Savior of Rural Landscapes or Solomon's Choice? Colorado's Experiment with Alternative Water Transfer Methods for Water (ATMs)

Lisa Dilling
Cooperative Institute for Research in Environmental Sciences, University of Colorado

John Berggren
Western Resource Advocates

Jennifer Henderson
Cooperative Institute for Research in Environmental Sciences, University of Colorado

Douglas Kenney
University of Colorado Law School

Citation Information

Lisa Dilling, John Berggren, Jennifer Henderson & Douglas Kenney, Savior of Rural Landscapes or Solomon's Choice? Colorado's Experiment with Alternative Water Transfer Methods for Water (ATMs), 6 Water Security (2019), Article 100027, https://doi.org/10.1016/j.wasec.2019.100027, available at https://scholar.law.colorado.edu/articles/1270/.

Water Security 6 (2019) 100027

Contents lists available at ScienceDirect

Water Security

journal homepage: www.elsevier.com/locate/wasec

Savior of rural landscapes or Solomon's choice? Colorado's experiment with alternative transfer methods for water (ATMs)

Lisa Dilling[a,*], John Berggren[b], Jennifer Henderson[c], Douglas Kenney[d]

[a] Western Water Assessment, Environmental Studies Program, Center for Science and Technology Policy Research, Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO 80309, USA
[b] Western Resource Advocates, Boulder, CO 80302, USA
[c] Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO 80309, USA
[d] Western Water Policy Program, Getches-Wilkinson Center, University of Colorado, Boulder, CO 80309-0401, USA

A B S T R A C T

This article focuses on the emerging landscape for Alternative Transfer Methods (ATMs) in Colorado, USA. ATMs are developing within a legal landscape of water rights governed by prior appropriation law, growing demand for water in urban centers driven by population growth, and an aging rural farm population whose most valuable asset may include senior water rights. Rural-urban water transfers in the past have been linked to the collapse of rural economies if pursued to the extreme extent of "buy-and-dry," where water rights were purchased outright and permanently removed from agricultural land (e.g. Crowley County). This article focuses on the emerging innovations of ATMs, which seek to accomplish the same purpose of providing additional water to growing cities but through more flexible mechanisms, such as rotational fallowing, interruptible supplies, and water banks, that aim to preserve rural economies as well. We review the history and context for water allocation in Colorado, the history of rural-urban transfers, and focus on ATMs and their pros and cons. We conclude with implications of ATMs for water governance and providing flexibility and sustainability in a changing climate.

1. Introduction

Competition for water in the arid western United States, including the state of Colorado, has been a fact of life for over a century. As a state that has adjudicated water rights for well over 100 years, and one that has been at the leading edge of experiments with water markets, Colorado's experience is relevant not only across the western U.S. but perhaps internationally as well for other arid and semi-arid regions hoping to improve resiliency in the face of climate change and drought. Located at the intersection of the Rocky Mountains and the eastern plains, Colorado is known as a "headwaters" state because the majority of its rivers originate within the state's borders. This includes major regional, national, and international rivers, such as the Colorado River, Rio Grande, and South Platte. Settlers to this region from the east coast of the U.S. in the 1860s developed a system of legally-based water rights allocation known as prior appropriation that has persisted to this day. Prior appropriation recognizes the right to use water as a matter of priority date. Specifically, users that put water to beneficial use at an earlier date have "seniority" over users whose first use came later in time. In addition to priority, another fundamental component to prior appropriation is that users must continue to beneficially use their entire water right (because the right is for *use* of water, not actual *ownership* of water), or they may risk forfeiting that right through what is known as abandonment.

In the western U.S., and Colorado specifically, numerous challenges face water managers as they attempt to balance supplies and demands with a range of stakeholders, sectors, and ecosystems. In addition to having some of the fastest growing urban centers in the country (Colorado's urban Front Range is projected to grow by 45% by 2050, State Demographer's Office)—and an overall trend from rural to urban economies—the region has experienced climate and hydrologic changes which threaten available supplies [22]. As temperatures in the region continue to increase, water managers can expect increased demands, earlier snowmelt and runoff, and an overall decrease in water availability [31]. Accordingly, effective water governance will become increasingly important to mitigate the challenges of climate change and population growth, and ultimately help societies grapple with fundamental supply and demand imbalances. Against this backdrop, water allocated to agriculture is a seemingly easy target to help meet the needs of growing urban populations.

Because many of the settlers in the 1800s were agricultural land owners, the most senior water rights in the West are generally owned by farmers and ranchers, with some (but not all) municipalities often being latecomers to the table to obtain rights for their residents. As the population of western urban centers burgeons, the pressure to reexamine this allocation pattern has intensified. While agricultural landowners

* Corresponding author.
E-mail address: ldilling@colorado.edu (L. Dilling).

https://doi.org/10.1016/j.wasec.2019.100027
Received 21 October 2018; Received in revised form 20 February 2019; Accepted 18 March 2019
Available online 27 March 2019

hold senior rights, and individuals are free to sell their water rights (subject to court approval), cities exert significant economic and political pressure to ensure they are able to supply their populations with sufficient water out into the future. In purely volumetric terms, the vast majority of water is allocated still to agricultural uses – whether for food crops or animal feed. In addition, a decline in natural flows due to human uses has had adverse effects on ecological systems, in some cases drying up entire reaches during peak summer months.

