Colorado State University

Colorado Water

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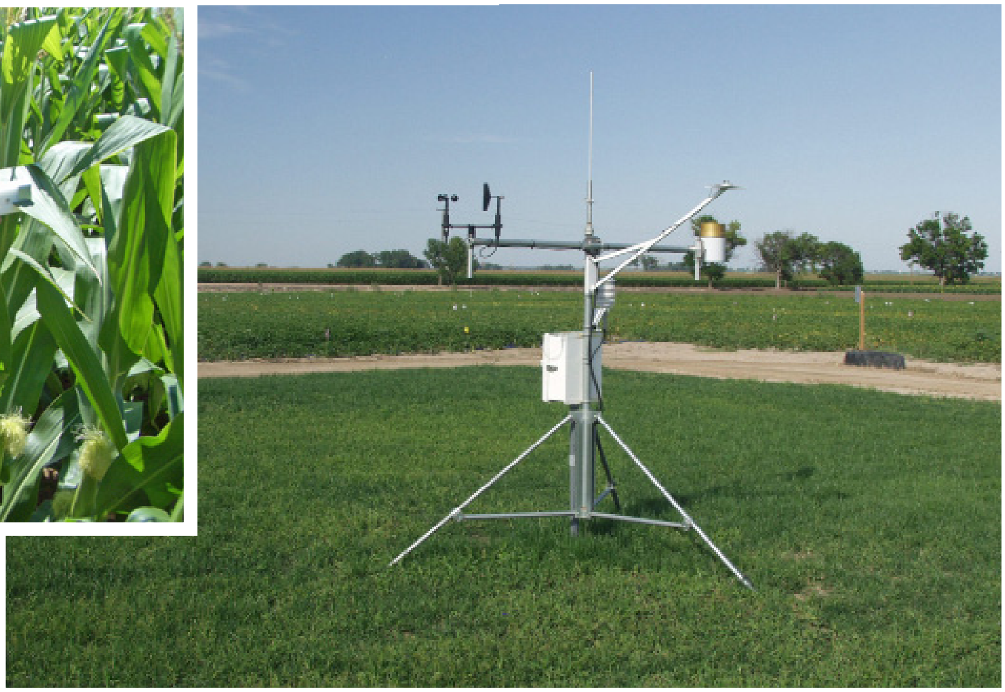
Theme

Alternatives to Ag Transfers



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Highlights

In Every Issue

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Editorial

by Reagan Waskom, Director, Colorado Water Institute

One positive result of the recent water planning efforts in Colorado is that we seem to be getting clearer about how the state will meet future water needs. For most water planners, it is a forgone conclusion that future urban growth will inevitably require more water, and given that we have appropriated the available supplies on the east side of the divide, only three realistic options exist: conservation, ag-to-urban transfers, and additional West Slope transfers. Of the three, only water conservation seems to have widespread acceptance.

Western Colorado residents generally seem to reject the idea that river flows in their basins should be further diminished so that future Front Range residents can enjoy green landscapes. The agricultural community suffers from an equally troubling dilemma: on the one hand, individual farmers want the economic benefits of a free market for water; on the other, we see the decline of agriculture and rural communities as water is transferred to urban markets. At the December 2009 Ag Water Summit hosted by the Colorado Ag Water Alliance, Pat O'Toole, president of the Family Farm Alliance, stated in regard to the loss of agricultural water, "Perhaps we've already gone too far. Perhaps, we've already impaired the security of our future food supply. We need alternative solutions that keep water in agriculture."

Since the close of the Reclamation Era, the vast majority of western water resources have been dedicated to agriculture, which is still the case today. Across the West this trend has begun to reverse as water is slowly moved out of agriculture to cities, industry, and environmental needs. The simple fact is that it takes a lot of water to grow food in arid environments. So, as we come to grips with the transfer to higher economic uses of water, thoughtful people are beginning to wonder if there should be a limitation on how much water we allow to be transferred from agriculture, and if so, how can that be affected in reality? Do we really need to keep irrigated agriculture as a significant component of Colorado's economy and rural fabric? These questions have broad application as water transfer from agricultural to urban and environmental uses is becoming increasingly common worldwide.

In response to these concerns, the Colorado Water Conservation Board (CWCB) recently developed the Alternative Agricultural Water Transfer Methods Grant Program to help determine if there are workable approaches to sharing agricultural water without permanent dry-up of irrigated lands. The Grant Program is currently focused on the Arkansas and South Platte Basins, as these basins are seeing the largest growth and most significant changes in agricultural water use.

This issue of *Colorado Water* focuses on current research and demonstration activity in alternatives to permanent agricultural dry-up. The good news is that there is an array of research on this topic. Reports include an update on the Lower Arkansas Water Conservancy District's Super Ditch, a plan that pools agricultural rights for leases by fallowing a portion of farm ground. A study at CSU's Arkansas Valley Research Center at Rocky Ford looks at what it takes to bring land back into production after it has been fallowed. Similar efforts are going on in the South Platte Basin, where the Colorado Corn Growers Association is working with Aurora and Ducks Unlimited to look at how farmers can use recharge credits for wetlands. The Farmers Reservoir and Irrigation Company (FRICO) is looking into a shared water bank concept—a study that takes the concept of sharing in a new direction, as FRICO determines whether it is feasible for cities to store water in the ditch system's reservoirs. The city of Parker and CSU have a joint program to determine if farmers can reduce the use of water on crops and lease the difference to cities. New cropping systems may allow producers to use less water while still remaining profitable, thereby facilitating permanent or temporary transfers to cities.

These projects all attempt to find alternatives that might reduce the impact of agricultural dry-up as population continues to grow. If successful, they may help reduce the loss of irrigated lands, but they do not reduce the increased demand our urbanizing society places on our water resources or alter the impacts of global change that may decrease useable supply. The confluence of water stress, food, energy, and climate portends to be the grand challenge of the mid-21st century. Our current challenge is to determine if there are ways to sustain agriculture and rural communities as water is moved, perhaps so that we are collectively better off as a result of the way these transfers are constructed.

CWCB's Alternative Agricultural Water Transfer Methods (ATM) Grant Program

by Todd Doherty, Program Manager, Colorado Water Conservation Board

According to a recent Colorado Water Conservation Board (CWCB) draft report, Colorado's population is projected to nearly double from 4.8 million to more than 10 million people by 2050. The majority of these new people will reside on the Front Range. The South Platte Basin alone is forecasted to grow from 3.3 million to 5.8–6.8 million people. As a result, by 2050 Colorado will need between 830,000 and 1.7 million acre-feet of additional water for municipal and industrial (M&I) needs. Most of this demand will be met through three main water supply strategies: conservation, agricultural transfers, and new water supply development.

Water providers have identified specific projects they plan to implement to meet future water demands. If 100% successful, these projects could yield approximately 511,000 acre-feet of water, but there could still be a water supply gap. Over the past several years, many of these water projects have been proceeding through the federal permitting process with no guarantee of their success. If these projects and others are not built, future water demand will have to be met mostly through a combination of agricultural transfers and conservation.

Traditional agricultural water transfers have been and will continue to be an important part of water providers' plans for meeting future water demands, and some farmers and ranchers are willing to sell their water rights. From this stems a concern that some water transfers may have negative third-party effects, such as impacts to the agricultural sector and rural economies. Economic and demographic factors also contribute to the reduction of farming and ranching in Colorado. To better understand and to help address this trend, the CWCB investigated alternatives to traditional purchase and transfer of water from irrigated lands to new uses in the *Statewide Water Supply Initiative—Phase 2 report* (November 2007). This report examined trends in irrigated acreage, dynamics leading to agricultural transfers, economic and social considerations, and alternative methods to permanent transfers of water rights for M&I purposes. Alternative methods identified and discussed in the report include:

- Interruptible supply agreements
- Rotational fallowing (long- and short-term)
- Water banks
- Reduced crop consumptive use
- Purchase and lease-back

While some of these alternative methods are already being used (e.g., Palo Verde Irrigation District and the Metropolitan Water District (MWD) of Southern California, Imperial Irrigation District and MWD, and the City of Aurora and the Rocky Ford High Line Canal Company), traditional water transfers predominate the market in Colorado. But, as municipal water demands continue to increase, irrigators will continue to see an increased interest in their water rights from cities. Irrigators may begin to view their water rights as another "crop," and cities may begin to view the cornfields as "reservoirs." Coloradoans are also increasingly interested in protecting instream flows for fish, wildlife, and aesthetics.

Most cities will probably not be interested in selling taps for homes that rely on a 20-, 30-, or 40-year water lease agreement that could potentially not be renewed. More likely, the leases will serve for drought mitigation, drought recovery, an emergency supply, and long-term conjunctive use. Historically, cities have often relied on restrictions on residential landscaping to provide for an emergency supply of water. Essentially, as the demand for a limited amount of water increases, all water users will need to optimize the use of a limited resource. This effort is only a part of the bigger picture, where one day in the future every drop of water will be accounted for through various metering and monitoring technologies. Possibly most important, revenues generated through the various agreements between irrigators and cities can provide much-needed capital to invest back into the farm or irrigation systems. Some of the key benefits derived from alternative methods include:

- Improving relationships between irrigators and municipalities—water sharing
- Capital to upgrade farm or irrigation system equipment or infrastructure
- Optimizing the use of a scarce resource
- Sustaining rural agricultural communities and economies
- Preserving productive agriculture open spaces
- Greater food security
- Sustaining the natural environment and wildlife habitat

One of the outcomes of this report was the recognition that the state of Colorado may be able to provide incentives

The Prairie Waters Project pipeline will deliver 3.3 billion gallons of water annually to the city of Aurora. (Courtesy of Aurora Water)

for M&I providers to consider alternative methods for their water supply options. The legislature authorized the CWCB to develop a grant program to facilitate the development and implementation of alternative agricultural water transfer methods (Senate Bill 07-122). Since its inception in 2007, the CWCB has awarded $1.5 million to various water providers, ditch companies, and university groups for the funding of six unique projects. The grant recipients are identified below, along with a brief description of each entity's approach to identifying viable alternative agricultural water transfer methods.

Parker Water & Sanitation District (PWSD)/Colorado State University (CSU) The Lower South Platte Irrigation Research and Demonstration Project is a four-year study to quantify potential consumptive water use savings resulting from the use of deficit irrigation practices. By reducing the consumptive use of irrigated crops, an incremental volume difference between historic and future consumptive use can be computed. With approval of the State Engineer's Office, it is believed that this volume of water could be transferred to municipal use. In addition to field-scale research, the test program will be implemented on three demonstration farms to ensure that working farmers understand the proposed practices and that the practices are operationally and economically practical. The project is expected to be completed at the end of 2010.

Colorado Corn Growers Association (CCGA) Working with Ducks Unlimited and the City of Aurora, the Colorado Corn Growers Association will investigate a variety of alternative agricultural water transfer methods. Five transfer methods will be selected for application to three constructed wetlands projects. These wetlands provide a number of benefits, including recharge to the South Platte alluvial aquifer, which can be used in an augmentation plan for out-of-priority groundwater pumping. The study will also produce a Business Plan, which will be made available to other water users to help facilitate practical utilization of alternative transfer methods. Included in this project is an analysis of exchange potential on key points along the lower South Platte River. The project is expected to be completed in March 2010.

Lower Arkansas Valley Water Conservancy District (LAVWCD) The grant funding provides for continued economic and engineering analyses of the Super Ditch Company, which would provide a means for irrigators to collectively lease agricultural water for other uses, including municipal use. Rotational fallowing is likely to be the primary means of alternative transfer. One of the project's goals is to understand whether there is a "tipping" point or "breaking" point, where so much water is transferred from a rural economy that it is not sustainable. Included is an economic analysis examining the 'tipping point' of rural economies due to a reduction in irrigated agricultural lands. The project is expected to be completed in March 2010.

Farmers Reservoir & Irrigation Company (FRICO) FRICO is investigating a number of alternative agricultural water transfer methods, including rotational fallowing, interruptible supply agreements, lease back agreements, and changes in cropping patterns. Much like the PWSD/CSU study, the objective of these methods is to reduce consumptive use for purposes of transferring the "saved" consumptive use to municipal or industrial users. The project also includes the evaluation of a water bank concept that would utilize existing FRICO infrastructure to store this "saved" water and then convey it to other agricultural or municipal users when needed. The project is expected to be completed early 2010.

Colorado State University Extension CSU Extension is conducting a four-year study to assess various technical aspects of returning fallowed land to production and maintaining or improving crop yields on those lands. The study will investigate weed and erosion control measures during fallow years and monitor soil nutrients and salinity once production resumes. The project is expected to be completed in June 2012.

High Line Canal Company The High Line Canal Company is conducting a project to explore implementation of various means of alternative water transfer, including interruptible water supply agreements, long-term land fallowing, spot market leases (for use during drought), and water banking. Water developed under these methods will be provided to other users via existing irrigation infrastructure or via a proposed pipeline. The project includes engineering studies to determine the amount of water that could be transferred and the location, timing, and volume of historical irrigation return flows that would need to be maintained to prevent injury to downstream water users. The project is expected to be completed at the end of 2012.

As these projects move forward, some common elements are beginning to surface. For example, both the PWSD/CSU study and the FRICO study seek to identify means to modify irrigation practices such that "saved" consumptive use water could be transferred from agricultural to municipal use. Synergies exist in the Arkansas Valley as well, with collaborative studies involving the Super Ditch Company, CSU Extension, and the High Line Canal Company. Moreover, most of the projects involve some level of analysis to assess the economic viability of selected alternative transfer methods. Through evaluations of production costs and estimation of acceptable prices to be paid for leased and/or transferred water, these analyses aim to assure farmers that the profitability of their operations can be maintained.

While these projects show promise, there are still uncertainties related to this new area of water resources management. If a portion of an irrigator's historic consumptive use of water is transferred from the farm and leased/sold to a city—how will the Division Engineer verify the actual use of water? Parker/CSU are examining the feasibility of using satellite monitoring for this purpose, but this technology is not perfect nor tested in a real-life situation. Water quality considerations will be challenging and not without significant costs. Will the cities be willing to pipe low-quality water long distances and pay high costs for advanced waste water treatment? Return flows must be maintained in timing and amount, a requirement that could be challenging in many situations. Are there institutional barriers that still need to be sorted out? As opposed to California's lease agreement, where there was one irrigation district and one water provider (PVID and MWD), Colorado has many smaller irrigation and ditch companies with various by-laws.

Realizing that the ATM Program could be a partial solution for Colorado's water supply future, the legislature approved an additional $1.5 million to further this area of water resources management (Senate Bill 09-125). The CWCB is currently involved in developing criteria and guidelines that will direct which grant applications receive funding. It is expected that the new grant program will favor projects geared towards breaking down the barriers listed above (e.g., water administration, return flows, water quality, etc.). One important note is that the legislation allows projects from any basin of the state to be considered, while the original grant program was limited to the Arkansas and South Platte Basins. The criteria and guidelines should be finalized in the beginning of 2010, with grant applications considered by the CWCB sometime in late 2010.

The Lower Arkansas Valley Super Ditch Company, Inc.

by Peter D. Nichols, Esq., General Counsel, Trout, Raley, Montano, Witwer & Freeman, P.C.

Acquiring irrigation water is the easiest and most efficient and economical way for growing Front Range municipalities to obtain additional supplies. This is because Colorado's major rivers are over-appropriated, agricultural conversions pose no new environmental impacts, and municipal values exceed agricultural values. This is evident from the loss of 24% of the irrigated land in the Lower Arkansas Valley since the 1950s. The water from this land now irrigates lawns in Aurora, Colorado Springs, Pueblo, and Pueblo West. The former agricultural land, in contrast, is largely abandoned—an unproductive, weed-infested fire hazard. Communities from Sugar City to Rocky Ford to Manzanola harbor empty storefronts along main streets, further illustrating the devastation caused by the loss of $33.5 million in annual economic activity.

The Colorado Water Conservation Board and Interbasin Compact Commission estimate that an additional 28% of the Lower Valley's irrigated land will be dried up by 2050 if municipal growth follows historical trends, leaving less than half of the historically irrigated acreage in production. The Lower Valley can ill afford to lose any more of its economic base.

