

2006 PRESIDENTIAL ADDRESS WATER MARKETS IN THE WEST: PRICES, TRADING, AND CONTRACTUAL FORMS

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Rising urban and environmental demand for water has created growing pressure to reallocate water from traditional agricultural uses. The evolution of water markets has been more complicated than those for other resources. In this paper, we first explain these differences by examining water rights and regulatory issues. Second, we place our research in the context of the economics literature on water marketing. Third, we present new, comprehensive data on prices and the extent, nature, and timing of water transfers across 12 western states from 1987 to 2005. We find that prices are higher for agriculture-to-urban trades versus within-agriculture trades, in part, reflecting the differences in marginal values between the two uses. Prices for urban use are also growing relative to agricultural use. Markets are responding in that the number of agriculture-to-urban transactions is rising, whereas the number of agriculture-to-agriculture transfers is not. Further, there is a shift from using short-term leases to using multiyear leases of water and permanent sales of water rights. This pattern underscores the need to consider the amounts of water obligated over time rather than examining only annual flows in assessing the quantities of water traded as is the common practice in the literature. Considering water obligated over time, termed committed water, we find significantly more is transferred and the direction of trading is different than if the focus is on annual flows. Finally, the data reveal considerable variation in water trading across the states. (JEL Q2, N5, L5, K3)

I. INTRODUCTION

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Farmers in the American West use roughly 80% of the region's water, often in low-value or subsidized crops, such as alfalfa, cotton, or rice. Farmers typically pay only for the pumping or conveyance costs for the water and not for its scarcity value.¹ Accordingly, much

1. Glennon (2005, 1883–1885). As pointed out by Hanemann (2005, note 29), this also is historically true for urban areas where metering did not become common until well into the 20th century.

ABBREVIATIONS

CAWCD: Central Arizona Water Conservancy District
C-BT: Colorado-Big Thompson Project
CVP: California Central Valley Project
ICR: Implicit Capitalization Rate
IID: Imperial Irrigation District
MRGCD: Middle Rio Grande Conservancy District
NCWCD: Northern Colorado Water Conservancy District

water use in agriculture has less value than if it were used in the West's rapidly growing urban areas and in many environmental and recreational uses. As a result, significant allocative gains arise if some water is moved from agriculture to other sectors.

For example, in 1992, Ronald Griffin and Fred Boadu reported that the value of water used in agriculture, capitalized over 50 yr, was \$300–\$2,300 per acre-foot (approximately 326,000 gallons) in the Rio Grande Valley of Texas. In contrast, urban water values, capitalized over the same period, ranged from \$6,500 to \$21,000 per acre-foot. Griffin and Boadu estimated that the average reallocation of water produced net benefits of \$10,000 per acre-foot.² For more contemporary evidence, in California, an acre-foot used in the semiconductor industry produces \$980,000 in gross state revenue; that same acre-foot used to grow cotton and alfalfa generates \$60.³ Groundwater for farming near Marana, Pima County, Arizona, costs approximately \$27 per acre-foot, whereas the same water supplied by Tucson Water, with an increasing block rate structure, will cost customers from \$479 to \$3,267 per acre-foot.⁴ In recent efforts to secure water from southeastern California's Imperial Irrigation District (IID), San Diego offered \$225 per acre-foot for water that IID farmers paid \$15.50.⁵ Even more dramatically, IID farmers paid \$13.50 per acre-foot in 2001, while a development near the South Rim of Grand Canyon National Park was prepared to spend \$20,000 per acre-foot to deliver the same Colorado River water.⁶ Although the costs of treating and distributing water for urban residents tend to be far greater than for rural and explain some of these price differences, the size of the differentials indicates the higher marginal benefits received by many urban versus rural users for water.

2. Griffin and Boadu (1992, 274–5).

3. See Peter Gleick, *Pending Deal Would Undermine State's Water Solutions*, Sacramento Bee, February 25, 2005, at B7. There are other inputs in production, of course, but this example demonstrates the potential marginal gains possible from water reallocation.

4. Based on personal communication with Paul Wilson, professor of agricultural economics at the University of Arizona; Ken Seasholes, director of the Arizona Department of Water Resources, Tucson Active Management Area; and Christopher Avery, Esq., Tucson City Attorney's Office. See Tucson City Code §27–33.

5. Dean E. Murphy, "Pact in West will Send Farms' Water to Cities." *New York Times.com*, 17 October 2003.

6. See Glennon, *Water Follies* (2002, 207).

These disparities in the value of water have occasioned calls for reallocation of water from lower value to higher value activities through water marketing. Such trades can benefit both parties: farmers receive more for their water than they could earn in agriculture and cities⁷ secure additional water at a lower cost than available alternatives, such as desalination. The need to develop water markets for the smooth, incremental transfer of water across sectors with minimum transaction costs has increased over the past 20 yr due to brisk population growth, urbanization, increased environmental concerns, and a rise in the economic contribution of services simultaneous with a relative decline in agriculture.

As the legal summary in Section II will make clear, water markets are more complex than markets for other resources, such as land. Property rights to water are less complete due to the mobile and uncertain nature of water supplies, the incomplete adjudication of water rights in many watersheds, and the fact that individuals have usufruct rights subject to state oversight.⁸ Further, because water rights often involve sequential users of the same water, water trades that change the location, nature, and/or timing of use, as is the case with most agriculture-to-urban transfers, are regulated by the states in order to limit harm to third parties, who might be adversely affected. Third-party objections to water transfers can and have slowed, limited, or blocked water transfers.⁹ Even though the interconnected nature of water rights has the potential to drive up transaction costs, water transfers are taking place.

This article addresses the extent and nature of western water marketing. It documents trading activity, identifies the sectors and states involved, describes the contractual forms used, and illustrates the trends in water transactions over time. Water markets as we

7. This analysis applies as well to securing water for environmental and recreational uses.

8. Sax (1990, 260). For more detailed discussion of water rights and regulation, see Brewer et al. (2007).

9. We do not object to the regulation of water transfers where significant third-party effects may occur. Rather, we note that the regulatory process can raise transaction costs because of additional time and resources required to secure regulatory approval for water transfers. Where there are important physical externalities, the added transaction costs, in part, reflect effort to more completely internalize those effects and thereby may reduce the number of water trades.

define them involve three different types of voluntary transactions: sales of water rights, 1-yr (short-term) leases, and multiyear (long-term) leases. Water transfers are affected by the timing of the transaction, location, quantity of water, and priority of water right (discussed below). We are primarily interested in three types of water trades: agriculture-to-agriculture, agriculture-to-urban, and urban-to-urban for the 12 western states. Our objective was to provide a comprehensive portrait of how water markets have developed in response to the price differences noted above.

Our data reveal a number of important features regarding water markets: (1) prices are higher for agriculture-to-urban trades relative to within-agriculture trades. (2) Agriculture is the origin of the majority of transactions. (3) The annual flow of water traded and the amount of water committed for transfer in a given year through long-term contracts (long-term leases and sales) reveal very different patterns regarding the movement of water. As measured by the amount of water *contractually committed* in a given year, the volume of water traded in the West is increasing over time, whereas, if measured by the *annual flow* of water traded, the amount is not rising. (4) The number of market transactions is increasing over time primarily due to agriculture-to-urban trades. (5) Sales and multiyear leases are growing, while 1-yr leases are not. (6) Whether measured as annual flow or committed water, Arizona, California, and Texas are among the top four states in the quantity of water traded.¹⁰ And, (7) agriculture-to-urban trades involve the majority of the water moved in most states when using the committed measure, whereas agriculture-to-agriculture trades involve the majority of water in most states when using the annual flow measure.

