to firm power. The estimates of hydropower value created by the water market are shown in Table 3. The

Table 3. Effect of Water Option Market Participation on Water Use and Value of Hydropower Production for Selected Idaho Farms.

	Water Delivery		Consumptive Use			kwh per ac-ft	Value of Hydropower Production				
							Individual Year			Pres Value 6%	
Farm[a]	Max	Min	Max	Min	Ave Reduc		Max	Min	Ave	acre	ac-ft
	(acre inches per acre)					(kwh)	($ per acre)			($ per ac-ft)	
1. CP-SC	19.48	9.55	16.21	8.11	0.662	1119	43	22	23	301	446
2. Rill-SE	58.31	18.08	19.26	9.58	0.769	1264	58	29	32	405	502
3. Rill-SC	46.74	16.83	17.90	9.13	0.702	1119	46	24	25	325	445
4. SR-SE	30.10	14.15	19.47	9.70	0.779	1246	58	30	32	409	502
5. SRL-SC	28.98	13.34	19.17	9.23	0.774	1119	52	27	29	368	444
6. SRH-SC	27.72	13.31	18.61	9.34	0.733	1119	49	25	27	343	444

[a] Farm types are described in footnote (a) in Table 2.

center pivot farm would create a present value of energy over this period of $301 per acre or $446 per acre-foot of water committed to the market.

The present value of farm income losses from market participation range from $27 to $36 per acre for farms in southcentral Idaho, as shown in Table 2. These average farm income losses are to be compared with the above stated gains in power values. The center pivot farm will have an average present value loss in net farm income of $34 per acre, and the comparable gain in the present value power created is $301, nearly a tenfold difference. There is more than adequate value created from energy produced through the water market to compensate farmers for their farm income losses.

Conclusions

Even under very conservative assumptions, the value of power created by an interruptible water market will exceed the foregone costs to agriculture. By concentrating the water markets in those sectors of agriculture with the greatest advantage for participation, it should be possible to compensate agriculture considerably more than the amount of lost farm income. The exact level of compensation cannot be determined by this analysis, but a Pareto better position is possible for all market participants. Agriculture's use of irrigation water would be changed very little, while creating considerable amounts of increased value in the hydropower sector. Some farm types would have lower costs for market participation than others. Those with the greatest advantage in participation would be expected to enroll at the highest rate.

References

Anderson, Terry L. Water Rights: Scarce Resource Allocation, Bureau, and the Environment, Pacific Institute for Public Policy Research, San Francisco, 1983.

Bernardo, Daniel and Norman K. Whittlesey. "Optimal Irrigation Management Under Conditions of Limited Water Supply," forthcoming research bulletin, College of Agriculture and Home Economics, Washington State University.

Gardner, Richard L. and Thomas A. Miller. "Price Behavior in the Water Market of Northeastern Colorado," Water Resources Bulletin, Vol. 19, No. 4, Aug. 1983.

Hamilton, J.R. and R. A. Lyman. "An Investigation into the Economic Impacts of Subordinating the Swan Falls Hydroelectric Water Right to Upstream Irrigation," Idaho Water and Energy Resources Research Institute, Moscow, 1983.

Houston, Jack E., Jr. and Norman K. Whittlesey. "Modeling Agricultural Water Markets for Hydropower Production in the Pacific Northwest." Accepted for publication, Western Journal of Agricultural Economics, 1986.

Saliba, Bonnie C. and David B. Bush. Water Markets in Theory and Practice. Westview Press, 1987.

Whittlesey, Norman K., Joel Hamilton, and Philip Halverson. An Economics Study of the Potential for Water Markets in Idaho," Idaho Water Resources Research Institute and the State of Washington Water Research Center, 1986.

Whittlesey, Norman K. and Jack E. Houston, Jr. "Water Markets for Stream Flow Augmentation." Water Resources Bulletin. Vol. 20, No. 3, June 1984.

Wong, Benedict D.C. and J. Wayland Eheart. "Water Resources Planning Using Integrated Systems of Marketable Water Rights and Reservoir Design and Operation," University of Illinois Water Resources Center, Urbana-Champaign, 1985.