Lower Arkansas Valley Water Conservancy District

In 2002, residents of the Lower Valley voted two to one to create the Lower District to protect the Valley's water resources, and with them, their social and economic future. While the Lower District has aggressively fought additional ag to municipal transfers, it has just as steadfastly worked to develop an alternative that will meet inexorable municipal demands while protecting and enhancing the value of remaining irrigation water.

Fallowing-Leasing

Rotational land fallowing and water leasing, pioneered during California's 1990s drought, emerged as the most promising answer for several reasons. First, fallowing-leasing would not require current irrigators to sell their water to realize its current value, preserving the long-term ownership of the water in the Valley. Second, most irrigated land would remain in production every year. Third, water leasing would create a "new crop," one with predictable cash flow that irrigators could use for on-farm improvements, debt reduction, equipment upgrades, and the like. Fourth, cities could obtain the water supplies they need. In essence, an irrigated field (like a residential lawn) is a reservoir that can be tapped when needed for more valuable municipal uses.

High Line-Aurora Lease

Shareholders of the High Line Ditch participated in a fallowing-leasing program with Aurora and Colorado Springs in 2004 and 2005 that allowed the cities to refill their reservoirs after the unprecedented 2002 drought. Farmers liked the deal because they made money on the lease, the diversification reduced their risk of farming by generating cash flow independent of crop values, and they received a reasonable rate of return on their water asset. Moreover, many people would not be farming today without that lease because they were able to use the cash to strengthen their finances. Tellingly, other Valley irrigators were envious of the Aurora lease.

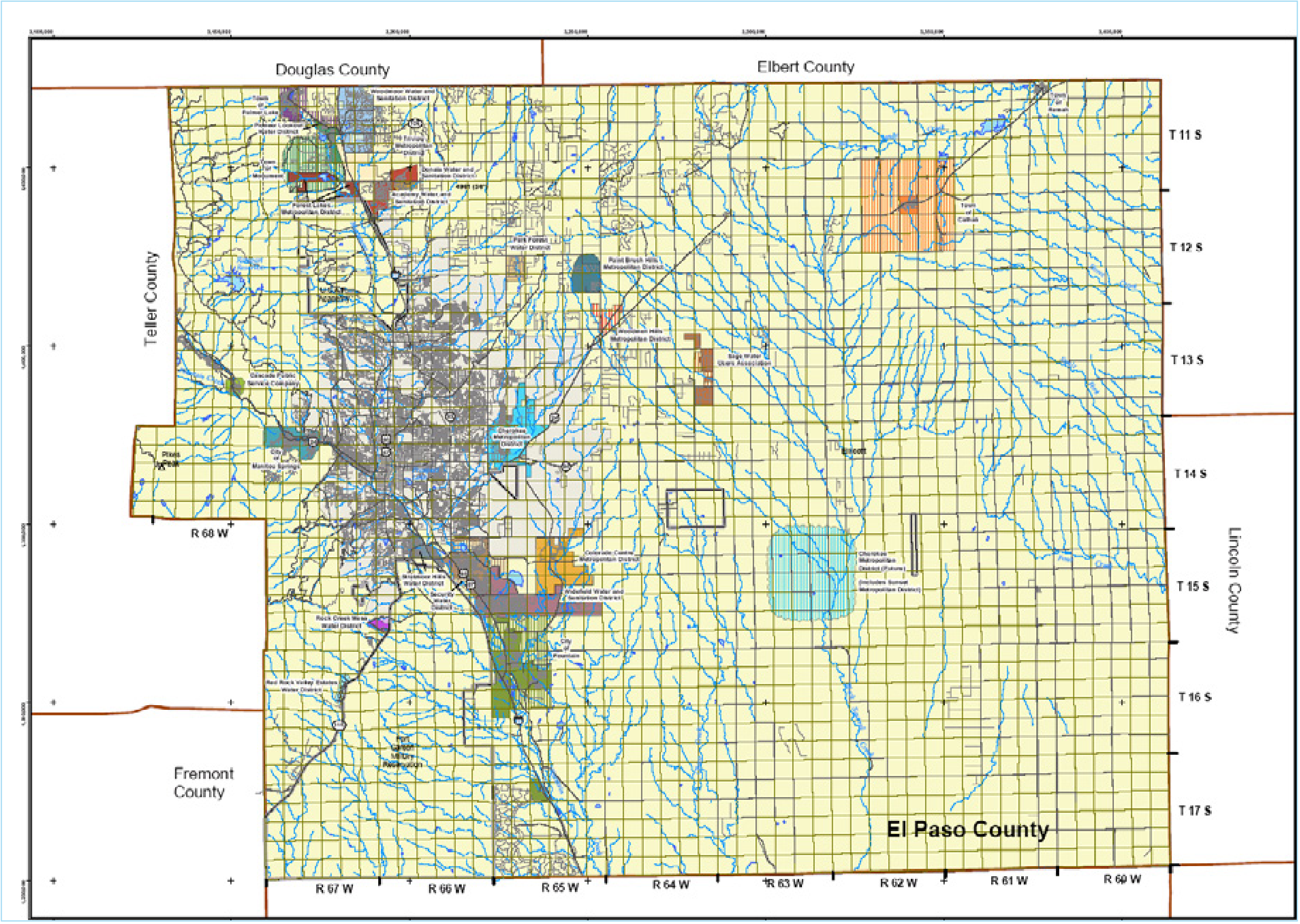
Moving Forward

Taking up the challenge, the Lower District sponsored a conference in 2005 featuring speakers from California and Idaho who talked about their fallowing-leasing programs. The Lower District subsequently hosted local irrigators on a 2007 trip to the Imperial Valley of California and the Palo Verde Irrigation District, which inked a 35-year fallowing lease arrangement with the Metropolitan Water District of Southern California in 2005. After "kicking the dirt" farmer-to-farmer, Lower Valley irrigators embraced fallowing-leasing and began developing a leasing organization. Concurrently, the Lower District sponsored proof of concept and detailed engineering studies to confirm the feasibility of a fallowing-leasing program.

Super Ditch

Shareholders of the Rocky Ford High Line Canal, Oxford Farmers Ditch, Otero Canal, Catlin Canal, Holbrook Canal, and the Fort Lyon Canal (later joined by the Bessemer Ditch) met in Rocky Ford on May 7, 2008, to incorporate the Lower Arkansas Valley Super Ditch Company, a Colorado for-profit corporation. The Super Ditch is managed by a Board of Directors elected by Valley irrigators and will forever remain under their control, pursuant to the articles of incorporation. The Company will issue shares to irrigators in proportion to the water they lease for the duration of their lease.

Creation of the Super Ditch established an organization that can negotiate on behalf of irrigators to make water available to other water users through long-term leases, interruptible water supply agreements, and water banking. Accordingly, the Super Ditch immediately began meeting with potential lessees and negotiating with about 20 municipal water users.



El Paso County, Colorado, Water Districts

<u>*Municipal Demand*</u>

In November 2009, the Super Ditch announced a conceptual agreement with six members of the Pikes Peak Regional Water Authority, including Fountain, Monument, and Cherokee Metropolitan Districts. The 40-year lease with a right to renew carries a base price of $500 per acre-foot per year. Deliveries will begin in 2011 at 2,000 acre-feet per year, rising to 8,000 acre-feet per year in 20 years. Negotiations continue with other potential lessors.

The Super Ditch expects to lease up to 24,000 acre-feet in a dry year, 50,000 acre-feet in an average year, and 80,000 acre-feet in a wet year. And in an exceptionally dry year like 2002—when there wasn't enough water to farm—the Super Ditch could also lease 80,000 acre-feet. The Super Ditch expects to deliver water into Pueblo Reservoir; lessees will then be responsible for transporting the water for their use.

<u>*Leases*</u>

The basis for leases will be acre-feet of transferable consumptive use, in the form of stock in ditch and reservoir companies on the mainstem of the Arkansas River and its tributaries (exclusive of Fountain Creek) at or below Pueblo Dam and above John Martin Reservoir. Shareholders in some companies will have to amend their articles of incorporation or bylaws to permit leasing.

The amount of foregone irrigation under various hydrological conditions (wet, dry, and average years) will be matched with lease demands, which are also expected to vary from lease to lease. For example, some municipalities need additional water in a dry year, some need water to recover after a drought, and still others need to reduce groundwater pumping in average and wet years to extend the lives of the aquifers they currently tap.

Although the Super Ditch will negotiate uniform terms and conditions with each new user, leases will be signed by individual farmers to avoid double taxation of lease payments. Individual farmers will decide whether, and to what extent, they want to participate. And if there is more interest in leasing than demand for some leases, the amounts will be prorated proportionately. An irrigator will be able to transfer his lease to another irrigator, so long as the municipal lessee receives the same amount of water. Leases will constitute a legal encumbrance upon the ditch company shares leased by the irrigators to the Super Ditch

Company, and will constitute a continuing obligation of the owner, assignor, or successor of the ditch company shares. In this manner, lessees will have certainty of supply.

Irrigators may fallow land in rotation or on some other basis, and will be responsible for weed and erosion control on their fallowed land. All irrigated land included in each lease will be fallowed the same percentage of the time over the life of the lease.

Anti-trust

An ongoing controversy over the Super Ditch idea involved anti-trust questions raised by municipalities. Analysis of the issue by Colorado's leading anti-trust attorney put that issue to rest, however, when he concluded the notion would likely withstand legal challenge.

1041 Permits

Super Ditch leases will transfer more than 1,000 acre-feet of water from agricultural to municipal use, triggering 1041 permitting requirements in Bent, Otero, Prowers, and Pueblo Counties. The Super Ditch Company will handle the permitting.

Water Court

Leases will require adjudication of changes in the type and place of use of the leased irrigation water for municipal purposes in different locations. The Super Ditch expects to pursue water court applications for specific leases with each municipality to meet the anti-speculation requirements of Colorado water law. The Super Ditch will also seek the State Engineer's annual approval of substitute water supply plans while applications are pending in order to begin immediate deliveries. Water court applications are likely to attract many objectors and take years to resolve.

Municipal Purchases

To avoid undermining the Super Ditch, a condition of leasing water is expected to be a voluntary agreement not to transfer irrigation water rights out of the Lower Valley while someone is leasing water. While lessees would not be expected to forgo purchasing additional water rights, they would be expected to make those water rights available for lease just like any other water right owner.

Alternatives to Permanent Water Transfers Using the Farmers Reservoir and Irrigation Company (FRICO) System

by Christopher Goemans, Assistant Professor;
Stephan Kroll, Assistant Professor; Department of Agricultural and Resource Economics, CSU
Kelly DiNatale, President, DiNatale Water Consultants

Prior to the recent downturn in the housing market, statewide municipal and industrial (M&I) water demand was forecasted to increase by 630,000 acre-feet by the year 2030. The vast majority of this increase was, and still is, expected to occur along Colorado's Front Range. While development has undoubtedly slowed over the past few years, this has likely only delayed what many consider inevitable: a near doubling of urban water demands in Colorado within the next 50 years. Given this growth, most would agree that the question is not whether water will move from agricultural to M&I uses, but rather when and how.

Traditionally, the permanent transfer of agricultural water rights/shares to municipal providers has been the primary means of reallocating water from agricultural to municipal users. However, considerable evidence shows that transfers of this type, which typically result in the permanent dry-up of agricultural land, can have significant negative impacts on the agricultural communities from which the water is transferred.

The Farmers Reservoir and Irrigation Company (FRICO) has partnered with researchers at Colorado State University and DiNatale Water Consultants, Inc., to develop, evaluate, and illustrate opportunities for FRICO shareholders to realize additional economic value from their shares and associated water assets using methods other than traditional agricultural transfers. Our primary objectives are to work with FRICO to identify which, if any, alternatives to permanent transfers are viable and to explore their impacts on the agricultural community.

Economists and policymakers have long promoted a variety of alternatives to permanent transfers. However, there are few examples of successful arrangements in which irrigators retain ownership of the right, remain in farming, and lease water to M&I suppliers. As a result, little is known about the conditions under which municipal and agricultural water users would be willing to pursue such alternatives, nor their potential effectiveness in delaying or preventing permanent water transfers.

In this project, we focus on the different types of agreements through which water can be transferred, as opposed to ways in which agricultural water can be freed up (e.g., rotational fallowing, deficit irrigation, etc.). This includes multi-year leases, interruptible water supply agreements, and a new "Shared Water Bank" concept.

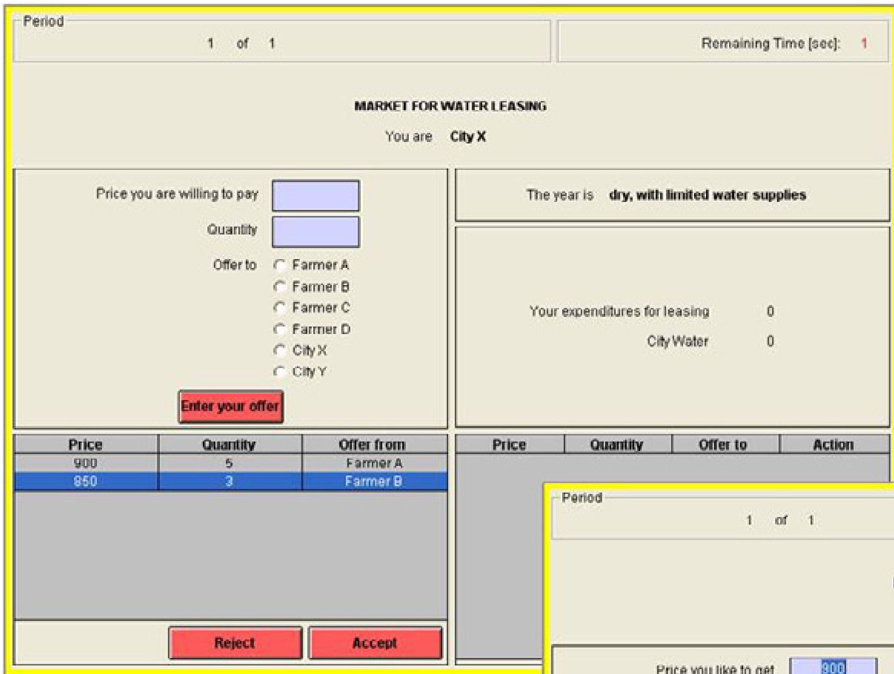
Along with water banks, multi-year leases and interruptible water supply agreements (IWSA) are the two most common alternatives to permanent transfers promoted by policymakers. Both allow irrigators to retain ownership of their rights, while generating revenue from the sale of all or a portion of the water associated with those rights. The big difference between the two relates to the frequency with which cities lease water from irrigators. Under multi-year leases, irrigators lease water to M&I suppliers every year over the course of the lease. With IWSA agreements, irrigators agree to lease water to M&I suppliers on an as-needed basis (under Colorado Law, IWSA are required to be 10 years in length with a maximum exercise frequency of 3 years out of 10). In years in which the option is not exercised, the irrigator has the right to use the water any way they wish.