As populations have grown and the drying of the western U.S. is anticipated from climate change, economists have argued that water needs to be allocated more efficiently through the functioning of a water market, rather than relying on "centralized, bureaucratic control" (pg. 439, Howe et al. [25]). Water markets have grown substantially since the 1980s in the semi-arid West. Prices were higher for agriculture-to-urban trades than for agriculture-to-agriculture trades, and ag-urban trades are rising more rapidly than the latter [4]. The value of water traded in western U.S. water markets ranges from year to year but was as high as $800 million in 2015, driven by a drought in California causing buyers to seek more reliable water rights portfolios [41]. A comparison of water markets across five countries found considerable variability in water markets as evidenced by institutional foundations, economic efficiency, and environmental sustainability [21]. Garrick et al. [17] have examined water markets in large basins in the U.S. and Australia to garner insights into how transaction costs interact with efficient water market institutions. The authors discuss the importance of avoiding institutional arrangements that create "lock-in" or path dependency as they limit flexibility as conditions change. Further, investments in institutional transition costs–such as conflict resolution reform or establishing water users associations – can prove effective in reducing transaction costs.

Water markets, Howe et al. [25] argued, need to have flexibility in allocation, security of tenure, information on true opportunity cost, predictable outcomes, perception of a fair and equitable process, and the incorporation of public values beyond individual water user interests. Water markets have been controversial and critiqued for their inability to fully capture and express public values such as ecological and cultural values [25,26,29]. Water transfers have resulted in impacts on rural areas, such as erosion of the local tax base, degradation of the formerly irrigated land, and threats to the economic health and lifestyle of rural areas [28,36]. The economic disparity between the "selling" area where the water rights originate and the "buying" area often result in a "tradeoff not only between the level of agricultural activities and alternatives made possible by the proceeds from water sales but between lifestyles and culture" (page 362, Howe [26]). In a court case over water rights in an *acequia* system (dating from the 1800s in New Mexico, USA), a judge rejected the inherent assumption that "greater economic benefits are more desirable than the preservation of cultural identity" (ibid).

However, the experience of the Murray-Darling Basin in Australia suggests that with an appropriate institutional framework and planning, water markets can function well to deliver both environmental outcomes and social goals [20], although the program is now being revisited as criticism mounts that outcomes have not met these expectations [19].

Water markets and transfers have been growing, but remain controversial, leading to a desire in some regions to try other mechanisms of transferring the right to use water that might be able to preserve social and environmental values while still meeting the growing demands of urban areas. In this article we develop a case study of the state of Colorado, examining how Alternate Transfer Methods (ATMs) are being developed and whether they work to offer the flexibility and economic efficiency of water markets while preserving social, cultural and environmental values. Flexibility is a key element of building adaptive capacity for water management under a changing climate [15]. Public perception of the procedural equity and fairness of what might seem like otherwise "rational" adaptation policies put forward by state and local governments is likely to be another critical and contentious area in the future [1]. While the programs discussed here should still very much be considered experiments, we argue that much can be learned about ways forward for addressing supply and demand imbalances, climate change adaptation, and more sustainable governance by examining the experience of ATMs in Colorado.

2. A tale of two water markets in Colorado

In 2015, the total value of water transfers in Colorado was $79 million, representing about 73,000 acre-feet (one acre foot is equal to the volume of water covering one acre of land one foot deep, or 1233.5 m^3) of water traded [41]. As discussed below, the experience with water markets in Colorado has been mixed [28].

2.1. Flexibility and Northern Colorado water conservancy District's water market

One water market in Colorado that has been viewed as relatively successful in terms of efficient water governance and low transaction costs is within the Northern Colorado Water Conservancy District ("Northern") in northeast Colorado. Northern is a public irrigation district that was created to help manage the Colorado-Big Thompson (CBT) Project, which is one of the major transbasin diversions discussed earlier. Somewhat unique in Colorado, Northern established a formal water market allowing users within the district's boundaries to voluntarily buy and sell water "shares" each year [27,28]. A "share" is not a specific quantity of water, but rather a proportion of what is available each year, depending on that year's snowpack and available surface runoff. Proportional allocation schemes, as opposed to fixed allocation schemes, have been suggested as providing greater institutional adaptability [35]. In the Northern context, this type of scheme provides resilience for water availability and for users of the system because it ensures that the amount of water delivered to users is scaled to what is available, allowing for automatic flexibility and responsiveness to environmental changes and access to at least some water by everyone on the system. The alternative prior appropriation model, that some users are prioritized to receive their full amount of water over others, means that some users would go without shares entirely in a drought year.

The price of water in Northern's market depends on numerous factors including the type of use, time of year, and the quota prescribed by Northern, which all means the price can fluctuate substantially inter- and intra-annually. For example, during the 2013 water year the price of one share fluctuated between $9500 and $18,500, demonstrating the volatility of the market [23]. Despite short-term fluctuations, however, the price of shares has continued to increase in the long-term, as municipalities compete to purchase the often-cheaper agricultural supplies within the district.

Additional features of Northern's market further distinguish it from other regions in the state. For example, the market within Northern's district does not require review by the state's water court—something that is required for most other water rights transactions and can often lead to a long, drawn out process for transferring water rights. This feature imparts flexibility and therefore resilience, as the system can respond more quickly to changing needs of users. However, while these features allow for a robust water market to operate within the district's boundaries, it is difficult to make direct comparisons to other regions throughout the state.

