WORKING PAPER

Price Determination and Efficiency in the Market for South Platte Basin Ditch Company Shares

by
Matthew T. Payne,
Mark Griffin Smith & Clay J. Landry

Colorado College Working Paper 2011-10
September, 2011

Department of Economics and Business
Colorado College
Colorado Springs, Colorado 80903-3298
www.coloradocollege.edu/dept/EC

PRICE DETERMINATION AND EFFICIENCY IN THE MARKET FOR SOUTH PLATTE BASIN DITCH COMPANY SHARES

Matthew T. Payne, Mark Griffin Smith, Clay J. Landry

Matthew T. Payne is a Research Associate with WestWater Research, LLC in Vancouver, WA.

Mark Griffin Smith is Professor of Economics at Colorado College in Colorado Springs, CO.

Clay J. Landry is Managing Director of WestWater Research, LLC in Boise, ID.

ABSTRACT: Water scarcity presents an obstacle to economic development in the western United States. Water right markets promote efficient allocation, helping states to derive the highest possible economic benefit from available resources, and allowing western water supplies to support new development and population growth. However, uncertainty surrounding water right market values threatens the ability of water markets to efficiently allocate water. To address this problem, we employ econometric analysis techniques to estimate the values market participants place on shares of ditch company water rights in Colorado's South Platte basin. Our analysis demonstrates that ditch company share buyers value proximity, reliability, and flexibility.

Keywords: Water Markets, Water Rights, Water Prices

Running Head: South Platte Basin Ditch Company Share Prices

Corresponding Author:

Matt Payne
WestWater Research LLC
805 Broadway St., Suite 415
Vancouver, WA 98660

Tel 360.695.5233
Fax 360.695.6105
Cell 208.859.3248
Payne@waterexchange.com

Colorado's Front Range has a long history of water trading. Starting in the early 1900's, neighboring farmers rented and traded water among themselves to adapt to varying hydrologic conditions (Anderson 1961). During the 1970's and 1980's, Front Range cities entered the market for water rights by acquiring agricultural appropriations for municipal and industrial uses. Cities purchased water rights to accommodate the inflow of new residents to Colorado that occurred in response to energy development on the Western Slope, and increased federal employment opportunities in Denver. Subsequent periods of economic prosperity and population growth necessitated additional water transfers to municipalities, resulting in a highly active market for water rights in Colorado (Smith 1990).

The South Platte River basin extends over the northeast quadrant of the state and includes the metro Denver area, the cities of Golden, Boulder and Ft. Collins along the Front Range, as well as productive farming country further downstream. In addition to being one of the most active water markets in the western United States (Brown 2006), the South Platte basin market has a number of other distinctive features. First, because market transactions occur along the full extent of the basin from Golden, upstream of Denver on Clear Creek, to Sterling some 150 miles downstream[1], water transfers in the market are particularly influenced by location. Transactions in the metro region are primarily agriculture to urban transfers whereas those downstream continue to include transfers among agricultural water users. In addition to distance, an elevation difference of 1,700 feet between Golden and the lower reaches of the South Platte makes the location of diversion an important consideration in acquiring water rights. Second, both direct flow and storage rights are traded in the basin. As a result, it is possible to determine the value of storage in this market. Third, valuing ditch company share reliability is problematic because

[1] In the 1970's and 1980's direct flow water rights from ranches in South Park, along the South Fork of the South Platte were purchased by the cities of Aurora and Thornton in the Denver metro area (Smith 1990). Thus earlier activity in the basin extended perhaps 100 miles further upstream along the South Fork.

shares represent a portfolio of water rights with varying levels of reliability, not a single water right and priority date. We introduce the coefficient of variation as a means of capturing the reliability of a share in a single number.

Determinants of Water Right Prices

A water right's individual attributes lend it value. These attributes include priority date (reliability), source (water body and a second indicator of reliability), location (point of diversion), and historic beneficial use (e.g., irrigation, mining, municipal). What effect do these attributes of water rights have on water right prices?

The influence of water right characteristics on price is analyzed for Colorado's South Platte basin. This region is characterized by one of the most active water markets in the western United States (Brown 2006), with water transfers frequently occurring in the form of ditch company share sales. A ditch company share entitles the owner to a pro rata percentage of the ditch company's total water supply each year (Rice and White 1987). While most water markets in the West facilitate transfers of water rights, ditch companies control the most valuable water rights in the South Platte basin. Purchasing shares in these companies represents a viable way for water users to acquire new water supplies.

We seek to extend knowledge of water markets in several ways. First, while previous studies analyzed the basin above Denver (Goodman and Howe 1997) and prices for shares in the trans-mountain water supplied by the Colorado-Big Thompson project (Person and Michelsen 1994; Brookshire et al. 2004), this article examines native surface water rights transfer data from the entire basin. Native surface water rights in the basin are rights to divert from above-ground water sources hydraulically connected to the South Platte River. Including sales from throughout the basin allows us to demonstrate that buyers value proximity. Moreover, the large number of transactions observed in the South Platte basin leads us to believe that the market for ditch company shares in this basin operates with greater efficiency than many other western water rights markets. In efficient water markets, water users are able to complete transactions as needed to accommodate their water demands. High levels of market activity indicate that such beneficial transactions are occurring. Another presupposition of market efficiency is that market prices reflect water rights' positive and negative qualities. Under this condition, water right attributes such as volume, reliability, flexibility, and location should statistically account for price dispersion among water rights. Our analysis confirms this indication of efficiency in the South Platte basin.

Second, we develop a new measure of reliability, the coefficient of variation of water supply. The coefficient of variation equals the ratio of the standard deviation of a ditch company's annual headgate deliveries to the company's average annual headgate deliveries. The coefficient of variation is frequently used as a measure of relative variability in a variety of applications (Howe 2010). However, to our knowledge, this study is the first to use the coefficient of variation as a measure of water supply reliability.

$$\text{COEFF VAR} = \frac{\text{Standard Deviation of Annual Water Supply}}{\text{Average Annual Water Supply}}$$

As agricultural activity grew in the South Platte basin, ditch companies perfected new water rights to support ditch extensions and cultivation of new farmland. Consequently, mutual ditch company shares are associated with a portfolio of priority dates, preventing a single priority date from serving as a proxy for the reliability of the water supply provided by ditch shares. Using the coefficient of variation as a measure of reliability allows us to characterize this portfolio of rights with a single number.

Third, our analysis shows that the ability to store water is valued independently of supply reliability. Ditch company share buyers, particularly municipalities, value storage rights for the additional flexibility they afford to systems operations.

BACKGROUND

The four most active water right markets in the West are the market in Colorado's South Platte basin, Nevada's Truckee River basin, California's Central Valley market, and the Rio Grande Valley market in New Mexico and Texas (Brown 2006; see figure 1). These areas are characterized by competition for available water supplies, and legal systems and geographic settings that enable water transfers to high-value uses.

Colorado's South Platte Basin

The South Platte basin encompasses over 27,600 square miles of Northeastern Colorado (see figure 2). The South Platte River runs from its mountain origins southwest of Denver to northern Colorado's high plains and on into Nebraska. Stream flows in the South Platte and its tributaries are primarily determined by snowmelt runoff and rainstorms, rendering the basin's surface water supply highly variable. (Colorado Water Conservation Board 2004).