Gauging FRICO Shareholder and M&I Water Supplier Interest in the Alternatives

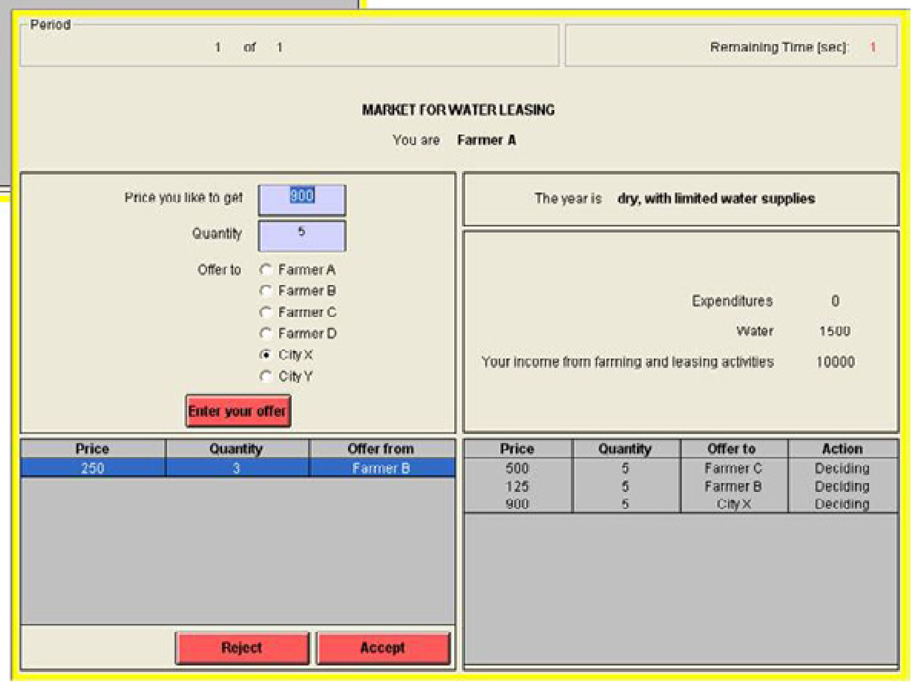
The first stages of this project have focused largely on meeting with and surveying FRICO shareholders and municipal water providers. Our goal has been to elicit information from both sides on their preferences for each of the alternatives, as well as to inform shareholders about the options that are available to them; the latter being especially important given what we have learned following the Arkansas River Water Bank. Commenting on the lack of activity in the Arkansas River Water Bank, former State Engineer Hal D. Simpson noted that "any operator of a water bank needs to make multiple, ongoing marketing efforts to promote the program and provide information to potential users allaying any existing fears" (*A Report to the Governor and Legislature on the Arkansas River Water Bank Pilot Program*, 2005).

While high transaction costs (e.g., legal fees, costly engineering studies, etc.) are typically cited as the reason for limited participation in water markets (permanent or otherwise), uncertainty and a lack of information regarding the alternatives have been the single biggest concerns raised by irrigators and municipal water suppliers during our meetings.

Among the FRICO shareholders who are irrigators, there is a widespread lack of trust in the legal system and the institutions that govern water allocation. Simply put, many of the irrigators we have spoken with do not feel as if their interests will be protected in any dealings with urban water



Screenshots of market experiment interfaces.



providers. Moreover, many are afraid that if they lease their water to a city, they won't get it back. These sentiments were reflected in the types of leases/IWSA that shareholders indicated they were most interested in: none were willing to consider a lease longer than five years.

For urban water suppliers who have the option to purchase water rights, there is little incentive to take on the uncertainty in market conditions once the agreement expires.

How would an increase in the use of multi-year leases and IWSA impact the market for permanent transfers and the agricultural community?

During our initial meeting with FRICO shareholders, the first question we were asked was, "what is this going to do to the value of my water right?" This is a question that we know very little about and, for the most part, has been ignored within the literature on water markets. Multi-year leases and IWSA represent a potential alternative source of supply to municipalities seeking to firm their water supplies. Depending on the level of activity, an active leasing/IWSA market would likely negatively impact the value of agricultural water rights and the ability for remaining irrigators to lease water from other farmers. The question is by how much?

We are using a technique called experimental economics to explore the qualitative and quantitative impact of water leasing to cities on water sale and lease prices, as well as the resulting distribution of benefits. When real-world data on market institutions are scarce and "trial runs" are costly and often irreversible, laboratory experiments provide an alternative for testing different market structures before they are actually implemented. Similar techniques have been used to testbed water banks in Georgia and New Mexico and carbon permit trading markets in the Northeast.

The basic premise of any laboratory experiment is that human subjects interact in a computerized market (with real money at stake) that is scaled down from the real-world market in question but still contains its major features and incentives.

In our experiment, we will have subjects participate in two water markets: one with permanent transfers only and one with a leasing market in addition to the permanent market (Figure 1). Everything else, in particular the number and induced preferences of traders, is held constant, so that we are able to observe what happens to prices in the permanent market once a leasing market is introduced. The experiment represents an opportunity to learn about the potential impacts of an actively functioning leasing market and educate people on how it would work.

The Shared Water Bank Concept

Not surprisingly, most of the focus on developing alternatives to permanent transfers has centered on the water rights owned by the agricultural community. However, as is the case with many ditch and reservoir companies, FRICO's extensive infrastructure is a valuable asset that is often overlooked. Extending approximately 3,500 square miles along the Front Range, FRICO's system includes four major reservoirs and approximately 400 miles of diversion and delivery canals. The FRICO system is situated so that it can wheel water to numerous water providers in Adams, Arapahoe, Boulder, Denver, Douglas, Jefferson, and Weld Counties.

The "shared" water bank concept would utilize existing FRICO infrastructure and recharge capabilities to capture and store, in wet years, otherwise unused or conserved agricultural and M&I consumptive use. Rather than leasing water, under this plan FRICO would essentially be "leasing" its infrastructure. M&I users would have the opportunity to firm existing supplies without additional investments in infrastructure and without having to permanently transfer additional supplies from current agricultural users.

We foresee several benefits accruing to both agricultural and M&I users. In exchange for facilitating the storage of otherwise unused or conserved water, FRICO shareholders would receive a portion of the augmentation credits. Other agricultural users (non-FRICO shareholders) would also benefit from having access to low cost augmentation credits that would otherwise not be available absent this arrangement.

Next Steps

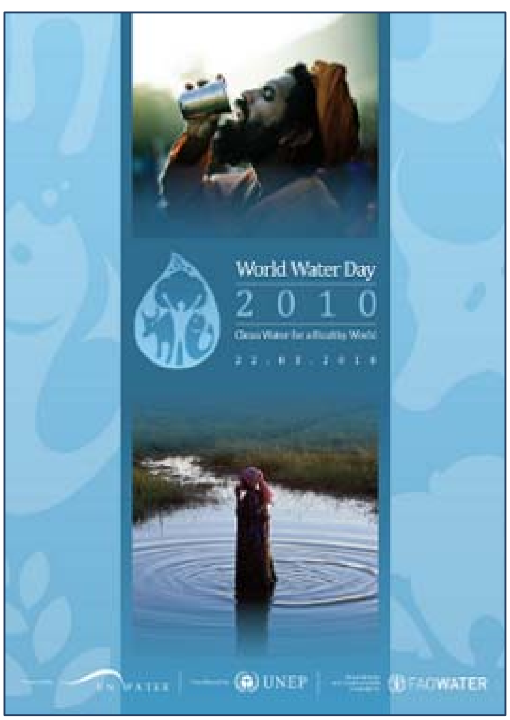
This is a long process. Irrigators in the Arkansas Valley have been discussing water banking, multi-year leases, and IWSA for more than a decade, the benefits of which are only now starting to emerge.

The shared water bank concept has garnered the most interest in terms of the alternatives we have presented. Parties on both sides have indicated an interest to further discuss the details of such an arrangement. In addition to ironing out the hydrologic and legal details of the bank, next steps will involve outlining an agreement between both sides.

World Water Day 2010 — 22 March 2010 — Clean Water for a Healthy World

Colorado State University

COLORADO STATE UNIVERSITY PRESENTS WORLD WATER DAY in conjunction with Hydrology Days



WHAT: **World Water Day**
WHEN: **Monday, March 22, 2010**
WHERE: **Lory Student Center, Fort Collins, CO**

KEYNOTE: **Dr. John Matthews**
Senior Program Officer of Freshwater Program, World Wildlife Fund

CSU is hosting its first World Water Day event at the Lory Student Center on March 22, 2010. Activities include a World Water Day Fair, dignitary and keynote speakers, workshops, demonstrations, and community service projects. World Water Day at CSU will highlight local, regional, and global educational and outreach programs.

For more information about CSU World Water Day and Hydrology Days please visit the CSU World Water Day web site at www.globalwater.colostate.edu. To participate, please contact faith.sternlieb@colostate.edu.

Developing Practical Alternative Agricultural Water Transfers

by Matt Lindburg, P.E., Brown and Caldwell Engineering

The Colorado Corn Growers Association (CCGA), Ducks Unlimited (DU), and the City of Aurora (Aurora) were awarded a CWCB grant to develop tools to help agricultural producers understand alternative agricultural water transfers such as rotational fallowing, interruptible supply agreements, deficit irrigation, and other methods. The CCGA, DU, and Aurora (the Team) are interested in a common goal—developing win-win alternative transfers of water that can meet growing urban and industrial demands and also maintain irrigated agriculture in Colorado.

The Team joined forces with a small group of water users and suppliers looking to form a water cooperative in the lower South Platte River (Co-op). One of the Co-op's goals is helping agricultural and other interests develop efficient means to retime and optimize excess water that is periodically available in the lower South Platte for agricultural and other beneficiaries. Assisting in the research for this project are the Colorado Water Institute (research engineers and economists from Colorado State University); Lind, Lawrence, and Ottenhoff, LLC (attorneys); Harvey Economics; and Brown and Caldwell (engineers).

The project's primary focus is to examine alternatives to traditional "buy and dry" that can maintain sustainable irrigated agriculture and provide water to other users. The Team proposes to accomplish this objective by rigorously investigating alternative transfer methods and developing tools to help facilitate alternative transfers, which will be tested on two specific projects in the South Platte Basin. The tools will be packaged as a Business Plan that can be used by agricultural producers, municipalities, and industry to evaluate and implement alternative agricultural water transfers in the South Platte River Basin and across Colorado.

A corn field and irrigation ditch. (Courtesy of Colorado Corn Growers)

"This project's primary focus is to examine alternatives to traditional 'buy and dry' that can maintain sustainable irrigated agriculture and provide water to other users."

The Business Plan will include guidance on the steps necessary to implement an alternative water transfer, as well as an economic evaluation tool that will allow an agricultural producer to understand the economic implications and benefits of a potential transfer. The Plan will be tested and validated by applying it to two proposed alternative water transfers (demonstration projects). In addition, agricultural producers associated with the CCGA will review the Plan, drawing on the practical experience gained from other water transfer projects completed by members of the Team. In each of the demonstration projects, which will involve wetlands owned or potentially owned by DU in the South Platte River Basin, an alternative water transfer will be developed to supply water to the wetlands and recharge the alluvial aquifer.

DU has a ten-year history of working cooperatively with agricultural producers, municipalities, and industry along the South Platte River in Colorado by providing water through alternative agricultural water transfers for multiple benefits. DU has constructed several recharge wetlands or ponds that provide high-quality habitat for migrating waterfowl along the South Platte River. These wetlands also offer recreational opportunities, improve water quality through increased filtration, and provide recharge to the South Platte alluvial aquifer, which can be used as augmentation credit for agricultural producers irrigating with groundwater or to wildlife agencies through various agreements and contracts.

As this project has progressed, it has become apparent that a marketing mechanism will be needed to facilitate moving water efficiently from water owners (agriculture) to those in need (both municipal and industrial users and other agricultural users). While developing this marketing mechanism is outside the scope of this project, research is being conducted to help develop a future marketing mechanism. For example, part of this project involved exploring the ability to exchange recharge credits from wetlands to municipal water suppliers. This research was enhanced by the involvement of the Co-op, which is interested in connecting those in need of water to those who may have occasional excess supplies. A third demonstration project focuses on the ability to exchange excess water that is periodically available and on analyzing potential enhancements that would optimize exchange capabilities. The research shows that, while several points of diversion act as “bottlenecks” for exchange, there is the potential to exchange water, especially in the area between Fort Morgan and the mouth of the Cache la Poudre River. Additional infrastructure is being considered that will enhance exchange and help provide reliability to a marketing mechanism that could facilitate alternative transfers.

The Business Plan is currently under development, and the Team is researching legal, engineering, and administrative issues related to the implementation of alternative transfers. The economic evaluation tool is a key component of the Business Plan. Based on feedback from members of the CCGA board, considerations such as tax implications, risk associated with commodity market variability, and tool complexity have been discussed and incorporated into draft versions of the tool. The draft tool is currently being tested by the Team and reviewed by agricultural producers. In addition, the Team is collaborating with Colorado State University Extension, which is developing a similar tool in the Arkansas Basin.

One of the project goals is to provide a reliable water supply for municipal and industrial water users in a win-win fashion that avoids permanent dry-up. The Team believes this project can result in perpetual supplies for several reasons:

- A recent survey conducted by Colorado State University suggested that at least 60% of respondents were willing to lease water rather than sell, provided they are suitably compensated.
- DU projects ensure long-term transfers by using conservation agreements that include 30-year water leases and conservation easements that provide protection of water supplies in perpetuity.
- The Business Plan tools will provide agricultural producers with a greater level of control over their water rights assets, thus making them more likely to enter into long-term leases.

An aerial view of Drake Land Farms wetland. (Courtesy of Ducks Unlimited)

It should be noted that the CCGA does not anticipate that this project will end permanent transfers of agricultural water to other uses. It is important to remember that agricultural producers are the owners of water rights and can sell their rights if they choose. The CCGA believes there is currently a trend for non-agricultural water interests to buy water rights as a hedge against future inflation of water prices. However, they also believe that non-agricultural water users are primarily interested in reliability of supply rather than ownership in and of itself. As these users satisfy their needs for purchased water, it is anticipated that there will be increased demand for temporary transfers of water to fulfill dry-year and other water needs. The results of this project will be applicable both as a potential alternative to purchased water and to directly fill the need for temporary transfers. In addition, this program will provide guidance to producers on alternatives they may not have fully understood in the past, and the CCGA is confident that this project will result in future perpetual leases of water that allow for the preservation of irrigated agriculture.

Wemlinger Water Treatment Plant. (Courtesy of Aurora Water)

Farming in the Lower Arkansas River Valley within the Context of Agricultural Water Rights Transfers

by Perry Cabot, Extension Water Resources Specialist, Colorado State University
Jim Valliant, Research Scientist, Arkansas Valley Research Center

The staid landscape of Colorado's Lower Arkansas River Valley seems a world apart from the dramatic beauty of the Rocky Mountains and Front Range. A windshield survey leaves one with the impression that the area is simply a space between places—barren and desolate and practically abandoned. On the contrary, over a century of agriculture resides in this vast expanse of shortgrass prairie. Beneath its austerity and sparseness, this region is linked by an historic bond to the present-day challenges that Colorado faces in collectively managing our treasured water resources.

Early pioneers of the Lower Arkansas Valley seized upon the opportunity offered by the landmark *Yunker v. Nichols* (1972) opinion of the Colorado Territorial Supreme Court, which laid the foundation of the Colorado Doctrine of prior appropriation rights. By abrogating pre-existing property rights formulations in favor of a "water use rights" framework, this doctrine allowed private and public entities to own the rights to water resources without owning land directly near streams and rivers. The doctrine had distinct implications for agricultural interests. In the Lower Arkansas Valley, where annual rainfall rates of 11-12 inches were not uncommon, these new water use rights were especially critical to anyone wishing to farm in the area. And, there were a surprising many that did. By the early 1900s, an intricate network of irrigation ditch and canal companies controlled the Arkansas River water shares that would someday be coveted by urban epicenters evolving out of distant Western settlements.

Although the Lower Arkansas Valley once experienced boom times in the years bracketing World War I, the region has never fully recovered economically from the Dust Bowl Era. Known for its breathtaking scenery and moderate climate, however, Colorado's Front Range drew residents quickly, and economic development followed in short order. By the 1960s, it was evident to municipal interests like Denver and Colorado Springs that water demand would soon exceed available supplies. Overtures were made by cities to purchase water shares owned by Lower Arkansas Valley farmers and ranchers who, faced with the difficulty of farming saline soils under recurrent drought conditions, were receptive to selling. In a sense, it was a perfect confluence of circumstances. Wealthy municipalities and industrial (M&I) interests desperately needed water—from wherever they could get it. Farmers on the plains had plenty of water rights to sell in a new market that emerged out of necessity in Colorado's arid climate. In the wake of these water rights transfers, however, thousands of farmland acres were fallowed and removed from production. The term "buy-and-dry" colloquially refers to the outcome that ensued as the dewatering of farmland had far-reaching effects on the region's rural economy.

Alternatives to Drying Up Agricultural Land

Agricultural land use in the Lower Arkansas Valley will continue to be impacted in the coming years by the competitive market for water rights. The diverse economy of our state requires much of the water once used exclusively for irrigation to be shared with M&I interests. These trends will require adaptation and adjustment within the region and will incur certain difficulties. However, it should not be considered a foregone conclusion that local agriculture is consigned to permanent deterioration.