2.2. Lower Arkansas valley water transfers: "Buy-and-Dry" in Crowley County—a cautionary tale

Crowley County is in the southeastern part of Colorado, just east of Pueblo along the Arkansas River. Formed in 1911 and farmed heavily over the next several decades, the area thrived mid-century with irrigation provided by a network of ditches that move water from the West

Slope via Twin Lakes Reservoir and Canal Company and the Colorado Canal Company onto fields in the eastern plains [18] where farmers grew sugar beets, tomatoes, onions and later melons. But chronic droughts, like the Dust Bowl in the 1930s, combined with economic stressors, such as ongoing debt, low commodity prices, and the loss of the Sugar City beet plant in 1967, left some producers questioning their solvency [38]. Until 1972, the Colorado Canal Company, which fed Crowley farms, had in its documents a requirement that water and land be sold together. Water speculators from the Crowley Land and Development Company, who purchased a majority of shares, went to court and had the two severed [34]. They sold their water rights to growing cities and municipalities like Pueblo, Aurora, and Colorado Springs, through what is now called buy-and-dry.

As farms dried up from water sales, cascading effects devastated the community. Buy-and-dry led to loss of tax revenue, decreased land values, and businesses and schools closing, leaving the county today with 3000 residents, half of the population at its height in the 1920s. More telling, the number of acres irrigated has declined from 56,000 in 1968 just as water sales started to 2000 today [13,33]. Buy-and-dry can unintentionally externalize the costs of growth in urban centers to rural communities who have less diverse economic options [13,28,36]. Moreover, this case reinforces the point that water markets are not panaceas for fragile economies with few economic options, and suggests that other under large scale climate change, other types of reforms may be needed. Still, today Crowley County is widely cited by state and local communities as a parable of worst case outcomes should buy-and-dry practices continue and, thus, has become motivation for new experiments in water management.

3. Experiments with alternative transfer methods (ATMS) in Colorado

3.1. The basics of ATMs

While it is true that the voluntary transactions of water markets serve the interests of both buyers and sellers (as is the case with Northern's water market), the resulting loss of water and agricultural production can bring a host of hardships for affected communities, including remaining irrigators, those in agricultural support industries, rural governments, and the general public dependent upon schools, law enforcement, and other social services funded by tax revenues – as was the case in Crowley County. Such transfers may also adversely affect the environment and may be viewed as predatory in nature, with wealthy cities and industries taking advantage of a financially stressed farmers and small rural communities with limited resources. As shown in the earlier case studies, the degree to which such characterizations are supportable vary from case to case and are subject to interpretation, but the fact remains that there is widespread interest amongst potential buyers and sellers, policymakers, and other interested parties in moving toward a better model of water management. That better model may be Alternative Transfer Methods (ATMs).

The ATM terminology is used broadly to describe a host of newer types of approaches to facilitate additional water transfers from rural areas, but in a way that minimizes local impacts or, in some cases, even produces local economic and/or environmental benefits (CWCB [9], Table 1 from Colorado Water Plan 2015). ATMs typically differ from buy-and-dry approaches in three ways: transfers are temporary, land is not permanently taken out of production, and the irrigator (at least in part) retains ownership of the water right. Central to this calculus is that some water remains in use for irrigation at all times, while a component of that water is transferred. Minimizing the pain in these arrangements relies on incentivizing cost effective ways for farmers to reduce use, with this "conserved" water being the subject of the transfer.

Conserved water is usually produced in one of three ways. The simplest of these is fallowing, which entails taking a given parcel of land out of production for a given period, typically a year or entire growing season. Often this is done on a rotational basis (e.g., one section of every ten is fallowed each year), while other forms entail taking lands out of production only in drought years or only in that part of the summer irrigation season where water consumption is highest relative to plant productivity (e.g., split-season fallowing). The other two techniques keep all lands in production but save water either by crop switching (i.e., replacing water thirsty crops with those using less water), or some form of deficit irrigation, in which crops are given a reduced amount of water on the premise that yields are likely to decrease in a proportion less than the amount by which water deliveries were reduced.

Table 1
Types of ATMs in Colorado (excerpted directly from Table 6.4-1 Colorado Water Plan, 2015, pg. 6–116).

Rotational fallowing: Rotational fallowing keeps land in irrigated production model while systematically fallowing specific plots. A rotation occurs to systematically fallow each plot in successive crop seasons.

Interruptible supply agreements: This type of ATM is between non-agricultural water users and farmers, shareholders, or a ditch company. Water is temporarily transferred from agricultural use to another use, such as municipal. Farms are fallowed during specific periods of time, and water is leased to the end-user based on the historical consumptive use portion of the water right.

Municipal-agricultural water-use sharing: This concept embodies a complex array of options based on continued farming operations for all lands associated with the sharing arrangement. Methods are used to reduce the consumptive use of crops, which makes water available for municipalities by sharing the historic consumptive use amount. Two main subcategories are continued farming and deficit irrigation, where crop watering is strategically limited to save water for other uses.

Water cooperatives: Although there are a number of ways a water cooperative could work, only one concept has been tested in Colorado. This concept identifies periodic excess water supplies that can be used for optimization in the system. It includes use of surplus augmentation water and other supplies. The framework involves mutually beneficial transactions that work within the existing system of water rights so no injury occurs.

Water banks: A water bank acts as an intermediary or broker based on water supply arrangements with owners of certain water rights. The bank could help avoid or endure a compact curtailment for example. Irrigators would be paid to reduce their consumptive uses, which could trigger fallowing of agricultural lands or deficit irrigation practices on a temporary basis.