Irrigated agriculture represents an important economic activity in the South Platte basin, with over 30% of the basin's land area and 68% of the basin's surface water dedicated to crop cultivation (Colorado Water Conservation Board 2004). Neighboring farmers established mutual ditch companies in the 1800's to deliver irrigation water to fields. These irrigators combined financial resources to construct water delivery infrastructure and perfect water rights. Participating farmers owned shares of company water, with each share representing a pro rata percentage of the company's annual water supply. Assessment fees were imposed on each share to fund the acquisition of new water supplies and infrastructure development projects. (Anderson and Snyder 1997). Ditch companies control the most senior water rights in the South Platte basin, with priority dates as early as 1861 (Goodman and Howe 1997).

In addition to its extensive agricultural areas, the South Platte basin is home to Colorado's largest urban area, Denver, as well as rapidly growing communities extending north and west to Ft. Collins and Boulder along the northern Front Range. While native flows and water imported from other basins provide 1,800,000 AF/year of water to the South Platte basin, approximately 4,000,000 AF/year of surface water rights have been appropriated to accommodate the area's high urban and agricultural water demands. (Wolfe 2005). New surface water rights remain available at low costs under Colorado water law (Colorado Constitution Art. 16 Sec. 6). However, appropriations perfected subsequent to the mid-1890's in the South Platte basin generally yield inconsistent water quantities (Hall 2007). The scarce nature of reliable water supplies engenders competition for senior appropriations, resulting in market transfers of water rights and ditch company shares (Hobbs 2009). As Denver suburbs have developed and metropolitan populations grow, competition for water intensifies, driving increased water trading from agricultural to urban uses (Goodman and Howe 1997).

Market Participants

Urban populations throughout the South Platte basin are projected to rise (Colorado Foundation for Water Education 2009). One viable way for cities to expand water supplies is to purchase ditch company shares from farmers, and change the shares' use through water court. Municipalities purchase ditch company shares frequently. Cities also receive ditch company share dedications from land developers, who are often required to purchase water rights and transfer them to water authorities as a precondition of plat approval. In addition, investors building portfolios of water assets have entered the market for ditch company shares in recent years. While these urban water users purchase more shares than other water buyers in the basin, agricultural buyers remain active in the water market.

Agricultural water users transfer water among themselves. If one agricultural activity is considerably more valuable than another, water is transferred to the more valuable use. In addition, new markets for agricultural water are forming. For example, land trusts buy irrigation water for permanent dedication to farmland in an attempt to preserve farming culture and communities (Hobbs 2009).

Many water purchases by non-municipal users occur to fulfill augmentation requirements. If a farmer withdraws groundwater for irrigation, and surface water supplies are depleted as a result of this groundwater pumping, the farmer must add surface water to the affected stream to prevent injury to more senior water appropriations (Colorado Foundation for Water Education 2004). Purchases of ditch company shares for augmentation purposes constitute a significant portion of the water transactions that occur in the South Platte basin (MacDonnell 2009), with 4% of the basin's water used in augmentation (Wolfe 2005).

Price Determinants of Ditch Company Shares

A number of factors influences the price of ditch company shares. These factors include the buyer type, volume transferred, reliability of the share, and the costs of delivering purchased water to the buyer's system.

The primary buyers of ditch company shares in the South Platte basin are irrigators and municipalities. Higher economic gains are derived from municipal water use than from applying water to agriculture. Anecdotal evidence suggests that, as a result of these differences in returns to water use, cities often pay more than farmers for ditch company shares (Person and Michelsen 1994).

The volume of water transferred in a ditch company share purchase influences share prices. Larger volumes yielded by an individual share result in higher total prices for the share because the buyer is able to receive more water. However, transfers of large quantities of water are expected to attract lower per-unit prices ($/AF consumptive use) than small-volume sales. These scale economies result from transaction costs that remain stable among water transfers of all volumes (Howe, Boggs, and Butler 1990), and from the low levels of demand that exist for large water rights.

A share's price reflects its reliability. Reliable shares yield a consistent quantity of water each year with little variation. Acquiring unreliable ditch company shares leaves the buyer's water supply uncertain. Because buyers are risk-averse, reliable shares garner higher sale prices. Ditch companies offering reliable shares hold water rights characterized by early appropriation and adjudication dates, and have reservoir storage to supplement deliveries to shareholders in dry years (Hobbs 2009; Hecox 2009).

The costs associated with delivering purchased water to the buyer's new place of use also affect price. For example, if a city must construct pipelines and pumps to deliver purchased water to its system, it will pay less than it would pay for water that enters its system cheaply. Ditch companies diverting long distances downstream from municipalities are expected to have less valuable shares than companies that divert near cities and use ditches that run through cities. (MacDonnell 2009).

LITERATURE REVIEW

Accurate valuation of water rights helps water markets to efficiently allocate scarce water supplies by allowing actors to make pragmatic purchasing and selling decisions (Anderson 1983). In many commodity markets, market price information provides correct valuation and the market operates efficiently, with prices reflecting the value of the commodity's positive and negative qualities. However, market price data for water rights is largely unavailable because information relating to water right transactions is private. Local governments rarely require buyers and sellers to report sale prices. In addition, water market participants fervently protect their proprietary data in hopes of leveraging asymmetric levels of information to derive increased economic benefits from water transactions (Howe and Wiener 2006). While some local engineering consulting firms offer water right price data, this information is often outdated and unverified. The proprietary and erroneous qualities of market price data result in a lack of price signals, causing water markets to function inefficiently.

Water market efficiency is further affected by imperfect competition, hydrologic and institutional uncertainty, and price-setting by a few market participants. These market failures cause market prices to inaccurately reflect the value of water rights' underlying characteristics. Studies estimating water right values based on current, accurate price data hold the potential to aid market participants in negotiating and completing sensible transactions, increasing the efficiency of water markets.

The hedonic pricing method is a revealed preference approach to the valuation of differentiated goods i.e., goods that possess multiple attributes that cannot be separated at the time of purchase (Rosen 1974). Such goods are purchased as a bundle of characteristics. Changing these characteristics is impossible because they are fundamental aspects of the good. Buyers recognize a good's attributes, and their preferences vary according to each product's individual qualities. The hedonic hypothesis, asserting that consumers value a good based the amount of utility each of the good's individual characteristics provides, forms the basis of the hedonic pricing method. Similar to other revealed preference techniques, the hedonic method statistically infers values market participants place on attributes of goods based on observed choices participants make within markets (Young 2005).

Hedonic pricing has been used to analyze the determinants of price both within individual markets and across a variety of markets. Several studies examine real estate transactions in which the land includes appurtenant water rights i.e., rights that cannot be severed from the land. These studies analyze the implicit value consumers attach to water rights to calculate the value that water contributes to land prices (Crouter 1987; Faux 1996; Byrd 2004). Other studies address markets in which water rights can be sold separately from land, and seek to identify the determinants of water rights prices within specific water markets (Anderson 1961; Saliba and Bush 1987; Colby, Crandall, and Bush 1993; Brookshire et al. 2004; Landry 1995; Goodman and Howe 1997; Person and Michelsen 1994). More recently, as data on water market transactions has become available through such publications as *The Water Strategist*, researchers analyzed water right transaction data aggregated across several states to determine if consumers in different markets place similar value on the attributes of water rights (Brown 2006; Brewer et al. 2008).

In her study of appurtenant surface water rights in Weld County, Colorado, Crouter (1987) concludes that the market is not efficiently pricing the value of water rights in real estate sales. Extending the same approach to groundwater, Byrd (2004) finds that aquifer productivity, supply certainty, and high soil quality are positively related to price in the northern high plains. Faux (1996) similarly demonstrates that, in sales of Oregon farmland, irrigation water rights and soil quality positively affect price.