Many Lower Arkansas Valley farmers wish to sustain their agrarian heritage and avoid further "buy-and-dry" outcomes. To this end, the concept of leasing (rather than selling) agricultural water rights has experienced a surge of support in the area, evidenced by arrangements between the Highline Canal and the City of Aurora, along with the recent incorporation of the Super Ditch Company in May 2008. Water leasing offers shareholders additional farm revenue and helps cities maintain adequate supplies during times of drought. Unlike traditional water sales, however, land is not permanently dewatered but is instead temporarily fallowed from irrigation for a period specified in the conditions of the lease.

Farming Land in a Context of Water Lease Arrangements

These alternative agricultural water rights transfers will likely require some shifts in farming arrangements and management practices. Moreover, those considering water lease arrangements are faced with a number of questions. For example, a farmer might reasonably ask, "How will fallowing my ground for the lease period affect my yields when I decide to farm this ground again? And how will my soil conditions change?" Another question often raised is, "What will it cost to maintain the fallow condition under the terms of the lease?" Still another inquiry might be, "What will it cost to reclaim the land after the lease is over?" Ultimately, these questions pertain to the dominant issue of whether leasing water is worth the cost of not farming.

Along these lines, Colorado State University (CSU) specialists in Extension and at the Agricultural Research Station have undertaken collaborative research projects to study the effect of fallowing on agricultural operations. In 2007, a basic study was initiated at the Arkansas Valley Research Center using corn as an index crop. The study has examined the effect on yield, nutrient needs, and land management involved in farming these fallowed lands when they are reclaimed for production, as compared to continuous corn production. Results thus far have indicated favorable annual carry-over of fertilizer (N, P, and K), provided that weed suppression is practiced successfully. Although we view our results with caution, this finding is significant because it suggests that the initial investment in fertilizer may not be lost, even if the farming cycle is interrupted by a water lease arrangement.

In 2009, with the support of the Colorado Water Conservation Board, the City of Aurora, and the Lower Arkansas Valley Water Conservancy District, CSU expanded its fallowing study to a larger scale. The expanded study will allow a broader study of nutrient carry-over, weed control, and management variables. Two demonstration sites were established in the Lower Arkansas River Basin on working farms owning shares in the Highline Canal and the Holbrook Canal (Figure 1). The Highline Canal Company owns senior water rights, whereas the Holbrook Canal is junior on the Arkansas River, but it does utilize a storage facility (Holbrook Reservoir) to conduct contract exchanges or "paper exchanges" with upstream water facilities.

Demonstration sites were prepared for the 2009 season with one area planted to corn and three other areas managed as if their farming cycles had been interrupted by fallowing periods lasting one, two, or three years (Figure 2). The fallow periods are derivative of Colorado House Bills 03-1334 and 06-1124, which authorize the state engineer to approve interruptible water supply agreements without the requiring adjudication in Colorado Water Court. These agreements are limited to arrangements in which water rights are transferred for 3 years (or fewer) out of 10 years. The research effort will quantify the requirements of managing fallowed lands and identify impacts on crop yield, nutrient needs, and land management on irrigated fields when they are brought back into production at the end of the lease period. Farmers in the Arkansas Valley have expressed a need for such assessments in order to consider water rights leasing arrangements individually or collectively.

Another strategy under examination by CSU researchers in the Lower Arkansas Valley may be viable for farmers in the region who wish to maximize the role of agriculture at the intersection of water use and renewable energy. Oilseed cropping (canola, sunflower, camelina), for instance, offers an alternative to currently grown crops (corn, alfalfa), which will be increasingly unrealistic in settings of reduced water supplies. More specifically, oilseed crops

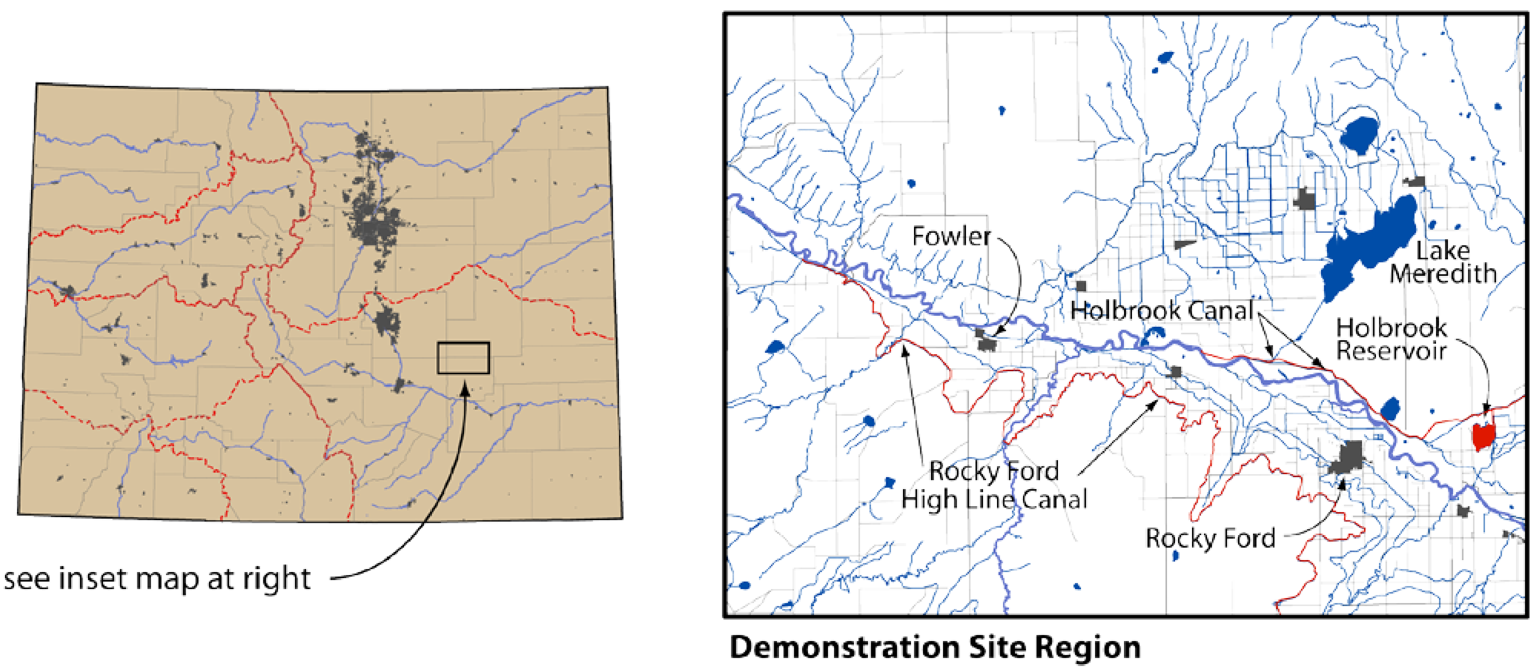


Figure 1. Regional location of demonstration sites in Otero County within the Arkansas River Basin (left). Both canal systems to be incorporated into this project (Holbrook and Rocky Ford High Line) are highlighted in red. Demonstration sites are expected to be approximately 20 miles apart between the towns of Fowler and Rocky Ford, CO (right).

are promising alternatives to promote continued farming under dryland, limited irrigation, or cool season conditions (e.g., winter farming) as interest develops in leasing water. By finding ways to combine income sources from both water rights leasing and oilseed farming, economic conditions in the Lower Arkansas Valley may stabilize and potentially improve. One positive scenario that needs further research would be where leasing arrangements allow water use for agricultural irrigation only during off-peak seasons (e.g., fall, winter), then switch to M&I use when water supplies are in greater demand (e.g., summer).

The results of these demonstrations will allow CSU Extension and the Agricultural Experiment Station to assist farmers in managing their land in the context of water lease arrangements. Such outcomes are far more desirable than the diminished agricultural productivity that has accompanied "buy-and-dry" land purchases of the past. These recommendations are needed as the farming situation changes in the Lower Arkansas Valley, but little information exists on the technical aspects of this new rotation strategy. When considering lease arrangements, our goal is to help farmers accurately calculate the market value of their water shares, relative to the value of continued farming as corn prices steadily rise and oilseed crops grow in popularity.

Limited Irrigation Research and Demonstration in the Republican River Basin

by Joel Schneekloth, Extension Specialist, Colorado State University

The combination of drought, groundwater depletion, and increasing urban competition for water has created water shortages for irrigated agriculture in Colorado and is driving the need to increase water use efficiency. A statewide water supply survey predicts that 428,000 irrigated farm acres may be converted to dryland cropping or pasture within the next 15 years, mostly due to transfer of water from agricultural uses to meet the water needs associated with population growth.

Water conservation options other than complete land fallowing are desirable because of the potential economic and environmental concerns associated with conversion to dryland. One approach to reducing consumptive use of irrigation water is adoption of limited irrigation cropping systems, in which less water is applied than is required to meet the full evapotranspiration demand of the crop. Crops managed with limited irrigation experience water stress and have reduced yields compared to full irrigation, but management is employed to maximize the efficient use of the limited irrigation water applied. These systems are a hybrid of full irrigation and dryland cropping systems and are currently of great interest to Colorado farmers. Successful limited irrigation systems are based on:

- managing crop water stress
- timing irrigation to correspond to critical growth stages for specific crops
- maximizing water use efficiency by improving precipitation capture and irrigation efficiency
- matching crop rotations with local patterns of precipitation and evaporative demand (Research in the Great Plains region illustrates that limited irrigation cropping systems are significantly more profitable alternatives than dryland.)

The primary goals of this project, which was funded by the Colorado NRCS Conservation Innovation Grant and the Republican River Water Conservation District, were to look at alternative water management strategies with cropping systems to decrease water use within the Republican Basin, due to compact-related issues with Kansas and Nebraska.

Methods

A large-scale demonstration site was developed in 2006 near Burlington, Colorado, on a silt loam soil. This field is center pivot irrigated. Alternative water management strategies were studied at this site within a 4-year crop rotation of corn-sunflower-soybean and winter wheat. The study looked at full irrigation management, an average allocation of 10 inches per year, and an intermediate irrigation management strategy that limits water applied between that of full irrigation and allocation management.

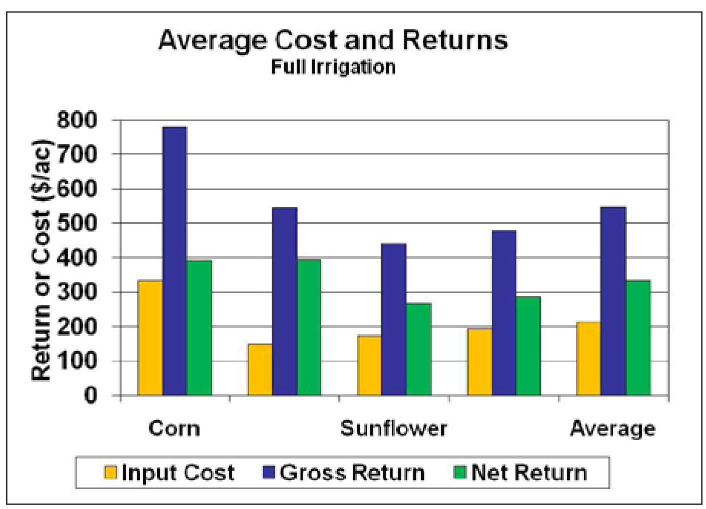
Results

Precipitation at Burlington, Colorado, for 2006 was above average for June and July. Precipitation in May and early spring was below average and near average for September and August. In 2007, precipitation was below average during the growing season except for August, which was near average. Total precipitation for 2008 was well above average but was variable, with both dry and wet periods in each of the three years.

Grain Yields

Soybeans

Soybean grain yields were greater for full irrigation than for either intermediate or allocation irrigation by 7 to 10 bushels per acre (bu/acre). Grain yields in 2006 were substantially less than would be expected, due to herbicide damage. Residual dicamba was in the farmers' sprayers, and damage occurred when the soybeans were



This chart shows average returns and cost of production for corn, soybean, sunflower and winter wheat with full irrigation management.

sprayed with glyphosate. Herbicide damage was evident by leaf cupping on the top of the soybean plants, with a potential for a 40% reduction in grain yields due to dicamba damage. Estimated soybean yields without herbicide damage would have been in the range of 60 to 70 bu/acre. In a test plot near this region, soybean yields for this variety averaged near 70 bu/acre.

In 2007, soybeans were drilled. Harvested grain yields ranged from 75 to 88 bu/acre for allocation to full irrigation. These yields were also verified by crop adjuster estimates. The irrigation requirement for full irrigation soybeans in 2007 was 13 inches, with 9 inches applied to allocation management.

Soybean yields in 2008 were lower than in 2006 and 2007, due to weather. At the time of emergence, a hailstorm damaged stands in the entire field and portions were replanted due to poor stands. Grain yields in 2008 were 55 bu/acre for full irrigation and 45 bu/acre for allocated. In addition to hail damage early in the season, below-average temperatures in August reduced pod set and growth. Soybeans do not respond well to below-average temperatures during the reproductive growth stage.

Corn

Corn grain yields for all irrigation strategies were similar in 2006. Precipitation during 2006 was above average for the growing season by 1.0 inches. Reduction of irrigation for the reproductive growth stage did increase early season utilization of stored soil moisture.

Grain yields in 2007 were lower than in 2006. Approximately two weeks prior to tassel, a severe infestation of corn rootworm was noted in the entire field. The allocated and intermediate corn was more severely impacted than the full irrigation corn. This indicates that limiting water with monoculture practices is more risky than rotating where rootworm control is not an issue.

In 2008, corn was planted after wheat and after corn in an effort to look at the yield impact of rotational corn. The corn after wheat was irrigated with full, intermediate, and allocated management, while the corn after corn was full and allocated irrigation management. Irrigated yields of full and intermediate irrigation management were similar, with yields of 201 and 208 bu/acre, even though the intermediate treatment included 2 inches less irrigation applied during the vegetative growth stage. Yields for the allocated management were approximately 30 bu/acre less than full irrigation management. However, irrigation was reduced by nearly 50% as compared to BMP management. Due to precipitation and cooler temperatures in August, corn required no additional irrigation after July 30.

Corn was grown after corn as a comparison for the yield and water use impact of rotating corn. Continuous corn yields for both the allocated and full irrigation management were 10 bu/acre less, as compared to the same water management strategies following wheat. In addition, harvest time for the corn following wheat was nearly three weeks earlier for a moisture content of 17% at harvest. Corn rootworm was present in the continuous corn and impacted root growth.