Flex Markets: These ATMs are defined as voluntary agreements between municipal and industrial water users, and environmental conservation water users. The idea is to change the use of a senior irrigation right to include multiple end uses in addition to irrigation. These markets establish trading platforms to help provide water used by all participants.

Once conserved, water is then transferred to urban or industrial users who compensate the farmer for expenses associated with equipment, transaction costs, and/or lost revenues. Presumably, this becomes a stable new revenue stream that supports rather than undercuts the rural agricultural economy, while allowing cities and industries to meet new growth pressures without looking to already overtapped rivers. In some cases, ATMs are also seen as a vehicle for augmenting instream flows, addressing drought emergencies, and dealing with potential inter- and intra-state curtailments associated with priority-based river administration.

All these applications are predicated on two frequently-occurring conditions: agricultural water uses that are less sensitive to periodic water shortages than other uses; and situations in which there are higher economic returns possible for water used for municipal and industrial waters than the same amount of water used in agriculture. With proper arrangements, these conditions can be a source of flexibility that can be creatively exploited for mutual benefit. In practice, however, a host of barriers have impeded the widespread application of ATMs in Colorado.

3.2. The use of ATMs in Colorado

While ATMs are in use in Colorado, it is still easier for municipalities to gain new water supplies through permanently fallowing agricultural land [6]. As a result, through pressures of growth both within and without the state, it has been estimated that Colorado could lose between 500,000 and 700,000 acres of currently irrigated farmland [10]. The state has articulated a goal of maintaining agricultural viability while supporting agricultural conservation and efficiency [11]. In addition, agricultural communities are not only experiencing pressure on their water supply from municipal and environmental needs, but are also experiencing demographic changes in their communities that threaten the workforce available for maintaining agricultural in the state. As a result Colorado's Water Plan not only seeks to find creative ways of sharing agricultural water with urban areas, but also seeks to implement programs to enable Coloradans to enter the agriculture industry [11]. The state has set a goal of sharing at least 50,000 acre-feet of agricultural water using voluntary ATMs by 2030 [11].

The Colorado Water Plan (2015) highlights a number of examples of ATMs underway in Colorado, including an arrangement between the Morgan Ditch Company and Xcel Energy, the major utility in the state, to lease water for Xcel Energy's Pawnee power station. In dry years, some of the farmland is fallowed to provide water for Xcel, and the rest is irrigated with sufficient senior water rights. The City of Thornton has also agreed to provide emergency water to another power company, the Platte River Power Authority. A Water Banking Working Group is exploring water banking on a larger scale within the Colorado River Basin. The City of Aurora has partnered with farmers to help purchase more efficient watering systems, farmers have reduced consumptive use, and Aurora has access to some of the conserved water. The City of Aurora has also entered into an interruptible supply agreement with the Rocky Ford Highline Canal group of farmers. These types of interruptible supplies allow for more flexible drought relief and recovery of water supplies following drought. Ducks Unlimited is a non-profit interested in preserving wildlife, and partnered with Aurora Water and Colorado Corn Growers to implement wildlife habitat of interest. In the Lower Arkansas Valley Water Conservancy District, irrigators organized into the Lower Arkansas Valley Super Ditch Company which allows for collective leasing of agricultural water and acts as a negotiating entity. They are engaged in a pilot program to temporarily transfer water from agricultural lands in the Catlin Canal system to municipal communities. The state hopes to learn from this experimental ATM implementation in the Arkansas basin. Castle et al. [6] summarize some of the discussion among different participants with an interest in ATMs in Colorado and find there are still many open questions, but there is strong interest in the state continuing its leadership role in facilitating progress on discussion on ATMs. The state has also provided over $1.5 million to study or pilot ATMs. These mechanisms – providing emergency water, linking delivery of water to a different use depending on the climate conditions, providing financing for upgrading efficiency while allowing use by cities, creating "interruptible" supplies, governing water in a negotiating entity instead of as single owners–all provide new ways of introducing flexibility, and therefore potentially produce adaptive capacity and resilience in an otherwise legally rigid system.

ATMs are not without tensions however. Municipalities value the permanence of water availability in the end [12]. The cost effectiveness of ATMs is also important—rate payers' willingness to support the costs of creative arrangements and new irrigation infrastructure, for example, may be limited. On the agricultural side, some farmers have expressed doubt that ATMs will really become a viable alternative to permanent fallowing of agricultural lands and are skeptical of participating as they fear ATMs may not be able to protect farmers' water rights in the end [37]. ATMs may provide stability in farm revenue but some producers worry that they may miss out on years of high commodity value by participating in some of these programs [6]. The question also remains about whether ATMs are scalable enough to be able to reverse the trend of permanent fallowing of agricultural land. Finally, as tools that work within the framework of prior appropriation water rights, ATMs do little to resolve some of the doctrines fundamental shortcomings, such as environmental protection. Interruptible supplies may be acceptable in some cases for balancing needs of farms and cities but unacceptable for preserving fish and wildlife who depend on river flows every year for survival. Ultimately, whether or not mechanisms such as ATMs confer resilience to climate change over the long term remains to be seen.

3.3. *Challenges associated with ATMs in Colorado*

A variety of barriers impede the development of well-functioning western USA water markets, including those based on ATMs. Some of these barriers are unique to the institutional and physical setting of Colorado, whereas others are more widely applicable. The major barriers to ATMs in Colorado are summarized below [9].