Studies examining specific water markets (Anderson 1961; Landry 1995; Colby, Crandall, and Bush 1993; Person and Michelsen 1994; Goodman and Howe 1997) arrived at more detailed conclusions regarding the water right and market characteristics that impact prices. These studies found that buyer type significantly affects price, senior priority dates attract higher prices, transaction size measured in terms of water quantity is negatively related to unit price, and that market segmentation can result in a price differences among individual water markets. In addition, factors influencing demand such as population growth, interest rates, and crop values affect water right prices. Such price information is important for aiding water market participants in negotiating and conducting sensible transactions, increasing the allocative efficiency of water markets.

Brown (2006) conducted a statistical analysis of water right transaction data between 1990 and 2003 aggregated for the 14 western states. This analysis examined the influence of year, drought conditions, transaction volume, county population, water source, and buyer type on price. Brown finds that water purchased for municipal and environmental purposes draws higher prices than irrigation water rights across markets, but emphasizes the need to understand the unique traits of individual markets. Brewer et al. (2008) examine water transaction data between 1987 and 2005 from 12 western states. Their analysis reveals that, as a result of market heterogeneity, prices and trading activity vary based on location and individual characteristics of local water markets. However, two patterns persist among all markets. Agriculture-to-urban trades demand higher prices than transactions among agricultural water users, and sales and leases for terms longer than one year have become increasingly common over time.

Brookshire et al. (2004) analyze over eleven years of data from Arizona's Central Arizona Project market, Colorado's Colorado Big Thompson project market, and New Mexico's Rio Grande Conservancy District. Their analysis indicates that characteristics of the market, such as buyer type and drought conditions, influence water right prices. While common price determinants exist among these different markets, the authors conclude that the markets are heterogeneous. Separate econometric analyses of water right transaction data from each individual market are required to provide meaningful insight into water right prices.

The most recent work on water markets has focused on two new issues: water purchases for environmental purposes and the effect of climate. Loomis et al. (2003) studied transactions for environmental purposes in the western United States and found that government agencies could find willing sellers, from low-value crops, at prices they were able to pay to provide for wildlife, recreation, and fisheries.

As leasing mechanisms have more fully evolved for short-term transactions, it has become possible for water users cover their within season demands with short-run contracts. Using data from the Goulburn Murray Irrigation District in Australia, Bjornlund and Rossini (2005) show that irrigators with "water dependent capital assets such as dairy and horticulture farmers" are willing to pay higher water prices in the face of low precipitation, hot weather and low water allocations to protect their long-term investments. Similarly, Pullen and Colby (2008) extend the early work of Colby, Crandall, and Bush (1993) in New Mexico's Gila-San Francisco Basin showing that both price and quantities transacted increase in drought years. Jones and Colby (2010) integrate similar strands of environment and climate showing that temperature, precipitation, regional income and population change affect the lease markets in four western U.S. states for both environmental and non-environmental purposes.

ANALYSIS

Our data[2] include 253 observations of completed ditch company share transfers in the South Platte basin between 2002 and 2008. Sales included in this data set transferred a total of approximately 12,408 acre-feet consumptive use (AF CU). Table 3 offers summary statistics from the data. Transfers included in this analysis occurred in Larimer, Morgan, Weld, Arapahoe, Adams, Jefferson, Boulder, Gilpin, or Clear Creek County (see figure 3).

The econometric model developed in this study to analyze the relationships between characteristics of ditch company shares, attributes of the South Platte basin water market, and the share prices is:

Unit Price = f(COEFF VAR, STORAGE, UPSTREAM, FRICO STANDLEY, CU, PREV USE, YEAR) + e

Where:

- COEFF VAR is a measure of water supply reliability. A low coefficient of variation denotes a highly reliable share.
- STORAGE represents the availability of reservoir storage from each ditch company. STORAGE is a binary variable that assumes a value of 1 if the ditch company owns storage water rights and reservoir capacity, and 0 if the company receives water from direct flow rights.

---

[2] WestWater Research L.L.C. made its proprietary dataset of ditch company share sales information available for this study. WestWater Research maintains a comprehensive database of current, verified water transaction information for each state in the West.

- UPSTREAM differentiates between ditch companies located upstream on the South Platte River near cities, and companies situated downstream, far from municipal areas. A value of 1 is attached to UPSTREAM if the company is located upstream from the confluence of Lost Creek and the South Platte River, and 0 for downstream companies. (See Figure 4)
- FRICO STANDLEY takes on a value of 1 for transfers of shares in FRICO Standley Lake Division and 0 for sales of other ditch company shares.
- CU represents the volume of water transferred in acre-feet of consumptive use.
- PREV USE differentiates between water transferred from agricultural uses and water originally used for urban purposes. This variable takes on a value of 1 for previous agricultural use and 0 for previous urban use.
- YEAR takes on the value of the year in which the transfer was completed to test for appreciation.
- e is an error term.

Unit price, or dollars per acre-foot of consumptive use is our dependent variable. Consumptive use is water permanently extracted from its source as a result of evaporation, human and livestock ingestion, or crop transpiration. Under Colorado water law, only the consumptive use portion of a ditch company share, measured in acre-feet, may be transferred to alternate beneficial uses (Rice and White 1987). Therefore, the dollars per acre-foot of consumptive use unit for the dependent variable accurately reflects the price that buyers pay for each usable unit of water they receive. Unit prices were adjusted for inflation and changed to 2008 dollars using the GDP deflator.

The unit price of ditch company shares is predicted to hold a positive relationship with the year the transaction occurred, the availability of reservoir shares, and upstream locations. Negative relationships are expected between agricultural previous use, the coefficient of variation for annual water supply, and the volume transferred and price.

This price model was estimated using the Ordinary Least Squares method. See Table 1 for the results of this estimation.

The R Square of 0.7199 indicates that the price model explains 72% of the unit price variation in the data set. The high t-statistics and low p-values for the YEAR, PREV USE, STORAGE, COEFF VAR, FRICO STANDLEY, and UPSTREAM independent variables signify that these variables are statistically significant at a 99% confidence level. The variable CU is statistically significant at a 95% confidence level.

Previous econometric analyses of water transfer data found that nonlinear relationships exist between water right prices and explanatory variables (Goodman and Howe 1997; Pullen and Colby 2008; Jones and Colby 2010). We used a Box-Cox transformation to test for hypothesized nonlinear relationships (Box and Cox 1964). Box-Cox procedures transform the variable Z to $(Z^\lambda - 1)/\lambda$. When $\lambda = 0$, Z is transformed to the natural log of Z. If $\lambda = 1$, Z remains linear. (Kennedy 1985). The dependent and independent variables were transformed separately using STATA's "lhsonly" and "rhsonly" options. Dummy variables were omitted from the "rhsonly" transformation because they include non-positive values. The results of both the dependent and independent variable transformations show that a linear specification is appropriate (see Tables 4 and 5). Consequently, we retain a linear specification to estimate the price model.

The Breusch-Pagan Test produced a p-value of 0.5525, allowing us to accept the null hypothesis of constant variance (homoskedasticity). A correlation matrix revealed no associations above 0.32 among independent variables. These low correlations, along with our small standard errors, indicate that collinearity does not significantly influence our estimation results.

Recent statistical analyses of water right prices have identified and corrected for endogeneity between price and the volume traded in each transaction (Pullen and Colby 2008; Jones and Colby 2010). Instrumental variables were used to correct for endogeneity.

The question of the endogeneity of price and quantity arises when using equilibrium observations of market transactions to estimate the determinants of price. Where price and quantity are endogenously determined, parameter estimates should be made with two-stage least squares to address the identification problem of equilibria occurring at the intersection of various supply and demand curves. For a number of reasons, permanent water transfers, as they work in practice, may not exhibit strong endogeneity between unit price and the consumptive use volume traded in a particular transaction.