Sunflower

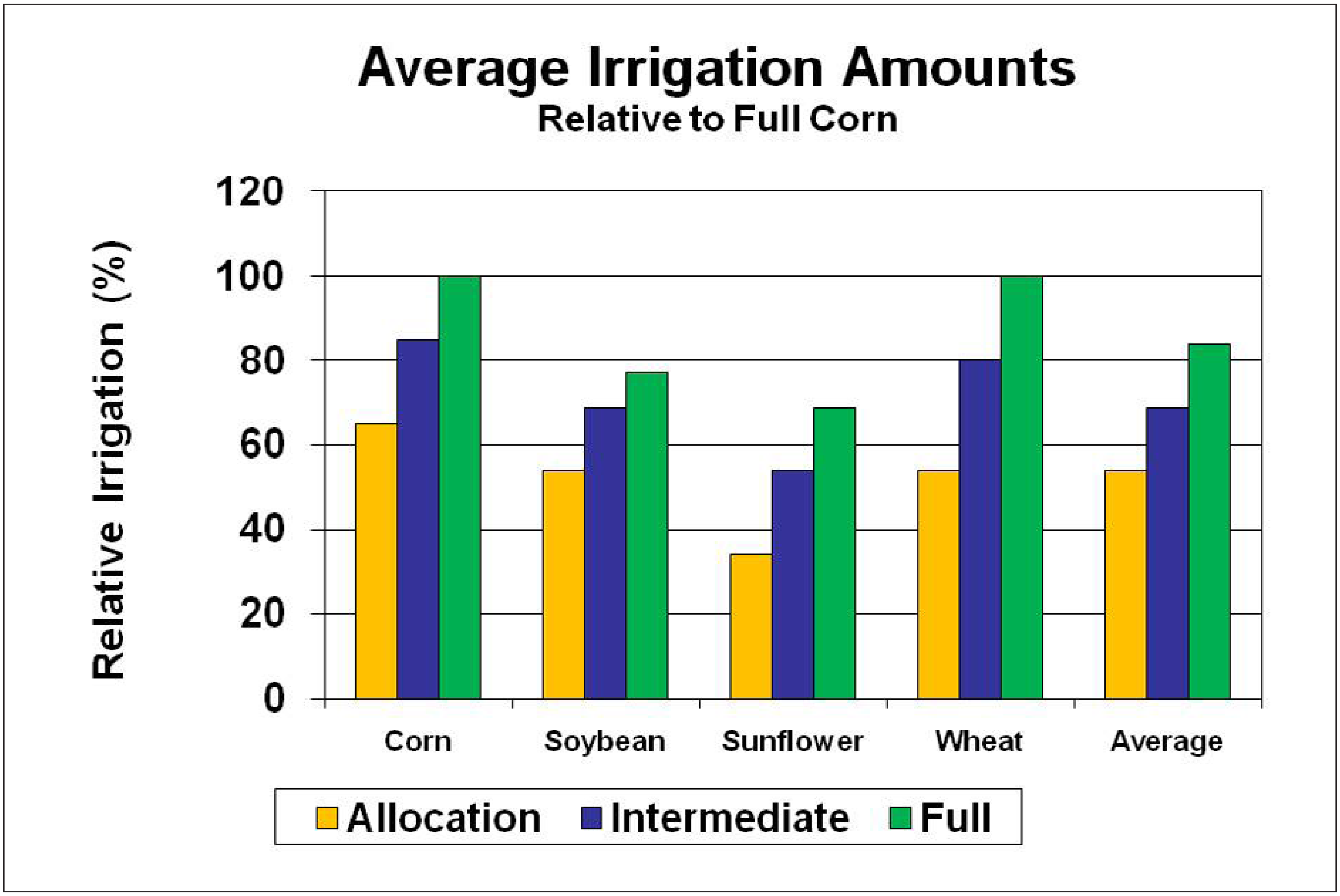
Sunflowers respond well to limited amounts of irrigation. Sunflower grain yields in 2006 averaged 2500 to 2600 pounds per acre for allocation and intermediate irrigation management. Full irrigation yields were 2400 pounds per acre. The irrigation requirement was 8 inches for full irrigation management and 4 inches for the allocation management.

In 2007, grain yields for sunflower were lower than in 2006. Full irrigation management averaged 2050 pounds per acre, while allocation and intermediate irrigation management averaged 1700 and 1550 pounds per acre, respectively. Harvest losses again had a significant impact on grain yields. Hand-harvested yields were approximately 2500 pounds per acre for each of the three management strategies.

Winter Wheat

Winter wheat was planted after soybean harvest in 2006 and 2007. Winter wheat yields in 2007 were extremely low for irrigated yields. Irrigation did not significantly impact grain yields in either year, with average yields for full irrigation of 53 bu/acre and 51 bu/acre for allocated. Some of the issues regarding yield may be due to fertility. Nitrogen was adequate for higher yields but was limited by another factor. Soils in the field tested very low for phosphorus, with a Bray test value of 3. In 2008, a strip of wheat was planted where the starter fertilizer application malfunctioned. The phosphorous deficiency was seen throughout the growing season (see photo).

This image shows a strip of irrigated wheat that is phosphorous deficient. (Courtesy of Joel Schneekloth)



This chart shows average relative irrigation amounts for crops and water treatments compared to continuous corn.

Irrigation Usage

Average irrigation amounts for each crop over the three-year period relative to full irrigation corn are shown in Figure 1. When utilizing a rotation with soybean, sunflower, and winter wheat with corn, irrigation amounts were reduced compared to full irrigation corn. Full irrigation management of this rotation reduced irrigation requirements by 16%. When the intermediate management strategy was employed, irrigation requirements were reduced by 31% compared to full irrigation corn. Utilizing an allocation of 10 inches on average, irrigation was reduced by 46%. Including alternative crops such as soybeans and sunflower can significantly reduce average irrigation pumping as compared to continuous corn.

Limited irrigation of crops is management intensive and is potentially more risky than full irrigation management. However, research and demonstration projects in Colorado have successfully shown that irrigation water can be reduced and economical yields obtained. Alternative crops such as sunflower and soybeans can reduce the amount of irrigation needed as compared to corn. Education and marketing will play an important factor in the acceptance of these crops for irrigation conservation.

The economics of alternative crops is an important issue. Generally, irrigated corn produces the greatest economic return (Figure 2), as compared to other crops. However, certain irrigated crops, such as soybean, can economically compete with continuous corn. The issues that need to be investigated include the economics of rotating corn, which increases yields and decreases input costs as compared to continuous corn.

Inclusion of crops other than corn that use less water greatly enhances water conservation. However, some crops have a lower income potential than corn. Keeping irrigated acres irrigated or transferring the saved water to higher income sources will increase the economic opportunity of limiting water.

Under current water law and regulations, water management such as limited water is not practical in years other than water short years in ditch and reservoir systems. In groundwater management areas, declining water resources and compact litigation may force limited irrigation changes with less water in the future.

Water Production Functions for High Plains Crops

by Thomas Trout, Walter Bausch, and Gerald Buchleiter, Water Management Research, USDA - Agricultural Research Service

Water consumptive use by a crop can be reduced through limited (deficit) irrigation. If the reduced consumptive use (CU) can be quantified, the saved water can be transferred to other users. If the value of the transferred water is greater than the farmer's loss of income due to lower yields, limited irrigation provides a means to sustain irrigated agriculture and meet other water needs.

This valve and flow meter manifold is used to control and measure irrigation applications. (Courtesy of Thomas Trout)

Past studies have shown that, in many cases, the relative reduction in yield with deficit irrigation is less than the relative reduction in irrigation water applied (for example, a 30% reduction in irrigation results in only a 10% reduction in yield). In economic terms, the marginal productivity of irrigation water applied tends to be low when water application is reduced from full irrigation. This is likely due both to increased efficiency of water applications (less deep percolation, runoff, and evaporation losses from irrigation and better use of precipitation), and to a physiological response in plants that increases productivity per unit of water consumed when water is limited.

Improved irrigation efficiency is not likely to produce much transferable water, because it results primarily in a reduction of return flows rather than a reduction in CU. Under Colorado water law, return flows generally must be maintained when water is transferred. If significant transferable water is to be produced by deficit irrigation, it must result from reduced CU, and result in improved efficiency of the crop to convert CU to yield. Thus, the goal of the "maximize crop per drop" slogan must, in reality, be to maximize crop per consumptively used drop.

Although many limited irrigation studies have been carried out in the High Plains and around the world, there continues to be a need for more information on crop responses to deficit irrigation. In 2008, USDA-ARS began a field study of the water productivity of four high plains crops—corn, dry beans, wheat, and sunflower—under a wide range of irrigation levels, from fully irrigated to dry land. We are measuring consumptive use of the crops under each of these conditions. We also strive to better understand and predict the responses of the crops to deficit irrigation, so that limited irrigation water can be scheduled and managed to maximize yields.

The Limited Irrigation Research Farm (LIRF)

A 50-acre research farm northeast of Greeley, Colorado, was developed to enable the precision water control and field measurements required to accurately measure consumptive use of field crops. The farm, originally known as the Potato Research Farm and later as the Northern Colorado Research and Demonstration Center, had been operated collaboratively by CSU and ARS for many years, but had not been in active research for over 20 years. The predominately sandy-loam soils and good groundwater well are ideal for irrigation research.

Four crops, winter wheat, field corn, sunflower (oil), and dry beans (pinto), are rotated through research fields on the farm. Crops are planted, fertilized, and managed for maximum production under fully irrigated conditions, but are irrigated at six levels that range from fully irrigated to only 40% of the fully irrigated amount. Deficit irrigations are timed to maximize production, usually by allowing stress during early vegetative and late maturity stages and applying extra water to reduce stress during reproductive stages.

We apply irrigation water with drip irrigation tubes placed on the soil surface in each row. In this way, we can accurately measure applications and be certain that the water is applied uniformly, which is

> “Results imply that nearly all of the increase in the marginal value of applied water with deficit irrigations results from more effective use of precipitation and increased use of stored soil water.”

essential to calculating crop water consumptive use. Water applied to each irrigation plot is measured with flow meters. Four crops, six irrigation levels, and four replications results in 96 individual plots.

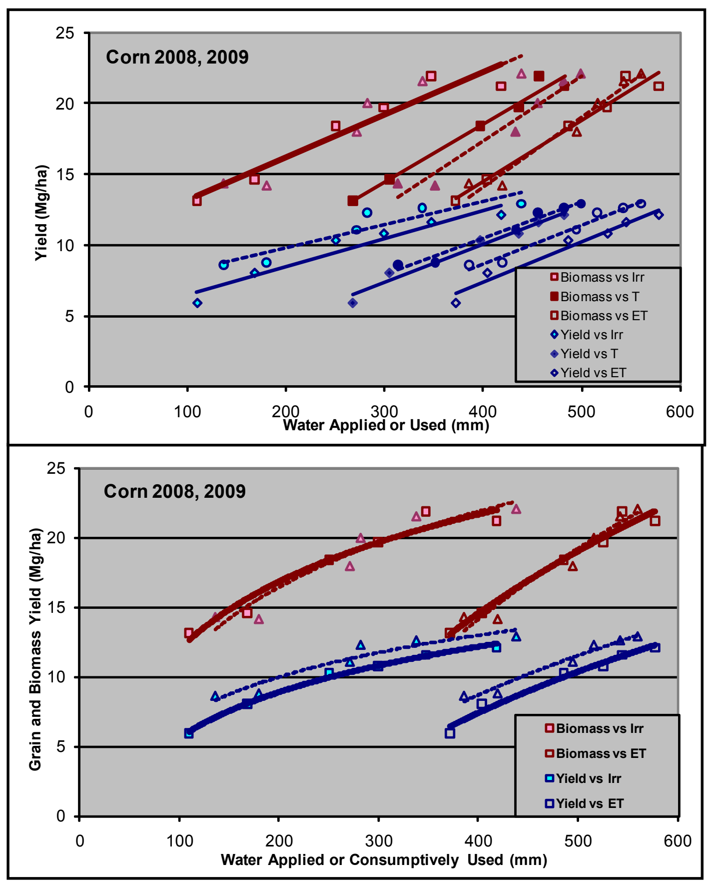
A CoAgMet (Colorado Agricultural Meteorological Network) automated weather station is located on the farm near the center of a 1-acre grass plot. Hourly weather data from the station are used to calculate ASCE Standardized Penman-Monteith alfalfa reference evapotranspiration (ETr). Soil water content (SWC), between six inches and six feet deep, is measured by a neutron probe from an access tube in the center of each plot. Soil water content in the surface six inches is measured with a portable TDR system. Irrigations are scheduled using both predicted soil water depletions based on ETr measurements and measured soil water depletion.

Plant measurements are taken periodically to determine crop responses to the water levels. We record plant growth stage and measure canopy cover with digital cameras. The digital cameras, along with spectral radiometers and an infrared thermometer, are mounted on a “high boy” mobile platform and driven through the plots weekly. Indicators of crop water stress, such as stomatal conductance, canopy temperature, and leaf water potential are measured periodically. At the end of the season, seed yield and quality and total biomass are measured from each plot. On one field on the farm, crop consumptive use is directly measured with energy balance instruments (Bowen Ratio method), which allows crop coefficients to be estimated for the crops. On other fields on the farm, we are cooperating with CSU faculty to test wheat and dry bean varieties under varying irrigation levels.

An important part of the research is to extend the results beyond the climate and soils at LIRF. We are working with the ARS Agricultural Systems Research group to use these field data to improve and validate crop models. Once we have confidence in the models, we can estimate crop water use and yields over a wide range of conditions.

Initial Results

This project began in 2008 and we have completed two crop years; this article summarizes the corn results. Figure 1 shows the yield:water relationship for corn for each year. Irrigation applications (the left two sets of data and lines in the figure) varied from about 430 millimeters (mm) for the fully irrigated crop down to 120 mm. When precipitation is added (about 230 mm each growing season), deep percolation below the root zone is subtracted, and depletion of stored soil water is included, the consumptive use, or crop evapotranspiration (ETc), for the crops varied from about 590 mm down to 380 mm. Of that ET, about 60–90 mm was evaporation from the soil surface and the remainder was transpiration through the plants. Soil evaporation would be higher with sprinkler or furrow irrigation. Irrigations were timed such that plant water stress for the deficit irrigation levels was lowest between tasseling and soft dough (growth stages VT to R4).



This graph shows water production functions for 2009 and 2009 corn. Red lines are total biomass (dry weight), and blue lines are grain yield (15.5% moisture content). Yields are plotted relative to irrigation amount (Irr) and cropET. Triangles and dashed lines represent 2008 data, and squares and solid lines represent 2009 data.

A mobile platform is used to measure crop canopy size, color, and temperature from 24 feet above the ground. (Courtesy of Thomas Trout)

The top (red) data in the figure show total above-ground biomass (dry weight), and the bottom lines (blue) represent grain yields. Grain yields varied from 13 Megagrams per hectare (Mg/ha), or about 200 bu/ac, at full irrigation down to 6 Mg/ha, and biomass was approximately double the grain yields. Hail damage in 2009 resulted in about 15% lower grain yields but little difference in total biomass. Harvest index (the portion of total biomass that is grain) ranged from 50–60% and did not vary with irrigation level.

The water production function for grain (blue lines), based on applied irrigation water, curves downward, showing that the decrease in yield for each unit decrease in water applied is relatively small when the deficit is small, but the rate of yield decrease increases as the deficit increases. This means that the marginal value of irrigation water is relatively low near full irrigation, showing the potential benefit to the farmer of transferring water to higher-valued uses. The marginal value of water increases from about 1.3 kilograms per cubic meter (kg/m^3) of water applied near full irrigation to 3 kg/m^3 at the lowest irrigation level.

However, the water production function for grain yield based on water consumed (ETc) is relatively straight. This implies that the corn is equally efficient in its use of each additional unit of water consumed, and the marginal value of the consumptively used water is fairly constant over the wide range of applications—about 3 kg/m^3.

These results imply that nearly all of the increase in the marginal value of applied water with deficit irrigation results from more effective use of precipitation and increased use of stored soil water, or conversely, the lower marginal value of water near full irrigation is due to inefficient use of rainfall and irrigation water. The marginal value of applied water near full irrigation would be even smaller with less efficient irrigation systems, since more of the applied water would be lost to runoff and deep percolation.

These results also imply that, based on consumptive use, there would be no yield benefit to deficit irrigation compared to fully irrigating only a portion of the land. In fact, fully irrigating less land would likely provide the highest economic returns due to lower production costs.

These preliminary results show the importance of developing water production functions based on the correct unit of water. If water value is based on cost of the water supply (e.g., pumping costs from a well), then productivity based on applied water is important. However, for the purpose of transferring consumptive use savings, the productivity must be based on water consumed. The value of limited irrigation based on CU savings will likely be less, and if the crop is efficient at converting increased CU to yield, there may be no economic benefit to limited irrigation.

These results are preliminary and may vary with different timing of water applications, different crops, or newly developed varieties. This limited irrigation study will be continued to confirm these initial results for each of the four crops.

This image shows a comparison of corn growth on July 31, 2008, just before tasseling. Rows at left and in the background are fully irrigated; rows at the right are at the lowest irrigation level. (Courtesy of Thomas Trout)

Using Cover Crops to Stabilize Previously Irrigated Land

by Troy Bauder and Neil Hansen, Department of Soil and Crop Sciences, Colorado State University

Temporary or permanent loss of irrigation water from farms in the semi-arid climate of Colorado can result in aesthetic, economic, and ecological problems. Without a sustainable and permanent vegetative cover, this previously irrigated land frequently will only support sparse, weedy vegetation that survives in unstable and often saline soils. The soil conditions that exist after decades of farming are not conducive to permanent grass establishment and are often impeded by soil salinity, low organic matter, and poor infiltration. Weeds tend to exploit the higher levels of plant-available nutrients, particularly nitrogen in these soils, giving them a competitive advantage over the higher ecological stages of desirable perennial vegetation. For example, evaluations documented adequate cover on only 35% of re-vegetation trials in southeast Colorado.