3.3.1. *Changes in consumptive use*

Under Colorado law, when water is sold and transferred to a new user, the amount actually moved is limited to the historical consumptive use and not the diversion amount. This is done to ensure that other rights holders on the stream where water is diverted will experience "no injury"—i.e., no reduction in water availability due to the transaction. Legally quantifying consumptive use occurs as part of a "change case" in water court (or in a State Engineer-approved substitute supply plan), typically supported by studies provided by water resource engineers and past records documenting diversions and irrigation practices (one of the reasons traditional and permanent water transfers can be a lengthy process).

The challenge is two-fold, establishing consumptive use before and after the proposed transfer. In both settings, a simple water balance is usually applied:

$$\text{Amount Diverted} - -\text{Return Flows} = \text{Consumptive Use}$$

For many irrigation rights, the diversion amount is often measured using a weir or other technology; however, the other two values can only be estimated. Often this entails the application of models and tables calibrated with data such as acreage, soil conditions, crop types, local climate conditions, and so on, all tailored to showing how changes to the irrigation regime affect evapotranspiration (ET). Getting agreement on these values can be very difficult.

Lurking beneath this technical challenge is a legal conundrum, often referred to the "use it or lose it" doctrine. The doctrine is based on the premise that the size of a water right is determined by actual past usage, and if a rights holder for some reason decreases their amount of consumption, then the size of a water right can be reduced accordingly. The farming practices employed to conserve water for the ATM, by design, reduce consumptive use, which means that participation in an ATM may make the irrigator vulnerable to a water right reduction, thereby negating any incentive to participate (*see* [39]). Such risks are common in the western states where only a few states (e.g., California, Montana, Washington and Oregon) provide any means for a water right owner to retain some ownership of conserved water [14]. In Colorado, the assumption is that conserved waters are to be returned to the stream and made "subject to call by prior appropriators" (*See* Colorado Water Conservancy District v. Shelton Farms, Inc. 529 P.2d 1321, 1325 (Colo. 1974)). The Colorado legislature has taken steps to alleviate these concerns and provide needed certainty to both buyers and sellers in ATMs, but doubts linger about how these issues might actually play out in the legal system. Given some negative experiences with previous buy-and-dry arrangements, such as Crowley County, public perception of ATMs is an important consideration.

3.3.2. *Infrastructure considerations*

The range of possible water transactions is dependent on the infrastructure available to physically move water from one place to another. In some situations, this is not a serious impediment: for example, transferring an upstream water right to a downstream user can be as simple as letting the water flow downhill in the natural streamcourse. However, if the seller is downstream of the purchaser, then the water either needs to be physically transferred upstream, or it has to be "exchanged" upstream with another water source. In some settings, such as Colorado's South Platte Basin, very little exchange potential remains, which suggests that new infrastructure—namely storage and pipelines—may be necessary to execute ATMs that otherwise are financially and legally viable [8].

Part of the appeal, as well as the physical mechanism, of ATMs is that they presumably would draw small percentages of water out of an agricultural region's water portfolio, leaving sufficient water in place to maintain crop production. Pulling 5% of water from all agricultural regions rather than 100% of water from 5% of those regions has dramatically better socioeconomic implications for rural areas. But doing so requires highly distributed infrastructure. Lacking such, disastrous buy-and-dry situations emerge, again as was the case with Crowley County, which was facilitated, in part, by the presence of existing storage and delivery infrastructure [13].

3.3.3. The costs of doing business

Much of the promise of water markets hinges on the observation that the economic value of water used in municipal and industrial (M&I) is often dramatically greater than its value in agriculture [2]. M&I users often have the financial resources to make such transactions beneficial to participating farmers; however, cities do not wish to overpay and farmers do not wish to undersell. Lacking information about what constitutes an appropriate price can deter participation in the market, especially for farmers who feel at a strategic disadvantage to cities with the expertise and resources to research the market. With a few exceptions (most notably, for water from the Colorado-Big Thompson Project, discussed earlier), relevant transaction prices are rarely available for comparison.

While determining appropriate pricing is a challenge to all water transfers, including traditional buy-and-dry transactions, ATMs raise two special complications. First, given the "partial" farming operations associated with ATMs, and the frequent market-driven changes in crop and livestock profitability, estimating the economic merits of leasing arrangements can be particularly challenging for farmers. In recent years, several tools have been developed to aid in these calculations [7,5,30,39]. Presumably, more experimentation with ATMs, along with efforts to better compile and publicly disseminate information about market activity, will help establish appropriate pricing structures and could overcome some reluctance to participation.

The other cost-related challenge is more fundamental and challenging, and it speaks directly to some of the issues noted below. A significant financial impediment to all water transfers is the transaction costs—namely, the legal and engineering fees associated with pursuing the change case in water court. Given that ATMs can modify diversion amounts, consumptive use levels, and return flow volumes in ways that are much more difficult to estimate than in a simple buy-and-dry arrangement, the transactions costs of ATMs are generally assumed to be "equivalent or higher as a permanent buy-and-dry" (CWCB [9]:9, citing research from CCGA et al. [7]). For cities that might already be reluctant to pursue temporary rather than permanent exchanges, the specter of added transactions costs is a significant additional barrier.

3.4. ATM experiences in the Lower Arkansas Valley

A recent analysis of the dynamics of drought decisions across different sectors along the Arkansas River demonstrates that Crowley County has become an example of "creeping resilience" in the region [24], a term that points to the fact that communities that have become highly vulnerable to stressors can become an example over time of decisions that might be avoided in the future. It is a slow resilience for some outside the system built upon the unintended consequences the arise from the vulnerability of others–namely buy-and-dry. ATMs are an important example of alternative or adaptive measures, however experimental they might be.