We report annual water transfers from 1987 through 2005 as listed in the trade journal, *Water Strategist*, a monthly publication that details transactions, litigation, legislation, and

10. In terms of annual flow, California (11,058,161 acre-feet), Arizona (8,375,767 acre-feet), Idaho (4,960,527 acre-feet), and Texas (2,559,140 acre-feet) are the leaders, and in terms of water committed for transfer over 19 yr, California (36,761,948 acre-feet), Texas (31,099,884 acre-feet), Arizona (21,889,597 acre-feet), and Colorado (14,913,506 acre-feet) are the leaders. These committed amounts are discounted as discussed later in the text.

other water marketing activities. Self-advertised as “the only source of published information on water transactions in the West,”¹¹ the *Water Strategist* publishes each month a “Transactions” section that lists, by state, each water transfer that occurred. From the publication, we can learn all or a subset of the following: the year of the transfer; the acquirer and supplier of the water (both labeled variously as municipality, developer, company, irrigator, farmer, rancher, conservancy district, irrigation district, state, federal agency, etc.); the amount of water transferred; the proposed use of the water; and, if applicable, the terms, such as the price and nature (lease or sale) of the contract. Our data set only includes transactions reported by the *Water Strategist* and no doubt misses some transactions. These are most likely to include within-organization (within-irrigation district) short-term trades.¹² Even so, *Water Strategist* listings are the most comprehensive available and, hence, capture the general pattern of water trading.¹³

In Section II, we offer an overview of water rights in the West and consider some critical legal and regulatory issues that affect water markets. Section III discusses issues raised in the economics literature that relate to water transfers, while Section IV addresses general data collection methodological issues and Section V explains how we measured the volume of water traded using a “committed” variable. Section VI presents price trends in western water markets, and Section VII offers an overview of the markets with data on the

11. <http://www.waterstrategist.com>

12. Brown (2006), who also used the *Water Strategist* data, pointed to some missing transactions. We compared our California transactions drawn from the *Water Strategist* with those reported by Hanak (2002) for the time period 1987–2001 for a sense of the completeness of the *Water Strategist* data. Hanak reported data collected from a variety of primary sources including the State Water Resources Control Board, the California Department of Water Resources, the U.S. Bureau of Reclamation as well as transfer records from within the Metropolitan Water District, the Westlands Water District, and other major organizations. For 1987–1996, the two data sets track closely, but for 1996–2001, our transaction volumes are lower than hers, suggesting some undercounting. We have no way of determining whether this problem also occurs in other western states. Nevertheless, we conclude that the *Water Strategist* data appear to be generally representative of water transactions.

13. Besides Brown (2006), other authors who have used the *Water Strategist* include Howitt and Hansen (2005), Brookshire et al. (2004), Adams, Crews, and Cummings (2004), Loomis et al. (2003), and Czetwertynski (2002). See discussion below.

contractual forms used, the categories of trades, the number of transfers across time, the changes in contract type over time, and differences in the markets across states. Finally, Section VIII offers a summary of some key findings.

II. APPROPRIATIVE WATER RIGHTS AND WATER MARKETS

To operate properly, any market requires reasonably secure property rights. Unfortunately, water rights are weaker than those for most resources due to water's physical characteristics and unique legal status. Because water moves, surface water cannot be bounded or partitioned easily across claimants and uses. Surface water often is hydrologically connected to groundwater, which also migrates and is unobserved.¹⁴ Moreover, simultaneous and sequential users of water make exclusion difficult and create numerous interdependencies. Consequently, the trade of water can inadvertently affect multiple parties.

In western states, individuals do not own water as they might own land. The state owns the water, which it holds in trust for its citizens. Individuals only hold usufruct rights to the water, subject to the requirement that the use be beneficial and reasonable and to oversight by the state in monitoring transfers to ensure that they are consistent with the public interest.¹⁵ Accordingly, water rights appear to have *less* protection or be more fragile than most other property rights.¹⁶

In general, western surface water rights are based on the prior appropriation doctrine that allows rights holders to withdraw a certain amount of water from a natural water course for private beneficial purposes on land remote from the point of diversion.¹⁷ Ownership of water is allocated through the rule of first possession or priority of claim.¹⁸ Those with the earliest water claims have the highest priority, and those with subsequent claims have lower

priority or junior claims. As such, there is a ladder of rights on a stream, ranging from highest in priority to the lowest. This allocative mechanism ranks competing claimants based on priority in order to ration water during times of drought. Lower priority water rights carry greater risk in water transfers because of possible shortfalls and accordingly are often of less value in water markets.

Failure by rights holders to continue to use their water may result in the rights being lost through the doctrines of abandonment or forfeiture.¹⁹ These doctrines create a perverse incentive for rights holders to use all their water. In many states, farmers who conserve water receive no benefit, as the water saved will go to the next-priority user on the river. As a result, farmers are motivated to devote large quantities of water to grow low-value crops. Until the development of water markets and recognition by state legislatures that conservation measures are consistent with beneficial use, farmers could do little else with their excess water. California eliminated this disincentive to conserve with a statute that provides that, when the use of water is reduced through conservation, the conserved water may be sold, leased, or transferred.²⁰

Because appropriative rights can be separated from the land and sold or leased, they can form the basis for private water trades.²¹ Even so, the process can be complicated. Appropriative rights are measured in terms of *diversion*, but transfers of water that change the point of diversion, timing, or nature of use are usually based on the amount of water *consumed*.²² Measuring transfers by consumption is important because it protects the rights of subsequent downstream diverters who have come to rely on the return flow from the first diversion. Hence, limiting trades to consumptive use reduces third-party effects on downstream diverters. However, calculating consumptive use is more difficult, thus driving up the transaction costs of trade.²³

19. Getches (1997, 176–180).

20. California Water Code, §1011.

21. Getches (1997, 156–60), Hirshleifer, DeHaven, and Milliman (1960).

22. MacDonnell (1990, Vol. I, p. 11).

23. Anderson and Johnson (1986) and Johnson, Gisser, and Werner (1981). Johnson et al. described how specifying a property right in water in terms of consumptive use with options for third-party grievances can be an effective method for promoting transfers. Howitt and Hansen (2005, 60) pointed to both transaction costs through property rights and regulatory differences and often high costs of transporting water.

14. Glennon (2002, 35–50).

15. Gould (1995, 94), Simms (1995, 321).

16. Sax (1990, 260), and Koehler (1995, 555).

17. Getches (1997, 74–189). California has a hybrid system that combines the prior appropriation doctrine with riparianism, a doctrine associated with the eastern United States that grants owners of land on rivers and streams rights to water. Glennon (2002, 14–15).

18. See discussion of first possession in Epstein (1979), Rose (1985), and Lueck (1995, 1998).

Water markets also are affected by differential water quality, especially cross-sector trades from agriculture to urban. Urban utilities generally prefer and will pay more for high-quality water that has less need for additional treatment. Within-sector trades may be easier because the level of water quality demanded and supplied may be more homogeneous. As we will see, municipalities and irrigators routinely transfer water among themselves.

Water markets also depend on conveyance opportunities, and the lack thereof can significantly reduce arbitrage possibilities.²⁴ This requirement includes access to canals and aqueducts, as well as to rivers or streams whereby water can be released by one diverter and appropriated by another.

Finally, water markets are generally local or, at most, statewide markets. There is little private water trading across state lines due to a variety of state regulatory restrictions and to the costs associated with transporting a heavy commodity (an acre-foot of water weighs 1,358 tons) to great distances. The price data bear out this situation by revealing the large arbitrage opportunities that exist among neighboring states.

III. WATER MARKETING IN THE ECONOMICS LITERATURE

A large economics literature has addressed water reallocation and the potential for water markets, and therefore, we only acknowledge representative articles. It is generally accepted that sharp differences in marginal water values among agricultural, urban, and environmental uses exist. Some authors, however, express puzzlement regarding the comparatively limited extent of voluntary exchange (Young 1986). One response has been to focus on the special characteristics of water that raise the costs of defining and enforcing water rights. These unique attributes result in pecuniary and technological externalities when water is transferred to a new location. Young and Haveman (1985) and Hanemann (2005) pointed to the simultaneous and sequential

use of water, its mobility, its unobservability (groundwater), as well as the variability and thus uncertainty of the supply. These factors link parties so that an action by one likely impacts others, thus increasing measurement and bounding costs (making it difficult to clearly assign property rights) and thereby raising transaction costs.

Related third-party effects from water transfers arise from a number of technological factors, including the hydrological and geological connection between surface water and groundwater. If farmers sell surface water and increase their groundwater withdrawal as a substitute, it may increase pumping costs, cause subsidence, and lower water quality (by salt water intrusion, e.g.) for other extractors (Glennon 2002). Conversely, a farmer who invests in ditch-lining and similar conservation actions may reduce groundwater recharge to the detriment of other groundwater users (Knapp et al. 2003). Groundwater is typically a common pool with very complex management requirements (Provencher 1993; Provencher and Burt 1993).

Another technical externality arises from lost return flows when water is shipped out of the watershed. This effect occurs not only with reduced groundwater recharge but also when upstream sales diminish downstream surface water. When a party diverts water from a stream, some water will be consumed but much of it (perhaps 50% or more) will percolate back to the stream for use by others. When the diverted water is sold, however, this return flow may be blocked. Chang and Griffin (1992) pointed out that water markets have formed where such effects are small, either due to a limited number of potential third parties or to a unique geography that makes return flow easy to quantify, track, and measure. Johnson, Gisser, and Werner (1981) argued that restricting transfers to consumptive use will limit these downstream effects.²⁵

Besides technical externalities, there also can be pecuniary effects if the agricultural economy is diminished from water transfers. Hanak (2003) discussed both pecuniary and technological third-party effects in examining county restrictions in California on water transfers. Government tax revenues may shrink if farmers fallow land or nonprofit entities (including municipalities) purchase water

24. Conveyance costs can be high. Hansen, Howitt, and Williams (2007, 3) reported that 55% of the \$250 that the Metropolitan Water District of Southern California paid in 2002 for water from Northern California was for the cost of conveying it.