Abruptly halting irrigated crop production on fields that have been intensively managed results in negative consequences: residual soil nutrients threaten water quality, weed infestations compete with perennial grass establishment, wind and water erosion can be significant, and compaction and salinity can initially limit non-irrigated crop and restoration planting choices. Using cover crops may bridge the transition from irrigated production to dryland crop production or grassland, or provide an interim solution to weed and soil management while waiting for irrigation water restoration.

Our primary goal in the project described here is to provide cover crop recommendations for farmers who need to temporarily fallow irrigated land, assume dryland production, or establish grasses in formerly irrigated fields. Thus, we began evaluating several cover crop options on a farm near LaSalle, Colorado. This site was similar to many other situations in the South Platte Valley in that it lost South Platte alluvial well water after court decisions curtailed junior pumping rights following the 2005 growing season.

The last irrigated crop on this field was sugar beets, leaving the loamy sand soil unstable with little residue for erosion control. Manure was applied that Fall, with the farmer anticipating growing a corn crop the following spring contributing to the high nutrient content in the soil. With irrigation water abruptly unavailable, corn was obviously not an option that growing season, and the field has been subsequently growing weeds that the farmer controls through mowing and herbicides. With only about 12 inches of annual precipitation and low soil water holding capacity, dryland farming is marginal at best on this and other farms losing irrigation water in the area.

The strategy examined at this demonstration site uses cover crops for nutrient mining and weed suppression during a transitional period between irrigation curtailment and perennial grass establishment. Beginning in 2006, we planted cover and forage crops at this site to assess their ability to suppress weeds, produce residue cover, and uptake nutrients. In varying rotations, we evaluated barley, winter wheat, triticale, forage sorghum, sorghum sudangrass, hay millet, and hairy vetch. We used no-till planting to minimize soil disturbance and erosion potential.

Herbicides, primarily glyphosate and 2,4D, were used to control weeds prior to planting. Herbicides were also used to burn down winter cover crops prior to seed formation to save moisture and provide residue cover for a summer crop. In fall 2008, we dormant-seeded a cool season grass mix into sorghum residue on two plots following two years of cover cropping. The following spring, a warm season mix was planted in adjacent plots after a winter cover crop sequence. Measurements taken at this site to assess the success of this strategy include plant biomass production, ground cover transects, soil nutrient analysis, soil moisture, and total plant nitrogen uptake.

Results from this work to date show that cover crops provide a viable source of soil cover and residue to reduce erosion, suppress weeds, and uptake nutrients for restoration of previously irrigated land. Weed suppression is allowing for proportionate increases in cover crop biomass with decreases in weed seed and biomass production. The cool season grass has shown greater potential to compete with weeds than the warm season grass (figure 2) has after two years of cover crop and one season of grass growth. Plans for 2010 include continuation of summer forage cover crops and a second planting of warm and cool season grass mixes in plots where cover crops have reduced nutrient levels and weed pressure to acceptable levels.

This work has generated considerable interest from the cooperating farmer and surrounding landowners; however, many questions remain regarding the proper conversion of dewatered irrigated land, particularly where water is unavailable for establishment of new vegetation. Additional research on weed control, soil ecological health, grass species selection, and appropriate planting techniques are needed to provide sound recommendations for landowners facing temporary or permanent loss of irrigation water.

Spring 2010
Interdisciplinary Water Resources Seminar

Sponsored by: CSU Water Center, USDA-ARS, Civil and Environmental Engineering, and Forest, Rangeland, and Watershed Stewardship

Wednesdays from Noon to 1:00 PM

February 3 LSC Room 228	**Tim Scheibe**, Pacific Northwest National Laboratory, Hydrology Group **2010 Darcy Distinguished Lecture--Flow and Reactive Transport: From Pores to Porous Media to Aquifers**
February 10 LSC Room 210	**Faith Sternlieb**, Colorado Water Institute, CSU **Planning for CSU's first World Water Day Celebration**
February 17 LSC Virginia Dale	**Mark Williams**, Institute of Arctic and Alpine Research, CU **Potential Climate Impacts on the Hydrology of High Elevation Catchments, Colorado Front Range**
February 24 LSC Room 210	**Jim Ascough**, Agricultural Systems Research, USDA-ARS **Spatially Distributed Modeling using the Component-Based AgroEcoSystem Model**
March 3 LSC Room 210	**Dennis Harry**, Geosciences, CSU **Opportunities and Adventures in Hydrogeophysics**
March 10 LSC Room 210	**David Theobald**, Human Dimensions of Natural Resources, CSU **Assessing Threats to Colorado Watersheds**
March 17	**No Seminar** **Spring Break**
March 24	**No Seminar** **Hydrology Days (LSC Cherokee Park Room); www.hydrologydays.colostate.edu**
March 31 LSC Room 210	**Tom Sale**, Civil and Environmental Engineering, CSU **Emerging Concepts in Subsurface Contaminant Transport and Remediation**
April 7 LSC Room 210	**Tim Steele**, TDS Consulting **Clear Creek Long Range Planning**
April 14 LSC Room 224	**Thijs Kelleners**, Renewable Resources, University of Wyoming **Measurement and Modeling of Water Flow, Heat Transport, and Gaseous Exchange in Rangeland Soils**
April 21 LSC Room 210	**Domenico Bau**, Civil and Environmental Engineering, CSU **Anthropogenic Uplift of Venice by Seawater Injection into Deep Aquifers**
April 28 LSC Room 210	**Mike Coleman**, Civil and Environmental Engineering, CSU **Soil Moisture Estimation**
May 5 LSC Room 210	**Romano Foti**, Civil and Environmental Engineering, CSU **TBA**

* Room may be changed if needed. Check weekly announcements.

All interested faculty, students, and off-campus water professionals are encouraged to attend.
For more information, contact Reagan Waskom at reagan.waskom@colostate.edu or visit the CWI web site.

The High Line Canal Company

by Dan Henrichs, Manager, High Line Canal Company

The High Line Canal Company is conducting a project to explore implementation of alternative water transfer means, including interruptible water supply agreements, long-term land fallowing, spot market leases (for use during drought), and water banking. Water developed under these methods will be provided to other users via existing irrigation infrastructure or via a proposed pipeline. The project includes engineering studies to determine the amount of water that could be transferred and the location, timing, and volume of historical irrigation return flows that would need to be maintained to prevent injury to downstream water users. Water made available will be leased to other water users.

The Rocky Ford High Line Canal (High Line) diverts from the main stem of the Arkansas River approximately 25 miles downstream of the City of Pueblo. The ditch extends for approximately 87 miles from its headwork's on the Arkansas River to Timpas Creek, south of the town of Rocky Ford. Engineering investigations of the historic use of the High Line water rights were performed in 2003 in support of Substitute Water Supply Plans (SWSP) that enabled a portion of the water rights and water use to be transferred (in 2004 and 2005) to the City of Aurora.

Specific project objectives include:

- Establishing an entity to broker leases of water from the Arkansas River to entities that need water
- Determining the amount of water to be provided and how it can be transferred to other locations
- Determining what canal structure improvements are required
- Considering water quality issues
- Determining pipeline location
- Determining whether an Augmentation Plan is required

Project Tasks

During our lease with Aurora and Colorado Springs we learned of the limited exchange potential back into Pueblo Reservoir. We have concluded that the only way to provide enough water is through a direct pipeline with taps off the main line to other users, but to build a pipeline it will take many partners on both ends of the spectrum. The first issue with a pipe line is with the water quality, is it good enough? We believe that using the river alluvium in the Boone area will provide a high quality source to use with minimal treatment cost. Quantifying the water quality at our location will determine a starting point for a pipeline.

This study will investigate using a well field as the source for the pipeline in conjunction with the High Line Canal Augmentation station to be able to cover depletions as they are occurring. We believe that the engineering will prove there is sufficient exchange potential between the High Line Canal Augmentation station and the Oxford Farmers ditch and the Catlin Canal, with some exchange potential from the Fort Lyon Canal. There is no problem with delivering water from the Bessemer Ditch downstream to the High line. The water will be made available to lease through rotational farming and temporarily drying up irrigated fields. By transferring only the consumptive use portion of the water rights to the lease, leaves the ownership and tax base intact within the community.

The purpose of this portion of the project is to perform a preliminary analysis for the delivery of water from the Boone area to the Front Range municipal areas. This portion of the project will include the pumping, pipeline, and treatment requirements from the Arkansas River alluvium assuming a new well field will be constructed." The CWCB funded portion of the project is further divided into six subtasks:

- Project definition/information gathering
- Evaluation of water quality
- Well field analysis
- Conveyance route
- Opinion of probable project costs
- Report and administrative tasks

If successful, the High Line Company hopes to create an entity that will broker leases of water that can be transferred to other locations, both in and out of the Arkansas River Basin.

Improving Agriculture to Urban Water Transfers

by John Wiener, Institute of Behavioral Sciences, University of Colorado at Boulder

This issue of *Colorado Water* shows that we are making progress by using alternative forms of ag-to-urban water transfer to tactically adapt to changes with less damage. But we can and should do new and strategically better things. Moving water affects an array of interests valued now and in the future, as shown in the *Arkansas Basin Roundtable Water Transfers Guidelines Committee Report* (available from the Colorado Water Conservation Board web site). We know more now about the impacts of water transfers, but unfortunately the ideas in the Committee Report's preface have not been taken seriously. The biggest obstacle to excellent outcomes from transfers, rather than merely less-damaging outcomes, is how we do or do not think about what we want. We may lose the chance to think strategically about the long term by talking about principles in the abstract while business-as-usual proceeds. Now, it is time for each ditch to bring in the missing interests and to take seriously what can be won or lost in the very near future.

We are entering a time of water re-allocation, with no new supplies and probably a significantly lower useable future supply, resulting from changes in flow timing under climate change and full use of urban water rights. Relative prices for land and water change very quickly compared to the social and physical realities underlying agricultural production capacity. Farm families learn their land and their skills over a lifetime. Topsoil formation occurs at roughly an inch or less per century, but it can be gone in a flash. In the long term, we can't afford to think only short term.

The Neighbors and the Future Neighbors

Water sellers' neighbors are usually involved only in a holding action, in defense of their own water rights and the individual and ditch status quo. Instead, farmers and their partners in cattle operations could act together as carefully and thoughtfully as any big-money land development company. David Carlson's work on Agricultural Protection and Development Associations explains this very well. If you owned "all the pieces" of a ditch system, like a huge corporate farm, you would likely combine the best soils and water supply for irrigation, the poorer soils and less-reliable water for supplemental watering, and you would manage pasture and grazing over the whole area to increase net gains and reduce risks.

> "We are entering a time of water reallocation, with no new supplies and probably a significantly lower useable future supply, resulting from changes in flow timing under climate change and full use of urban water rights."

Working markets do that, but the high financial and human costs of water transfers have gotten in the way. Imagine "re-designs" using a long-term rotating fallow plan and water banks to gain the resilience and stability of horizontal and vertical integration for many of the businesses, while families retain ownership and future flexibility. The author's position is available at www.colorado.edu/ibs/eb/wiener.

Land-and-water owners planning seriously with a city representing the range of its citizen's interests could maximize present and future value, with farm-friendly long-term development covering some costs and determining timing. The value of smaller parcels depends on land use patterns that can be well thought out, or left to chance by letting the personal and financial issues that affect a family acting alone determine what will or will not be possible for everyone else. Fewer and bigger farms ever more dependent on purchased inputs has been the trend, but direct sales, organics, local specialty crops, and unpredictable fuel and input costs push in the other direction. Will great possibilities for the children and grand-children (and the productive soils) be lost to uncoordinated decisions? This is a challenge, but it is worth the effort.

Bring on the Townspeople, Ranchers, Rural Economies, and Governments

Many others who are not involved are vulnerable to transfer effects by business links to farms, including the economically critical mesh of cattle and feeding businesses. Small towns and counties are vulnerable to development that reduces agricultural productivity and imposes long-term costs higher than generated revenues. Yet, farmers may have no choice, unless local governments collaborate with land-owner groups to create and spread value by planning and timing service provision (cutting costs and avoiding problems, such as in sewage treatment and water supply). The key is increasing certainty about future conditions and preventing waste. Cities have always planned inside and out of their boundaries. Now, it is time rural places did the same. This is not inventing money or debt, but planning wisely to support and attract development that pays for itself with regional cooperation, so one town doesn't compete with another for less benefit and more cost. Among the obstacles is lack of will to talk and plan, but as the Fountain Creek project shows, it can be done. Those who doubt community planning must think the ditches appeared by magic.

Urban People: They're Citizens, Members, Recreators—Not Just Water Rate-Payers

City officials often claim very narrow mandates, but city residents have much broader interests. Taxes and water rates do with one hand what citizens try to undo with the other, through elections so far providing nearly $4 billion in Colorado (Trust for Public Land), opinion polls supporting agriculture, and paid memberships in groups such as American Farmland Trust, The Nature Conservancy, Environment Colorado, and Ducks Unlimited. Many groups buy what they value, often applying the best science. Why is that financial power and scientific perspective not welcomed to the table? Scientifically favored conditions are frequently quality of life amenities that increase value, avoid problems, and secure conditions that people want for their homes, their recreation, their environment, and their community. These are real interests with real financial clout that can help direct city capacities toward more than only "cheap water now."

Taxpayers and Future Coloradoans

Avoiding problems such as water quality or environmental and biodiversity impacts (not only under the Endangered Species Act) is important. When small changes add up to cumulative impacts that cross a limit, the costs can be substantial, and when the state has to act, everyone is affected. When limits are finally hit, the people who made their deals are usually gone, and the costs are left for others to bear. It is hard to imagine a case where a good avoidance strategy costs near as much as a bad problem. I have yet to meet anyone in the agricultural and water communities who doesn't care about the future, but I have met people convinced that not enough other people care. We must not cripple ourselves by letting naysayers tell us what we can't do together.

Farmers and their allies can plan for the long term and work with cities representing all citizen interests. This is easier than we think—if we really try it instead of keeping all the talk abstract until there isn't much left to talk about. Each place is special—forget one-size-fits-all, and forget "you can't do that!" What legacy do we want to leave to the future?

USGS science for a changing world — Recent Publications

Depth to Water, Saturated Thickness and Other Geospatial Datasets Used in the Design and Installation of a Groundwater Monitoring - Well Network in the High Plains Aquifer, Colorado by J.L. Flynn, R.L. Arnold and S.S. Paschke. http://pubs.usgs.gov/ds/472/

Design and Installation of a Groundwater Monitoring - Well Network in the High Plains Aquifer, Colorado by L.R. Arnold, J.L. Flynn, and S.S. Paschke. http://pubs.usgs.gov/ds/456/

Planning for an Uncertain Future - Monitoring, Integration and Adaption. Edited by R.M.T Webb and D.J. Semmens. http://pubs.usgs.gov/sir/2009/5049

Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado by J.P. Capesius and V.C. Stephens. http://pubs.usgs.gov/sir/2009/5136

DayCent-Chem Simulations of Ecological and Biogeochemical Processes of Eight Mountain Ecosystems in the United States by M.D. Hartman, J.S. Baron, D.W. Clow, I.F. Creed, C.T. Driscoll, H.A. Ewing, D.B. Haines, J. Knoepp, K. Lajtha, D.S. Ojima, W.J. Parton, J. Renfro, R.B. Robinson, H. Van Miegroet, K.C. Weathers, and M.W. Williams. http://pubs.usgs.gov/sir/2009/5150

U.S. Geological Survey Colorado Water Science Center: http://co.water.usgs.gov

Early Colorado Irrigators: Colorado Water Use Before the 20th Century

by Linda Meyer, Archivist, Colorado Agricultural Archive, Colorado State University Libraries

To commemorate the 50th anniversary of Colorado statehood in 1926, the governing board of the state agricultural college commissioned Colorado Extension Service specialist Alvin T. Steinel to write a history of agriculture in Colorado. Steinel's associate, Daniel W. Working, spent more than two years gathering historical data from primary source materials to compose the book. Working also wrote the introductory chapter. Much of the information in this article comes from Steinel's *History of Agriculture in Colorado* and from the *Papers of Daniel W. Working*, a collection of documents gathered by Working and now preserved in the Colorado Agricultural Archive of the Colorado State University Libraries.