Given the amount of water being bought by municipalities throughout the 1980s and 1990s, efforts to end buy-and-dry practices increased. The Lower Arkansas Valley Water Conservation District, formed in 2002 through a ballot initiative, began a program to keep water in the valley through conservation easements. In 2005, others began to explore experimental leases, including rotational fallowing programs, creating agreements between municipalities to lease water from farmers who fallow fields for three of ten years at a specified amount of money per share. In Otero County, an area adjacent to Crowley, one pilot program, the Super Ditch, includes a collective of seven canal companies that hope to demonstrate how such alternatives might work on a larger scale [13]. Still, an important consideration in the success of ATMs is the perceptions of success and value by those in the agricultural community.

Attitudes about ATMs along the Arkansas River are mixed. Henderson et al. [24] find that some agricultural producers express enthusiasm about the possibility that ATMs affords, both as a continuation of a way of life valued by agricultural producers and as a benefit to their individual businesses during times of drought. These people see ATMs as a positive option for both the farmer, who gets financial reimbursement, and the municipality, who gets supplemental water, during times of drought. Some have gone so far as to suggest that the Super Ditch has been popular among producers and has garnered widespread interest across the state. In part, this willingness centers on how experiments shift practices from buying to leasing, which means producers can share water instead of selling it, thus keeping it in agriculture. It is an effort that further emphasizes the agricultural producers' desires to keep control of the water right – and keep water on farms – while still being able to work with water utilities to fulfill their obligation to communities. Municipalities, on the other hand, are less enthusiastic about leases because of potential costs for transfers and risk tolerance related to securing permanent water versus short term supplies [16]. Still, there is potential for ATMs to benefit both sectors. As one local Arkansas Basin farmer noted of ATM's potential as an alternative to buy-and-dry, "If we can make [these experiments] work, it will be a win-win situation for everyone involved. The farmers will have something they can lease every year and cities get guaranteed water supplies" [32].

But agricultural producers' optimism is not simply about controlling individual rights to water. It also potentially indicates an attitudinal shift in the broader producer community, a desire to sustain agriculture as part of the future of Colorado. Henderson et al. note that there is a shift to a responsible community attitude, which is as much about the heritage of agriculture as it is about the importance of considering impacts of water sales on one's neighbors who depend on collaborative solutions in an interconnected system. ATMs may have also shifted values from those that emphasize self-interest and self-reliance of individuals to a collective community of agriculture that requires compromise and self-sacrifice. This finding substantiates other literatures that suggest Crowley County proved a tragic but useful lesson for all along the Arkansas about how bad it can get [3,40,42]. Attitudinal shifts may also permit flexibility in approaching how water arrangements might be made in the future as climates change, as well. Thus, ATMs potentially encourage a more holistic thinking about the kinds of consequences and interconnections that exist in water transfers.

For those who are skeptical of ATMs, the reasons span a scale of micro to macro. One problem with the lease-fallowing programs, for example, is the effect on the land, especially the soil and its ability to recover. The ground may not recover after lying fallow for a year or more, with changes to the microbial health and other organic matter. Another potential concern is the loss of clients for some farmers should they sacrifice one crop as part of their lease agreements. And still others worry about farm laborers finding new places to work and not returning to those areas where ATMs could disrupt their seasonal jobs [24]. In these instances, then, an experiment that might generate compromises in water use is not worth risks to an individual farmer's productivity and finances. In this way, decisions about water use in the West may be seen as proxies for competing societal goals around continued growth, changing cultural values, and the survival of particular ways of life and livelihoods.

4. Conclusion

Despite all the promise of ATMs, the fact remains that their application in Colorado has been slow and isolated. ATMs bring out deep divisions among various water constituencies, with some parties arguing that streamlined transfers and a broader adoption of ATMs is key to avoiding buy-and-dry and protecting rural economies, while others argue that ATM reforms only make it easier to accelerate the dry-up of agricultural lands. In part, this is a question of differing philosophies, but in part it is also a question of trust, particularly among some residents of rural Colorado. Some irrigators are fearful that ATM reforms will be unduly shaped by urban and environmental interests, and by senior water rights holders who feel that efforts to build flexibility and administrative ease into transfers do so by removing the substantive and procedural protections currently afforded to them in water court. Some also fear that a focus on ATMs may do nothing to quell the trend of transfer activity being concentrated in areas that have the "misfortune" of being in regions that—due to geography, economics, and the presence of infrastructure—are most desirable for Front Range urban customers.

Given this reality, it is critical to acknowledge an important overarching impediment that is not often captured in the literature—namely the political reality that ATMs are rarely anyone's preferred option: their "Plan A." While those in the agricultural community generally view ATMs as preferable to buy-and-dry, it is still less desirable than having no ag-to-urban water transfers at all. Cities are generally eager to avoid the bad publicity of buy-and-dry, but the fact remains that ATMs are often not seen as offering the same level of reliability and predictability as outright purchases, and can entail proportionally larger transactions costs. Environmentalists and public interest advocates are often more focused on managing urban demands—for both environmental and financial reasons—than promoting ATMs that expand urban consumption (and sprawl) and create a need for new infrastructure. Political leaders are also torn—attempting to facilitate ATMs on one hand, while also working to maintain existing protections for other rights holders and establishing new protections to those third-parties historically impacted by transfers. Given this, it is not unusual for the legislature to simultaneously consider competing bills that both streamline and further regulate water transfers.