25. See also Livingston and Miller (1986).

rights or secure long-term water leases. Further, rural political influence may be lost when large water transfers are made, populations migrate away, and there is no clear mechanism for compensation. Political opposition to water transfers over these issues can arise even when the actual costs are likely to be fairly small.²⁶ Similar equity issues associated with water trades are addressed by Charney and Woodard (1990), Howe, Lazo, and Weber (1990b), Howitt (1994), and Howe and Goemans (2003).²⁷ These distributional effects increase opposition to water markets (Haddad 2000, 33–48).

To reduce the third-party effects of water trades, states have established review processes for transfers. Regulatory requirements, however, can impact trades. The analysis by Howe, Boggs, and Butler (1990a) shows a wide range of transaction costs in nine case studies of water transfers. They found that costs tend to be smaller if: (1) larger amounts are involved, (2) there is less opposition to the transfer, and (3) the water right has a higher priority. Similarly, Colby (1990) found that regulatory review in some states could significantly delay the process and raise transaction costs.²⁸

While some institutional structures can retard trading, others can promote it by reducing transaction costs. Notable is the Colorado-Big Thompson Project (C-BT) and the associated Northern Colorado Water Conservancy District (NCWCD) whose institutional structure facilitates intertemporal and intersectoral water trades. Carey and Sunding (2001) compared the C-BT with the California Central Valley Project (CVP). With a much larger service area, the CVP has multiple water districts with differing regulations and procedures for transfers. Whereas internal district water trades are customary and of low cost, interdis-

trict water transfers within the CVP are more complicated with lengthy approval processes. One issue involves environmental concerns when water is shipped north to south through the Sacramento Delta. In part because of these conditions, most trades are within CVP districts and involve short-term leases. There are relatively fewer water sales or other cross-district transactions. In contrast to the CVP, within the C-BT, environmental conditions are more homogeneous, and there is an active water sales market among irrigators and between agricultural and urban users. Water allocations are uniformly defined and proportionally adjusted as water supplies vary; trading rules are the same; and because there is only a single water district within the C-BT, all return flow effects are internalized within the organization, facilitating adjustments to minimize any third-party losses from a trade.²⁹

Despite problems of developing water markets, most of the economics literature emphasizes the gains from expanding water trading.³⁰ Anderson and Snyder (1997) summarized the overall benefits. Howitt (1994) pointed to the role of the water bank established by California during 1991 in mitigating the effects of drought. Colby, McGinnis, and Rait (1991) examined the use of voluntary transfers to augment instream flows and improve habitat in the Truckee-Carson drainage of Northern Nevada.³¹ Howe, Schurmeier, and Shaw (1986) outlined a range of benefits of greater reliance on water markets.

Four recent papers use *Water Strategist* data to outline trends in water market activity in the western United States (Brookshire et al. 2004; Brown 2006; Howitt and Hansen 2005; Loomis et al. 2003).³² Loomis et al. used price and quantity data from the trade journal for 5 yr (1995–1999) to evaluate the extent of water sales and leasing from agriculture to accomplish environmental objectives in nine western states. They concluded that water

26. Hanak's survey of the literature (2003, 81) points out that effects of fallowing irrigated farmland is likely to have not more than a 1% effect on overall county economic activity, even when payments for economic adjustments are not included.

27. See the readings included in National Research Council (1992) and the volume edited by Carter, Vaux, and Scheuring (1994). Brewer et al. (2007) introduced water market data and discussed regulatory issues.

28. Various state regulations regarding transfers are outlined in Hogge et al. (1990); MacDonnell (1990) for Utah; Brown et al. (1990) for New Mexico; MacDonnell, Howe, and Rice (1990) for Colorado; Woodard and McCarthy (1990) for Arizona, and Squillace (1990) for Wyoming.

29. See also discussion of the C-BT institutional structure in Howitt and Hansen (2005, 60).

30. See the summary of benefits in Haddad (2000, 19–32).

31. Instream flow rights have particular problems because they require relaxing beneficial use requirements in appropriate water rights and because they are costly to enforce from downstream diversion. See Anderson and Johnson (1986).

32. See also Adams, Crews, and Cummings (2004), Czetwertynski (2002), and the recent working paper by Hansen, Howitt, and Williams (2007).

markets are more likely to be a means of facilitating the smoother reallocation of water than reliance on (nonvoluntary) regulatory reallocation.

Brookshire et al. used price data between 1990 and 2001 from 608 trades to compare the relative development of water markets in the Central Arizona Water Conservancy District (CAWCD), the NCWCD, and the Middle Rio Grande Conservancy District (MRGCD) in New Mexico. The authors found that water trading is most active and routine in the NCWCD, followed by the MRGCD and the CAWCD. Institutional details regarding the nature of water rights and the associated transaction costs of trading explain the differential roles of water markets across the three regions. Howitt and Hansen examined transfers between 1999 and 2002 across 14 states to determine the relative volumes and prices for water rights sales and water leases. They concluded that leases account for 90% of the volume of transactions (as measured by annual flow) but that sales prices are substantially higher than lease prices. They found a mean implicit capitalization rate (ICR) for lease to sales prices at 6.6%, which is slightly below a standard commercial capitalization rate. In examining this observation, the authors suggest that sales prices are being driven up in order to mitigate the risk of water shortfalls during drought.

Brown's study is most similar to the present one. He analyzed 1,380 water transactions between 1990 and 2003 in 14 states.³³ He argued that more water is traded via leases than through sales. According to his data, the number of leases grew over the 14-yr period, roughly doubling in number, whereas the number of sales did not. Further, leases involved larger amounts of water on average than did sales. The most active lease transactions involved large government-funded projects, such as the Central Arizona Project and the State Water Project in California. Municipal leases of water grew relative to those for agricultural and environmental uses after 1998. In terms of

sales, most purchases of water rights were by municipalities from irrigators.

With regard to prices, Brown reported that lease prices for municipal use were higher than those for agricultural and environmental leases but that sales prices for municipal water were only slightly higher than those for irrigation water. Both were greater than environmental sales prices. Brown also computed ICRs, finding a median ICR of 1.94%, well below that reported by Howitt and Hansen and any standard commercial capitalization rate. He argued that the low ICR reflects both low lease prices in agriculture and high prices paid by water rights purchasers. Even so, Brown found that lease prices have been rising in real terms since the late 1990s but sales prices have had no clear trend. These studies describe an active water market, especially through leasing water for trades within agriculture.

In the next section, we present more comprehensive data from 1987 to 2005 for 3,232 water transfers in 12 semiarid western states. Unlike the above studies, we break leases into single- and multiyear transactions and analyze them separately with respect to volumes and prices. In comparing leases and sales amounts with respect to prices, we focus on sales and 1-yr leases, rather than a composite of leases as has been done in other studies. This is important because multiyear leases can have much higher prices than 1-yr leases and thereby alter any ICR calculations. In addition to examining the annual flow of water in each transaction, we calculate the water committed through sales and multiyear leases. This approach is important because the committed measure substantially changes the assessment of the quantities conveyed by contract type across sectors and across time.

For example, in our data, 79% of all leases are for 1 yr (771) and they account for 91% of all leased water, measured by annual flow. If, however, the amounts of water obligated through multiyear leases are considered, the amounts involved in 1-yr leases fall to only 47% of the total water transferred by leasing agreements. Accordingly, it is important to consider the separate role of each contract type and how it facilitates the movement of water from one party to another. Because of the number of transactions included and the approach we adopt, our study yields the most complete view of the development of water markets in the American West.

33. Because he was concerned about very active C-BT trading overwhelming the summary statistics, Brown combined all C-BT transactions for a simple purpose for a given month into a single case. This reduces the overall number of transactions from 2,450 to 1,729 in his data set. Another 349 are dropped because of missing information, leaving 1,380.

IV. DATA COLLECTION METHODOLOGY

To assemble our water market data, we recorded every transfer listed in the *Water Strategist* from January 1987 through December 2005 for Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Texas, Utah, Wyoming, and Washington. Two of the most important variables were the original and the proposed use of each transfer. We classified these uses as agriculture, urban (municipal and industrial), or environmental. This classification system provided for nine possible combinations.³⁴ Because we are particularly interested in water reallocation, we focus on cross-sector trades, from agriculture-to-urban and within-sector trades from agriculture-to-agriculture and urban-to-urban.