According to Daniel Working's research notes, the first irrigation ditch "constructed by Americans in Colorado" was built near Bent's Fort shortly after the fort was completed in 1833. This ditch watered fields between the fort and the ford of the Arkansas River. However, U.S. citizens were by no means the first people to irrigate crops in this region.

Archaeological excavations have uncovered evidence of the prehistoric use of irrigation canals and dams among the native peoples of the American Southwest, including the cliff dwellers of Mesa Verde and other ancient settlements in southwestern Colorado. Spanish colonists, traveling north from their previous landholdings in Mexico, sometimes rebuilt the dams and canals of the Pueblo Indians for use in irrigating their own crops. The first court decrees for irrigation rights to Colorado streams were granted in 1852 to the descendents of these early Spanish settlers in Costilla and Conejos Counties. Both Decree No. 1 (the San Luis People's Ditch) and Decree No. 2 (the San Pedro Ditch) of District 54 were granted for water taken from the Culebra River, while Decree No. 3 (the Acequia Madre Ditch, filed in 1853) dealt with water from the Costilla River.

Albert D. Richardson, author of *Beyond the Mississippi*, traveled to the San Luis Valley in 1859 and noted that *Irrigation makes the parched, sandy soil wonderfully productive. In most wheat-growing states a yield of fifteen fold from the seed is an excellent crop. But this seeming desert often produces fifty-fold and sometimes a hundred-fold*. Later that year, Ceran St. Vrain arrived in Denver with 26 wagons loaded with 1,100 sacks of flour made from San Luis Valley wheat and watered by ditches supplied by Rio Grande tributaries.

This image shows the cover of "The Irrigation Era," a Denver publication that described irrigation and other agricultural resources for prospective settlers in Colorado. (From papers of Daniel W. Working, Colorado Agricultural Archive, Colorado State University)

David K. Wall, an early irrigator in the Clear Creek area near present-day Golden, came to Denver in 1859 with the intention of supplying provisions for the gold miners. Wall had successfully irrigated potatoes nine years earlier near the California gold fields, and upon his arrival in Colorado he planted two acres of potatoes and other vegetables, watered by a ditch tapped from Clear Creek. By the end of the year, Wall's receipts from the sale of this produce totaled $2,000. The first recorded ditch filing made on water from Clear Creek was for the Wanamaker Ditch. Jonas F. Wanamaker, like David Wall, arrived in Colorado in the spring of 1859 and planted crops on land two miles east of Golden.

The necessity for food crops to be grown near the gold camps meant that the water needs of the gold miner and the farmer might be provided by the same ditch. This was the case with the first canal of the Platte Valley Ditch Company, built approximately eight miles

This undated photo shows potato fields under irrigation. (From Records of Colorado Cooperative Extension, Colorado Agricultural Archive, Colorado State University)

west of Denver in 1860 to fill the sluice boxes of the placer miners, as well as the ditches of the farmers.

In northern Colorado, irrigation developed along the South Platte River and its tributaries. Fur trapper Antoine Janis staked a claim in 1844 along the Cache la Poudre River, and 14 years later, he and others formed a company that surveyed and platted the town site of Colona (which would be renamed La Porte in 1862). The original Colona settlers irrigated their crops with water from the Cache la Poudre, and the first decreed water right to that river was dated 1860. Some 20 miles farther south, in 1858, Mariana Modena settled on land along the Big Thompson River, a few miles west of the present town of Loveland. Modena and other settlers who arrived during the next few years used water from the Big Thompson to irrigate their farms.

To the east, participants in the Union Colony, which founded the town of Greeley in 1870 near the confluence of the Cache la Poudre and South Platte, developed a practical, cooperative irrigation system that became a pattern for other water districts in Colorado. Colony leaders emphasized the importance of irrigation to their farming endeavors, and members of the Union Colony cooperative were responsible for maintaining the ditches that provided their water supply.

Evidence of the critical role played by irrigation in agricultural pursuits in Colorado during the late 19th century can be seen in the pages of the monthly publication, *The Irrigation Era*, which described itself in 1898 as *not only the largest but the most handsomely illustrated journal in western America*, and, as an advertising medium, *far in the lead of any western farm publication*. Published in Denver between 1887 and 1902, *The Irrigation Era* purchased and merged with Daniel Working's *Irrigation Review* in 1898. Although, as its name implies, this journal described irrigation systems being developed and already in place throughout the state, the *Era* also included detailed information concerning the growth and development of numerous Colorado cities and towns. The May 1900 issue featured the many attractions of Canon City, including abundant orchards and fruit farms watered by the Arkansas River and its tributaries.

> "Archaeological excavations have uncovered evidence of the prehistoric use of irrigation canals and dams among the native peoples of the American Southwest."

In the years after the Civil War, a flood of settlers began pouring into the region surrounding the Rocky Mountains, establishing farms and digging ditches to water their crops. Within a few years of Colorado achieving statehood in 1876, agricultural areas along the Front Range were described as "one vast network of irrigating canals." Elwood Mead, a professor of engineering at the new state agricultural college, advocated irrigation experiments and careful measurement of precipitation and stream flows to plan for future developments in water use.

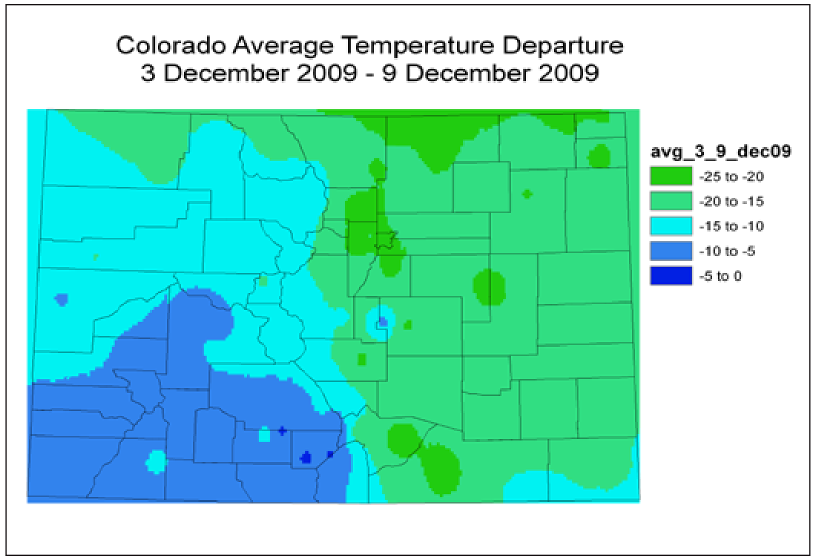
As awareness of the value of water rights increased, the decades following Colorado statehood would see an influx of Eastern speculators and foreign investment companies providing capital to finance the construction of water projects. In response, as they prepared to enter a new century, Mead urged a gathering of Colorado farmers to work for conservation, reform wasteful irrigation practices, and enlist the state legislature to create policies that would ensure more efficient and fair delivery systems for this precious resource.

This undated photo shows men digging a section of the Deadman Ditch in northern Colorado. (From the University Historic Photographs Collection, Archives and Special Collections, Colorado State University)

Winters Can Still Be Cold—Really Cold!

by Nolan Doesken, Colorado State Climatologist, Colorado Climate Center

If someone were to tell you that winters in Colorado just aren't as cold as they used to be, there is some evidence to support that claim. Since the early 1990s, most winters in Colorado have been near or above the long-term average. Extreme subzero cold has been occurring less often than in previous years—until recently.



So, don't start thinking that we no longer have to contend with harsh winter weather. That's just not true, as the December 2009 Colorado cold wave clearly demonstrated. After one of the coldest Octobers in recorded history for parts of Colorado this past autumn, November bounced back with above-average conditions. But weather patterns quickly reversed again on December 1. The mean temperature for the first 11 days of December was at least 16 degrees F below average in many areas of Colorado (see figure at right). On December 9 and 10, temperatures plummeted. Fruita, near Grand Junction, dipped to a record low of -27F for that date, and Fort Collins had temperatures at or below -15F for the first time in 14 years.

We've had other recent cold weather as well—think back a year or two. If you were in Gunnison or Alamosa during the winter of 2007-08, you would have been hard pressed to describe a warming trend, as temperatures frequently fell below -20F and occasionally dropped below -30F.

We can't predict with confidence what lies ahead for the rest of the 2009-2010 winter, but based on historical data, we've still got lots of cold weather ahead. In fact, in 50-60% of all years, January is the coldest month. December is the coldest month about 30% of the time, with February picking up most of the rest. Only rarely (perhaps once or twice in a century), the coldest temperatures of the year occur in November or March.

Tracking Trends

If you are interested in exploring Colorado's climate trends on your own, the Colorado Climate Center recently launched a new website that may be of interest: http://climatetrends.colostate.edu

This web site provides quick and easy access to historical temperature and precipitation data for some of Colorado's best long-term climate stations. The data are updated each month (with about a two-month lag for processing and quality control). Data can be presented graphically or extracted for more in-depth research.

The unique aspect of this site is the narrative description that accompanies each station. No weather stations have perfect homogeneous data time series. Each time a weather station is moved, human observers change, instrumentation is upgraded, land use surrounding the station is modified, or the schedule for daily observations is changed there is a potential for introducing changes or biases to the long-term time series. As much as we wish that all our historic data were free from changes, they are not. We can't change that. Instead, we have attempted to identify and describe each known change at only the stations with the fewest changes. Users should take these changes into account as they interpret the local climate history.

The Climate Trends web site is still under development, and you'll be seeing more improvements and more data in the coming months. Thanks to support from the Cooperative Institute for Research in the Atmosphere (CIRA) and the Department of Atmospheric Science here at CSU, along with the Western Water Assessment at the University of Colorado at Boulder, which provided joint funding to complete this important project.

If you have questions about the Colorado Climate Trends web site, please contact Nolan Doesken at nolan@atmos.colostate.edu or (970) 491-3690.

And stay warm!

Crossing State Lines for Water Tables 2010

by Patricia J. Rettig, Head Archivist, Water Resources Archive, Colorado State University Libraries

On Saturday, February 20, 2010, the Colorado State University (CSU) Libraries will host Water Tables, its annual fundraiser for the Water Resources Archive. This year's theme is "Across State Lines: Sharing the Resource." At the event, table hosts will include not only Colorado water experts, but also experts from Wyoming, Nevada, Montana, and Mexico.

The evening will begin with a reception and open house at the Water Resources Archive in CSU's Morgan Library. This time provides guests with special access to view archival treasures and the opportunity to meet some of the West's most prominent water leaders. During the dinner, 20 water experts will host table discussions on topics related to the theme while a gourmet meal is served.

Bringing these knowledgeable professionals together to talk about how the West has shared its waters is an unparalleled event in the state, held in a relaxed setting surrounded by historical evidence of how cooperation has (or hasn't) worked in the past. A selection of table topics shows the diversity included:

- *Interstate Comity is for the Birds*, discussed by Alan Berryman of the Northern Colorado Water Conservancy District
- *Why We Have to Share—Limits on our Right to Consume*, discussed by David Robbins, attorney and president of Hill & Robbins, P.C.
- *Perspectives from Wyoming on the Regional Watershed Supply Project–Green River Pipeline*, discussed by Harry LaBonde, Jr., Wyoming Deputy State Engineer
- *The Colorado River as an International River: Mexico's Perspective*, discussed by Mario López Pérez from the National Water Commission of Mexico

This year's table hosts include:

- **Don Ament**, Former Colorado Commissioner of Agriculture
- **Alan Berryman**, Assistant General Manager, Engineering Division, Northern Colorado Water Conservancy District
- **Derek Everett**, Visiting Assistant Professor, History Department, Metropolitan State College of Denver
- **Jennifer Gimbel**, Director, Colorado Water Conservation Board
- **Neil Grigg**, Professor of Civil and Environmental Engineering, Colorado State University
- **Taylor Hawes**, Colorado River Program Director, The Nature Conservancy
- **Tom Iseman**, Program Director for Water Policy and Implementation, Western Governors Association
- **Frank Jaeger**, District Manager, Parker Water and Sanitation District
- **Eric Kuhn**, General Manager, Colorado River Water Conservation District
- **Harry LaBonde, Jr.**, Wyoming Deputy State Engineer
- **Mario López Pérez**, Engineering and Technical Standards Manager, National Water Commission of Mexico
- **Patrick O'Toole**, President of the Family Farm Alliance and former member of President Clinton's Western Water Policy Review Advisory Commission
- **Jennifer Pitt**, Senior Resource Analyst, Environmental Defense Fund
- **Rock Ringling**, Managing Director, Montana Land Trust
- **Bill Rinne**, Director of Surface Water Resources, Southern Nevada Water Authority
- **David Robbins**, President and Co-founder, Hill & Robbins, P.C.
- **Randy Seaholm**, Former Chief, Water Supply Protection, Colorado Water Conservation Board
- **Steve Vandiver**, District Manager, Rio Grande *Water* Conservation District

See the complete list of hosts and discussion topics at http://lib.colostate.edu/develop/events/2010/watertables/. This is also where to make online reservations and find out about the generous sponsors of Water Tables. Reservations can also be made by calling (970) 491-1833. Limited seating is available; reservations will be filled on a first-come, first-served basis. Tickets for the event are $125 per person.

Proceeds from Water Tables support the Water Resources Archive, which works to preserve, promote, and make available records of Colorado's water history. For more information about the Water Resources Archive, please visit http://lib.colostate.edu/archives/water/ or call (970) 491-1844.

The 2009 Ag Water Summit

by Reagan Waskom

The Colorado Agricultural Water Alliance (CAWA) sponsored its third Ag Water Summit on December 1, 2009, at the Jefferson County Fairgrounds. At a reception the previous evening, Governor Bill Ritter kicked off the Summit by stressing the importance of agriculture to Colorado's economic and cultural identity. Farm Bureau's vice president and current CAWA chairman Don Shawcroft opened the program by stating the mission of the Alliance and describing the history of irrigation development in Colorado. The Alliance is a group of agricultural organizations dedicated to preserving water and agriculture in Colorado.

Pat O'Toole, president of the Family Farm Alliance and rancher from the Little Snake River Valley north of Steamboat Springs, was the opening keynote speaker and set the tone for the Summit, stating that every state in the West has water conflict and that issues will only become more difficult with population growth and a changing climate—both will increase the pressure on agricultural water. O'Toole emphasized the importance of food production in the United States and stated that protecting working private lands in West is the key to preserving wildlife and the environment. The Family Farm Alliance proposes structural solutions to our water problems—more water storage is needed across the West.

A legislative panel moderated by Senate Ag Chair Mary Hodge included Rep. Sal Pace, Rep. Jerry Sonnenburg, Rep. Randy Fischer, Rep. Randy Baumgardner, Sen. Bruce Whitehead, and Sen. Gail Schwartz, all of whom discussed potential 2010 water legislation.

An agency panel moderated by commissioner of agriculture John Stulp addressed water agency priorities and issues. Dan McAulliffe discussed the CWCB's Colorado River Water Availability study and the need for stability in the construction fund. State engineer Dick Wolfe discussed the loss of irrigated lands and the increased implementation of sprinkler irrigation in Colorado. Alex Davis, Department of Natural Resources deputy director for water, indicated how vexing agricultural water problems are for water managers and expressed the desire to keep a productive agriculture in Colorado.

The remainder of the Ag Water Summit focused on potential solutions for Colorado agriculture. CSU professor Neil Hansen presented data on five years of limited irrigation trials in eastern Colorado. Water managers Eric Wilkinson of Northern Water and Mark Pifer of Aurora Water described their water projects. Todd Doherty discussed the CWCB's Alternative Water Transfer Methods grant program and methods being studied to share water between agriculture and municipalities. Jay Winner of the Lower Arkansas Valley Water Conservancy District focused on one of these projects—the SuperDitch. Greg Larson of the Republican River Water Conservancy District provided details on the $21 million 12-mile pipeline that will carry water to Nebraska to resolve the compact compliance dispute.

Finally, Chris Treese of the Colorado River District briefed participants on the proposals for new Wild and Scenic River designations, and Sen. Bruce Whitehead showed photos of the newest water project—the filling of Nighthorse Reservoir. In all, some 130 participants were thoroughly briefed on potential solutions and mechanisms to preserve water in agriculture. The Colorado Ag Water Alliance will continue to meet quarterly and may be contacted through Crystal Korrey at the Colorado Farm Bureau.