First, farmers sell either surplus water or water coming out of low-value production. Sellers may also be quitting farming all together. Because ditch company shares yield specific volumes of water and can be difficult to divide, ditch share transactions are “lumpy.” They are not marginal transactions in which more shares or partial shares could be offered for a marginal increase in the price. The water rights judicial or administration process associated with a change of use further decrease the simultaneity with which price and volume are determined. The high transactions costs associated with the water court process disincentivize purchasing partial shares or marginally smaller water quantities.

Second, it is our experience that short term droughts of one or two years, while influencing the lease market, do not affect prices in permanent transactions. Consequently, the volume of water yielded by the transacted share in the year of the sale, which is a function of hydrologic conditions, is not simultaneously determined with price. Price is influenced by factors other than drought.

Third, the water court establishes the consumptive use volume provided by the share, not the share's market price. During the change case, the court will examine evidence regarding historic use as well as objectors' filings to determine the quantity that is transferable to a new use without injuring other existing water rights. This determination of transferable volume is often uncertain and difficult to account for in price negotiations.

In our model, the variable CU assumes the value of transaction volume. We employed the Hausman-Wu test to determine if correcting for endogeneity between unit price and CU was necessary. The Hausman-Wu test compares the estimation results of a two-stage least squares (2SLS) model to the single-stage estimation results. If the estimated parameters are significantly different, the null hypothesis of exogeneity is rejected. Our 2SLS model expressed CU as a function of average yield per share for the ditch company, an interaction term that multiplied Colorado's FHFA House Price Index (Federal Reserve Bank of St. Louis) by urban buyer types, the transaction year, a dummy variable separating ditches with senior water rights from junior diversions, and an error term. While some of these explanatory variables held statistically significant relationships with CU, no highly accurate predictor of transaction volume was identified. Previous studies employing instrumental variable techniques to correct for endogeneity encountered similar challenges in modeling transaction volume (Pullen and Colby 2008). CU values predicted by the first stage were included in the price model as an instrumental variable. The Hausman-Wu test showed that the 2SLS model failed to estimate results significantly different from the OLS model (P-value =0.7917), allowing us to accept the null hypothesis that unit price and volume are exogenous.

The Value of Water Storage

A measure of the reliability and flexibility of water supplies provided by ditch company shares is the availability of reservoir storage. Reservoirs permit ditch companies to store excess water in wet years for use in dry years, allowing the companies to provide more consistent water supplies to each shareholder. In addition, storage enables year-round municipal use of seasonal agricultural water purchased by cities (Howe 2009). The coefficient of 1,786.4** on the variable STORAGE shows a positive relationship between the prices buyers are willing to pay for water and a ditch company's storage capacity. This new result indicates that water buyers in the South Platte basin value shares that provide reliable and flexible water supplies, and provides insight into the economic value of water storage.

Water Supply Reliability

The reliability of the water supply associated with a ditch company share affects the price buyers are willing to pay for the share. Purchasing reliable shares creates a consistent water supply for the buyer, mitigating risks related to uncertain water supplies. A direct measure of the reliability of ditch company shares is the coefficient of variation for the annual water supply of each company. The coefficient of variation (COEFF VAR) equals the ratio of the standard deviation of yearly water supply to the average yearly water supply.

A high coefficient of variation means that the company receives an inconsistent volume of water each year at its headgate, preventing the company from delivering reliable supplies to its shareholders. Low coefficients of variation indicate a reliable water supply. The coefficient

-3,883.4** on the variable COEFF VAR reveals that unit prices are higher for ditch shares providing reliable annual water yields. Previous studies similarly found that buyers value reliable water supplies (Landry 1995; Colby, Crandall and Bush 1993). These studies used a dummy variable separating senior water right from junior water rights to estimate the impact of reliability on water right prices. In their study of ditch company share prices in the basin above Denver, Goodman and Howe (1997) used the ratio of the share's firm yield to average yield as a measure of water supply reliability. However, the coefficient of variation represents a new measure of water supply reliability that the authors consider highly useful for assessing the risk versus return associated with a water right acquisition.

FRICO Standley Lake Division

Farmers Reservoir and Irrigation Company (FRICO) Standley Lake Division is characterized by several desirable traits that keep its share prices high. Standley Lake, an important water storage reservoir for FRICO, is located near the cities of Westminster, Northglenn, and Thornton, and represents the primary source of water for these municipalities. The relatively high elevation of the reservoir (5,506 ft.) enables cheap transportation of its water, because gravity allows the water to flow naturally to municipalities situated at lower elevations. Westminster, Northglenn, and Thornton are actively acquiring new water supplies, including ditch company shares, as a result of rising levels of demand for water stemming from rapid population growth (Goodman and Howe 1997). In response to this population growth and the cost-effectiveness of delivering water from Standley Lake, these cities pay high prices for FRICO Standley Lake shares despite the junior priorities of the company's water rights.

To more accurately explain ditch company share prices in the South Platte basin we needed to account for the unique characteristics of FRICO Standley Lake shares that attract higher prices. Therefore, the binary variable FRICO STANDLEY was added to the model to separate FRICO Standley Lake shares from shares of other companies. This variable assumes a value of 1 for transfers of FRICO Standley Lake shares and 0 for sales of other shares. The coefficient of 11,164.5** on the variable FRICO STANDLEY indicates that shares in Farmers' Reservoir and Irrigation Company (Standley Lake Division) are worth over $11,000 per acre-ft more than shares in other ditch companies.

Ditch Company Location

Shares in ditch companies located upstream from the confluence of the South Platte River and Lost Creek command higher prices than shares in companies situated downstream from this point (see Figure 4). The majority of high-value share buyers are upstream of this confluence, and legal and physical barriers exist to upstream transfers. Water courts often disapprove upstream transfers from downstream ditch companies because upstream transfers can impair other water rights (Smith 1990). In addition, ditch companies located downstream from this confluence are a long distance from most Front Range municipalities. These cities represent the buyers in a large portion of the water sales in the South Platte basin. Transporting water long distances is expensive: approximately $1,000 per acre-foot of additional capacity for each mile conveyed via pipelines and pumps (Wright Water Engineers Inc. 2009). As a result of these considerable conveyance costs, municipal water purchasers pay less for shares in downstream ditch companies. The variable UPSTREAM has a coefficient of 4,434**, meaning that shares in ditch companies located upstream from the confluence of Lost Creek and the South Platte are worth $4,434.00 per acre-foot more than shares of downstream ditch companies, *ceteris paribus*. Previous studies used similar methods to analyze geographic price dispersion in water markets (Landry 1995; Colby, Crandall and Bush 1993).

Previous Use of Ditch Company Shares

Ditch company share sales transfer water from low-value uses to higher-value uses (Brookshire et al. 2004). The revenue the seller receives for selling water outweighs the economic gains derived from continuing to use the water, while the buyer benefits economically from increasing its water supplies. Previous studies have demonstrated that in water markets throughout the western United States, agricultural water users constitute low-value water users and frequently sell irrigation water rights to municipalities and other urban water users. These urban water users derive higher economic returns from purchased water supplies (Brown 2006). We tested for this agriculture-to-urban water transfer trend in the South Platte basin using the variable PREV USE. This binary variable takes on a value of 1 if the previous use of the ditch company share was irrigation, and 0 for shares previously owned by urban water users. Irrigators acted as the seller in approximately 98% of the transactions in our data. The coefficient of -7,479.5**on the independent variable PREV USE indicates that an acre-foot of water previously applied to irrigation in the South Platte basin is $7,479.50 cheaper than an acre-foot used for urban purposes, *ceteris paribus*.