For the majority of transfers, the *Water Strategist* explicitly indicated both the original and the ultimate purpose of the water and briefly described the details of each transaction. In cases where the entry did not explicitly state the nature of use before or after the transaction, it often was easy to determine the origination and destination uses from the context of the description. For a few transactions where the entry did not include the original and ultimate uses and the transaction description was not informative, we developed rules for classifying these transactions.³⁵

According to our rules of thumb, we classified a use as agricultural if the name of the lessor, lessee, seller, or buyer was an irrigator, an irrigation district, a water district, a farmer, a ranch, a canal company, a ditch company, or an individual.³⁶

34. The nine classifications are: agricultural-to-agricultural, agricultural-to-urban, agricultural-to-environmental, urban-to-agricultural, urban-to-urban, urban-to-environmental, environmental-to-agricultural, environmental-to-urban, and environmental-to-environmental.

35. In selected cases where the description of the transfer contained in the *Water Strategist* was ambiguous, we relied upon Robert Glennon's knowledge of water institutions in the West (aided by Google searches). These transfers primarily occurred in Arizona and California and consisted of approximately 55 of the 3,317 transfers in the data set.

36. One could potentially argue that an individual should be classified as an urban user instead of an agricultural user, but we decided that it was more likely that an individual (not a city, a corporation, or another entity reflecting municipal or industrial use) was an agricultural user, especially if the individual was a seller. The *Water Strategist* described an individual as a seller of water 88 times and as the buyer 9 times. The total water that was transferred when either the buyer or the seller was listed as an individual was 22,467 acre-feet. This amount is less than 0.01% of the total water transferred in our data set. One transfer by an individual accounted for 15,000 acre-feet of the total 22,467 acre-feet transferred.

Similarly, we designated a use as agricultural if the description of the transaction stated that the water was employed in agriculture, if the water was provided by land fallowing, or if the description discussed widespread farming in the district from which the water was supplied.

We classified a party as environmental if it was a state department of fish and wildlife or a nature conservancy. The U.S. Bureau of Reclamation, generally an agricultural water supplier, was labeled environmental when it acted to improve or maintain instream flows, to help fish stocks, or to preserve water quality levels or engaged in other similar activities. When a party was a water conservation or conservancy district, we designated the transfer as agricultural, urban, or a combination agriculture and urban trade, not environmental. Most water conservation or conservancy districts are primarily involved in agricultural activities or in some cases urban and/or a combination of agriculture and urban.

Last, in cases where either the *Water Strategist* did not explicitly discuss the use of the water or its description was too vague, we assigned urban when cities, townships, municipal water districts, developers, manufacturing and mining companies, golf courses, and landscape irrigators were involved.

Despite our best efforts to develop classification rules that would reliably identify transactors, the information, in some cases, was simply incomplete. These transfers lacking an identifiable origin or destination use were relatively rare, accounting for 85 (2.6%) of the 3,317 transactions in our data set. They are excluded from our data set, and thus, the tables and analyses provided below are based on the remaining 3,232 observations.³⁷

Finally, a single transaction occasionally involved multiple transfers and sectors. For example, an entry might include an irrigator and a city that transferred a combined 10,000 acre-feet of water to another city. In this case, the destination of the transfer is clearly urban, but the origination came from agriculture and urban. In many instances, the description included a breakdown that allowed us to identify the sectors. For example, if the irrigator

37. These unknown transfers account for 798,932 acre-feet of water, about 2.5% of the total in our data set. Our data set is available on the web page of Donald Bren School of Environmental Science and Management, Water Policy Program, University of California Santa Barbara.

and city each transferred 5,000 acre-feet, we noted two transactions, one of 5,000 acre-feet provided from agriculture-to-urban and the other of 5,000 acre-feet from urban-to-urban. If the information did not allow use to make such attributions, we classified the transfers as “combination” transfers. Of the 3,317 transfers in our data set, 161 (4.9%) were combination transfers.³⁸

V. MEASURING THE VOLUME OF WATER TRADED

We measure and report the volume of water traded in two ways. The measure used in the literature is the *annual flow of water* as listed in the *Water Strategist*. Unfortunately, this annual flow measure reflects only the *amount of water transferred in the initial year of the transaction*. For example, a transaction in the *Water Strategist* typically states that 1,000 acre-feet was leased for a specified number of years or sold. The annual flow measure would only record the 1,000 acre-feet transferred in the year the transaction originated. By this measure, a sale or multiyear lease of 1,000 acre-feet is identical to a 1-yr lease. This approach substantially biases downward the impact of multiyear leases and sales on the volume of water traded. An alternative and perhaps more intuitive measure would annually record water traded through multiyear leases and sales for the duration of the contract (in perpetuity for sales). This measure, however, would be misrepresentative in our sample, because any sales and multiyear leases consummated before 1987 (at the start of the data set) would necessarily be ignored, thus possibly creating an artificial upward trend.

Accordingly, we introduce a committed water variable that avoids the undercounting associated with the annual flow variable and any downward bias early in the sample. The committed variable includes all transfers that originated in a given year. It projects the annual flow forward for the term of the transaction, that is, 5 yr for a 5-yr lease or in perpetuity for a sale, and then discounts the flow by 5% per year and sums the series to arrive at a single committed amount of water analo-

gous to a present value of a series of annual payments.³⁹ As we show below, sales and multiyear leases are an important part of water markets, and this procedure better reflects the actual amounts of water involved than has been reported previously.⁴⁰

VI. PRICE TRENDS: EVIDENCE OF REALLOCATION PRESSURES

Of the 3,232 transactions in our data set with information on the transacting parties, amounts, and nature of use, a smaller number, 2,154, had price data.⁴¹ Of these, 1,836 involved the three classifications of primary interest: within-sector, agriculture-to-agriculture and urban-to-urban transactions and across-sector, agriculture-to-urban trades.

39. To illustrate the differences between the annual flow and the committed variables, consider a 5-yr lease of 1,000 acre-feet per year beginning in 1990. The annual flow metric would record 1,000 acre-feet in 1990 only. The committed variable instead would discount the 1,000 acre-feet transacted annually across the 5 yr of the contract at 5% and sum the total. In so doing, 4,329 acre-feet would be recorded for 1990, rather than 1,000 acre-feet.

40. For example, see the annual flow measures used by Brown (2006) and Howitt and Hansen (2005). We recognize that during dry years, the actual amount of water available may be substantially less than the contractual amount if sales or leases involve very junior priority rights. For example, dry-year contingencies in long-term contracts may allow for reduced volumes to flow by specifying that *up to* a certain amount would be traded or that the transfer would be *between* two amounts. Unfortunately, in our data set, we do not observe the actual amounts transferred. To account for potential biases when contingent transfers were involved, we created three separate measures for both the annual flow and the committed variables calculated in our data set: minimum, maximum, and the mean amount transferred. For a 2-yr lease of up to 1,000 acre-feet annually, the minimum annual flow (committed) amount was 0 acre-feet (0 acre-feet), the maximum annual flow (committed) was 1,000 acre-feet (1,859 acre-feet), and the average annual flow (committed) was 500 acre-feet (930 acre-feet). The results reported in this paper use the mean annual flow and mean committed amounts. Because there are relatively few contingent contracts in our data set, the results and conclusions do not change in any meaningful way if either the minimum or the maximum amounts are used instead.

41. In our data set, 2,189 transfers had price information, but 35 of these were “unknown” transfers, those where we could not determine the sector where they originated or ended. For that reason, we use 2,154 transfers where we had such information. Overall, there were 85 unknown transfers in our data set and 50 of them did not have price data. The disparity between the overall number of transfers in the data set, 3,232 and 2,189, is due to cases in which the *Water Strategist* did not provide price information or the entry coupled the sale of land and water into one price and we had no way of disentangling the two in order to determine the price of the water.

38. Combination transfers account for 4,939,997 acre-feet, about 15.5% of the total in our data set.

TABLE 1
Water Transfer Prices (per Acre-Foot) by Sector

	Agriculture-to-Urban Leases	Agriculture-to-Agriculture Leases	Agriculture-to-Urban Sales	Agriculture-to-Agriculture Sales
Mean price (\$)	114	29	4,366	1,747
Median price (\$)	40	10	2,643	1,235
Number of observations	189	178	1,013	169

We converted all prices into dollars per acre-foot of water for comparison across time and contract type. Prices for 1-yr transactions were easily presented in per acre-foot terms. For example, if 1,000 acre-feet of water was leased for 1 yr for a total price of \$100,000, then the per acre-foot price was \$100. Prices for sales could be handled in two ways. First, consider a sale of 1,000 acre-feet of water for a total price of \$2 million. The per acre-foot price is \$2,000. This price, however, is not directly comparable to the 1-yr lease price because the sale commits a flow of water to the buyer in perpetuity. Therefore, we construct a second price which is analogous to a 1-yr lease price. By discounting quantity flows, using the same methodology as for determining the present value of a perpetual bond, we calculate a single committed quantity. With this discounted quantity, we convert the total sales price into a per acre-foot price that is directly comparable to a per acre-foot, 1-yr lease price. In the example of a sale of 1,000 acre-feet of water for a total price of \$2 million, using 5% to discount the quantity flows leads to discounted sales price of \$100 per acre-foot (multiyear lease prices are converted in the same manner one would use to find the present value of a multiyear bond). Finally, rather than assuming a discount rate, we took the mean (or median) sales and mean (or median) 1-yr lease price and found the discount rate that equates the two. This computed discount rate is termed the ICR.