Pat O'Toole, president of the Family Farm Alliance, speaks at the 2009 Ag Water Summit.

20th Annual South Platte River Forum

by Laurie Schmidt, Colorado Water Institute

On October 21-22, 2009, 180 attendees gathered for the 20th annual South Platte Forum in Longmont, Colorado. With the theme *1989 to 2029: A River Odyssey*, the two-day meeting took a look back at the Forum's evolution over the past 20 years, as well as a look forward at water issues and challenges on the horizon.

Robert Ward, former director of the Colorado Water Institute, kicked off the meeting with a brief history of the Forum, noting the gradual change in the meeting's tone during its first five years. "In the first year, we were simply trying to get both sides in the same room, but by the fifth year—any subject was open for discussion," he said. Colorado State Senator Brandon Shaffer followed up with a discussion of challenges facing the state, including a skyrocketing state population that he said will triple water consumption rates by 2050. "We need to improve efficiency, increase conservation efforts, and plan for water storage projects," he said.

The meeting's first session focused on Colorado water law. Justice Gregory Hobbs provided a look back at Colorado Supreme Court water decisions, and Paul Frohardt, Colorado Water Quality Control Commission, examined changes in water quality policy. David Getches, dean of the University of Colorado Law School, discussed the unique challenges posed by the intersection of Colorado's growing population and hotter, drier climate conditions, saying that a combination of management, cooperation, and planning is essential to survival. "It is about scarcity, not business as usual," he said. "We may be entitled to it, but if nature doesn't provide it—it's not there."

Justice Gregory Hobbs (left), Diane Hoppe, and Jon Altenhofen catch up during the morning break at the 2009 South Platte Forum.

State climatologist Nolan Doesken, recipient of the 2009 Friends of the South Platte Award, and South Platte Forum coordinator Jennifer Brown at the 2009 South Platte Forum.

The final morning session, titled *Scenic Overlook*, included retrospective discussions by Jeris Danielson, a 20-year state engineer, and Alan Berryman, a 20-year division engineer. Max Dodson, retired assistant regional administrator for EPA Region 8, talked about "180-degree turns," including the dramatic "renaissance" of the South Platte River as an environment that provides resources for diverse interests. We face difficult challenges, such as population growth, climate change, new pollutants, and infrastructure deterioration, Dodson said, "but there will be continuing successes in improving and maintaining the aquatic environment."

During the lunch break, state climatologist Nolan Doesken was honored with the sixth annual Friends of the South Platte Award in recognition of his contributions to the South Platte River Basin and the South Platte Forum. Doesken was presented with a framed "South Platte Sunset" photo donated by Colorado photographer John Fielder. Following the award presentation, Denver Water manager Chips Barry gave the keynote address titled *From the DNR to Denver Water* and discussed how the Two Forks decision changed the culture and approach at Denver Water.

In an afternoon session titled *River Trippin'*, the discussion turned to the subject of river conservation and native fish protection. Jay Skinner, wildlife manager with the Colorado Division of Wildlife (CDOW), provided an overview of the CDOW's efforts to assist the IBCC basin roundtables in prioritizing fish and wildlife values in the South Platte Basin. Next, Ryan Fitzpatrick, also of the CDOW, identified reasons for

> "It [water] is about scarcity, not business as usual. We may be entitled to it, but if nature doesn't provide it - it's not there."
>
> David Getches | Dean of University of Colorado Law School

declining fish populations: habitat alteration, non-native species, water quality, and changing flow regimes.

Linda Bassi, Colorado Water Conservation Board, gave an overview of the state's Instream Flow Program, focusing particularly on the challenges faced by the CWCB in implementing the program with its limited authority. "The CWCB cannot unilaterally reduce a decreed instream flow without water court approval," she said. The session concluded with a talk by Jeff Shoemaker on the Greenway Foundation's preservation and enhancement efforts on the South Platte and its tributaries during the past 35 years. "This is what can happen when a city or community gets together to right a wrong," he said.

The final session on Wednesday focused on Colorado climate, with Nolan Doesken reporting on the state of climate research 20 years ago—the foundations for automated weather networks were in place, and climatologists were beginning to use digital elevation model maps and GIS to map climate variables. "Back then, climate change was more an academic discussion than a topic to be taken seriously," he said. NOAA research meteorologist Martin Ralph concluded the session with a climatic look forward, focusing on the subject of atmospheric rivers, which are critical to the global water cycle and to the distribution of precipitation.

On Thursday, the Forum reconvened with Brian Werner quizzing the audience about events of 1989–the fall of the Berlin Wall, the San Francisco earthquake, the Broncos' Super Bowl bid, and the year's top song, "Don't Worry, Be Happy." Brighton vegetable farmer Robert Sakata reflected on how his family's farming business has changed as municipal growth has surrounded the family's land. Sakata concluded with the certainty that farmers and municipalities are going to have to learn to cooperate for the sake of all involved.

Robert Ward (left), former director of the Colorado Water Institute, discusses the morning session with Andy Pineda, Northern Water, at the 20th Annual South Platte Forum.

CSU professor James Pritchett discussed his recent study on the impact of biofuel production on South Platte commodity and water prices and availability. His data show that the four Colorado ethanol plants have had little impact on water supplies or grain prices, as Colorado is a grain importing state and new ethanol plants are unlikely now due to market saturation. Other Thursday speakers included Joe Frank, manager of the Lower South Platte Water Conservancy District; Carol Ekarius of the Coalition for the Upper South Platte; Tom Cech of the Central Colorado Water Conservancy District; and Mark Waage and Melissa Elliot of Denver Water.

The 21st Annual South Platte Forum will be held on October 21-22, 2010. Stay tuned to www.southplatteforum.org and future issues of *Colorado Water* for details.

Faculty Profile

Tom Sale, Associate Professor, Department of Civil and Environmental Engineering, Colorado State University

Nearly 30 years ago, undergraduate classes and research at Miami University in Ohio left me fascinated with the field of groundwater. Through subsequent M.S. and Ph.D. degrees at the University of Arizona and Colorado State University (CSU), and an evolving career in consulting engineering, research, and academia, my fascination with groundwater has grown. In August 2009, I received a tenure-track appointment in the Department of Civil and Environmental Engineering at CSU. I am pleased to be a member of what historically has been one of the strongest groundwater programs in the world.

Consulting Engineering

As the third son of a self-employed civil engineer/surveyor, my exposure to engineering began early. Long before I got to college, I received an invaluable education in surveying, drafting, and subdivision design. Upon receiving my bachelor's degree in 1980, I moved to Oklahoma, where I worked for a small engineering firm that specialized in groundwater development in the U.S. central plains and environmental services for the petroleum industry. This position exposed me to well drilling, geophysical logging, pump tests, pump selection, well design, well completion, and well maintenance. A highlight of my time in Oklahoma was working with a team of engineers and scientists that developed a system of wells to recover petroleum that had been inadvertently released under an active petroleum refinery over nearly seven decades of operations. Our peak production was a remarkable 2,200 barrels of petroleum liquids per day, and we developed methods that were subsequently employed at other refineries in North America and around the world.

After receiving my M.S. degree, I moved to Colorado and went to work for a large engineering firm (CH2M HILL). During my 11 years there, my responsibilities evolved through the positions of project hydrologist, project manager, department manager, and senior technical resource for remediation projects. I co-proposed and co-led a $15-million dollar research program, funded by Union Pacific Railroad, to identify alternatives to excavation and incineration of creosote impacted soils. Results from this pioneering effort led to a novel technology that recovered 8,000 tons of reusable creosote oil from an alluvial aquifer in Wyoming. Furthermore, the work played a key role in an ongoing policy debate regarding the technical practicality of restoring aquifers impacted by our legacy of past industrial practices.

Research

From 1995-1998, Dr. David McWhorter at CSU supported my Ph.D. studies through a Chair position funded by Boeing, and after graduation I remained at CSU in a research position. During the past 10 years, I have been the primary force behind the development of the Center for Contaminant Hydrology in the Department of Civil and Environmental Engineering at CSU. The Center conducts approximately $700,000 per year in remediation-related research and has provided research funds for 5 Ph.D. students, 14 M.S. students, and 14 undergraduate research assistants. Current funding comes from the University Consortium for Field-Focused Groundwater Contamination Research, DuPont, U.S. DoD, Suncor Energy, American Petroleum Institute, ExxonMobil, GE, ARCADIS, CH2M HILL, and TriHydro Corp. In the last six years, the Center has acquired five complete and two pending patents. In addition, students and staff in the Center are working on Denver Basin water supply issues with support from the Town of Castle Rock, the State of Colorado, and the Colorado Water Institute.

Teaching

During the past 10 years, I have taught introductory groundwater, remediation, and contaminant transport classes at CSU, as well as numerous short courses at locations across North America. Most recently, Dr. Dominico Bau and I have been updating the groundwater courses offered at CSU. This has involved soliciting input from industry, students, CSU faculty, and peers at other academic institutions regarding future opportunities for students and what needs to be taught.

Publications and Outreach

Publications to date include 10 peer-reviewed journal articles, portions of three books, five U.S. patents, and seven peer-reviewed industry publications. At a national level, my abilities are reflected in selection for the Environment Protection Agency DNAPL Source Expert Panel (2003-2005), the National Research Council's Army-funded Committee on Source Removal of Contaminants in the Subsurface (2004-2006), and the Interstate Technology & Regulatory Council's Committee on Integrated DNAPL Source Strategies (2007-Present).

Water Research Awards

Colorado State University (October 15 to December 15, 2009)

Andales, Allan A, Soil and Crop Sciences, Natural Resources Conservation Services, Using the ASCE Standardized Reference Evapotranspiration Equation and Appropriate Crop Coefficients, $74,617

Bau, Domenico A, Civil and Environmental Engineering, Department of Energy, Multi-Objective Optimization Approaches for the Planning of Carbon Geological Sequestration Systems, $299,960

Chavez, Jose L, Civil and Environmental Engineering, Agricultural Research Service, Crop Evapotranspiration Determination Using Eddy Covariance Fluxes, High Resolution Remote Sensing Imagery and a Surface Temperature Approach, $40,000

Cooper, David J, Forest Rangeland Watershed Stewardship, National Park Service, Developing a Wetland Delineation & Restoration Plan for Sand Creek, GRSA, $12,000

Cotton, William R, Atmospheric Science, National Science Foundation, Collaborative Research: Inhibition of Snowfall by Pollution Aerosols, $157,744

Culver, Denise R, Fish, Wildlife and Conservation Biology, Environmental Protection Agency, Colorado State University 2009 Wetland Program Development Grant: Teller County, $153,951

Davies, Stephen P, Agricultural and Resource Economics, New Mexico State University, Afghanistan Water, Agriculture and Technology Transfer Program, $435,589

Fausch, Kurt D, Fish, Wildlife and Conservation Biology, National Science Foundation, RiverWebs: Optimizing a Documentary on Stream Ecology for Science Teachers in the U.S. & Japan, $18,777

Fausch, Kurt D, Fish, Wildlife and Conservation Biology, National Science Foundation, RiverWebs: Optimizing a Documentary on Stream Ecology for Science Teachers in the U.S. & Japan, $30,339

Garcia, Luis, Colorado Water Institute, Various "Non-Profit" Sponsors Developing a Decision Support System for the South Platte Basin, $10,000

Garcia, Luis, Civil and Environmental Engineering, Agricultural Research Service Module Development for OMS, $40,000

Garcia, Luis, Civil and Environmental Engineering, Bureau of Reclamation Development of Crop Coefficients for the South Platte Based on Multi-Temporal High-Resolution Remote Sensing of ET, $50,000

Gates, Timothy K, Civil and Environmental Engineering, Bureau of Reclamation Toward Optimal Water Management in Colorado's Lower Arkansas River Valley, Monitoring and Modeling, $50,000

Gates, Timothy K, Civil and Environmental Engineering Lower AR Valley Water Conservancy District, Monitoring and Modeling Toward Optimal Management of the Lower Arkansas River, $20,000

Julien, Pierre Y, Civil and Environmental Engineering, Korea Institute of Construction Technology, Study on Physical Evaluation for the Abandoned Channel Restoration, $64,000

Kampf, Stephanie K, Forest Rangeland Watershed Stewardship, Christopher Reynolds Foundation, Inc., Improved Water Management to Protect Biodiversity in the Ciego de Avila Conservation Reserve Area, Cuba, $18,000

Myrick, Christopher A, Fish, Wildlife and Conservation Biology, Colorado Springs Utilities Flathead Chub Swimming Performance, $10,000

Niemann, Jeffrey D, Civil and Environmental Engineering, Bureau of Reclamation Implementing a Framework to Assess Uncertainty in Hydraulic and Hydrologic Models, $20,000

Oad, Ramchand, Civil and Environmental Engineering, New Mexico State University, Afghanistan Water, Agriculture and Technology Transfer, $218,424

Oad, Ramchand, Civil and Environmental Engineering, New Mexico Interstate Stream Commission, Decision Support Systems for Efficient Irrigation Management in the Middle Rio Grande, $175,271

Sharvelle, Sybil E, Civil and Environmental Engineering, Water Environment Research Foundation, Landscape Irrigation Using Household Graywater Experimental Study, $24,000

Thornton, Christopher I, Civil and Environmental Engineering, Erosion Prevention Products Overtopping Tests on Two Articulating Concrete Block Systems, $20,695

Waskom, Reagan M, Civil and Environmental Engineering, Coop State Research, Education & Extension Coordinated Regional Water Resources Programming for the Northern Plains and Mountains Region, $600,000

Winkelman, Dana, Cooperative Fish and Wildlife Research, Colorado Division of Wildlife Population and Community, Level Effects of Endocrine Disrupting Compounds on Eastern Great Plains Fishes, $180,000

Calendar

February

20 Water Tables 2010; Fort Collins, Colorado
Benefit dinner for the Water Resources Archive at Colorado State University.
http://lib.colostate.edu/develop/events/2010/watertables/

21-24 Utility Management Conference; San Francisco, California
Water and wastewater professionals discuss all aspects of utility management.
http://www.awwa.org/index.cfm

21-25 2010 Land Grant & Sea Grant National Water Conference; Hilton Head Island, South Carolina
Water scientists, educators, and managers discuss current and future water resource management issues.
http://www.usawaterquality.org

March

7-9 2010 WateReuse California Annual Conference; San Diego, California
Discuss the design, management, operation, and use of water recycling facilities.
http://www.wateruse.org

9 Augmentation for Ditch Companies; Denver, Colorado
This workshop will encompass all phases of augmentation.
http://www.cwi.colostate.edu/other_files/DARCA2009-2010workshops.pdf

12 CSU/ARS Evapotranspiration Workshop; Fort Collins, Colorado
Meeting will focus on using the best available science to estimate consumptive use.
http://wsnet.colostate.edu/cwis10/ocs/calendar/calendar.aspx

15-18 20th Annual AEHS Meeting & International Conference; San Diego, California
Environmental professionals gather to discuss soils, sediments, water, and energy.
http://www.aehs.com/conferences/westcoast/overview.html

22-24 Hydrology Days; Fort Collins, Colorado
The 30th Annual Hydrology Days, held on the Colorado State University campus.
http://hydrologydays.colostate.edu

23-26 USCID Water Management Conference; Sacramento, California
Theme is "Upgrading Technology and Infrastructure in a Finance-Challenged Economy."
http://www.uscid.org/10idconf.html

29-31 2010 AWRA Spring Specialty Conference; Orlando, Florida
The AWRA's biennial survey of the state of knowledge in GIS and water resources.
http://awra.org

April

11-15 2010 Ground Water Summit and Ground Water Protection Council Spring Meeting; Denver, Colorado
This year's theme is "Groundwater for a Thirsty World."
http://www.ngwa.org/summit2010/index.aspx

11-15 SAGEEP 2010; Keystone, Colorado
Symposium on the Application of Geophysics to Environmental and Engineering Problems.
http://www.eegs.org/sageep/index.html

25-29 7th National Monitoring Conference; Denver, Colorado
This year's theme is "Monitoring from the Summit to the Sea."
http://www.acwi.gov/monitoring/conference/2010

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Eastern Colorado wheat harvest. (Courtesy of Troy Bauder)