The future of ATMs in Colorado is uncertain. While there is clearly a willingness to experiment with these mechanisms, and the state of Colorado is showing strong leadership in setting a goal for 50,000 acre-feet to be shared through ATMs by 2030, some remain skeptical and the ability to scale widely is uncertain. It may be difficult to protect the value of preserving agricultural and rural landscapes in Colorado in the face of economic pressures to sell water to growing cities. Experimentation with ATMs is being watched closely, while traditional water transfers also continue apace. The Colorado State Water Plan and the willingness of some agriculturalists and municipalities to engage the experiment suggests a broad desire to preserve the state's agricultural heritage. There is no doubt that some are going to great lengths to demonstrate that the water transfer mechanism can be made to work to support social and cultural values. This period of experimentation is providing valuable information on options for adapting to climate change in the future in Colorado. Still, at this point, the answer of how widespread a role ATMs may play in Colorado's water landscape, or indeed, nationally or internationally is incomplete.

As Garrick et al. [17] note, there is much to learn about the trade-offs, path dependencies and institutional tradeoffs of water markets in the future. Water markets are only one possible mechanism to confer resilience on systems managing water scarcity under a changing climate. The experience of Colorado suggests that the political, social, and historical context matter for designing effective water markets, and that we should not necessarily expect to find a "one size fits all" design that can be applied in the same way everywhere. Furthermore, we should not see these mechanisms as remaining static over time but as learning opportunities that we revisit, revise, and update as experience with their impacts and effectiveness is gained.

Acknowledgements

This research has been supported by a NOAA CIRES Visiting Postdoctoral Fellowship for JH and the Western Water Assessment (a NOAA-funded Regional Integrated Sciences and Assessment (RISA), Grant Number NA10OAR4310214). We thank two anonymous reviewers for their helpful comments. The authors are responsible for all content.

References

[1] W.N. Adger, Changing social contracts in climate-change adaptation, Nat. Clim. Change 3 (4) (2013) 330–333, https://doi.org/10.1038/nclimate1751.
[2] B. Annes, The Value of Water in the Colorado River Basin: A Snapshot of a Fluid Landscape, Colorado River Governance Initiative, Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, Boulder, CO, 2015.
[3] A. Best, Flex Time for Colorado Water, Headwaters Magazine, Colorado Water Education, 2017.
[4] J. Brewer, R. Glennon, A. Ker, G. Libecap, 2006 presidential address water markets in the west: prices, trading, and contractual forms, Econ. Inq. 46 (2) (2008) 91–112, https://doi.org/10.1111/j.1465-7295.2007.00072.x.
[5] P. Cabot, J. Valliant, J. Tranel, M. Bartolo. 2012 Fall Annual Report to Colorado Water Conservation Board, Alternative Agricultural Water Transfer Methods, 2012.
[6] A. Castle, M.L. Smith, J. Stulp, B. Udall, R. Waskom, Where now with Alternative Transfer Methods—ATMs—in Colorado? A report of the Colorado Water Institute as Colorado State University, 2017. http://www.cwi.colostate.edu/media/publications/SR/31.pdf (last accessed October 17, 2018).
[7] CCGA (Colorado Corn Growers Association), Ducks Unlimited, Aurora Water, and Lower South Platte Water Cooperative, Completion Report: Development of Practical Alternative Agricultural Water Transfer Measures for Preservation of Colorado Irrigated Agriculture, Prepared by Brown and Caldwell, Colorado Water Resources Research Institute, Harvey Economics, and Lawrence Jones Custer Grasmick LLP, 2011.
[8] CWCB (Colorado Water Conservation Board), Colorado's Water Supply Future – Alternative Agricultural Water Transfer Methods Grant Program Summary, Final Report Prepared by CDM Smith, 2011.
[9] CWCB (Colorado Water Conservation Board), Alternative Agricultural Water Transfer Methods Grant Program Summary and Status Update, Technical Memorandum. November Prepared by CDM, 2012.
[10] CWCB (Colorado Water Conservation Board). Colorado's Water Plan, 2015. https://www.colorado.gov/pacific/cowaterplan/plan (last accessed October 17, 2018).
[11] CWCB (Colorado Water Conservation Board). Ripple Effects: Colorado's Water Plan in Action, 2017. https://www.colorado.gov/cowaterplan (last accessed October 17, 2018).
[12] A. Davis, One Opinion about ATMs, Colorado Water Jan/Feb 2018, 2018 (last accessed October 17, 2018).
[13] B. Devine, Moving Waters: The Legacy of Buy-and-Dry and the Challenge of Lease-Fallowing in Colorado's Arkansas River Basin, Dissertation University of Colorado, Boulder, 2015.
[14] D. Duval, B. Colby. Overview: Western States Conserved & Salvaged Water Programs, 2013. Available from: https://www.colorado.gov/pacific/sites/default/files/13WaterResources1030WesternStatesConservedandSalvagedWaterPrograms.pdf.
[15] N.L. Engle, Adaptive capacity and its assessment, Global Environ. Change 21 (2) (2011) 647–656, https://doi.org/10.1016/j.gloenvcha.2011.01.019.
[16] Environmental Defense Fund. Alternative Water Transfers in Colorado A Review of Alternative Transfer Mechanisms for Front Range Municipalities, 2016. https://www.edf.org/sites/default/files/alternative-water-transfers-colorado.pdf (last accessed February 12, 2019).
[17] D. Garrick, S.M. Whitten, A. Coggan, Understanding the evolution and performance of water markets and allocation policy: a transaction costs analysis framework, Ecol. Econ. 88 (2013) 195–205, https://doi.org/10.1016/j.ecolecon.2012.12.010.
[18] M. Goodland, Buying and Drying: Water Lessons from Crowley County, The Colorado Independent, 2015 (last accessed February 12, 2019).
[19] R.Q. Grafton, D. Hatton MacDonald, D. Paton, G. Harris, H. Bjornlund, J.D. Connor, J. Quiggin, J. Williams, L. Crase, R. Kingsford, S. Wheeler, The Murray Darling Basin Plan is not delivering - there's no more time to waste, The Conversation, 5 February 1-5, 2018 (last accessed February 12, 2019), https://ro.uow.edu.au/smartpapers/219/.