Price Appreciation

The data set analyzed in this study includes ditch company share sales completed between 2002 and 2008. Throughout the South Platte basin water prices are appreciating. The independent variable YEAR (the year the share sale was completed) has a coefficient of 813.6**. This coefficient reveals a positive relationship with unit price of ditch company shares, confirming of the hypothesized time trend ditch company share prices. Because unit prices were adjusted for inflation, this positive coefficient indicates that real prices are appreciating at a rate of approximately $813 per acre-foot per annum. Dividing this coefficient by the mean water right price in the dataset results in an average annual real appreciation rate of 11%. The high level of appreciation can be attributed to increasing levels of demand for water in the South Platte basin stemming from population growth. Population is growing primarily in cities. For example, the Denver Metropolitan Area grew at an average rate of 1.9% annually between 1998 and 2008 (MDEDC 2009). In the South Platte basin, several municipalities that actively acquire ditch company shares compete for the same water supplies as a result of their close proximity to one another. Rising demand for municipal water over time and competition for scarce supplies drives increasing water prices. This finding is consistent with previous studies of other regional water markets that used the same variable to test for a time trend among water right values (Colby, Crandall, and Bush 1993; Pullen and Colby 2008). Interestingly, Brown (2006) found that no statistically significant relationship exists between transaction year and annual water lease rates.

Volume Transferred

Previous studies demonstrate that economies of scale exist in water transfers, meaning that sales of large quantities of water are associated with lower unit prices (Landry 1995; Colby, Crandall, and Bush 1993). Scale economies result from transaction costs that are relatively constant across the size of the transfers. Transaction costs arise from the due diligence studies, water court proceedings, and lengthy negotiations that often accompany water transfers. Because ditch share sales of all volumes necessitate similar transaction costs, transfers of large water quantities are associated with lower transaction costs per acre-foot traded. (Howe, Boggs, and Butler 1990). This study uses the variable CU to test for economies of scale in South Platte basin water transfers. The variable CU represents the volume transferred in acre-feet of consumptive use. The coefficient on CU of-4.40* shows a negative relationship with unit price. This coefficient indicates that with each additional acre-foot of water purchased, the price per acre-foot decreases by $4.40, *ceteris paribus*. This negative relationship confirms that economies of scale exist in the South Platte basin water market.

New Use of Transferred Ditch Company Shares

Previous water markets studies indicate that urban water uses are the most valuable applications of water in the western United States (Brown 2006; Brewer et al. 2008). Because urban entities derive the highest economic benefits from water supplies, water rights transferred to new municipal and industrial uses are thought to attract higher prices than water traded to new agricultural or environmental applications. Following previous studies (Brown 2006; Brookshire et al 2004), we tested for hypothesized premium prices paid by urban ditch company share buyers using dummy variables separating agricultural and urban buyer types. However, no statistically significant relationships between new use variables and unit price were found. New use dummy variables were eliminated in the final model to reduce collinearity among independent variables.

The absence of statistically significant relationships between new use variables and ditch share prices reveals a unique condition of the South Platte basin water rights market. While water right price differences across new uses are observed in many regions, prices in the South Platte basin remain stable regardless of the buyer's new use for acquired water. Consistent prices across new uses indicate that the South Platte basin water market is efficient. Where prices vary by new use, arbitrage incites rapid price convergence if the market operates efficiently. Our analysis shows that such price convergence has occurred in the South Platte basin. In inefficient markets, differences in water right prices across new uses persist, allowing new use variables to statistically account for price dispersion.

SUMMARY & CONCLUSIONS

In many areas throughout the West, water supplies are insufficient to meet the needs of water users. Water markets can help accommodate the water demands of diverse water users by allowing the purchase and sale of water rights. However, where information is incomplete, buyers and sellers will not be able to make informed decisions, resulting in an inefficient market. Water resource allocation can be improved through a better understanding of the factors that influence price.

Consistent with previous water market studies, our analysis shows that ditch company share buyers value reliable water supplies. The introduction of coefficient of variation as a means to characterize share reliability proved successful in conveying the variation of the portfolio of priorities dates that compose a ditch company share. We also confirm that small sales attract higher unit prices. We further show that buyers pay a premium for shares located in close proximity to their water systems, and for shares rendered more reliable and flexible by reservoir storage. In addition, agricultural water users are willing to accept lower prices for water supplies than municipal water users. Throughout the South Platte basin ditch company share prices are appreciating at a rate of 11% above inflation.

The price model developed for this article explains approximately 72% of the price variation among ditch company shares. This model’s high level of descriptive capacity indicates that water buyers base their purchasing decisions on the reliability, flexibility, location, previous use, and transferable volume of ditch company shares. The ability of buyers to recognize these characteristics of ditch company shares and make informed purchases based on them suggests that the South Platte basin water market operates with greater efficiency than many other water markets in the western United States.

The findings of this article hold implications for the decision-making processes of urban water supply planners, water project developers, and investors. Municipal water providers can employ our results to develop least-cost strategies for acquiring reliable water supplies. In addition, increased knowledge of water right values enables investors and water project developers to predict returns on water rights investments, complete feasibility studies, and estimate the break-up value of their assets if a project plan is abandoned. Similar studies examining current, complete water transfer data from other water rights markets in the West are needed to improve the decisions of market participants and promote efficient allocation of water resources in those regions.