Table 1 reports mean and median water prices for agriculture-to-urban and agriculture-to-agriculture leases (1-yr and multiyear combined) and sales. The prices are per acre-foot, and the amounts are the annual flows during the first year of the contract as described in the *Water Strategist*. As shown, the annual mean and median sale and lease prices for agriculture-to-urban transactions are significantly higher than are agriculture-to-agriculture trades (using a Wilcoxon signed-rank test at a 5%

level of significance).⁴² This condition in part indicates the benefits of out-of-sector water transfers.⁴³ Other factors, such as more senior rights that may be associated with agriculture-to-urban transfers and higher wheeling costs, also explain the higher prices. Further, because sales involve the transfer of water rights and a perpetual claim on water flows as compared to leases, which involve a shorter term (often 1 yr) transfer of the right to use water, sales prices will be higher than lease prices.⁴⁴

Figure 1 plots the annual median sales price per acre-foot from 1987 through 2005 for agricultural-to-agricultural and agricultural-to-urban trades. As illustrated, the price differences between agriculture-to-urban and agriculture-to-agriculture water sales have been pronounced and growing since 1995. Using the paired annual differences and calculating a Wilcoxon signed-rank test statistic, we find that the annual median sales prices are statistically higher for agricultural-to-urban trades relative to agricultural-to-agricultural trades at a 5% significance level. Similar pricing patterns and test results are revealed if committed water is used rather than annual flows in calculating the per acre-foot prices.

Figure 2 plots the annual median combined lease price from 1987 to 2005. Consistent with sales prices, lease prices for urban uses are

42. The Wilcoxon signed-rank test is similar to the standard difference-in-means *t*-test. However, its non-parametric nature allows additional flexibility, as it does not require a priori assumptions on the distribution of its components.

43. Because our sample covers the years 1987–2005, prices were converted into real dollars to compare prices across years. All prices were converted into 1987 dollars using the consumer price index—all urban consumers average from the Bureau of Labor Statistics. The patterns shown in the table hold if median prices are used instead of mean values although the differences are narrowed. Further, if transactions in the very active water market state of Colorado are removed, the price differences remain but the number of observations is reduced.

44. As we have noted earlier, sales prices may also be higher if the priority of the water right is higher for water sold than for water leased.

FIGURE 1
Median Sales Prices, Annual Flows, 1987–2005

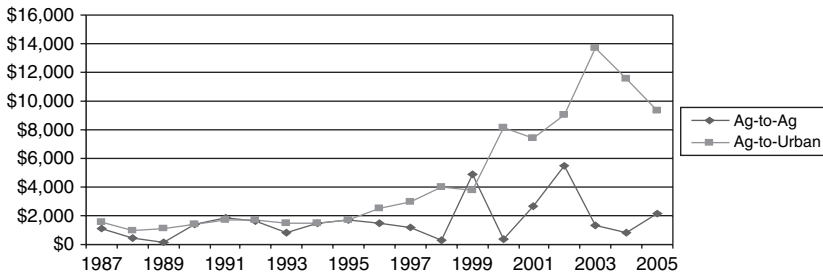
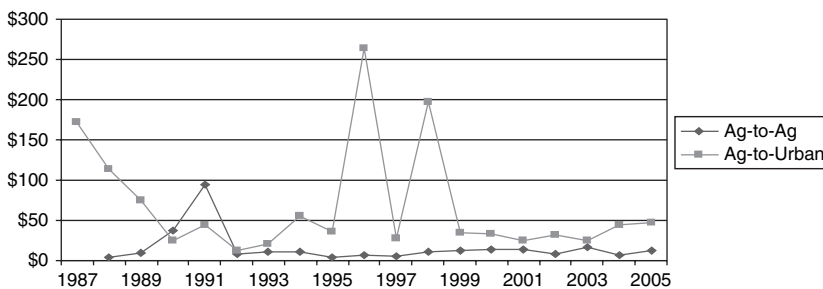


FIGURE 2
Median Lease Prices, 1987–2005.



Note: Multiyear lease quantities are discounted at 5%.

significantly higher than are those for agricultural uses (using a Wilcoxon signed-rank test at a 5% significance level). The low number of leases explains the relatively noisy time series. We report the combined (discounted) multiyear lease and 1-yr lease prices because the latter dominate in agricultural transactions, whereas multiyear leases are common in agriculture-to-urban transactions.⁴⁵

Table 2 presents median prices by sector and contract type for each of the 12 western states for 1-yr leases and sales. Also calculated is the implicit conversion rate, ICR. The “*” denotes where the number of sales or 1-yr leases with price data in the given state is less than 10, whereas “n/a” denotes where there were no sales and/or leases with price data for that given

state. Because multiyear leases would require discounting, which implies an ICR, and we are interested in finding it, we only use 1-yr lease prices to compare to the sales price.⁴⁶

While the median prices vary across states and sectors for both sales and 1-yr leases, there is significantly more variation *across states* than *across sectors*. This phenomenon is illustrated by the ICRs. Across states, ICRs for all-sector trades vary from a low of 0.5% (Colorado) to a high of 8.1% (Montana). By contrast, the ICR for agriculture-to-agriculture transfers is 0.9%

46. Brown (2006) also calculated ICRs. His price data are for 1990–2003, while ours are for 1897–2005. Nevertheless, the calculations are quite similar if we use his time period (Brown’s categories).

45. There are more 1-yr agriculture-to-agriculture leases (222) than 1-yr agriculture-to-urban leases (165), but fewer agriculture-to-agriculture multiyear leases (18) than agriculture-to-urban multiyear leases (86). Although we combine short- and long-term leases in Figure 2, the price trends for median lease prices are similar for both short-term and long-term leases.

	Brown, 1990–2003	Our Calculations, 1990–2003
Urban (municipal)	2.64%	2.73%
Agriculture (irrigation)	0.65	0.87
Environment	5.37	6.78
All states	1.94	2.00

TABLE 2
Prices by State and by Sector

	All Sectors			Agriculture-to-Agriculture			Agriculture-to-Urban		
	1-yr Leases (\$)	Sales (\$)	ICR (%)	1-yr Leases (\$)	Sales (\$)	ICR (%)	1-yr Leases (\$)	Sales (\$)	ICR (%)
Arizona	43.12	786.16	5.5	33.03	721.65	4.6*	54.81	182.57	30.0*
California	44.53	641.45	6.9	39.11	864.35	4.5*	83.41	641.45	13.0
Colorado	12.54	2,693.38	0.5	13.67	1,487.55	0.9*	28.70	3,687.12	0.8
Idaho	4.43	59.70	7.4	4.43	59.76	7.4*	2.40	106.37	2.3*
Montana	8.14	100.22	8.1*	3.49	n/a	n/a	17.60	n/a	n/a
New Mexico	28.94	1,250.00	2.3	13.69	1,150.00	1.2*	n/a	1,592.86	n/a
Nevada	23.77	1,992.28	1.2*	n/a	n/a	n/a	23.77	1,952.55	1.2*
Oregon	7.49	111.37	6.7*	4.88	n/a	n/a	6.49	n/a	n/a
Texas	18.87	461.79	4.1	17.42	217.29	8.0*	18.82	465.41	4.0
Utah	4.63	356.22	1.3	4.29	681.87	0.6*	92.15	331.29	27.8*
Washington	20.21	289.93	7.0*	10.30	n/a	n/a	25.01	417.85	6.0*
Wyoming	27.27	1,073.22	2.5*	2.38	121.85	2.0*	45.10	1,440.41	3.1*
All	27.69	1,752.06	1.6	10.68	1,235.39	0.9	41.00	2,642.70	1.6

*Number of sales or 1-yr leases with price data in the given state is less than 10; n/a, no sales and/or leases with price data for the given state.

compared to 1.6% agriculture-to-urban transfers. The variation in price across the states reflects differences in demand and supply characteristics, transaction type, as well as transaction costs—all of which are primarily state driven (e.g., population, weather, water endowments, conveyance potential, political and legal institutions) and the regulatory restrictions that prevent arbitrage across the states.⁴⁷

To further explore price patterns, Table 3 presents the median prices for 1-yr leases and sales and the corresponding ICRs over time. As sales prices have risen and lease prices have fallen, the ICRs have dramatically decreased over time. A sign test reveals that there is a significant downward trend. Sales of water rights, which carry more security and are used more in agriculture-to-urban trades, are in growing demand relative to short-term leases, which are used more in agriculture-to-agriculture transactions.