[20] R.Q. Grafton, J. Horne, S.A. Wheeler, On the marketisation of water: evidence from the Murray-Darling Basin,Australia, Water Resour. Manage. 30 (3) (2016) 913–926, https://doi.org/10.1007/s11269-015-1199-0.
[21] R.Q. Grafton, G. Libecap, S. McGlennon, C. Landry, B. O'Brien, An integrated assessment of water markets: a cross-country comparison, Rev. Environ. Econ. Policy 5 (2) (2011) 219–239, https://doi.org/10.1093/reep/rer002.
[22] R.Q. Grafton, J. Pittock, R. Davis, J. Williams, G. Fu, M. Warburton, J. Quiggin, Global insights into water resources, climate change and governance, Nat. Clim. Change 3 (4) (2013) 315–321, https://doi.org/10.1038/nclimate1746.
[23] Greeley Tribune. Cost of water share nearly doubles in Northern Colorado, 2013. July 7, 2013. https://www.denverpost.com/2013/07/07/cost-of-water-share-nearly-doubles-in-northern-colorado/ (last accessed February 12, 2019).
[24] J. Henderson, L. Dilling, R. Morss, O. Wilhelmi, In preparation. Creeping Resilience: Unintended Consequences that Arise from Drought Decisions Along the Arkansas River in Colorado. To be submitted to Weather, Climate and Society.
[25] C. Howe, Innovative approaches to water allocation: the potential for water markets, Water Resour. Res. 22 (4) (1986) 439–445.
[26] C. Howe, Protecting public values in a water market setting: Improving water markets to increase economic efficiency and equity, U. Den. Water. L. 3 (2000) 357–372.
[27] C. Howe, Water pricing: an overview, J. Contemp. Water Res. Educ. 92 (1) (2011).
[28] C. Howe, C. Goemans, Water transfers and their impacts: lessons from three Colorado water markets, J. Am. Water Resour. Assoc. (2003) 1055–1065.
[29] H. Ingram, C. Oggins, The public trust doctrine and community values in water, Nat. Resour. J. 32 (1992) 515–537.
[30] Colorado Water Institute, 2012. Annual Technical Report, 2012. Available online at: https://water.usgs.gov/wrri/AnnualReports/2012/FY2012_CO_Annual_Report.pdf (last accessed March 22, 2019).
[31] J. Lukas, J. Barsugli, N. Doesken, I. Rangwala, K. Wolter, Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A Report for the Colorado Water Conservation Board, Western Water Assessment, 2014 (last accessed October 17, 2018).
[32] L. Ozzello, Just One Chance, Headwaters Magazine, Water Education Colorado, 2007.
[33] J. Robbins, Water Sales Drain Life From Rural Colorado County, Chicago Tribune, 1992.
[34] R. Sanchez, High + Dry. 5280: Denver's Mile High Magazine, 2014. Available from: https://www.5280.com/?s=high+%2B+dry.
[35] E. Schlager, T. Heikkila, Left high and dry? Climate change, common-pool resource theory, and the adaptability of western water compacts, Public Admin. Rev. 71 (2011) 461–470, https://doi.org/10.1111/j.1540-6210.2011.02367.x.
[36] S. Shupe, G.D. Weatherford, E. Checchio, Western water rights: the era of reallocation, Nat. Resour. J. 29 (1989) 413–434.
[37] J. Smith, Voices from the field: Gene Manuello, Headwaters Magazine, Colorado Water Education. Fall 2017, 2017 (last accessed October 17, 2018).
[38] L.E. Spence, "Water leasing for instream flow," in: Second Annual Conference on Montana Water Law, Helena1995. https://archive.org/stream/upperclarkforkwavol1vol3upperich/upperclarkforkwavol1vol3upperich_djvu.txt (last accessed February 19, 2019).
[39] M. Squillace, A. McLeod, Marketing conserved water. 46, Environ. Law J. 1 (2016).
[40] M. Verlee, Thirsty Cities, Dry Farms: Part 1 and Part 2, Buy and Dry, Colorado Public News Story, 2011 (last accessed February 12, 2019).
[41] WestWater Research, Water Market Insider, 2016. http://www.waterexchange.com/wp-content/uploads/2017/01/WMI_2016Q2_011117.pdf (last accessed October 7, 2018).
[42] C. Woodka, Crowley County: A painful lesson in water sales, The Pueblo Chieftain, 2009 (last accessed February 12, 2019), http://www.chieftain.com/news/local/crowley-county-a-painful-lesson-in-water-sales/article_1a3634ca-ed12-58d8-8d9e-b175e0d93c88.html.