Figures and Tables

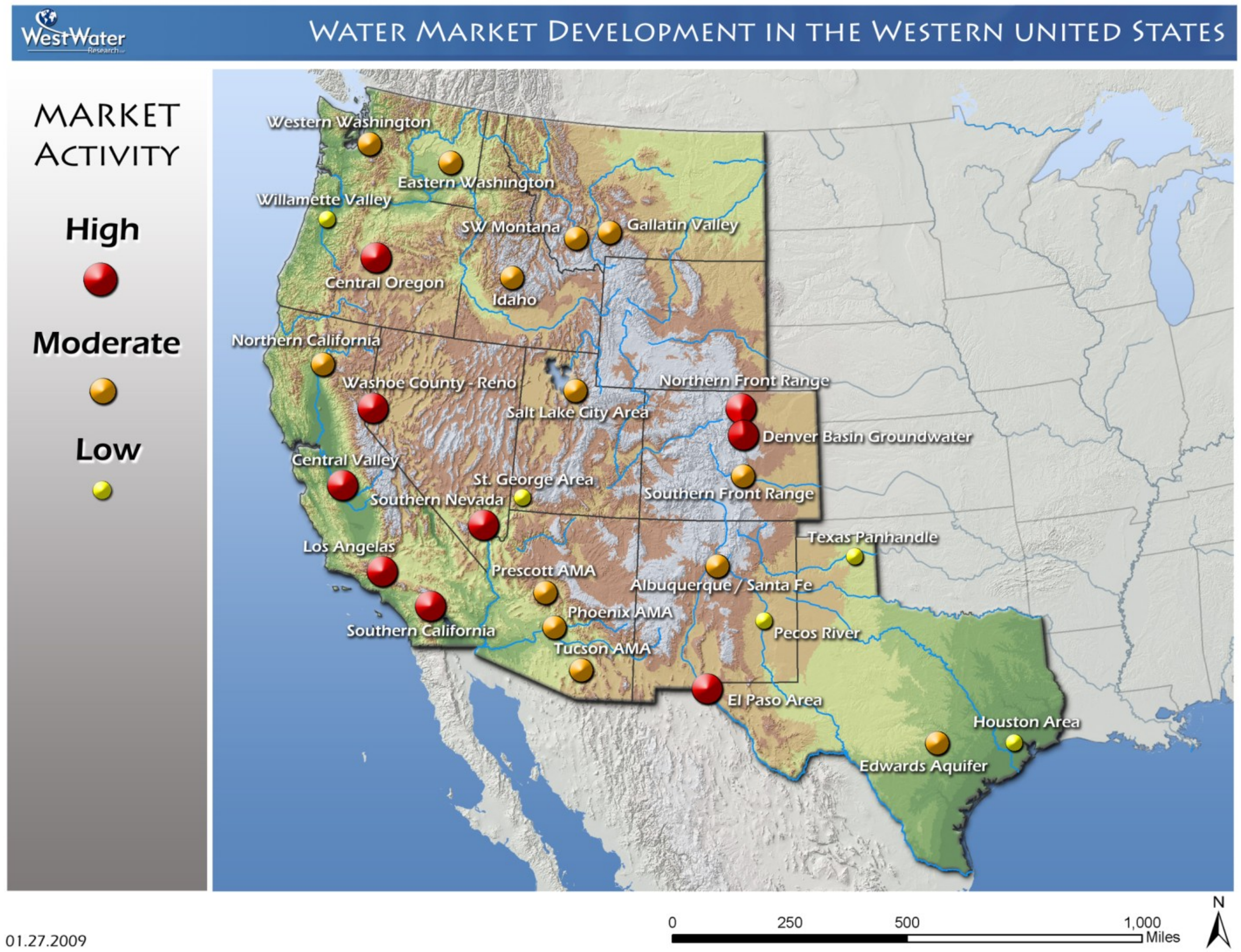

Figure 1. Western Water Markets by Level of Market Activity

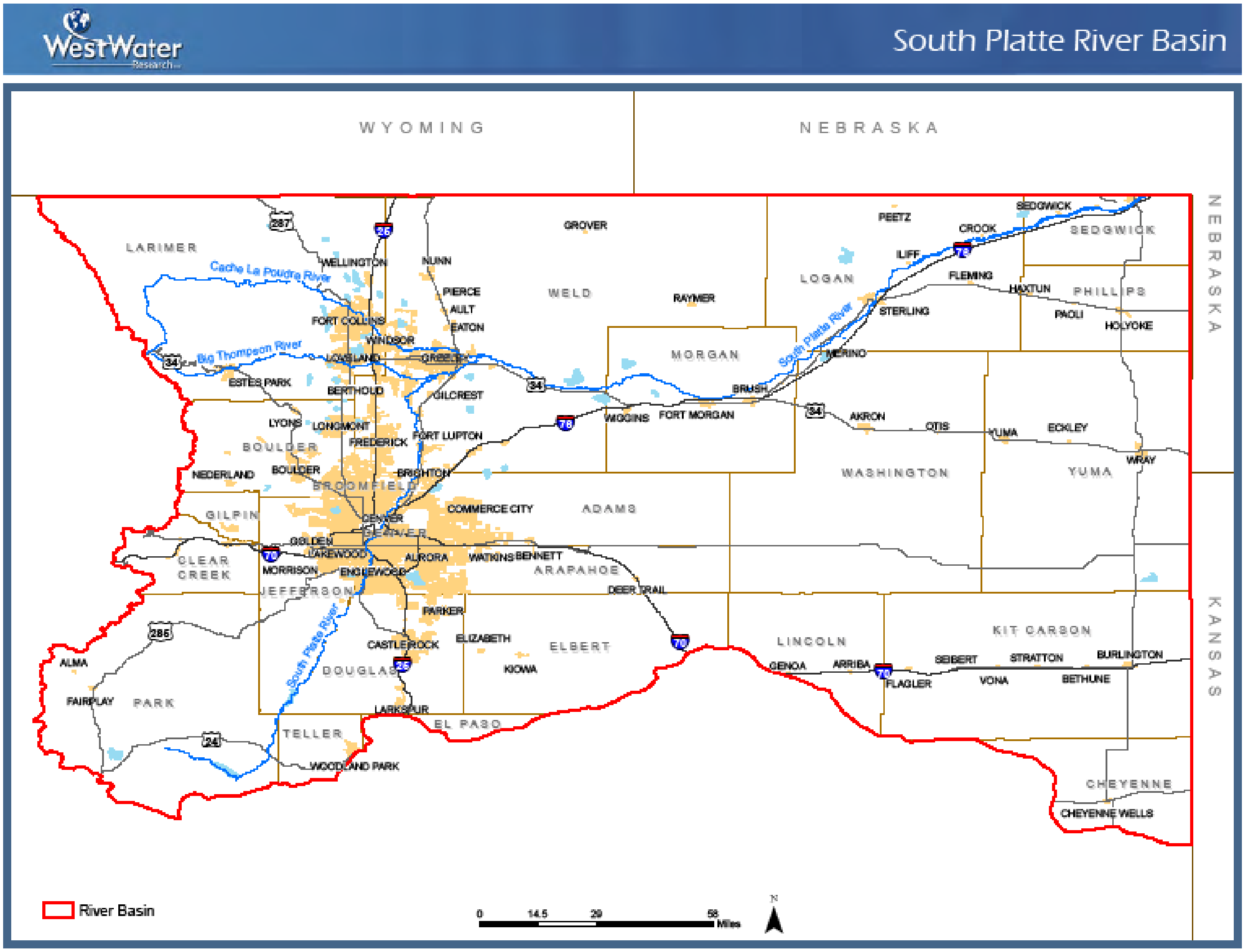

Figure 2. The South Platte Basin

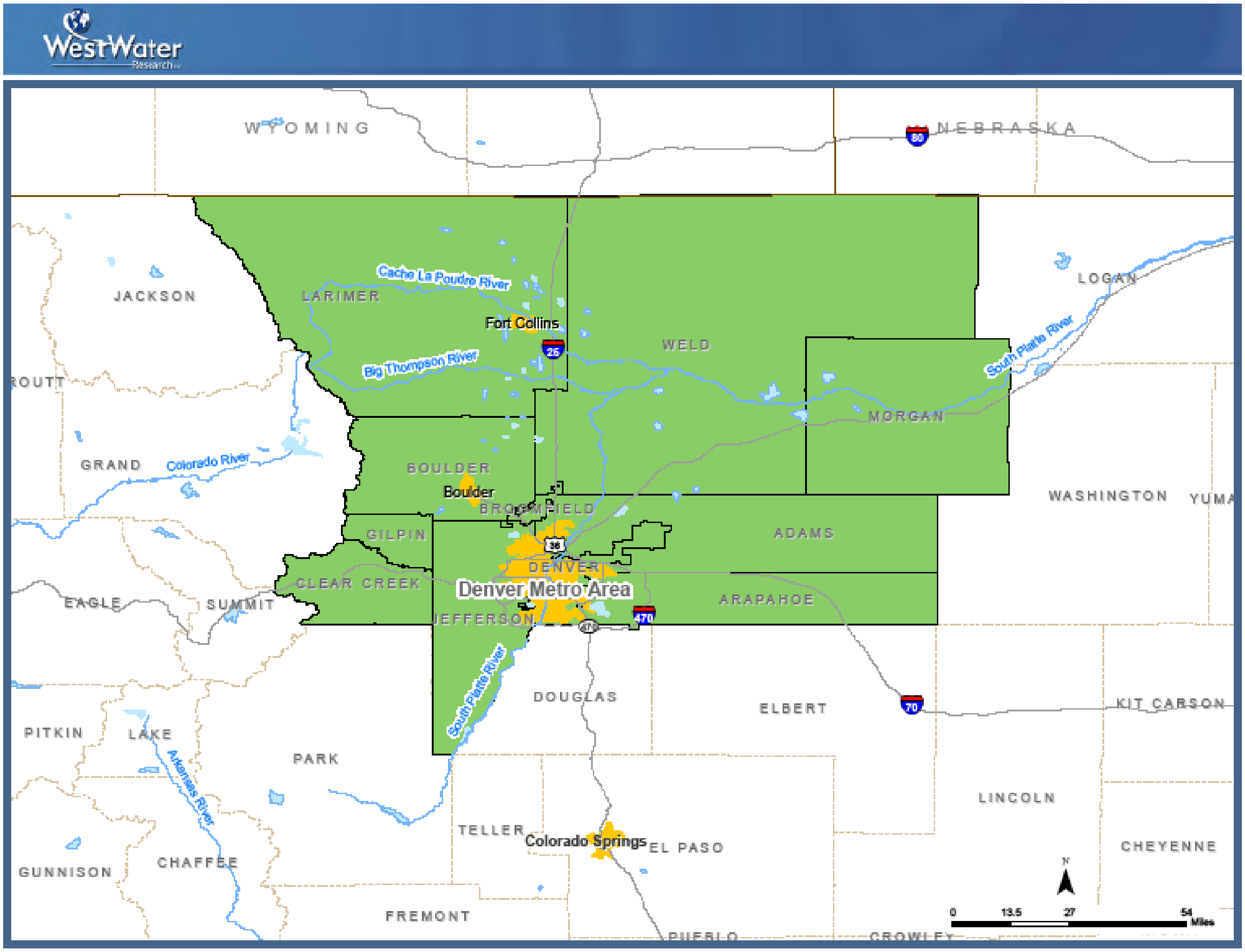

Figure 3. South Platte Basin Study Area

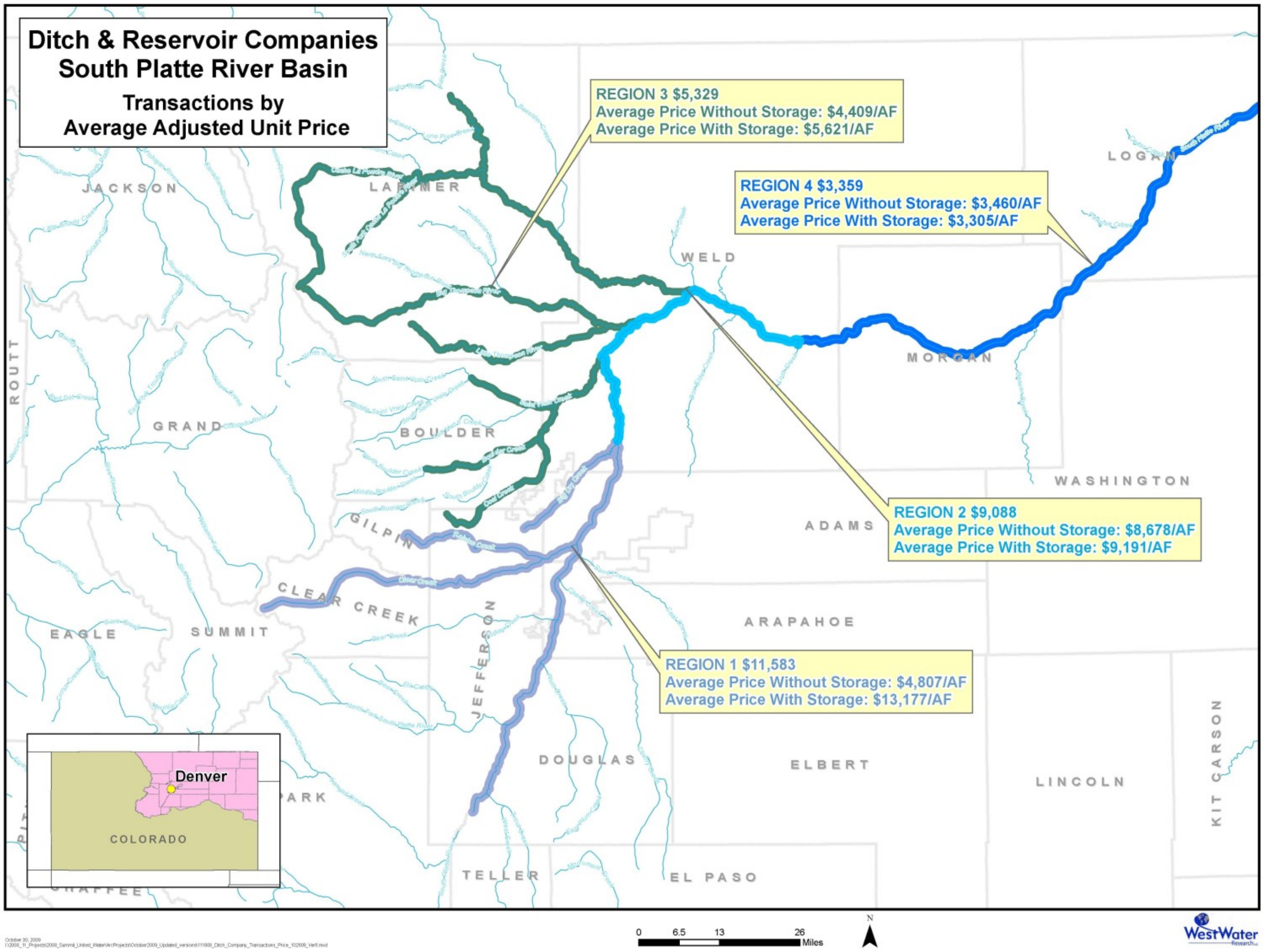

Figure 4. The Influence of Ditch Company Location on Share Prices

Table 1. Regression Results

	Coefficients	*Standard Error*	*t Stat*	*P-value*
YEAR	813.5711**	105.9273	7.68	0.000
CU	-4.3977*	1.8860	-2.33	0.021
PREV USE	-7479.496**	1266.272	-5.91	0.000
STORAGE	1786.397**	390.444	4.58	0.000
COEFF VAR	-3883.402**	997.7736	-3.89	0.000
FRICO STANDLEY	11164.48**	557.0734	20.04	0.000
UPSTREAM	4434.184**	480.2171	9.23	0.000
Constant	-1621151	212605.2	-7.63	0.000

R Square = 0.7199   Adj. R Square = 0.7119   n = 253   F Statistic = 89.94

Note: Asterisk (*) signifies statistical significance at a 95% confidence level, and double asterisk (**) represents statistical significance at a 99% confidence level

Table 2. Relationships between Share Attributes, Market Characteristics, and Unit Price

Variable	**Relationship with Unit Price**
COEFF VAR	Negative
STORAGE	Positive
FRICO STANDLEY	Positive
UPSTREAM	Positive
CU	Negative
PREV USE	Negative
NEW USE MUNICIPAL	Uncertain due to insignificant correlation with unit price
NEW USE IRRIGATION	Uncertain due to insignificant correlation with unit price
YEAR	Positive

Table 3: Summary Statistics for Ditch Company Share Transactions in the South Platte Basin, 2002 -2008

	Volume Traded (AF CU)	Unit Price ($/AF CU)
Mean	49.01	$7,416.81
Median	16	$6,432.45
Min	0.66	$434.44
Max	885	$25,555.55
St. Dev.	90.82	$4,854.71
Count	253	253