In summary, the price data reveal that (1) state water markets are quite different as reflected in the varying state prices and (2) there are few arbitrage activities across the states to narrow those differences. While state price variations can be explained in part by sector-specific dominance in one state versus another, the variance of prices across states is much greater than the variance across sec-

tors within a state. The price data also indicate a growing premium to purchase water rights rather than lease water. Finally, the price data demonstrate that urban users pay considerably more in purchasing and leasing water relative to agricultural users.

TABLE 3
Median Prices by Year across All States and Sectors

	1-yr Leases (\$)	Sales (\$)	ICR (%)
1987	60.76	1,200.00	5.1
1988	50.41	960.27	5.3
1989	41.23	1,112.44	3.7
1990	39.11	1,432.79	2.7
1991	91.75	1,752.45	5.2
1992	18.22	1,656.23	1.1
1993	11.79	1,411.66	0.8
1994	29.13	1,450.94	2.0
1995	13.69	1,680.55	0.8
1996	29.69	2,389.29	1.2
1997	17.59	2,818.40	0.6
1998	19.51	3,902.82	0.5
1999	14.72	3,550.23	0.4
2000	26.39	7,586.53	0.3
2001	31.37	7,171.72	0.4
2002	31.57	8,299.21	0.4
2003	29.02	10,905.56	0.3
2004	30.07	10,624.32	0.3
2005	27.34	8,912.00	0.3
Median	27.69	1,752.06	1.6

47. In other work, we are examining the effects of state regulatory and property rights regimes on observed water transfers, controlling for economic, political, water supply, and infrastructure characteristics.

TABLE 4
Leases by Lease-Length

Duration (yr)	Number	Frequency (%)	Average Size
1	771	79	30,416
2-5	65	7	12,088
6-9	4	0	6,287
10-19	40	4	8,759
20-29	39	4	5,558
30-39	12	1	7,699
40-49	18	2	14,718
50-74	10	1	50,086
75	13	1	2,126
100	9	1	14,632
Total	981	100	26,347

VII. WESTERN WATER TRANSFERS

A. Contractual Form

As we have shown, in responding to opportunities to move water within and across sectors in response to price differentials, various contractual forms are possible: 1-yr leases, multiyear leases, and sales. Although leases involve the right to use water and not the transfer of the water right, some can be quite long as indicated in Table 4, which lists leases by their duration. As shown, most leases have short terms, with nearly 80% being 1 yr or less and over 85% being 5 yr or less. Some leases, however, approximate sales with terms of 50 or more years.

Table 5 provides additional information on the relative importance of each type of contract in terms of number and amount of water moved (committed and annual flow) for the three sectors.⁴⁸

The data in Table 5 show that most agriculture-to-urban transfers occur through sales that involve comparatively small amounts, 837 acre-feet on average as measured by the annual flow and 16,734 acre-feet on average as measured by the amount committed.⁴⁹

48. Eighty-six transfers were neither leases nor sales and are not included in Table 4. An example of such a transfer would be an exchange for service between two parties. For example, a developer might give his water right to the city free of charge in return for a service.

49. The *Water Strategist* sometimes referred to transactions as sales that transferred the water but not necessarily the water right. In our data set, these are referred to as short-term sales. Short-term sales can be thought of in a similar manner as a 1-yr lease and are thus included in all 1-yr leases categories. Of the 110 short-term sales that occurred over the 19 yr in our data set, 80 were in California. There were 71 permanent sales in California.

In part, as noted earlier, this pattern reflects the large number of small transactions that take place in Colorado within the C-BT. Sales occur less frequently for agriculture-to-agriculture and urban-to-urban transactions. Even if we omit Colorado sales and recalculate, average sales size is 6,273 acre-feet (annual flow); sales transfers typically are smaller than those for long-term or 1-yr leases in agriculture-to-urban transactions.⁵⁰

Within-sector, urban-to-urban transfers have more permanent sales (269) than leases (146), but the average sale size is small, at 2,251 acre-feet, compared to the average size of 1-yr and multiyear leases, at 40,791 and 13,877 acre-feet, respectively. Over four times the amount of water measured by annual flows is transferred between cities and from businesses or mining companies by 1-yr leases than by multiyear leases and sales. When committed amounts are considered, however, sales and multiyear leases involve over ten times the amount of water traded through short-term leases.

The data in Table 5 also reveal the importance of 1-yr leases for balancing short-term water demand and supply conditions among agricultural and urban users. One-year leases were used to temporarily move 3,251,123 acre-feet from agriculture to cities and 4,247,688 acre-feet to cities from other urban users. Transaction sizes (annual flow) for 1-yr leases in agriculture-to-urban trades also are large, averaging 19,704 acre-feet, more than double the size of multiyear leases and almost 24 times the mean size of each sale. These transactions may be large because they do not imply a permanent loss of water in the watershed. Multiyear leases, which involve longer term commitments of water, are less common than are 1-yr leases, 86 compared to 165, and are smaller as measured by annual flow. Of the multiyear leases, 18 are for less than 5 yr and 68 are for more than 5 yr.

Agriculture-to-agriculture trades usually occur (240) through a lease, generally for 1 yr. Like cross-sector leases, agriculture-to-agriculture leases involve much larger amounts of water (28,628 acre-feet) than do water sales as measured by the annual flow. Farmers

50. Dropping Colorado transactions leaves 566 sales transactions for 3,550,415-acre-feet annual flows.

TABLE 5
Water Transactions by Contract Type and Category, 1987–2005

	Agriculture-to-Urban	Agriculture-to-Agriculture	Urban-to-Urban	Agriculture-to-Urban	Agriculture-to-Agriculture	Urban-to-Urban
	Number of Transfers			Number of Transfers		
Sale	1,543	215	269	1,543	215	269
Lease						
One-year	165	222	97	165	222	97
Multiyear	86	18	49	86	18	49
	Total Quantities: Committed (acre-foot)			Total Quantities: Annual Flow (acre-foot)		
Sale	25,821,328	8,422,685	12,109,620	1,291,066	421,134	605,481
Lease						
One-year	3,251,123	6,355,338	4,247,688	3,251,123	6,355,338	4,247,688
Multiyear	8,794,128	990,393	9,961,049	729,732	90,659	679,996
	Committed Average Size (acre-foot)			Annual Flow Average Size (acre-foot)		
Sale	16,734	39,175	45,017	837	1,959	2,251
Lease						
One-year	19,704	28,628	43,791	19,704	28,628	43,791
Multiyear	102,257	55,022	203,287	8,485	5,037	13,877

trade water among themselves routinely using short-term leases to meet temporary shortfalls or for other transitory market reasons. Many of these transactions take place locally often within the irrigation district to which both farmers belong.⁵¹ As noted earlier, these transactions can involve water of lower quality and with lower priority appropriative water rights than required for agriculture-to-urban transactions. Sales within agriculture are numerous but generally involve small amounts of water with a mean transaction size of 1,959 acre-feet (annual flow), although the average committed size is much larger at 39,175 acre-feet.

Table 6 summarizes all water transfers from 1987 through 2005 by contract type. Although sales account for 67% of all transactions, they involve just 13% of the water traded as measured by annual flow. Considering perpetual commitments, however, raises the amount of water involved to 58% of the water traded. Leases account for only 30% of transactions but transfer 83% of water as measured by annual flow. Considering committed water, however, lowers the amount of water traded by leases to 36%.

51. Irrigation districts are political subdivisions of the state that supply farmers with irrigation water. Elected governing boards run irrigation districts. For discussion, see Thompson (1993, 687–701). Internal district water transactions may not be included in our data set from the *Water Strategist* because they may not be reported.

B. Aggregate Transfer Data by Category

Table 7 provides a comprehensive overview of 3,232 water transfers in the 12 western states between 1987 and 2005.⁵² Although we are primarily interested in agriculture-to-agriculture, agriculture-to-urban, and urban-to-urban trades, the table provides information for all major sector transactions.

As shown in Table 7, agriculture is the origin of 78% of all trades and 60% of all water traded, as measured by annual flows, and 54% of all water committed. Agriculture-to-urban trades are by far the most numerous, accounting for 56% of all transfers and involve 5.5 million acre-feet or 18% of all water transferred as measured by annual flows and 39.7 million acre-feet or 29% of committed water. Agriculture-to-agriculture transactions represent 15% of all trades and involve 23% of the water transferred as measured by annual flow and 12% of the committed water.

The data reveal a significant movement of water out of agriculture in response to the price differentials discussed earlier. Urban-to-urban transactions account for 14% of the number of transfers and involve 18% of annual flows and 19% of water committed. If these two major within-sector categories are combined,

52. Less 85 unknown transfers. For more complete discussion of the legal issues involved in water transfers, see Brewer et al. (2007).