Table 4: Box-Cox Transformation Results – Left-Hand Side

Dependent Variable Transformation					
adjusted_price	**Coef.**	**Std. Err.**	**z**	**p-value**	**95% Conf. Int.**
theta	0.6201	0.0752	8.2400	0.0000	0.4727-0.7675
Test H0	**Restricted log likelihood**	**LR Stat. Chi2**	**p-value**		
theta = -1	-2629.9	595.04	0.000		
theta = 0	-2369.7	74.57	0.000		
theta = 1	-2344.9	24.98	0.000		

Table 5: Box-Cox Transformation Results – Right-Hand Side

Independent Variable Transformation:					
adjusted_price	**Coef.**	**Std. Err.**	**z**	**p-value**	**95% Conf. Int.**
lambda	2.2760	0.8129	2.80	0.005	0.6828-3.8692
Test H0	**Restricted log likelihood**	**LR Stat. Chi2**	**p-value**		
lambda = -1	-2349.1	12.71	0.000		
lambda = 0	-2348.3	11.19	0.001		
lambda = 1	-2344.9	4.36	0.037		

REFERENCES

Anderson, R.L. 1961. "The Irrigation Water Rental Market: A Case Study." *Agricultural Economics Research*. June 1961.

Anderson, T.L. 1983. *Water Crisis: Ending the Policy Drought*. Baltimore: The Johns Hopkins University Press.

Anderson, T.L., and P. Snyder. 1997. *Water Markets: Priming the Invisible Pump.* Washington, D.C.: Cato Institute.

Bjornlund, H. and P. Rossini, 2005: Fundamentals determining prices and activities in the market for water allocations. *Water Resources Development*, **21 (2)**, 355-369.

Box, G.E.P, and D.R. Cox. "An Analysis of Transformations." *Journal of the Royal Statistical Society*. Series B (Methodological), Vol. 26, No. 2. (1964), pp. 211-252.

Brewer, J., R. Glennon, A. Ker, and G. Libecap. 2007. "Water Markets in the West: Prices, Trading, and Contractual Forms." *Economic Inquiry* 46, no. 2.

Brookshire, D.S., B. Colby, M. Ewers, P. Ganderton. 2004. "Market Prices for Water in the Semi-Arid West." *Water Resources Research* 40, no. 9.

Brown, T.C. 2006. "Trends in Water Market Activity and Price in the Western United States." *Water Resources Research* 42 (2006).

Byrd, H.A. 2004. "Estimating the Value of Groundwater Rights to Irrigated Agriculture: An Application of the Hedonic Price Model in the Northern High Plains." MS Thesis, Colorado State University.

Colby, B.G., K. Crandall, and D.B. Bush. 1993. "Water Right Transactions: Market Values and Price Dispersion." *Water Resources Research* 29, no. 6: 1565.

Colorado Constitution, art. 16, sec. 6. http://law.justia.com/colorado/constitution/cnart16.html

Colorado Foundation for Water Education. 2009. *Headwaters: South Platte Edition*. Denver: Colorado Foundation for Water Education.

Colorado Foundation for Water Education. 2004. *Citizen's Guide to Colorado Water Law.* Denver: Colorado Foundation for Water Education.

Colorado Water Conservation Board. "Statewide Water Supply Initiative." (2004). Available from http://cwcb.state.co.us/IWMD/SWSITechnicalResources/.

Crouter, J.P. 1987. "Hedonic Estimation Applied to a Water Rights Market." *Land Economics* 63, no. 3.

Faux, J. 1997. *Hedonic Price Analysis to Reveal Value of Water in Irrigation: An Application to Northern Malheur County, Oregon.* MS Thesis, Oregon State University.

Federal Reserve Bank of St. Louis. Economic Data – FRED. Federal Housing Finance Agency House Price Index for Colorado. Website. Online at http://research.stlouisfed.org/fred2/series/COSTHPI.

Goodman, D.J., and C.W. Howe. 1997. "Determinants of Ditch Company Share Prices in the South Platte River Basin." *American Journal of Agricultural Economics*, 79, no. 3.

Hall, J. 2007. "South Platte River Basin Task Force Presentation." Division Engineer, Water Division 1, Colorado Division of Water Resources. Presentation on July 27, 2007. Accessed online

Hecox, E. Manager of the Office of Interbasin Compact Negotiations, interview by author, 23 January 2009, Denver, CO.

Hobbs, G. Colorado Supreme Court Justice, interview by author, 20 January 2009, Denver, CO.

Howe, C.W., Professor Emeritus of Economics at University of Colorado-Boulder, interview by author, 23 January 2009, Boulder, CO.

Howe, C.W., Professor Emeritus of Economics at University of Colorado-Boulder, personal correspondence with author, 9 November 2010.

Howe, C.W., C.S. Boggs, and P. Butler. 1990. "Transaction Costs as Determinants of Water Transfers." *University of Colorado Law Review*, 61, 393.

Howe, C.W., J.D. Wiener. 2006. "Moving Towards more Efficient Water Markets: Institutional Barriers and Innovations." Proceedings from UCOWR annual meeting, Santa Fe NM, 18-20 July.

Jones, L. and B. Colby, 2010: Weather, Climate and Environmental Water Transactions. *Weather, Climate and Society* (forthcoming).

Kennedy, P. 1985. *A Guide to Econometrics*. 2nd edition. The MIT Press, Cambridge, Massachusetts.

Landry, C.J. 1995. "Giving Color to Oregon's Gray Water Market: An Analysis of Price Determinants for Water Rights." MS Thesis, Oregon State University.

Loomis, J. B., K. Quattlebaum, T. C. Brown, and S. J. Alexander, 2003: Expanding institutional arrangements for acquiring water for environmental purposes: Transactions evidence for the western United States. *Water Resources Development,* **19 (1)**, 21-28.

MacDonnell, L. Ph.D. – Porzak, Browning & Bushong, interview by author, 20 January 2009, Boulder, CO.

Metro Denver Economic Development Corporation. "Demographics: Population." [cited 2009]. Available from http://www.metrodenver.org/demographics-communities/demographics/population.html

Person, P. and A. M. Michelsen. 1994. "Determinants and Trends in Water Right Prices: An Econometric Analysis." Laramie. U. S. DOI Geological Survey and Wyoming Water Resources Center, University of Wyoming. WWRC-94-06.

Pullen, J. L. and B. G. Colby, 2008: Influence of Climate Variability on the Market Price of Water in the Gila-San Francisco Basin. *Journal of Agricultural and Resource Economics* ***3*3 (3)**, 473-487.

Rice, L., and M.D. White. 1987. *Engineering Aspects of Water Law.* New York, NY: John Wiley & Sons, Inc.

Rosen, S. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition." *The Journal of Political Economy* 82, no. 1: 34.

Saliba, B.C. and D.B. Bush. 1987. *Water Markets in Theory and Practice: Market Transfers, Water Values, and Public Policy.* 12th ed. Boulder, CO: Westview Press.

Smith, M.G. 1990. "The Water Market in the Southern Front Range of Colorado." *Proceedings of the Symposium on International and Transboundary Water Resource Issues.* March 1990.

Wolfe, D. 2005. "Regulation of Well Pumping in the South Platte River Basin." *Colorado Division of Water Resources.* Denver CO.

Wright, K. and Flood, P. 2009. "Water Prices: The Essentials." Wright Water Engineers, Inc. CLE Presentation. Denver, CO.

Young, R. A. 2005. *Determining the Economic Value of Water.* Washington, DC: Resources for the Future.