TABLE 6
Water Transactions by Contract Type 1987–2005

	No. of Transfers	Frequency (%)	Committed		Annual Flow	
			Amount (acre-foot)	Frequency (%)	Amount (acre-foot)	Frequency (%)
One-year leases	771	24	23,450,450	17	23,450,450	76
Multiyear leases	210	6	26,759,628	19	2,395,430	8
All leases	981	30	50,210,078	36	25,845,880	83
Sales	2,165	67	79,496,161	58	3,974,808	13
Miscellaneous ^a	86	3	8,353,065	6	1,143,890	4
All transfers	3,232	100	138,059,304	100	30,964,578	100

^aMiscellaneous transfers are listed as “exchanges” and “storages” in the *Water Strategist*.

TABLE 7
Water Transfers by Sector, 1987–2005

Classification	No. of Transfers	Frequency (%)	Committed		Annual Flow	
			Amount (acre-foot)	Frequency (%)	Amount (acre-foot)	Frequency (%)
Agriculture-to-Agriculture	471	15	16,241,925	12	7,138,480	23
Agriculture-to-urban	1,825	56	39,747,584	29	5,533,394	18
Agriculture-to-environment	233	7	18,186,143	13	6,014,228	19
Urban-to-agriculture	38	1	2,549,986	2	326,440	1
Urban-to-urban	440	14	26,600,020	19	5,657,591	18
Urban-to-environment	54	2	8,925,447	6	1,054,031	3
Environment-to-agriculture	0	0	0	0	0	0
Environment-to-urban	1	0	62	0	62	0
Environment-to-environment	6	0	4,171,200	3	284,560	1
Combination	164	5	21,636,938	16	4,955,791	16
Total	3,232	100	138,059,303	100	30,964,577	100

they comprise 29% of water trades, 41% of annual flows, and 31% of committed water. The difference between the committed and the annual flow measures confirms what was found in Table 5: within-sector trades rely more on 1-yr leases, while out-of-sector trades rely more on sales and long-term leases. These transfers, particularly agriculture-to-urban transactions, are more numerous but comparatively small. These transfers typically involve changes in the location, timing, and/or nature of water use, all of which can have important effects on other users. These types of transactions are significantly more controversial and generally require state regulatory review. Because larger transfers are more likely to affect third parties, agriculture-to-urban trades are smaller, roughly one-fourth to one-fifth the size

of agriculture-to-agriculture and urban-to-urban transfers. Smaller transfers likely have fewer external effects.

C. Water Transfers across Time

Figure 3 details water market activity across time. The figure shows that: (1) the total number of water transfers is increasing (statistically significant), (2) agriculture-to-urban trades are also rising (statistically significant), and (3) neither agriculture-to-agriculture trades nor urban-to-urban trades show a discernable trend (statistically insignificant). Given that Colorado dominates the number of transactions, we note that the trends remain the same but are less pronounced when Colorado is removed.

FIGURE 3
Water Transfers by Sector, 1987–2005

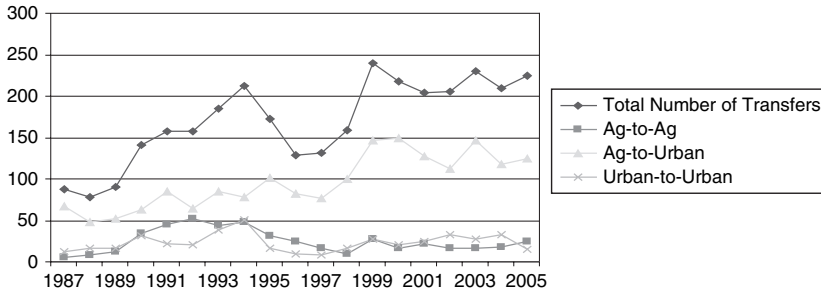


Figure 4 shows the quantities of water transferred across time. Importantly, if we measure the total quantity of water transferred by annual flow, there is no statistically significant upward trend, whereas if we measure the water traded by total water contractually committed, there is a statistically significant upward trend (at a 5% significance level).⁵³ The rising trend of the committed measure is capturing the fact that the number of sales is increasing over time (see Figure 7).

Figures 5 and 6 illustrate the water traded over the 19-yr period by sector for annual flow and committed water measures, respectively. With respect to Figure 5, we find no significant trend in agriculture-to-urban trades, a significant downward trend in within-agricultural trades, and no significant trend in urban-to-urban trades. In Figure 6, however, where committed water is reflected, we find a significant upward trend in agriculture-to-urban trades and no significant trend for within-agricultural trades or urban-to-urban trades. As shown, water is increasingly moving out of agriculture and into urban uses over time reflecting the widening price differentials between urban and agricultural uses (see Figure 1).

D. Contract Type over Time

Figure 7 describes how the total number of transfers moves over time by contractual form. We find the following: (1) a significant

53. A Wilcoxon signed-rank test is used to test trend by first differencing more recent realizations with early realizations and then second proceeding with a simple Wilcoxon signed-rank test. A 5% significance level is used in all tests.

upward trend in total transactions, (2) a significant upward trend in sales transactions, (3) a statistically significant upward trend in multiyear leases, and (4) nonsignificant trend in 1-yr leases.⁵⁴ This is consistent with the decreasing ICRs over time found in Table 3.

E. Analysis of Water Transfers by State

Table 8 outlines the number of water market transactions by state and by contract form from 1987 through 2005. Colorado dominates in terms of total market transactions, reflecting the institutional advantages of the C-BT, where most of the transactions are sales. Other active market states are California, Texas, Arizona, Nevada, and New Mexico. Within California and Texas, short-term leases are the most prevalent contract but multiyear leases and sales are also important. In Arizona, Nevada, and New Mexico, sales are common, but, not surprisingly, Montana and Wyoming, the least urban of the 12 western states, have the fewest water sales.

Table 9 provides a detailed breakout of water transfer patterns for agriculture-to-agriculture, agriculture-to-urban, and urban-to-urban transactions within each of the western states. The table shows the relative percentages of the amounts traded by origination and destination classifications for both annual flow and committed measures within the three categories. For example, within Arizona, 15% of the annual flow of water transferred was in agriculture-to-urban trades, while 46% and 39% were part of agriculture-to-agriculture

54. All tests for trend are undertaken by differencing the data and then undertaking a simple Wilcoxon signed-rank test at a 5% significance level.

FIGURE 4
Transfer Amounts over Time (acre-feet)

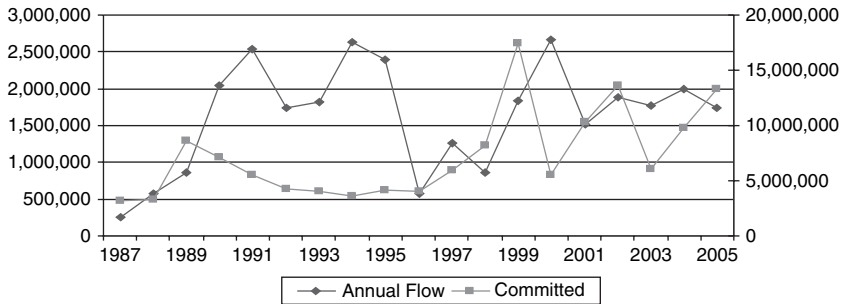


FIGURE 5
Water Transferred by Sector, Annual Flows, 1987–2005

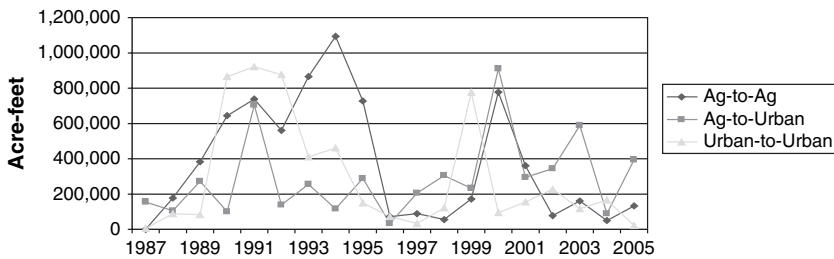
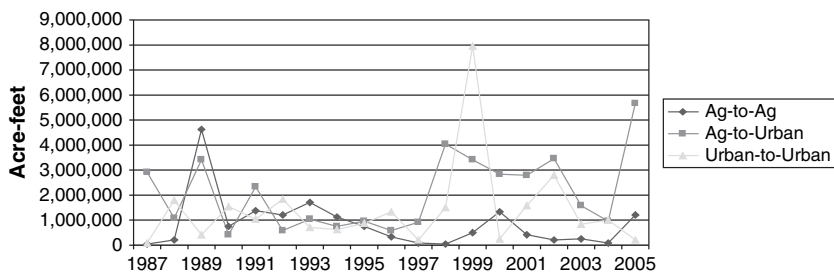


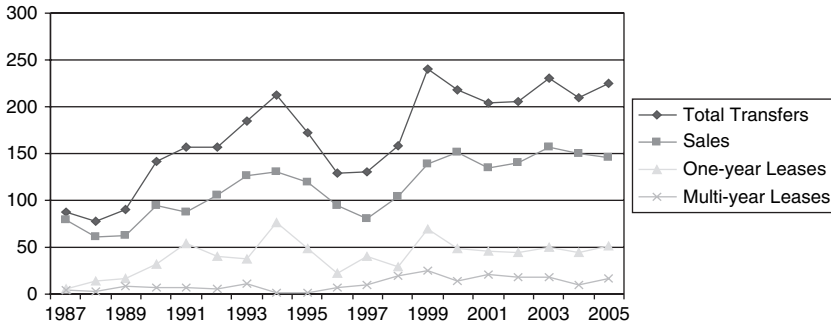
FIGURE 6
Water Transferred by Sector, Committed Water, 1987–2005



and urban-to-urban trades, respectively. Using the committed water measure, 31% of Arizona’s traded water was part of agricultural-to-urban trades, 37% in agriculture-to-agriculture trades, and 32% in urban-to-urban transfers. By either measure, within-sector trades clearly are the most common type of transaction in Arizona.

Using the annual flow measure, more water is traded within these three categories in Arizona than in any other state. This may reflect Arizona’s reliance on groundwater and the clustering of agriculture and urban areas near the same groundwater basins. With respect to the committed measure, however,

FIGURE 7
 Number of Water Transfers by Contract Type, 1987–2005



Texas trades the most water. While in most states, the total committed water is usually double or triple the total annual flow, in Texas the total committed is almost 15 times greater, reflecting the importance of sales and multi-year leases in that state for moving most water. In Texas, the establishment of the Edwards Aquifer Authority in 1993 created an opportunity for urban interests, particularly in the San Antonio area to purchase long-term rights to water (Glennon 2002).

Aside from Arizona and Texas, California accounts for the next largest amount of water marketed in these categories. California has a broad range of transactions with agriculture-to-urban trades the largest activity. This situation reflects the efforts of Los Angeles and San Diego, especially through the Metropoli-

tan Water District of Southern California, to secure agricultural water to meet growing urban demand. Colorado is heavily dominated by agriculture-to-urban trades, but the overall amounts are less than in Arizona, California, or Texas. Additionally, even though the amounts are smaller, agriculture-to-urban trades are important in Montana, Nevada, Utah, and Washington, whereas agriculture-to-agriculture trades are most important in Idaho, Oregon, and Wyoming.

Table 10 provides a cross-state comparison of how much each state contributed to the total amount of water transferred in each of the three classifications for both measures. Notice that the committed water measure only doubles the annual flow quantity in agriculture-to-agriculture trades because of the prevalence of short-term leases in agricultural trades, whereas in the other classifications, the committed measures are almost five times the annual flow quantities. With respect to agriculture-to-urban trades, Arizona, California, and Texas lead the way. When using the annual flow measure, California accounts for 45% of the water traded but falls to 13% when using the committed measure, reflecting California's propensity to engage in 1-yr leases. Conversely, Texas only accounts for 13% of the water transferred when using the annual flow measure but increases to 36% when using the committed measure. With respect to agriculture-to-agriculture trades, Arizona and California dominate using either measure. Finally, Arizona, California, and Texas make up the large majority of urban-to-urban trades. Note that when using the annual flow measure, Texas makes up 12% of the water traded but

TABLE 8
 Water Transactions by Type and State

	Number of All Transactions	Number of Sales	Number of Short-Term Leases	Number of Long-Term Leases
Arizona	175	118	41	12
California	481	71	305	60
Colorado	1,707	1,599	60	31
Idaho	105	27	74	2
Montana	23	2	10	11
New Mexico	118	64	36	15
Nevada	126	112	4	3
Oregon	77	12	44	17
Texas	253	82	119	50
Utah	75	56	15	3
Washington	45	16	24	5
Wyoming	47	6	39	1
Total	3,232	2,165	771	210

TABLE 9
Share of Each Transfer's Classification to a State's Total Quantity Transferred

	Annual Flow				Committed			
	Agriculture-to-Urban (%)	Agriculture-to-Agriculture (%)	Urban-to-Urban (%)	Total (million acre-foot)	Agriculture-to-Urban (%)	Agriculture-to-Agriculture (%)	Urban-to-Urban (%)	Total (million acre-foot)
Arizona	15	46	39	8.34	31	37	32	21.72
California	41	32	27	5.04	37	32	31	12.60
Colorado	51	29	20	0.59	75	8	17	5.88
Idaho	39	55	6	1.59	29	67	5	2.36
Montana	55	45	0	0.02	95	5	0	0.22
New Mexico	15	78	7	0.10	36	55	10	0.91
Nevada	84	0	16	0.22	72	0	28	2.39
Oregon	0	100	0	0.10	0	100	0	0.29
Texas	48	15	37	1.75	50	3	47	25.30
Utah	38	32	29	0.31	53	3	44	4.05
Washington	49	36	15	0.16	79	3	18	1.93
Wyoming	37	63	0	0.10	38	62	0	0.41

increases to 44% when the committed measure is used, again reflecting the reliance upon sales and long-term leases in the state.

VIII. CONCLUDING REMARKS

Relative price data reflect the growing pressure to move water from traditional uses in agriculture to meet increased urban demand. This paper has presented a new data set that documents the growth of water trading between 1987 and 2005 for 12 western states in response to shifting demand. Data for the analysis come from the *Water Strategist*,

a monthly publication that details transactions, litigation, legislation, and other water market activities in the West. The data reveal a number of important features regarding water market development.

First, the data confirm the widely held belief that prices are higher for agriculture-to-urban trades versus within-agriculture trades, in part, reflecting the differences in marginal values between the two uses. Not only are prices higher for urban use but also they are growing relative to agricultural use over time. Presently, approximately 80% of the West's diverted water supply is employed

TABLE 10
Relative Percentage of State to Each Classification's Total Transfer Amount

	Annual Flow			Committed		
	Agriculture-to-Urban (%)	Agriculture-to-Agriculture (%)	Urban-to-Urban (%)	Agriculture-to-Urban (%)	Agriculture-to-Agriculture (%)	Urban-to-Urban (%)
Arizona	20	53	58	19	49	26
California	45	23	24	13	25	14
Colorado	5	2	2	13	3	4
Idaho	10	12	2	2	10	0
Montana	0	0	0	1	0	0
New Mexico	0	1	0	1	3	0
Nevada	3	0	1	5	0	3
Oregon	0	1	0	0	2	0
Texas	13	4	12	36	5	44
Utah	2	1	2	6	1	7
Washington	1	1	0	4	0	1
Wyoming	1	1	0	0	2	0
Million acre-feet	6.23	7.13	5.66	35.21	16.24	26.60

in agriculture, part at least, for comparatively lower use values than in urban areas. The economically and statistically significant price differences reported above suggest the potential for large economic gains from reallocating water through a market mechanism. The data reveal that markets are responding. Agriculture is the origin of the majority of trades, and the number of agriculture-to-urban transactions is rising over time, whereas the number of agriculture-to-agriculture transfers shows no such pattern.

Second, there is a pronounced trend for the acquisition of water for longer periods of time, either through multiyear leases or through sales of the water right. Sales are the most often used contractual form, and the number of sales is increasing over time. The number of multiyear leases is increasing over time as well, while the number of 1-yr leases is not growing. This trend is likely due in part to the security of water supplies long-term contracts provide. Buyers are willing to pay a premium for water rights.

Third, the growing importance of sales and multiyear leases in water transactions underscores the need to consider the amounts of water obligated over time rather than examining only annual flows in assessing the quantities of water traded as is commonly done in the literature. Considering committed water, we find that more water is transferred and the direction of trading is very different than if the focus is on annual flows. While the latter suggests that most water is transferred within agriculture, the committed variable reveals that more is transferred from agriculture-to-urban and through urban-to-urban trades. This difference arises because most agriculture-to-agriculture transfers are through 1-yr leases, whereas agriculture-to-urban and urban-to-urban transfers are primarily through sales and multiyear leases.

Finally, the data reveal considerable differences in water trading across the states. Some of this pattern is due to differences in water supply and demand characteristics. The states with the most rapidly growing urban populations tend to exhibit the largest number and greatest amounts of water in agriculture-to-urban transactions, and the states with the smallest urban growth have the lowest amounts of water traded. We have noted, however, that water rights are less secure than for other assets and that, because of the interconnected nature of water use and trading among parties, each

state has a regulatory structure to review and approve market transactions, especially those that involve changes in the nature, timing, and location of use, as is the case for most agriculture-to-urban transfers. The nature of property rights to water and the regulatory review process varies across the states. Accordingly, some of the interstate differences in observed water transactions are due to differences in transaction costs associated with varying property rights and regulatory requirements. Identifying and quantifying those factors is an important next step in analyzing the development of water markets in the West.

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